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Effect of Soil Microbes on Nitrate, Phosphate and Total Hydrocarbon Content of Various Concentrations of Oilfield Wastewater

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Authors' contributions

This work was carried out in collaboration between both authors. Author AO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author OO managed the analyses of the study and managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

The effects of soil microbes on nitrate, phosphate and total hydrocarbon content of various concentrations of oilfield wastewater were investigated for a period of 28 days using standard methods. Periodic sampling of the treatment options from each flask were carried out after 24 hrs and subsequently at 7 days interval for nitrate, phosphate and total hydrocarbon content analysis. The nitrate, phosphate and total hydrocarbon content were higher in all the treatment options than in the control (0%). The concentration of nitrate and phosphate in the soil treatment options reduced significantly at day 28. Total hydrocarbon content of the 0% (control) on 24 hrs was 48 mg/kg and 26 mg/kg on 28th day, while 10, 25, 50 and 75 (%) were 160 and 98, 162 and 94, 163 and 98, 163 and 96 mg/kg respectively. There was significant reduction between the incubation period (24 hr and 28 days) in the various treatment option including the control. The results revealed that nutrients (nitrate and phosphate) were been utilized by the soil microbes and further enhanced microbial utilization of hydrocarbons. This suggests that oilfield wastewater could serve as nutrient enhancement medium for indigenous soil microbes in bioremediation process.

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Keywords: Soil microbes; oilfield wastewater; nitrate; phosphate; total hydrocarbon content.

1. INTRODUCTION

Oilfield wastewater or produced water is a formation and injection water that contains production chemicals that is generated during the production of crude oil and gas from onshore and offshore wells [1,2]. The production water is a complex mixture of dissolved and particulate organic and inorganic chemicals in water that ranges from essentially freshwater to concentrated saline brine. Produced waters most abundant organic chemicals are water soluble low molecular weight organic acids and monocyclic aromatic hydrocarbons.

Aromatic hydrocarbons, some alkyl phenols and a few metals are chemicals of great environmental concern in produced water because their concentration may be high enough to cause bioaccumulation and toxicity. Discharge of produced water into aquatic environment is of considerable concern because of the potential danger of chronic ecological harm. Aquatic organisms near a produced water discharge may bioaccumulate metals, phenols and hydrocarbons from the ambient water, their food or bottom sediments. Upon discharge to the aquatic environment or water body, produced water dilutes rapidly, often by 100 fold or more within 100m of the discharge.

The nutrient status of soil has direct impacts on microbial activity of biodegradation. To grow heterotrophic bacteria require in addition to an organic compound that serves as a source of carbon, electron donor and a group of other nutrient elements. Many bacteria and fungi also require low concentration of one or more amino acids and vitamins. Nitrogen and phosphorus are necessary for cellular metabolism and can be found in low concentration in many soils including Arctic soils [3,4,5].

The salinity of produced water introduces microorganisms to a challenge of dealing with osmotic stress, if biological treatment is applied. The low solubility of hydrocarbon substrates makes them difficult to biodegrade, because all known hydrocarbon-oxidizing enzymes are cell-bound [6]. Hydrocarbons with chain lengths above C_{12} are almost insoluble in water and bacteria capable of degrading them need to produce biosurfactants either to attach to the substrate or to solubilize it for uptake [7]. These molecules are also chemically very inert and need to be activated by specific enzymes for biological conversion [7]. Some properties of these produced water or oilfield wastewater can be used as supplement or enrichment medium for soil microbes.

Therefore the objective of this study was to investigate the various concentrations of oilfield wastewater and its effects on soil microbes.

2. MATERIALS AND METHODS

2.1 Collection of Wastewater and Soil Samples

Oilfield wastewater was collected from Ogbogu Flow Station; an onshore oil production platform located in Ogba Egbema Ndoni local government Area (ONELGA) of Rivers State, Nigeria. The Oilfield wastewater samples were collected using 4 Litre capacity plastic bottles and stored in an ice packed cooler.

On the other hand, the soil samples were collected 80 meters away from the pond at a depth of 0-15 cm with a sterile spatula into sterile polythene bags and stored in an ice packed cooler. The collected and appropriately labeled oilfield wastewater and soil samples were immediately transported to the laboratory for analysis within 24 hours for processing and analyses.

2.2 Oilfield Wastewater Impact Studies on Soil Microorganisms

Studies on the impact of oilfield wastewater on soil microorganisms was carried out by inoculating 0 ml, 10 ml, 25 ml, 50 ml and 75 ml (0%, 10%, 25%, 50% and 75%) of oilfield wastewater into separate soil samples (100 g each) in a conical flask and incubated in a rotary shaker under room temperature. Samples were withdrawn at different time intervals or incubation periods and analyzed for pH, nitrate, phosphate and total hydrocarbon content (THC). pH of the samples was determined using Jenway pH meter (model 291 MK2). The meter was switched on and allowed for 15 minutes to heat up. It was then standardized with buffer solutions of higher (8-9) and lower (1-6) pH by dipping the electrode in the buffer solutions. After which the electrode was finally dipped into the sample and the pH value recorded. Nitrate, phosphate and total hydrocarbon content were determined using the method described by APHA [8]. The toluene extraction method used by Odu et al. [9] was adopted for measurement of total hydrocarbon content and the extract was read directly at 420 nm using spectronic 20. Hydrocarbon concentration was calculated by multiplying with the appropriate dilution factor.

2.3 Statistical Analysis

Statistical analysis was also conducted using Duncan Multiple Range test and Analysis of variance to determine whether there is significant difference between the various concentrations and incubation period.

3. RESULTS

The range of the pH value of the treatment options for 0%, 10%, 25%, 50% and 75% are as follows: 6.5 to 6.8. 6.0 to 6.8, 6.0 to 7.0, 6.8 to 7.2 and 6.5 to 7.3 respectively.

The nitrate value in the soil treatment options showed progressive decrease from 24 hrs to day 28. The control 0% option had the least value from the 24 hrs 1.304 mg/kg to 28days 0.960 mg/kg.

All the treatment options decrease as the experiment progressed. 0% 0.454 to 0.283 mg/kg, 10% 1.343 to 1.160 mg/kg, 25% 1.350 to 1.118 mg/kg, 50% 1.368 to 1.094 mg/kg and 75% 1.369 to 0.894.

The result of the total hydrocarbon content in 0, 10, 25, 50 and 75 (%) as shown in Table 4 decreased as the experiment progressed, the control had the least hydrocarbon content 48 to 26 mg/kg.

Table 1. pH from soils treated with various concentrations of oilfield wastewater

Soil treatment with oilfield wastewater	Incubation period (Hrs/Days)				
	24 hrs	**Day 7**	**Day 14**	**Day 21**	**Day 28**
0% (control)	6.7	6.5	6.8	6.5	6.68
10%	6.6	6.3	6.5	6.0	6.8
25%	6.8	6.3	6.0	6.0	7.0
50%	6.8	7.0	7.2	7.0	7.0
75%	6.5	7.0	7.1	7.15	7.3

Table 2. Nitrate from soils (mg/kg) treated with various concentrations of oilfield wastewater

Soil treatment with oilfield wastewater	Incubation period (Hrs/Days)				
	24 hrs	**Day 7**	**Day 14**	**Day 21**	**Day 28**
0% (control)	1.304	1.286	1.220	1.101	0.960
10%	4.4032	4.2024	4.0261	3.641	2.967
25%	4.4051	4.2981	4.1900	3.7600	2.9421
50%	4.4600	4.3851	4.1130	3.8941	2.1362
75%	4.4631	4.3631	4.0012	3.6849	1.937

Table 3. Phosphate from soils (mg/kg) treated with various concentrations of oilfield wastewater

Soil treatment with oilfield wastewater	Incubation period (Hrs/Days)				
	24 hrs	**Day 7**	**Day 14**	**Day 21**	**Day 28**
0% (control)	0.454	0.403	0.386	0.301	0.283
10%	1.343	1.323	1.206	1.191	1.160
25%	1.350	1.318	1.145	1.136	1.118
50%	1.368	1.342	1.306	1.193	1.094
75%	1.369	1.320	1.114	1.096	0.894

Table 4. Total hydrocarbon content from soils (mg/kg) treated with various concentrations of oilfield wastewater

Soil treatment with oilfield wastewater	Incubation period (Hrs/Days)				
	24 hrs	Day 7	Day 14	Day 21	Day 28
0% (control)	48	42	34	30	26
10%	160	146	138	123	98
25%	162	154	143	136	94
50%	163	158	141	128	98
75%	163	150	140	122	96

4. DISCUSSION

The pH values in all the treatment options were ranged between 6.0-7.3. The result implies that the soil was favourable for microbial degradation. Obire and Nwaubeta [10] reported pH range of 5.7-6.8 in soil contaminated with hydrocarbons. Soil pH is important because most microbial species can survive only within a certain pH range. Furthermore, soil pH can affect availability of nutrients. There was no significant difference in the nitrate and phosphate values on the soil samples treated with various concentrations of the oilfield wastewater. However there was significant difference between the controls (0%) and the soil treated with various concentration of the oilfield wastewater as a result of the inorganic and organic constituents oilfield wastewater contains. There was significant reduction of the nitrate and phosphate in all the samples at the end of the experimental period. This could suggest that the indigenous microbes in the soil sample utilized the nutrients that promote microbial growth and activity. Many studies have reported the use of oilfield wastewater as nutrient supplement [11,12,13]. Benson et al. [14] reported decrease in nitrate content of amended soil and increase in un-amended soil. Onuh et al. [15] also observed a decrease in nitrogen availability with increased levels of crude pollution. Owhonka et al. [16] also reported reduction of nutrients as a result of microbial utilization. The total hydrocarbon content was more in all treatment options than in the 0% (control), possible reason could be that the oil field wastewater added may have contained hydrocarbon constituents. Total hydrocarbon content (THC) reduced as the experiment progressed in all the soil treatment options and the un-contaminated soils. THC reduction in all the treatment options was quite different from the one observed in the control. This confirms the view that biodegradation is impeded by nutrient deficiency. Wemedo [17] also reported reduction in total hydrocarbon content with time in all the soil options and traces of hydrocarbon were observed in uncontaminated soil samples. The oilfield wastewater added to the soil sample could be referred to as biostimulation since the reduction of the nutrients suggests microbial activities. According to Betancur-Galvis et al. [18], biostimulation increases the bacteria activity of various strains present in contaminated soil through the addition of nutrients. Several studies of the effects of biostimulation with mainly NPK or oleophilic fertilizers have reported positive effects on oil decontamination [19,20].

5. CONCLUSION AND RECOMMENDATION

The result indicates that nitrate and phosphate were utilized by the indigenous microorganisms which may have influenced the residual concentration of the hydrocarbon content. Suggesting that the oilfield wastewater can serve as a source of nutrient in soil thereby enhancing the activity of biodegraders present in contaminated samples.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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