Evaluating the Suitability of Post-treated Produced Water for Offshore Disposal: 'BANGO' Oilfield Niger Delta, Nigeria.

George Uchebike Ozulu, M.Sc.

Department of Earth Sciences, Salem University Lokoja, PMB 1060 Lokoja, Kogi State, Nigeria

E-mail: georgeozulu@yahoo.com

ABSTRACT

Physicochemical analyses were carried out in post-treated produced water and the recipient environment to ascertain the suitability of the post-treated produced water being disposed into offshore water. Effluent samples were collected from production facilities of "BANGO" oilfield within the interval of two weeks. After the disposal of the produced water, samples of the recipient water from five designated points were also analyzed to determine the level of compliance of physicochemical parameters with the Department of Petroleum Resources (DPR) standards.

Results from the analyses showed the pH values(6.25-6.40), chlorides (15,679-16,334.21 mg/l), and total dissolved solids, TDS (31,400.00-31,430.00mg/l). These did not meet the DPR standards for disposal offshore and therefore requires further treatment. Total hydrocarbon content, THC (13.00-17.31mg/l), turbidity (10.70-11.00), total suspended solids (10.00-12.00mg/l) and temperature (29.50-29.75^{o}C), all fall within the DPR allowable limits. Gross organic parameters of biochemical oxygen demand, BOD (61.25-64.30mg/l) and chemical oxygen demand, COD (92.10-95.33mg/l) were also within the DPR limits.

(Keywords: post-treated, produced water, effluent, DPR, offshore, disposal, oilfield waste, brine)

INTRODUCTION

Produced water is defined as the water (brine) brought up from the hydrocarbon bearing strata during the extraction of oil and/or gas and this may include formation water, injection water, small volumes of condensed water and trace amount of treatment chemicals (Ayes and Parker, 2001). Produced water is by far the largest volume bi-product of waste stream associated with oil and gas production and its properties (both physical and chemical) as well as volumes, vary considerably depending on the geographical location of the field, the geological formation, the type of hydrocarbon products, and the lifetime of the reservoir. (Amyx et al., in Ayes and Parker, 2001).

Produced water can have different potential impacts depending on where it is discharged. Discharges to small streams are likely to have a larger environmental impact than discharges made to the open ocean by virtue of dilution that takes place following discharges (Abdolhamid et al., 2008). Regulatory agencies, like the Department of Petroleum Resources (DPR), have recognized the potential impacts that produced water discharges can have on the environment and have prohibited discharges in most onshore or near-shore locations in Nigeria and monitor regulatory offshore disposal locations.

Produced water is known to be toxic to fish and other marine organisms. The presence of polycyclic aromatic hydrocarbons (PAH_s), such as authracene, phenanthrene, benzo(a)pyrene, and benzo(a)authracene, together with heavy metals have been considered the most harmful contaminants in produced water (Middledich, 1984). Similarly, produced water discharge could constitute a problem because the produced water treatment systems currently in use by most oil producing companies is primarily designed to remove particulate or dissolved oil and therefore has little effect on the concentrations of dissolved petroleum hydrocarbons and other agencies in the produced water (Lysyi, 1982).

This study, therefore, is focused on evaluating the physico-chemical parameters in post-treated produced water so as to determine its suitability for offshore disposal and impact of its disposal in the recipient water.

Study Area

The study area is within the offshore operational production facility of Agip Energy and Natural Resources (AENR). The area is located within the mangrove and beach ridge zone of the Niger Delta. The Niger Delta Region is underlain by Quaternary to Recent Sedimentary formations (Short and Stauble, 1967; Weber and Daukoru, 1975).

MATERIALS AND METHODS

Sampling points were carefully selected to obtain samples that are truly representatives of the post-treated produced water. Grab samples were collected with sterile 1000 liters Wheaton glass bottles from flowing effluent at the point of final discharge to the receiving water, this was done at an interval of two weeks.

In-situ analyses of unstable parameters such as pH, conductivity, and total dissolved solid, were done with the aid of portable field equipment. DspH-3, pH/conductivity meter, OAKTONTDS meter, YSI 550A dissolved oxygen meter and Gun-type infra-red thermometer. All laboratory analyses were carried out according to standard methods as described in EGASPIN (2002) and FEPA (1991) guidelines; APHA-AWWA-WPCF (1998) and the annual book of ASTM standards, (ASTM, 2002). These were used without modifications for the relevant analyses. In addition, all laboratory procedures were adequately standardized and all instruments appropriately calibrated. The following parameters were analyzed for: turbidity, TSS, THC, BOD, COD, salinity, and trace metals.

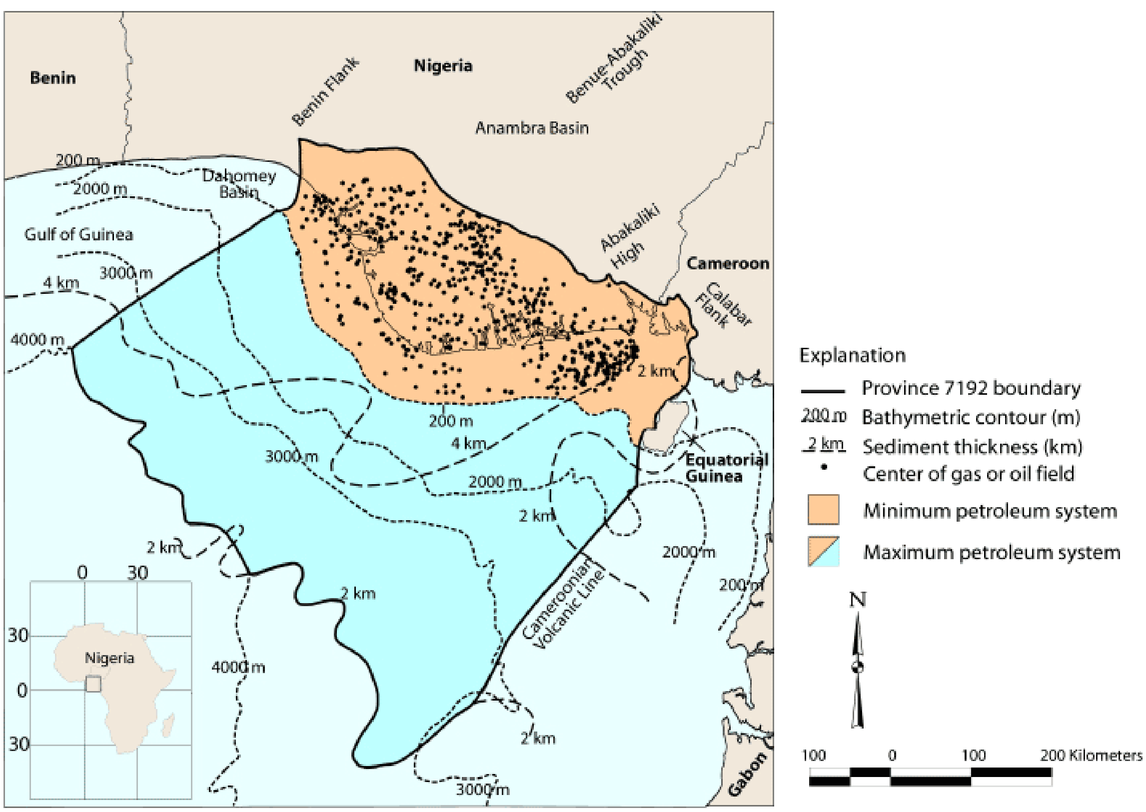

Figure 1: Index Map of Nigeria and Cameroon.
Map of the Niger Delta showing Province outline (maximum petroleum system); bounding structural features; minimum petroleum system as defined by oil and gas field center points (data from Petroconsultants, 1996a); 200, 2000, 3000, and 4000 m bathymetric contours; and 2 and 4 km sediment thickness.

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RESULTS AND DISCUSSION

Produced Water

Results of the analyses of the physico-chemical properties of produced water is shown in Table 1. The pH (6.25-6.40), chloride (15,679-16,334.21mg/l) and total dissolved solids-TDS (31,400.00-31,430mg/l). These did not meet the DPR standards for disposal offshore and therefore requires further treatment to bring these parameters within allowable limits.

Recipient Water

Results of the analyses or the physico-chemical parameters of the recipient marine water from five designated points to the effluent plant (North, South, Central, East and West), is shown in Table 2.

Table 1: The Physical, Chemical, and Biological Characteristics of the Post –treated Produced Water.

Parameters	Unit	DPR Limit	Method	Week 1	Week 2	Mean	SD
Date sampled				19/07/10	27/07/10		
pH	-	6.5-8.5	API-RP45	6.25	6.40	6.33	0.11
Temperature	^{O}C	30.0	API-RP45	29.50	29.75	29.75	0.36
THC	mg/L	40.0	API-RP45	17.31	13.00	15.16	3.05
Chloride	mg/L	2000.0	API-RP45	15,679.40	16,334.21	16,006.81	463.02
Turbidity	mg/L	15.0	APHA214A	10.70	11.00	10.85	0.9
TDS	mg/L	5000.0	APHA208C	31,430.00	31,400.00	31,415.00	21.21
TSS	mg/L	50.0	ASTM208	10.0	12.00	11.00	1.41
COD	mg/L	125.0	ASTM D1252	95.33	92.10	93.72	2.28
BOD	mg/L	125.0	ASTM D310A	61.25	64.30	62.78	2.16
Lead	mg/L		ASTM D3559	0.004	0.002	0.003	0.001
Iron	mg/L		ASTM 1068	0.630	0.659	0.645	0.021
Copper	mg/L		ASTM D1688	0.084	0.077	0.080	0.005
Chromium	mg/L	0.5	ASTM D1687	0.005	0.007	0.006	0.001
Zinc	mg/L	5.0	ASTM D1691	0.166	0.173	0.170	0.005

Table 2: The Physical, Chemical, and Biological Characteristics of the Recipient Water.

Parameters	Units	Methods	DPR Limits	North	South	Central	East	West
Ph	-	API-RP45	6.5-8.5	8.14	8.20	7.41	8.27	8.35
Temperature	^{O}C	API-RP45	30.0	29.3	29.3	30.2	29.5	29.0
Conductivity	ms/cm	APHA205	-	34.1	33.9	40.0	34.2	43.7
THC	mg/L	API-RP45	40.0	< 0.01	< 0.01	0.10	0.03	< 0.001
TOC	mg/L	ASTM D2579	-	5.43	5.50	6.91	5.11	5.0
DOC	mg/L	APHA422F	3.0	4.8	4.6	4.0	4.9	5.2
BOD	mg/L	APHA310A	125.0	46.2	47.11	60.1	47.04	47.0
COD	mg/L	ASTM D1252	125.0	60.18	59.39	72.01	61.0	61.41
TDS	mg/L	APHA208C	5000	36,337	36,300	36,500	36,510	36,400
Chloride	mg/L	API-RP45	2000.0	20,105	20,110	21,420	20,218	20,228
Turbidity	mg/L	APHA214A	-	7.00	6.87	8.00	7.00	6.50
Phenols	mg/L	ASTM D1783	0.01	0.01	< 0.01	0.02	0.02	<0.01
Cyanide	mg/L	ASTM D2036	-	0.002	0.004	0.006	0.005	0.001
Ammonium	mg/L	APHA418D	-	4.906	4.970	6.118	4.600	4.613
Nitrate	mg/L	APHA419D	-	0.230	0.228	0.126	0.201	0.230
Nitrogen	mg/L	ASTM D3589	-	1.400	1.404	1.300	1.355	1.326
Phosphorous	mg/L	ASTM D515	-	0.035	0.042	0.050	0.046	0.040
Arsenic	mg/L	ASTM D2972	-	0.002	0.003	0.004	0.0002	0.001
Lead	mg/L	ASTM D3559	-	< 0.001	<0.001	0.003	0.001	0.001
Zinc	mg/L	ASTM D1691	-	0.230	0.220	0.225	0.226	0.215
Chromium	mg/L	ASTM D1687	-	< 0.001	< 0.001	0.008	<0.001	<0.001
Nickel	mg/L	ASTM D1887	-	< 0.001	< 0.001	<0.001	<0.001	<0.001
Vanadium	mg/L	ASTM D3373	-	< 0.001	< 0.001	<0.001	<0.001	<0.001
E-coil	MPN/100Ml	APHA9221F/ API-RP38	200MP	37.00	41.00	56.0	41.00	38.00

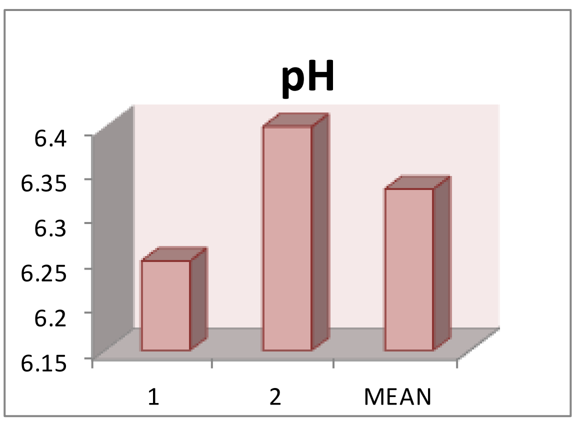

Figure 2: pH Variation in Weekly Post-Treated Produced Water.

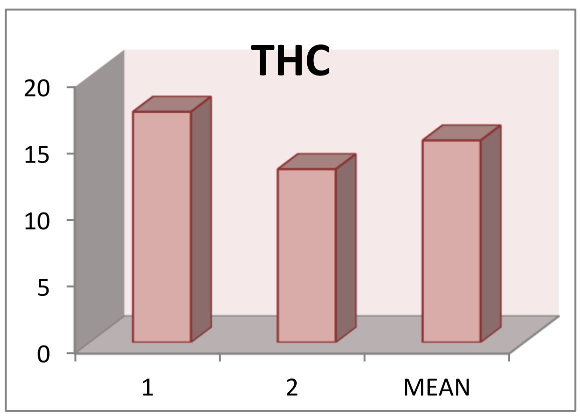

Figure 3: Total Hydrocarbon Levels in Weekly Post-Treated Produced Water (mg/L).

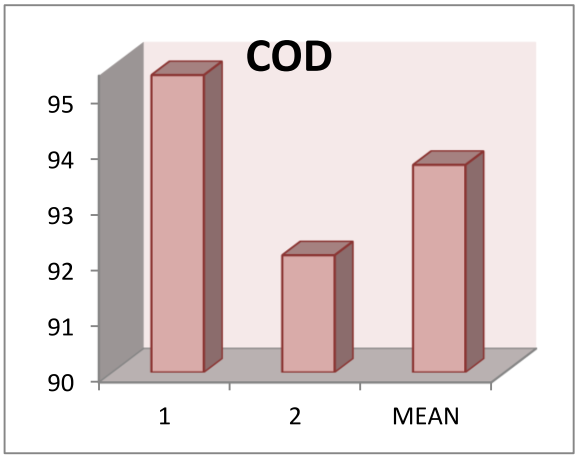

Figure 4: Chemical Oxygen Demand in Weekly Post-Treated Produced Water (mg/L).

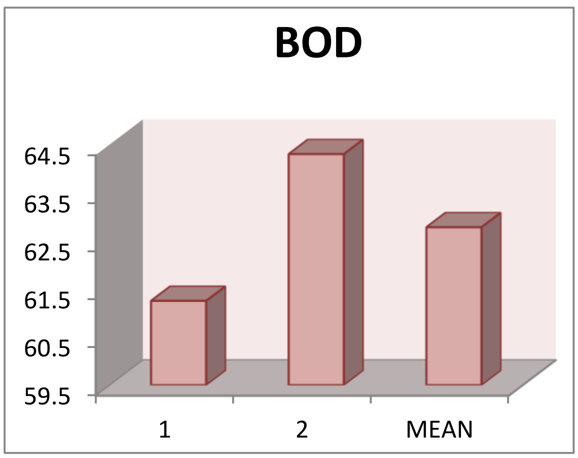

Figure 5: Biochemical Oxygen Demand in Weekly Post-Treated Produced Water (mg/l).

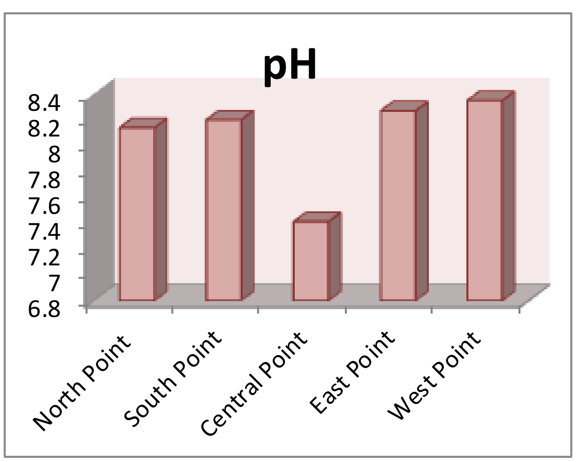

Figure 6: pH Variation at Five Points in Recipient Water.

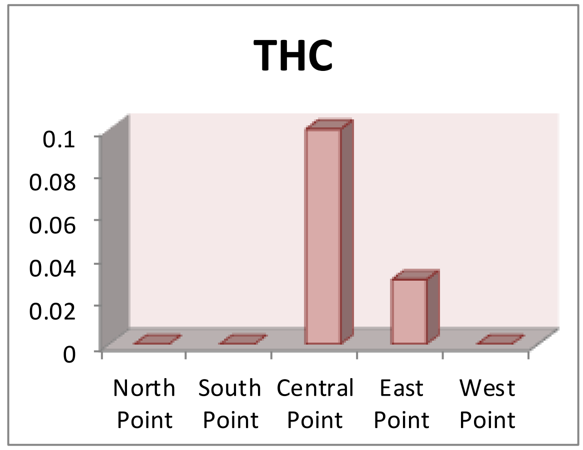

Figure 7: Total Hydrocarbon (THC) at Five Points in Recipient Water (mg/L).

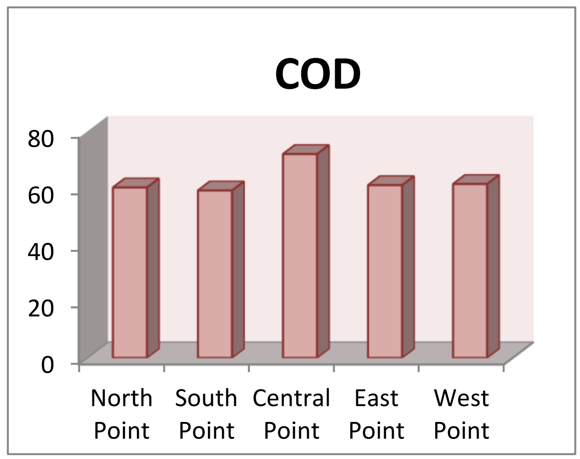

Figure 8: Chemical Oxygen Demand (COD) at Five Points in Recipient Water (mg/L).

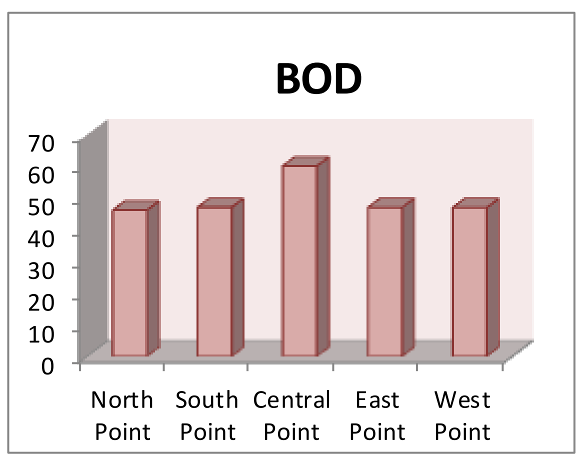

Figure 9: Biochemical Oxygen Demand (BOD) at Five Points in Recipient Water.

DISCUSSION OF RESULTS

Total Hydrocarbon Content, THC (13.00-17.31mg/l), turbidity (10.70-11.00mg/l), total suspended solids, TSS (10.00-12.00mg/l), and temperature (29.50-29.75^{o}C), all fall within the DPR allowable limits and therefore do not constitute any treat to the recipient marine environment. This was also the case of the chemical oxygen demand, COD (92.10-95.33mg/l), biochemical oxygen demand, BOD (61.25-64.30mg/l), and heavy metals of lead, iron, copper, chromium, and zinc.

The pH of the recipient marine water showed compliance with the DPR standards unlike that of the produced water with a mean value of 6.33. The central discharge point with a pH value of 7.41 indicates the point maximum concentration of the effluent discharge thereby having a near neutral pH.

The total hydrocarbon concentration (THC) was 0.1mg/l at the central discharge point. The north, south, east, and west points had values of 0.01mg/l, 0.01mg/l, 0.03mg/l, and 0.01mg/l. This gives the following implications:

(1) THC emanates from a source and enters the recipient water.
(2) THC entering the recipient water emanates from the central discharge point.
(3) The source concentration is higher than other points.
(4) The recipient water at the east point is slightly affected.

The dissolved oxygen content (DOC) values show a non-compliance with DPR standards. The total dissolved solid (TDS) also show a level of non-compliance with DPR standards.

Other parameters such as nitrate, ammonium ion, cyanide, phosphate, phenols, *E. coli*, and trace metals showed compliance with DPR standards.

In all the physico-chemical parameters evaluated, the central discharge point showed slight variations in value showing that this was the point of maximum concentration before dilution with distance from the discharged point.

It is obvious that produced water have potential impacts on the recipient environment depending on where it is being discharged. For example, discharges to small streams are likely to have a larger environmental impact than discharges made to the open ocean by virtue of dilution that takes place there.

CONCLUSION

The present study have demonstrated that from the produced water discharged, the average pH, temperature, chloride and total dissolved solid did not comply with the DPR limits of (6.5-8.5), (30^{0}C), (2000mg/l), and (5000mg/l), respectively. In addition, COD and BOD concentrations, though below limit were approaching guideline limits. Recipient water recorded non-compliance in all five points for TDS and chloride. Other parameters analyzed in the entire sampling points were within the limit.

It is recommended, therefore, that appropriate base solution should be added to the effluent water to neutralize the pH. To bring down the COD values, flush water should be mixed with 30% Hydrogen peroxide to oxidize the hydrocarbons present. Effluent should be stored in a secondary environment. The flush being used in the facilities should be checked, because the pipes may have been corroded which may result in a high level of contaminants such as the trace metals in the saver pit. Skimming of the saver pit should be done regularly to achieve regulatory compliance.

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ABOUT THE AUTHOR

George Uchebike Ozulu, holds a Master of Science (M.Sc.) degree in Petroleum Geology from Nnamdi Azikiwe University, Awka. He is currently a doctoral student with research interest in petroleum geology- reservoir characterization in the Niger Delta and biostratigraphic and sequence stratigraphic studies within the Middle Niger basin. He is a Lecturer II in Earth Sciences Department of Salem University Lokoja, Nigeria.

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