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Performance Evaluation of Activated Sludge Wastewater Treatment Plant (ASWTP) At QIT, Ibeno Local Government Area of Akwa Ibom State, Nigeria.

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ABSTRACT
This research was conducted to ascertain the performance of Activated Sludge Wastewater Treatment Plant (ASWTP) at QIT, Ibeno Local Government Area of Akwa Ibom State. The aim of the study was to investigate the level of effectiveness of the activated sludge process. The study involved the analysis of the wastewater samples collected at the influent aeration tank and the effluent discharge by standard methods. The performance evaluation was based on the removal efficiency of the characteristic wastewater. The result showed that wastewater had no smell with clear colour at normal temperature and equilibrium pH value of 7. The TSS, TDS, total alkalinity reduction values were 4.68, 8.61 and 0% respectively. The DO value reduction was in the range of 40 to 45% and the BOD and COD values reduced by 28 to 32.79% and 46.42 to 49.54%, respectively. The total coliform removal efficiency was between 17 and 21%. On the basis of the results of the study the wastewater treatment plant, has good potential to produce high quality effluent on a continuous bases. It is recommended that operators of the plant should be adequately trained and maintenance ensured.

KEYWORDS: *Wastewater, efficiency, effluent, activated sludge process, performance*

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I. INTRODUCTION

The evaluation of activated sludge wastewater treatment plant (ASWTP) at QIT, Ibeno Local Government Area of Akwa Ibom State, Nigeria was conducted to ascertain the performance of activated sludge wastewater treatment plant used at QIT in Ibeno. The tank design can affect oxygen transfer rates, (Mackinne, 1989). Location of the inlet, outlet and diffusers are important. Tank turnover time must be minimum when oxygen demand rates are high. Tank turnover is the time its takes to mix the contents of the aeration tank. In tended aeration, the mixed liquor suspended solids (ML.SS), is recommended to be 5000 to 6000mg/l (Pfeffer, 1989). However, many extended aeration plants operate below these values because solids separation and handling become more difficult at higher levels for some systems.

Effluent polishing, aeration and chlorination should be considered in the design. Effluent discharge standards may require very good effluent in certain areas or at certain times. As regulations become more stringent, it may be necessary to incorporate post treatment into old plants.The activated sludge process is a system in which biologically active growth is continuously circulated with incoming biologically degradable waste in the presence of oxygen, (Agunwamba, 2001).The untreated or pre-settled wastewater is mixed with 20 to 50 percent of its own volume and return sludge. The mixture enters an aeration tank where the organisms and wastewater are mixed together with a large density of air (Mckinney, 1989). The organisms oxidize a portion of the waste organic water to form carbondioxide and water and produce new microbial cells. The mixture then enters a microorganisms settle and are removed from the effluent stream. The return sludge which as a fraction of the microorganisms or activated sludge recycled to the influent end of the aeration tank, mixed with wastewater. Newly activated sludge is continuously being produced in this process and the excess sludge produced each day (waste activated sludge) must be disposed of together with the sludge from the primary treated facilities as shown in Figure 1.

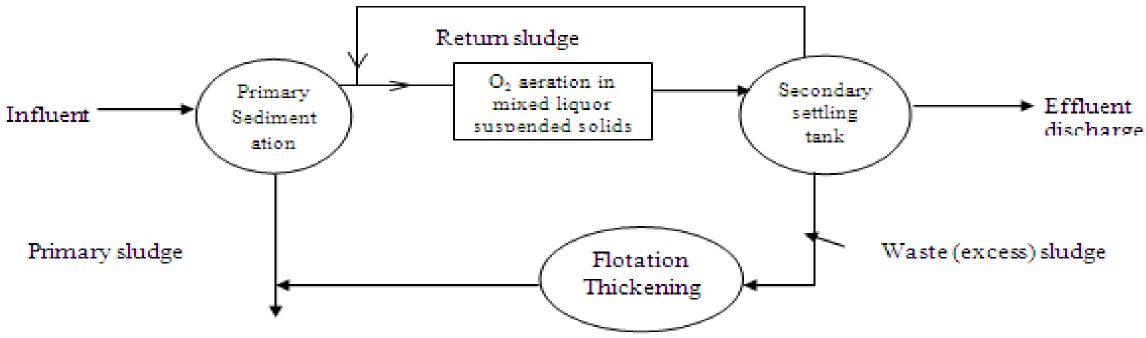


Figure 1: Activated sludge process system

However, certain problems may be encountered during the operation of an activated sludge plant (Sawyer, 1990). They include: biotransformation of organic matter due to the development of bacteria in the aeration tank and separation of the bacterial flocs from clarified water inside the secondary settling tank, (Goodman, 1999). The conventional aeration activated sludge system is a plug flow reactor operated with cell recycle. Oxygen is supplied at a uniform rate throughout the aeration tank since oxygen requirement decreases towards the tank outlet, there is a waste of oxygen in this process, (McKinney, 1989).Wastewater or sewage discharges after treatment into stream or a large body of water such as lake or sea. (Sewage is the wastewater from a community consisting of human excreta, urine and sludge such as wastewater from bathroom, laundry and kitchen) that contains pathogenic organisms, organic and nutrients. It is therefore important to treat sewage prior to disposal. According to (Agunwamba, 2001), the objectives of wastewater treatment include: reduction of biological oxygen demand (BOD), reduction of suspended solids (SS), destruction of pathogens and removal of nutrients, toxic compounds, non-biodegrable compounds and dissolved solids, (Viessman and Hammer, 1993).The activated sludge systems are designed in various forms, such as the conventional system; tapered, stepped, contract stabilization, extended aeration and high rate process systems (Pipes, 2005).The extended aeration is just one form of the conventional aeration system. In this system screened or comminuted raw sewage are fed directly into the aeration tank and maintained for a period much longer than the case of the conventional process. The rate of return sludge is high, (Aguwamba, 2001). There are many variations of activated sludge because of its potential to economically stabilize organic constituents in wastewater.

The quality of treated effluent wastewater are expected to conform to prescribed standards in Tables 1, 2 and 3.

Table 1: Effluent Limitation Guidelines (Domestic Wastewater)

Parameters (mg/l)	**Values**
pH	>10
TSS	>5000
TDS	1500 – 10000
BOD	25 – 50
COD	10 – 150
Total Alkalinity	50 – 200
Oil and Grease	>48

Source: WHO, 1973

Table 2: Effluent Reuse Standards

Parameter (mg/l)	**Agricultural/Irrigation**	**Fish Rearing**	**Recharge**
BOD	No limit	<10	<5
SS	<30	100	<30
TS	2500	<2000	Low
TN	No limit	<0.3	None
NH3	No limit	No limit	<0.5
TP	No limit	No limit	<10
FC (MPN/100ml)	<1000	<1000	<1000

Source: Khurshid, 2000

Table 3: Effluent Limitations on Treated Sanitary Wastewater

	Effluent Characteristics (mg/l)	**Values**
1.	Residual Chlorine (mg/l)	0.8 – 1.5
2.	BOD5 (mg/l)	30 – 45
3.	TSS (mg/l)	45
4.	Fecal Coliform Colonies/100ml	200 – 400 MPN/100ml
5.	Dissolved Oxygen (DO) mg/l	4.0 – 5.0

Source: Principal Legislative Petroleum Act, DPR, 1969

The principal difference between extended aeration and conventional activated aeration and conventional activated sludge is that the extended aeration system has no primary clarifiers. It has a reduced organic loading, an extended aeration time, and far less excess sludge. In the basic extended aeration plant, the influent is mixed with the mixed liquor suspended solids (ML.SS) and the return sludge. This allows for immediate absorption and absorption of organic by microorganisms in the aeration tank. The returned sludge maintains the level of active bio-mass in the system by not allowing it to escape the system to the effluent.
After approximately 24 hours the aeration, the mixed liquor suspended solids (ML.SS) is allowed to settle in the sedimentation tank. The settled sludge is returned to the aeration tank to maintain the level of active microorganisms in the system. The supernatant of the settled sludge leaves the system as effluent that may be chlorinated or given further treatment.Although activated sludge plants are widely used in wastewater treatment, they are associated with certain problems. Biological foams or scums are often formed on the liquid surface of activated sludge plants. The stable foam is grey to cream-brown in colour, quite heavy in consistency and upto 30cm deep. The scum or foams appear on the aeration tank and then eventually cover most of the liquid surfaces including that of the final effluent from the plant. The scum or foam consists of many Gram-positive, branching filamentous bacteria (Blackall and Chudoba, 1991). The predominant organism that had been isolated from the foam was identified as Nocradia amarac, (Viessman and Hammer, 2003), Rhnodocuccus rhodochrus, (Young, 2006) and other nocardioform actimomycetes (Viessman and Hammer, 2003) and (Vanden Berg and Kennedy, 2004).

The objective of the study was to evaluate the performance of the wastewater treatment through the evaluation of activated sludge wastewater treatment plant at QIT, Ibeno, inorder to investigate the influent and effluent composition of wastewater and to compare the level of compliance of the parameters to WHO/DPR standards, as well as to determine the effectiveness of the sewage treatment plant. The study will only be limited to the wastewater characteristics at QIT, Ibeno.Figures 2 and 3 shows the plan view and section of the extended aeration activated sludge system at Ibeno.

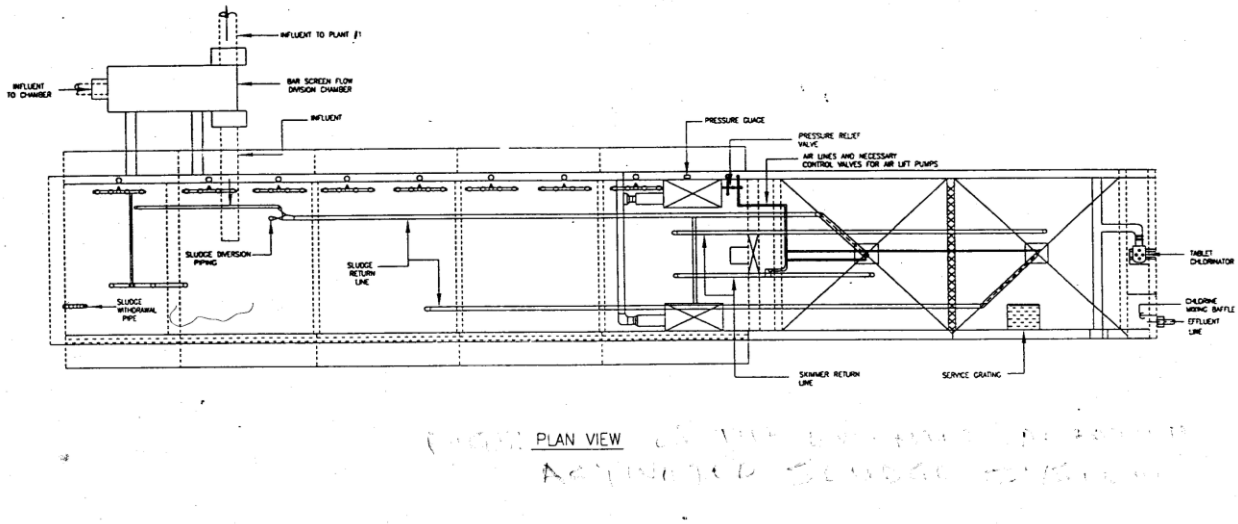


Fig. 2: Plan View Of The Extended Aeration Activated Sludge System

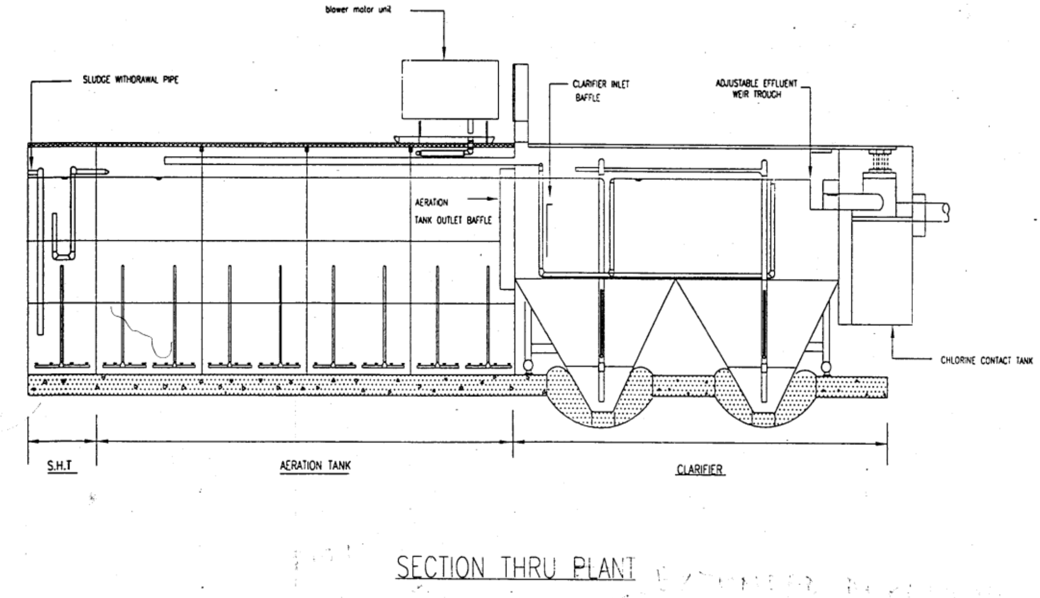


Fig. 3: Section Thru Extended Aeration Sludge System

II. MATERIALS AND METHODS

2.1 Description of the Study Area

The QIT is a crude oil terminal of Mobil Producing Nigeria Unlimited (MPNU), a subsidiary company of Exxon Mobil located in Ibeno Local Government Area, Akwa Ibom State of Nigeria along the coast of the Atlantic Ocean. Ibeno Local Government Area (Figure 4) was created out of the defunct Uquo Ibeno Local Government Area on December 4, 1996 by the Federal Government of Nigeria. Ibeno Local Government Area has a coastal area of over 1,200 square kilometers. It is situated on the Eastern flanks of Niger Delta which in turn is part of the Gulf of Guinea (UNICALCONS, 2003). It is located at the south end of Akwa Ibom State with Latitude 4^o 32^1 and 4^o 34^1 North of Equator and Longitude 7^o 54^1 and 8^o 02^1 East of Greenwich Meridian. Ibeno LGA shares borders with Eket, Esit Eket, Onna and Mbo in the North, Eastern Obolo Local Government Area on the West and Cross River Estuary on the East (Daniel and Akpan, 2006). It occupies the largest Atlantic coastline of more than 129km in Akwa Ibom State (Akpan *et al,* 2002). The communities on the west bank of the Qua Iboe River do not have access to the hinterland except by boat through the river and creeks. Qua Iboe River Estuary which lies within the study area coordinates has Douglas Creek emptying into it. This creek is about 900m long and 8m deep. It is the point where petroleum exploration and production (E&P) waste from the Exxon Mobil Qua Iboe Terminal (QIT) tank farm are transferred to the lower Qua Iboe River Estuary and adjourning creeks through two 24" diameter pipes. The Exxon Mobil oily sludge dumpsite is located adjacent to this creek and the flare stack where gas is flared continuously is also situated a few meters from this creek (Akpan, 2003). The creek also serves as the boundary from Exxon Mobil Crude Expansion Project (UNILAG CONSULT, 1997).

Some communities in Ibeno LGA are located at the bank of Qua Iboe River while some are located on the Atlantic Littoral. Communities such as Mkpanak, Upenekang, Iwuoachang, are located on the east bank of the Qua Iboe River and Okorutip and Ikot Inwang are on the west bank of the Qua Iboe River while Iwuopom-Opolom, Itak Abasi, Akata, Okoroitak are located on the Atlantic coastline (UNICALCONS, 2003).

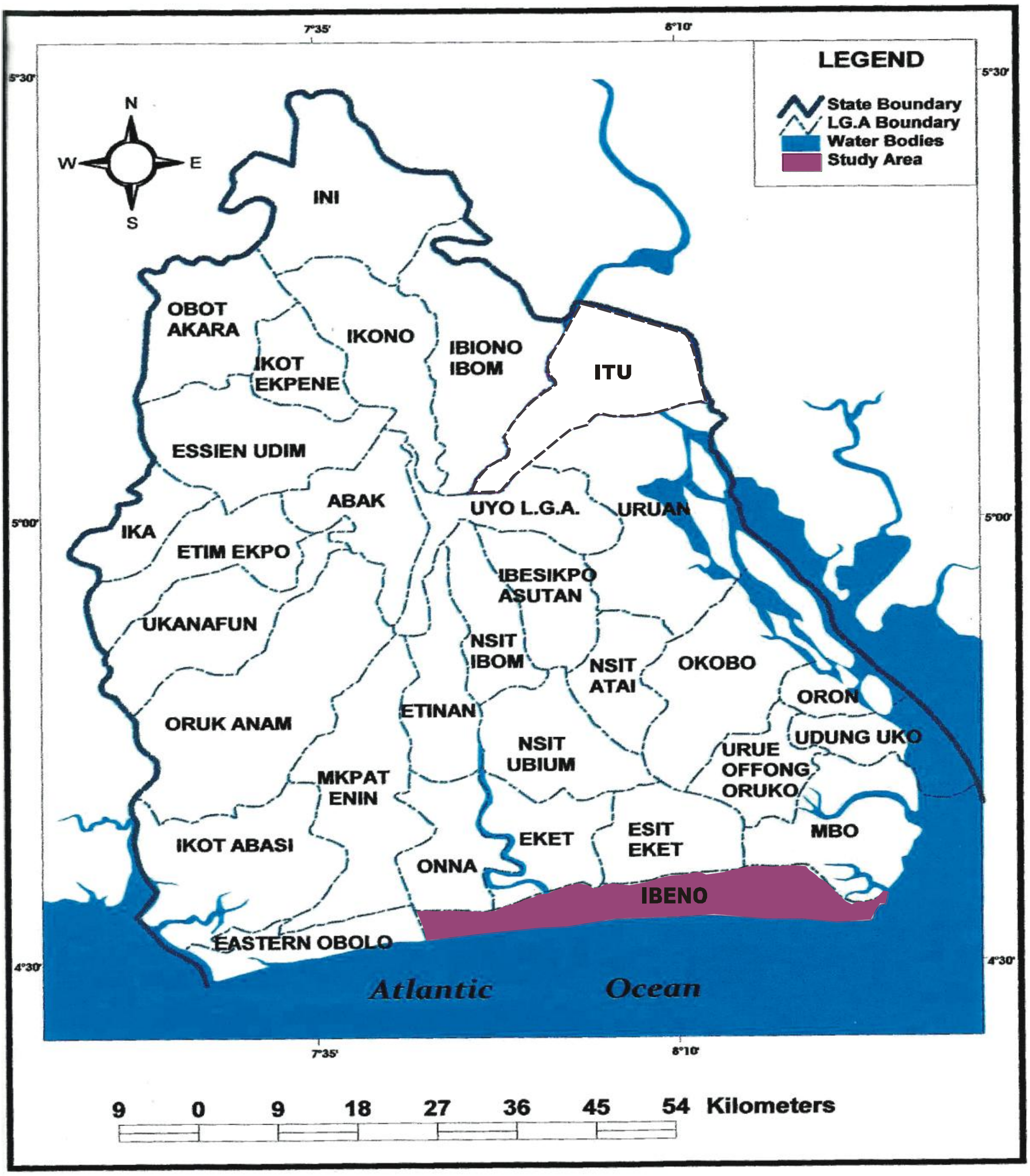


Figure 4: Map of Akwa Ibom State showing Ibeno L.G.A - the study area

2.2 Description of QIT Wastewater Treatment Plant

The sewage treatment plant is a factory package steel unit manufactured by Purcstream, Inc., Florence, USA. The system is based on the extended aeration method of sewage treatment. The method of treatment consists basically of four operations.

1) **Screening:** The first part of entry on sewage in the plant.
2) **Aeration:** Decomposition of sewage by aerobic bacteria and other organisms into carbon dioxide and water and other minor constituents.
3) **Settling:** The treated sewage passes to the settling chamber or clarifier. Here heavy activated sludge mass settles to the bottom while the clear water liquid flows over a vertical plate or weir into a discharge line.

4) **Chlorination:** The treated liquid (the effluent) from settling chamber is chlorinated to kill disease carrying (pathogenic) bacteria and treated effluent passes into the chlorine, usually for 30 minutes and pass out of the tank through the final plant discharge. See figures 2 and 3 respectively.

2.3 Experimental Methods

Samples were collected into sterilize plastic containers measuring about three litres and were clearly labeled for identification and then placed on ice until arrival at the laboratory where it was stored in a refrigerator at 2°C and they were allowed to freeze. Samples were collected at monthly interval between February, 2011 and May, 2011. The samples were collected at the following three points for analysis, influent line, aeration tank and the effluent end are were taken to the laboratory for the physical and chemical analysis.
The test conducted include: BOD, COD, TDS, pH, DO, Odour, Colour, temperature, TSS, Total Alkalinity, Oil and grease and total coliform per 100ml according to the standard method as described by (APHA, 1998).
The pH was determined by using electronic pH meters, model 240 with probe, screen and control knobs. The instrument was switched on and the probe inserted in beaker containing sample and the reading taken. The colour was visually determined.Also the total suspended solid (TSS) was determined by the use of DR 2010 spectrophotometer. The procedures are as described by (APHA, 1998). The dissolved oxygen (DO) was measured using the dissolved oxygen meter. The procedure was carried out by rotating the wave length dial gauge until the gauge display showed 535mm, then press the read/enter knob and fill a blue ampul cap with sample in the cell holder. Finally press read/enter knob and wait for the result to display for recording.The biological oxygen demand (BOD_5) was carried out by the method similar to (DO). In BOD_5 test, the water samples were incubated at 20°C for 5 days in the dark container. After one day incubation period, DO was measured as DO_1. The procedure was repeated for five days incubation dissolved oxygen, DO_5 and the difference between DO_1 incubation and DO_5 incubation period gave the BOD_5 measured in mg/l. The instrument used for the measurement of chemical oxygen demand (COD) are also described by (APHA, 1998).

III. RESULTS

The results of experimental analysis are presented in Tables 4, 5, 6 and 7 respectively.

Table 4: Wastewater characteristics in QIT Ibeno for the month of February, 2011

Parameter	Influent		Aeration Tank		Effluent		Remarks
	MHE Phase 1	MHE Phase 2	MHE Phase 1	MHE Phase 2	MHE Phase 1	MHE Phase 2	Percentage reduction
Odour	Foul smell	Foul smell	Foul smell	Foul smell	AHL No smell	AHL No smell	No smell
Colour	Black	Black	Black	Black	Clear	Clear	Clear
Temperature (°C)	30.5	29.4	29.6	29.4	28.20	28.20	Normal temperature
PH	5.54	6.50	5.34	6.20	5.66	6.80	Equilibrium
TSS	4000	3000	3000	2300	45	45	1.23
TDS	8500	6000	2190	2080	3400	2800	32.94
Total Alkalinity	150	140	140	130	130	120	80
Dissolved Oxygen (DO) (mg/l)	10	8	10	8	4.5	4.0	40
BOD_5 (mg/l)	213.5	200	180	120	108	70	32.79
COD (mg/l)	131.2	100	95	80	81	65	49.54
Oil and grease	12.8	5.6	8.6	2.04	5.6	0.04	0.31
Total coliform per 100ml	1000	950	850	700	240	210	21

Source: Author’s field work (2010)

Table 5: Wastewater characteristics at QIT Ibeno for the month of March, 2011

Parameter	Influent		Aeration Tank		Effluent		Remarks
	MHE Phase 1	MHE Phase 2	MHE Phase 1	MHE Phase 2	MHE Phase 1	MHE Phase 2	Percentage reduction
Odour	Foul smell	Foul smell	Foul smell	Foul smell	No smell	No smell	No smell
Colour	Black	Black	Black	Black	Clear	Clear	Clear
Temperature (^oC)	29.8	29.6	30.0	29.6	29.5	28.0	Normal
pH	5.60	6.4	5.84	6.10	5.81	7.01	Equilibrium
TSS	4050	3100	3100	2200	46	45	1.11
TDS	8600	6108	2200	2050	3200	2500	29.07
Total Alkalinity	152	139	138	130	136	129	84.87
Dissolved Oxygen (DO) (mg/l)	10	8	10	8	4.5	4.0	4.0
BOD_5 (mg/l)	220	130	130	100	90	70	53.85
COD (mg/l)	135.2	90.5	90.0	80	65	60	44.38
Oil and Grease	12.50	5.20	4.20	3.00	2.10	0.06	0.48
Total coliform per 100ml	1010	950	800	700	220	190	18.81

Table 6: Wastewater characteristics at QIT Ibeno for the month of April, 2011

Parameter	Influent		Aeration Tank		Effluent		Remarks
	MHE Phase 1	MHE Phase 2	MHE Phase 1	MHE Phase 2	MHE Phase 1	MHE Phase 2	Percentage reduction
Odour	Foul smell	Foul smell	Foul smell	Foul smell	No smell	No smell	No smell
Colour	Black	Black	Black	Black	Clear	Clear	Clear
Temperature (^oC)	30.10	29.2	29.0	29.0	28	28	Normal
pH	5.32	5.61	5.50	6.20	5.71	6.91	Equilibrium
TSS	4010	3150	3100	2100	47	44	1.1
TDS	8710	6410	2300	2100	3100	2200	25.26
Total Alkalinity	150	141	139	129	129	128	85.33
Dissolved Oxygen (DO) (mg/l)	10	8	9	8	5	4.5	45
BOD_5 (mg/l)	225	132	132	105	95	75	33.33
COD (mg/l)	137	92.5	91.50	81.0	64.5	59.5	43.43
Oil and Grease	12.80	5.40	4.10	3.20	2.80	0.09	0.70
Total coliform per 100ml	1000	900	780	670	210	180	18

Table 7: Wastewater characteristics at QIT Ibeno for the month of May, 2011

Parameter	Influent		Aeration Tank		Effluent		Remarks
	MHE Phase 1	MHE Phase 2	MHE Phase 1	MHE Phase 2	MHE Phase 1	MHE Phase 2	Percentage reduction
Odour	Foul smell	Foul smell	Foul smell	Foul smell	No smell	No smell	No smell
Colour	Black	Black	Black	Black	Clear	Clear	Clear
Temperature (^oC)	30.51	29.50	29.40	29.40	28.50	28.50	Normal
pH	5.60	6.50	5.80	6.25	5.78	7.01	Equilibrium
TSS	4000	3100	3100	2100	45	45	1.23
TDS	8600	7100	2090	2070	3500	2700	31.40
Total Alkalinity	152	148	148	130	140	120	78.95
Dissolved Oxygen (DO) (mg/l)	10	8	10	8	5	4.0	40
BOD_5 (mg/l)	250	230	103	95	90	70	28
COD (mg/l)	140	100	98	97	80	65	46.43
Oil and Grease	9.0	7.0	8.90	5.20	4.10	0.05	0.56
Total coliform per 100ml	1000	900	800	600	200	170	17

IV. DISCUSSION OF RESULTS

The result in Table 4 shows that the effluent wastewater has no smell, shows clear colour, normal temperature and equilibrium pH value while the TSS, TDS and total alkalinity reduces by 1.23, 32.94 and 80% while the DO increases by 71.43% with the reduction of BOD_5, COD and oil and grease by 32.79, 49.54 and 0.31% showing high performance of the treatment plant.

Similarly, Tables 5, 6 and 7 also show similar results with the total coliform decreasing by 21, 18.81, 18 and 17% respectively showing high performance of the treatment plant. From Tables 4, 5, 6 and 7, it was observed that the influent values of the wastewater characteristics were high and begins to show some reduction from Phase 1 and 2 of the aeration tank and gives a remarkable result at the effluent in Phase 1 and 2. The final results are as shown in the histogram in Figure 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 and 16 respectively. The results of the wastewater treatment plant (ASWTP) has good potential to produce high quality effluent analysed for the months of February, March, April and May, 2011 respectively. The results are as discussed below:

[1] **pH:** The pH gives equilibrium values in all the months the samples were analysed.

[2] **TSS and TDS:** The TSS and TDS resulted in 1.23, 1.11, 1.1 and 1.23% while the TDS gives 32.94, 29.07, 25.26 and 31.40% reduction.

[3] **Total Alkalinity:** The total alkalinity decreases by 80, 84.87, 83.55 and 79.95% as shown in Tables 4, 5, 6 and 7 respectively.

[4] **Dissolved Oxygen:** The aeration system treatment relies on oxygen for it treatment. Hence the DO reduces by 40, 45 and 40%.

[5] **BOD_5 and COD:** The BOD_5 and COD give an indication to the treatment plant. From Tables 4, 5, 6 and 7, it shows that BOD_5 reduces by 32.79, 53.85, 33.33 and 28% while the COD values reduces by 49.54, 44.38, 43.43 and 46.43% respectively, showing the performance of the treatment plant.

[6] **Oil and Grease Values:** The oil and grease values also decreases to 0.31, 0.48, 0.70 and 0.56% respectively.

[7] **Total Coliform per 100ml:** From Tables 4, 5, 6 and 7, the total coliform per 100ml decreases by 21, 18.81, 18 and 17% respectively.

V. CONCLUSION

[1] Based on the result of this study, the following conclusion can be drawn:

[2] The wastewater in the aeration tank has foul smell and black colour. This indicates that the sewage was septic due to insufficient aeration and after treatment the effluent produce has no smell and clear colour.

[3] The wastewater was strong on BOD basis but high on SS content. The low BOD of waste treatment or even high volume of water usage that dilutes the sewage.

[4] The operators of sewage treatment plant could not monitor the degree of waste treatment or even ensure its sufficiency because they did not carry out daily measurement of parameters such as sludge solids volume, dissolved oxygen and pH.

[5] Although some of the effluent results meet DPR/WHO standard, they are deficient in the areas of total alkalinity.

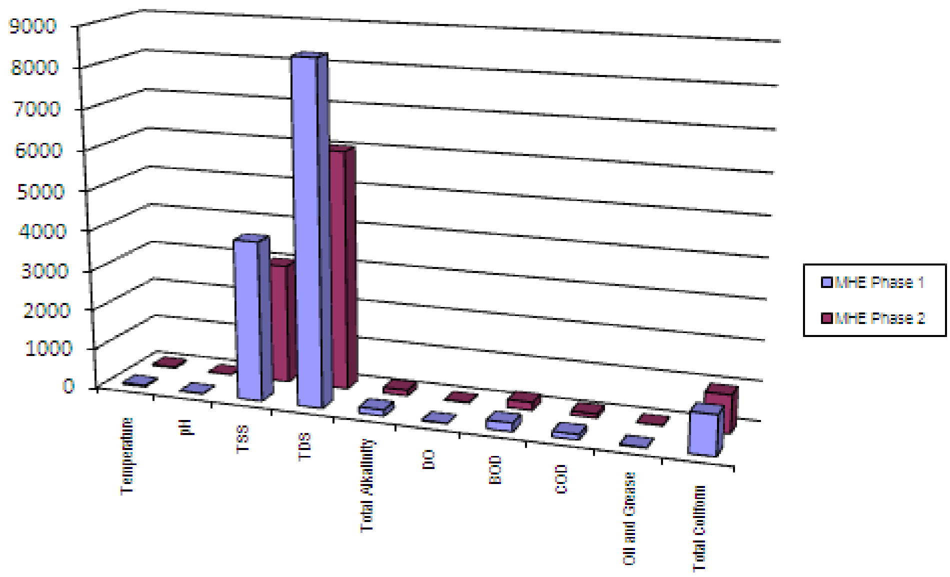


Fig. 5: Influent Characteristics

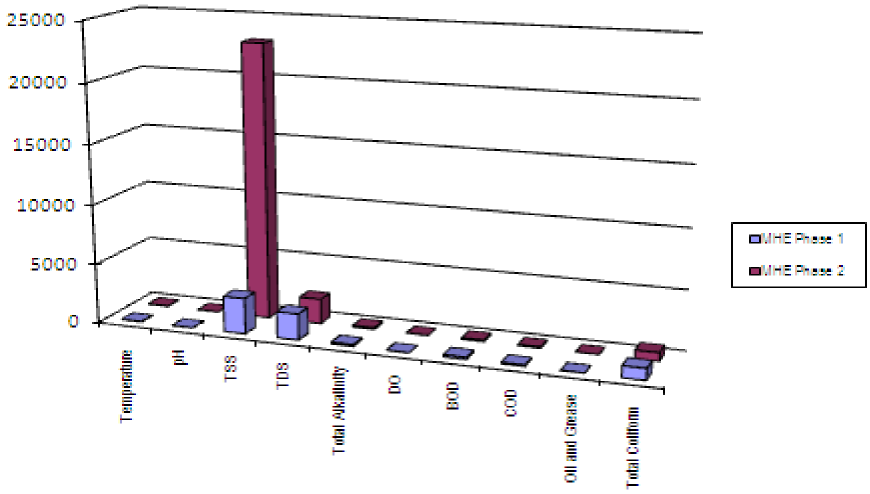


Fig 6: Treatment Plant Aeration Tank Characteristics

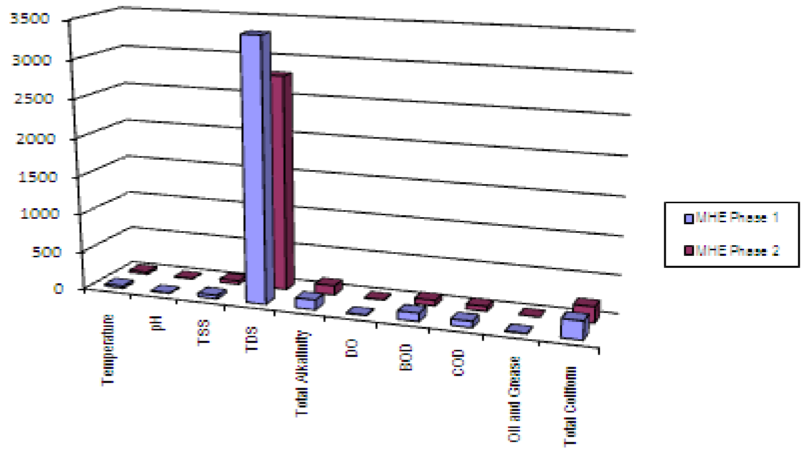


Fig. 7: Effluent Characteristics

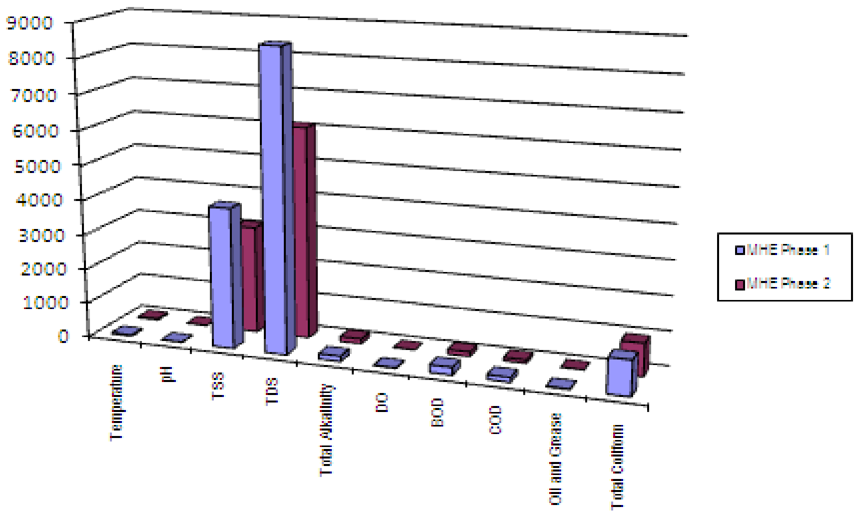


Fig. 8: Influent Characteristics

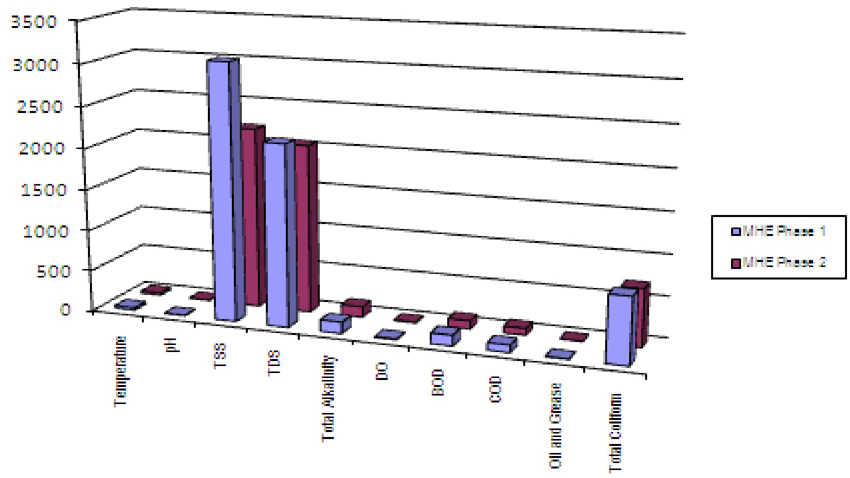


Fig. 9: Treatment Plant Aeration Tank Characteristics

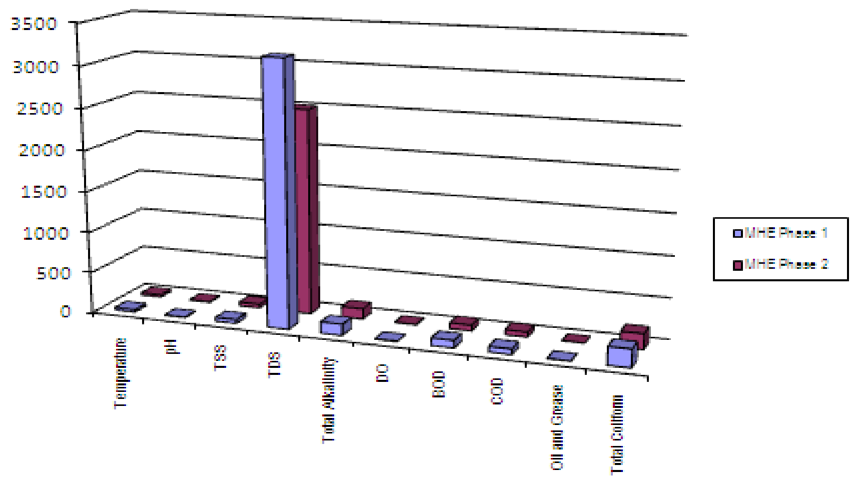


Fig. 10: Effluent Characteristics

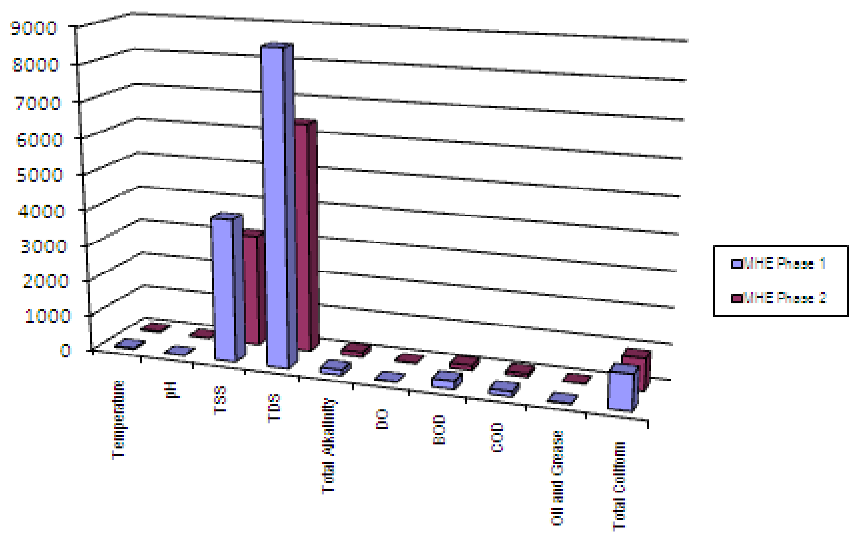


Fig. 11: Influent Characteristics

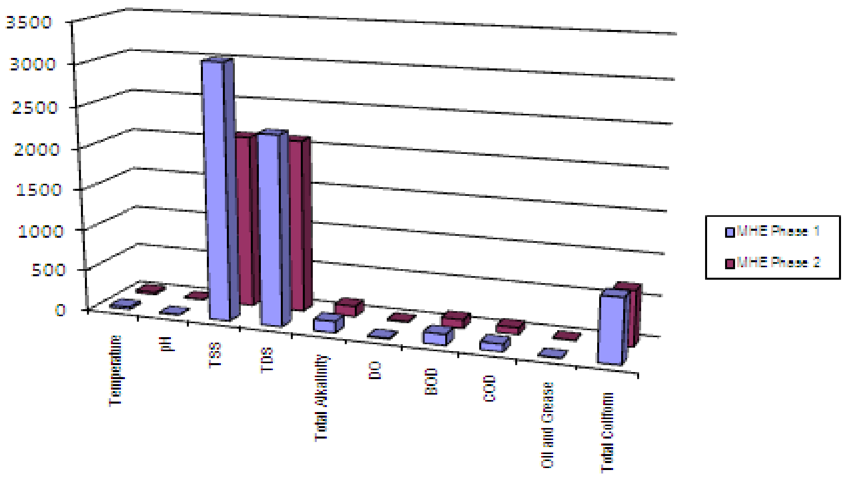


Fig. 12: Treatment Plant Aeration Tank Characteristics

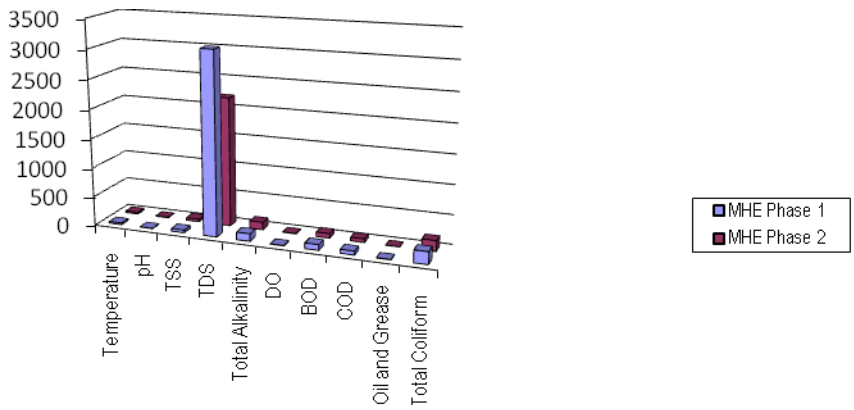
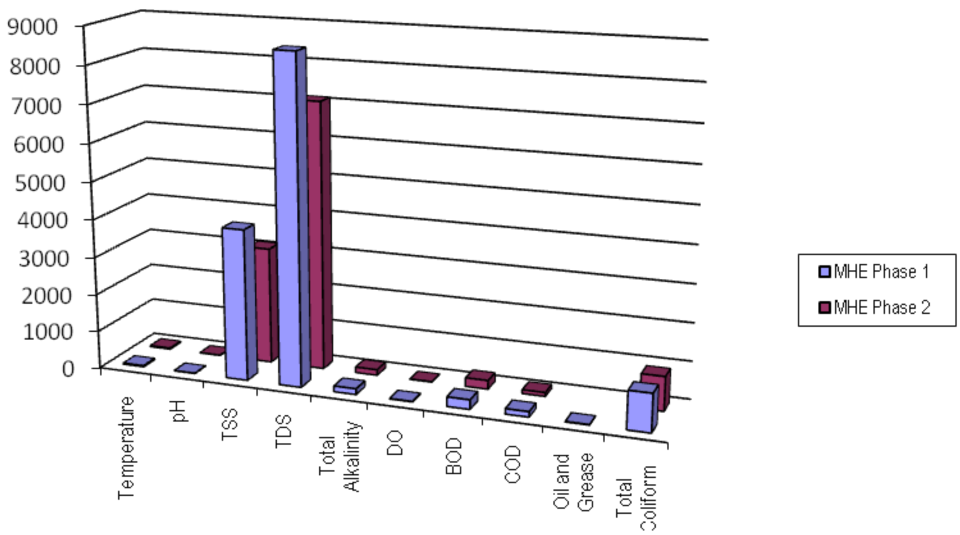


Fig. 13: Effluent



Characteristics

Fig. 14: Influent Characteristics

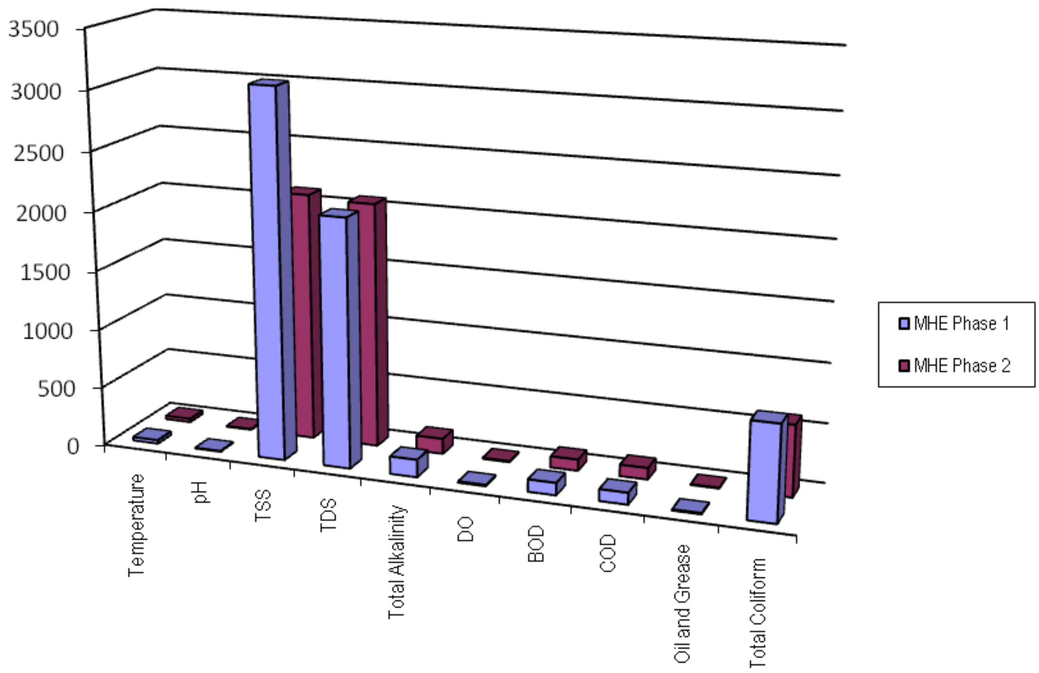


Fig. 15: Treatment Plant Aeration Tank Characteristics

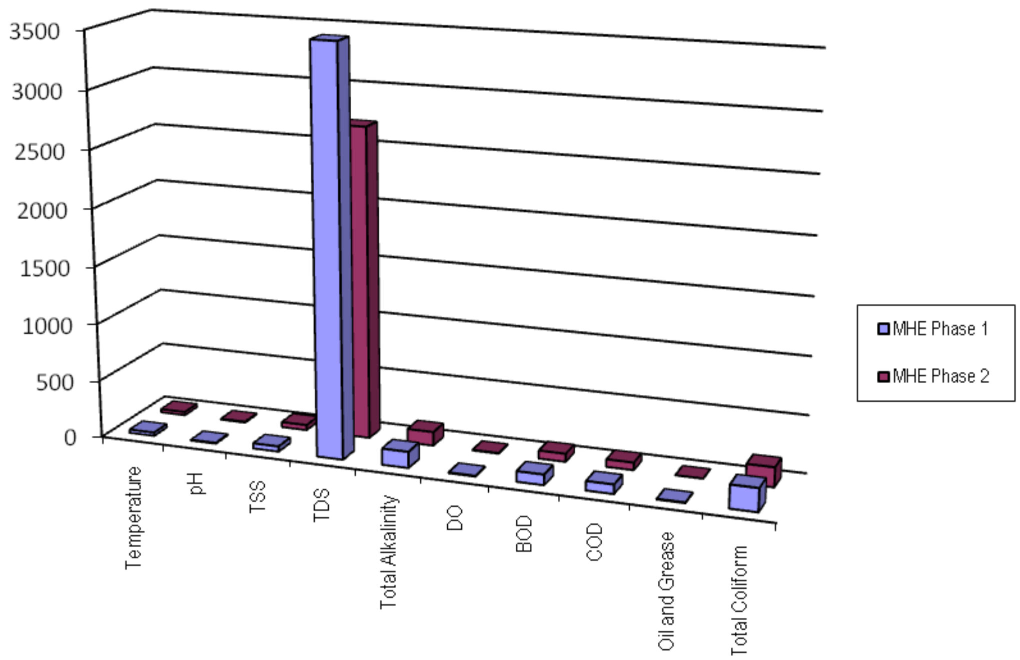


Fig. 16: Effluent Characteristics

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