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Research Article

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Physico-chemical Analysis of Effluent Wastewater from Petrochemical Industry

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Abstract The safety of the human environment takes precedence in every process design considerations. The wastewater emanating from process industries should be such that would not destabilize the aquatic ecosystem and entire biodiversity. The contaminants from these processes industries have deleterious impact on the health of plants and animals that inhabit the receiving environment. The aim of this study is therefore to analyze given samples of effluent from petrochemical industry in order to find out the amount of the basic pollution parameters present so as to establish the extent of safety of the receiving waters and entire human environment. The characteristics tested for include: temperature, sulphate ion, phosphate ion, chloride ion, total dissolved solid, total suspended solid, pH, conductivity, phenols and heavy metals. These parameters were however found to agree in amount to the standards set by DPR and WHO (2001) and Federal Environmental Protection Agency (FEPA).

Keywords Petrochemical effluent, chemical treatment, biotreatment, remediation.

Introduction

The activities of process industries are such that the overall effect is the production of useful output accompanied by waste generation. From economic view point, the operations of petrochemical industries achieve maximum economic results via manpower and industrial development, hence the ever increasing need to develop and expand the industry for higher output scale. However, the expansion of petrochemical plants and other industries in the country creates some negative economic and environmental consequences [1]. This industry being involved in continuous daily operations of complex process plants generate liquid wastes referred to as effluents which are usually discharged by means of pipes to a unit designed for treatment before they are finally discharged. For the safety of human lives and the environment, these waste products have to strictly undergo both chemical and microbiological evaluation prior to discharge into the environment [2-3]. Useful products from such industries may include polypropylene, ethylene, butane, aromatics.

The quality of water depends largely on its physico-chemical and biological characteristics [1]. For example, the presence of these organic matters in wastewater leads to oxygen depletion and foul odour [4]. Also the presences of suspended solid particles which essentially is directly linked to the cloudiness of the liquid (turbidity) and also provide a site for attachment of bacteria [5] also constitutes a major challenge. The first step necessary to ascertain the treatability of wastewater is its characterization [2]. This research work therefore focuses on the analysis of petrochemical effluent from the point of generation, treatment and disposal employs the available standard techniques to explore, analyze and characterize the effluent specimens from various points. These waste waters emanate from sources such as: process water, oily rain water (contaminated rain water), sanitary effluent containing faecal matter and coliforms [6-7] dimersol effluent, chemical wastewater, boiler blowdown and clean water system. These waste waters if allowed into the environment at its exit temperature could limit the volume of oxygen available for aquatic life [8] and also pose negative chemical and biochemical consequences on the receiving water bodies [9-10]. Hence, adequate treatment strategies need to be put in place in order to limit their potential disastrous effects as far as reasonably practicable. Petrochemical effluent treatment is a stagewise operation involving is a battery of process units (basins): *equalization (sewage holding) basin*, *rapid mixing basin*, *flocculation basin, dissolved-air floatation basin, biological treatment basin and clarifier basin.* Effluent pollution parameter analysis serves as a source of useful information needed to establish the type, nature and characteristics of effluent components required for statistical validity for making valuable industrial process decisions.

Although the ideal and most effective method of controlling petrochemical effluents discharges is to eliminate at source and or adjust the chemistry of the manufacturing process to generate little waste, such a process modifications and plant control practices are however often impracticable from a technological and economic point of view.

Materials and Method

The wastewater samples for analysis were collected from petrochemical plant located in southern Nigeria. The collection points were the equalization basin (process wastewater), rapid mixing basin, flocculation basin, dissolved air flotation basin (DAF) and sanitary wastewater. All beakers, flasks, pipettes, burettes, measuring cylinders, funnels used for the laboratory analyses were made of glass. These glasswares were rinsed with distilled water and dried in an oven at 105 °C, pipettes and flasks were soaked in concentrated chromic acid washing solution overnight before rinsing and use. Plastic wares such as wash bottles were washed with soap and dried in drying racks overnight. All chemicals and reagents used were of high grades. Anhydrous salts were properly dried and desiccated before use. Distilled water was used for all reagent preparations and dilutions. Analytical balances of accurate precisions were used for weighing samples.

Table 1: Utilities and chemical requirements

Chemicals	**Doses/day**
Sulphuric acid as 98% H_2SO_4	Max: 300 kg/d
Sodium hydroxide as 30% NaOH	Max: 270 kg/d
Alum as 100% $Al_{2}(SO_4)_3.18H_2O$	Max: 110 kg/d
Nutrient as $NaH_2PO_4.H_2O$	Max: 60 kg/d
Cationic polyelectrolyte as 100%	Max: 3 kg/d
Calcium hypochlorite as 65%	Max: 131 kg/d

Table 2: Effluent Quality Analysis

Effluent parameter test	**Test procedure**	**Method/Instrument**
Temperature (°C)	Use of mercury–in-glass thermometer.	Thermometry/Mercury-in-glass thermometer.
pH	The amount of hydrogen ions present in the sample	Digital pH meter
Total suspended solid (TSS)	Taking the difference between TDS and TSS	Evaporation/ evaporating dish, heat, filter paper.
Total dissolved solid (TSS)	Evaporate sample to dryness by heat	Evaporating dish, filter paper, weighing balance, pipette, sample.
Total solid (TS)	Evaporate sample to dryness by heat	Evaporating dish, filter paper, weighing balance, pipette, sample.
Dissolved oxygen	Amount of oxygen available in the sample	Iodometric (Titrimetric) method

(DO) (ppm)		
Magnesium	Chemical analysis by titration	Titrimetric method
Calcium and magnesium in add mixtures	Titration of hydroxylamine hydrochloric salt against sample wih solochrom black T indicator.	Titrimetric method/ Pipette, conical flask and burette
Calcium	Titration of sample with a mixture of KOH and hydroxylamine hydrochloric salt	Titration/ conical flask, pipette, burette
Lead	Chemical analysis/ absorbency test at 430 nm	Volumetric flask, pipette and spectrophotometer
Phenol	Absorbance of the sample read off at 500nm in the uv spectrophotometer	Absorbance test/ measuring cylinder, volumetric flask, bench reagents.
Phosphate (PO_4^{3-})	Chemical analysis/ absorbency test at 735 nm	Volumetric flask, measuring cylinder, pipette, cuvette, Bausch and Lomb spectrophotometer.
Sulphate ion (SO_4^{2-})	Chemical analysis using $BaSO_4$ and $MnSO_4$ and test for absorbance	Absorbance test/Barium sulphate, beaker, $MnSO_4$
Conductivity	Amount of ions presents.	Conductivity meter
Chloride (Cl^-)	Sample plus K_2CrO_4 with $AgNO_3$	MOHRS method/ conical flask, burette, pipette.
Bicarbonates (HCO_3^-)	The decrease in absorbance measured at 366 nm is proportional to the amount of the bicarbonate present in the effluent sample.	Chemical analysis using CDR apparatus
Alkalinity	Titration of sample with HCl using phenolphthalein and methyl orange indicators	Double indicator titrimetric method

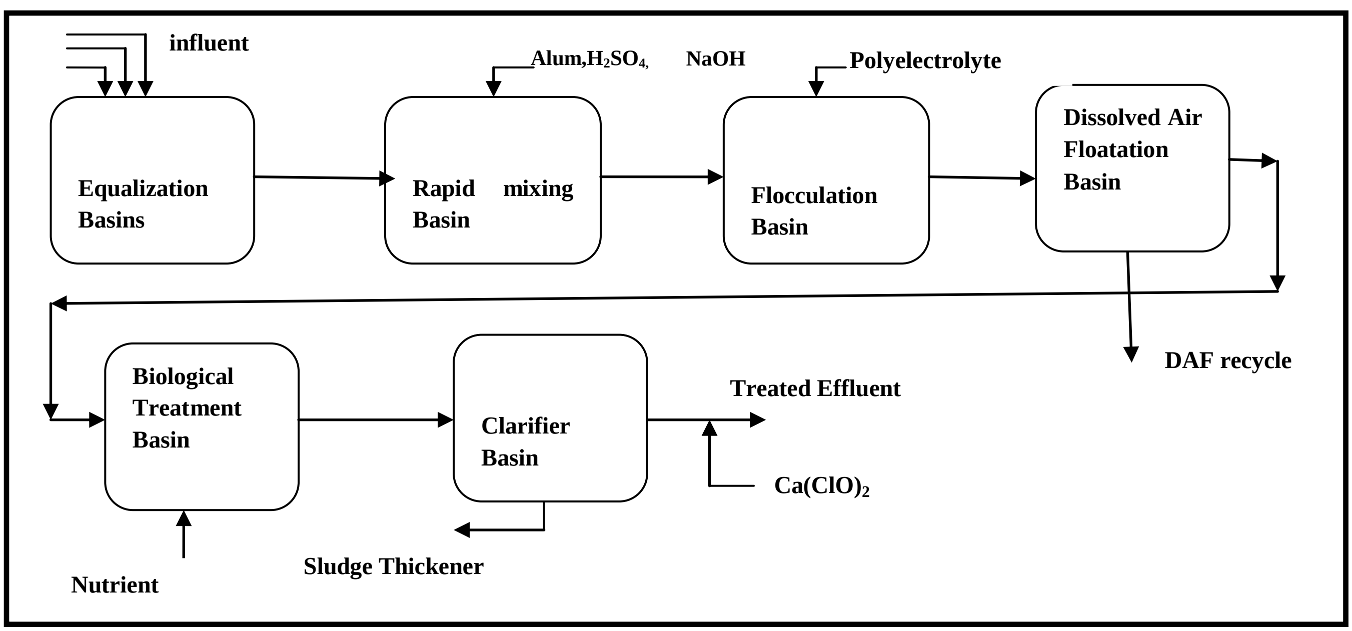

Figure 1: Flow Chart for petrochemical Effluent Treatment plant

Experimental Results

Parameter	**Process wastewater**	**Effluent from DAF basin**	**Effluent from clarifier basin**	**Sanitary wastewater**	**Final discharge wastewater**
Temperature (°C)	29.10	29.10	29.8	30.50	28.1
pH	6.90	6.92	7.90	6.95	6.92
Total susp. solid	600	56.70	55.00	171.7	101.21
Total diss. solid	1880	81.90	36.51	949.33	564.7
Total solid	2480	138.60	91.51	1221.03	665.91
Dissolved oxygen	5.6	5.8	5.2	6.1	4.8
Sulphur	0.20	0.17	0.06	0.86	0.002
Calcium	0.25	1.83	0.766	0.573	0.94
Lead	0.10	0.001	0.058	0.007	0.092
Magnesium	0.35	0.01	0.01	0.01	0.01
Phenol	8.48	0.737	3.47	4.016	8.24
Phosphate	0.205	0.0352	0.043	1.0473	0.028
Sulphate	19.75	170.08	83.00	65.09	16.05
conductivity	428.70	123.0	57.56	1424.0	847.0
Chloride	2700	1600	285.6	208.7	44.375
Bicarbonates	30.5	24.50	19.23	29.00	18.30

Discussion of Results

The purpose of testing is to determine the average concentrations of several parameters which affect the quality of the industrial effluent with a view to assessing their controllability before discharge to the human environment. These basic components or characteristics of the petrochemical industrial effluent are sourced from equipment such as boiler blowdown, polypropylene plant, polyethylene plant, sanitary stream and miscellaneous sources.

The successive treatment stage of effluent from petrochemical plant ranges from physical, chemical to biological methods. The physical methods utilize gravity, and filtration equipment operations. The chemical methods employ the use of sulphuric acid, sodium hydroxide, nutrients, cationic polyelectrolyte, alum. The biological treatment is fixed bet type loaded with various bacteria such as *sarcodina, flagellate protozoa, ciliated protozoa, free ciliated protozoa, pedunculate ciliated protozoa, suctoria, and rotifers.*

Such parameters tested for include: TSS, pH, temperature, toxicity, turbidity, heavy metals, phenol, benzene, ethylbenzene, oil and grease, dissolved oxygen, biochemical oxygen demand, alkilinity, sulphate ion, and phosphate ion. The value of each parameter was compared with standard values set by DPR and WHO for treated water quality to ascertain their level of concordance. Environmental Protection Agency (EPA, 2018) recommended an acceptable pH range of 6.5 to 8.5 for municipal drinking water The heavy metals: lead, copper, manganese, calcium, and magnesium, were analyzed usng the Atomic Absorption Spectrophotometer (AAS) (Spectronic 20 model). The levels of absorbance of these metals of ultra violet light were detected for each metal and recorded. Calcium and magnesium were analysed for concentration and hardness in the sample and the values obtailed found to agree with the standards.

With the aid of mercury-in-glass thermometer the temperatures of the samples were measured and the results were within the DPR acceptable limit of 30 °C. However sanitary wastewater showed an exceptional value of 30.5 °C which is a little above the standard.

The results obtained for pH values for various samples all fall within the required range as set by WHO as 7-10 and DPR as 6.5-8.5.

Conductivity, which is an indication of the amount of ions present in the waste water [11-12] as determined using a conductivity meter indicated a downward trend in the potential levels from process waste water sample to the final discharge sample. The conductivities of the DAF basin sample, process wastewater, clarifier water and final discharge sample fall within the acceptable WHO range of <10,000, however, not applicable to drinking water.

The total dissolved solid, TDS was found to decrease along the treatment stages. The application of polyelectrolyte (a coagulant) in the rapid mixing basin induced coagulation of particles [13] which settled as sludge in the DAF basin. However the TDS of sample at the final discharge point was found to be unexpectedly high compared to that of portable water due to addition of some chemical agents such as calcium hypochlorite, and also coliforms from biological basin, though still within the DPR and WHO standard ranges. The tendency might have arisen from the uncontrollable faecal matter of coliform in the chemical utilities and also due to atmospheric influence. The overall effect of these affected boat the conductivity and absorbance of the sample at that point.

During the analysis to determine the phosphate in the sample, is was found that the concentration varies from one stage of the effluent to the other. In fact the values were found to decrease along the treatment stages with the least value at the final discharge point. The amount of phosphate in the sample from DAF basin is exceptional high. This may have been as a result of the oil component of the sample in the unit.

Phenol was also found to be in excess amount in most of the samples than expected. This may have been due to the continuous atmospheric oxidation of the hydrocarbon in the sample.

The concentration of chlorides and bicarbonates were found also to decrease along the treatment stages with the effluent from the final discharge point having the least value. The implication of this is that the effluent discharged into the environment is considered safe and less hazardous to aquatic life.

The concentration of lead in the effluent sample was found to be within WHO and DPR limits. However, when compared with the effluent form petroleum refinery, it was found that lead content of petrochemical effluent is relatively high. This may have been because the refinery process plant produces high octane number gasoline without the addition of tetraethyl lead as anti-knock agent.

Finally, the values of the effluent water parameters obtained for the treated water, though within acceptable WHO and DPR safety limits, do not guarantee its suitability fo drinking. The specific contaminants such as phenol, ethylbenzene, benzene, toluene, impart some odour that discourages consumption. Beside the presence of faecal coliform, aggregates of microorganisms which escaped treatment mabes the water unsafe for human consumption. However in order to further control the effect of these microorganisms, the waste water is usually chlorinated before discharge. Hence, effluent analysis is an important aspect of every industrial process as it provides useful information on the specific amount of constituents of the waste, the types of constituents, their possible effect of the ecosystem when the waste is discharged finally on the sub-surface.

Conclusion

The whose purpose was to analyse the content of petrochemical effluent with respect to its physicochemical characteristics (TSS, TDS, heavy metals, Dissolved oxygen, sulphate, phosphate) showed that the wastewater at final discharge orifice contained contaminants whose level was within permissible limit by WHO and FEPA. However, the treated water at that state was not suitable for drinking or any form of domestic use.

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