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Treatment of Automotive Gas Oil (Ago) - Contaminated Water Using Activated Carbon from Indian Bamboo

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Abstracts

This study investigated the ability of activated carbon extracted from Nigerian-grown Indian bamboo, to absorb hydrocarbon from automotive gas oil -contaminated water. The water was polluted in the ratio of 3:1 (that is, 3parts of water to 1part of automotive gas oil), and then made to flow through 250µm and 500µm activated carbon in a fixed bed adsorption experimental set-up. The effluent from each size of activated carbon was then analysed. The result showed that the activated carbon's ability to reduce contaminants was, in part, a function of its pore size. Although, the two pore sizes of the activated carbon were able to achieve almost 100% reduction of total petroleum hydrocarbon (TPH) and total hydrocarbon content (THC), the 250µm pore size could only reduce 67.7% of the hydrocarbon utilizing fungi count, compared to 70.4% by the 500µm size. For the hydrocarbon utilizing bacterial count, the levels of reduction were 68.6% and 73.2% for 250µm and 500µm respectively. On the whole, the activated carbon had great potential for the reduction of contaminants from automotive gas oil contaminated water.

Keywords: Activated carbon, Indian bamboo, contaminated water, pore size.

Introduction

Khamehchiyan et al, (2006) aver that oil spill , in most cases, is accidental, and that this may occur either during transport or drilling processes. However, most oil spill incidences in the Niger Delta region of Nigeria are caused mainly by the negligence of oil companies and, to some extent, by sabotage. These oil spills occur on land, swamp and the offshore environment (Nwilo and Badejo, 2005). The worst oil spill in Nigeria was that which occurred in 1998 due to Royal Dutch Shell equipment failure, (Vidal, 2011). The UNDP (2006) also reported that between the periods of 1976-2001, 3 million barrels of oil were lost in 6,817 oil spill incidences of which over 70% of the spilt oil was not recovered (Twumasi and Merem, 2006).

Oil spills can cause severe damage to sea and shoreline organisms (Whitfield, 2003). The attendant pollution upsets the ecological balance of the oil spilled area (Uzoije et al., 2011). Oil contamination from drilling processes creates problems that disrupt the lives of people living in close proximity to oil camps, wells, pumping stations, and pipelines (Jernelöv, 2010). Oil-polluted water often contains other substances as well as oil (Pasila, 2004) and petroleum can also contain some sulfur and nitrogen compounds (Viswanathan, 2006) . The activity of petroleum production has worsened the contamination of water, thereby making it difficult for potable water to be supplied to many communities (Ayotamuno et al, 2006). The existing cleaning processes are also complex and may consist of different water purification units (Muhammad et al, 2012).

The removal of hydrocarbons dissolved in water by adsorption technique, which involves the physical adhesion of the hydrocarbons onto the surface of a solid, is an efficient method. The most commonly-used adsorbent is the highly-porous activated carbon, which has a relatively small volume, yet an enormous surface area per unit mass of about 1000 m^2/g (Masters, 1991). The objective of this research, therefore was to determine the effect of activated carbon extracted from Nigerian-grown Indian bamboo on automotive gas oil-contaminated water .

Materials and methods

Description of study area.

The experiment was carried out in the Industrial Chemistry Resources Laboratory, University of Port Harcourt, Port Harcourt, Nigeria. Port Harcourt is characterized by high humidity (≥80%), and moderately high temperature between 25- 30^0C, (Fubara-manuel and Jumbo, 2014). Port Harcourt city is within the tropical- rainforest belt of Nigeria. It is located within latitude $4^O47'21''$N and 6^o 30' N, and longitudes 6^O 59'54''E and 8^o 00' E .The mean annual rainfall is about 3,000 mm.

Materials and Equipment .

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The materials used for the experiment were powdered activated carbon, AGO (automotive gas oil), water, cotton wool, distilled water and phosphoric acid (0.05M), while the equipment used were electronic weighing balance (Ohaus top loading balance), a laboratory electrical oven (Gallenkamp hot box oven with fan), and laboratory electric muffle furnace (Type: OH85TR). Other apparatus were manual grinding machine, pH meter, refractometer, conductivimeter, spectrophotometer, hot plate heater, measuring cylinder, and column.

Carbonization

The carbonization of 500g of washed, cut, and dried Indian bamboo was carried out in a paralyzer plant which allowed a limited supply of air. The bamboo was then carbonized at about 400ºC. After being kept all through the night, the charred product was allowed to cool to room temperature (25^0C). The charred material was crushed to different sizes using a manual grinding machine.

Preparation of H_3PO_4(0.05M)

This was done by diluting 3.4ml of concentrated H_3PO_4 (0.05M) with 1000ml of distilled water, using volumetric flask.

Chemical Activation

25g of sieved bamboo carbon was weighed into a 2 litre beaker and 500ml of 0.05M H_3PO_4 was added to it. Red hot heat was applied to the mixture using hot plate until the mixture was almost dry. The sample was placed in a crucible while furnace heat was applied for 30mins at a temperature of 300ºC. The activated carbon sample was then washed to a pH of 6 and dried in the oven at 80ºC for 8hrs.

The Experimental Methods

The experimental set-up is shown in plate 1.

Plate 1: Experimental set-up of Fixed Bed Adsorption

The internal diameter of the experimental glass column was FC7/44. The adsorption material was the activated carbon extracted from Nigerian-grown Indian bamboo. Cotton wool was used at the end of the column to support the activated carbon contained therein.

The activated carbon was transferred into the column and the pore spaces were filled up by shaking. After the cotton wool had been placed at the end of the column, another quantity of cotton wool was place on top of the activated carbon to prevent the contaminated water from getting direct contact with the activated carbon. This acted as a boundary between activated carbon and the contaminated water.

The potable water sample used for the investigation was contaminated with automotive gas oil (AGO) in the ratio of 3:1(that is 300ml of water to 100ml of automotive gas oil). After the mixing, 200ml of the automotive gas oil-contaminated water sample was measured and transferred into two (2) separate columns, each column with a different size of activated carbon. The sizes of activated carbon were 500µm and 250µm.

Before each run, the columns were wetted by passing distilled water through them to improve the wetting characteristics of the activated carbon. This is necessary for the provision of high interfacial area. The distilled water was allowed to drain, after which the feed sample was made to flow through the column by gravity. The discharge from each column was determined by collecting known volume of water from the column for a specific time. An average feed flow rate of 3.1464 x 10^{-4} m^3/hr. was maintained by the output valve. The effluent from the fixed bed was collected at different time intervals for seven hours per day for four days. For effective identification, the samples were labelled as follows: Sample A: AGO; Sample B: Water + AGO; Sample C: effluent from 250µm activated carbon; Sample D: effluent from 500µm activated carbon.

Laboratory Analysis.

The samples were taken to the laboratory and tested for physico-chemical and microbial parameters such as pH, diesel range organics(DRO), polycyclic aromatic hydrocarbon(PAH), total petroleum hydrocarbon(TPH), total hydrocarbon content (THC), and BTEX (benzene toluene ethylebenzene and xylenes). Other were Microbiological parameters such as THBC (total heterotrophic baterial count), HUBC (hydrocarbon utilizing bacterial count), THFC (total heterotrophic fungi count) and HUFC (hydrocarbon utilizing fungi count).

Results and discussion

The physico-chemical and microbial parameters are shown in Table 1.

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Table 1: Physico-chemical and microbial parameters .

Parameters	A	B	C	D	USEPA and NIS Standards
	AGO	Water + AGO	250µm	500µm	
pH	6.40	5.80	5.80	6.10	6.5 – 8.5
PAH, mg/l	<0.001	<0.001	<0.001	<0.001	0.007
TPH, mg/l	-	21515	1.43	1.13	0.5 – 1000
THC, mg/l	-	21518	1.45	1.17	0.1 – 1000
BTEX, mg/l	-	-	-	-	-
DRO (Diesel Range Organics)	C8-C35	C8-C35	C10-C26	C9-C24	C10-C28
Total Heterotrophic Bacteria Count (cfu/ml) $x10^3$	1.89	1.60	2.80	2.10	500
Hydrocarbon Utilizing Bacteria Count (cfu/ml) $x10^2$	-	4.55	1.43	1.22	100
Total Heterotrophic Fungi Count (cfu/ml) $x10^3$	1.80	1.48	2.40	2.00	500
Hydrocarbon Utilizing Fungi Count (cfu/ml) $x10^2$	-	4.02	1.30	1.19	100

USEPA-United States Environmental Protection Agency
NIS-Nigeria Industrial Standard

Table 1 indicates that the AGO was less acidic, but the acidity increased with the mixture of water. However, as the contaminated water flowed through the 500µm activated carbon, the effluent became less acidic. The effluent from the 250µm activated carbon had the same pH (5.80) with that of the original contaminated water, thus indicating that the 250µm activated carbon had no effect on pH. The PAH in all the samples was less than 0.001 mg/l, thus indicating a lower risk. PAH of 1 mg/l and above can seriously affect human organic system.

The table also shows a drastic reduction of TPH by activated carbon. The reduction of TPH by the 250µm and 500µm activated carbon were almost 100%. This is in agreement with the findings of Johnson and Hallberg, (2005). The same level of reduction also occurred for THC. Comparing the two sizes of activated carbon, the result indicated a better performance by the 500µm activated carbon due to its pore size, and hence larger surface area. Ayotamuno et al. (2006), also posit that the adsorptive property of activated carbon is influenced by factors such as particle size distribution, concentration of the adsorbent, surface area and contact time.

The BTEX in each sample was nil, which indicates that there is no associated health hazard. BTEX is known to have harmful effects on the central nervous system. DRO has a standard of C10-C28 for ASTM. Before treatment, the level of DRO in the water and AGO mixture was C8-C35. However, treatment with activated carbon reduced the level of DRO. Treatment with 250µm activated carbon reduced the DRO content in the sample to C10-C26, while 500µm activated carbon reduced the level of DRO content present in the sample to C9-C24. The also result indicated a better performance by the 500µm activated carbon, which agrees with the findings of Johnson and Hallberg, (2005).

Table1futher indicates that using 250 µm and 500 µm activated carbon increased THB in the effluent by 75% and 31.3% respectively. There was however a reduction in HUB. The 250µm and 500µm activated carbon reduced HUB by 68.6% and 73.2% respectively. In the case of total heterotrophic fungi count, the 250µm activated carbon increased this parameter by 62.2%, while there was an increase of 35.1% caused by the 500µm activated carbon. Furthermore, hydrocarbon utilizing fungi count was reduced by 67.7% and 70.4%

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as the effluent passed through the 250µm and 500µm activated carbon respectively.

Conclusion and recommendation

Conclusion

The following conclusions are drawn from the study:

1. Activated carbon is capable of reducing TPH and THC in automotive gas oil contaminated water by almost 100%.
2. Different sizes of activated carbon have different capacities for purification. 500µm activated carbon, for example, performed better than the 250µm activated carbon because of the difference in pore sizes, and surface areas.

Recommendation

1. The fixed bed can still be optimized to obtain a more efficient and effective process. This can be achieved by using numerical software packages that runs a finite element analysis on the fixed bed, which will in turn help to detect the internal stresses in the fixed bed, areas that need reinforcements and areas that are safe.

2. The performance of the fixed bed can also be optimized effectively through the use of response surface approach so as to obtain a governing model for the activated carbon.

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