Original Research Article

Analysis of the Reduction in Pollutants from Oilfield Wastewater on the Receiving Environment

ABSTRACT

Oilfield wastewater from discharge pond and soil around the discharge pond of an oil producing vicinity were collected using standard procedures. The heavy metals and physicochemical constituents of the soil and wastewater from the receiving pond were examined according to normal procedures in compliance with the Environmental Protection Agency. The presence of negative numbers in the results indicates that there was an influence on the physicochemical parameters. It was discovered that the salinity of the soil surrounding a discharge pond was-73.80±53.20 mg/kg during the rainy season. Soil moisture content recorded a negative value of -43.77±9.477 during the rainy season. Potassium, nitrate, phosphate, calcium, magnesium, sulphate, total nitrogen, organic carbon, zinc, and copper recorded negative values in both dry and raining seasons. However higher values of -2309±486.4 mg/kg for potassium, -450.3±65.30 mg/kg for phosphate, -2779±274.2 mg/kg for calcium, -717.4±80.53 mg/l for zinc were obtained during the dry season. High values of -133.4±8.937 mg/kg for nitrate, -262.6±23.27 mg/kg for magnesium, -923.7±101.1 mg/kg for sulphate, -133.3±15.09 mg/kg for total nitrogen, -2788±276.9% organic carbon, -275.7±39.28% for TOM, -3.567±9257 mg/kg for alkalinity and -114.0±77.45 mg/l for copper were obtained during the raining season. For the wastewater from the receiving pond during the dry season, total dissolved solids (TDS), dissolved oxygen (DO), biological oxygen demand (BOD), nitrogen, phosphate, and polycyclic aromatic hydrocarbon recorded negative values of -4083±4.122 mg/l, -18.33±9.208 mg/l, -18.33±9.208mg/l, -70.35±39.50 mg/l, -312.9±170.7 mg/l and 617007±3.93 mg/l, respectively. High negative values during the raining season were obtained in turbidity (-17.57±94.87 NTU), TSS (-303.7±54.37 mg/l), TOC (-6276±6.294%), and total petroleum hydrocarbon (-105.1±162.1 mg/l). The heavy metals recorded high negative values of -6767±809.0 mg/l for lead, -14433±238 mg/l for chromium, -3317±2347 mg/l for copper, and -1967 ±66.67 mg/l for cadmium during the rainy season. High values obtained in the dry season were -59668±34243 mg/l for zinc and -2213±1472 mg/l for a nickel. The results suggest that oilfield wastewater impacts the receiving environment negatively.

Keyword: Oilfield wastewater, Heavy metals, Physicochemical parameters, Pollutants, Receiving environment

Introduction

Oilfield wastewater is defined as water that is created during the extraction of oil or gas. Because oilfield wastewater has such diverse physicochemical qualities, it is important to understand how they vary from one another. Petroleum fields create more than 60% of all oilfield wastewater produced worldwide (Abass, 2020). The majority of the wastewater created is dumped into the aquatic environment, which is not ideal (Neff et al., 2011). In oilfield wastewater, chemical compounds used in the drilling process, the production process, and the separation of water and oil are present, as is water utilized in the separation process. Composition of oilfield wastewater is complex, and it includes dissolved oil, dissolved hydrocarbons, dissolved gasses, organic acids, phenols, metals (Tibbetts et al., 1992). These chemical components in oilfield wastewater may have an impact on the coefficients of partition, toxicity, bioavailability, and biodegradability of the wastewater (Hedar and Budiyono, 2018). It is dependent on the physical, chemical, and biological makeup of an area that the influence of oilfield wastewater will have. When compared to crude oil, the organic and inorganic chemicals found in oilfield wastewater have a greater potential for toxicity. In addition to endangering aquatic life and agricultural resources, the discharge of these toxic elements and pollutants into the aquatic environment may also harm aquatic life and agricultural resources by disrupting the natural condition of the aquatic environment (Neff et al., 2011). Organic material is the component of oilfield wastewater that has the greatest potential for causing environmental harm to the environment (Yazdan et al., 2020). It is possible to find two types of organic materials in product water: scattered oil and non-hydrocarbon organic material. Dispersed oil is made up of tiny, distinct droplets that are suspended in a liquid. Nonhydrocarbon organic substance is dissolved in water and is not a hydrocarbon (Ekins et al., 2007; Stephenson, 1992). Instead of precipitating at the seafloor, dispersed oil and droplets rise to the surface of the water. Compounds that are volatile and/or poisonous evaporate. The wastewater from certain oilfields contains compounds that are very harmful to sensitive marine animals and may be toxic even at low quantities. Aromatic hydrocarbons, some alkylphenols, and a few metals are the chemicals of greatest environmental concern in produced water because their concentrations may be high enough to cause bioaccumulation and toxicity. Aromatic hydrocarbons, some alkylphenols, and a few metals are the chemicals of greatest environmental concern in produced water because their concentrations may be high enough to cause bioaccumulation and toxicity. Most metals and naturally occurring radionuclides are present in oilfield wastewater in chemically reactive dissolved forms at concentrations that are comparable to or only slightly higher than those found in seawater, and as a result, they are unlikely to cause adverse effects in the receiving water environment when present in these forms (Aleruchi and Obire, 2020). Heavy metal toxicity is lower in oilfield wastewater than the toxicity of nonpolar organics. The discharge of partially treated or sometimes totally untreated oilfield wastewater into shallow estuarine and marine waters may result in the accumulation of certain metals, as well as higher molecular weight aromatic and saturated hydrocarbon compounds, in sediments near the oilfield wastewater discharge, which may be detrimental to the health of bottom-living biological communities (Yazdan et al., 2020). Oilfield wastewater have adverse impact on the environment as it contains different types of toxic and complex organic and inorganic compounds (Ghafoori et al., 2022). The findings of this study corroborate the findings of Dejong (1980), who discovered that oil pollution modifies both the chemical and physical aspects of soil, as well as degrading soil fertility. Oil has been shown to have negative impacts on soil qualities as well as the plant community. Researchers such as Barker (1970), Amadi et al. (1993), and Osuji et al. (2005) have noticed that oil concentrations more than three percent have been described as progressively detrimental to biota and crop development. The purpose of this research therefore is to determine the reduction in pollutants from oilfield wastewater on the receiving environment.

MATERIALS AND METHODS

The Study Area

The study was carried out in Ogbogu Flow Station; an onshore oil production platform located in Ogba/Egbema/Ndoni Local government Area (ONELGA) of Rivers State, Nigeria. It lies on Latitude 5.34167N and Longitude 6.65556E.

Samples Used

Samples used for the study include:

A. **Receiving pond water:** samples were collected from the receiving water body where the produced water is being discharged.

B. **Soil Samples:** were collected around the pond where the oilfield wastewaters are discharged and also 80m away from the pond which served as control.

Collection of receiving pond water samples

The receiving pond water sample was randomly collected at four different points in the pond using composite sampling method. The plastic bottles were appropriately labeled and stored in an ice-packed cooler. The stored samples were immediately transported to the laboratory within 24 hours for processing and analysis. The four replicate samples were thoroughly mixed to form a composite. Samples were collected for a period of one year (January to December 2018) to cover both dry and rainy seasons.

Collection of soil samples

The soil samples were randomly collected at four different parts around the pond and 80 meters away from the pond (control) at a depth of 0-15cm with a clean auger into sterile polythene bags. The samples (500g each) were labeled and transported to the laboratory in a cooler packed with ice blocks for analysis.

Heavy metal and physicochemical analysis of the soil samples

Heavy metals and physicochemical analyses of the soil samples were conducted according to the standard procedures of APHA (1998) and ASTM (1999). Salinity, soil moisture content, potassium, nitrate, phosphate, calcium, magnesium, sulphate, total nitrogen, organic carbon, total organic matter, alkalinity, total hydrocarbon content, polycyclic aromatic hydrocarbon, zinc, iron, and copper were also analyzed or determined for the soil samples.

Heavy metal and Physicochemical analysis of receiving pond water samples

Heavy metals and physicochemical analyses of the receiving pond water samples were conducted according to the standard procedures of APHA (1998) and ASTM (1999). The physicochemical parameters determined include salinity, turbidity, conductivity, total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), biological oxygen demand (BOD5), chemical oxygen demand (COD), nitrogen, phosphate, total organic carbon (TOC), total petroleum hydrocarbon, polyaromatic hydrocarbons (PAHs), and heavy metals such as nickel, lead, zinc, aluminum chromium, selenium, arsenic, copper, and cadmium.

Determination of the reduction in pollutant concentrations on physicochemical parameters of soil around discharge pond

$$\%\text{ reduced} = \frac{Initial\ value\ (soil\ around\ pond) - Final\ value\ (soil\ 80\ m\ away)\quad \times\ 100}{Initial\ value\ (soil\ around\ pond)}$$

Equation ………..1

Where soil 80 m away served as control. Negative values obtained indicated impact on the soil physicochemical parameters.

Determination of the reduction in pollutant concentrations on receiving pond

% reduced =

$$\frac{Original\ value\ (Oilfield\ Wastewater) - Final\ value\ (Receiving\ pond\ water)}{Original\ value\ (Oilfield\ Wastewater)} \times 100$$

Equation………….. 2

Negative values obtained showed that the physicochemical parameters on the receiving pond were impacted.

Results

Reduction in pollutant concentration on the soil around discharge pond and receiving pond water

The reduction in pollutant concentrations on physicochemical parameters of soil around discharge pond during the dry and raining season are shown in Table 1. Results with negative values show the impact of the oilfield wastewater on the physicochemical parameters of soil around the discharge pond. Salinity recorded a negative value of -73.80±53.20 mg/kg during the rainy season and was significantly different from the value of 28.77±13.32 mg/kg obtained during the dry season. Soil moisture content recorded a negative value of -43.77±9.477 during the rainy season and was significantly different from the value of 14.88±10.89% obtained during the dry season. Potassium, nitrate, phosphate, calcium, magnesium, sulphate, total nitrogen, organic carbon, zinc, and copper recorded negative values in both dry and raining seasons. However higher values of -2309±486.4 mg/kg for potassium, -450.3±65.30 mg/kg for phosphate, -2779±274.2 mg/kg for calcium, -717.4±80.53 mg/l for zinc were obtained during the dry season. High values of -133.4±8.937 mg/kg for nitrate, -262.6±23.27 mg/kg for magnesium, -923.7±101.1 mg/kg for sulphate, -133.3±15.09 mg/kg for total nitrogen, -2788±276.9% organic carbon, -275.7±39.28% for TOM, -3.567±9257 mg/kg for alkalinity and -114.0±77.45 mg/l for copper were obtained during the raining season. Tables 2 and 3, showed the effects of the oilfield wastewater on the physicochemical parameters and heavy metals, respectively on the receiving pond water. Results with negative values during the dry and raining seasons indicate effects. During the dry season, total dissolved solids (TDS), dissolved oxygen (DO), biological oxygen demand (BOD), nitrogen, phosphate and polycyclic aromatic hydrocarbon recorded negative values of -4083±4.122 mg/l, -18.33±9.208 mg/l, -18.33±9.208mg/l, -70.35±39.50 mg/l, -312.9±170.7 mg/l and 617007±3.93 mg/l, respectively. High negative values during the raining season were obtained in turbidity (-17.57±94.87 NTU), TSS (-303.7±54.37 mg/l), TOC (-6276±6.294%), and total petroleum hydrocarbon (-105.1±162.1 mg/l). There was no significant difference in the values obtained between the dry and rainy seasons. The heavy metals in Table 3 recorded high negative values of -6767±809.0 mg/l for lead, -14433±238 mg/l for chromium, -3317±2347 mg/l for copper, and -1967 ±66.67 mg/l for cadmium during the rainy season. High values obtained in the dry season were -59668±34243 mg/l for zinc and -2213±1472 mg/l for a nickel.

Table 1: Reduction in pollutant concentrations on physicochemical parameters of soil around discharge pond during the Dry and Rainy Season

Parameter	Dry Season ± SEM	Raining Season ± SEM	P Value
Salinity (mg/kg)	28.77 ± 13.32	-73.80 ± 53.20	0.0370
Soil moisture content (%)	14.88 ± 10.89	-43.77 ± 9.477	0.0110
Potassium (mg/kg)	-2309 ± 486.4	-837.1 ± 133.6	0.0793
Nitrate (mg/kg)	-122.4 ± 19.96	-133.4 ± 8.937	0.7237
Phosphate (mg/kg)	-450.3 ± 65.30	-345.7 ± 82.86	0.3731
Calcium (mg/kg)	-2779 ± 274.2	-2663 ± 442.8	0.8222
Magnesium (mg/kg)	-226.7 ± 31.31	-262.6 ± 23.27	0.4805
Sulphate (mg/kg)	-852.5 ± 71.14	-923.7 ± 101.1	0.5820
Total nitrogen (mg/kg)	-70.40 ± 5.129	-133.3 ± 15.09	0.0015
Organic carbon (%)	-1896 ± 881.2	-2788 ± 276.9	0.5152
TOM (%)	-86.02 ± 60.48	-275.7 ± 39.28	0.0787
Alkalinity (mg/kg)	0.01667 ± 5.021	-3.567 ± 9.257	0.7179
THC (mg/kg)	79.60 ± 2.140	95.53 ± 0.3480	0.0014
PAHs (mg/kg)	7.850 ± 23.55	31.87 ± 4.245	0.5099
Zinc (mg/l)	-717.4 ± 80.53	-549.5 ± 37.74	0.2059
Iron (mg/l)	17.35 ± 3.166	13.77 ± 0.8192	0.4676
Copper (mg/l)	-9.333 ± 31.79	-114.0 ± 77.45	0.1722

KEY: $P \leq 0.05$ are significantly different, TDS=total dissolved solid, TSS= total suspended solid, DO=dissolved oxygen, BOD= biological oxygen demand, COD= chemical oxygen demand, TOC=total organic carbon, TPH=total petroleum hydrocarbon, PAHs=polycyclic aromatic hydrocarbons

Table 2: Reduction in pollutant concentrations on physicochemical parameters on receiving pond water (Dry and Rainy Season)

Parameter	Dry Season ± SEM	Raining Season ± SEM	P-Value
Salinity	15.05 ± 12.25	53.57 ± 1.633	0.0693
Turbidity (NTU)	22.42 ± 14.94	-17.57 ± 94.87	0.5629
Conductivity (µS/cm)	11.75 ± 36.56	56.40 ± 4.475	0.4324
TDS (mg/l)	-4083 ± 4.122	67.03 ± 5.272	0.5137
TSS (mg/l)	-231.9 ± 159.0	-303.7 ± 54.37	0.7695
DO (mg/l)	-18.33 ± 9.208	13.47 ± 9.202	0.0682
BOD (mg/l)	-5.200 ± 27.52	10.10 ± 20.35	0.7290
COD (mg/l)	21.18 ± 31.85	39.13 ± 5.438	0.7125
Nitrogen (mg/l)	-70.35 ± 39.50	-56.50 ± 23.35	0.8235
Phosphate (mg/l)	-312.9 ± 170.7	-31.93 ± 31.93	0.2993
TOC (%)	-341.4 ± 237.6	-6276 ± 6294	0.1944
TPH (mg/l)	-2.767 ± 34.03	-105.1 ± 162.1	0.4118
PAHs(mg/l)	-617007 ± 393324	-3900 ± 1998	0.3223

KEY: $P \leq 0.05$ are significantly different, TDS=total dissolved solid, TSS= total suspended solid, DO=dissolved oxygen, BOD= biological oxygen demand, COD= chemical oxygen demand, TOC=total organic carbon, TPH=total petroleum hydrocarbon, PAHs=polycyclic aromatic hydrocarbons

Table 3: Reduction in Concentrations of Heavy Metals from Oilfield Wastewater when discharged into Pond (Dry and Rainy season)

Parameter	Dry Season ± SEM	Raining Season ± SEM	P-Value
Lead (mg/l)	-6408 ± 1675	-6767 ± 809.0	0.8904
Zinc (mg/l)	-59668 ± 34243	-9980 ± 2920	0.3549
Nickel (mg/l)	-2213 ± 1472	-1833 ± 66.67	0.8653
Aluminum (mg/l)	69.37 ± 13.95	55.00 ± 7.292	0.5155
Chromium (mg/l)	-13353 ± 7549	-14433 ± 2338	0.9256
Selenium (mg/l)	0 ± 0.0000	0 ± 0.0000	-
Arsenic (mg/l)	0 ± 0.0000	0 ± 0.0000	-
Copper (mg/l)	-211.8 ± 197.8	-3317 ± 2347	0.0874
Cadmium (mg/l)	-969.8 ± 694.5	-1967 ± 66.67	0.3599

KEY: $P \leq 0.05$ are significantly different

Discussion

The release of raw and ill-treated wastewater onto receiving bodies has both short- and long- term effect on the environment and human health. Receiving bodies have been negatively impacted by wastewater. Such impacts dependent on the composition and concentration of the wastewater contaminants as well as the volume and frequency of wastewater effluents entering surface water source. Eutrophication of water sources may also create environmental conditions that favor the growth of toxin producing cyanobacteria, and exposure to such toxins is hazardous to human beings (Joshua et al., 2017). In this present study, negative values in the physicochemical characteristics in the soil around the pond and wastewater in the pond indicates that they have been impacted by the oilfield wastewater.

In the soil around the pond, during the rainy season, the salinity, soil moisture content, and alkalinity all recorded negative values. In addition to the oilfield wastewater activities taking place in the area surrounding the receiving pond, it is possible that the wet season had an influence on the soil salinity and soil moisture content. Both the dry and rainy seasons saw a decrease in the concentrations of potassium, nitrate, phosphate, calcium, magnesium, sulfate, total nitrogen, organic carbon, total organic matter, zinc, and copper, among other elements. That is, regardless of the season, the oilfield wastewater had an effect on these physicochemical parameters, resulting in a change in the soil physicochemical parameter. The presence of continuous oilfield wastewater operations in that region will result in increased physicochemical characteristics in the not-too-distant future. Because of the toxicity associated with oilfield wastewater, this may also have an impact on microbial activity.

The influence of oilfield wastewater on receiving pond water showed the concentration levels of different physicochemical elements in the oilfield-produced water, as well as the consequences of these concentrations on the environment. The findings show that such physicochemical factors were concentrated in the pond since the values were negative in the results. As demonstrated by the negative mean values obtained for the total suspended solids (TSS), nitrogen, phosphate and total organic carbon (TOC), total petroleum hydrocarbon (TPH), polycyclic aromatic hydrocarbons (PAHs), lead, zinc, nickel, chromium, copper and cadmium, the oilfield wastewater discharged into the pond contaminates the pond due to the continuous discharge in both seasons. It was only during the wet season that turbidity registered negative readings. In this case, it is possible that rainfall or runoff may have also contributed to the lower-than-expected water dilution efficiency. Only during the dry season did total dissolved solids (TDS), dissolved oxygen (DO), and biological oxygen demand (BOD) have mean levels that were lower than normal. A greater concentration of nutrients in a receiving water body may promote the development of microorganisms and phytoplankton in that water body (Rivkin et al., 2000; Khelifa et al., 2003). Increased turbidity may pose challenges for water purification procedures (Igbinosa and Okoh, 2009), as well as having an adverse effect on aquatic life. It is possible that a high concentration of TDS may be harmful to aquatic life, as well as create changes in taste and excessive scaling in water pipes, water heaters, boilers, and other home equipment when used in large quantities. In receiving water bodies, high conductivity implies the presence of large amounts of total dissolved solids (TDS) (Yilmaz and Koc, 2014). BOD and COD concentrations beyond a certain threshold indicate the presence of organic and inorganic pollution, both of which are hazardous to aquatic life. According to Neff (2002), some generated water includes compounds that are very harmful to sensitive marine species even at low quantities, and this is true even when the water is treated. PAHs are a significant environmental problem in generated water because they have the potential to induce bioaccumulation and toxicity. When produced water is released to shallow, confined coastal water or when the discharge is of low density, the concentration of produced water chemicals may stay high for an extended period of time, causing ecological damage to the environment. The accumulation of large concentrations of heavy metals in sediments at the site of water production may be detrimental to bottom-dwelling biological communities, causing them to die.

Conclusion

The physicochemical parameters obtained in the surrounding soil and receiving pond with negative values indicates that they have been impacted by the oilfield wastewater. Characterization of wastewater and sampling has to be done on a regular basis to secure receiving bodies.

References

Abass, A.O. (2020). Recent advances on the treatment technology of oil and gas produced water for sustainable energy industry-mechanistic aspects and process chemistry perspectives. Chemical Engineering Journal, 4(15), 1-13.

Aleruchi, O. & Obire, O. (2020). Quality Characteristics of an Oilfield Produced Water and Its Recipient Quality Characteristics of an Oilfield Produced Water and Its Recipient Discharge Pond. *E-Journal of Science & Technology (e-JST), February*.

Amadi, A., Dickson, A. A. and Meate, G. O. (1993). Remediation of oil-polluted soils, effects of the organic and inorganic nutrient supplement on the performance of maize. *Soil Pollution*, *66(1/2)*, 59-76.

American Public Health Association (APHA). (1998). Standard methods for the examination of water and wastewater. 20th edition, American Public Health Association, American Water Works Association, and Water Environment Federation. The USA. ISBN 0- 87553-235-7, ISSN 55-1979.

American Standard for Testing and Materials (ASTM). (1999). Water and environmental technology. Annual book of ASTM standards. American Society for Testing and Materials, Philadelphia, PA. Section 11: 01-05, ISBN 0-8031-2686-7. 4.

De Jong, E. (1980). The effect of a crude oil spill on cereals. *Environmental Pollution Series an Ecological Biological*, *22*, 187-196.

Ekins, P., Vanner, R. and Firebrace, J. (2007). J. Clean. Prod., 15, 1302–1315

Igbinosa, E. O. and Okoh, A. L. (2009). Impact of discharge wastewater effluents on physicochemical qualities of receiving watershed in a typical rural community. *International Journal of Science and Technology*, *6*, 175-182.

Joshua, N.E., John, O.O. and Olatunde, S.D. (2017). Impact of wastewater on surface water quality in developing countries: A case study of South Africa. IntechOpen, 401-415.

Khelifa, A., Pahlow, M., Vezina, A., Lee, K. and Hannah, C. (2003). Numerical investigation of the impact of nutrient inputs from produced water on the marine planktonic community. In: Proceedings of the 26th Arctic and Marine Oilspill Program (AMOP) Technical Seminar, Victoria, BC. June 10-12, 2002. Pp. 323-334.

Neff, J.M. (2002). Bioaccumulation in marine organisms. Effects of contaminants from oil well produced water. Elsevier Science Publishers, Amsterdam. Pp 452. 16.

Neff, J.M., Sauer, T.C., and Hart, A. (2011). Bioaccumulation of hydrocarbon from produced water discharged to offshore waters of the U.S. Gulf of Mexico. In: produced water: Environmental Risks and Mitigation Technologies. Lee, K. and Neff, J. (eds.), Springer Publishing. 17.

Osuji, L. C., Egbuson, E. J. and Ojinnaka, C. M. (2005). Chemical reclamation of crude oil inundated soils from the Niger Delta, Nigeria. *Chemistry and Ecology*, *21 (1)*, 1-10.

Rivkin, R.B., Tian, R., Anderson, M.R. and Payne, J.F. (2000). "Ecosystem Level effects of offshore platform discharges Identification, assessment, and modeling." In: Proceedings of the 27th Annual Aquatic toxicity workshop, St John's Newfoundland, Canada, October 01-04, 2000. Canadian technical report of fisheries and Aquatic Sciences. 2331:3-12.

Stephenson, M.T. (1991). Components of produced water: A compilation of results from several industry studies. Proceedings International conference on health, safety, and environment, Hague, Netherlands, November 10-14, 1991. Soc. Petrol. Eng., pap. No.23313, pp.25-38.

Yazdan, M.M.S.; Ahad, M.T.; Jahan, I.; Mazumder, M. (2020). Review on the Evaluation of the Impacts of Wastewater Disposal in Hydraulic Fracturing Industry in the United States. Technologies, 8, 67.

Yilmaz, E. and Koc, C. (2014). Physically and chemistry evaluation for the water quality criteria in a farm on Akcay. J. water resources. Prot. 6:63-67.