Treatment of Produced Oilfield Water by Adsorption Using Banana Peel as Adsorbent

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Abstract *— As part of oilfield production operations, produced water represents a waste product that require treatment before proper disposal or reuse. This study analyses the efficacy of using banana peel as low cost adsorbent to remove the oil component of produced water samples collected from three Niger Delta oilfields. The banana peel was treated with n-hexane to remove all fatty acid and colour pigment and subsequently washed with distilled water, dried, and applied to the three samples. The produced water samples were analysed before and post-treatment. The study results shows that the concentration of contaminants in the treated water is within allowable limits; when compared with Central Coast Regional Water Quality Control Board (CCRWQCB) criteria for irrigation and the Department of Petroleum Resources (DPR) standard for disposable water. Thus, making banana peel an excellent adsorbent for the removal of oil from produced water with an oil removal efficiency exceeding 96%.*

Keywords — *Produced water, Reflux Condenser, Banana peel, Flow-station, Oilfield*

I. INTRODUCTION

Produced water is any water that is present in a reservoir with the hydrocarbon resource and is produced to the surface with the crude oil or natural gas [5]. In subsurface formations, naturally occurring rocks are generally permeated with fluids such as water, oil, or gas (or some combination of these fluids). There is more in produced water than water and oil. Often times, there are concentrations of Barium, Beryllium, Cadmium, Chromium, Copper, Iron, Lead, Nickel, Silver, Zinc, and small amounts of natural radioactive materials. Proper management of produced water should start from accurate estimation of the volume produced. However, study shows that there are still a lot of challenges on this even in the United States [6]. On the other hand, the need to properly manage effluents from oil and gas operations due to their possible effects on the environment has long been recognized.

Treatment of oil spills and oil contaminated water remains one of the major challenges in the petroleum industry. Many workers have reported using biological waste materials to treat different pollutants ranging from metals to organic dyes found in waste water. For example bio-sorption studies of Cadmium, Copper, Nickel, and Zinc in aqueous solution on activated sludge [1]. Banana peel was used as sorbent in the removal of cadmium ion from aqueous solution [2]. Sugarcane bagasse was used for the removal of erythrosine B and methylene blue from aqueous solution [3]. Kinetic study of Ni (II) using activated clay minerals [4]. The purpose of this study is to determine whether the produced water from WXY Delta flow-station, XYZ Edo flow-station and XYZ Edo field that are being discharged can be treated to meet irrigation standard using banana peel and distillation.

II. METHODOLOGY

Banana peel was collected from a local market in Nigeria. Three samples of produced water were collected from WXY flow-station (Delta state), XYZ flow-station (Edo state) and XYZ field (Edo state). The produced water sample to be analysed was collected from the detention pit in the flow-station. The sample was collected in a transparent plastic bottle and was covered properly and put under cold condition (refrigerator) until it was ready to be analysed in the laboratory. Upon collection of the water sample, analysis of unstable parameters such as pH, total dissolved solids (TDS), conductivity, turbidity were performed with the aid of portable field equipment. The pH, total dissolved solids, conductivity and turbidity are all in-situ parameters.

A. Bio-Sorbent Preparation Layout

The banana peel was washed with water several times and sun dried and subsequently grounded to particle size between 2-3 mm. The grounded banana peel was washed with n-hexane in a reflux condenser for 2 hours in order to remove all fatty acid and colour pigment. The n-hexane treated banana peel was then washed with distilled water and dried in an oven at a temperature of 100^{o}C for 12 hours. Consequently, the oven dried banana peel was further crushed and sieved through a 600 micron sieve and packaged in an air tight plastic container as raw banana peel.

B. Produced Water Treatment with Raw Banana Peel

1. 200ml of produced water from three different locations were poured into three different well labelled conical flasks.

2. 300mg of raw banana peel was measured in a weighing balance and added into the different samples of produced water.
3. The top of each conical flask were sealed with foil paper and set in a mixer rotating at 191rpm for 30 minutes after which the produced water was filtered to remove the raw banana peel from the produced water.
4. The filtrate was collected in a clean bottle and labelled properly.

C. Distillation Process of Produced Water

1. The filtrate obtained after treatment with raw banana peel was poured into the round bottom flask and connected together with the compartment and condenser.
2. Distillation apparatus was set up and the circulatory water bath was turned on followed by the heating mantle at a temperature of 100^{o}C.
3. As heat is continuously applied to the sample water begin to vapourize out of the sample, as the water vapour rises to the condensation part of the distillation apparatus it begins to condense and fall back to the compartment.
4. The produced water in the compartment was allowed to cool and poured in a plastic bottle

III. RESULT AND DISCUSSION

Table 1 and 2 show the Physio-chemical properties of produced water sample from WXY flow-station before and after treatment.

Table 1: Physicochemical Properties of Produced Water Sample from WXY Flow-station before Treatment

PARAMETER	UNIT	VALUE
pH	-	7.66
Temperature	^{0}C	26.6
Total Dissolved Solids (TDS)	mg/l	1885
Conductivity	us/cm	3624
Total Hydrocarbon content (THC)	mg/l	40.48
Biochemical Oxygen Demand (BOD)	mg/l	60
Total Suspended solids (TSS)	mg/l	22
Chemical Oxygen Demand (COD)	mg/l	201
Total Coliform count	cfu/100ml	25
Alkalinity	mg/l	285
Carbon oxide	-	<0.01
Sodium	mg/l	13.82
Salinity as (Cl)	mg/l	430
Lead	mg/l	0.01
Copper	mg/l	0.01
Iron	mg/l	1.50
Barium	mg/l	0
Zinc	mg/l	0.01
Sulphate	mg/l	0
Cadmiums	mg/l	0.01
Manganese	mg/l	0.03
Magnesium	mg/l	2.12
Calcium	mg/l	7.00

Table 2: Physicochemical Properties of Produced Water Sample from WXY Flow-station after Treatment

PARAMETER	UNIT	VALUE
pH	-	6.33
Temp	^{0}C	26.60
Total Dissolved Solid (TDS)	mg/l	6.00
Conductivity	us/cm	11.92
Total Hydrocarbon Content (THC)	mg/l	1.50
Biochemical Oxygen Demand (BOD)	mg/l	7.30
Total Suspended solids (TSS)	mg/l	1.00
Chemical Oxygen Demand (COD)	mg/l	1.00
Total Coliform count	cfu/100ml	0
Alkalinity	mg/l	5.6
Carbon oxide	mg/l	<0.01
Sodium	mg/l	0.4
Salinity as (Cl)	mg/l	1.99
Lead	mg/l	0.01
Copper	mg/l	0.02
Iron	mg/l	<0.01
Barium	mg/l	<0.01
Zinc	mg/l	0.01
Sulphate	mg/l	<0.01
Cadmium	mg/l	<0.01
Manganese	mg/l	<0.01
Magnesium	mg/l	0.30
Calcium	Mg/l	0.89

Table 3: Analysed Results of the Produced Water Before and After Treatment with the Percentage Overall Removal after Treatment

Parameters	Unit	Value Before	Value After	Overall Removal (%)
pH	-	7.66	6.33	17.36
Temperature	^{O}C	26.6	26.60	0
TDS	mg/l	1885	6.00	99.68
Conductivity	us/cm	3624	11.92	99.67
THC	mg/l	40.48	1.50	96.29
BOD	mg/l	60	7.30	87.83
TSS	mg/l	22	1.00	95.45
COD	mg/l	201	1.00	99.5
TC count	cfu/100 ml	25	NIL	100

Alkalinity	mg/l	285	5.6	98.38
Carbon oxide		<0.01	<0.01	0
Sodium	mg/l	13.82	0.4	97.11
Salinity as (Cl)	mg/l	431	1.99	99.54
Lead	mg/l	0.01	0.01	0
Copper	mg/l	0.01	0.02	0
Iron	mg/l	1.50	<0.01	99.33
Barium	mg/l	0	<0.01	0
Zinc	mg/l	0.01	0.01	0
Sulphate	mg/l	0	<0.01	0
Cadmium	mg/l	0.01	<0.01	0
Manganese	mg/l	0.03	<0.01	0
Magnesium	mg/l	2.12	0.30	85.84
Calcium	mg/l	7.00	0.89	87.28

The result of the analysis run on WXY flow-station was compared with DPR requirement for disposable water and Central Coast Regional Water Quality Control Board (CCRWQCB) Criteria for irrigation. Both standards are shown in Table 4 and Table 5 respectively.

Table 4: Effluent Water Discharge Limits in Nigeria

Effluent characteristic	**Inland area**	**Near shore**	**Offshore**
pH	6.5-8.5	6.5-8.5	No limit
Temperature ^{o}C	25	30	-
Oil/Grease content	10	20	40
Salinity	600	2,000	No limit
Turbidity	>10	>15	-
Total dissolved solid	2,000	5,000	-
Total suspended solids	>30	>50	-
Chemical oxygen demand	10	125	-
Biochemical oxygen demand	10	125	-
Lead	0.05	No limit	-
Iron	1.0	No limit	-
Copper	1.5	No limit	-
Chromium	0.03	0.05	-
Effluent characteristic	Inland area	Near shore	Offshore
pH	6.5-8.5	6.5-8.5	No limit
Temperature ^{o}C	25	30	-
Oil/Grease content	10	20	40

Table 5: CCRWQCB Criteria for irrigation

Compound	**CCRWQCB (Agricultural use) Criteria**	**Unit**
Aluminium	5	Mg/L
Arsenic	0.1	Mg/L
Ammonia – Nitrogen	5 – 30	Mg/L
Beryllium	0.1	Mg/L
Bicarbonate	90 – 120	Mg/L
Boron	0.75	Mg/L
Cadmium	0.01	Mg/L
Chloride	150	Mg/L
Chromium	0.1	Mg/L
Cobalt	0.05	Mg/L
Copper	0.2	Mg/L
Fluoride	1	Mg/L
Iron	5	Mg/L
Lead	5	Mg/L
Lithium	2.5	Mg/L
Manganese	0.2	Mg/L
Molybdenum	0.01	Mg/L
Nitrate-Nitrogen	5 – 30	Mg/L
pH	6.5 – 8.4	-
Salinity	0.75 – 3	mmho/cm
Selenium	0.02	Mg/L
Sodium	70	Mg/L
Sodium Adsorption Ratio	3-9	-
Sulfate	150	Mg/L
TDS	600	Mg/L
(oil and grease)	35	Mg/L
TOC	2	Mg/L
Vanadium	0.1	Mg/L
Zinc	2	Mg/L
Compound	CCRWQCB (Agricultural use) Criteria	Unit
Aluminium	5	Mg/L

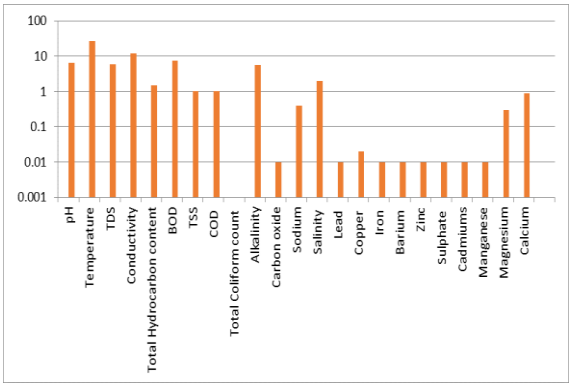

***Fig. 1**: Initial Physicochemical Properties Represented in Log Scale*

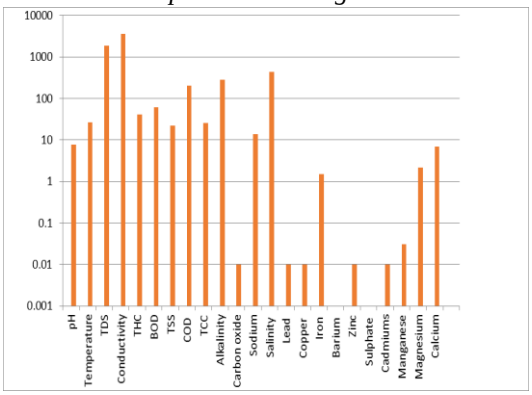

***Fig. 2:** Final Physicochemical Properties Represented in Log Scale*

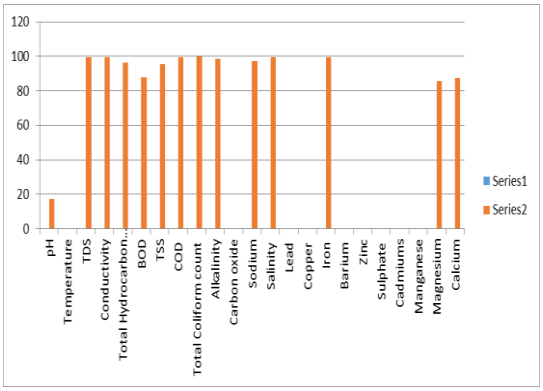

***Fig. 3**: Overall Physicochemical properties removal*

From Table 3, it can be seen that the contaminants removed from the produced water sample is very high. One of the major dissolved gases in the produced water is carbon dioxide, they are formed naturally by the activities of bacterial or by chemical reactions in the water. The carbon dioxide value is very low which dictates that bacterial activities are zero. This is also verified from the Total Coliform count value after the treatment. The concentration of barium ions in produced water gives a strong indication of radium isotopes present in it. Barium concentration in this water sample is very low; hence radioactivity is of no value.

Comparing the concentration of the produced water after treatment with CCRWQCB (Agricultural use) and DPR standard for disposable water, the treated produced water sample can either be used for crop irrigation or dispose off, since its value after analysis lies within the range specified by the two standards

IV. CONCLUSIONS

Produced water is inevitable for oil and gas production, this offers both opportunities and challenges for sustainable recovery of hydrocarbon resources and water resources. Produced water has the potential to be recycled or re-used for many purposes. With proper treatment of produced water it has the potential to play a key role in relieving demand on natural freshwater systems and reducing pollution. The bio-sorption studies with the peel showed that it can be used in the removal of oil (both dissolved and dispersed) from produced water providing above 96% removal at an equivalent dosage representing 300mg banana peel in produced water (from WXY flow-station) after 30minutes exposure and initial oil concentration of 40.48mg/l.

Among the existing techniques used for oil treatment, sorption is a popular technique because it is cheap, simple and effective. Among the various sorbents used, banana peel appears attractive in terms versatility and abundance. It is worthy to note that the use of banana peel alone cannot treat produced water to meet irrigation standard. To meet irrigation standard, the banana peel treated produced water has to be distilled. The concentration of contaminants in the treated water is within allowable limits as recommended by CCRWQCB criteria for irrigation and DPR standard for disposable water.

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