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Determination of Adsorption of Diesel onto a Poultry Waste: Chicken Feather

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ABSTRACT

Chicken feather is a poultry waste. With the recent development of waste management strategy viz; waste recycle, re-use and waste reduction etc., chicken feather has been put to various uses such as in the production of animal feed, organic fertilizer, biodegradable plastic and others. It has been mentioned in some text/resource that chicken feather can be used to mop oil spill. However, there is scarce literature on the mopping account of hydrocarbon oil by chicken feather. This led to the study. In this study the equilibrium adsorption capacity (q_e) of diesel onto chicken feather, the amount of adsorbed diesel recovered from chicken feather and the amount of diesel retained by chicken feather was determined by simple kinetic studies and compared with that of a conventional synthetic sorbent used in mopping oil spill in the oil industry. This conventional synthetic sorbent served as standard. Both sorbents were compared under the same experimental condition and the experiment was carried out at room temperature 29^0C. Linearized adsorption isotherms of Langmuir, Freundlich, Elovich, Temkin and Dubinin-Radushkevich were used to verify the adsorption process of both sorbents. The result of the study shows that the equilibrium adsorption capacity (q_e) of diesel onto chicken feather is 11.04g/g, the time required to attain equilibrium adsorption is 80 minutes, while that of the standard is 10.20g/g at 60 minutes. This shows that chicken feather has a higher adsorption capacity. The best fitting isotherm for the adsorption process of both sorbents is the linearized form Ce/qe versus Ce of the Langmuir adsorption isotherm with coefficient of determination (r^2) of 0.999 for both sorbents (chicken feather and standard). The validity of Langmuir model was check by calculating the average percentage error (APE %). The APE values obtained for chicken feather and standard are 0.0024 and 0.005 respectively. The low APE values show that Langmuir model is valid in describing the experimental data. This indicates that, one molecule of diesel is adsorbed on a layer of ground chicken feather/synthetic and there is no interaction between the adsorbed molecules of diesel.The constants of Langmuir isotherm; maximum adsorption capacity (q_m) and intensity of adsorption/affinity constant (b) for chicken feather are 11.49g/g and 1.00 while for the standard they are 10.20g/g and 1.00 respectively. The b and q_m values indicates that both sorbents have same affinity for diesel however, chicken feather has a larger surface area than standard and therefore adsorbs more diesel than standard. The favourable nature of the adsorption process of both sorbents was confirmed from the values of dimensionless separation factor equilibrium parameter K_R. The K_R values for both sorbents are 0.0022. The value shows that the adsorption process is favourable. About 10.00g/g and 8.00g/g of the adsorbed diesel can be recovered from ground chicken feather and conventional synthetic sorbent, while, 1g/g and2 g/g of the adsorbed diesel can be retained respectively. This make chicken feather a better sorbent when diesel recovery is required. To determine the mopping profile of diesel on water by chicken feather and synthetic sorbent, the experiment was repeated with mixture of dieselon water. The amount of water adsorbed together with diesel on water was negligible; 0.08dm^3 adsorbed onto synthetic and 0.05 dm^3 adsorbedonto chicken feather, which means that both sorbents can be used to mop diesel spill on land and water. The result of the study shows that chicken feather adsorbed more diesel per unit mass than the conventional synthetic sorbent used as standard in this study. Chicken feather is an efficient natural sorbent that can be used to mop diesel spill on land and water, and it is efficient for diesel recovery.

Keywords: Chicken feather, Conventional synthetic sorbent mat, diesel, equilibrium adsorption capacity and adsorption isotherm.

1. INTRODUCTION

Poultry waste includes a mixture of faecal and urinary excreta (manure), bedding material or litter (e.g. wood shavings or straw), waste feed, dead birds, broken eggs packing material and feathers removed from poultry houses[1]. Chicken feather and all feathers are organic materials, mainly composed of 91% protein (keratin)[1-2]. They are converted to feather meal with usage as animal feed, organic fertilizers and feed supplements[1]. They are also used in making biodegradable plastic, technical textiles E.T.C.

There are steps usually taken to clean-up an oil spill. The first is that effort is made to confine the floating oil, i.e. to ensure that it does not spread to other areas. In the confined state, it is then easier to pick up the oil. Oil can be removed from a spill site by means of skimmers, sorbents, gelling agents, dispersants, and microorganisms' E.T.C. Sorbents are insoluble materials or mixture of materials used to recover liquids through the mechanism of absorption, or adsorption, or both. There are different types of sorbents; natural and synthetic sorbents: Synthetic sorbents include; polyurethane, polystyrene, polyester and urea formaldehyde E.T.C. Natural sorbents can be organic or inorganic. Examples of natural inorganic sorbents include; perlite, talc and vermiculite. Natural organic sorbents are saw dust, straw, bark, peat, corncob powder E.T.C[3].

The assessment or performance of sorbing materials often needs to be compared[4] In order for the comparison of two or more sorbents to be fair, it must be done under the same experimental conditions. By performance of the sorbent is usually meant its uptake (q) of a sorbate. The sorbents can be compared by their respective maximum

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equilibrium adsorption capacity q_m values which are calculated. A good sorbent would feature a high sorption uptake capacity q_m. Also desirable is a high affinity between the sorbent and sorbate. The amount of a sorbate adsorbed onto a sorbent can be obtained using kinetics and adsorption isotherm[5]. The kinetics experiment is done as a function of time. Then by plotting amount adsorbed against time a graph is produced from which the equilibrium adsorption capacity of the sorbent, equilibration time of the adsorption process and the rate of adsorption can be obtained. Adsorption isotherm is defined as a graphical representation showing the relationship between the amount adsorbed by a unit weight of adsorbent and the amount of adsorbate remaining in a test medium at equilibrium, and it shows the distribution of adsorbable solute between the liquid and solid phases at various equilibrium concentrations[4-6]. The three well-known isotherms are Freundlich, Langmuir and BET adsorption isotherms[7]. Adsorption process is usually described through adsorption isotherm. Usually, to obtain experimental data to be fitted into an adsorption model, different initial concentrations of the sorbate and/ or different mass of the sorbent is used during the experiment, so as to produce other values of equilibrium adsorption capacity (q_e) and equilibrium concentration (C_e) at the end of the experiment[4].

The aim of this study is to determine the equilibration adsorption capacity (qe) of diesel onto chicken feather, the quantity of adsorbed diesel that can be recovered from chicken feather and the quantity of diesel retained by chicken feather, compare this values with that of a conventional synthetic sorbent mat (used as standard) determined under the same experimental condition, so as to assess its (chicken feather) efficiency in mopping diesel.

2. MATERIALS AND METHOD

2.1 *Sampling area and sample collections*

The diesel used in this study was obtained from Total filling station located in Asaba, Delta State, Nigeria, while chicken feather was obtained from Hausa market located in Asaba, Delta state, Nigeria. Conventional synthetic sorbent mat used as standard in this study to compare the mopping efficiency of diesel by chicken feather was obtained from Shell Petroleum Development Company, Port Harcourt, Rivers State, Nigeria.

2.2 *Sample Preparation*

The chicken feather was thoroughly washed with detergent, rinsed severally with copious amount of water and sun-dried for two weeks. The feather was ground using a mechanical blender into a fluffy form. The conventional synthetic sorbent which was in form of a matwas cut into smaller dimension.

2.3 *Analysis Of Sample*

The experiment of the adsorption of diesel onto chicken feather/synthetic sorbent mat was carried out in two stages. The first stage of the experiment involves kinetic study of the adsorption process to establish the exposure time necessary for the given sorbents to reach the equilibrium state (equilibration time of the adsorption process) and the equilibrium adsorption capacity (q_e) of the adsorbent. In the second stage of the study performed at the equilibration time obtained from the kinetic study, five different initial concentrations of diesel were used in the experiment to determine the adsorption process of diesel onto ground chicken feather and synthetic sorbent mat. The experimental data; equilibrium adsorption capacity (q_e) and the concentration of diesel at equilibrium (C_e) obtained were fitted into Freundlich, Langmuir, Elovich, Temkin and Dubinin-Radushkevich adsorption model to describe the adsorption process.

2.3 *Kinetic Study Of Adsorption Of Diesel Onto Ground Chicken Feather/Synthetic Sorbent Mat*.

One (1) dm^3 of diesel whose weight had been predetermined was poured into a 2000ml beaker. The weight of the diesel was used as the initial concentration of diesel. Five (5) grams of chicken feather/synthetic sorbent was weighed and added into the diesel in the beaker. The sorbate – sorbent system was left for a contact time. The contact time used in this study are 10,20,30,40,50,60,70,80,90 and 100 minutes intervals. At the end of each contact time, the sorbate (diesel) was carefully (ensuring that no sorbent was decanted along with the sorbate) decanted into another pre-weighed 2000ml beaker. The remaining content (sorbent and some sorbate) in the beaker was passed through Whatman filter paper 185 mm fitted onto a glass funnel. The glass funnel was inserted into the 2000ml beaker containing the previous decanted sorbate. At the end of the filtration, the weight of the 2000ml beaker containing the unadsorbed diesel (decanted and filtered oil) was weighed. The weight of the unadsorbed diesel was obtained by difference in weight. The weight of the unadsorbed diesel was used as the final concentration of diesel.
The amount of diesel adsorbed onto a unit mass of chicken feather/synthetic sorbent was calculated from:

$$q = \frac{C_i - C_f}{M}$$

Where q = the amount of diesel adsorbed onto a unit mass of chicken feather/synthetic sorbent, C_i = initial concentration of diesel in grams (g), C_f = final concentration of diesel in grams, M = mass of sorbent in grams (g).

Or

$$q = \frac{\text{Initial weight of diesel – Final weight of diesel}}{M}$$

At the end of the experiment, graph of amount of diesel adsorbed onto chicken feather/synthetic sorbent mat (q) at different contact time used in the study was plotted. From the graph, the equilibration time of the adsorption process and the equilibrium adsorption capacity (q_e) of diesel were determined for both sorbents.

2.4 ***Recovery of Diesel Adsorbed onto Chicken Feather/Synthetic Sorbent Mat***

Chicken feather/synthetic sorbent retained on the filter paper at each contact time was weighed and the weight noted. The filter paper was folded over the sorbents and subjected to pressing using a carver hydraulic press, Model M, serial No. 12000 – 137, operated at a pressure of 25 tonnes, for five minutes, at 28 ^oC. After pressing, the weight was noted and the weight of diesel recovered was determined by weight difference.

The amount of diesel recovered per unit mass of the sorbents was determined from the expression:

$$q = \frac{\text{Initial weight – Final weight}}{\text{Mass of sorbent}}$$

Average of three (3) determinations was made for the adsorption and recovery and the standard deviation calculated. The experiment was conducted at room temperature 29^{o}C.

The amount of diesel retained per unit mass of the sorbents was obtained from the expression:

q = Quantity of diesel adsorbed per unit mass of sorbent – Quantity of diesel recovered per unit mass of sorbent.

2.5 ***Verification of Adsorption Process of Diesel onto Chicken Feather/Synthetic Sorbent Using Adsorption Isotherm***

The adsorption of diesel onto chicken feather/synthetic sorbent mat, using five different initial concentrations of diesel; 0.5 dm^3 (442g), 0.75 dm^3 (651g), 1.00 dm^3 (866g), 1.25 dm^3 (1110g) and 1.5 dm^3 (1320g) was determined at this stage, using the same procedure and experimental condition as above. The sorbate – sorbent system was left to contact for 80 minutes. Triplicate determination was conducted for each initial concentration, and the average taken.

The experimental data (q_e and C_e) obtained were fitted into Freundlich, Langmuir, Elovich, Temkin and Dubinin-Radushkevich adsorption models.

2.6 ***Determination Of Adsorption And Recovry Of Diesel On Water From Chicken Feather And Synthetic Sorbent Mat***

In order to determine the behavior and mopping ability of chicken feather and synthetic sorbent when diesel spill on water, the experiment was repeated using diesel on water. Four (4) dm^3 of water was poured into a pre-weighed transparent plastic bowl of 10 dm^3 capacity and weighed. The weight of the water was obtained by difference in weight and recorded. Two dm^3 of diesel whose initial weight had been predetermined was added into the water in the bowl. Diesel is immiscible with water; hence it floated on the water. Five grams of chicken feather/synthetic sorbent was weighed and added into the diesel on water. The sorbent – sorbate system was left for a contact time. The contact time was same as used in the kinetic study in above.

It was observed that the chicken feather/synthetic sorbent remained in the diesel (organic) layer. At the end of each contact time, the diesel layer containing the chicken feather/synthetic sorbent was carefully decanted into another pre-weighed transparent bowl. The remaining sorbate (diesel) containing the sorbent, was carefully passed through a filter paper fitted onto a glass funnel which was placed inside the transparent bowl containing the previous decanted diesel. Small amount of diesel which formed the boundary layer between water and diesel were not separated from water during the filtration, because water will be lost. This (diesel) was carefully removed using syringe and added to the diesel in the transparent bowl.

The separated diesel and water were weighed, and their weight obtained by difference. The experiment was conducted at room temperature 29^0 C. Two determinations were performed for each contact time and the average and standard deviation calculated. The amount of diesel adsorbed onto a unit mass of the sorbents at each contact time was calculated, the graph plotted from which the equilibration time of the adsorption process and the equilibrium adsorption capacity (q_e) were determined for both materials.

2.7 ***Ftir Spectroscopic Analysis Of Conventional Synthetic Sorbent Mat***

The name and chemical composition of the synthetic sorbent was not disclosed by the oil company it was obtained from, therefore,the functional groups present in the sorbent were determined by FTIR spectroscopy. The FTIR analysis was carried out using SHIMADZU FTIR-8400S spectrophotometer with a NaCl cell. The sample was ground into fine powder and spread uniformly in between two NaCl based cells. The cells were fixed into the machine and an incident ray of light passed through it. The FTIR spectrophotometer was operated under the following conditions; interferometer: Michelson type with 30^0 incident angle, dynamic alignment, sealed desiccated, optical system: single beam optics, beam splitter: germanium-coated HBr plate, light source: high brightness ceramic, detector: temperature controlled high sensitivity detector (DLATGS detector) , S/N ratio: greater than 20,000: 1 (KRS-5 window), 4cm^{-1} , 1 minute, 2200cm^{-1}, P-P, wavenumber: 7,800cm^{-1}-350cm^{-1} , resolution: 0.85, 1, 2, 4, 8, 16 cm^{-1} , mirror speed: 3 steps; 2.8, 5, 9mm/sec, data sampling: He-Ne laser, sample compartment: W200mm x D230mm X H170mm, temperature: 15-30^{0} , relative humidity: less than 70%.

3. RESULTS AND DISCUSSION

The kinetic study of the adsorption of diesel onto chicken feather and conventional synthetic sorbent mat show that chicken feather has a higher diesel uptake than conventional synthetic sorbent. The amount of diesel adsorbed onto chicken feather at equilibrium (q_e) is 11.04g/g at an equilibration time of 80 minutes, while, that of standard (conventional synthetic sorbent) is 10.20 at an equilibration time of 60 minutes. Tables 1 and 2, and Figure 1 shows these values.

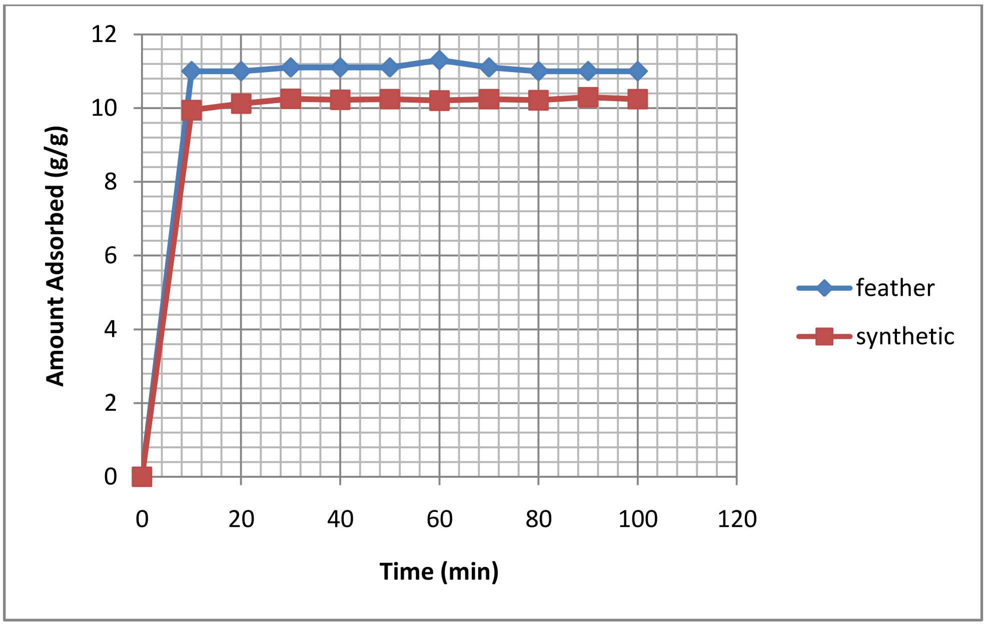

Fig-1: Amount of diesel adsorbed onto chicken feather and synthetic sorbent mat per unit mass against time

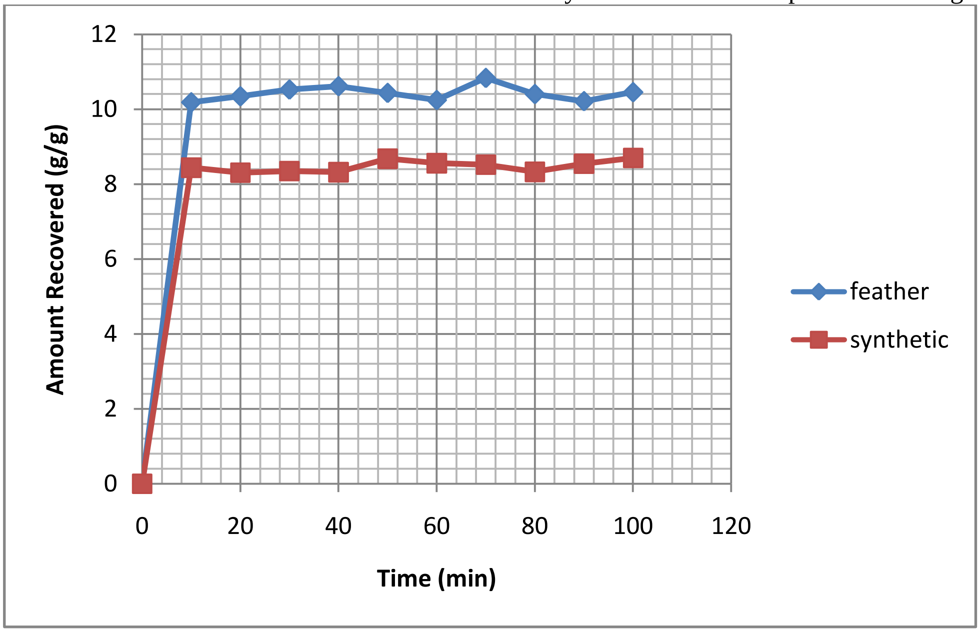

Fig-2 :Amount of diesel recovered from chicken feather and synthetic sorbent mat per unit mass against time.

The experimental data obtained using five different initial concentrations of diesel to verify the adsorption process are shown on tables 3 and 4. The adsorption isotherms applied to the experimental data to describe the adsorption process are Freundlich, Langmuir, Elovich, Temkin and Dubinin-Radushkevich adsorption models. The Freundlich equation can be written as $q_e = K_F C_e^{I/n}$ (8). K_F is a constant indicative of the relative adsorption capacity of the adsorbent (mg $^{I-(I/n)}$ L $^{I/n\ g-I}$ and n is a constant indicative of the intensity of the adsorption. The Freundlich expression is an exponential equation and therefore, assumes that as the adsorbate concentration increases, the concentration of adsorbate on the adsorbent surface also increases. The Freundlich isotherm can be linearized by plotting Log q_e against Log C_e or lnq_e against lnC_e. The Langmuir equation may be written as $q_e = q_m b C_e$

1 + bC$_e$

Where q_e is the amount of solute adsorbed per unit weight of adsorbent at equilibrium (mg /g), C_e the equilibrium concentration of the solute in the bulk solution (mg L^{-1}), $q_m$the maximum adsorption capacity (mg/g), and b is the constant related to the energy of adsorption and temperature, and affinity between the sorbent and sorbate (4,9).

Table-1: Amount of Diesel Adsorbed onto Chicken Feather, Recovered from Chicken Feather and Retained by Chicken Feather.

Amount of diesel adsorbed per unit mass (q) (g/g)	Amount of diesel recovered per unit mass (g/g)	Amount of diesel retained per unit mass (g/g)	Contact time (Min)
11.08 ±0.14	10.18 ±0. 21	0.90	10
11.01 ±1.02	10.34 ±0.67	0.67	20
11.15 ±0.71	10.52±0.64	0.63	30
11.17 ±0.96	10.61 ±0.80	0.56	40
11.18 ±0.27	10.43 ±0.42	0.75	50
11.34 ±1.07	10.24 ±0.78	1.10	60
11.13 ±0.32	10.83 ±1.08	0.30	70
11.04 ±1.01	10.40±0.89	0.64	80
11.08 ±0.91	10.21±0.56	0.87	90
11.06 ±0.97	10.45±0.27	0.61	100

The assumptions made in the derivation of the Langmuir model are that: adsorption is a reversible process, fixed number of adsorption sites, a fraction of the surface sites Θ is occupied by adsorbed molecules, and the fraction 1 – Θ is free, all sorption sites are uniform i.e. constant heat of adsorption, one sorbate molecule reacts with one active site, no interaction between sorbed species (4). The Langmuir isotherm relation is of a hyperbolic form, a plot of q_e versus C_e produces a non linear graph. It can be linearized to five different forms, out of which the forms $1/q_e = 1/bq_m 1/c_e+1/q_m$ (plot $1/q_e$vs.$1/C_e$) and $C_e/q_e= 1/q_mC_e+ 1/q_mb$ (plot $C_e/q_{evs}C_e$) are the most frequently used by several researchers because of the minimized deviations from the fitted equation resulting in the best error distribution. Accordingly, a plot of C_e/q_e against C_e produces a linear graph with slope = 1/ q_m and intercept 1/ $K_aq_m$and a plot of 1/ $q_e$versus $1/C_e$gives a linear graph with slope =1/ K_aq_m and intercept 1/ q_m..

Table-2: Amount of Diesel Adsorbed onto Synthetic Sorbent Mat, Recovered from Synthetic Sorbent Mat and Retained by Synthetic Sorbent Mat**.**

Amount of diesel adsorbed per unit mass (q) (g/g)	Amount of diesel recovered per unit mass (g/g)	Amount of crude oil retained per unit mass (g/g)	Contact time (Min)
9.94 ±1.00	8.44 ±0. 57	1.50	10
10.12 ±0.43	8.31 ±0.48	1.81	20
10.25 ±0.90	8.35±0.83	1.90	30
10.22 ±0.71	8.32 ±0.74	1.90	40
10.24 ±0.56	8.68 ±0.85	1.56	50
10.20 ±0.87	8.56 ±0.71	1.64	60
10.24 ±0.94	8.52 ±0.92	1.72	70
10.21 ±0.66	8.33±0.81	1.88	80
10.29 ±0.69	8.55±0.60	1.74	90
10.24 ±0.87	8.70±0.74	1.54	100

The equation defining the Elovich (10) model is based on a kinetic principle assuming that the adsorption sites increase exponentially with adsorption, which implies a multilayer adsorption. It is expressed by the equation:

$$q_e/q_m = K_E C_E \exp (q_e/q_m)$$

where K_E is the Elovich equilibrium constant (L mg^{-1}) and q_m is the Elovich maximum adsorption capacity (mg^{-1}). If the adsorption obeys Elovich equation, Elovich maximum adsorption capacity and Elovich constant can be calculated from the slopes and the intercepts of the linear plot

$$\ln (q_e/C_e) \text{ versus } q_e.$$

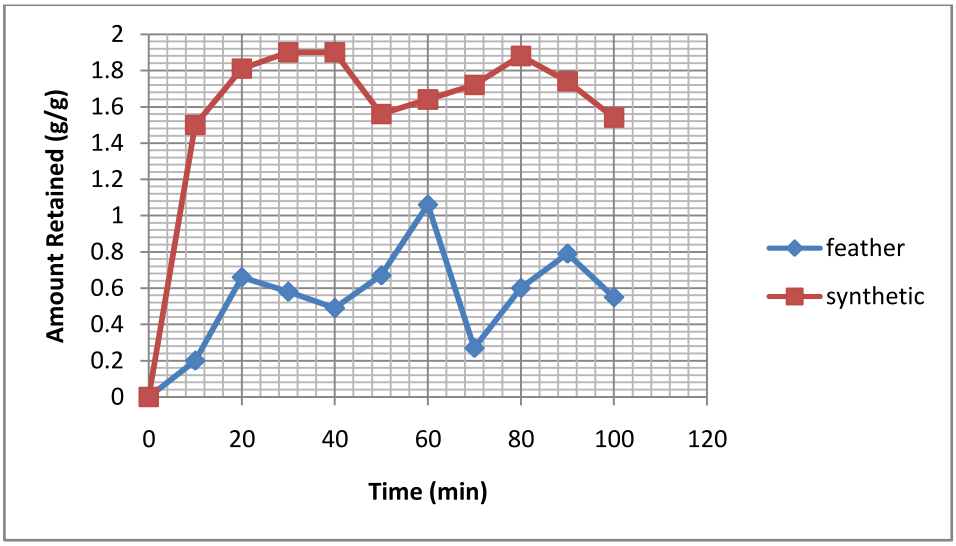

Fig-3: Amount of diesel retained by chicken feather and synthetic sorbent mat per unit mass against time

Table-3: Experimental Data Obtained for the Adsorption of Diesel onto Chicken Feather

Initial concentration(C_O) in volume (dm^3)	**Initial concentration(C_O) in gram (g)**	**Equilibrium concentration (C_e) (g)**	**Equilibrium adsorption capacity (q_e) (g/g)**
0.50	408	352.5	11.10
0.75	615	558.8	11.24
1.00	820	763.5	11.30
1.25	1025	968.6	11.28
1.50	1179.25	1179.25	11.15

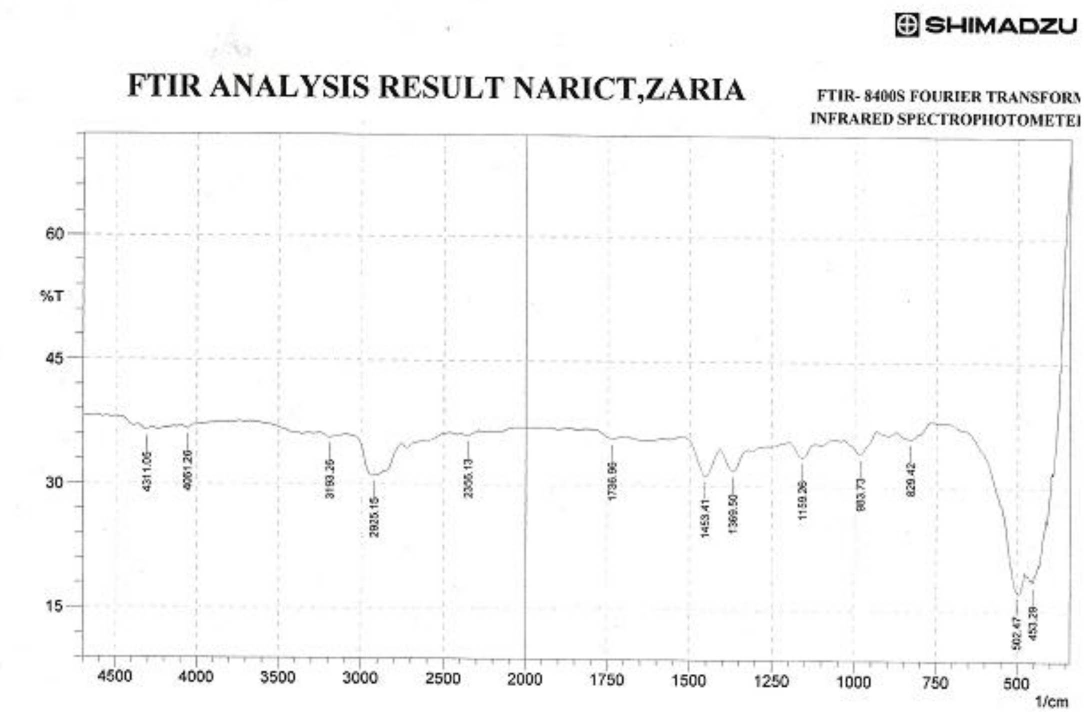

Fig-4: FTIR spectrum of synthetic sorbent mat.

Table-4: Experimental Data Obtained for the Adsorption of Diesel onto Synthetic Sorbent Mat

Initial concentration(C_O) in volume (dm^3)	**Initial concentration(C_O) in gram (g)**	**Equilibrium concentration (C_e) g**	**Equilibrium adsorption capacity (q_e) g/g**
0.50	408	356.5	10.30
0.75	615	563.7	10.26
1.00	820	768.75	10.25
1.25	1025	974.10	10.18
1.50	1235	1183.65	10.27

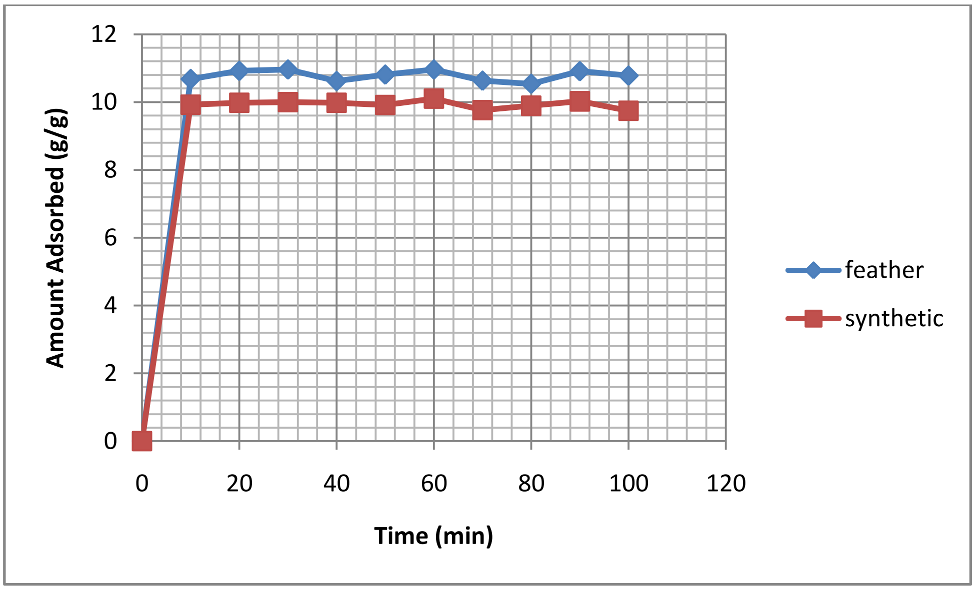

Fig-5: Amount of diesel on water adsorbed onto chicken feather and synthetic sorbent mat per unit mass against time.

Table-5: Data for Plotting Langmuir, Freundlich, Elovich, Temkin and Dubinin-Radushkevich Adsorption Isotherms.

	C_e (g)	q_e (g/g)	$1/q_e$	$1/C_e$	Ce/qe	lnqe/Ce	Log q_e	Log C_e	lnq_e	lnC_e	RT ln (1+1/C_e
Chicken feather	352.50	11.10	0.09	0.0028	31.75	-3.47	1.04	2.54	2.40	5.86	4.70
	558.80	11.24	0.09	0.0017	49.71	-3.91	1.05	2.74	2.41	6.32	3.96
	763.50	11.30	0.09	0.0013	67.56	-4.26	1.05	2.88	2.42	6.63	2.97
	968.60	11.28	0.09	0.00010	85.86	-4.50	1.05	2.98	2.42	6.87	2.22
	1179.25	11.15	0.09	0.0008	105.76	-4.66	1.14	3.07	2.41	7.07	1.73
Synthetic sorbent mat	357.75	10.05	0.09	0.0027	35.59	-3.57	1.00	2.55	2.30	5.87	6.44
	565.75	9.85	0.10	0.0017	57.43	-4.07	0.99	2.75	2.28	6.33	3.96
	769.45	10.11	0.09	0.0012	76.10	-4.34	1.00	2.88	2.31	6.64	2.72
	975.50	9.90	0.10	0.0010	98.53	-4.60	0.99	2.98	2.29	6.88	2.22
	1186	9.80	0.10	0.0008	121.02	-4.82	0.99	3.07	2.28	7.07	1.73

The Temkin (11) isotherm equation assumes that the heat of adsorption of all molecules in the layer decreases linearly with coverage due to adsorbent-adsorbent interactions, and that the adsorption is characterized by a uniform distribution of the binding energies, up to some maximum binding energy. Temkin model is given by

$$q_e = \frac{RT}{b} \ln(A_T C_e)$$

$$q_e = \frac{RT}{b} \ln A_T + (RT/b) \ln C_e$$

$$B = RT/b_T$$

$$q_e = B \ln A_T + B \ln C_e$$

where A_T = Temkin isotherm equilibrium binding constant (L/q)
b_T = Temkin isotherm constant
R = universal gas constant (8.314J/mol)
T = Temperature at 298k
B= Constant related to heat of sorption(J/mol)
From the linear plot q_e against lnC_e the constants can be determined from the slope and intercept.
The Dubinin-Radushkevich isotherm estimates the characteristics porosity of the sorbent and apparent energy of adsorption[12]. The model is represented as:

$$q_e = q_D \exp(-B_D[RT \ln(1+1/C_e)]^2$$

Where, B_D is related to the free energy of sorption per mole of the sorbate as it migrates to the surface of the adsorbent from infinite distance in the solution and q_D is the Dubinin-Radushkevich isotherm constant related to the degree of sorbate sorption by the sorbent surface.
The linear form of equation is given as:

$$\ln q_e = \ln q_D - 2B_D RT \ln(1+1/Ce)$$

The plot of $\ln q_e$ against RT ln $(1+C_e)$ yields straight line. The values of q_D and B_D can be calculated from the intercept and slope. Table 5 shows the values used to plot the adsorption models. Table-7 shows that the linearized form C_e / q_e versus C_e of the Langmuir adsorption isotherm produced the best fitted isotherm for the adsorption of diesel onto chicken feather and synthetic sorbent. This shows that the adsorption obeys the Langmuir model. This implies that the interaction of both sorbents with diesel is monolayer adsorption, that is, one sorbate molecule is adsorbed on a layer of adsorbent. There is no interaction between adsorbed molecules.

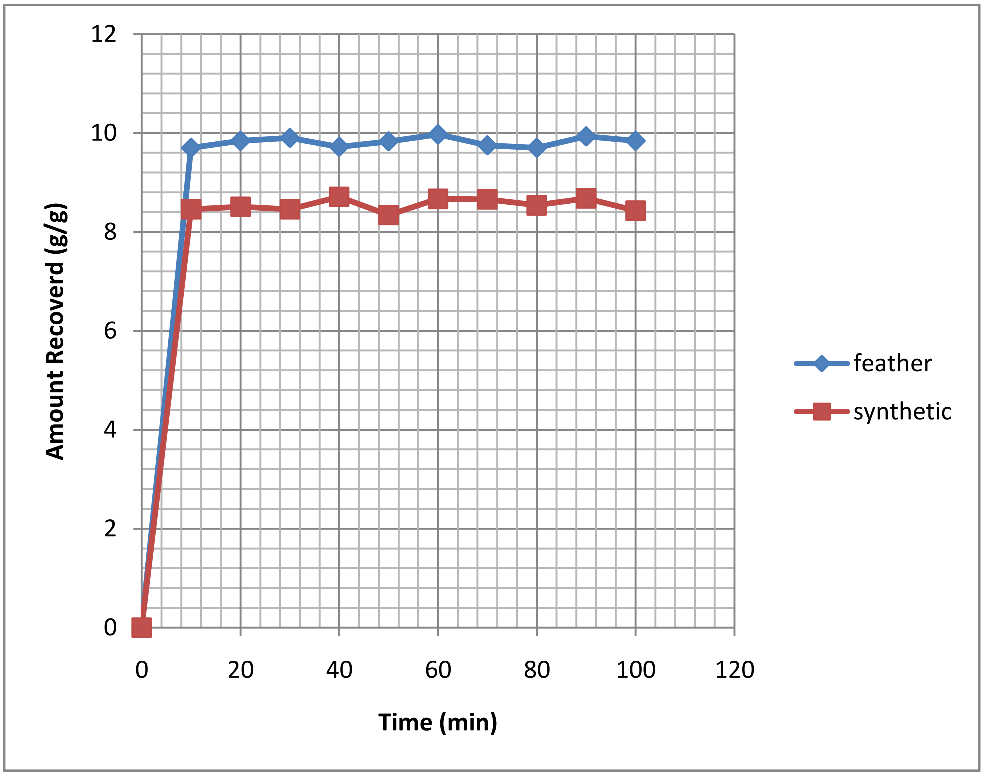

Fig-6: Amount of diesel on water recovered from chicken feather and synthetic sorbent mat per unit mass against time.

Sorbents can be compared by their respective maximum adsorption capacity q_m and b values obtained from the Langmuir equation (4). The maximum adsorption capacity q_m is obtained from the isotherm model while q_e is the equilibrium adsorption capacity obtained from experiment (8). q_m can be interpreted as the total number of binding sites that are available for sorption, and q_e as the number of binding sites that are in fact occupied by the sorbate at the concentration C_e(4). The constant b and q_m are obtained from the slope and interception of the plot and are presented in Table 6. The b values for both chicken feather and synthetic sorbent are 1.00. This implies that both sorbents have same affinity for diesel. The q_m value of 11.49g/g for chicken feather is higher than that of synthetic sorbent, 10.20g/g. This indicates that chicken feather has more total number of binding sites than the synthetic sorbent, which implies that, chicken feather has a larger surface area and higher diesel uptake than the synthetic sorbent. The q_m shows that chicken feather is a better sorbent than the conventional synthetic sorbent mat.

Table-6: Parameters of Langmuir Isotherm for the Adsorption of Crude Oil onto Chicken Feather and Synthetic Sorbent Mat

Isotherm	Ground chicken feather	Synthetic sorbent mat
Langmuir (C_e / q_e versus C_e)		
b ($L\ g^{-1}$)	1.00	1.00
q_m($g\ g^{-1}$)	11.49	10.20
r^2	0.999	0.999
APE (%)	0.024	0.005
K_R	0.0022	0.0022

The coefficient of determination r^2 between the experimental data and isotherms was determined using solver add-in with Microsoft's spreadsheet, Microsoft Excel[13-14]. The results are presented in Table 6 and 7. The r^2 value shows good correlation between experimental data and the linearized form Ce/qe versus Ce of the Langmuir isotherm. This indicates that the adsorption process follows the Langmuir isotherm.

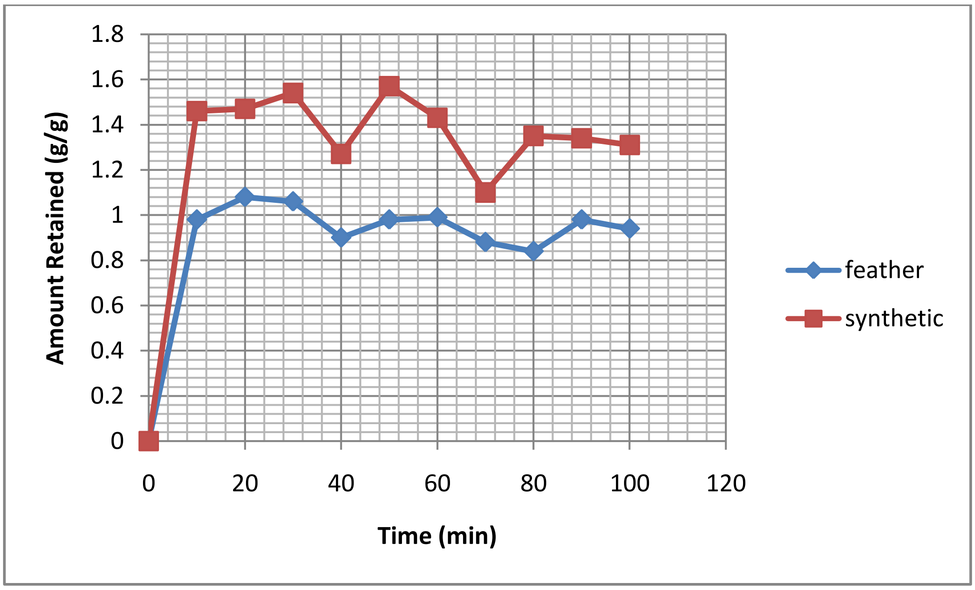

Fig-7: Amount of diesel on water retained by chicken feather and synthetic sorbent mat per unit mass against time.

Table-7: Coefficient of Determination (r^2) Values of Adsorption Isotherms Used in Verification of Adsorption Process of Crude Oil onto Chicken Feather and Synthetic Sorbent.

Isotherm	Ground chicken feather	Synthetic sorbent mat
Langmuir (C_e/q_e versus C_e) r^2	0.999	0.999
Langmuir 1/qe versus 1/Ce r^2	2E-15	0.319
Freundlich Log qe versus Log Ce r^2	0.026	0.344
Freundlichlnqe versus lnCe r^2	0.467	0.065
Elovich lnqe/Ce versus qe r^2	0.187	0.284
Temkin qe versus lnCe r^2	0.169	0.106
Dubinin-Radushkevich lnqe versus RTln(1+1/Ce r^2	0.412	0.079

In order to check the validity of the Langmuir model, it is interesting and essential to recalculate the adsorbed amounts using the equilibrium concentration values and Langmuir parameter $q_{m.}$ to obtain the average percentage errors (APE) according to the equation:

$$\mathbf{APE\ (\%) = \frac{\Sigma^{N}_{i=1}(q_e)_{,exp} - (q_e)_{,cal} / (q_e)}{N} \quad x\ \ 100}$$

The low value of APE obtained for chicken feather and synthetic sorbent (table 6) shows that the Langmuir model can describe the equilibrium data.

The favorable nature of adsorption can be expressed in terms of dimensionless separation factor equilibrium parameter of Hall et al[15] which is defined by the following relationship, $K_R = 1/1 + K_aC_o$, where K_R is a dimensionless separation factor, C_o is initial concentration (mg L^{-1}) and K_a is Langmuir constant (L mg^{-1}). The values of K_R indicates the type of isotherm to be irreversible ($K_R = 0$), favourable ($0<K_R<$), linear ($K_R = 1$) or unfavourable ($K_R>$). The dimensionless separation factors calculated for chicken feather and synthetic sorbent are 0.0022. K_R values were less than 1 and greater than zero indicating favourable adsorption.

The quality of sorbent material is judged not only according to how much sorbate it can attract, but also on how much sorbate it can retain (4). Tables 1 and 2 shows the amount of diesel recovered and retained by chicken feather and synthetic sorbent, the result shows that the synthetic sorbent mat retains more of the adsorbed diesel than chicken feather. In the light of this, chicken feather with a higher diesel uptake is better than the synthetic sorbent mat, however, in terms of retainability, the synthetic sorbent mat is better. Tables 1 and 2 and Figure 2 shows that, substantial amount of the adsorbed/absorbed diesel; about 10.00g and 8.00g was recovered from both chicken feather and the synthetic sorbent respectively, but more of diesel was recovered from chicken feather. Since much diesel was recovered from both sorbents, it means that the sorbate are attracted and held to the sorbent surfaces, including internal fibre walls by physical bonds that becomes easily broken on pressing.

Figure 4 shows the FTIR spectrum of the synthetic sorbent. The prominent peaks are 829.42 cm^{-1} (s) C-H of alkene, 983.73 cm^{-1} (s) C-H of alkene, 1159.26 cm^{-1} , (s) C-C of alkane, 1369.50 cm^{-1} (s) C-H of alkane , 1453.41 cm^{-}1(s) C-H of alkane, 2925.15 cm^{-1}(s) C-H of alkane . These suggest that the synthetic sorbent mat is a polyhydrocarbon.

Table-8: Amount of Diesel on Water Adsorbed onto Chicken Feather, Recovered from Chicken Feather and Retained by Chicken Feather

Amount of diesel on water adsorbed per unit mass (q) (g/g)	Amount of diesel on water recovered per unit mass (g/g)	Amount of diesel on water retained per unit mass (g/g)	Contact time (Min)
10.68 ±0.20	9.70 ±0. 88	0.98	10
10.92 ±0.57	9.84 ±0.90	1.08	20
10.96 ±0.77	9.90±0.45	1.06	30
10.62 ±0.64	9.72 ±1.07	0.90	40
10.81 ±1.11	9.83 ±1.00	0.98	50
10.96 ±0.85	9.97 ±0.94	0.99	60
10.63±1.09	9.75 ±079	0.88	70
10.54 ±0.91	9.70±0.47	0.84	80
10.91 ±0.78	9.93±0.91	0.98	90
10.78 ±1.00	9.84±1.10	0.94	100

Chicken feather and all feathers are mainly composed of 91% protein (keratin) (1). Keratins are long chains of amino acids. Based on the side chain of an amino acid, it can be classified as hydrophobic, polar or charged . The side chains of the hydrophobic amino acids are nonpolar; mainly hydrocarbon. The polar amino acids side chains are hydrocarbons containing atom(s) that can form hydrogen bond. The side chain of the charged amino acids contains hydrocarbons carrying negative or positive charges[16]. Sorption results from a variety of different types of attractive forces between the sorbate and sorbent[17-18]. Organic sorbates chemically bond to the sorbent, if the sorbate and sorbent have mutually reactive moieties. Also, the extent of intermolecular attraction depends on molecular chain length and on surface area.

Table-9: Amount of Diesel on Water Adsorbed onto Synthetic Sorbent mat, Recovered from Chicken Feather and Retained by Chicken Feather**.**

Amount of diesel on water adsorbed per unit mass (q) (g/g)	Amount of diesel on water recovered per unit mass (g/g)	Amount of diesel on water retained per unit mass (g/g)	Contact time (Min)
9.92 ±0.72	8.46 ±0. 94	1.46	10
9.98±0.29	8.51 ±0.81	1.47	20
10.00 ±0.63	8.46±0.80	1.54	30
9.98 ±0.48	8.71 ±0.72	1.27	40
9.91 ±0.74	8.34 ±1.12	1.57	50
10.10 ±1.00	8.67 ±1.01	1.43	60
9.76 ±0.67	8.66±1.00	1.10	70
9.89 ±0.90	8.54±0.97	1.35	80
10.02 ±0.93	8.68±1.06	1.34	90
9.74 ±1.04	8.43±1.00	1.31	100

The synthetic sorbent mat and diesel are composed mainly of hydrocarbons, in order words they have mutual reactive moieties, attracting each other by Van der Waal forces, London forces and other dispersion forces. This explains why the much diesel adsorption/absorption by the synthetic sorbent. The amino acid content of feather is highly hydrophobic; containing side chains that are mainly hydrocarbon[19]. This hydrocarbon side chains accounts for the intermolecular bonds formed between chicken feather and diesel, leading to the sorption of the diesel on feather. Also, the β conformation of feather makes it have large surface area, a look under a microscope shows that there are lot of empty space in quill, shaft, rami and barbules of feather[20]. The large surface area makes it possible for the trapping, entanglement and occlusion of diesel within the feather void.

Another quality attributed to an ideal sorbent is that it should be oleophilic (oil attracting) and hydrophobic (water repelling)[21].Tables 8 and 9 shows that the amount of diesel on water adsorbed, recovered and retained by chicken feather and synthetic sorbent mat compares closely with that obtained with the experiment involving diesel only. During the experiment, the difference in volume between the initial volume of water added to transparent bowl, and final volume of water after experiment are 0.08 dm^3 and 0.05 dm^3 for synthetic sorbent and ground chicken feather respectively. This suggests the amount of water sorbed by both sorbents is negligible. This is not surprising because the amino acid content of feather is hydrophobic[1-19]. The synthetic sorbent mat been a polyhydrocarbon is also hydrophobic. Therefore both sorbents can be conveniently used in mopping diesel on water.

4. CONCLUSION

The equilibrium adsorption capacity (q_e) of diesel onto chicken feather is 11.04g/g, the time required to attain equilibrium adsorption is 80 minutes, while that of the standard is 10.20g/g at 60 minutes. This shows that chicken feather has a higher adsorption capacity. The best fitting isotherm for the adsorption process of both sorbents is the linearized form Ce/qe versus Ce of the Langmuir adsorption isotherm with coefficient of determination (r^2) of 0.999 for both sorbents (chicken feather and standard). The low APE values show that Langmuir model is valid in describing the experimental data. This indicates that, one molecule of diesel is adsorbed on a layer of chicken feather/synthetic and there is no interaction between the adsorbed molecules of diesel. The constants of Langmuir isotherm; maximum adsorption capacity (q_m) and intensity of adsorption/affinity constant (b) indicate that both sorbents have same affinity for diesel however, chicken feather has a larger surface area than standard and therefore adsorbs more diesel than standard. The K_R value for chicken feather and synthetic sorbent shows that the adsorption process is favourable. About 10.00g/g and 8.00g/g of the adsorbed oil can be recovered from ground chicken feather and conventional synthetic sorbent, while, 1g/g and 2 g/g of the adsorbed oil can be retained respectively. This make chicken feather a better sorbent when diesel oil recovery is required. The amount of water adsorbed together with diesel on water was negligible, which means that both sorbents can be used to mop diesel spill on land and water. The result of the study shows that chicken feather adsorbed more diesel per unit mass than the conventional synthetic sorbent used as standard in this study. Chicken feather is an efficient natural sorbent that can be used to mop diesel spill on land and water.

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