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Secondary Treatment of Produced Water from an Oilfield in Niger Delta Using Phytoremediation Technique

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Abstract

This study reports an advanced treatment method employing Eichornea crassipes (water hyacinth) as a treatment medium. Results showed that the biological oxygen demand (BOD), chemical oxygen demand (COD), sulphate (SO_4^{2-}), chloride (Cl^-), iron (Fe^{2+}), total hardness (TH) and total dissolved solid (TDS) of the treated produced water decreased significantly to 11.0, 582, 19.3, 8952, 10.5, 145.0 and 488 mg/l from initial concentrations of 25.6, 641, 38.7, 8987, 10.7, 157.2 and 527 mg/l respectively. This indicates an improvement in effluent quality, which is due to the efficiency of the water hyacinth in absorbing the nutrients in the produced water. It is recommended that future research should be focused on further testing and experimentation to identify promising plant species and to further isolate and understand the biochemical mechanisms behind phytoremediation in order to improve on them.

Introduction

Produced water can be defined as the water brought up from the hydrocarbon bearing reservoir during the extraction of oil and or gas[1]. Water is found together with petroleum fluids in the underground reservoir where the water as a consequence of higher density than oil lays in vast layers below the hydrocarbons in the reservoir media. This water which occurs naturally in the reservoir is called formation water, interstitial water or sometimes, connate water. Oil and gas wells can initiate water production after production has occurred for a long time, depending on drive mechanism operating in the reservoir[2]. Produced water is basically a mixture of formation water, injection water and condensed water but also contains smaller quantities of dissolved organics (including hydrocarbons), traces of heavy metals, dissolved minerals, suspended oil (non-planar), sand silt (solids) and chemicals.

Most times, produced water has very little value and should be disposed of. Other times the water may be used for water flooding or reservoir pressure maintenance[3]. Generally, produced water must be treated to lower its hydrocarbon content to acceptable limits. In offshore operations, government regulations specify a range of 15 to 50 mg/l depending on the location[4]. With increased understanding of the enzymatic processes involved in plant tolerance and metabolism of xenobiotic chemicals, there is new potential for engineering plants with increased phytoremediation[5].

Generally, wastewater treatment using plants is termed phytoremediation. Phytoremediation deals with de-polluting contaminated soils, water or air with plants which are able to contain, degrade or eliminate metals, pesticides, solvents, crude oil and its derivatives and various other

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contaminants from the medium that contains them[6]. Aquatic treatment systems are broken into two types[7]. The first type uses floating type plants which are distinguished by their ability to meet their need for carbon dioxide (CO_2) and oxygen (O_2) directly from the atmosphere. The second type of treatment system consists of submerged plants which are distinguished by their ability to absorb O_2, CO_2 and minerals directly from the water column. Submerged plants are easily inhibited by high turbidity because their photosynthetic plants are under water. Once plants have accumulated waste materials, they can be harvested, with disposal or subsequently processed by different methods dependent on the turbidity of the end products, the storage locations and relative concentrations of contaminants within plant tissue[8].

The suitability of using vascular aquatic plants such as *Eichornea crassipes* (water hyacinth) for wastewater treatment emanated from their capacity for nutrient removal from aqueous solution.[9] Water hyacinth in particular is preferred because of its hardiness and high productivity especially when grown in wastewater. The plant grows luxuriantly in wastewater and has an extensive root system that allows it to absorb nutrients directly from wastewater. Studies have shown that the plant is very efficient in the removal of very large quantities of nutrients from wastewater[10] estimated a potential hyacinth productivity of 150 mart per hectare per year – the mart (mt) represents water hyacinth forming rhizomes or base, while Macdonald and Wolverton[11] projected a hyacinth productivity of 154 mt/hectare/yr. Ayade[12] investigated the potential of adapting water hyacinth in sewage treatment and concluded that the plant survived with normal growth and was efficient in the removal of pollutants in synergy with microorganisms. Wolverton[13] studied effluent sewage from a wastewater lagoon with a retention period of 14 days and observed a 97 % reduction in influent and 77 % reduction in effluent waste. Macdonald and Wolverton[14] obtained 94 % reduction in BOD from a facultative wastewater lagoon during summer.

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The present study was aimed at determining the effectiveness of the water hyacinth plant in treating produced water from an oilfield and then to compare the quality of discharged treated effluent with that of discharge from conventional treatment methods with a view to ascertaining the impacts on environment and health when the effluent is discharged to the environment. The phytoremediation process is hereby presented and discussed.

Brief Description of Study Area

The oilfield OML 117 is located in Andoni, Rivers State, in the oil-rich Niger Delta region of Nigeria. The Niger Delta lies between latitudes 4 ^{o} 15'N and 6 ^{o} 30'N and longitudes 5 ^{o} 00' E and 8^{o} 00'E. The area falls within the tropical rain forest vegetation belt of the country; rainfall ranges from 2400 – 2700 mm, while the average temperature is 27^{o}C.

Materials and Methods

Sample Collection

Produced water sample was obtained from MNI oilfield OML 117 while water hyacinth plant *(Eichornea crassipes)* was obtained from a stream in Yenagoa, Bayelsa State, Nigeria.

Experimental Methodology

The produced water was put into a carefully washed plastic bucket from where a sample was taken to obtain the reading termed "Before phytoremediation." The plants were then placed in the bucket containing the produced water. The water and plants were left to stand. After a week interval, a second batch of the tests was carried out to obtain the readings termed "After phytoremediation." All samples were subjected to physico-chemical analysis.

Physico-Chemical Parameters

The samples were analyzed according to the standard methods for the examination of water and wastewater[15] for the following parameters: total dissolved solids (TDS) using standard glass filters to determine the filterable and non-filterable residues, BOD, pH, chloride, iron, total hardness, sulphate and temperature. A formula by Talini and Anderson[16] was used to compute chemical oxygen demand (COD).

Results and Discussion

Test data on the performance indicators of the phytoremediation experiment are given in Table 1 below and presented pictorially or graphically in Fig. 1.

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Table 1: Results of parameters evaluated before and after phytoremediation experiment.

Parameter	Before Phytoremediation	After Phytoremediation
pH	6.68	6.65
Temperature (^oC)	30.2	30.0
Cl^- (mg/l)	8987	8952
Fe^{2+} (mg/l)	10.7	10.5
TH	157.2	145
BOD	25.6	11.0
COD	641	582
SO_4^{2-} (ppm)	38.7	19.3
TDS (ppm)	527	488

Fig. 1 – Column Diagram of parameters evaluated before and after phytoremediation experiment.

It was observed that the effluent quality showed marked improvement. This may have been due to the efficiency of the water hyacinth in absorbing the nutrients in the produced water. Most significant reductions were observed in the BOD which showed 5 % efficiency and sulphate

(SO_4^{2-}) with about 50 % removal. This indicates a reduction in the organic waste and an improvement in the taste and odour. The total hardness reduction of about 7.5 % is not too significant as the effluent is still moderately hard (140-210 ppm). The TDS value reduction is quite small (about 7.4 %), although the treatment has brought the TDS level below EPA standards of less than 500 ppm. The iron content reduction of about 2.15 % is quite negligible. The pH level remained acidic while the chloride content shows that the water is still highly saline.

Conclusion and Recommendation

The phytoremediation technique employed in this study has contributed to the removal of pollutants as organic and inorganic compounds. Furthermore, with increased understanding of the enzymatic processes involved in plant tolerance and metabolism of xenobiotic chemicals, there is new potential for engineering plants with increased phytoremediation capabilities.

It is recommended that future research should be focused on further testing and experimentation to identify promising plant species and to further isolate and understand the biochemical mechanisms behind phytoremediation in order to improve on them. To ensure optimum benefit from this technique the following recommendations are made:

- Proper selection of appropriate plant species is critical for the success of this technology.
- Genetic engineering of transgenic plants and cross breeding is needed to produce plant species with properties that would enable them treat a wider range of pollutants and with greater tolerance for pollutants.