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Research Article

A Water Purification System using Locally Sourced Materials and Removal of Total Petroleum Hydrocarbon in Contaminated Water

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Abstract

The contamination of surface and ground water through oil spillage resulting from the production and exploration of crude oil is a critical problem in the world today. This study was focused on constructing a simple and cheap technology using natural and readily available materials as filter beds for the remediation of water polluted by crude oil. Filter bed materials used were clay, corn cobs, activated carbon, fine sand, sand, egg shells, cotton wool and pebbles. Four glass filters were blown from glass columns of lengths 32cm and inner diameters of 3.3cm each. The filter performance was assessed by analysing the physical and chemical water quality determinants such as Turbidity level, pH TSS, Hardness, Nitrate, TDS COD,BOD,DO and ECW. The total petroleum hydrocarbon (TPH) level determined using a gas chromatography and electron capture (GC-ECD). The result showed that the total petroleum hydrocarbon contaminants in water at an initial concentration of 77.09mg/L were adjusted to 5.07mg/L in the treated sample after 20 days. The results in this study suggest that the filter made of locally sourced materials purified crude oil contaminated water and can be used as an efficient water remediation tool for areas faced with oil spillage issues.

Keywords: Crude oil, Water pollution, Filter beds, Adsorption, Total petroleum hydrocarbon

INTRODUCTION

Water is considered a critical resource to all living organisms and to environmental systems and processes. However, the availability of water continues to dwindle with increasing exploitation, changing climate and pollution of sources, all of which have collectively compromised the quality of water for various uses including ecosystem services function, domestic and commercial usage (Adams et al.,2016). Water pollution through the spillage of crude oil and its fractions is now an existing problem over the years in various parts of the world and consequently drawn universal attention in recent years. Surface and ground water resources contamination via crude oil and related products is now common place in the oil bearing regions of the world (Adams et al., 2017).

A mean value of about 83 million barrels of crude-oil spillage took place yearly between 1994 and 1996 in the United States according to research records; for every of this spill made a contribution of about 50,000 barrels of crude oil.

Oyedeji (2016) According to research about 9 to 13 million barrels of crude oil were spilled in 2010 and yet during clean up exercise, how about 70% of it was not recovered Obi (2012). The Sustainable Development Goal (SDG) number 6 seeks to ensure the sustainable management and availability of water and sanitation for all by the year 2030. Specifically, Goal 6.1 aims to ensure universal and fair access to safe and affordable drinking water for all while Goal 6.3 focuses on improving water quality by decreasing emissions, preventing contamination and minimizing release of toxic chemicals and materials, halving the proportion of untreated wastewater, and increasing recycling and safe reuse of water by a considerable percentage, globally

UN(2018). To attain this goal, massive water purification must be adopted at the local levels in low-income nations including Nigeria. Effective water purification requires a good understanding of the type, nature and sources of pollutants which invariably inform the development of and adoption of appropriate water purification techniques (Adams et al., 2016).

In Nigeria, the Niger Delta region is one of the areas acquainted with this problem and it has resulted to the distortion of the aquatic life and has denied the indigenes access to clean water and ecosystem services. (Osarokaka et al., 2021) due to the extensive level of pollution and contamination since oil exploitation began in commercial quantities over 5 decades ago. It has been reported that such contaminations are often as a result of industrial effluents from oil wells and refineries, ships, pipeline vandalization and illegal oil bunkering (Onwuteaka, 2016; Olajide et al., 2009).

Currently, multiple methods of purification have been developed for the treatment of waste waters from crude oil contamination. These methods include Photocatalytic reduction, Reverse Osmosis, Advanced oxidation processes, Distillation, adsorption/absorption and Electro dialysis amongst others.

However, research has shown however that the application of these methods of water treatment is quite expensive for a low-income economy such as Nigeria and many times ineffective in the removal of the pollutants (Yoon et al., 2000) wikipedia Khana_Rivers.

It has become imperative to develop affordable, environmentally congenial and technologically appropriate methods of water treatment using locally sourced and modified adsorbents. This study used biological and non-biological but readily available and easily affordable locally-sourced materials such as corn cobs, sand, clay, egg shells, activated carbon and cotton wool to develop a water purification technique for water contaminated with crude oil and total petroleum hydrocarbons.

MATERIALS AND METHODS

Study area

The crude oil contaminated water was obtained from the Kpean community, Khana Local government area of River state Nigeria. Khana local government has its headquarters in a small town called Bori, with an area of 560 km² and a population of 294,217 as at 2006 census. The local dialect among the indigenes is Khana (Yoon et al., 2000) wikipedia Khana_Rivers. The indigenous members of the community are mainly peasant farmers mostly cultivating farm produce such as tubers and vegetables. Crude oil exploration and development is the major industrial operation in kpean region of Rivers State, Nigeria.

Collection of Water Sample

Crude oil contaminated water (10 liters) was collected in two polyethylene gallons. The temperature was determined on site using a mobile thermometer and an average temperature of 26.400C was recorded. 10ml of 0.2M H2SO4 was added to the sample obtained and it was stored at a temperature of about 4 0C as recommended by (Ikpe et al., 2016; Ekwere et al., 2016)

Collection of Materials

Coconut shells, Corn cobs, Egg shells, Pebbles, gravel, fine sand and clay (earthenware) were collected from Jos north metropolis and their sizes were reduced using pestles, mortars and sieves to a range of 0.2mm-2.0mm and stored in a cool and dry cupboard for further application

Filter Design

A glass column of about 32cm in length with an inner diameter of 3.3cm and was blown into a filter column and clamped using a retort stand**, (Figure 1a).**There were major things to consider in building the filter beds which affected the filter performance. That was the filter‟s length or width, the diameter and thickness of its individual constituents. These were the length or depth of the filter, the diameter and the thickness of its individual constituents (Adams et al., 2016; Agbozu et al., 2016; Umembamalu et al., 2020). The disposition was based essentially on the function of the single ingredient present in the filter column. From top downward there are clay, corn cobs, egg shells, activated carbon, fine-sand, sand, activated carbon, cotton wool and pebbles, as shown in **(Figure 2a and Figure 2b)**.

RESULTS AND DISCUSSION

The filters containing the sample were permitted to stand for one hour to ensure full interaction with the filter beds, after which the highest, lowest and average flow rates were determined as described by (Adams et al., 2016; Adams et al, 2017; Umembamalu et al., 2020; Ibrahim et al., 2010). From the graphical representations **(Figure 3, 4, 5 and 6)** the flow rate for

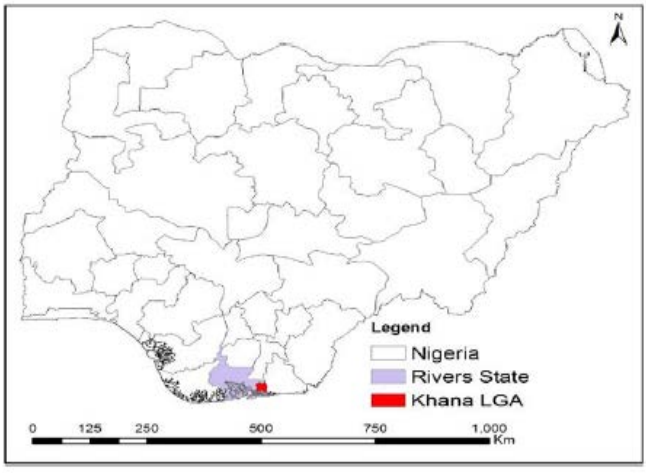

Figure 1. Map of Nigeria, Showing Study Area (Khana LGA).

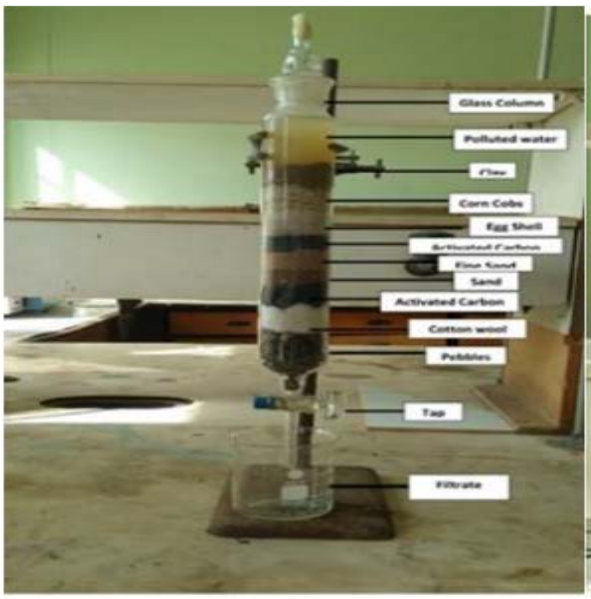

Figure 2A. Filter Profile.

Figure 2B. Filter stand.

Flow rate studies (Graphical representation of flow rates as function of time)

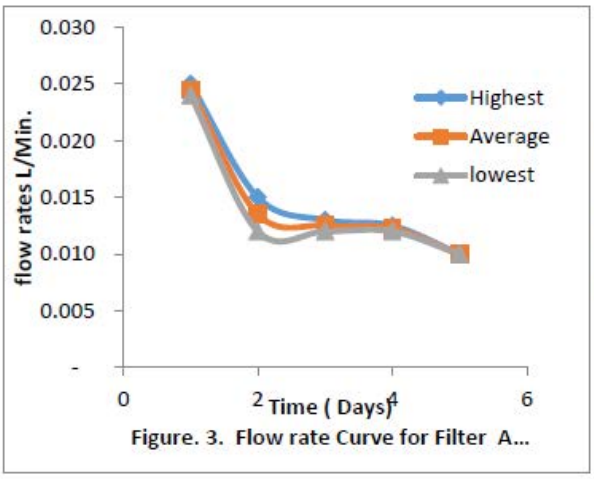

Figure. 3. Flow rate Curve for Filter A...

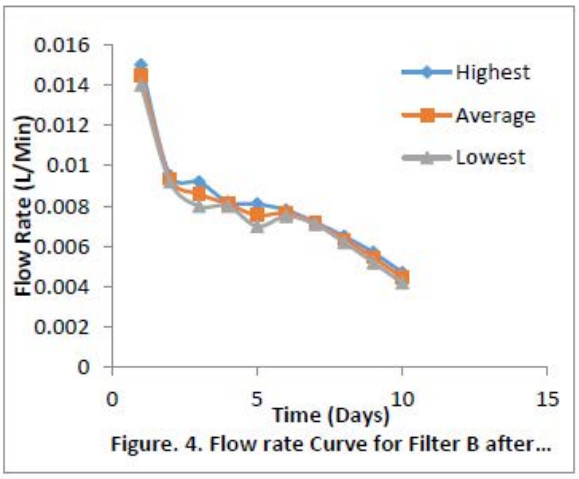

Figure. 4. Flow rate Curve for Filter B after...

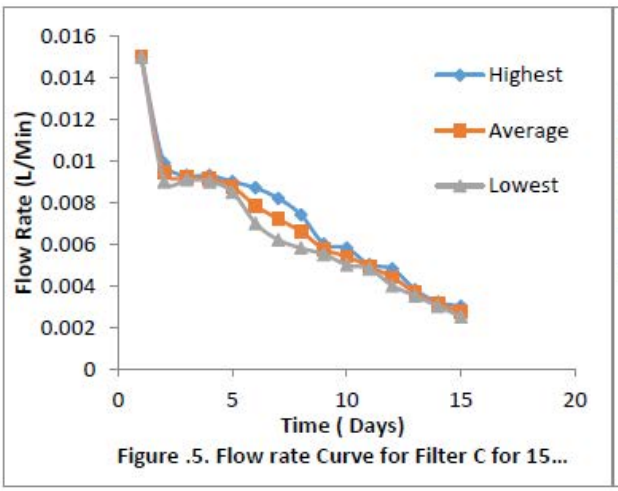

Figure .5. Flow rate Curve for Filter C for 15...

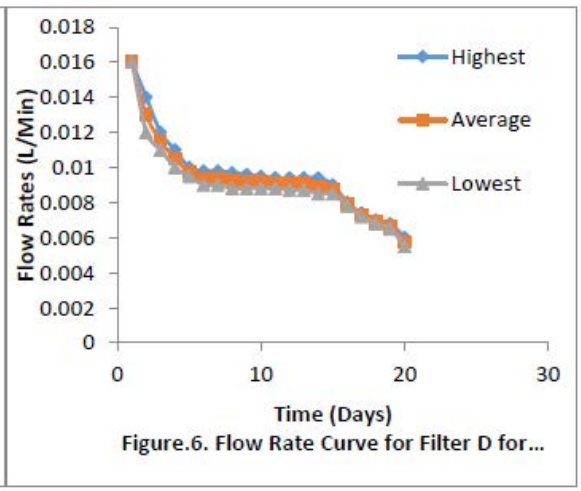

Figure.6. Flow Rate Curve for Filter D for...

each of the filters was observed to reduce as filtration time increased. The longer it took for the contaminated water to flow through the filter beds the better the filtration was observed. The graphs showed a quick decline in flow rate as the time passed by. In the beginning the sharp decline through the filter was larger than it was after some time and the difference in the maximum, minimum and average values were seen until around the 5th, 6th, 13th and 16th days. The graph shows that the ability for water to flow through the filter beds was greater at the beginning, and as time passed by the permeability of the filter decreased as a result of clogging particles present hence decreasing the flow rate. (Adams et al.,2016; Adams et al,2017, Umembamalu et al., 2020; Olufemi et al., (2010)

Water quality is characterized by three basic parameters which is the chemical, physical and it‟s rheological parameters based on its conviviality for specific uses such as portable, agricultural, and household uses. (Adams et al, 2017) indicators of water quality are divided into three groups which is physical, chemical and biological. Temperature, conductivity, turbidity, total dissolved solids, colour, odour, and water taste are known as physical indicators. While PH, total hardness, dissolved oxygen and chemical oxygen demand are referred to as chemical indicators include (Adams et al, 2017).

The measure of acidity is defined as PH, this an important water quality indicator as small changes in its value can adversely affect life. From **(Table 1)** the PH value of untreated was slightly acidic (5.96) and as the purification process went on, it was observed that there was agradual adjustment from (5.96-7.27). This was significantly close to the control and also within the prescribed guidelines of FEPA (2007) and NIS (2007) in collaboration with SON governing council guidelines for drinking water.

When the concentration of suspended particles in water increases there is a tendency that the amount of sunlight penetrating the water surface decreases hence turbidity increases (Okoye et al., 2014). Water can be considered to be dangerous to the aquatic life if it is highly turbid (,Seiyaboh et al.,2017; Johna et al.,2020), however it will not be correct to think that clear water is healthy always (Okoye et al.,2014)). Water that is slightly turbid can be very healthy, while microscopic toxins or impermissible levels of nutrients could be present in clear water (Brix et al., 2010; Jaffar et al., 2020). From Table 1 it is observed that the turbidity of the untreated water was 670 NTU and decreased as the number of days of treatment passed by for each of the filters, Indication that the dissolved and suspended matter constituting the water contamination was gradually adsorbed as the contact time was increased. The results also indicated that the turbidity value was relatively high and slightly above the control value (18mg/L) for filter D and significantly above the prescribed guidelines. This could be attributed to the granular and particulate nature of the adsorbents used in the filters. (Adams et al, 2017).

TDS comprises of ionic particles, dissolved organic matter as well as sand particles. In determining the quality of water the analysis of TDS is critical as it gives useful information about the purity of water (Seiyaboh et al., 2017). Impure water may have high values of TDS indicating that the water may be harmful to aquatic life such as fish and consequently affect fish eggs depending on the ionic properties of water (Brix et al., 2010). From **(Table 1),** the TDS value of the untreated sample of water was analyzed to be 405 mg/L. The results revealed that as the contact time increased, TDS level was adjusted from 405 (Untreated) to 360.0, 251.0, 140.0 and 121.0mg/L for the filters A, B, C and D respectively as a result of adsorption of dissolved solids on the surface of the adsorbents over time.

(Table1). shows that the untreated water detected a nitrate content of 350mg/L, and after treatment the nitrate content was reduced to 41.3, 18.0, 4.1 and 1.5mg/L for filters A, B, C and D respectively, indicating that the adsorbents used were capable of adsorbing nitrate contaminants on to their surface hence removing them from water by 88.20%, 94.85%, 98.82%, 99.57% for filters A, B, C and D respectively (Adams et al,2017) The results also showed that although filtrate from filter D still had some nitrate content (1.5mg/L), they had no adverse health effects to humans, plants and aquatic animals as it was still within the permissible limits for water use when compared with standard guidelines (10-50mg/L).

The total suspended solid (TSS) is a measure of the undissolved solids in a solution which gives an indication

Table 1. Obtained water quality results for treated and untreated water.

Filter	pH	Turbidity(NTU)	TDS(mg/L)	Nitrates(mg/L)	Viscosity(cp)	Ash content %
Untreated	5.96	670	405	350	3.32	0.38
A	6.06	78.8	360	413	3.08	0.35
B	6.86	51.1	251	18	3.07	0.02
C	6.95	38.9	140	4.1	3.07	0.02
D	7.72	21	121	1.5	3.07	0.02
Control	7.4	18.8	117	0	3.07	0.02
WHO(2011)	8.2-8.8	1.5	-	50	-	-
USEPA(2018)	-	-	-	10	-	-
FEPA(2007)	6.5-8.5	-	500	50	-	-
NIS(2007)	6.5-8.5	5	500	50	-	-

of the concentration of Total solids (TS) and (TDS) of water (Okoye et al., 2014). **(Table 1)** shows the initial concentration of TSS as 4500mg/L and after treatment the TSS was observed to have decreased for filter A,B,C and D as 3832, 2100,1500 and 1300 mg/l respectively, while the control sample was found to be 1000mg/L. The ability of oil to attract particulates matter to itself causing a thick layer to be formed on the surface of water he may be responsible for the increases TSS and TS Tully Jnr (2000)

The susceptibility levels of oxidation of organic and inorganic substances present in water bodies, sewage and industrial effluents are often analyzed using chemical oxygen demand (COD) (Okoye et al.,2014; Jaffar et al.,2020). From **(Table 2),** the COD for untreated water samples appeared to be higher (205.0mg/L) but it was observed to reduce gradually by significant amounts as the filtration process went on for filters A, B, C, D and the control. The recorded values of 150.0, 122.0, 79.0, 37.0 and 15.0 mg/L were shown for filter A, B, C, D and the control sample respectively, which were within the guidelines of the World Health Organization (WHO 2011).

The biological oxygen demand (BOD) is used to determine the level of carbon loading in the water as well as biochemically degraded organic matter (Okoye et al., 2014; Jaffar et al., 2020). From **(Table 2)**, the BOD for the untreated water sample was analysed to be 2.01mg/L and after treatment it was observed that the BOD was found to increase for filters A, B, C and D as 2.33, 2.40, 2.66 and 2.85 respectively, with the control sample as 4.10mg/L.

The quantity of gaseous oxygen dissolved in water which is considered a very important factor for all forms of aquatic life is known as dissolved oxygen (DO). Almost all forms of chemical and biological activity within water bodies are influenced by the amount of oxygen dissolved in water (Okoye et al., 2014, Etim et al., 2013). When there is no less than 2mg/L of oxygen in a particular water sample it means life cannot exist in it and also it indicates the presence microorganisms or particles in it therefore the amount of oxygen dissolved in a sample must not be less than 2mg/L. From **(Table 2)**, the dissolved oxygen for untreated water was determined to be 1.5mg/L. It was observed that there was a significant increment in the concentration of the dissolved oxygen for all of the filters (A, B, C and D) with the values of 3.0, 5.0, 4.0 and 6.5mg/L, respectively.

the measures the salinity and the extent to which water is able to conduct an electric current is referred to as electrical conductivity in water (ECw) and it is measured in micro Siemens per centimeter (us/cm). ECw gives information about the concentrations of (TDS) or the level of salt in a particular water body (Okoye et al., 2014; Johna et al., 2020). **(Table 2)** shows the electrical conductivity of untreated water, which was determined to be 280µs/cm for the untreated water and increased to 290 and 300µs/cm for filters A and B, respectively. The increase in magnitude of the electrical conductivity was as a result of the nature of the adsorbents such as the egg shells used as they produced more dissolved solids and CO32- ions in the treated water, hence giving rise to a high electrical conductivity of water.

From **(Table 2),** filters C and D were observed to have a lower and constant electrical conductivity value of 190µs/cm as a result of the saturation of the filter beds in filters C and D, respectively. This value was also observed to be very close to that of the control sample. When compared to standard guidelines for water quality, it was found that the electrical conductivity was within the set guidelines (1000µs/cm) for both treated and untreated water samples.

The amount of petroleum-based hydrocarbons in the environment that can be measured is generally referred to as TPH. The results of TPH simply indicate that petroleum hydrocarbons are present in a sampled media.

To extract polar organic substances from the non-polar hydrocarbons present in the solvent, the crude oil contaminated water extracts were pretreated with silica-gel. TPH was determined using gravimetric analysis. Gas chromatography (GC) was used to determine the total petroleum hydrocarbon (TPH) from the analysis of petroleum hydrocarbon (PH) .Using a gas chromatography (Perkin model 5890) with an electron capture detector (Ni 63) and a low polar HP-5 column of 30m length, 0.32mm i.d, and thickness of 0.25µm film was used. The carrier gas was nitrogen flowing at a rate of 50ml/s. A HP 3396 integrator was used for the data processing. For this research the temperatures of 240 and 310 0C was set for the

Table 2. Obtained Water Quality results for Treated and Untreated water.

Parameters	TSS(mg/L)	COD(mg/L)	BOD(mg/L)	DO(mg/L)	E/C(µs/cm)	T0C
Untreated	4500	205	2.1	1.5	280	29.6
A	3832	150	2.33	3	290	27.3
B	2100	122	2.4	5	300	27.1
C	1500	79	2.66	4	190	27.3
D	1300	37	2.85	6.5	190	27.5
Control	1000	15	4.1	8	180	27.5
WHO(2006)	1000	12.5	0.8-5.0	7.14	1000	Ambient
USEPA(2018)	1000	-	-	-	1000	Ambient
FEPA(2007)	1000	-	-	-	1000	Ambient
NIS(2007)	1000	-	-	-	1000	Ambient

injector while the oven temperature for the detector was programmed at 150 0C in the beginning (5 minute hold) and was finally increased to 310 0C at the rate of 5 0C/min for a total duration of 35 minutes analysis. (Ekwere et al., 2016).

The TPH concentration for treated and untreated water samples. The GC-ECD analysis showed that the organic contaminants were of the alkane homologues series and were detected from C14 to C30 with an initial TPH concentration of 77.01mg/L for the untreated water sample shown in **(Figure 7)**. After treatment the organic compounds were removed individually by significant amounts from a range of 60.66% to 99.80% with the complete removal of pentacosane (C25) from the treated water (Adams et al., 2017). The TPH concentration after treatment with filter D (20 days) was analyzed and found to have reduced to 5.07mg/L shown in **(Figure 8** and **Table 3**) with a total removal of 93.42%. When compared with the standard guidelines set by (DPR, 2002) and (FEPA, 2007), the result obtained for the treated water was within their permissible limits of 10mg/L.

While several studies have been conducted to show levels of water pollution in parts of Nigeria, the novelty of this study is in the fact that it seeks to develop a local solution to water treatment, a much needed effort towards achieving the SDG 6 in a country like Nigeria where resources are scarce in the face of extensive water pollution caused by decades of neglect and poor management of crude oil activities. The combination of locally sourced materials as adsorbents used in the purification of crude oil contaminated water is capable of removing organic compounds such as pentacosane (C25) completely from water while reducing other polluting agents by very significant amounts in the range of 60.66% to 99.80%, resulting to a TPH Removal of 93.42%. An adjustment in water pH, turbidity, TDS, TSS, COD, BOD, Nitrates, Ash Content and viscosity was observed for the four filters A(5 Days), B(10 Days), C(15 Days), and D(20 Days) as the number of days for the experiment increased. The filters generally showed an adjustment in the water quality parameters of the treated water samples when analysed. It also was seen that the water quality parameters were adjusted to a level significantly close to the guidelines set by WHO, USEPA, FEPA, NIS, and DPR. Filter D (20Days) was observed to give the best filter performances in terms of water quality obtained when compared to filters A (5 Days), B (10 Days) and C (15 Days).

From the outcome of this study, it is suggested that further

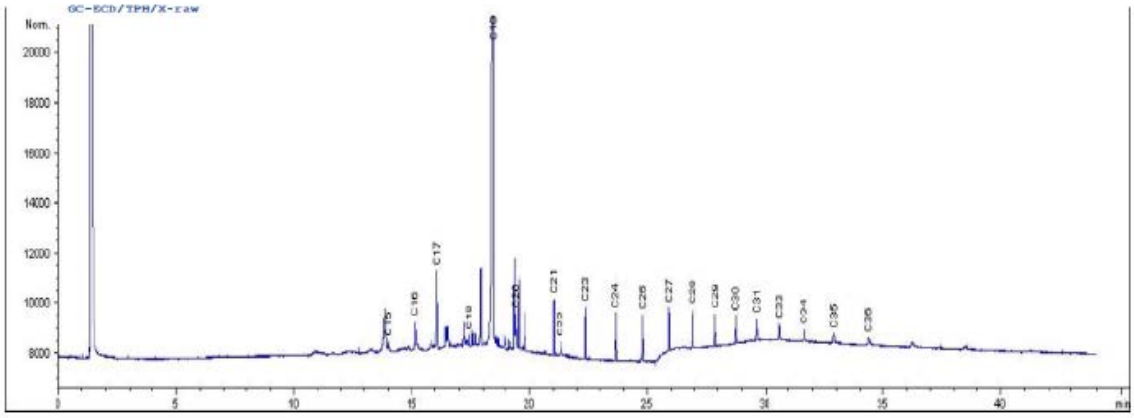

Figure 7. GC-ECD Chromatograph for Untreated Water Sample.

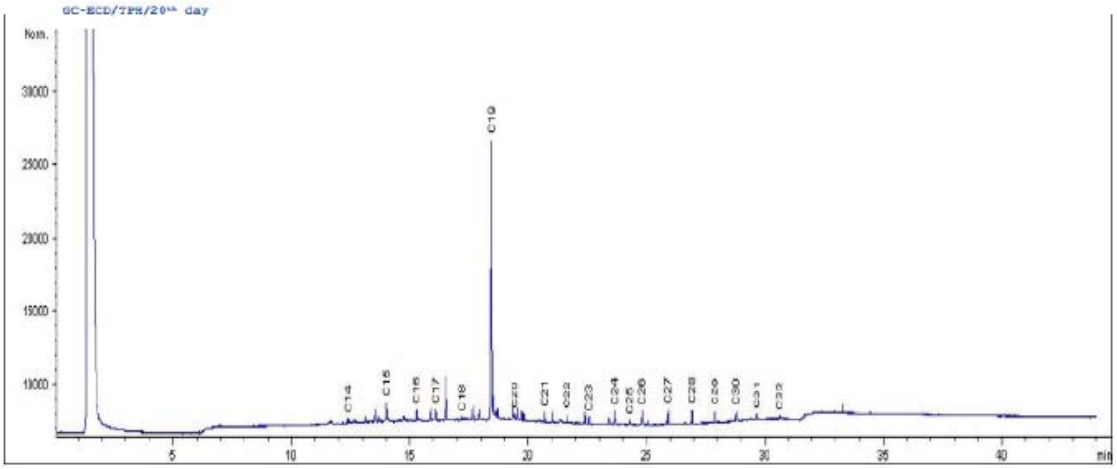

Figure 8. GC-ECD Chromatograph for Treated Water Sample.

Table 3. GC-ECD Results for Untreated and Treated water samples.

Compounds	Retention	Untreated Sample Conc.	Treated Sample Conc.	% Removal
	Time[min]		[Filter D= 20 days]	
n-8	9.524	ND	ND	-
n-9	10.502	ND	ND	-
n-10	11.716	ND	ND	-
n-11	12.357	ND	ND	-
n-12	13.864	ND	ND	-
n-13	14.876	ND	ND	-
n-14	15.782	ND	ND	-
n-15	16.685	3.54463	0.04431	98.74%
n-15	17.521	2.85761	0.25149	91.19%
n-16	18.448	6.89344	0.49754	92.78%
n-17	18.928	0.85433	0.33613	60.66%
n-18	20.026	8.56542	0.01598	99.80%
n-19	20.665	6.12383	1.07583	82.43%
n-20	21.436	4.34065	0.04064	99.06%
n-21	22.161	0.65454	0.04047	93.80%
n-22	22.819	7.64534	0.22532	97.05%
n-23	23.464	7.81154	0.31852	95.92%
n-24	24.058	7.35455	0.32506	95.92%
n-25	24.827	7.35455	ND	-
n-26	25.501	7.55465	0.49964	93.38%
n-27	26.355	3.67546	0.48853	86.70%
n-28	27.262	3.44454	0.49754	85.56%
n-29	28.382	3.78964	0.02664	99.30%
n-30	29.701	1.00116	0.34656	65.38%
n-31	31.206	0.9765	0.0355	96.36%
n-32	33.187	ND	ND	-
n-33	33.53	ND	ND	-
Total		∑ 77.08783	∑ 5.0657	93.42

work should be carried out to determine the effect of the filters on biological parameters such as E-coli form and viruses from organic, inorganic and faeces produced by humans and animals. Also, the effect of a longer contact time and filter saturation point should be investigated to maximize the purity and safety of the treated water. The results obtained have shown that better quality and purity of water is obtained from the filter when the water takes a longer time to flow through the filter beds. However, the safety and lifetime of the filter should be ascertained in order to know the biological and health implications of the treated water at any given time.

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REFERENCES

1. Adams FV, Hategekimana F, O Donnell PS (2016). Crude oil contaminated water treatment: Development of water filter from locally sourced materials. Procedia manufacturing. 7: 465-471.
2. Adams FV, Peter A, Joseph IV, Sylvester OP, Mulaba-Bafubiandi AF (2017). Purification of crude oil contaminated water using fly ash/clay. J Water Process Eng. 11: 1-6.
3. Oyedeji AA (2016). Impacts of selected leguminous tree species and kaolinite pre-amendment on oil- contaminated soil for bioremediation in the oil- bearing region of Nigeria. University of Wolverhampton, UK.
4. Obi C (2012). Contamination of Soils with Crude Oil.
5. Onwuteaka J (2016). Hydrocarbon oil spill cleanup and remediation in the Niger Delta. JGEESI. 4: 1-18.
6. Olajide PO, Ajisebutu SO, Williams SB, Ogbeifun LB (2009). Fish kills and physiochemical qualities of a crude oil polluted river in Nigeria. Res J Fish Hydrobiol. 4: 55-64.
7. Yoon Y, Westerhoff P, YOON WJ, Snyder SA, (2000). Removal of 17β estradiol and fluoranthene by nanofiltration and ultrafiltration. Int J Environ Eng. 130: 1460-1467.
8. Ikpe EE, Akpakpan AE, Nsi EW, Ekanem AN (2016). Determination of the level of petroleum hydrocarbon in water, fishes and plants from part of river Ethiope, Oghara in Delta State, Nigeria. Int J Appl Chem. 2: 1-10.

9. Ekwere Daniel, Joe Nna (2016). Total petroleum hydrocarbon concentration in surface water of Cross River Estuary, Niger Delta, Nigeria. Asian J Enviro Ecol. 1: 1-7.

10. Agbozu IE, Bassey U, (2016). Kinetic Modeling for Removal of Pb, Cd, Ni, and Cr Ions from Petrochemical Effluent using Termite Soil. Int J Sci. 5: 1-6.

11. Igwebe CA, Umembamalu CJ, Osuagwu E, Oba A (2021). Studies on Adsorption Characteristics of Corn Cobs Activated Carbon for the Removal of Oil and Grease from Oil Refinery Desalter Effluent in a Down flow Fixed Bed Adsorption Equipment. Eur J Sustain Dev Re. 5: em0145.

12. Umembamalu CJ, Igwebe CA, Osuagwu EU, Nwabanne JT (2020). Packed bed column adsorption of oil and grease from refinery desalter effluent, using rice husks derived carbon as the adsorbent: influence of process parameter and Bohart-Adams kinetics study. WNOFNS. 31: 155-174.

13. Ibrahim MB, Jimoh WLO (2010). Biosorption of Cr (VI), Ni(II) and Fe(II) By maize(Zea Mays) Cobs. Chemsearch Journal 1: 43-47.

14. Olufemi GA, Tunde EO, Temitokpe AO (2010). Determination of total petroleum hydrocarbons and heavy metals in surface water and sediment of Ubeji River, Warri, Nigeria. Bioremediation, biodiversity and bioavailability, Global science books. 5: 46-51.

15. Okoye CO, Okunrobo, Lovette A (2014). Impact of oil spill on the land and water and its health implication in Odu-gboro community, Sagamu, Ogun state, Nigeria. World Journal of environmental Science and engineering. 1: 1- 21.

16. Seiyaboh EI, Izah SC, Oweibi S (2017). Assessment of water quality from sagbama Creek, Niger Delta, Nigeria. Biotechnol Res. 3: 20-24.

17. Brix KV, Robert G, Nathan C, Amanda K, Martin G (2010). The effects of total dissolved solids on egg fertilization and water hardening in two salmonids-Arctic Grayling (Thymallus arcticus) and Dolly Varden (Salvelinus malma). Aquat Toxicol. 97: 109-115.

18. Jaffar A, Norashikin MT, Amin MSA, Maisan MF, Yassin AIM (2020). The Influence of Physico- Chemical Parameters to Determine Water Quality: A Review. JEESR. 17: 116-121.

19. Tully Jnr (2006). Mode- selective control of surface reactions. Science. 312: 1004-1005.

20. Etim EE, Odoh R, Itodo U, Umoh SD, Lawal U (2013). Water Quality Index for the Assessment of Water Quality from Different Sources in the Niger Delta Region of Nigeria. Frontiers in science. 3: 89-95.

21. Johna UE, Avoaja DA, Hanson HE, Nnana GP (2020). Studies on Plankton diversity and water quality of a tropical rainforest River, Niger Delta, Nigeria. Int J Fish Aquat Sci. 8: 532-536.

22. Osarokaka AJ, Nzeako SO, Imafidor HO, Living-jamala U (2021). Soil nematodes status of crude oil polluted sites in bodo community, Gokana Local Government Area, Rivers State, Nigeria. Afr J Environ Sci Technol. 15: 85-97.