Research article

EFFECT OF OILFIELD WASTE WATER ON MICROBIOTA OF A FRESH WATER IN NIGERIA

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ABSTRACT

Effect of oilfield wastewater to the Microbiota of the fresh river water was investigated. This was conducted by the determination of some physicochemical parameters which included pH, turbidity, total dissolved solids (TDS), total suspended solids (TSS), chloride, exchangeable cations and heavy metals as to ascertain the concentration of these constituents in the water samples; and the determination of total viable aerobic heterotrophic bacterial count, total coliform count and coliform types. The mean pH values ranged from 7.36 to 9.06, total dissolved solids (TDS) ranged from 24.00mgL-1 to 7,600.00mgL-1 while chloride values ranged from 30.13mgL-1 to 3,722.25mgL-1. The results obtained showed that with the exception of turbidity, total suspended solids, and sulphate which values were highest in the raw river water, values of all other parameters determined were highest in the oilfield wastewater. The order of decreasing concentration was oilfield waste water > mixture > raw river water. Total aerobic heterotrophic bacterial count ranged from 0.5 x 106 cfuml-1 to 8.2 x 106 cfuml-1 while the coliform population ranged from 0.07 x 106 cfuml-1 to 0.84 x 106 cfuml-1. Generally, there was a reduction in bacterial populations of the river water after the addition of the oilfield wastewater (5% V/V). The species of coliforms isolated belonged to four genera of Enterobacteriaceae which were *Citrobacter, Enterococcus, Escherichia* and *Klebsiella*. *Escherichia coli* was the most predominant in each of the water samples with a percentage occurrence of 50% and 36.36% in the raw river water and polluted water respectively; while *Citrobacter* sp was the least predominant in the raw river water (7.14%). The present investigation has therefore revealed the necessity of oilfield wastewater treatment prior to discharge into the recipient water body.

Key words: wastewater, coliforms, Physicochemical, oilfield, Nigeria.

INTRODUCTION

Formation water also known as connate water, produced water, or oilfield brine is water that does not participate in the hydrologic cycle. This kind of water is associated with oil and gas and is present in the rocks just before drilling [1,2].

The offshore drilling for oil and gas produces very large amounts of formation water, (known as oilfield wastewater) which in most cases is discharged into the surrounding aquatic environment or into a pit. Water co-produced with oil and gas and separated for discharge (oilfield wastewater) retains up to 50mgL-1 of separate phase oil as small droplets and also may contain up to 35mgL-1 of dissolved hydrocarbons [3]. The numerous inorganic constituents dissolved in formation water can be potentially or actually far more hazardous than the crude oil itself [4]. The ecological health of many river systems is threatened by the discharge of toxic compounds and the accumulation of these contaminants in these aquatic environments[5].

Nigeria oilfield formation waters contain 3,000 to 9000mgL-1 chloride ions [6,7] and the continuous discharge of such wastewaters into a freshwater environment could cause major damage to aquatic and agricultural resources.

In recent years, oilfield formation water has been regarded as a major pollutant of the aquatic environment in Nigeria[6,8]. To reduce the impact of oilfield formation water, it is subjected to some form of treatment before it is discharged into the aquatic or terrestrial environment [8].

The Amassoma river is that stretch of the Nun river which runs through Amassoma town in Bayelsa State of Nigeria. Inhabitants of Amassoma depend on the Amassoma river as a sole source of water supply for drinking, bathing and other domestic, agricultural and industrial purposes. Crude oil exploration activities are being carried out around the community and the river is the most likely receptacle for oilfield wastewater that would be generated. The discharge of oilfield wastewater into such freshwater body will surely affect the organisms that inhabit the water.

Water supplies used for human consumption must be free from organisms and from concentration of chemical substances that may be hazardous to health [9]. Supplies of drinking water also should be as pleasant to drink as circumstances permit, it should be free of colour, taste and smell, which are important for public water sources used for drinking [10].

Quality standards for most natural water sources are based on fecal coliform counts. The most widely used fecal coliform indicator is *Escherichia coli* from human and animal waste.

Microorganisms are useful in predicting the impact of a particular stress on the environment and micro organisms often respond to the introduction of a pollutant through shifts in their numbers [11].

There is no information available as yet on the effect of the discharge of oilfield wastewater on a freshwater stream in an oil producing area of the Niger Delta. Obire and Amusan (2003) reported the effect of oilfield wastewater on a freshwater stream in a non-oil producing area in Ondo State.

The aim of this study was to carry out a comparative analysis of water quality of Amassoma river water and oilfield wastewater and to check the effect of the addition of oilfield wastewater (5% V/V) on the bacterial population of Amassoma river water.

The objectives of this study therefore were:-

- To determine the concentrations of some physicochemical constituents of the oilfield wastewater, raw river water, and of their mixture (1:1).
- To cultivate and enumerate the total viable heterotrophic bacteria and total coliform in the river water and in 5% polluted water samples.
- To isolate, characterize and identify some coliforms isolated from the samples.

The results obtained will provide a comparative analysis of some constituents of treated oilfield wastewater and those of Amassoma freshwater and of their mixture (1:1); and reveal the impact of the wastewater on bacterial populations of freshwater in an oil producing area. The results obtained also will serve as baseline data to which future discharges of oilfield wastewater into the Amassoma River could be assessed.

MATERIALS AND METHODS

Source of Materials

Treated oilfield wastewater was collected from an oilfield in Rivers State of Nigeria where oil-water separation and oil-gas pumping operations are being carried out, while water sample for analysis was collected from the Amassoma axis of the Nun River in Bayelsa State, Nigeria.

Physicochemical Analysis

Physicochemical analyses were conducted according to standard procedures of APHA (1998) and ASTM (1999) [12-13]. The physicochemical parameters determined include pH, turbidity, total dissolved solids (TDS), total suspended solids (TSS), total hardness, conductivity, chloride, calcium and heavy metals such as lead, zinc, iron, and manganese.

Determination of Total Aerobic Heterotrophic Bacterial Count and Total Viable Coliform Count

The total aerobic heterotrophic bacterial count and total coliform count of the river water and of the 5% polluted river water samples were determined at different storage periods (0hr, ½day, 1day, 2days, 3days, 4days, 5days, 6days and 7days) by inoculating 0.1ml aliquot of 10-4 dilution of each replicated sample into sterile Petri dishes containing nutrient agar and eosin methylene blue (EMB) agar respectively. Cultured nutrient agar plates were incubated at room temperature while cultured EMB plates were incubated at 37±2oC for 24 - 48 hours.

Identification of Isolated Coliforms

Pure isolates of coliforms were presumptively identified on the basis of their cultural, morphological and physiological characteristics. Identification of isolates was accomplished by comparison with those of known taxa and with reference to Bergey's Manual of Determinative Bacteriology [14].

RESULTS

Values of the physico-chemical parameters determined are as shown in Table 1. Table 1 also shows FEPA (1991) [15] effluent limitation guidelines in Nigeria for all categories of industries for comparative purposes. Most of the constituents were higher for the oilfield wastewater than for the river water and their mixture.

Population of total viable aerobic heterotrophic bacteria and of Coliforms of raw river water and 5% oilfield wastewater polluted river water sample Table 1: Concentrations of Physico-chemical Con stituents of Raw River Water, Oilfield Wastewater (formation water) and their Mixture

Parameter	Method	Formation Water	RawRiver Water	50% (1:1) Mixture	FEPA Limit
pH	APHA 4500H+B	9.06	7.36	9.04	6 – 9
Turbidity (NTU)	APHA 2130B	94	215	151	<50
TDS (mg/l)	APHA 2510B	7,600.00	24.00	3,975.00	2000
TSS (mg/l)	APHA 2540D	38	158	110	30
Conductivity (µS/cm)	APHA 2510A	15,200.00	47.70	7,950.00	<200ìs/cm
Total Hardness (mg/l)	ASTM D1126	85.00	12.46	43.75	NI
Chloride (mg/l)	APHA 4500Cl- B	3,722.25	30.13	1,896.58	<20
Total Alkalinity (mg/l)	ASTM D1067B	4,286.52	275.56	2,296.35	NI
Phosphate (mg/l)	APHA4500-P D	1.03	0.77	1.13	<20
Sulphate (mg/l)	APHA 4500 SO42-E	Nil	27.5	15.0	<20
Calcium (mg/l)	APHA 3111D	16.50	2.00	8.75	<20
Magnesium (mg/l)	APHA 3111B/ASTM D3561	10.50	1.79	5.25	<20
Sodium (mg/l)	APHA 3111B/ASTM D3561	6,137.75	49.68	3,127.08	<20
Heavy Metals					
Lead (mg/l)	APHA 3111B	<0.001	<0.001	<0.001	<1
Zinc (mg/l)	APHA 3111B	108.75	3.69	56.75	<1
Total Iron (mg/l)	APHA 3111B	11.50	1.48	7.00	<1
Manganese (mg/l)	APHA 3111B	0.25	0.04	0.25	<1

Figure 1: Total viable count of aerobic heterotrophic bacteria and coliform bacteria (X 106 CFUml-1) of raw river water and 5% wastewater polluted river water

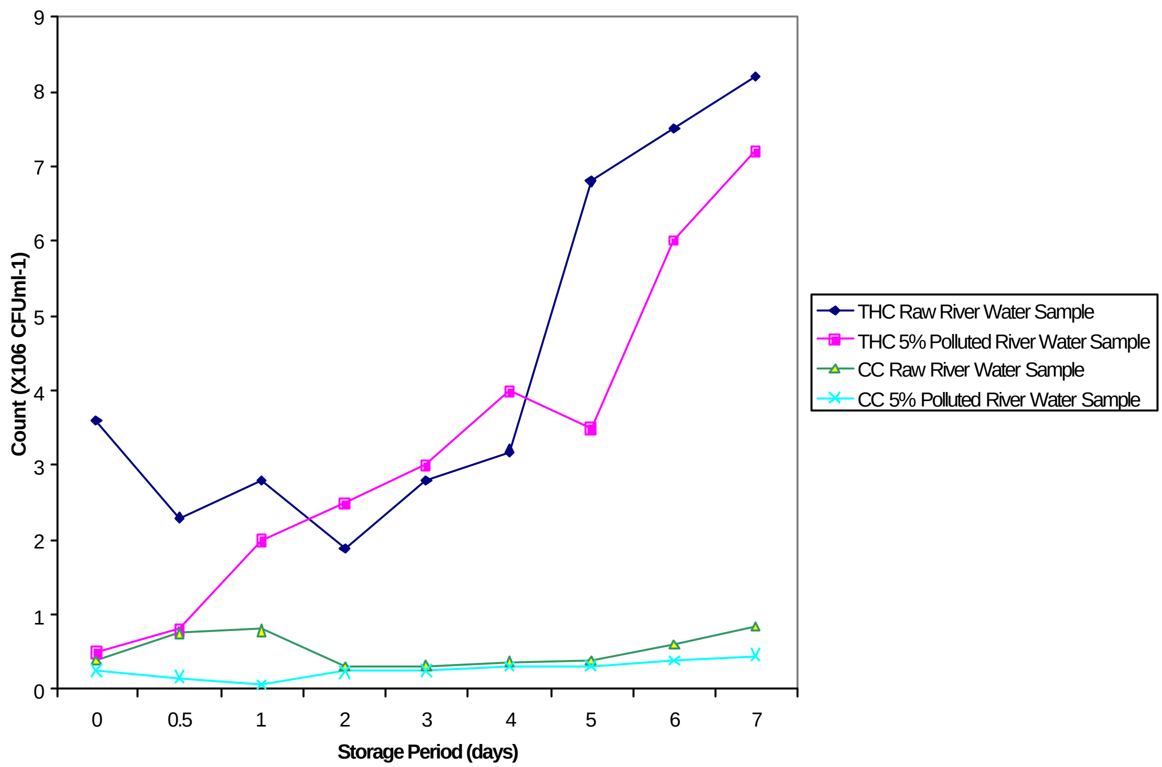
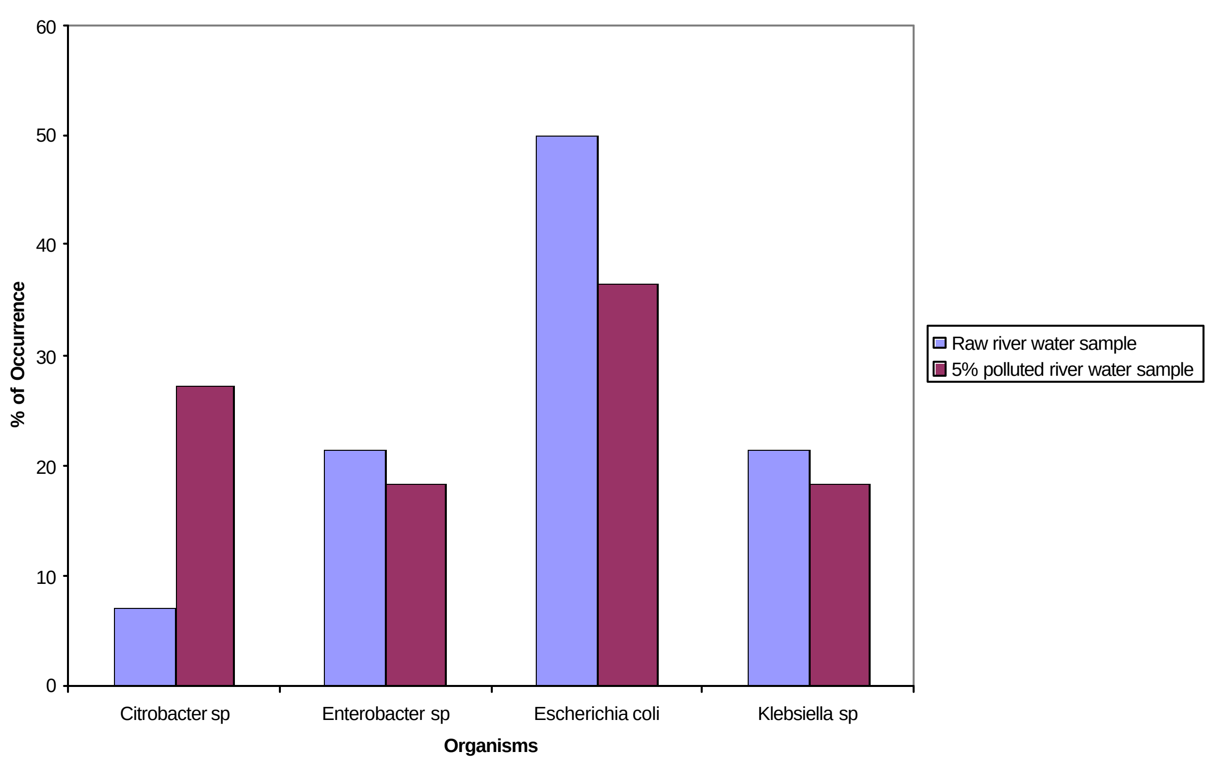


Figure 2: Incidence and Percentage of Occurrence of Coliforms in the Water Samples



Population of total viable aerobic heterotrophic bacteria and of Coliforms of raw river water and 5% oilfield wastewater polluted river water sample

The count of total viable aerobic heterotrophic bacteria and of total coliforms of the raw river water sample and 5% polluted sample are as shown in Figure 1.

The total viable aerobic heterotrophic bacteria count in the raw water ranged from 1.9 x 10^6cfu/ml to 8.2 x 10^6cfu/ml after 7days of incubation at 37^0C with an average of 4.34 x 10^6cfu/ml while the count in the polluted sample water ranged from 2.0 x 10^6cfu/ml to 7.2 x 10^6cfu/ml with an average of 3.27 x 10^6cfu/ml.

The total coliform count in the raw river water ranged from 3.0 x 10^6cfu/ml to 8.4 x 10^6cfu/ml with an average of 5.32 x 10^6cfu/ml while the count in the polluted water sample ranged from 0.7 x 10^6cfu/ml to 4.7 x 10^6cfu/ml with an average of 2.74 x 10^6cfu/ml.

Identification of Coliforms

Four distinct genera of Enterobacteriaceae were identified. These were *Citrobacter, Enterococcus, Escherichia* and *Klebsiella*.

Incidence and Percentage of Occurrence of Coliforms in the Water Samples

The incidence and the percentage of occurrence of coliforms in the samples are as shown in Figure 2. For the raw river water sample, their percentage occurrence were *Citrobacter* (7.14%), *Enterococcus* (21.43%), *Escherichia* (50%) and *Klebsiella* (21.43%); while for the polluted river water sample, their percentage occurrence were *Citrobacter* (27.27%), *Enterococcus* (18.18%), *Escherichia* (36.36%) and *Klebsiella* (18.18%).

DISCUSSION

The present investigation has revealed the values of some physicochemical parameters, the bacterial counts or population of aerobic heterotrophic bacteria, population of coliform and some bacteria types in Amassoma river water and oilfield waste water.

The physicochemical parameters such as pH, total dissolved solids, total hardness, chloride, total alkalinity, and exchangeable cations of the oilfield wastewater and the 1:1 mixture samples were much higher in concentration than their corresponding concentrations in the raw river water sample (control). Concentration of most of the constituents including some heavy metals of the oilfield wastewater and of the mixture are much higher than recommended FEPA (1991) effluent limitation guidelines in Nigeria for all categories of industries.

The colour of the freshwater may have been the result of extraction of certain pigments from human deposits and vegetation around the river. The colour of the treated formation water may have been imparted by marine plants and animal life which were transformed into crude oil that occurs in association with formation water [16]. The high alkalinity value of formation water can be said to have a direct effect on the extent to which aquatic organisms can utilize available oxygen. The value of the chloride concentration for the formation water and raw river sample are 3,722.25mgL^{-1} and 30.13mgL^{-1} respectively. The high values of chloride will not allow adequate solubility of oxygen due to its high salinity.

pH affect toxicity under alkaline conditions, ammonia is harmful to aquatic organisms. A rise in pH have toxic concentration and pH rises with storage period. The measured values of phosphate are 1.03mgL^{-1} and 0.77mgL^{-1} for formation water and the raw river water sample respectively.

The bacteria counts showed that except for the 2nd to the 4th day of incubation, the counts were generally higher in the raw river water (control) than in the 5% polluted river water. While the counts of coliforms were generally higher in the raw river water than in the 5% polluted river water. The average populations of both aerobic heterotrophic bacteria and coliforms were higher in the raw river water than in the 5% polluted river water. This is a proof that there were more active microorganisms in the river water sample than there were in the polluted water sample. The results of the present study also showed that the effect of the addition of the oilfield wastewater in the reduction of the bacteria population was immediate with regards to the period of incubation, *i.e* between 1hr and 1day. The Lowest heterotrophic population (0.5 x 10^6cfu/ml) being recorded as 0hr, while the lowest population of coliforms 0.7 x 10^6cfu/ml) was recorded after 1day of incubation. This "immediate effect" must have been caused by the very high concentration of certain constituents of the oilfield wastewater such as sodium chloride which was 6,137.75mgL^{-1} as compared to it's concentration in the raw river water which was just 49.68mgL^{-1}. *Escherichia coli* was the most predominant coliform in each of the water samples with a percentage occurrence of 50% and 36.36% in the raw river water and polluted water respectively; while *Citrobacter spp* was the least predominant in the raw river water (7.14%).

The addition of the wastewater with such high salt content must have resulted in osmotic shock that led to the immediate reduction in the bacteria population. The waste water therefore stimulated an inhibitory or bactericidal effect on the indigenous bacteria of the river water. The pollution effect of petroleum hydrocarbons and the associated wastewater has been reported to have inhibitory or bactericidal effect [17-18] (Bartha and Atlas, 1977; Obire and Amusan, 2003). Conditions that retard or alter the routine of microorganisms may affect the environment adversely [17,19].

The subsequent increase in microbial population after 24hours of incubation with treated formation water is as a result of adaptation of the micro-organisms in the sample to the constituents of the formation water.

The reduction in the microbial population in the polluted sample has demonstrated how severe the effect of relatively small amounts of the treated oilfield formation water used in this study can be on a water system. The continuous discharge of such treated oilfield formation water will have a deleterious effect on the proper functioning of the freshwater aquatic ecosystem thereby affecting aquatic and agricultural resources that are of economic importance[18].

CONCLUSION

The present investigation showed that concentrations of constituents such as chloride, total dissolved solids, total hardness etc of treated oilfield formation water can be hazardous. High concentrations of these constituents have direct effect on the extent to which aquatic organisms can utilize available oxygen. Since the present investigation has shown that the constituent concentrations of the treated formation water are higher than those of the freshwater stream; and also that the treated formation water has potential for adverse environmental effect on a freshwater system, further treatment of the treated formation water such as that used in this study is necessary if such formation water is to be discharge into a Freshwater environment.

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