Evaluation of the bioremediation system applied for hydrocarbons removal from produced water in Heglig oil field

Mohamed Osman. Zooalnoon, Adam Musa

***Abstract*— This paper reviewed bioremediation system applied for hydrocarbons removal form produced water in Heglig field using Phragmites Australis plant, to produce clean water and recover valuable materials from produced water with minimal negative impact on the environment. To evaluate effectiveness of bioremediation system three quantitative analysis methods (gravimetric method, spectrophotometric method and IR method) were used for determination of oil in water before and after treatment using bioremediation technology for Heglig field produced water. The results of analysis showed that determination of oil content by IR method is more accurate than by spectrophotometer and gravimetric method. According to the IR results the effectiveness of bioremediation system for hydrocarbons treatment by Phragmites Australis plant can remove more than 86.72% oil content of produced water. One qualitative analysis method (GC method) was used for determination of oil in water before and after bioremediation treatment for Heglig field and the results showed that most hydrocarbons treated by bioremediation system are n-C10 and n-C11 while components of high number of carbon (n-C22 to n-C29) are almost untreated.**

***Index Terms*— Phytoremediation, bioremediation, produced water, Phragmites Australis**

I. INTRODUCTION

Bioremediation is a treatment process that uses naturally occurring microorganisms (yeast, fungi, or bacteria) to break down, or degrade, hazardous substances into less toxic or non-toxic substances. In biological digestion, bacteria cultivated under controlled conditions utilize organic matter as their food, producing products of respiration, such as CO_2 in aerobic and CH_4 in anaerobic systems. The system requires medium and long residence time for the organisms to grow and stabilize for effective operation [1 and 2].

Generally, bioremediation is the optimization of the natural biodegradation process used by bacteria to alter and break down contaminants, transforming them into harmless substances and phytoremediation can be defined as the use of plants to achieve the conditions necessary to facilitate the breakdown of contaminants [3 and 4]. Wetland species draw oxygen down to their root network in order to survive water logged conditions; this improves the soil environment, offering both aerobic and anaerobic pockets of degradation. Such conditions allow a vast range of microbial species to flourish. Microbial species, just like humans, eat and digest organic substances (carbon source) for nutrition and energy. The microorganisms break down the organic contaminants into harmless products mainly carbon dioxide and water [5 and 6].

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II. HEGLIG BIOREMEDIATION SYSTEM

In 2003, Oceans-ESU Ltd was commissioned by GNPOC to undertake the construction, management and maintenance of a bioremediation system in Heglig oil field. The system functions as a means to clean produced water by removing oil contamination. The produced water first undergoes mechanical treatment to remove impurities like oil, grease and suspended solids. The effluent is then pumped to a series of reed bed lagoons planted with the reed, *Phragmites Australis*. As the effluent flows through the soil mass rooted with the reed, hydrocarbons and other chemicals are devoured by indigenous microbes that live in the soil, resulting in clean water. The reed also uses some of the carbon and nitrogen contained in the water to synthesise its own cellular material. As the roots grow and extend themselves throughout the soil mass, the porosity of the soil increases, allowing for better percolation of the effluent. The reed also pumps oxygen into the soil via its root system. Microbes along the root mass then use the oxygen to digest and break down the contaminants present in the effluents [7].

III. MATERIALS AND METHODS

During the research water samples were taken from the outlet water line from CPF (inlet to bioremediation system) and outlet line from bioremediation system in Heglig field. Analar grade chemicals and Analytical Grade Reagent were used. The following Instruments and Apparatus (Gas chromatography - Varian CP-3800, Oil analyzer IR- Horiba OCMA-310, Spectrophotometer -Hash DR 5000, Rotary evaporator – Steroglass 202, Conical flasks, Beakers, Sensitive balance, Duran sample bottle, Cuvette 1 cm, Separatory funnel, 1-L, with TFE stopcock) were used in the determination of oil contents. Materials used, experimental equipment, experimental procedures and sampling procedures are all according to American Public Health Association (APHA), American Water Works Association (AWWA), and Water Environment Federation (WEF), Standard Methods for the Examination of Water and Wastewater [8].

IV. RESULTS AND DISCUSSION

The oil content in water results for Heglig field produced water is given in (Table 1). (Table 2) present GC results for Heglig produced water.

Table 1. Oil content in water results for Heglig field produced water.

Test method For oil content	Test method standard	Unit	Results	
			Before treatment	After treatment
gravimetric	APHA 5520 B	ppm	6	Nil
Spectro photometer	APHA 5520 C	ppm	9	1
IR Oil analyzer	APHA 5520 D	ppm	11.30	1.5

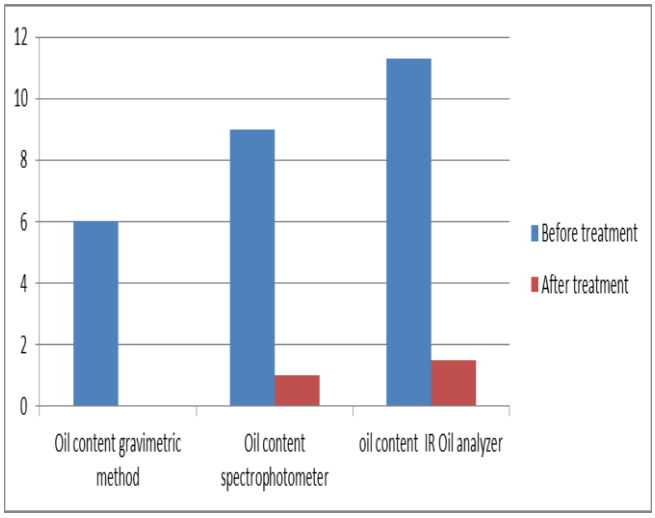

Figure 1. Oil in water results for Heglig field produced water

From oil content results in (Table1) all methods showed that oil content after treatment was under acceptable limit of 5 ppm according to the regulation of Sudanese Ministry of Energy and Mining. Comparing between the obtained results from the above three methods it was found that the determination of oil content by IR method seems to be more accurate than that by spectrophotometric and gravimetric method. IR determination gave higher concentrations before and after treatment 11.3 ppm and 1.5 ppm respectively, flowed by spectrophotometric method 9 ppm and 1ppm and then by the gravimetric method which gave 6 ppm before treatment and zero ppm after treatment
which explains that the gravimetric method is not suitable for determination of low concentrations.
During monitoring Heglig bioremediation treatment system the suitable analysis technique to be used for measuring the oil in water is IR oil analyzer or spectrophotometer, the gravimetric method alone is inadequate.
The difference between the IR and the spectrophotometer results can be attributed to that the spectrophotometer absorption depends on the color of the component, and the colorless component will not be absorbed while infrared absorbed in 3.4 to 3.5 micron region which is common to all hydrocarbons except the solvent S-316.

Table 2. GC results for Heglig produced water test method APHA 2720 C.

Component	Results			
	Before treatment		After treatment	
	Area	wt%	Area	Wt%
Benzene	57630	0.00942	47584	0.00774
2,3DMC5	3219354	0.52624	3259167	0.53035
n-C7	274	0.00005	706	0.00012
2,2-DMC6	1697	0.00028	7340	0.00119
1,2,4-TMCC5	4565	0.00075	5851	0.00095
3-MC7	243693	0.03983	198565	0.03231
n-C9	1612	0.00026		
n-propylbenzene	1990	0.00033	445	0.00007
1,2,4-Trimethylbenzene	5675	0.00093	697	0.00011
n-C10	16796	0.00275	1227	0.00020
n-Butylbenzene	1641	0.00027	247	0.00004
n-C11	31089	0.00508	2113	0.00034
1,2,4,5-Tetramethylbenzene	5053	0.00083	487	0.00008
n-C12	1628	0.00027	343	0.00006
n-C13	923	0.00015	194	0.00003
n-C14	1055	0.00017	559	0.00009
n-C15	722	0.00012	117	0.00002
n-C16	792	0.00013	226	0.00004
n-C17	468	0.00008		
Pyristane	645	0.00011		
n-C18	111	0.00002		
n-C19	438	0.00007		
n-C20	387	0.00006		
n-C21	148	0.00002		
n-C22	144	0.00002	113	0.00002
n-C23	211	0.00004	270	0.00004
n-C24	462	0.00008	474	0.00008
n-C25	581	0.00010	646	0.00011
n-C26	632	0.00010	830	0.00014
n-C27	562	0.00009	701	0.00011
n-C28	259	0.00004	410	0.00007
n-C29	486	0.00008	598	0.00010
(m+p)xylene			199	0.00003
o-xylene			138	0.00002

From GC result showed in (Table 2) the compounds n-C9, n-C17, Pyristane, n-C18, n-C19, n-C20 and n-C21 appeared before treatment in small amount according to the peak areas, disappeared after treatment which means completely treated to amounts bellowed the detection limit by the microorganism, while the compounds m-,p-and o-xylene appeared after treatment and were not detected before treatment which means it's their concentration were below the detection limit before cumulative quantities due to evaporation. The peak areas for the components Benzene, 3-MC7, n-propylbenzene, 1,2,4-Trimethylbenzene, n-C10, n-Butyl benzene, n-C11, 1,2,4,5-Tetramethylbenzene, n-C12, n-C13, n-C14, n-C15 and n-C16 decreased after treatment

which means partially treated by the microorganism. While the components n-C22, n-C23, n-C24, n-C25, n-C26, n-C27, n-C28 and n-C29 detected in small

amounts according to the peak areas before treatment and the peak areas increased after treatment which means these components were not treated by the microorganisms and the increasing in the quantities coming from the cumulative influence of produced water due to evaporation. The compounds n-C10 and n-C11 have been treated largely by microorganisms according to the peak areas before and after treatment. The largest amounts of hydrocarbon component detected in Heglig produced water is 2,3DMC5 and

3-MC7 according to the peak area and both are partially treated by the microorganisms. Form GC results showed in (Table 2) we found that the hydrocarbons with high numbers of carbon (n-C22 to n-C29) were not treated by the microorganisms. The total peak area of hydrocarbons compound decreased after treatment by bioremediation technology.

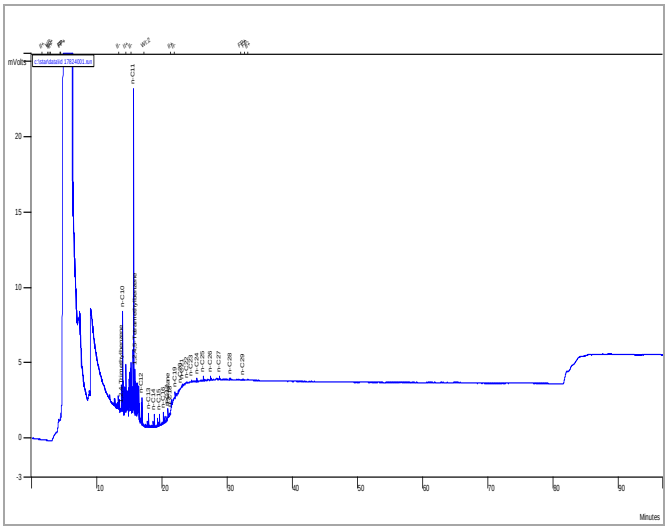

Figure 2. GC chromatogram before treatment

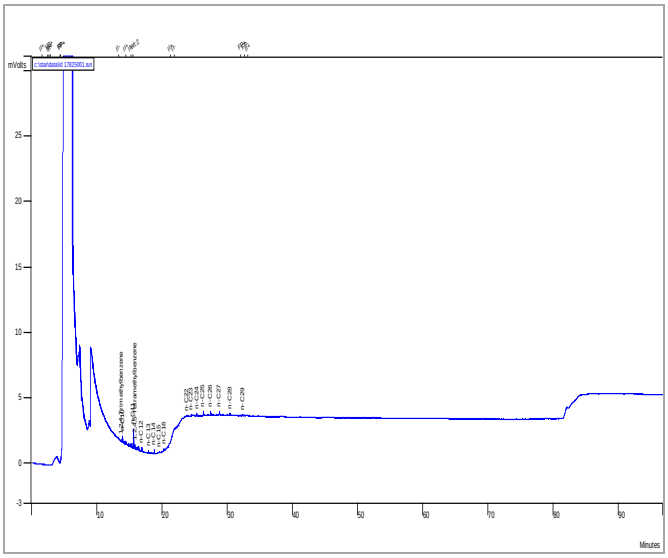

Figure 3. GC chromatogram after treatment

V. CONCLUSION AND RECOMMENDATION

This paper reviewed the bioremediation system applied for hydrocarbons removal form produced water in Heglig field by *Phragmites Australis* plant, to produce clean water and recover valuable materials from produced water with minimal negative impact on the environment.

Following conclusions can be drawn from this study:

1. According to the IR results, the bioremediation treatment by *Phragmites Australis* plant can remove more than 86.72% oil content from produced water.
2. Determination of oil content by IR method is more accurate than by spectrophotometer and gravimetric method, and during monitoring Heglig bioremediation treatment system the suitable analysis technique to be used for measuring the oil in water is IR oil analyzer or spectrophotometer, the gravimetric method alone is inadequate.
3. Most treated hydrocarbons by bioremediation system are n-C10 and n-C11 while components of high number of carbon (n-C22 to n-C29) are almost untreated.
4. The amounts of components benzene, 3-MC7, n-propylbenzene, 1,2,4-trimethylbenzene, n-C10, n-butyl benzene, n-C11, 1,2,4,5-tetramethylbenzene, n-C12, n-C13, n-C14, n-C15 and n-C16 decreased after treatment which means partially treated by the microorganisms.

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