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Determination of Physicochemical Properties of Wastewater from the Petrochemical Industry

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Abstract
Industrial wastewater has been a significant source of environmental pollution for quite a long time. Therefore, it is very essential to make sure that the wastewater discharged from a petrochemical plant meets the regulations set by the authorities. To confirm this fact, a study was performed as a reaction to the issues raised by determining the physicochemical parameters of the water samples taken from different locations and comparing their levels with those of the World Health Organization (WHO) standards and specifications. The standards have been adopted for all the tested parameters. Three of the measured parameters: pH, electrical conductivity (EC), and turbidity had values that were within the intervals of 7.3 – 8.2, 741 – 1297 µS/cm, and 26 – 71 NTU, respectively. The rest of the variables had ranges as follows: total dissolved solids (TDS, 401 – 619 mg/L); total suspended solids (TSS, 20–40 mg/L); dissolved oxygen (DO, 47–60 mg/L); chemical oxygen demand (COD; 87–130 mg/L); oil and grease (O&G, 2–10 mg/L); biochemical oxygen demand (BOD, 12–20 mg/L).

Keywords: Water, wastewater, pH, Turbidity, Total Suspended Solids, Total Dissolved Solids, Conductivity.

Introduction

Water is the main source that makes life possible on the planet and is thus the most valuable natural resource by far. People were given water for free by nature but are still using it in a manner that is not sustainable. The water issue is a good example of a paradox - that while the number of water-scarce areas keeps growing, water is still being wasted, polluted and distributed unevenly in some parts (Usharani et al., 2010).

Water without a doubt is the factor that keeps the world running and one of the most valuable gifts of Mother Nature along with air and soil. Yet, the paradox of human water consumption which is the worst problem keeps deteriorating is paradoxical - as the shortage of water is increasing, water is being wasted, polluted and unevenly distributed in different places. Besides, water pollution, to which contributes the water shortage, in some areas, is a cause of the crisis of fresh water in others, while the phenomenon of freshwater being wasted in regions that have access to clean water is happening (Baroni et al., 2007).

Water is the second most basic human need after food and the source of all life. However, the resource that nature has bestowed upon mankind and all other living creatures on earth has been taken for granted. Water has always been there but it still follows the same natural laws and rules as before and weather is still a very important factor. So water will be at the forefront of many basic commodities rising in price rapidly and in the same way as many other basic commodities in the future.

Actually, water is the primary source of life on the planet, the essential factor that builds and maintains the biological and ecological equilibrium in nature that still considers the water supply, but humans continue to exploit water resources without any signs of remorse and self-destruction is the inevitable outcome of such behavior. The life of humans without water is hard to imagine as water is the largest and most significant single natural resource in the world and the main catalyst in the progress of human society.

Close to 70.9% of the earth's surface is covered with water which is a very necessary source for all living beings on the planet. Water is one of the most abundant elements in nature, and at the same time, it possesses the characteristics of a chemical compound and is clear, tasteless, odorless, and almost colorless (Baroni et al., 2007). Water makes rivers, lakes, and oceans on the earth and is also the main fluid in most living beings. Nevertheless, water that requires no calories or organic nutrients is still absolutely necessary to life.

Water, is one of the most essential natural materials, is, however, the worst of global resources in terms of management. The quality of water has been deteriorating at a very rapid speed and the main causes of this are waste disposal through non-scientific methods, water resources mismanagement, and the outbreak of lack of care for nature, which, in turn, results in drinking water shortage that adversely affects people's health (Agarrkar & Thombre, 2010). Water is a potable one only if it meets the physical, chemical, and microbiological criteria that ensure the water is safe for drinking and other domestic purposes (Tebutt, 1983).

The study of water bodies indicates that pollution has been substantially elevated recently, which has caused both the environment and public health to be heavily endangered, and therefore, the surface water quality (streams, lakes, ponds, and rivers) has been decreasing due to the discharges of the untreated sewage effluents and other wastes into these bodies. That is the reason why the chemical and physical parameters are being checked for the provided system. Wastewater refers to water that has been contaminated with human or domestic waste and water that has been polluted as a result of human activities. Wastewater may be a product of Industrial, commercial, and agricultural activities; Surface run-off or stormwater; and any Sewer inflow or Sewer infiltration (Tilley et al., 2014). Wastewater contains physical, chemical, and biological pollutants.

Industrial releases after industrial activities have been leading among the major environmental problems that the world is facing. The wastewaters that are discharged to the water resources are full of human waste, chemicals, and heavy metals. This way of waste generation has caused the disappearance of aquatic food chains, and in addition, it threatens human health.

Besides, almost all industrial and domestic wastes have been disposed of in water bodies such as rivers, lakes, oceans, etc. This has caused severe pollution of water bodies due to industrial activities and other human-induced activities. The wastes that have been dumped are highly dangerous for the environment and have become the main causes of environmental degradation for the last years period (Ethan et al., 2003). The introduction of such substances into the environment can lead to a wide range of implications that can be both direct and indirect, the ecosystem.This research is confined to the evaluation of wastewater from the petrochemical industry that may contain pollutants such as petroleum hydrocarbons, heavy metals, and various acids, alkalis, ammonia, and other chemicals that may drastically alter the physic-chemical properties of water. From a chemical point of view, all these are extremely dangerous and can even be lethally toxic to fish and other aquatic fauna. (Chakravarty et al., 1959).

The aim of this research is to determine the physicochemical properties of waste water from a petrochemical industry. In other to achieve this aim, the specific objectives were set as follows;

i. Determine the physicochemical properties of waste water collected from discharge sites of a petrochemical industry.
ii. Employ appropriate standard methods in the analysis of the waste water sample.
iii. Apply some statistical models to interpret the physicochemical properties of waste water from a petrochemical industry.
iv. Suggest appropriate measures for treatment of waste water before being discharged to the environment.

Materials and Methods

The reagents used for this laboratory work were analytical grade of high purity, therefore, they require no pre-treatment.

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Collection of water samples
The wastewater being tested is the discharge from the Eleme Petrochemical Industry. In addition, the wastewater samples were collected from the discharge point for six different sampling points between 7.00 am and 09.00 am daily for three days for the analysis of physicochemical parameters. The materials for the sampling containers are selected in such a way that they will not cause contamination of the sample by adding or reducing the actual concentration. Furthermore, the samples were collected in 2-liter adequately cleaned plastic containers and iced in coolers from the field to the laboratory for the analysis. Also, the samples that were not immediately analyzed were put in a refrigerator at 4°C.

Analysis of waste water samples for physicochemical properties
pH Measurement:
The pH of the wastewater was measured by a pH meter (Orion Digital pH meter).
Before measuring pH, the pH meter was calibrated via three-buffering solutions. The buffers used were 4.0, 7.0, and 10.0, and the pH meter automatically recognizes these points when it is in calibration mode.
Turbidity: Turbidity was determined by a turbidity meter (HACH 2100N). The turbidity meter was set with a formazin standard prior to measuring the samples. The formazin standard used for calibration were <0.1 NTU, 20NTU, 200NTU, 1000NTU, and 4000NTU.
Total suspended solids: Total suspended solids were measured by the HACH spectrometer (DR/890).
Conductivity: Conductivity was measured with the aid of a conductivity meter (Thermo orion 150A plus). The device was prepared with 0.01M KCL standard.
Total dissolved solids: The total dissolved solids were measured by drying the wastewater samples (AOAC, 1990).
Calculation;

$$\text{TDS (mg/L)} = \frac{(W2 - W1)\ X\ 10^6}{Volume\ of\ sample\ in\ ml}$$

Organic waste consumes oxygen during its decomposition. The dissolved oxygen in water was recorded with the help of a D.O meter.
Initially, the device was calibrated with a zero-solution.
Chemical oxygen demand (COD): The COD determination was very accurate with the help of a COD digester and a HACH Spectrophotometer at a wavelength of 600nm. The device was first calibrated with 100ppm and 500ppm COD standard solutions.

Biological oxygen demand (BOD): Besides that, extremely high levels of BOD in water may also indicate that oxygen in water will be used for the decomposition of pollutants, thus, it will be taken away from aquatic organisms (Narley et al., 2012).

BOD determination is made from the sample COD result. The accurate determination of the sample volume was carried out using the table below;

Sample volume	Measuring range (mg/l)	Factor
432	0 – 40	1
365	0 – 80	2
250	0 – 200	5
164	0 – 400	10
97	0 – 800	20
43.5	0 – 2000	50
22.7	0 – 4000	100

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Results

pH, turbidity and TSS results

The result of the pH, turbidity and TSS obtained in waste water samples from six (6) different stations are shown in Table 1. Also indicated, are Means ± standard deviations for each parameter.

Table 1. pH, Turbidity and TSS parameters of the waste water station samples.

Parameters	Unit	WHO STD	1	2	3	4	5	6
pH	-	6.0-9.0	7.4±0.12	8.2±0.12	8.1±0.25	7.8 ±0.29	8.2±0.12	7.3±0.25
Turbidity	NTU	-	62±2.49	52±2.49	55±2.49	38±1.25	71±2.36	26±1.63
TSS	mg/L	60	38±2.94	32±0.94	35±0.94	25±2.36	40±6.24	20±2.12

Values are represented as mean±SD.

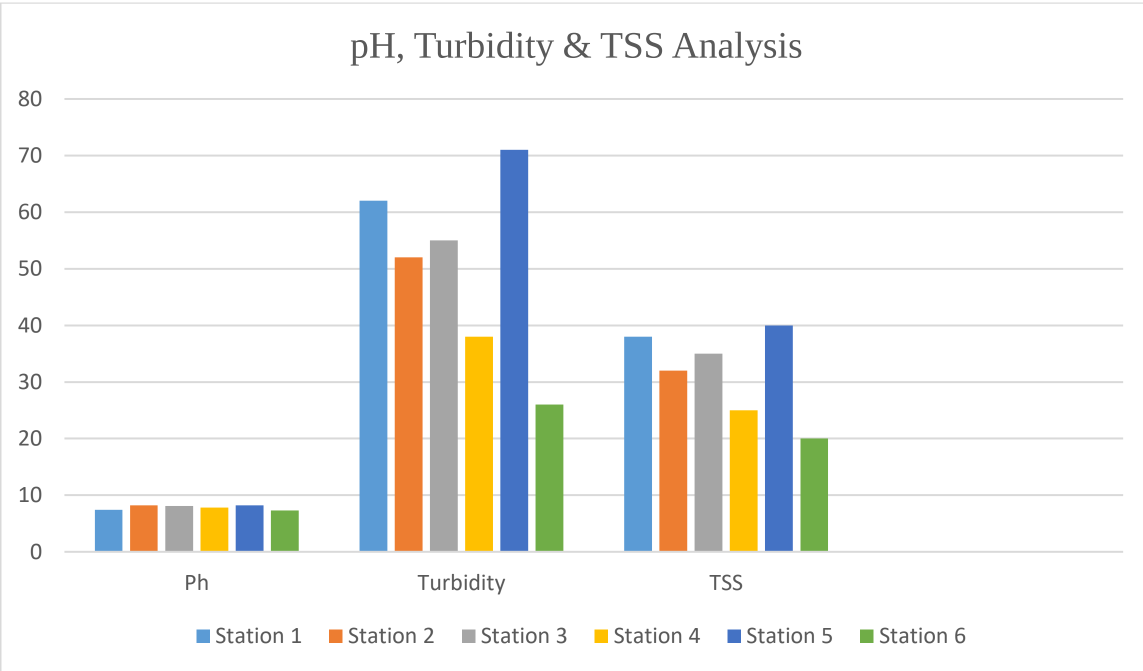

Figure 1: Clustered chart showing the ph, turbidity and TSS of waste water from different stations.

Conductivity and TDS Results

The result of the Conductivity and TDS obtained in waste water samples from six (6) different stations are shown in Table 2. Also indicated, are Means ± standard deviations for each parameter

Table 2. Conductivity and Total dissolved solids parameters of the waste water station samples.

Parameters	Unit	WHO STD	1	2	3	4	5	6
Conductivity	µs/cm	-	1205±12.0	953±61.4	1005±9.93	771±29.5	1297±134.2	741±32.2
TDS	mg/L	1500	533±28.1	496±31.8	598±59.56	404±36.54	619±53.71	401±32.1

Values are represented as mean±SD.

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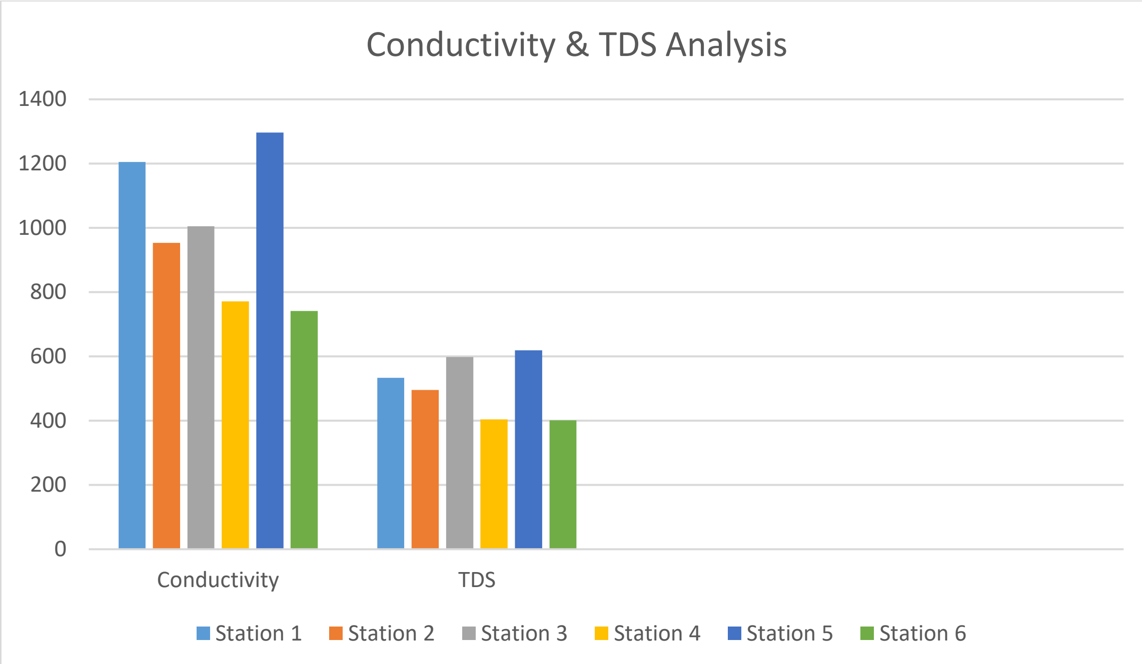

Figure 2: Clustered chart showing the Conductivity and TDS of waste water from different stations

Oil/Grease, DO, COD & BOD RESULTS

The result of the Oil/Grease, DO, COD & BOD obtained in waste water samples from six (6) different stations are shown in Table 3. Also indicated, are Means ± standard deviations for each parameter

Table 3. Oil/Grease, DO, COD & BOD parameters of the waste water station samples.

Parameters	Unit	WHO STD	1	2	3	4	5	6
Oil/Grease	mg/L	-	8.0±0.08	2.0±0.08	5.0±1.12	2.0±0.08	10.0±1.12	1.0±0.05
DO	µg/L	<1mg/L	50±4.08	52±2.35	50±2.36	47±4.71	55±4.08	167±14.36
COD	mg/L	150	120±4.08	98±4.71	95±4.71	87±6.24	130±2.36	75±6.24
BOD	mg/L	60	17±2.45	18±1.24	12±2.05	13±0.94	16±1.63	20±1.63

Values are represented as mean±SD.

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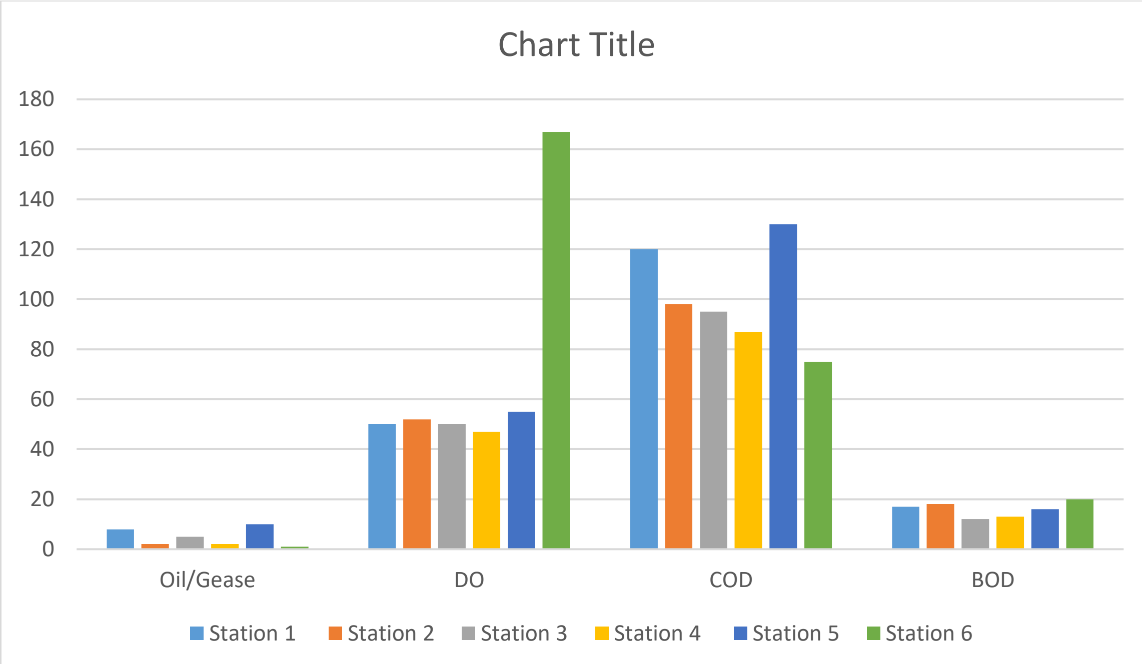

Figure 3: Clustered chart showing the Oil/Grease DO, COD & BOD of waste water from different stations

Discussion

Sewage water pH had the most significant impact on the overall situation of the water, out of all the factors that contributed to it. That is why it is mainly one of those waters that can cause the death of the entire biosphere if released directly. The changes in pH as well as the distances between the sampling points are presented in Table 1.

The pH values at different sampling points varied between 7.3 and 8.2. Points 1 and 6 were the nearest to neutral, while the others were more alkaline. The maximum pH value of 8.2 was found at both points 2 and 5. It can be assumed that the alkaline wastewater at these two points is a result of the presence of such substances as carbonates and bicarbonates that are normally added to cooling waters for production plants, caustic soda that is often used for acid gases absorption, and some other basic components. The present study revealed that the pH of the samples was in line with the WHO standards for wastewater parameters.

Moreover, turbidity was measured in the NTU unit, and Station 5 was the one to go up to its highest value, while station 6 had the lowest. The figures given stand for the changes in turbidity at the sampling points. The highest turbidity (71 NTU) was determined at station 5, and the lowest turbidity (26 NTU) was recorded at station 6. In addition, turbidities of stations 2 and 3 were nearly identical. Besides that, station 1 recorded a value that was a little bit more than 62. Turbidity is the extent to which water can absorb light, and it originates from very tiny particles in water of those stations where turbidity is being measured. Station 5 was much more turbidity than the rest of the stations. The most plausible causes could be the chemicals dissolved in the sample ponds, suspended solid particles, and run-off discharges.

TSS or Total Suspended Solids is a very significant matter that mainly concerns the amount of particulate matter that is suspended in water. In addition, TSS, as an indicator of the pollution level of wastewater, may also become a major source of water turbidity (Sulaiman et al., 2016). The lowering of TSS has brought their concentration levels in all sampling locations to be in line with the WHO standards. On top of that, the amount of TSS varied from 20 to 40 mg L-1. We can observe the TSS problem at different places on the graph, and the result is that the TSS levels at site 5 were much higher than at the other sites. The average levels of TSS at stations 4 and 6 are 20 and 25 mg L-1, respectively, which are quite low. The TSS level might have been caused by some inorganic particulate matter such as pigments and additives from the effluent of the polymer plant.

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EC or electrical conductivity is the measurement of the extent to which a water solution can conduct an electric current and this largely depends on the number of ions in the solution (Julian et al., 2018). High EC is basically the result of a large number of inorganic ions in the wastewater. EC is very closely related to TDS (Total Dissolved Solids) content of a sample. Simply put, high EC in wastewater is a sign that the concentration of total dissolved solids is quite high too. Additionally, the electric current that is going through the wastewater is in direct proportion to the number of ionic solutes in the water. Electronic conductivity (EC) varied from 741 to 1297 μScm-1. The changes in EC at various sites were very significant.

On the other hand, the differences in EC between stations 4 and 6 and stations 1 and 5 were not so many with the latter having more EC than the former where the average electrical conductivity value of 741 μScm-1 was quite a bit lower than that at the other stations. If we exclude station 4 from our consideration, then the high EC levels at most of the stations can be explained by the dissolved ion resins, TDS that was taken up by the run-off water, and the additives that are being used in the polymer and utility plants. The discharge of wastewater with high EC into the local watershed can unbalance water for aquatic organisms, which in turn may lead to a serious drop in dissolved oxygen concentration in water (Imo et al., 2017).

When comparing water pollution sources, oil and grease seem to be the main perpetrators of water pollution besides being at the top of the list. To support this claim with data, oil, and grease are heavy and a little bit sticky, and are from petroleum sources. Even though they are of low-density by nature; they can still be easily detected on the surface of water. Khwakarami et al. (2016) has indicated that if oil and grease stay in water for a long time this may result in water productivity reduction.

According to Table 3, the first and the fifth locations had the highest concentrations of oil, and grease were recorded (8 mg/L and 10 mg/L, respectively). The case may have been caused by the release of lubricants and heavy hydrocarbons as a result of the natural gas industry, which is the local standard practice, therefore, the place where these wastewaters are discharging. Apart from that, 2nd, 3rd, 4th and 6th stations had only trace amounts of O and G. Oils and fats that remain on the water surface form a layer that prevents the solar rays from reaching the water since the rays are taken by the barrier thus the oxygen level in the water bodies decreases. Besides that, Julián et al. (2018) also pointed out that DO levels in water are influenced by local chemical, physical, and biochemical processes taking place in the water.

Besides that, factors like water temperature water movement, and salinity can also determine the amount of dissolved oxygen. Oxygen is a gas that dissolves only a little in water and its solubility depends on atmospheric pressure positively and water temperature, and salinity negatively. The minimum dissolved oxygen was 47 while the maximum was 167 µg L-1. Oxygen levels at Station 6 were significantly higher than those at the other stations. However, there are also slight changes in dissolved oxygen in other samples.

If the DO level is insufficient in the discharged water, it indicates that microbial activities have been intensified due to the presence of biodegradable organic matter, acryl compounds as an example. Chemical oxygen demand is the amount of oxygen that an oxidizing agent chemically needs to oxidize the organic matter in a sample. One of the indicators that reflect the extent of water pollution by organic matter is chemical oxygen demand (Sulaiman et al., 2016).

Chemical oxygen demand fluctuated between 87 and 130 mg L-1 according to the data. The average value of 130 mg L-1 at station 5 was considered to be significantly higher than other places. The major contributor to the increase in the chemical oxygen demand concentration of the analyzed samples is the emission of oxidizable inorganic materials such as pigments and additives.

BOD represents the amount of oxygen that is fed to microorganisms, which, however, they consume this oxygen to decay the organic compounds in water. By doing the BOD test, one can figure out the pollution level in wastewater as well as the treatment process efficiency of the effluent.

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Daytime oxygen concentration +DOB is mostly influenced by water BOD. BOD has a direct link to oxygen depletion, thus oxygen depletion will be even more that of the environment if the BOD level is higher.
The oxygen required for biochemical reactions was between 12 and 20 mg L-1. The BOD level in stations 3 and 4 was relatively low. BOD levels at stations 1, 2, and 6 were high, with the average values of 17 mg L-1, 18 mg L-1, and 20 mg L-1, respectively, that were reported, thus indicating the presence of a large amount of organic matter. The BOD level in the wastewater may be due to the presence of organic compounds such as acrylic compounds and organic pigments that are decomposable by microorganisms.

Conclusion

The assessment of pH and other such physiochemical parameters of the wastewater from a petrochemical industry in Rivers State showed that the pH, Conductivity, Turbidity, TSS, TDS, Oil/grease, BOD, COD, DO were mostly within the limits set by the World Health Organization standards for wastewater discharge (WHO 1970,1971,1979). Therefore, river/stream station 7 wastewater source in this study, i.e., the location where water is discharged after treatment, can actually be regarded as a somewhat safe environment, and the water can be recycled for other uses like irrigation if it had only undergone further treatment which would most likely lower the concentration of the few heavy metal elements to a level that would no longer pose any threat to health and society. Water quality is not only vital for the survival of the human species, but also human societies that rely on terrestrial, aquatic, and marine ecosystems.

Recommendations

Chlorination is among the methods most commonly known for the treatment of chlorinated sewage. The chlorination system as a unit is the one that is mostly responsible for the removal of those pollutants which constitute the main cause of a petrochemical wastewater mixture. Besides, the chemical treatment can also lower the pollutant levels to levels that are below the accepted limits.
Therefore it is not only the Standard Organization of Nigeria (SON) and the World Health Organization (WHO) that should be doing their inspections and evaluations regularly, but also being the supervisors of the industrial activities that discharge waste water into the environment.
The primary aim of this research is to verify the treatment efficiency by means of testing and that waste water quality limits are not being exceeded.
The following recommendations were made in with the findings of the study

1. Proper treatment of petrochemical waste water is, by far, the most important step for the protection of water and human life against the harmful activities of the petrochemical industry. Such water should not be discharged into any river or the open environment, even if it is without treatment.
2. A regulatory body should be closely monitoring the activities of the petrochemical industries that are concerned with proper waste management, especially wastewater treatment, so that it can be sure that the industry is always carrying out the correct treatment procedures.

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