Correlation of the equilibrium sorption of crude oil by expanded perlite using different adsorption isotherms at 298.15 k

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Abstract
In this work the recently published experimental data on the sorption capacity of expanded perlite to crude oil were correlated with the equilibrium isotherm of Langmuir, Freudlich, Tempkin and the three parameter Redlich-Peterson isotherms. The results obtained from each specified isotherms were compared and accuracy of the models were favorably discussed. Accuracy of each model was obtaining function. The effect of type of objective function on the final results was investigated. To bring up the idea the ERAV, ERRSQ, HYBRID, MPSD and Chi-Square objective function were used and the accuracy obtained using each objective function. The results showed the Redlich-Peterson model can better represent the equilibrium isotherm data for the crude oil to be up taken on the expanded perlite.

Keyword: Expanded perlite, Sorption capacity, adsorption isotherms

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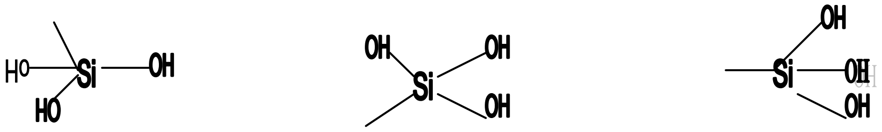
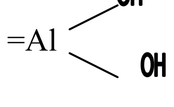
Introduction
Sorption techniques produce high-quality treated effluents and sorption processes have been investigated as method of removing crude oil from seawater [1]. Exfoliated graphite and activated carbon are high effective for the removal of spill oil from seawater [2]. However, the use of exfoliated graphite and activated carbon may not be suitable in developing countries because of its high cost. Thus, it is more suitable to use adsorbents such as clay minerals, peat and wood powder [3-5]
Among them clay minerals such as perlite has received great deal of attention. Perlite has a low density, high surface area, and a low thermal conductivity. Also since most perlite samples have high silica content (usually greater than 70%), they are high privileged with adsorptive characteristics [6]. The adsorptive character of perlite is due to the silanol groups, which are formed by silicon atoms on the surface of perlite [7]. The types of silanol groups are shown as follows:



The hydrous oxide surface groups in alumina are given as follows (Bilal.Acemioglu, 2004).

$\equiv Al - OH$ Or



The silicone atoms at the surface tend to maintain their tetrahedral coordination with oxygen. They complete their coordination at room temperature by attachment to monovalent hydroxyl groups, forming silanol groups. The surface of perlite becomes more negatively or positively charged according to the pH of the medium. This situation affects sorption capacity.

Also expanded perlite is an inert chemical that can be used as excellent filter aid and as filler in various processes and materials [8].

Theory

The successful representation of the dynamic adsorptive separation of solute from solution onto an adsorbent depends upon a good description of the equilibrium separation between the two phases. Adsorption equilibrium is the amount of solute being adsorbed onto the adsorbent is equal to the mount being desorbed. At this point, the equilibrium solution concentration remains constant. By plotting solid phase concentration against liquid phase concentration graphically it is possible to depict the equilibrium adsorption isotherm. There are many theories relating to adsorption equilibrium.

Langmuir isotherm

$$q_e = \frac{K_L C_e}{1 + a_L C_e} \tag{1}$$

The Langmuir constant, K_L and a_L are evaluated of the linearization of Eq.1. The linear expression takes the following form:

$$\frac{C_e}{q_e} = \frac{1}{K_L} + \frac{a_L C_e}{K_L} \tag{2}$$

Hence by plotting C_e/q_e against C_e it is possible to obtain the value of K_L from the intercept that is $(1/K_L)$ and the value of a_L from the slope, which is (a_L/K_L).

Freundlich isotherm

$$qe = K_F C_e^{b_f} \tag{3}$$

In this equation K_F and b_f are the Freundlich constants.

Redlich - Petertson isotherm

$$qe = \frac{K_R C_e}{1 + a_R C_e^{\beta}} \tag{4}$$

This equation reduces to a linear isotherm at low surface coverage

$$\frac{C_e}{q_e} = \frac{1}{K_R} + \frac{a_R}{K_R} C_e^{\beta} \tag{5}$$

Plotting C_e/q_e against C_e^{β} yields a straight line with slope= $\frac{a_R}{K_R}$ and intercept $= \frac{1}{K_R}$.

Tempkin isotherm

$$qe = \left(\frac{RT}{b}\right) \ln AC_e \tag{6}$$

Eq. (6) can be expressed in its linear form as:

$$q_e = B \ln A + B \ln C_e \tag{7}$$

With

$$B = \frac{RT}{b} \tag{8}$$

Conclusion

The equilibrium adsorption of two-type crude oil by expanded perlite has been reported. The results revealed the potential of the expanded perlite is suitable to be a low-cost sorbent for clean-up crude oil. The equilibrium results have been modeled and evaluated using four different isotherms and five different error functions including a linear transform model. The results showed that the equilibrium data for all the crude oil–sorbent systems fitted the Redlich-Peterson and Freundlich isotherms model best. The linear transform model provided highest correlation coefficient for the case of the Redlich-Peterson isotherm (R^2=0.999). The R^2 for Langmuir isotherm is 0.9132 troughs 0.93561. And the sum of square of the average squares of the errors (ERAV) equal 2.36451 for Langmuir isotherm. The Langmuir isotherm theory assumes monolayer coverage of adsorbate over a homogenous adsorbent surface. Using of the error functions for optimization showed that often the isotherms were generally better represented using the ERRSQ, HYBRID and Chi-Square errors function.

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Table 1. Langmuir isotherm constants a_L and K_L and errors function

Oil Type	a_L	K_L	R^2	Chi-Square
I. O. L	6.584*10^{-2}	0.42311	0. 9132	9.2314*10^{-1}
M. As	7.248*10-2	0.4756	0.9356	1.152*10^{-1}
Oil Type	ERAV	ERRSQ	HYBRID	MPSD
I O.L	2.3645	0.7860075	1.073953	10.36317
M. As	2.5463	0.82314	1.15243	11.4567

Table 2. Freundlich isotherm constants K_f and b_f and errors function

Oil Type	K_F	b_f	R^2	Chi-Square
I. O. L	2.531	0.23278	0.989	5.8513*10^{-2}
M. As	2.7846	0.2506	0.988	6.54*10^{-2}
Oil Type	ERAV	ERRSQ	HYBRID	MPSD
I. O. L	0.928562	1.081*10^{-2}	6.5227*10^{-3}	0.8078
M. As	0.98251	1.15*10^{-2}	8.754*10^{-3}	0.9423

Table 3.Redlich-Peterson isotherm constants K_R, a_R, β, R^2 and errors function

Oil Type	K_R	a_R	β	R^2	Chi-Square
I .O.L	5.190622	1.90345	0.78	0.999	$1.025*10^{-2}$
M. As.	5.092	2.0452	0.79	0.999	$4.32*10^{-2}$
Oil Type	ERAV	ERRSQ	HYBRID	MPSD	
I.O. L	0.1927	$9.445*10^{-3}$	$1.132*10^{-3}$	0.7254	
M. As	0.2841	$7.458*10^{-3}$	$7.674*10^{-3}$	0.9843	

Table 4.Tempkin isotherm constants A, B, R^2 and errors function

Oil Type	A	B	R^2	Chi-Square
I.O.L	12	0.6678	0.98	$4.2664*10^{-2}$
M .As	14	0.7845	0.974	$4.537*10^{-2}$
Oil Type	ERAV	ERRSQ	HYBRID	MPSD
I.O.L	0.3105	$8.3224*10^{-2}$	$1.410318*10^{-1}$	3.7554
M.As	0.98251	$2.5*10^{-2}$	$9.724*10^{-2}$	4.658

Captions for figures

Figure 1 langmuir isotherm and model data; ▲ Medium Asian, ♦ Iranian Oil light, □ Model data

Figure 2 Redlich- Peterson isotherm and Model data; ▲ Medium Asian, ♦ Iranian Oil light, □ Model data

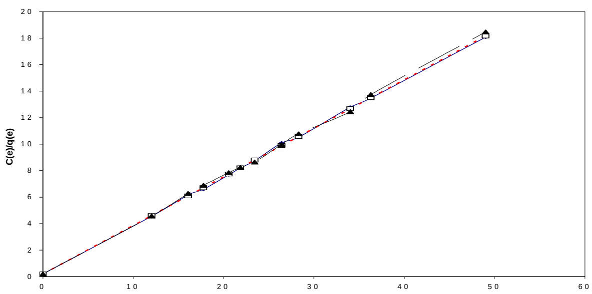

Fig. 4

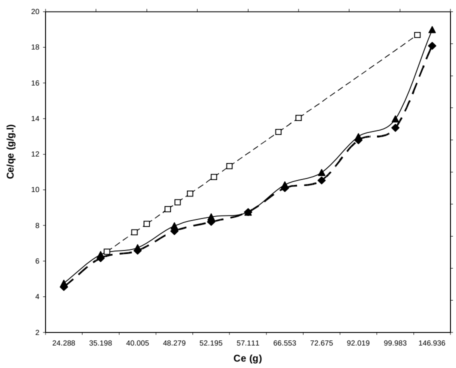

Fig.1