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Monitoring of some Physicochemical Properties of Stagnant Water Environment Contaminated with Crude Oil

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ABSTRACT

Characteristics of some physicochemical properties were monitored in a stagnant water environment contaminated with crude oil. The contaminates experience the effect of microbial action, which resulted to the degradation of the crude oil as well as the variation in the physicochemical properties of the selected components analgised and investigated in this research. However, the parameters monitored are total dissolved solid, conductivity and pH with the characteristics of pH revealing a decrease in value for Salt water and increase in fresh water environment for crude oil degradation. Indeed, in terms of conductivity value showcase the characteristics of both media to have experienced decreased with increase in time. The total dissolved solid (TDS) experienced increase with increase in time for salt water environment and in case of fresh water environment decrease in TDS was experienced with increase in time. Finally, these characteristics was observed to have enhanced the rapid growth of the microorganisms and mitigate degradation of the crude oil concentration in the process.

Key words: Monitoring, physicochemical properties, stagnant water, environment, contaminated, crude oil

1. INTRODUCTION

The huge operations of the petroleum sector, particularly in Nigeria, with a specific focus on the Niger Delta Area, have a negative impact on environmental quality. It is nearly difficult to use oil and other natural resources without incurring losses: losses are common throughout exploration, mining, shipping, refining, storage, and usage [1-3].

Crude oil output in the globe totals more than three billion tonnes per year, with nearly half of that being carried by sea. As a result, tanker transportation of petroleum is common. Whenever a ship discharges its ballast water, it pollutes the ocean and harms marine life [4]. In addition, tanker accidents have a devastating effect on the maritime ecology in the area where they occur [5]. Another source of crude oil contamination is the widespread use of offshore drilling to discover new oil resources. Marine pollution by crude oil seems to be mostly caused by runoff from the land. It is believed that more than two million metric tonnes of crude oil are dumped into the ocean each year [6].

Environmental specialists have faced significant hurdles as a result of contamination caused by crude oil spills. Significant attempts have been undertaken to limit crude oil's continual polluting of the environment. Modeling the rate at which this crude oil degrades is critical since it will aid in containing the threat [7]. Crude oil spills are a concern posed by oil exploration and exploitation, particularly in crude oil producing regions inside the mangrove ecosystem. Despite nature's natural capability for purification and recycling, the environmental demand imposed by large volumes of crude oil pollution surpasses nature's aptitude and absorption capacity [8]. As a result, global supplies of arable agricultural land are steadily dwindling, posing a threat to farmlands where staple foods such as rice, maize, cassava, yams, and plantains are grown. Because to petroleum pollution in soil, surface and ground water have been adversely affected, as well as crops' ability to germinate and flourish in such soil. Petroleum Hydrocarbons (PHCs) deplete the soil's recovery ability, preventing crops from growing and yielding for an extended length of time [9-10]. The possibility of a crude oil leak will undoubtedly deprive residents, who are mostly farmers and fishermen, of their fields and water supplies [11]. The physical and chemical disruption of natural habitats, fatal and submittal harmful effects, and aquatic and terrestrial ecosystems are all examples of the environmental impact of crude oil component pollution [12-14].

Crude oil includes volatile organic carbons (VOCs) and semi-volatile organic carbons (SVOCS), such as polycyclic aromatic hydrocarbons (PAHS), which have been linked to genotoxicity in the past [15-18]. They have an accumulative impact on the Central Nervous System (CNS), causing dizziness, fatigue, memory loss, and headaches, and the severity of the effect is dependent on the length of exposure [19-24].

Peroxide compounds with mutagenic and carcinogenic qualities are produced by the metabolism of petroleum hydrocarbons in the human body in numerous circumstances, affecting the skin, blood immune system, liver, spleen, kidney, lung, and developing foetus [25-28]. The aforementioned hazardous impacts of crude oil spillage on the environment and human in oil producing areas has been the major causes of agitations and militancy which threatens the national integration and reduce the economy of the nation to the barest minimum [30-31].

2. MATERIALS AND METHODS

Materials

The following Materials were used; crude oil, salt water, fresh water and two (2) cylindrical batch reactors, bulb mercury thermometer, photometer, conical flask, desiccators, Erlenmeyer flask, burette, pipette, drying oven, Millipore, filter paper, mechanical shaker, and pH-meter.

Methods Sample Collection

Samples of crude oil were collected from Port Harcourt Refinery Company and were brought to the River State University. The sample was analyzed for the presence of bacteria spp. and changes in the composition of oil and physiochemical properties were determined. The fresh water samples were collected from Orashi Rivers in Omoku Town, Ogba/Egbema/Ndoni Local Government Area of Rivers State, while the salt water samples were collected from the Ntawaba Creek in Eagle Island, Port-Harcourt Local Government Area of Rivers State. The samples were collected using manual and composite sampling methods where the bulk water was divided into a number of imaginary point/segment and samples were collected from the points/segments at random using Sampler which were eventually transported and delivered to the Rivers State University Chemical/Petro-Chemical Laboratory.

The delivered samples were emptied into two cylindrical fabricated/constructed batch reactors of one thousand five hundred litres (1,500 litres) volume, fitted with six (6) plastic taps at constant interval of 25cm. The two batch reactors were for salt water and fresh water respectively. The sampling processes were repeated severally in accordance with the claim of custody procedure for the maintenance of sample integrity until the two batch reactors were filled with salt and fresh water respectively.

Experimental Procedures

Various experimental analyses were carried out to achieve the study aims and objectives. The two batch reactors containing salt and fresh water respectively were vigorously agitated to achieve a homogenous mixture and samples were collected from each reactor for physicochemical, Total Bacteria Count and Total Petroleum Hydrocarbon content analyses. The physicochemical parameters analysed are presented in Table 1.

Table 1: Physicochemical Parameters and Method of Analysis

S/N	Parameters	Test Method
1.	Total Dissolved Solid (mg/L)	APHA 2510B
2.	Conductivity (μS/cm)	APHA 2510B
3.	pH	APHA 4500T

Subsequently, each batch reactor was polluted with two hundred and fifty cubic centimetres (250cm^3) volume of crude oil and test samples were collected from the six (6) different constantly spaced points from both reactors in order to obtain values for the physicochemical parameters afore-mentioned for the week (0), injection point values. The procedures were repeated every two weeks for the three months duration of the analysis.

Determination of Total Dissolved Solids

The entire number of compounds or particles in solution in any particular water sample is known as total dissolved solids. Fresh water and salt water samples were gathered from various locations and processed through a standard glass fibre to dryness in a weighted plate before being dried at 180oC to a consistent weight. The total dissolved solid was used to calculate the increase in dish weights.

Determination of Conductivity

Electrical conductivity refers to a solution's capacity to enable current to flow through it due to ion movement, and it is determined by the presence of ions, their concentration, mobility, valence, and measuring temperature.

Determination of pH

The pH-Meter was standardized by means of the standard solution followed by the immersion of the electrode(s) of the pH-Meter into the water sample. The pH of the salt and fresh water samples was determined by electrometric method since the method is not affected by coloured or opaque solution. 40ml±5ml water sample was poured into glass beaker and stirred vigorously using a clean glass stirring rod. To allow the temperature to stabilise, the sample was covered with watch glass and let to stand for at least one hour. The sample temperature was taken, and the pH-Meter controller's temperature was set to match the sample temperature. To ensure proper contact between the water and the electrode, the beaker was slightly twisted. The pH level was determined and recorded.

3. RESULTS AND DISCUSSION

The dispersion of crude oil in stagnant water has been studied with experimental analysis. The physicochemical and bacteria analysis over the experimental investigation were equally studied. In addition, the rate of sedimentation and TPH content in the water were studied using mathematical models.

Physicochemical Properties of Polluted Water

The physicochemical parameters of crude oil polluted stagnant water was analysed biweekly to determine the variability of the tested parameters along the depth of the water column and with time.

Variations in Total Dissolved Solids

The total dissolved solids in the fresh and salt water samples determined over the period of the experimental investigation are shown in Figures 1 and 2.

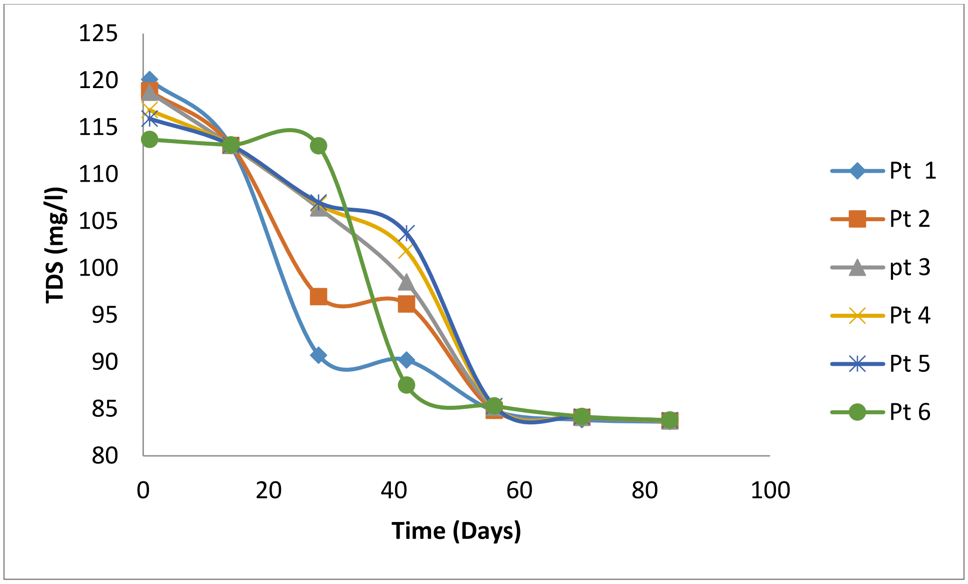

Figure 1: Variation of TDS in the Polluted Stagnant Fresh Water

Pt 1 (0m), pt 2 (0.25m), pt 3 (0.5m), pt 4 (0.75), pt 5 (1m) and pt 6 (1.25).

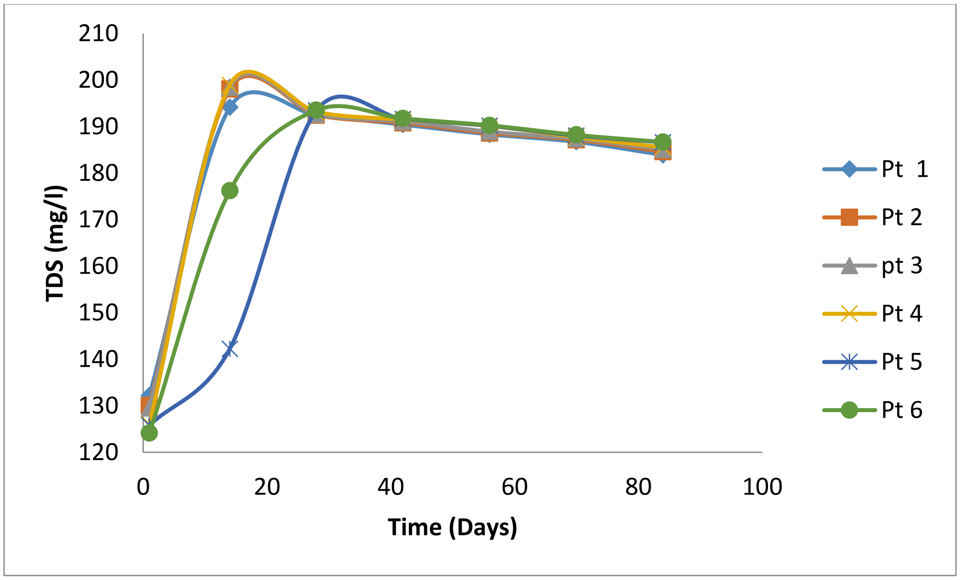

Figure 2: Variation of TDS in the Polluted Stagnant Salt Water

Pt 1 (0m), pt 2 (0.25m), pt 3 (0.5m), pt 4 (0.75), pt 5 (1m) and pt 6 (1.25).

Figure 1 shows the variation in total dissolved solids (TDS) with time at various depths 7along the tank containing crude oil polluted fresh water, while the TDS variation in stagnant salt water is shown in Figure 2. The analysis of revealed that the pattern of TDS variation in both water types differs. Thus, the concentration of TDS before the release of crude oil in the water was 31.0mg/l in fresh water and 28.11mg/l in salt water, but after the oil was released, the concentration of TDS increased up to 120.08mg/l on the fresh water surface and up to 132.2mg/l on the salt water surface. In addition, the TDS concentration in fresh water, for any depth in the stagnant water column, decreased as time was increased. However, at any given time, there was random variation in TDS concentration as depth increased from 0.25 to 1.25m. On the contrary, TDS concentration in salt water increased initially from the first day up to day 14 from the water surface to 0.75m depth, and up to day 28 from 1.00 to 1.25m depth. Thereafter, TDS decreased correspondingly as time was increased further to 84 days across the depths in the stagnant salt water column. At every given time, TDS concentration variation as depth increased from 0.25 to 1.25m was not uniform.

Across the sampling points, the concentrations of TDS in fresh water ranged between 83.63mg/l and 120.08mg/l at the surface, 83.7mg/l and 118.9mg/l at 0.25m depth, 83.72mg/l and 118.74mg/l at 0.5m depth, 83.75mg/l and 116.85mg/l at 0.75m depth, 83.79mg/l and 115.93mg/l at 1.0m depth, 83.8mg/l and 113.7mg/l at 1.25m depth. Similarly, across the sampling points in salt water, the concentrations of TDS ranged between 132.2mg/l and 194.11mg/l at the surface, 130.06mg/l and 198.06mg/l at 0.25m depth, 129.5mg/l and 198.91mg/l at 0.5m depth, 126.0mg/l and 198.5mg/l at 0.75m depth, 125.8mg/l and 193.45mg/l at 1.0m depth, 124.11mg/l and 193.5mg/l at 1.25m depth. The level of TDS in both water types is within permissible limit of 500mg/l.

It was observed that TDS concentration after pollution increased in the stagnant water, implying that the crude oil inhibited lots of dissolved solids. Also, TDS in salt water was lower than fresh water, but became more concentrated by TDS after crude oil release. This implied that the stagnant salt water may possess substances that have the ability to dissolve solids entrained with the crude oil easily and distribute same across the water body, compared to the fresh water. Studies have shown that oil in salt water is influenced by double-layer repulsion, steric interaction and van der Waals' force of attraction: these forces can increase dissolved solid, especially in sea and salt water. After 84 days, it was noticed that TDS level in the fresh water was slightly below its initial value before pollution, while in the salt water the concentration was still far above the initial value recorded before pollution. This showed that the crude oil has great impact on TDS in stagnant salt water than the stagnant fresh water.

Variation in Conductivity

The conductivity of fresh and salt water samples determined over the period of the experimental investigation is shown in Figures 3 and 4.

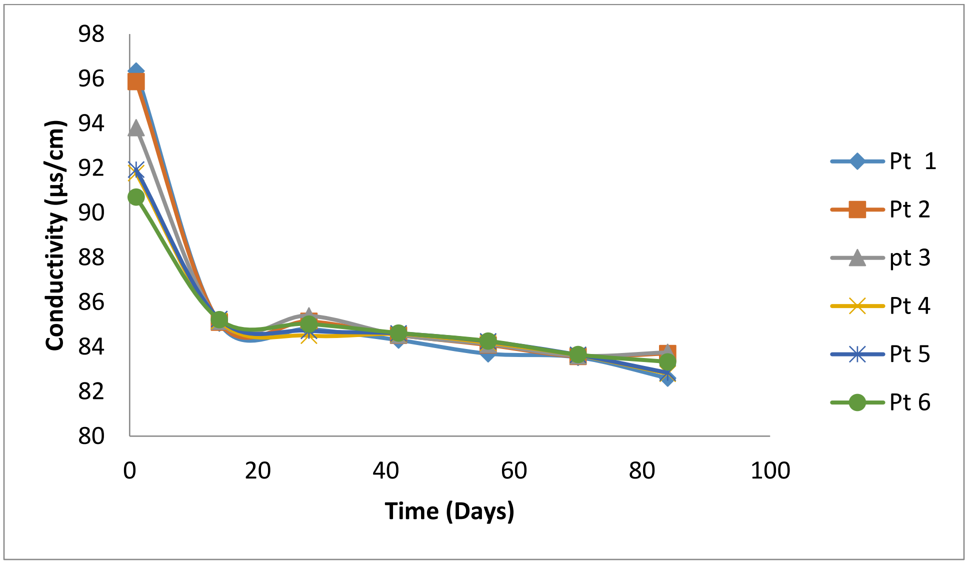

Figure 3: Variation of Conductivity in the Polluted Stagnant Fresh Water

Pt 1 (0m), pt 2 (0.25m), pt 3 (0.5m), pt 4 (0.75), pt 5 (1m) and pt 6 (1.25).

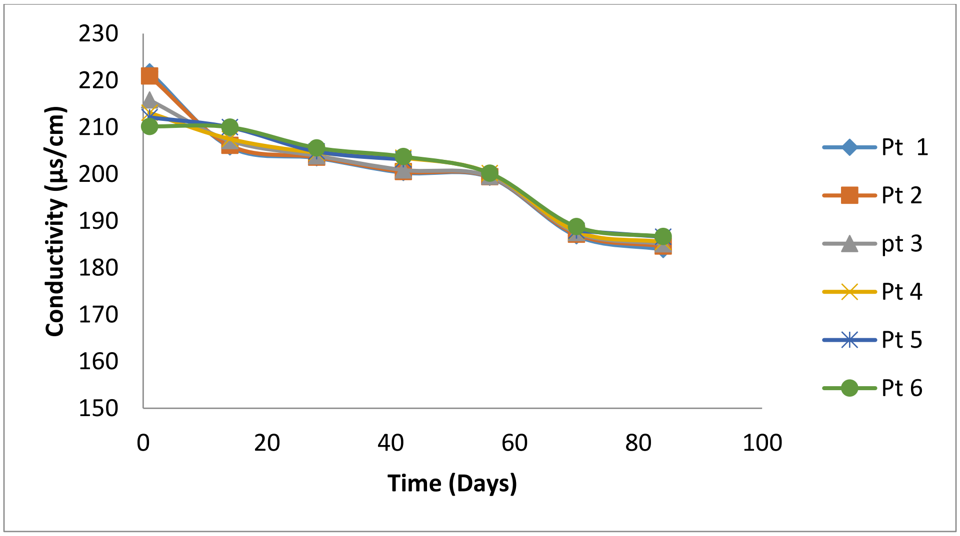

Figure 4: Variation of Conductivity in the Polluted Stagnant Salt Water

Pt 1 (0m), pt 2 (0.25m), pt 3 (0.5m), pt 4 (0.75), pt 5 (1m) and pt 6 (1.25).

Figure 3 shows the variation in conductivity with time at various depths along the tank containing crude oil polluted fresh water. Also, the conductivity of the stagnant salt water is shown in Figure 4. Again, the variation of conductivity in fresh and salt water differs. Thus, conductivity before the release of crude oil in the water was 36.9µs/cm in fresh water and 45.33µs/cm in salt water, but after the oil was released, it increased up to 96.34µS/cm on the fresh water surface and up to 221.81µS/cm on the salt water surface. The conductivity of the fresh and salt water at any depth in the column, decreased as time increased, but at any given time, conductivity decreased as depth increased from 0.25 to 1.25m, except at the surface.

Across the sampling points, the conductivity of the fresh water ranged between 82.6µS/cm and 96.34µS/cm at the surface, 82.57µS/cm and 95.88µS/cm at 0.25m depth, 82.75µS/cm and 93.81µS/cm at 0.5m depth, 82.8µS/cm and 91.78µS/cm at 0.75m depth, 82.84µS/cm and 91.93µS/cm at 1.0m depth, 83.33µS/cm and 90.7µS/cm at 1.25m depth. Likewise, the conductivity of salt water across the sampling points ranged between 183.9µS/cm and 221.81µS/cm at the surface, 184.6µS/cm and 220.94µS/cm at 0.25m depth, 185.1µS/cm and 215.8µS/cm at 0.5m depth, 185.52µS/cm and 213.08µS/cm at 0.75m depth, 186.6µS/cm and 212.11µS/cm at 1.0m depth, 186.66µS/cm and 210.18µS/cm at 1.25m depth. Conductivity level in both fresh and salt water is within permissible limit of 2000µS/cm.. The results of the conductivity of are shown in Tables 4A and 5A of Appendix A for fresh and salt water.

The increase in conductivity of the water after pollution increased may be attributed to high concentration of dissolved salts, metallic ions, temperature and total dissolved solids in the crude oil. Again, the conductivity of salt water was higher compared to fresh water before oil pollution, but remained very high throughout period of the investigation. This could be due to the present of mineral salt.. After 84 days, it was noticed that conductivity in salt water was higher in the fresh water. The range of conductivity reported in this study was lower than those reported for non-stagnant fresh water at the surface water (45.39 to 49.9µS/m) and in the bottom (43.07 to 47.73µS/m). However, the decrease in conductivity recorded agreed with reports of other studies.

Variation in Water pH

The pH of fresh and salt water samples determined over the period of the experimental investigation is shown in Figures 5 and 6.

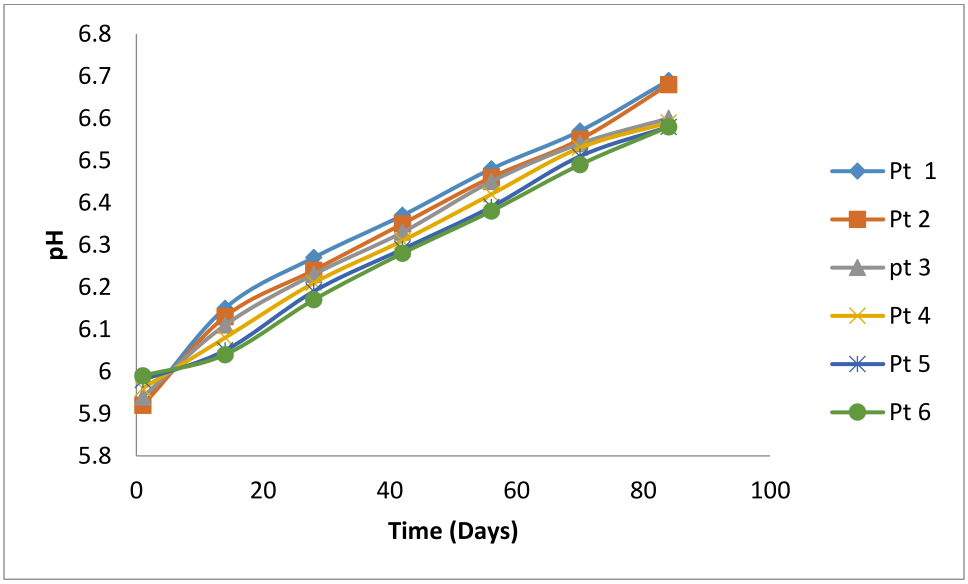

Figure 5: Variation of pH in the Polluted Stagnant Fresh Water

Pt 1 (0m), pt 2 (0.25m), pt 3 (0.5m), pt 4 (0.75), pt 5 (1m) and pt 6 (1.25).

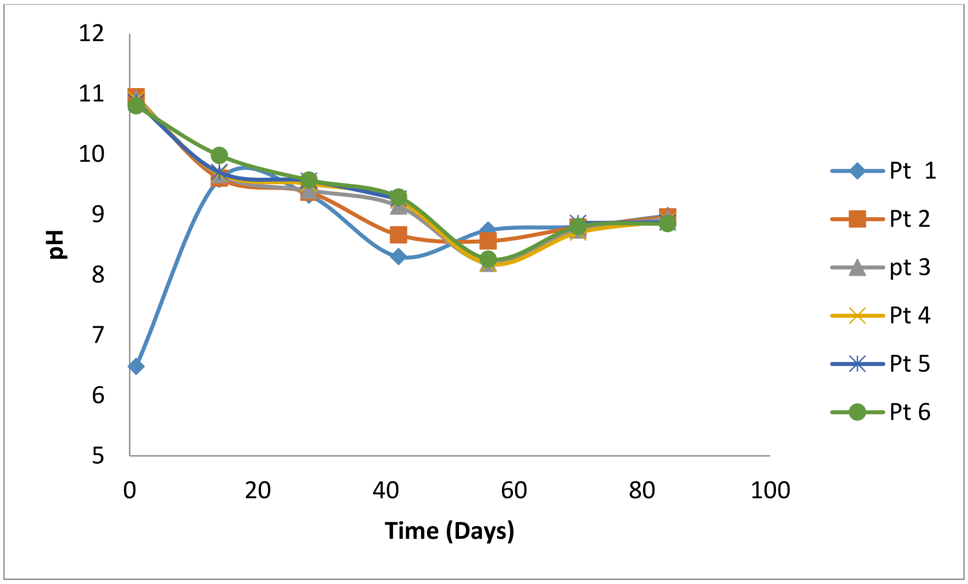

Figure 6: Variation of pH in the Polluted Stagnant Salt Water

Pt 1 (0m), pt 2 (0.25m), pt 3 (0.5m), pt 4 (0.75), pt 5 (1m) and pt 6 (1.25).

Figure 5 shows the variation in pH with time at various depths along the tank for fresh water. Also, the pH of the stagnant salt water is shown in Figure 6. While the variation of pH in fresh water uniformly increased with time across the depths, the pH in salt water varied randomly with time, especially at the surface (Pt 1). The pH before the release of crude oil in the water was 6.83 in fresh water and 7.01 in salt water, but after the oil was released, it decreased to 5.92 in the fresh water surface and to 6.48 in the salt water surface. However, the pH in fresh water after pollution generally increased with time and column depth, but in salt water, pH after pollution generally decreased with time and randomly varied with depth. Across the sampling points as the increased, the pH in fresh water ranged between 5.92 and 6.69 at the surface, 5.92 and 6.68mg/l at 0.25m depth, 5.94 and 6.60 at 0.5m depth, 596 and 6.59 at 0.75m depth, 5.98 and 6.58 at 1.0m depth, 5.99 and 6.58 at 1.25m depth. Likewise, decreased of pH in salt water across the sampling points ranged between 6.48 and 8.98 at the surface, 10.95 and 8.96 at 0.25m depth, 10.92 and 8.93 at 0.5m depth, 10.90 and 8.89 at 0.75m depth, 10.86 and 8.87 at 1.0m depth, 10.80 and 8.85 at 1.25m depth. The pH level across the sampling points in fresh water is within permissible limit, while that of salt water are above WHO limit (6.5 – 8.5).

The increase in pH after pollution is attributed to high concentration of dissolved salts, temperature, hydrogen ion concentration, among other factors. Salt water pH was higher than pH in fresh water. This could be due to the present of mineral salt. And the trends in pH agreed with reports of other studies.

4. CONCLUSION

The monitoring of crude oil degradation in stagnant water media was studied experimentally in terms of physicochemical properties and the following observations were drawn:

i. The physicochemical parameters of the stagnant water media varied with increase in depth and time. The study also showed that crude oil has significant impact on the properties of fresh and salt water, as most of the properties investigated were immediately altered after crude oil pollution. Thus, the concentrations of total dissolved solids (TDS), conductivity, pH decreased after pollution. TDS, conductivity and pH decreased with increase in time.

ii. Crude oil significantly altered the physicochemical properties of stagnant water, even at depths below the surface.

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This study has not received any external funding.

Conflicts of interests

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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