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Removal of Heavy Metals (Pb²⁺, Zn²⁺, Cu²⁺, Hg²⁺, Co²⁺, Cr²⁺ and Cd²⁺) From Water by Trimethyl Phenyl Ammonium Cation (TMPA⁺) Based Organoclay: Experimental and Statistical TestKelechi E. Onwuka^{1*}, Okechukwu C. Atasi², Solomon E.O. Okereke¹, Nnamdi E. Enenwa¹ and Godwin I. Ogbuehi¹

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Abstract

In this study, trimethyl phenyl ammonium cation (TMPA⁺) intercalated bentonite was used as an adsorbent for adsorptive removal of seven heavy metal ions namely: Pb (II), Zn (II), Cu (II), Hg (II), Cr (II), Co (II) and Cd (II) in aqueous solution via batch adsorption process. The developed adsorbent, ab initio has been characterized by scanning electron microscopy (SEM), X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR). The operational parameters evaluated on the adsorption efficiency were solution pH, initial metal ions concentration, temperature, adsorbent dosage, and contact time. The adsorption of Pb (II), Zn (II), Cu (II), Hg (II), Cr (II), Co (II) and Cd (II) ions were found to have attained equilibrium positions in 120 min for the concentration range tested, respectively. Two generally applied linearized adsorption isotherm models; Langmuir and Freundlich tested, when compared, revealed that Langmuir isotherm fitted well to the experimental data judging from the higher correlation coefficient values (R²) and lower values of the error functions (chi-square (χ²), the sum of square error (ERRSQ/SSE) and the sum of absolute error (EABS)) with monolayer adsorption capacities of 17.66, 21.12, 14.64, 14.98, 16.60, 13.81 and 15.50 mg/g for Pb (II), Zn (II), Cu (II), Hg (II), Cr (II), Co (II) and Cd (II) ions, respectively. Adsorption kinetic models investigated by pseudo-first-order and pseudo-second-order showed the conformity of pseudo-second-order model to the process of adsorption as informed by the higher values R² and Adj. R², maximum log-likelihood and smaller ERRSQ/SSE, χ², Akaike information criterion (AIC), Bayesian information criterion (BIC), and Hannan-Quinn information criterion (HQIC). Result from kinetic data revealed the adsorption mechanism of Pb (II), Zn (II), Cu (II), Hg (II), Cr (II), Co (II) and Cd (II) ions onto Bt-TMPA as a chemical adsorption.

Keywords : Adsorption, isotherm, heavy metals, kinetics, organoclay.

Introduction

Frequent occurrence of heavy metals in the environment is highly problematic owing to their toxicity and abundance. Existence of heavy metals in surface and ground water has been known to cause various health disorders to living organisms (Uddin, 2017; Alkan & Dogan, 2001). Due to the presence of heavy metals in pesticides, municipal waste, mines residues, fertilizers, smelting industries and sludge, they are regarded as the main group of inorganic pollutants and contaminate a large area of land (Halim et al., 2003). Generally, heavy metals display carcinogenic properties and may be detrimental to humans health because of their accumulative nature, non-degradability and persistency (Balasubramanian et al., 2009; Gupta et al., 2004; Rao & Kashifuddin, 2014). Some heavy metals, however, are vital to life and play very crucial role in the human metabolic system like the functioning of critical enzyme sites, but in excess, it can harm the organism (Howard & Michael, 2002), whereas, some other metals are xenobiotics i.e. they play no vital role in human physiology (and most other

living organisms) and even at trace levels of exposure, may cause disorders. Huge quantity and varieties of heavy metals are involved in industrial processes and the discharge of these heavy metals results to a severe environmental hazard as these metals are water soluble and accumulates fast in living tissues. Higher concentration of different heavy metals, Cd, Cr, Cu, Hg, Pb, Zn adversely affect the living body as these are typically hazardous metals (Uddin, 2017; Waseem et al., 2014; Ahmed & Ahmaruzzaman, 2016; Waseem & Arshad, 2016; Wahab et al., 2019).

Numerous physical and chemical techniques such as adsorption (Zain et al., 2010), solid phase extraction (Xue et al., 2009; Dalida et al., 2011), chemical precipitation (Hui et al., 2005), membrane separation (Qdaisa & Moussab, 2004) and ion exchange (Ijagbemi et al., 2009), among several others have been widely applied for removal of heavy metals in aqueous media. Most of these processes are complicated, expensive

and may be even ineffective at low metal ion concentrations making them unsuitable for this purpose (Kurniawan et al., 2006). Previous studies have reported adsorption technique as the most preferred and effective method for heavy metal ions uptake from aqueous medium owing to simplicity and high effectiveness (Liang et al., 2010). Adsorption technique is characterized by adsorbent regeneration, reusability, applicability for very low metal ion concentration, ease of operation and suitability for both batch and continuous processes, among other advantageous properties, compared to other heavy metal removal technologies (Mohanty et al., 2006). With regards to this attributes, adsorption has been widely applied and thus many researchers have reported the use of different adsorbent materials such as tea waste (Mondal, 2010), microorganisms (Gulper & Sarioglu, 2013), fertilizer waste (Gupta et al., 2010), date pits (Banat et al., 2003), lateritic minerals (Ahmad et al., 2002), red mud (Gupta et al., 2001), charcoal (Yadav et al., 2014), yeast (Li et al., 2013), sludge ash (Weng, 2002), biomass materials (Annadurai et al., 2003; Vazquez et al., 2012) and clay (Naseem & Tahir, 2001; Hamidpour et al., 2010), in an attempt to improve the removal of heavy metals from the environment via the adsorption route (Malima et al., 2018).

Clays are for the most part hydrous aluminosilicates which comprise of blends of fine grained earth minerals, metal oxides, and precious stones of different minerals (Demiral et al., 2008). Bentonite consists of montmorillonite with composition of Al_2O_3 , MgO , CaO , SiO_2 , K_2O , and Fe_2O_3 (Ngah et al., 2011). The 2:1 layer structure of bentonite comprise of an octahedral alumina sheet fit in the two contradicting tetrahedral silica sheets. The thickness of these layers are in few nanometers range and length is several microns and arranged into stacks with the gap filled with exchangeable metal cations (Wahab et al., 2019; Alexandre & Dubois, 2000). Bentonite clay finds application as an adsorbent for removal of metal ions owing to its adsorptive capacity for different organic and inorganic ions, cation exchange capacity, swelling properties as well as its larger surface area (Donat et al., 2005). Besides various applications of clay composites (Munir et al., 2019), bentonite shows some high degree of hydrophilicity, in order to increase its adsorption capacity and surface modification, usually organic molecules (most often surfactants) is used to transform its properties from hydrophilic to more hydrophobic (Nafees & Waseem, 2014; Nafees et al., 2013; Ullah et al., 2017). Because of the hydrophobic nature of organoclays, this filter material can be used for purification of water (Wahab et al., 2019; Xi et al., 2010). Although clay possesses the ability of adsorption of various hydrophilic substances, the modification of their surface can successfully enhance their capabilities (Liu, 2007; Monvisade & Siriphannon, 2009). In our previous study (Onwuka et al., 2022), we have investigated the adsorptive removal of antimony (II) ion by org nano montmorillonite in aqueous solution. However, current study investigates the adsorptive behaviours of seven (7) heavy metals (Zn, Pb, Cr, Hg, Cd, Co and Cu) onto Trimethyl phenyl ammonium cation intercalated bentonite. Basic adsorption parameters such as effect contact time, metal ion concentration, pH and adsorbent

dosage on heavy metal ion removal has been evaluated to study adsorption behaviour.

Experimentals

Adsorbents

Bentonite clay with CEC of 30.94 meq/100 g used in this study was supplied by Mansid Chem. Nigeria Ltd, Port Harcourt, Rivers State Nigeria and was beneficiated according to previous work (Onwuka et al., 2020). The Surfactants: trimethylphenyl ammonium chloride (TMPA-Cl, $C_9H_{14}ClN$, MW. 171.5) was purchased from Sigma Aldrich Switzerland. Salts of different metal ions were procured from Aladdin Co. Ltd and were used without any further purification.

Preparation of TMPA based organoclay has been previously described in detail (Onwuka et al., 2020) and has been also characterized for specific surface area by Sear's method, cation exchange capacity (CEC) by ammonium acetate procedure, IR spectra properties by FTIR spectrophotometer (Buck scientific M530 USA FTIR), basal spacing by X-ray diffraction (Bruker, D8ADVANCE, Germany) using Ni-filtered Cu $K\alpha$ radiation (1.5406 Å), and morphology by scanning electron microscope (Seron, AIS-2100, Republic of Korea). The values obtained for CEC and specific surface area; Characteristics and physical properties of the unmodified bentonite (BT) and the organo-modified bentonite (BT-TMPA) were also described (Onwuka et al., 2020).

Adsorbate

Stock solutions of different metal salts such as zinc sulphate, cobalt chloride, lead nitrate, mercuric nitrate, cadmium acetate, copper sulphate and potassium chromate were prepared in 0.1M nitric acid. These stock solutions are used to prepare other solution standards of desired concentrations for adsorption experiment in deionized water.

Batch adsorption experiment

A known mass of organoclay with 20 ml of aqueous solution of different heavy metal salts with known concentration are kept on a hot plate with continuous stirring for a fixed time. After stirring, the solutions were removed and centrifuged to remove the composites. The residual metal ions concentration in the reaction mixture were quantified by atomic absorption spectrometer. The effect of various sorption parameters such as: contact time, pH, initial concentration of metal ions, temperature and adsorbent dosage on adsorption of heavy metals by Bt-TMPA were investigated, using Atomic absorption spectrometer. The percentage efficiency (S%) and adsorption capacity at equilibrium for adsorption of heavy metal ions were estimated according to equation (1) and (2) respectively;

$$\text{Sorption efficiency (S\%)} = \frac{C_i - C_e}{C_i} \times 100 \quad (1)$$

$$q_e = \frac{C_i - C_e}{m} \times V \quad (2)$$

Where q_e is the adsorption capacity (mg/g), C_i and C_e are the initial and equilibrium concentrations of individual metal ions

(mg/dm³), respectively, V is the volume (dm³) and m is the mass of organoclay (g).

Results and Discussions

Effect of contact time

Effect of contact time on the adsorption of Pb (II), Zn (II), Cu (II), Hg (II), Cr (II), Co (II) and Cd (II) ions respectively in water by BT-TMPA was investigated at initial concentration of 10 mg/L for all the heavy metals. Figure 1 displays the contact time required to attain maximum adsorption of the metal ions. At the initial stage of the adsorption process, rapid adsorption of the metal ions were observed, until after 80 minutes of contact time when the rate of adsorption decreased, before equilibrium sorption was attained at 120 minutes with adsorption efficiencies of organoclay (Bt-TMPA) obtained as 79, 97.4, 88.8, 77.9, 81.1, 98 and 85.1% for Pb (II), Zn (II), Cu (II), Hg (II), Cr (II), Co (II) and Cd (II) respectively. The rapid adsorption observed at the initial stage of the adsorption process could be due to the availability of many active vacancy sites on the surface of the adsorbents as well as higher surface area and availability of pores on adsorbent's surface (Gandhi et al., 2014). As a result, maximum contact time of 120 minutes was applied to the rest of the experiments.

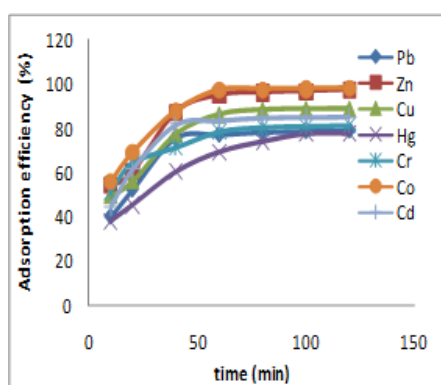


Figure 1: Effect of contact time on the adsorption of metal ions by BT-TMPA

Effect of pH

In adsorption process, pH plays a crucial role, because it influences the surface properties of the adsorbents. The influence of pH on heavy metal uptake by the organoclay was carried out by taking initial metal ion concentration of 10 mg/L at 120 minutes contact time and 0.025 g of organoclay, with pH variation of 2 to 10. Figure 2 represents the effect of pH variation on the adsorption of Pb (II), Zn (II), Cu (II), Hg (II), Cr (II), Co (II) and Cd (II) ions by Bt-TMPA. Obviously, the heavy metals were properly sorted by the organoclay. Result showed that the increase in pH resulted in decrease in adsorption efficiency of the organoclay. Increased pH initiates precipitation of metal ions and hydroxide formation (Anirudhan et al., 2012) which prohibits normal functioning on them (Wahab et al., 2019). At pH of 6 ion-exchange and complex formation mechanism remain the major processes of heavy metal removal in the solution. Again, pH of 6 was applied for the other experiments to enhance optimization.

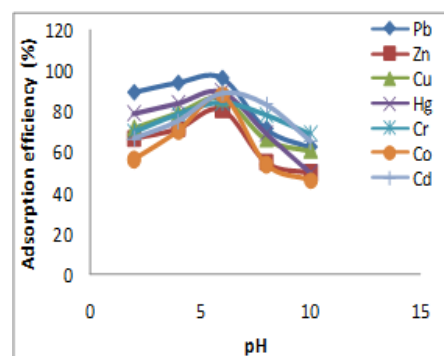


Figure 2: Effect of pH on the adsorption of metal ions by BT-TMPA

Effect of Adsorbent Dosage

To investigate the effect of adsorbent dosage on the adsorption of the heavy metals by the organoclay, various concentrations of the individual metal ions were mixed with the adsorbent, varying adsorbent quantity from 0.025 to 0.125 mg and agitating for 120 minutes under room temperature (27°C) and optimal pH. The results are displayed in figure 3. As expected, increasing adsorbent dosage resulted to corresponding increase in adsorption efficiency, which could be due to increase in the number of active vacant sites and increased surface area available for metal ion sorption. More availability of active binding sites on organoclay surface enhanced increased metal ion uptake (Tomul & Basoglu, 2010).

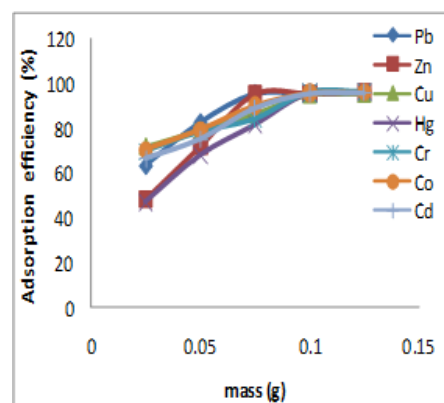


Figure 3: Effect of adsorbent dosage on the adsorption of metal ions by BT-TMPA

Effect of Metal ion Concentration

To study the influence of metal ions on heavy metal adsorption behaviour onto organoclay, solution of metal salts were prepared with metal ion concentrations ranging from 1 to 50 ppm and solutions were agitated for 120 minutes adding 0.025 g of adsorbent at optimum adsorption conditions. Evidently, increased metal concentration decreased adsorption efficiency (figure 4). This is because at decreased concentration, small ratio is obtained between available active adsorption sites and metal ions as a result adsorption takes place independently on metal ion concentration but when concentration increases, higher competition among metal ions for active binding sites increases. Even though adsorption efficiency decreased with increase in the metal ion concentration, adsorption capacity of

organoclay increased likewise (El-Maghrabi & Mikhail, 2014).

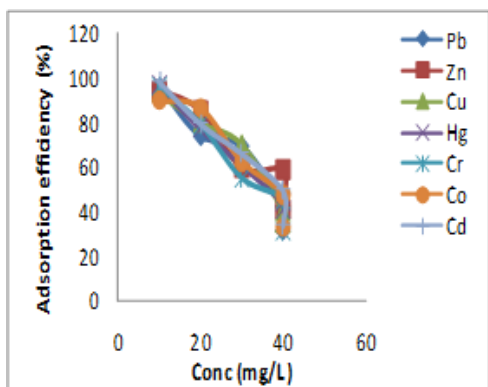


Figure 4: Effect of initial metal ion concentration on the adsorption of metal ions by BT-TMPA

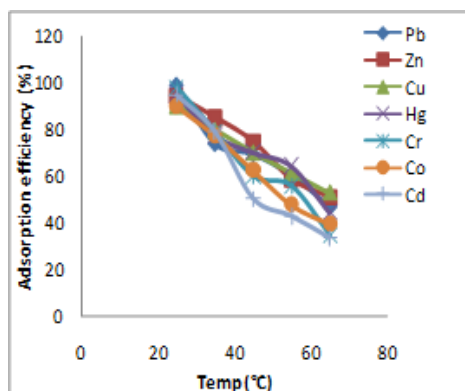


Figure 5: Effect of temperature on the adsorption of metal ions by BT-TMPA

Effect of Temperature

To investigate the influence of temperature on the absorption of Pb (II), Zn (II), Cu (II), Hg (II), Cr (II), Co (II) and Cd (II) ions by Bt-TMPA, solution of their individual salts were taking along with constant stirring for 120 minutes at 25°, 35°, 45°, 55° and 65°C respectively. The result obtained can be seen in figure 5. Maximum adsorption efficiencies of 98.8, 94.5, 90.2, 94.8, 98, 89.9 and 94.9% were obtained for Pb (II), Zn (II), Cu (II), Hg (II), Cr (II), Co (II) and Cd (II) ions respectively at lowest temperature of 25°C, implying that lower-temperature enhanced higher adsorption efficiency. Decreased adsorption efficiency observed as a result of increased temperature could be due to increase in available thermal energy that causes desorption. At higher temperature the heavy metal ions became highly mobile and this resulted to desorption (Gandhi et al., 2014).

Adsorption Isotherm

Langmuir model was adopted to assess the adsorption equilibrium between adsorbent the adsorbate system, where the adsorbate adsorption is limited to a mono layer at/or prior to when a unity relative pressure was attained. The linearized form is evaluated according to Eq. (3) (Saha & Orvig, 2010).

$$\frac{1}{q_a} = \frac{1}{Q_m} + \frac{1}{K_f q_m C_a} \quad (3)$$

Where q_m represents the maximum adsorption capacity of heavy metal ions (mg/g).

Freundlich model is based on multilayer adsorption between adsorbed molecular interaction. The linear form is presented in Eq. (4) (Mohan & Pittman, 2006).

$$\ln q_e = \ln k_f + \frac{1}{n} \ln C_e \quad (4)$$

Where K_f and n represents the Freundlich constant; n gives speculations about the favourability of the adsorption process (Obayomi ET AL., 2022) and K_f is the metal ions adsorption capacity.

The Langmuir and Freundlich adsorption models were further validated to enable describe which isotherm model gave best fit to experimental data, as well better descriptor to entire adsorption process. Error analysis methods like the sum of absolute error (EABS), chi-square (χ^2) and the sum of square error (ERRSQ/SSE) were applied and compared to the correlation coefficient (R^2) obtained. The values obtained from correlation coefficient (R^2) is likely not enough to validate the basis for the best adsorption model selection because it only signifies the fitness between linear forms of the isotherm equations and experimental data [54]. Based on minimization and maximization error, convergence criteria, distribution between experimental data and predicted isotherms usually involves nonlinear regression (Foo et al., 2010). The lower the EABS, χ^2 chi-square and ERRSQ/SSE values for the isotherm models, studied the better fitness to the adsorption process. The Sum of absolute error (EABS) equation, the error function of chi-square and the Sum of square error (ERRSQ/SSE) is represented by Eqs. (5), (6) and (7) respectively:

$$EABS = \sum_{i=1}^N -q_{e,cal} \quad (5)$$

$$\chi^2 = \sum_{i=1}^N \frac{(q_{e,exp} - q_{e,cal})^2}{q_{i,cal}} \quad (6)$$

$$SSE = \sum_{i=1}^N (q_{e,cal} - q_{e,exp})^2 \quad (7)$$

Where the sample number is represented by N , q_e, exp is the experimental adsorption capacity at equilibrium (mg/g), q_i, cal represents calculated adsorption capacity from the isotherm equation at equilibrium (mg/g).

Table 1a : Isotherm parameters for the adsorption of heavy metals by Bt-TMPA

Adsorbent	Metal ions	Langmuir			Freundlich				
		Calculated	Exp.	Langmuir	R _L	R ²	Kf(mg/g)	n	R ²
		Q _m (mg/g)	Q _m (mg/g)	K _L (L/mg)					
	Pb (II)	17.66	17.23	2.44	0.03	0.998	5.21	3.51	0.976
	Zn (II)	21.12	20.89	1.65	0.032	0.998	7.63	1.67	0.901
Bt-TMPA	Cu (II)	14.64	14.1	3.08	0.021	0.995	7.05	2.22	0.887
	Hg (II)	14.98	15.07	1.33	0.015	0.987	7.26	1.88	0.679
	Co (II)	16.6	16.42	2.12	0.031	0.996	6.55	3.22	0.722
	Cr (II)	13.81	14.02	1.64	0.033	0.998	6.49	2.54	0.955
	Cd (II)	15.5	15.19	1.34	0.019	0.978	5.92	1.93	0.986

Table 1b: Statistical validation of isotherm models

Isotherms	Parameters	Metal ions						
		Pb (II)	Zn (II)	Cu (II)	Hg (II)	Co (II)	Cr (II)	Cd (II)
	EABS	5.311	4.514	5.998	10.645	3.218	13.762	5.419
Langmuir	χ ²	0.433	3.232	3.212	0.652	1.114	6.142	0.871
	ERRSQ/SSE	7.129	10.252	22.541	14.721	8.625	27.651	13.132
	EABS	20.667	14.669	7.786	17.623	11.624	42.669	14.299
Freundlich	χ ²	4.564	7.111	5.897	4.491	7.163	5.982	6.846
	ERRSQ/SSE	32.716	40.125	31.762	27.849	20.632	83.515	43.659

Table 1a and 1b displays the adsorption isotherm model parameters and results from error analysis respectively. From the results, it is obvious that the Langmuir isotherm best described the adsorption of Pb (II), Zn (II), Cu (II), Hg (II), Cr (II), Co (II) and Cd (II) ions onto the organoclay with highest R² ranging from 0.978 to 0.998 compared to the Freundlich isotherm whose R² values were found to be less than 0.987. Furthermore, subjecting isotherm data to statistical error analysis such as the sum of absolute error (EABS), Chi-Square (χ²) and the sum of square error (ERRSQ/SSE) gave very lower values for the Langmuir isotherm, on like the Freundlich isotherm whose values were relatively high, thereby justifying Langmuir isotherm as best fit to experimental data. This result is in accordance with that reported by Hamzat et al. (Hamzat et al., 2019), whose findings were based on adsorption of cadmium and hexavalent chromium from electroplating waste water; and also with those of Obayomi et al. (Obayomi et al., 2022). According to Langmuir adsorption model, this process of adsorption followed monolayer and homogenous mechanism of adsorption. Therefore, maximum adsorption capacities of 17.66, 21.12, 14.64, 14.98, 16.60, 13.81 and 15.50 mg/g was obtained for Pb (II), Zn (II), Cu (II), Hg (II), Cr (II), Co (II) and Cd (II) ions, respectively.

Adsorption kinetics

The pseudo first order and pseudo second order kinetic models were adopted to study the adsorption kinetics of Pb (II), Zn (II), Cu (II), Hg (II), Cr (II), Co (II) and Cd (II) ions removal by the organoclay (Bt-MPA) according to Eq. (8) and (9) respectively:

$$\log(q_e - q_t) = \log q_e - \left(\frac{k_1}{2.303}\right)t \quad (8)$$

$$\frac{1}{q_t} = \frac{1}{k_2 q_e^2} + \frac{t}{q_e} \quad (9)$$

Where q_e and q_t are the amounts of heavy metals adsorbed (mg g⁻¹) at equilibrium and at time t (min), respectively, k₁ (min⁻¹) is rate constant of first-order adsorption and k₂ (g mg⁻¹ min⁻¹) represents the rate constant for pseudo-second-order model.

Table 2a: Parameters for the Pseudo first order and Pseudo second order kinetic models for the adsorption of heavy metals by Bt-TMPA

Adsorbents	Metal ions	k1 (min ⁻¹)	Pseudo first Order			Pseudo second Order		
			qe(mg/g)	R ²	k2(g/mg.h)	qe _{cal} (mg/g)	qe _{exp} (mg/g)	R ²
	Pb (II)	0.032	7.01	0.888	0.004	6.54	6.11	0.975
	Zn (II)	0.076	7.33	0.954	0.006	5.23	5.45	0.985
Bt-TMPA	Cu (II)	0.011	7.87	0.966	0.034	6.17	6.65	0.998
	Hg (II)	0.031	7.19	0.987	0.036	5.34	5.09	0.987
	Co (II)	0.062	8.44	0.975	0.002	5.77	6.01	0.991
	Cr (II)	0.048	7.87	0.906	0.004	6.14	5.99	0.996
	Cd (II)	0.006	7.75	0.895	0.037	5.86	5.55	0.998

Table 2b: Statistical validation of kinetic data

Kinetic models	Parameters	Metal ions						
		Pb (II)	Zn (II)	Cu (II)	Hg (II)	Co (II)	Cr (II)	Cd (II)
Pseudo first order	Adj. R2	0.868	0.948	0.951	0.945	0.966	0.917	0.901
	χ^2	1.625	0.772	0.488	1.227	0.323	0.554	1.222
	SSE	0.554	0.473	0.921	0.143	0.881	0.234	0.287
	SIC	7.623	2.564	2.661	9.601	4.301	3.227	5.008
	AIC	6.432	2.714	2.703	10.247	4.667	3.893	5.665
	HQC	6.691	2.134	2.781	10.555	4.983	4.351	5.687
	Log-likelihood	-0.623	9.211	4.685	-0.452	-0.563	6.173	10.674
	Adj. R ²	0.972	0.981	0.996	0.987	0.993	0.996	0.999
	χ^2	1.007	0.416	0.125	0.934	0.128	0.117	1.086
	SSE	0.0673	0.0054	0.0653	0.0543	0.0045	0.0234	0.0983
Pseudo second order	SIC	-22.643	-12.865	-7.234	-12.941	-7.343	-17.234	-6.771
	AIC	-23.551	-14.342	-8.237	-12.976	-8.769	-18.542	-7652
	HQC	-24.224	-15.282	-9.659	-13.225	-9.888	-19.241	-8.881
	Log-likelihood	13.611	16.773	10.441	22.871	13.673	9.653	15.889

Table 2a represents the regression coefficients and table 2b displays the error functions and information criteria for the two investigated kinetic models. Judging by higher R² values displayed by pseudo second order kinetic model comparative to the pseudo first order kinetic model whose R² values were less than 0.988, the pseudo second order kinetic model gave best fit to the experimental data in this regard, implying chemisorption. Suitability of the pseudo second order kinetic model to fitting of adsorption data was further validated and justified by the higher log-likelihood values and smaller values recorded for χ^2 , SSE, AIC, BIC and HQIC. According to table 2b, the positive values of log-likelihood resulted in negative criterion values (HQIC, BIC and AIC) and vice versa. Furthermore, a closer observation of the values obtained for experimental adsorption capacity at equilibrium (qe, exp.) were similar to those of calculated adsorption capacity (qe, cal.) for the pseudo second order kinetic model; whereas for the pseudo first order kinetic model, their values were inconsistent (Table 2a). Similar results have been reported by Wahab et al. (Wahab et al., 2019) and Obayomi et al. (Obayomi et al., 2022).

Conclusion

Bentonite clay enhanced TMPA surfactant up to 100% CEC has been applied as adsorbent for successful removal of seven different heavy metal ions (Pb (II), Zn (II), Cu (II), Hg (II), Cr (II), Co (II) and Cd (II)) in water via batch adsorption process. Equilibrium adsorption of heavy metal ions by organoclay was attained after 120 minutes of contact time. Among the two traditional isotherm models (Langmuir and Freundlich), the Lagmuir isotherm gave best fit to the adsorption data with maximum adsorption capacities of 17.66, 21.12, 14.64, 14.98, 16.60, 13.81 and 15.50 mg/g for Pb (II), Zn (II), Cu (II), Hg (II), Cr (II), Co (II) and Cd (II) ions, respectively. Pseudo first order and Pseudo second order kinetic models were employed in order to predict the mechanism of adsorption. The results validated pseudo second order kinetic model as best fit to adsorption equilibrium data. Adsorption mechanism of Pb (II), Zn (II), Cu (II), Hg (II), Cr (II), Co (II) and Cd (II) ions adsorption onto organoclay revealed chemisorption. Therefore, the application of organoclay (Bt-TMPA) as cheap, eco-friendly, readily available and non-toxic adsorbent

for adsorptive removal of heavy metals in water has shown promising result with auspicious future large scale application.

Conflict of Interest

Authors declare no conflict of interest

Funding

None

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