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Performance Evaluation of Produced Water Quality from a Nearshore Oil Treatment Facility

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ABSTRACT: Produced water, which is a mixture of organic and inorganic compounds, is a major waste stream generated in oil and gas industries. Its negative impacts on the receiving water bodies have become a worrisome environmental issue. The effluent quality of a crude Oil processing and exporting installation located in the coastal area of the Niger Delta was studied for six months to ascertain the efficiency of the company's produced water treatment processes. Physicochemical parameters were monitored at the inlet and outlet of the produced water treatment plant. Parameters examined were Temperature, pH, Oil and Grease, Total Dissolved Solids TDS, Total Suspended Solids TSS, Biological Oxygen Demand BOD_5. The average temperature of the produced water was reduced from 42.0°C to 25.9°C. The average pH of the samples, which was mostly alkaline prior to treatment, improved from 6.3 to 6.7. The Oil and Grease was reduced from 645.3mg/l to 8.2mg/l. The average concentration of the TDS was reduced from 3836.2mg/l to 965.8mg/l, while the average TSS was reduced from 72.5mg/l to 31.0mg/l. The average Biological Oxygen Demand was reduced from 986.0mg/l to 92.0mg/l. The produced water treatment facility had capability of bringing the final effluent to dischargeable limit. @JASEM

Keywords: Produced water, Oil and Gas, Coastal environment, Pollution, Treatment

Oil and gas reservoirs have a natural water layer called formation water, that, being denser lies under the hydrocarbons. Also, to maximize oil recovery, additional water is often injected into the reservoirs to help force the oil to the surface. Essentially, Produced water is a mixture of formation water and injected water but also contains smaller quantities of dissolved organics (including hydrocarbons), traces of heavy metals, dissolved minerals, suspended oil (non-polar), solids (sand, silt) and production chemicals added in the production/separation line (Jacobs et al., 1992). Improper management of produced water will not only harm the environment but also put the oil producing enterprise in a bad publicity (OGP, 2002). It has been observed that every aspect of oil operations, though in varying degrees, poses significant negative impacts on the environment and that the environmental consequences impose economic effects on the indigenes of that locality (Nwokoma and Anene, 2010; Joel et al, 2009; Ugochukwu and Leton, 2004; Orubu et al., 2004 ; Onosode, 2003; Onah, 2001).

The daily management of produced water poses a significant cost and challenge. Deferred production causes high economic losses and thus oil industries always strived for continuous operations. The capacity, reliability and performance of the produced water treatment system is often critical for continuous oil production especially in mature oil fields where water production can greatly exceed the oil production. Also, the formation rock of oil wells are highly porous, thus the produced water to be re-injected into the well formation must be free from solids, oil and scaling salts to avoid plugging of the formation rocks and corrosion tendency of drilling equipment. The vista of treating produced water is, from one viewpoint, an approach to reducing adverse environmental impact; from the other a robust possibility to optimize and increase crude oil production, which means increase profitability.

This study focuses on the efficiency and effectiveness of a certain Nearshore Produced Water Treatment Facility to receive, contain and treat the daily throughput from different flow lines to a satisfactory level. Produced water samples were taken from the Nearshore Crude Oil installation and the pH, temperature, oil and grease content, and BOD analysed. These parameters were analysed using standard methods; American Society for Testing and Materials, ASTM; Standard Methods for the Examination of Water and Wastewater by American Public Health Association (APHA) and Analysis of Oilfield Waters - API RP-45.

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MATERIALS AND METHODS

Sampling and Preservation of Samples: The sampling and preservation of the produced water samples were conducted according to procedures stipulated in the Annual book of ASTM Standards, volume 11.01 by American Society for Testing and Materials; Standard Methods for the Examination of Water and Wastewater by American Public Health Association (APHA) and Analysis of Oilfield Waters - API RP-45. The samplings were done daily and the weekly average taken for six months (February - July).

Temperature and pH determination: Temperature and pH were measured on-site. The pH was calibrated /standardized with buffers solution of pH 4 and pH 7 before usage. The pH of the produced water samples were measured using a portable water proof pH meter (Jenway, 3150, USA). The temperature was measured using portable thermometer (Hanana, HI-93510, USA).

Oil and Grease determination: About 50ml of xylene was measured into the graduated glass bottle bearing 500ml produced water sample and the bottle was shaken vigorously for about 3mins. The contents was poured into a separating funnel and agitated vigorously, with intermittent opening of the stopper to release pressure build up. The contents of the funnel were allowed to settle and the bottom layer of the solution drained into a clean centrifuge tube. The extract in the centrifuge tube was spin using a centrifuge machine, after which it was poured into a cuvette. The cuvette was put into Spectrophotometer (DR2008) and the concentration of oil and grease read off from the instrument.

BOD_5 determination: Series of dilutions were prepared in 300ml BOD bottles. The initial dissolved oxygen, DO was measured for the dilutions using the membrane electrode method. The samples were stoppered tightly, water sealed and incubated for 5 days at 20±1^{o}C, after which the BOD was calculated from the difference between the initial and the final dissolved oxygen.

Determination of Total Solids, Total Dissolved Solids and Total Suspended solids: Clean porcelain evaporating dish was heated to 105^{o}C for 1 h, stored in a desiccator to cool and weighed as W_1. 100 ml of the well-mixed sample was measured from the approximate midpoint and mid-depth of the sample container using a pipette into the pre-weighed dish. The sample was evaporated on a steam bath and oven dried for 1 h at 103 to 105^{o}C. The dish was allowed to cool briefly in air before placing it, while still warm, in a desiccator to completely cool. The dish was re-weighed as W_2. The weight of the total solids was gotten as $(W_2 - W_1)$ mg, therein the total solids per litre was calculated.

The sample was stirred with a magnetic stirrer and 100 ml of sample measured using a 100 ml wide bore pipette onto a glass-fiber filter with applied vacuum. It was washed with 10 ml of deionized water trice, allowing complete draining between washings, and continued suction for about 3 minutes after filtration was complete. The filtrate (with washings) was transferred to a pre-weighed evaporating dish (W_3). The filtration flask was rinsed with 10 ml deionized water and transferred to the dish W_3 containing the sample filtrate. The dish was evaporated to dryness on a steam bath and oven dried at 180^{o}C for 1 h. The dish was allowed to cool in a desiccator, to equilibrate to room temperature and weighed as the total dissolved solids, W_4. The cycle of drying, cooling, desiccating and weighing was repeated until a constant weight was obtained. The total dissolved solids per litre and the total suspended solids were then calculated.

RESULTS AND DISCUSSION

Table 1 outlined the quality of the untreated Produced water from the nearshore crude oil treatment facility. It shows that the quality of the Produced water fell below Environmental admissible standards and should be adequately treated before disposal.

Table 2 showcases the measured in-situ temperature of the treated Produced water, while Figure 1 illustrates the temperature profile of the treated produced water between February and July. The temperature profile of the treated produced water ranged from 25.4^{o}C to 27.1^{o}C (the highest temperature throughput being 27.1^{o}C). It shows that the temperature of the Produced water reduced having undergone treatment and is comparatively lower than the DPR limit of 30^{o}C (DPR, 1991; 1999).

Table 1: Quality of Untreated Produced Water from the Nearshore Oil Processing Facility

S/N	Parameter	Value		
		Minimum	Maximum	Average
1	Temperature, °C	23.0	87.0	42.0
2	pH	2.8	7.3	6.3
3	Oil and Grease, mg/l	27.9	4661.0	645.3
4	Total Dissolved Solids (TDS), mg/l	73.0	650.0	3836.2
5	Total Suspended Solids (TSS), mg/l	26.2	130.0	72.5
6	Biological Oxygen Demand, mg/l	78.5	10, 957	986

Table 2: Temperature (°C) Profile of Treated Produced water

Week	Month					
	February	March	April	May	June	July
1	25.6	26.2	25.0	26.7	25.9	24.8
2	27.0	25.8	25.5	24.5	26.1	25.2
3	26.5	28.3	26.4	26.0	24.3	25.4
4	29.1	24.5	25.6	25.2	27.0	26.1
Average	27.1	26.2	25.6	25.6	25.8	25.4

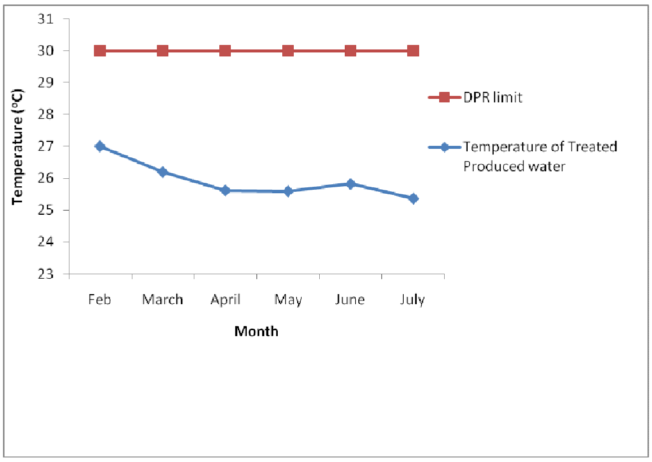

Figure 1: Temperature of treated Produced water

The measured pH of the treated Produced water from February to July is given in Table 3. The six month analytical data as depicted in Figure 2 shows that the pH of the treated water increased from its typical raw state of 6.2 to 6.7. It also portrays that pH level of the treated water falls within the statutory limit of between pH 6.5 to 8.5. The experimental results for oil and grease concentration in the Produced water from February to July are given in Table 4. The concentrations of oil and grease in the treated produced water as illustrated in Figure 3 indicates a reduction of oil and grease concentration from an average value of 645.3mg/l to 8.22mg/l. It implies that the treated produced water has an oil and grease concentration below DPR limit of 20mg/l (DPR, 1991; 1999) for near shore disposal

Table 3: pH of the Treated Produced water

Week	Month					
	February	March	April	May	June	July
1	6.8	6.2	6.6	6.1	7.3	5.8
2	7.2	5.8	5.7	7.5	6.2	7.5
3	5.3	5.9	6.9	6.9	7.7	6.7
4	7.3	6.7	7.8	7.5	6.9	7.4
Average	6.7	6.2	6.8	7.0	7.0	6.9

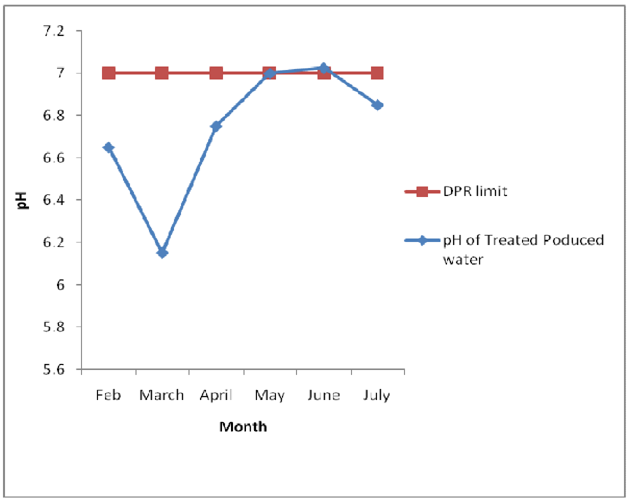

Figure 2: pH of treated Produced water

Table 4: Oil and Grease Concentration of the Treated Produced water

WEEK	Month					
	February	March	April	May	June	July
1	7.96	9.83	6.01	7.38	11.04	6.46
2	8.42	6.13	8.75	10.13	9.21	8.29
3	13.93	6.46	9.67	6.01	12.42	5.09
4	8.29	7.84	6.92	5.55	10.58	4.63
Average	9.65	7.57	7.84	7.27	10.81	6.15

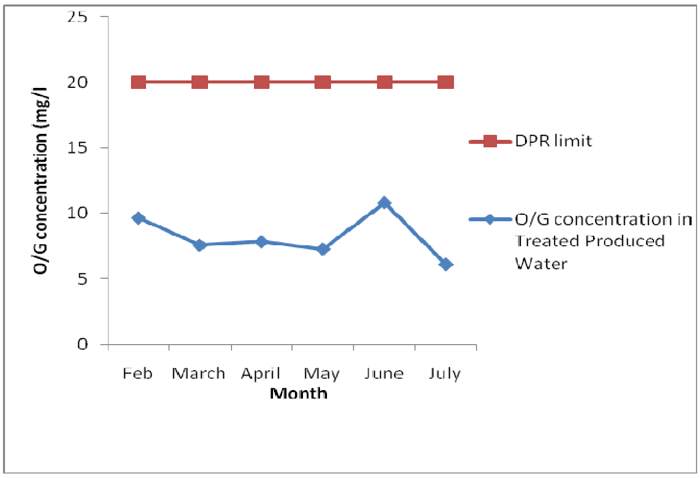

Figure 3: Oil and Grease Concentration of treated Produced water

Table 5: BOD_5 Concentration of the Treated Produced water

Week	Month					
	February	March	April	May	June	July
1	42.4	95.2	116.0	58.1	74.9	43.0
2	55.0	250	86.6	116.5	83.2	87.6
3	112.4	89.5	93.8	86.6	109.5	71.4
4	90.0	109.0	56.1	78.8	97.3	106.0
Average	75.0	135.93	88.1	85.0	91.2	77.0

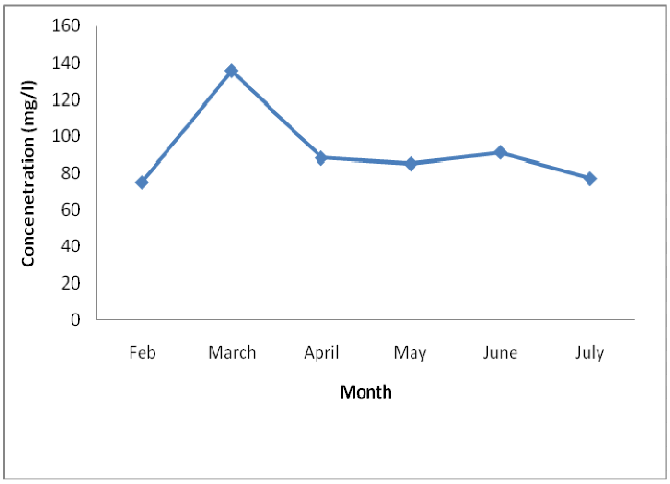

Figure 4: BOD_5 Concentration of treated Produced water

The measured Biological Oxygen Demand (BOD) of the treated Produced water from February to July is shown in Table 5. The BOD_5 trend of the treated produced water for the months studied is shown in Figure 4. Though, there is no specified limit by DPR for nearshore/offshore BOD_5 discharge, but considerable reduction of the BOD is noticed whereby the average BOD_5 per month is less than that of the untreated produced water, which has average BOD concentration of 986mg/l. The efficiency of the treatment plant in reducing the high BOD load could be attributed to hydrocarbon utilizing-microorganisms found within the sediment of the treatment facility.

Table 3.6: TDS Concentration of the Treated Produced Water

WEEK	MONTH					
	February	March	April	May	June	July
1	158.0	274.7	636.0	876.3	712.6	470.8
2	870.3	890.1	430.4	645.5	900.4	540.3
3	459.9	721.0	560.8	870.7	650.0	815.0
4	537.8	645.5	238.7	355.2	599.6	676.1
AVERAGE	1231.5	958.0	802.4	936.93	815.7	1050.6

The measured concentrations of Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) in the produced water after the treatment process are shown in Tables 6 and 7 respectively. The concentrations of total dissolved solids TDS and total suspended solids TSS in the treated produced water are shown in Figures 5 and 6. The concentrations of TDS and TSS of the treated produced water were reduced far below DPR limit of 2000mg/l and 50mg/l respectively, (DPR, 1991; 1999). These levels of improvement on the quality of the produced water could be credited to the efficiency of the different stages of the produced water treatment facility.

Table 7: TSS Concentration of the Treated Produced Water

Week	Month					
	February	March	April	May	June	July
1	45.0	23.3	43.2	35.6	30.0	24.3
2	30.5	15.6	10.5	45	63.2	29.5
3	28.8	32.2	18	67.3	14.0	37.0
4	40.0	25.8	16.7	33.4	9.8	26.1
AVERAGE	36.1	24.2	22.1	45.3	29.3	29.2

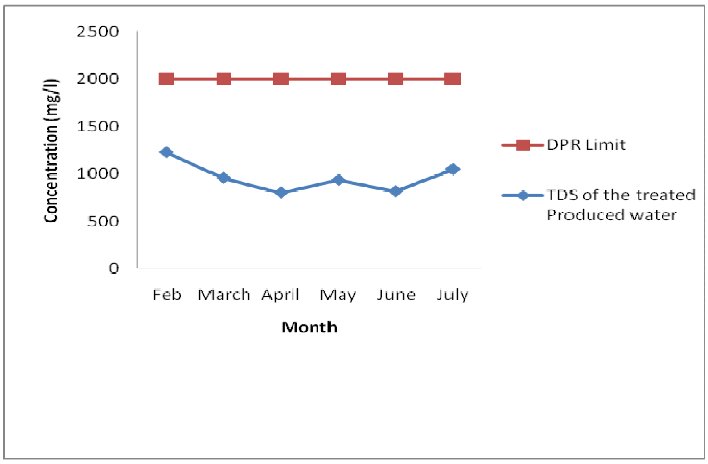

Figure 5: TDS Concentration of treated Produced water

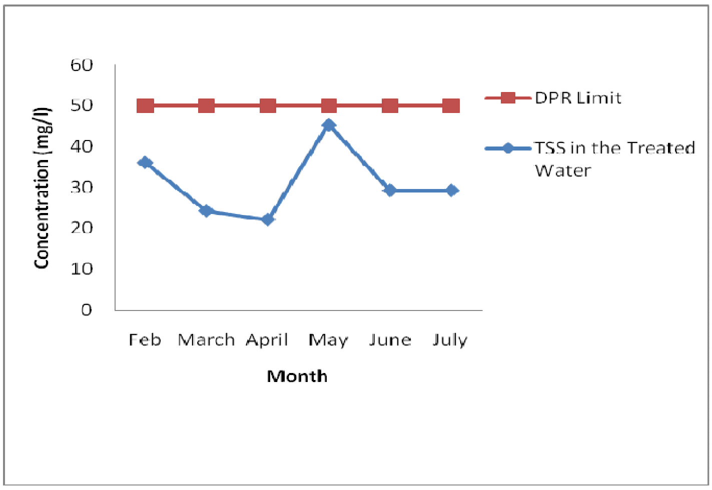

Figure 6: TSS Concentration of treated Produced water

Conclusion: The present study has demonstrated that the produced water discharged from the crude oil processing and export facility into the near shore environment is below statutory limits. It implies that the Produced water treatment facility is efficient in handling, treating and discharging of effluent water that meets environmental standards, though additional polishing technologies are available which could further reduce the dispersed oil contents, and in some cases reduce the level of associated soluble aromatics.

But such technologies sometimes require extra energy and treatment chemicals to achieve the lower effluent discharge levels, and in many cases their application will be limited, due to weight and space constraints, to low volume applications (<1000m^3/d).

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