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Composite Filter for Treatment of Hydrocarbon Contaminated Waters

*[1]Nwachukwu, M. A., [1]Gilbert, C.,[1]NwachukwuJ. I., [2]Nwachukwu, A. N.
[1]Department of Environmental Management, [2]Department of Civil Engineering
Federal University of Technology Owerri, Nigeria

Abstract:- This paper presents a novel approach to the efficient management of toxic waste water that are often discharged into the environment by petroleum and related industries without treatment posing major threat to both biotic and abiotic organisms.A locally produced model hydrocarbon filter called Composite Hydrocarbon Filter (CHF) with double polymer membrane packs, gravel and sand pads, with membrane life span of between 1-2 years is discovered for treatment of waste water contaminated with hydrocarbons. A very unique characteristic of CHF is its adaptation to discharge pipe of well head or storage tank, customization of the filter membrane, gravel and sand pads for easy replacement and removal of total hydrocarbon compounds (PAH and TPH) from water. CHF,whose major components can be locally sourced and characterized by high end product quality will achieve approximately 100% filtration of hydrocarbon compounds when water contaminated with hydrocarbon is passed through it.The model is been tested at Umuakpara community where well water contaminated by hydrocarbon compounds migrating from the Osisioma NNPC depot waste water pit has contaminated shallow aquifer source of domestic water to the community;threatening life and wellbeing of the people.

I. INTRODUCTION

Our research motivation was drawn from the persistent exposure of over 4000residents of Umuakpara community in Osisioma local government area of Abia state to groundwater seemingly contaminated by hydrocarbons originating from the unlined effluent discharge pit (Figures 1& 2) of the Nigerian National Petroleum Corporation (NNPC) Depot serving Abia and Imo states, domiciled in the community. This followed the close observation of not fewer than 14 private water wells visited by our research team in the community with 10 active and pumping water smelling hydrocarbon, 2 abandoned, and 2 pumping water free of smell.The impacted Umuakpara, houses one of the largest police (MOPOL) barracks in south-eastern Nigeria which the entire community is in danger and helpless.

Our research team also witnessed crowd of children playing and drinking tap water smelling fuel oblivious of the real danger associated with their continuous exposure to this type of water. Figure 3, describes the potential pathways for hydrocarbon pollution of groundwater and consequent human exposure in Umuakpara, particularly children.This research aims at introducing first of its type, cheap local filter capable of removing hydrocarbon from pumped water and from waste water resulting from oil and gas operations. Umuakpara community is used as a case study of impacted area, with figure 4 showing area map of NNPC depot waste pit, and the contaminated water wells investigated.


Fig. 1: Waste Water Discharge Chanel from Depot


Fig. 2: Unlined Depot Waste Water Discharge Pit

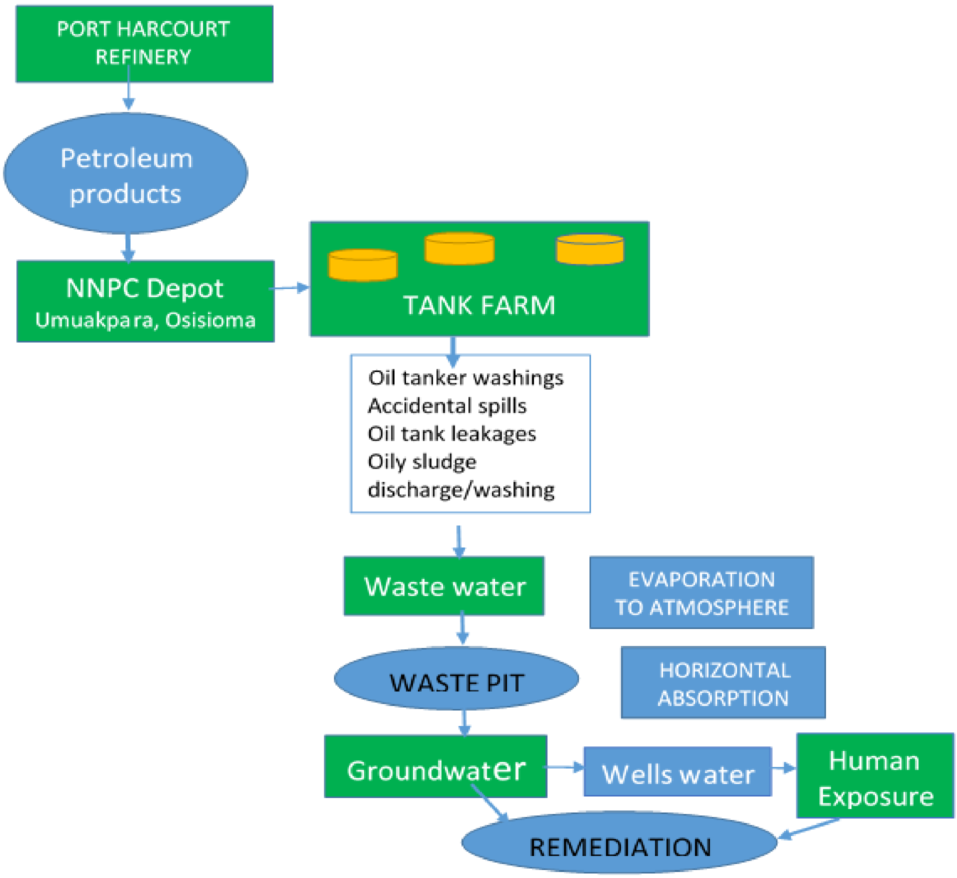

Fig. 3: Potential pathways for hydrocarbon pollution of groundwater and consequent human exposure in Umuakpara, particularly children

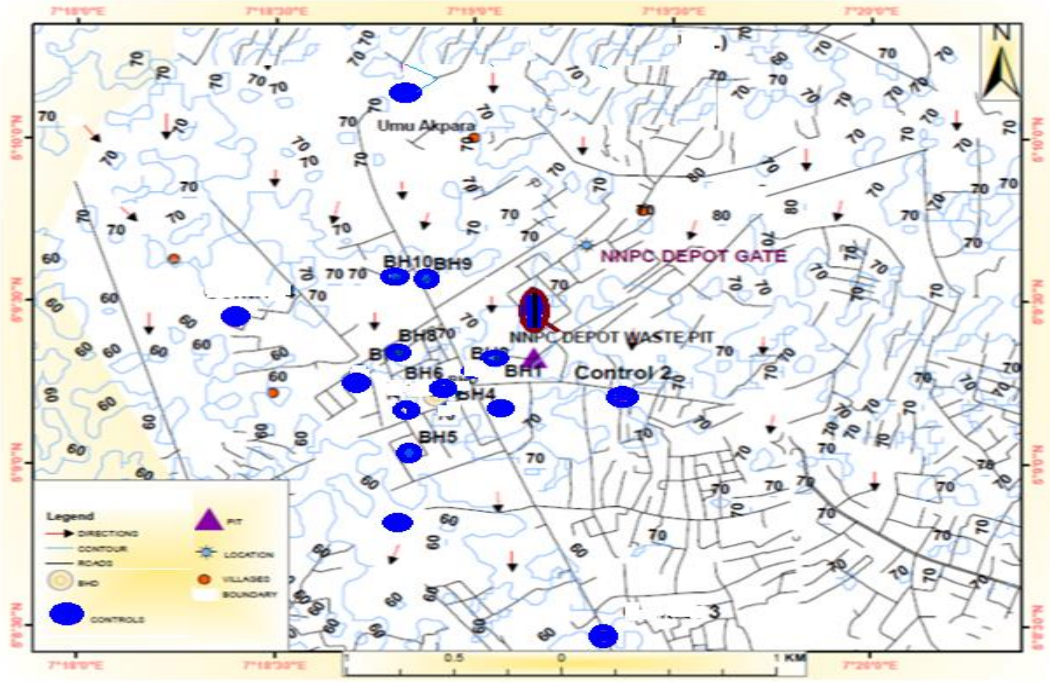

Fig. 4: Umuakpara impacted area map showing NNPC depot waste pit and the water wells

In the light of the above, this paper presents a new model hydrocarbon filter called Composite Hydrocarbon Filter (CHF) that will be placed at the discharge end of storage tank, close to the well head of all productive wells producing hydrocarbon contaminated water especially for domestic use. This filter which will compete with any type in the market will be locally produced, cheap and available. It will have a double polymer membrane packs, gravel and sand pads, and with membrane life span extended to 1-2 years. A peculiar feature of the CHF is the customization of the filter membrane, gravel and sand pads for easy replacement and removal of total hydrocarbon compounds (PAH and TPH) from water, thereby making the water good for drinking.

According to WHO and UNICEF globally, 2.1 billion people, lack access to safe, readily available water at home,asreported by Lewis et al. (1998), and 4.5 billion, lack safely managed sanitation and more than 840,000 people die from water related diseases annually for not following the five water purification designsas presented by the University of Florida (2015)athttps://www.ufonline.ufl.eduFurther, Scott et al. (2016) and Singhal and Gupta (2010)reported that contaminated water is the number one cause of death in developing countries. The UNEP/UNESCO project reporton pollution status and vulnerability of aquifers in African cities relates water pollution to poor on-site sanitation and solid waste disposal systems (Xu and Usher, 2006); a condition that increases vulnerability of soil and groundwater to leachate contamination (Christensen et al., 2001). Though,Onyekachi et al. (2019) remarked that groundwater is considered the most resilient source of drinking water across most Africa countries, Wang et al. 2012,andLapworth et al. 2017 added that inefficient management policies amidst unrestrained urbanization remains a growing concern. Areview of studies by Nwachukwu (2018)on groundwater degradation in Owerri remarked that population density and depth to groundwater level are two significant factors that influence groundwater pollution. His remarks had earlier been reported by Sorichetta et al., 2013, Ouedraogo and Vanclooster, 2016).

Many authors including Wang et al., (2012); and Xu and Usher, (2006) have confirmed that improper waste management remains a major source of groundwater pollution. With the increasing global dependence on groundwater resource for drinking purposes, Eckstein and Eckstein, (2003)decried human exposure to potentially toxic elements (PTEs) and polycyclic aromatic hydrocarbons (PAHs) especially from petroleum industries due to careless effluents discharge without prior treatment. They maintain that such discharge even to surface water bodies finally reach groundwater systemsthrough base flow.Singhal and Gupta (2010) also described how such contaminated groundwater can typically get into the human system. Various deleterious effects on human health that exposure to such substances portend have been documented by Reis et al., 2016, hence the urgency for novel mechanisms that could mitigate or avert it became criticalto this innovation. Tormoehlen et al. (2014 stated thatacute hydrocarbon exposure can result in a wide array of pathology, such as encephalopathy, pneumonitis, arrhythmia, acidosis, and dermatitis. They emphasized that intentional inhalation and accidental ingestion exposures with aspiration lead to the greatest morbidity and mortality.

Previous studies have focused on various water treatment techniques such as chlorination, filtration, reverse osmosis, ion exchange, distillation, use of solar disinfectants and water purifiers to improve both the bacteriological and chemical quality of water for human consumption (Mwabi et al., 2011; Sobsey, 2002; Stauber et al.,2006; Murcott,2006). In a historical review of water treatment methods visa vis modern technologies and ensuing challenges, Angelakis et al., (2020), acknowledged that conventional water treatment technologies may not adequately treat trace organics and nano particles that are predominantly found in most water supply sources, hence the need for innovative water treatment approach for a long –term water sustainability.

II. MATERIALS AND METHODS

A. Depth to water table

Contamination of groundwater is a function of rate of infiltration while rate of infiltration depends on factors of porosity and permeability. Notwithstanding, groundwater contamination depends on the depth to water table. When water table is near surface, contamination of groundwater through infiltration is more obvious. Groundwater vulnerability is higher to shallow aquifers than deep aquifers through infiltration. It is therefore necessary to ascertain depth to water table and characteristics of the subsurface in this project in order to understand the contamination process. To map the water table and investigate characteristics of the subsurface, we followed the method adapted by Nwachukwu et al. (2017).In this method, Allied Geophysics OHMEGA-Electrical Resistivity equipment was used to conduct a Vertical Electric Sounding (VES). The popular Schlumberger electrode array was used for a total spread (L) of 320 m. A VES station was located beside the abandoned well at the police barracks office approximately400 m away from the depot pit. A distance of 160 m (L/2) was covered on the right, and another 160 m (L/2) was run on the left across the police barracks. All necessary precautions required in geo-electric measurement were duly considered. The survey lasted between 13.00 hr. to 15.00 hr. under favorable weather condition.All field data was subjected to Schlumberger automatic analysis using the Advanced GeosciencesIncorporation (AGI) 1D resistivity inversion software. Figure 5, is a print-out of the resistivity model.

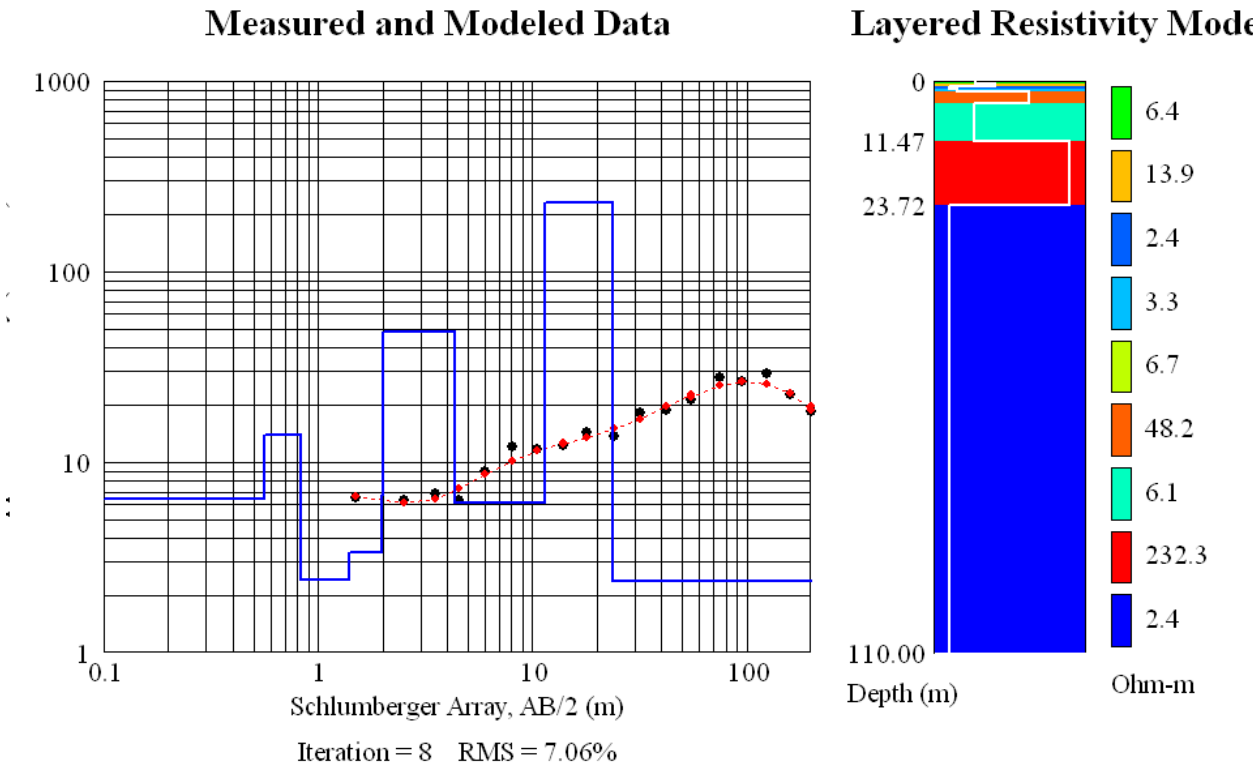

Fig. 5: VES model showing depth to water table**,** corresponding layers, resistivity and thickness of the layers.

Layer#	Ohm-m	Bottom Depth (m)	Lithology
1	13.90	0.827	Topsoil
2	6.74	2.011	Silty sand
3	48.18	4.319	Siltstone
4	6.08	11.472	Silty sand
5	232.28	23.719 (Water Table)	Sandstone
6	2.38	Sand (saturated aquifer unit)	

Table 1: Geo-electric layers constrained to 6 lithologic layers

The shallow water table ofdepth 23m as shown and the sandy subsurface accounted for the gradual transport of petroleum compounds into the groundwater in the community, for which the fate is from water wells to human population.

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B. Water analysis and confirmation of contamination

Water samples from ten of the shallow wells were tested for polycyclic aromatic hydrocarbon (PAH), total petroleum hydrocarbon (TPH) and level of acidity (pH) in the laboratory using gas chromatographyfollowing the method of Olga (2013). The result confirmed a significant high concentration well above acceptable limits as contained in tables 2 and 3, measured in 2019 and 2021.

CONCENTRATIONS OF pH ,TPH AND PAH IN BOREHOLE SAMPLES IN 2019								
S/N	SAMPLE ID	pH	TPH			PAH		
1	BH 1	7.6	4.41	4.5	4.51	0.023	0.024	0.022
2	BH 2	7.8	2.45	2.54	2.52	0.062	0.061	0.061
3	BH 3	7.8	2.09	2.08	2.07	0.055	0.056	0.057
4	BH 4	7.2	3.34	3.33	3.32	0.082	0.083	0.084
5	BH 5	7.6	2.01	2.02	2.03	0.024	0.025	0.026
6	BH 6	7.5	2.16	2.17	2.18	0.021	0.021	0.022
7	BH 7	7.7	2.24	2.23	2.22	0.021	0.022	0.023
8	BH 8	7.4	2.21	2.22	2.23	0.021	0.021	0.022
9	BH 9	7.8	2.14	2.14	2.13	0.0153	0.0154	0.0155
10	BH 10	7.9	2.31	2.32	2.33	0.0133	0.0134	0.0135

Table 2: Chromatographic analysis of water samples collected 2019

CONCENTRATIONS OF pH ,TPH AND PAH IN BOREHOLE SAMPLES IN 2021								
S/N	SAMPLE ID	Ph	TPH			PAH		
1	BH 1	6.3	5.31	5.33	5.32	0.0304	0.0305	0.0306
2	BH 2	6.4	5.226	5.227	5.228	0.0231	0.0233	0.0232
3	BH 3	5.2	2.652	2.651	2.652	0.0294	0.0295	0.0296
4	BH 4	5.6	2.313	2.314	2.315	0.027	0.0271	0.0272
5	BH 5	5.4	2.43	2.42	2.44	0.0232	0.0233	0.0231
6	BH 6	6.4	2.782	2.781	2.783	0.0274	0.0273	0.0272
7	BH 7	6.8	2.46	2.45	2.47	0.0297	0.0298	0.0299
8	BH 8	6.3	1.92	1.921	1.922	0.0086	0.0087	0.0088
9	BH 9	6.2	2.186	2.187	2.188	0.0221	0.0222	0.0223
10	BH 10	6.1	2.202	2.203	2.201	0.0294	0.0295	0.0296

Table 3: Chromatographic analysis of water samples collected 2021

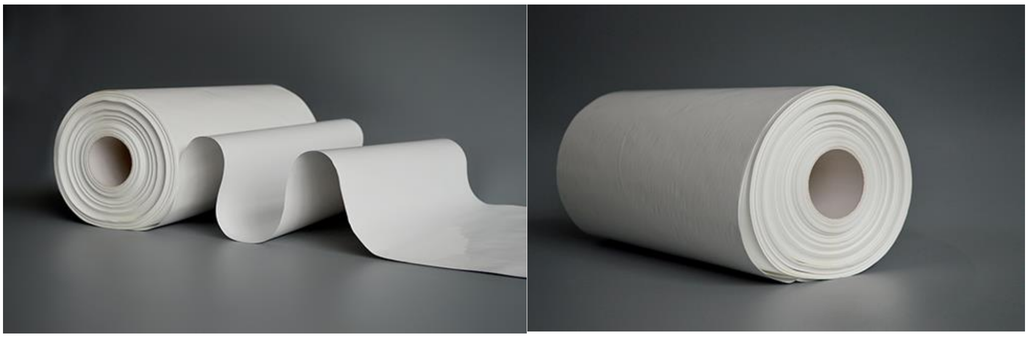
Placing the model composite filter at the well site linked to the discharge from storage tank achieved approximately 100% filtration of hydrocarbons passed through it. The model description and operational details are as presented below.

III. CHF MODEL DESCRIPTION

A. Technical Components of the Innovation

Necessity brings challenge, challenge brings innovation and innovation brings development, our research faces the challenge of providing emergency response to save souls, stop further exposure of the people of Umuakpara to hydrocarbon. This model filter when installed all the pumping wells has the potential to remove total petroleum hydrocarbon from pumped water before it is discharged for use. The innovative model filter shall be locally made, available and affordable so that it will be applicable to other wells having similar cases in different parts of the Niger delta. The model filter will also treat waste water including the smallest quantity resulting from oil and gas operations before such water can be discharged to the environment.

Our filter will be based on a composition of sand and gravel pads and polymer membrane filter (Figure 5). There are many advantages of gravel-sand-membrane filtration when used in hydrocarbon removal from pumped water used for drinking and other domestic uses where quality cannot be compromised. It has lower overall production costs and high end product quality similar to other membrane filters aspresented at https://www.alfalaval.com. In considering this innovation, other makes of hydrocarbon filters such as Q-max HF hydrocarbon filter; PEP Filters; United Filters International; Allied Group Inc. and Permeable reactive barrier applicable in hydrocarbon removal were all evaluated.



5a: PTFE membrane 5b: PES membrane

Fig. 5: Samples of Polymer Membrane Filters to be used

B. Model specifications and Mechanism

Based on our vision, a new model hydrocarbon filter called Composite Hydrocarbon Filter (CHF) cab be produced following our design and specifications (Figure 6). The CHFSpecifications *(adjustable at production)* include the following: Height (16cm); Length (61 cm); Width (16 cm); Sieve 2000 µm (0.08 inches);Flexibility *(Adjustable dimensions);* Energy requirement (Zero). Others include: Inlet flow rate *(adjustable);* Outlet flow rate *(adjustable to inlet);* Gravel-Sand-Membrane replacement (1-2 years); Additional membrane pack (4 per supply); Guarantee (2 years).This new model filter can be placed at the discharge end of storage tank, or close to the well head of any producing well in Umuokpara and other locations where water wells are polluted with hydrocarbon and or other contaminants. This filter which will compete with any type in the market will be locally produced, cheap and available.

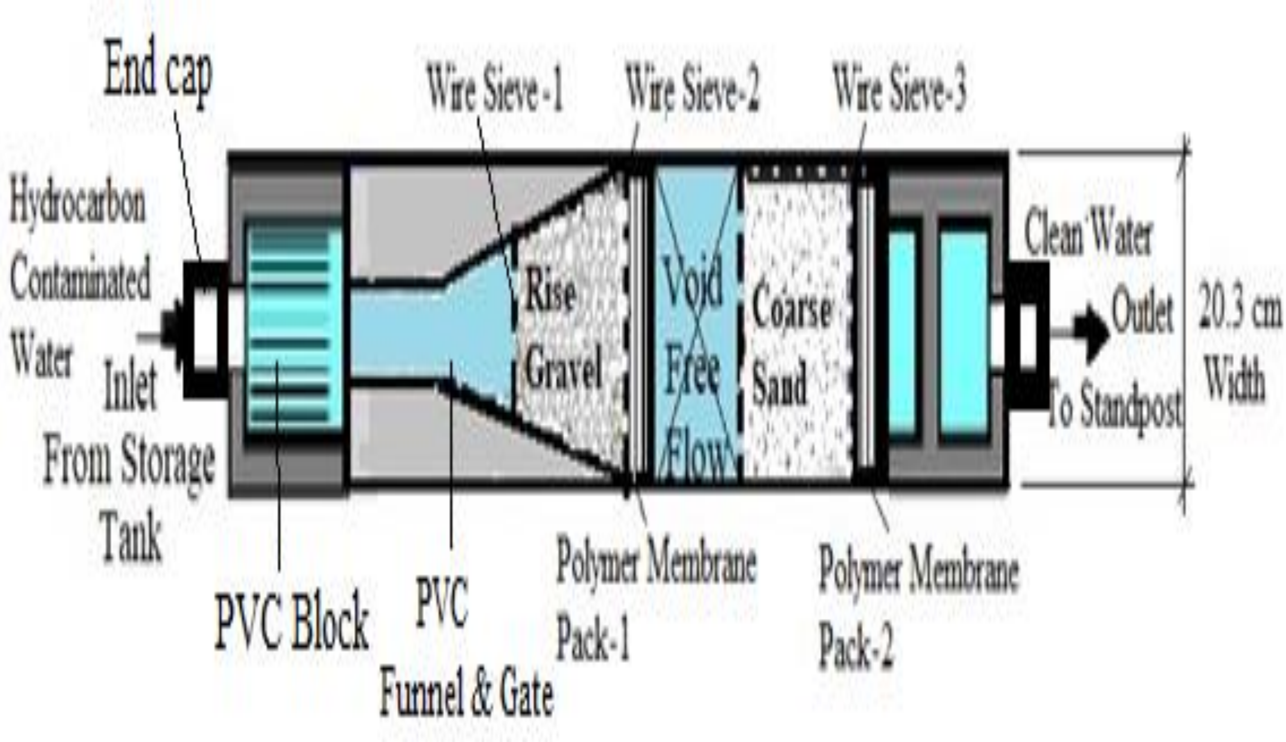


Fig. 6: Layout of the proposed Composite Hydrocarbon Filter (100% hydrocarbon removal)

A peculiar feature of the CHF is the customization of the filter membrane, gravel and sand pads for easy replacement and removal of total hydrocarbon compounds (PAH and TPH) from water, thereby making the water good for drinking. Installation of CHF (Figure 7) in those private shallow wells in Umuakpara community is a perfect emergency response operation to save life, health and well-being of the people of Umuakpara.Hydrocarbon compounds passing through the rise gravel get stopped at the sand pad, but any that persists through the sand pad is certainly filtered by the second polymer membrane, making the contaminated water 100% free of hydrocarbon. The polymer membrane hardens more as it gets contact with hydrocarbons, thus preventing passage of the hydrocarbon.

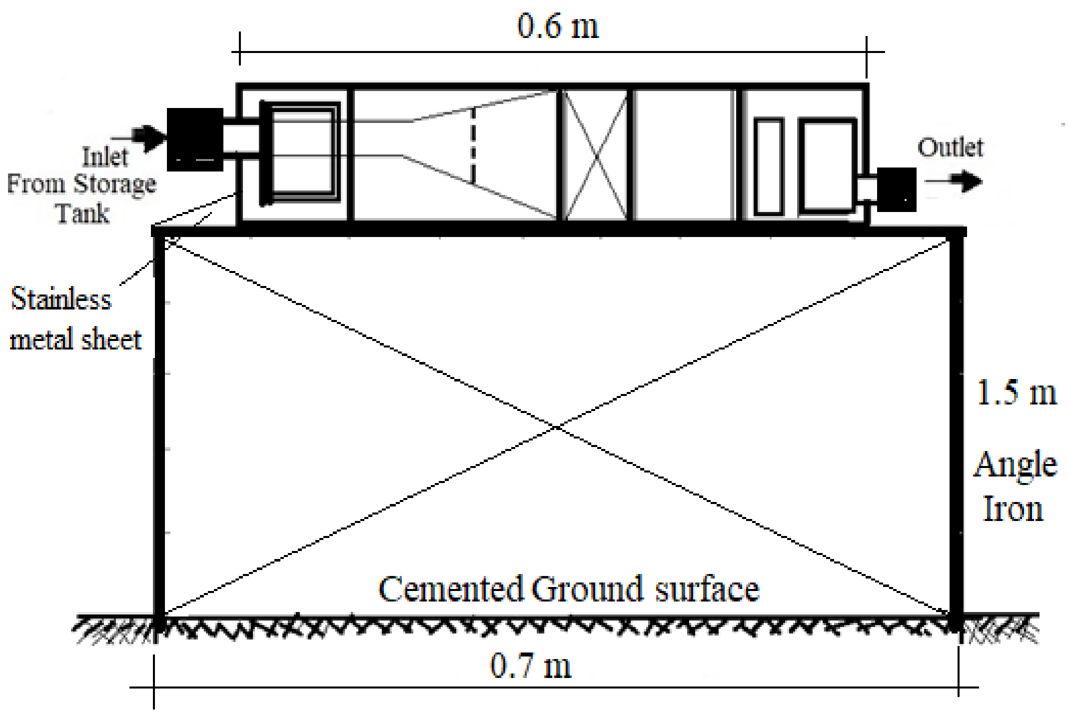


Fig. 7: Well Site Installation of CHF applicable in Umuakpara

IV. Marketing and Distribution

CHF will be advertised and commissioned to real time marketers who trade on water filters. CHFwill have two models; (a) a water well-storage tank discharge pipe fitted model and (b) a waste water discharge channel model. The two models will be in great need in all parts of Niger delta as water and sanitation tool in water services and oil and gas operations. At oil and gas production sites and flow stations, not excluding depots, where waste water containing hydrocarbons is carelessly disposed on land or often directed to surface water-ways untreated. This practice can be stopped by creating a sizeable channel where CHF can be installed to treat the waste water before discharged (Figure 8). CHF will be affordable with the rise gravel-polymer membrane-sand pad arrangement which is economical, available andeasily replaceable.

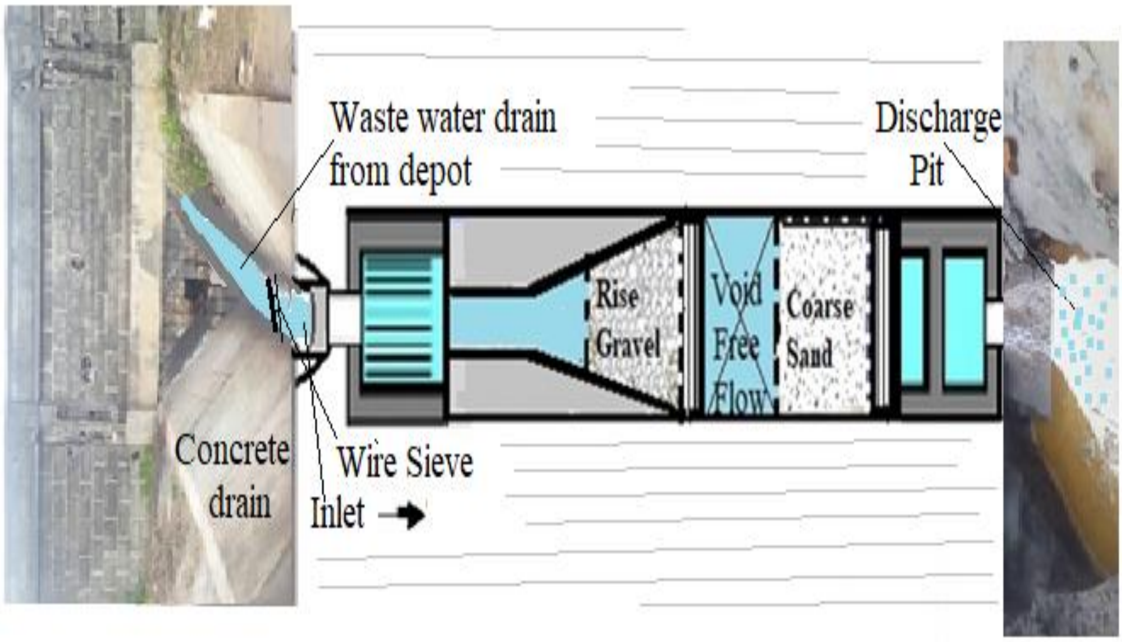


Fig. 8: Adaptation of CHF to waste water treatment applicable toNNPC Depot in Umuakpara

V. CONCLUSIONS

Given the importance of innovation in the mitigation of human exposure to toxic elements in groundwater, the CHFis expected to boost the efficient removal of hydrocarbons and other chemical substances from contaminated groundwater prior to distribution for public consumption. The model, designed to treat all waste water including industrial effluents which can be toxic to both biotic and abiotic organisms can be used to solve the water scarcity caused by industrial and allied activities across major cities of the sub Saharan Africa. CHF is cost effective, and has the potential to not only improve the Gross Domestic Product of the Nigeriannation; it also will go a long way in improving access to portable water to both rural and urban communities, eliminate water contamination problems associated with aging infrastructure, enhance conservative and sustainable management of groundwater resources through recycling and reuse, and ultimately avert potential health crises from ingestion of hydrocarbon contaminated groundwater.

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