QUALITY ASSESSMENT OF DISPOSED OILFIELD PRODUCED WATER IN THE NIGER DELTA

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ABSTRACT

Oilfield produced water is the largest waste stream generated during oil and gas production and it has a high potential for contamination of marine environments when disposed without treatment. However, effective treatment before disposal is acceptable, but meeting the approved standards for discharge remains a challenge for the petroleum industry. To determine the extent of compliance with regulated standards in the Niger Delta, the physicochemical properties of produced water from two oil fields before and after treatment were investigated in this study. Concentrations of heavy metals and organic compounds in the water samples were analysed using atomic absorption spectrophotometer and gas chromatography respectively. Results show that oilfield waters from the Niger Delta contain high concentrations of heavy metals and organic compounds. It is observed that treated produced waters for disposal fall below the approved standards for heavy metals and organic compounds while concentrations of dissolved oxygen fall below 5mg/l which is detrimental to aquatic organisms. Disposal of large volumes of such waters into the ecosystem over an extended period of time endangers aquatic lives and degrades the marine environment. It is therefore recommended that produced water be re-injected back into the very formations from where they are produced to ensure environmental protection and preservation of marine ecosystems.

Keywords: Heavy metals, concentration, dissolved oxygen, environment.

INTRODUCTION

Petroleum production plays a very important role in many modern economies and is vital in ensuring continuous economic growth for oil and gas producing countries. However, waste products that emanate from oil and gas operations can impact negatively on environments of host communities and can rake havoc on the ecosystem. Amongst these waste products is oilfield produced water which must be disposed in the environment and can result in environmental degradation of a different category and scale. It is therefore essential that oilfield waters be properly treated before disposal to minimize environmental damage. Most times, oilfield waters are discharged directly from

production platforms into surrounding marine environments following approved limits on levels of contaminants based on regulatory laws. Waste water treatment before discharge is commendable and essential for environmental preservation and protection but monitoring strategy to ensure that stipulated standards for effluent discharge is met is also necessary. In this work, the environmentally unfriendly composition of oilfield waters are determined before and after treatment and they are compared against approved discharge limits.

It is speculated that produced water from conventional onshore fields will double globally over the next 10 years from 2019 to 2028. A similar forecast by Produced Water Society [1] has been made for produced water discharge from conventional onshore and offshore fields as presented in Figures 1(a) and 9b). This implies that very large volumes of produced water will be disposed in future, stressing the need to comply with regulations otherwise the level of contamination in marine environments will be enormous. This will endanger aquatic plants, animals, microorganisms, the food chain and the entire ecosystems if strategic measures are not put in place to ensure compliance to requirements of regulatory bodies.

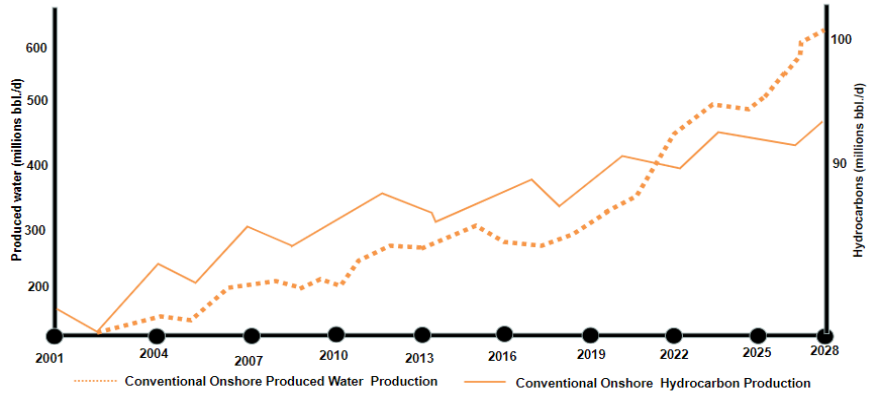

Figure 1(a): Projected Global Onshore Produced Water and Hydrocarbon Production

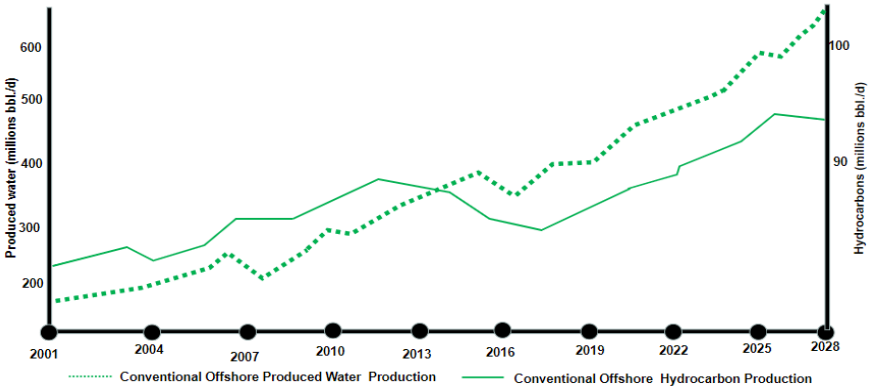

Figure 1(b): Projected Global Offshore Produced Water and Hydrocarbon Production

CHARACTERISTICS OF PRODUCED WATER

The composition of oilfield waters is reported to be toxic to human health through dermal contact, ingestion or inhalation [2]. It causes reduction of plant growth and can lead to destruction of aquatic life [3]. Organic compositions such as phenols and polycyclic

aromatic hydrocarbons (PAHs) like anthracene, phenanthrene, pyrene, naphthalene and benzene, toluene and xylene (BTX) mixtures, all of which are aromatic hydrocarbons have been considered the most harmful contaminants in produced water. All these as well as heavy metals are hazardous and environmentally unfriendly [4 -6]. They have been categorized as high priority chemicals for both environmental safety and public health, despite their small fractions of less than 1% [7 - 14].

Biological or biochemical oxygen demand (BOD) is the amount of dissolved oxygen required by aerobic organisms to break down organic materials present in a given water sample at certain temperature over a specific time period. A decline in dissolved oxygen implies a high level of biological oxygen demand because dissolved oxygen is inversely proportional to biological oxygen demand. In water bodies, dissolved oxygen is expected to be 5mg/l and above because at values lower than 5mg/l, fishes and other living things in water will not thrive. When dissolved oxygen falls below 5mg/l or less, the mortality rate of some marine organisms rise while other marine creatures move away to areas where the concentration of dissolved oxygen is conducive [15]. High concentration of phosphorus in water increases eutrophication which can lead to the death of some species of marine organisms due to low dissolved oxygen [16, 17].

REGULATORY POLICIES IN NIGERIA

In Nigeria, National Environmental Standards and Regulations Enforcement Agency (NESREA) is responsible to ensure environmental safety of lives of humans, plants, animals and the ecosystem. According to the Principal legislation of Petroleum Act 1969 (Revised Edition 2002), established guidelines and discharge standards are enforced by the Department of Petroleum Resources (DPR). Part of the established environmental guideline states that wastewater from production platform terminal operations, process water and produced water, shall be treated to the satisfaction of DPR before disposal. Another stated guideline is that produced water from offshore/deep waters may be discharged into offshore and deep-water areas if oil and grease content of less than 40mg/l is achieved after treatment [18]. This shows that permission is granted to dispose oilfield waters into offshore waters only on the grounds that certain stipulated composition limits for disposal are met but these requirements have not often been met [19].

METHOD OF STUDY

Produced water samples used in this work were obtained within the Niger Delta region of Nigeria; specifically, in an onshore operational production facility in Delta state. Produced water from facilities in the area is usually treated using the activated sludge process after which it is discharged directly into nearby rivers. Two sets of produced water samples were collected from two separate facilities in the region and each set of water samples consists of untreated and treated samples. The untreated samples were treated before disposal and the physicochemical properties of these water samples were determined. Concentrations before and after treatment for heavy metals (zinc, cadmium, lead, chromium, iron, nickel and copper) and organic compounds (BTX, phenol, PAHs and benzene) were also determined. Atomic absorption spectrophotometer with air-acetylene and gas chromatography were deployed to conduct this study.

Sterilized one litre sample bottles were used to collect untreated produced water at the influent line while treated produced water was collected at the effluent end. To reduce the loss of concentration and the growth of bacteria, samples were wrapped in a cooler containing ice cubes using a cellophane bag. Before treatment, samples were taken at different locations for the daily throughput while post treated samples were taken at different time intervals and average result values were obtained and used for each case.

RESULTS AND DISCUSSIONS

Results of conducted tests with two sets of oilfield water samples collected before and after treatment and compared with the approved DPR standard are presented in Figures 2 to 7. Results for heavy metal concentration in cases 1 and 2 are presented in Figures 2 and 3 respectively. Figure 2 shows that out of the six heavy metals present in the produced water, four (cadmium, lead, chromium and nickel) fall short of the DPR standards after treatment but were disposed into the river. In fact, the concentrations of zinc that met the approved standard were already low even before treatment, while the concentration of iron was already close to the standard before treatment. In the second case (Figure 3), the result of zinc is similar to case 1, while the result for iron after treatment was good. However, the concentrations of cadmium, chromium, copper and nickel did not meet the approved standards. This implies that the mechanism for oilfield water treatment for heavy metals is inefficient and as such, water bodies where large volumes of these oilfield waters have been disposed over the years are highly contaminated with heavy metals.

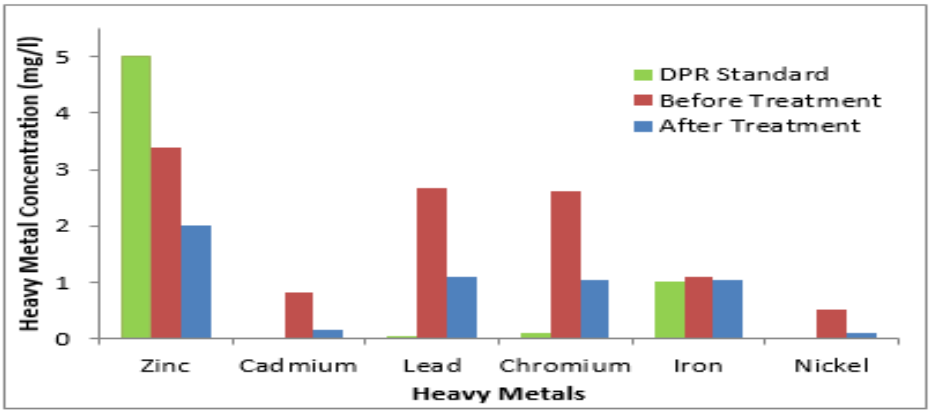

Figure 2: Results of Heavy Metals for Case 1

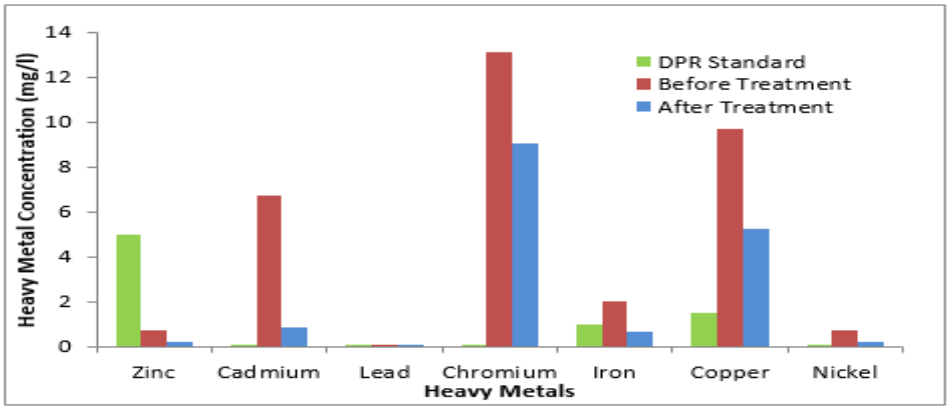

Figure 3: Results of Heavy Metals for Case 2.

Concentrations of organic compounds contained in samples of the produced waters before and after treatment are presented in Figures 4 and 5. These two sets of results show that the concentrations of phenol and PAH after treatment fall short of approved standards, however, BTX in case 1 is below standard while BTX in case 2 met the required standard after treatment. The presence of aromatic hydrocarbon compounds in water such as phenol, PAH and BTX are toxic to biotic factors in an environment with effects such as reduced fertility, high mortality rate and growth inhibition. Thus, the presence of such compounds below approved standards in a marine ecosystem is environmentally unfriendly.

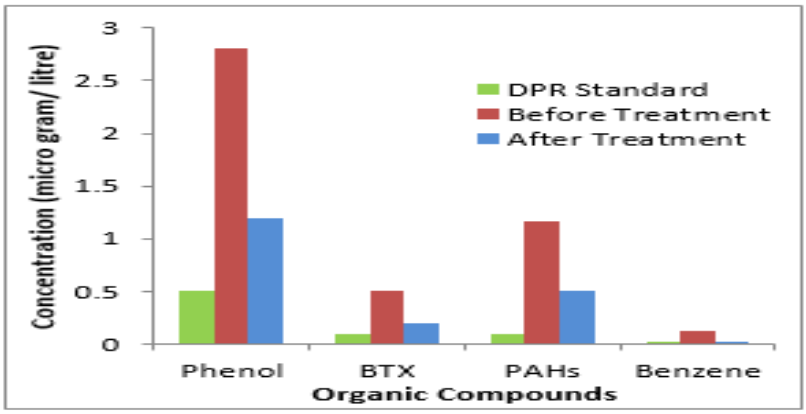

Figure 4: Results of Organic Compounds for Case 1

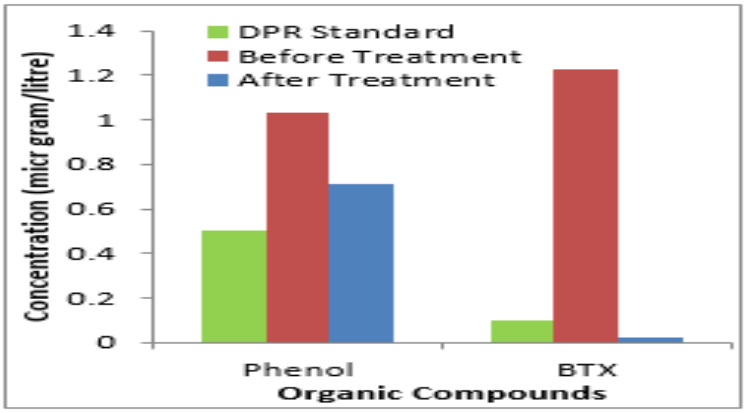

Figure 5: Results of Organic Compounds for Case 2

Figures 6 and 7 show the results of phosphorus, biological oxygen demand (BOD) and dissolved oxygen (DO). These three parameters are inter-related because high phosphorus concentrations can lead to high BOD and less DO. However, the results show that phosphorus concentrations are low especially in case 1 while in case 2, the concentration of the treated case is still below standard. The approved standard for DO is expected to increase above 5mg/l not lower, hence the DO for cases 1 and 2 are below approved standards. Living organisms require oxygen to thrive and most of these organisms survive in water bodies with DO level of 5mg/l and above. Therefore, DO levels below 5mg/l are not conducive for the existence of most marine organisms.

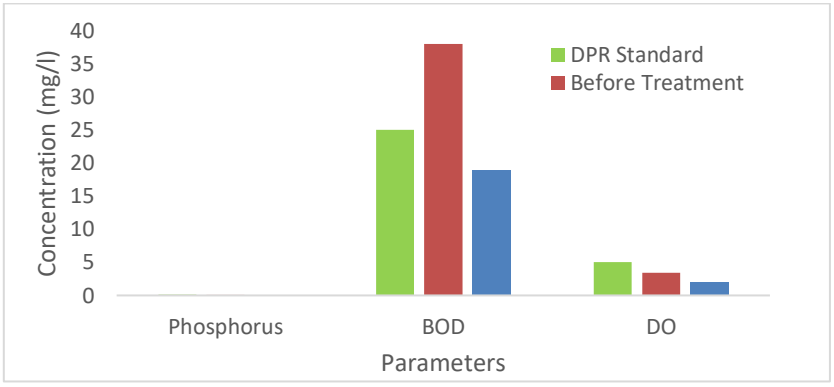

Figure 6: Other Oilfield Water Parameters for Case 1

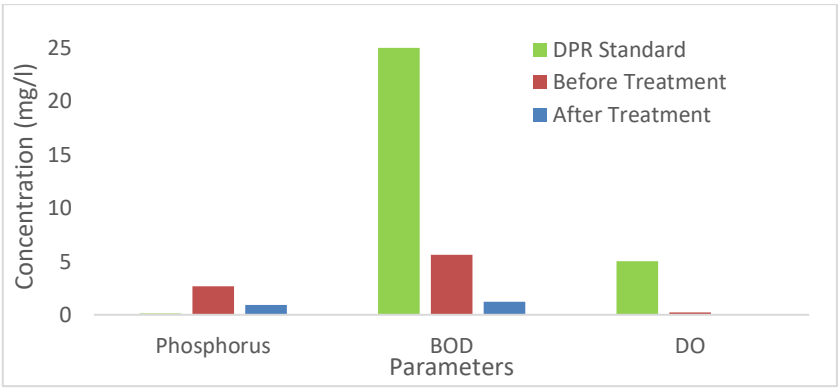

Figure 7: Other Oilfield Water Parameters for Case 2

Results of physicochemical characteristics of the oilfield waters are presented on Table 1. Generally, the after treatment results of parameters on the Table are either within or close to approved standards except for few cases.

***Table 1**: Other characteristics of the obtained oilfield water samples*

S/No.	Parameter	DPR Approved Standard	Case 1		Case 2	
			Before Treatment	After Treatment	Before Treatment	After Treatment
1.	Temperature (°C)	25 - 30	33	27.75	36	25
2.	pH	6.5 - 8.5	8.6	6.1	7.7	6.5
3.	Turbidity (NTU)	10 - 15	28	7.1	54	28
4.	Total Suspended Solids (TSS) (mg/l)	30 - 50	107.13	26.1	310	51
5.	Oil and Grease (mg/l)	10 – 40	75	18.1	12.21	5.21
6.	Salinity (mg/l)	600-2000	1743	676.5	996.2	101.1
7.	Chlorides (mg/l)	600	866.6	134	351.9	146
8.	Sulphate (mg/l)	200 - 300	4.7	0.71	117.4	64
9.	Total Hydrocarbon Content (THC) (mg/l)	10	98.1	63	56.2	12

Result analysis from this work has shown that treated produced water in the Niger Delta is hazardous to marine ecosystems. This is because most of the stipulated standards for disposal of oilfield waters are not met, yet large volumes of such waters have been dumped into marine environments for years. In the light of the foregoing, it is evident that

marine environments of the Niger Delta where produced waters are disposed have been highly contaminated and degraded. It is therefore imperative that more stringent regulations be implemented to ensure protection of marine ecosystems in the Niger Delta where oilfield waters are dumped. An effective strategy that can curb this menace is re-injection of produced water in the very formation where it is produced as practised in some developed Western countries.

CONCLUSION

The concentration of heavy metals in some oilfield waters in the Niger Delta is high and such waters after treatment still do not meet approved standards for disposal. Some treated produced waters in the Niger Delta contain organic compound concentrations that do not meet stipulated standards. The concentration of dissolved oxygen in some treated oilfield waters in the Niger Delta is below 5mg/l which is below the approved standard and is not conducive for the survival of some marine organisms. Generally, the physicochemical properties of some treated oilfield waters produced from the Niger Delta region such as temperature, pH, turbidity, salinity and total suspended solids fall within approved standards. To ensure protection and preservation of marine ecosystems where oilfield waters are disposed in the Niger Delta, it is recommended that produced waters be re-injected into the very formations from where they are produced.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Produced Water Society – PWS. Global Hydrocarbon Production, 2019. Retrieved from https://www.producedwatersociety.com/

[2] Abdel-Shafy, H.I. and Mansour, M.S., A review on polycyclic aromatic hydrocarbons: source, environmental impact, effect on human health and remediation. *Egyptian journal of petroleum, 25*(1), 107-123, 2016.

[3] Pichtel, J., Oil and gas production wastewater: Soil contamination and pollution prevention. *Applied and Environmental Soil Science, 2016*.

[4] Ihebuzor, V., Onyeneke, O. and Obasi, O., *Water Injection in Complex Geology: A Case Study of a Field in the Niger Delta.* Paper presented at the SPE Nigeria Annual International Conference and Exhibition, 2020.

[5] Obasi, P.N. and Akudinobi, B.B., Potential Health Risk and Levels of Heavy Metals in Water Resources of Lead-Zinc Mining Communities of Abakaliki, Southeast Nigeria, *Applied Water Science*, 10, Number 184, Pp. 4, 11, 2020.

[6] Okogbue, C., Oyesanya, O., Anyiam, O. and Omonona, V., Assessment of pollution from produced water discharges in seawater and sediments in offshore, Niger Delta. *Environmental Earth Sciences, 76*(10), 359, 2017.

[7] Richardson, S.D. and Ternes, T.A., Water analysis: emerging contaminants and current issues. *Anal. Chem.*, *77*(12), 3807-3838, 2005.

[8] Gong, Y., Zhao, X., Cai, Z., O'Reilly, S., Hao, X. and Zhao, D.J.M., A review of oil, dispersed oil and sediment interactions in the aquatic environment: influence on the fate, transport and remediation of oil spills. *Mar Pollut Bull. 79*(1-2), 16-33, 2014.

[9] Chavan, A. and Mukherji, S., Treatment of hydrocarbon-rich wastewater using oil degrading bacteria and phototrophic microorganisms in rotating biological contactor: effect of N: P ratio. *Journal of hazardous materials*, *154*(1-3), 63-72, 2008.

[10] Gaya, U.I. and Abdullah, A.H., Heterogeneous photocatalytic degradation of organic contaminants over titanium dioxide: a review of fundamentals, progress and problems. *Journal of photochemistry and photobiology C: Photochemistry reviews*, *9*(1), 1-12, 2008.

[11] Chong, M.N., Jin, B., Chow, C.W. and Saint, C., Recent developments in photocatalytic water treatment technology: a review. *Water research*, *44*(10), 2997-3027, 2010.

[12] Dwyer, B.P. and McDonald, F. Treatment of Oil & Gas Produced Water. *Sandia National Laboratories (SNL-NM)*, Albuquerque, NM (United States), 2016.

[13] Jimenez, S., Micó, M., Arnaldos, M., Medina, F. and Contreras, S., State of the art of produced water treatment. *Chemosphere*, *192*, 186-208, 2018.

[14] World Health Organizatio - WHO, Water, sanitation,hygiene and health. *World Health Organization*, (2019). Retrieved from https://apps.who.int/iris/bitstream/handle/10665/330100/WHO-CED-PHE-WSH-19.149-eng.pdf?ua=1

[15] Fondriest Environmental, Inc. Dissolved Oxygen and Aquatic Life, Fundamentals of Environmental Measurements 2013. Retrieved from https://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/

[16] Conley, D.J., Paerl, H.W., Howarth, R.W., Boesch, D.F., Seitzinger, S.P., Havens, K.E., Lancelot, C. and Likens, G.E., Controlling eutrophication: nitrogen and phosphorus. *Science*, *123*, 1014-1015, 2009.

[17] Litki, D.W., Review of Phosphorus Control Measures in the United States and their Effects on Water Quality, US Geological Survey Water Resources Investigations Report, 99 – 4007, National Water Quality Assessment Program, Denver, Colorado, 1999.

[18] Environmental Guidelines and Standards for the Petroleum Industry in Nigeria, Revised Edition, Pp. 284-290, 2002.

[19] Isehunwa, S. and Onovae, S., Evaluation of produced water discharge in the Niger Delta. *Journal of Engineering and Applied Sciences*, 6(8):66-72, 2011.

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