Equilibrium Study of Single component Adsorption from Waste Effluent on Bentonite Clay

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The objective:

-is to use Saudi bentonite clay in removing copper and nickel ions from wastewater under different temperature regimes.

-The thermodynamic parameters are calculated for the adsorption of copper and nickel on bentonite clay.

-isotherm models are developed by using MATLAB and tested to specify the appropriate model that can describe the experimental data well.

characterization and analysis:

Characteristic properties of bentonite clay

Characteristics	Values
BET surface area	62.5671 m^2/g
Pore volume (p/po=0.97)	0.098005 cm^3/g
Average pore width	62.656 Å
Average pore diameter	95.650 Å

Chemical analysis of bentonite clay by XRF

Composition	Content (wt. %)
SiO_2	58.0
Al_2O_3	20.0
TiO2	1.25
Fe_2O_3	5.17
MgO	1.85
CaO	2.00
Na_2O	2.00
K_2O	1.00
P_2O_5	0.20
Mn_2O_3	0.02
LOI	8.51

The results from the XRD verify the attendance of Kaolinite (9 %), montmorillonite (82%), quartz and illite (9 %) in natural bentonite clay.

Results and Discussion:

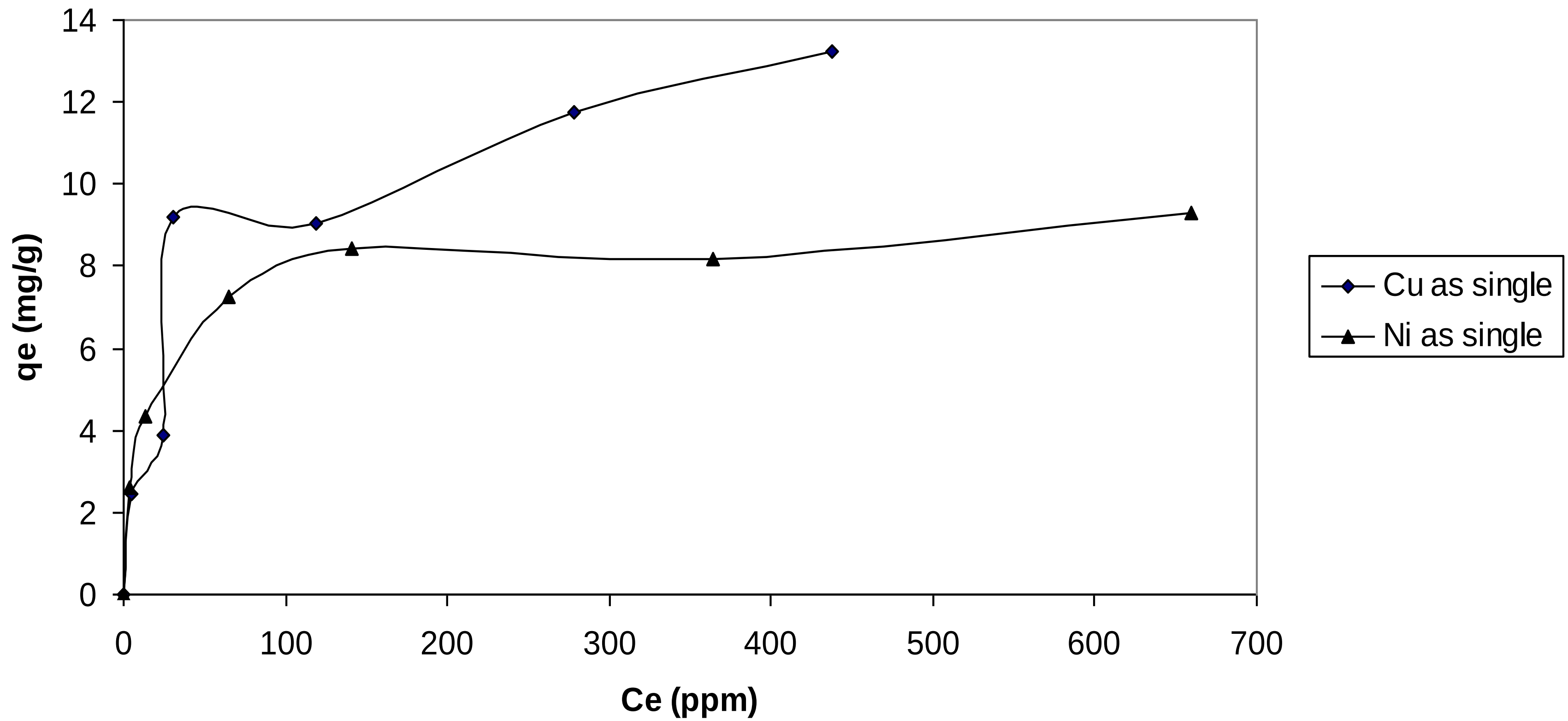

Fig.1. Equilibrium isotherm for adsorption of copper and nickel in waste water on bentonite clay at a room temperature (20 ^{o}C)

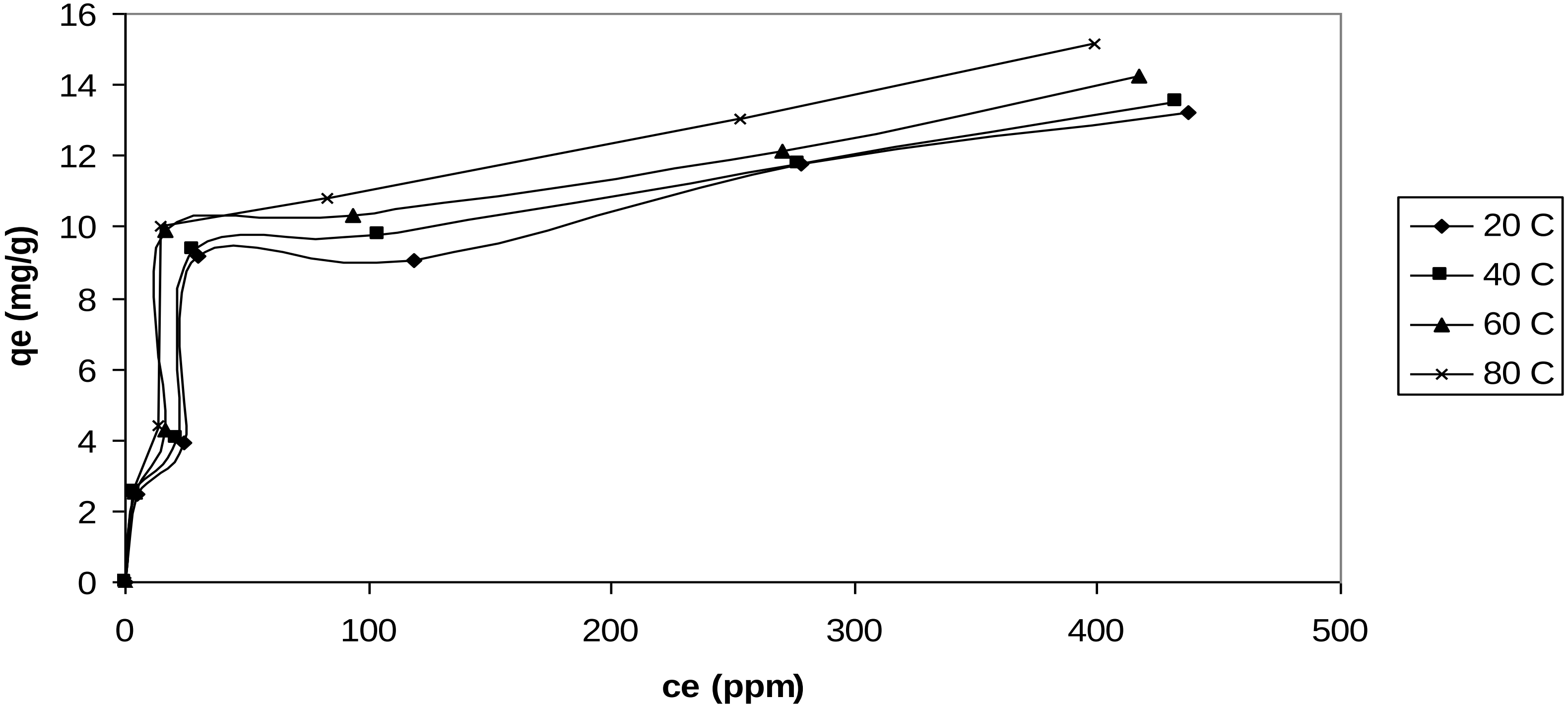

Fig.2. Equilibrium isotherm for adsorption of copper in waste water on bentonite clay at different temperature levels

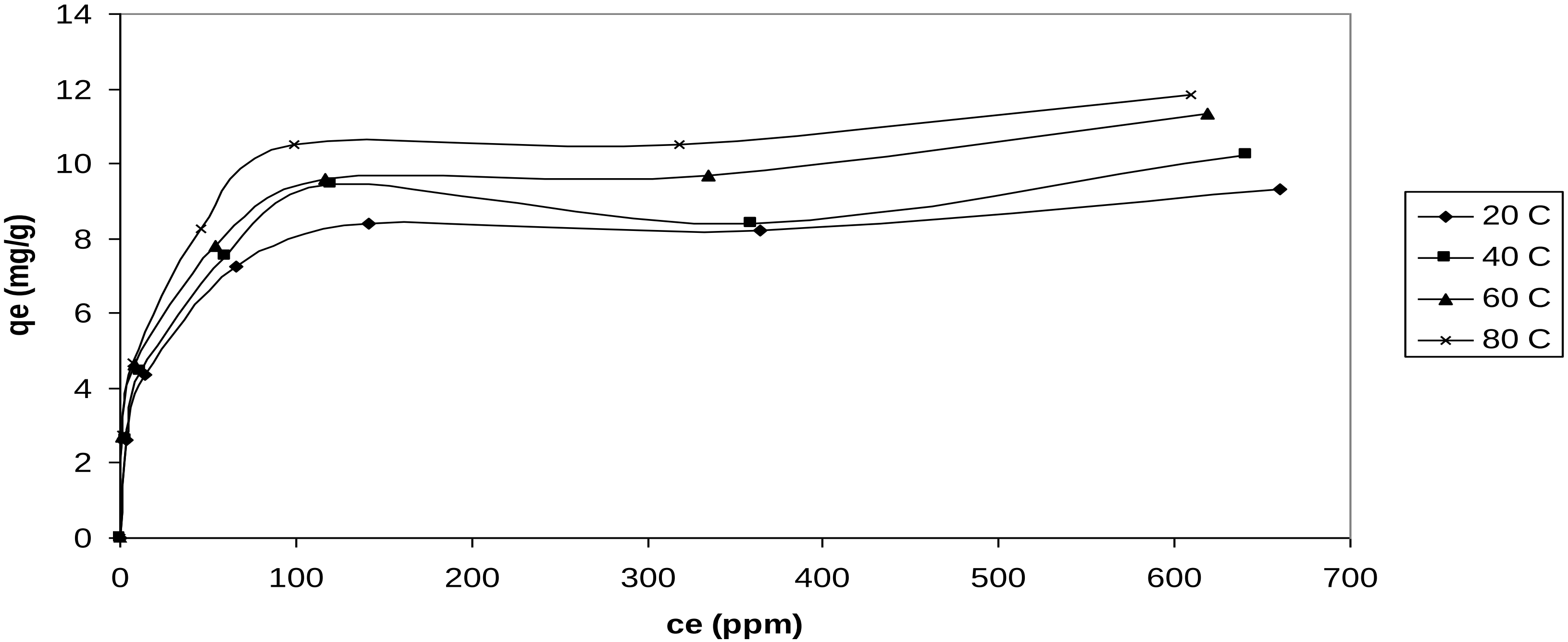

Fig.3. Equilibrium isotherm for adsorption of nickel in waste water on bentonite clay at different temperature levels

Thermodynamic parameters calculations

The enthalpy change:

$$\ln K = \ln k_o + \left(\frac{-\Delta H}{R T} \right)$$

a plot of ln *K* versus [1/T] provides the enthalpy change

The standard Gibbs free energy change:

$$\Delta G = -R T \ln K$$

The entropy change:

$$\Delta S = \left(\frac{\Delta H - \Delta G}{T} \right)$$

Thermodynamic parameters for nickel ions adsorption on bentonite clay

T (K)	K	1/T (1/k)	ln K	ΔH (KJ/mol)	ΔS [KJ/(mol. K)]	ΔG (KJ/mol)
293	0.2817	0.003413	-1.26691	4.8	0.005849	3.086202
313	0.3185	0.003195	-1.14413	4.8	0.005823	2.977356
333	0.3662	0.003003	-1.00458	4.8	0.006062	2.78123
353	0.3895	0.002833	-0.94289	4.8	0.005759	2.767237

Thermodynamic parameters for copper ions adsorption on bentonite clay

T (K)	K	1/T (1/k)	ln K	ΔH (KJ/mol)	ΔS [KJ/(mol. K)]	ΔG (KJ/mol)
293	0.604	0.003413	-0.50418	3.3	0.007071	1.228186
313	0.625	0.003195	-0.47	3.3	0.006636	1.223082
333	0.683	0.003003	-0.38126	3.3	0.00674	1.055543
353	0.7603	0.002833	-0.27404	3.3	0.00707	0.804271

- **the value of the enthalpy is positive value, that means, the adsorption is endothermic.**

- **with the increase of temperature, the values of standard Gibbs free energy decreases which mean that the adsorption system is favorable at high temperature levels**

- **The value of the entropy is positive values, that mean, the system becomes more random at the interface of the clay - metal ions solution during the adsorption of metal ions on clay**

Equilibrium isotherm models:

-Langmuir isotherm model:

$$q_e = \frac{KC_e}{1+bC_e}$$

-Freundlich isotherm model:

$$q_e = K_F \, C_e^{1/n}$$

Langmuir constants for the copper ions adsorption on clay at different temperature levels

Temperature (°C)	K (lit/g)	b (lit/mg)	AARD%	R^2	X^2
20	0.4523	0.0345	21.1	0.85	2.1
40	0.5454	0.0410	21.1952	0.8726	1.9561
60	0.8620	0.0642	19.3241	0.8233	2.4491
80	0.9595	0.0670	19.0508	0.8401	2.5219

Langmuir constants for the nickel ions adsorption on clay at different temperature levels

Temperature (°C)	K (lit/g)	b (lit/mg)	AARD	R^2	X^2
20	0.7115	0.0795	7.4121	0.9723	0.2305
40	0.7614	0.0785	9.5839	0.9451	0.3764
60	1.0851	0.1047	13.9189	0.9168	1.8816
80	1.1273	0.1004	15.8607	0.9184	4.1407

Freundlich constants for the copper ions adsorption on clay at different temperature levels

Temperature (°C)	K_F (lit/g)	n (-)	AARD	R^2	X^2
20	2.2562	3.4069	21.5317	0.8460	2.4640
40	2.6020	3.6494	22.3778	0.8542	2.2963
60	3.1373	3.9903	26.9225	0.8060	3.3718
80	3.2829	3.9035	27.4265	0.8279	3.4146

Freundlich constants for the nickel ions adsorption on clay at different temperature levels

Temperature (°C)	K_F (lit/g)	n (-)	AARD	R^2	X^2
20	2.8144	5.2111	14.0714	0.8867	0.6928
40	2.9932	5.1245	17.0047	0.8429	1.1001
60	3.2857	5.0815	10.7900	0.9444	0.4637
80	3.6860	5.2668	13.0772	0.9229	0.7146

Conclusions:

1- The adsorption capacity of clay increase with temperature. In addition, the maximum capacity was 13.22 mg/g at 20 ^{o}C for copper, while, the maximum capacity was 9.29 mg/g at 20 ^{o}C for nickel.

2-Several isotherm models were used to describe the experimental data and to obtain the constant parameters. It was found that, Frundlich isotherm model correlated the experimental data well.

Thank you