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Application of Gure modified clay for adsorption of heavy metals in polluted underground water

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ARTICLE INFO

Article type:
Research article
Article history:
Received December 2022
Accepted June 2023
July 2023 Issue
Keywords:
Modified clay
Gure community
Contaminated borehole water
Adsorption
Heavy metals

ABSTRACT

The performance of modified clay obtained from Gure community in Khana Local area of Rivers State as adsorbent for the removal of heavy metals from well water was investigated. This was motivated by the increasing pollution of local wells, the source of water for domestic use by rural dwellers. Effects of dosage, pH, temperature, contact time and initial metal concentration on the capacity of the modified Gure clay to adsorb chromium(VI) (Cr^{6+}), copper(II) (Cu^{2+}) and zinc(II) (Zn^{2+}) ions from borehole water were also studied. Adsorption isotherms, kinetics and thermodynamics models were used to evaluate the experimental results. Thus, from 0.5 to 2g dosage, amount of metals removed increased from 69.81 to 83.43% for Cr^{6+}, 54.51 to 78.24% for Cu^{2+} and 82.15 to 91.16% for Zn^{2+}. From 5.5 to 8.5 pH, the amount removed increased from 71.68 to 84.18% for Cr^{6+}, 64.79 to 80.48% for Cu^{2+} and 78.56 to 92.09% for Zn^{2+}. From 30 to 120 min contact time, the amount removed increased from 71.68 to 84.18% for Cr^{6+}, 64.79 to 80.48% for Cu^{2+} and 78.56 to 92.09% for Zn^{2+}. On the contrary, from 29 to 60ºC, the amount removed decreased from 71.68 to 84.18% for Cr^{6+}, 64.79 to 80.48% for Cu^{2+} and 78.56 to 92.09% for Zn^{2+}. Also, from 25 to 100 mg/l initial metal concentration, the amount removed decreased from 71.68 to 84.18% for Cr^{6+}, 64.79 to 80.48% for Cu^{2+} and 78.56 to 92.09% for Zn^{2+}. The adsorption of Cr^{6+} and Cu^{2+} reached equilibrium at 60 min, while that of Zn^{2+} was at 90 min. All the adsorption isotherms showed good fit, but the Langmuir isotherm correlated better with the experiment. The maximum adsorption capacities obtained from the Langmuir isotherm were 26.738 mg/g, 28.902 mg/g and 22.831 mg/g for Cr^{6+}, Cu^{2+} and Zn^{2+}, respectively. Also, the pseudo second order kinetics compared well with experimental data, while thermodynamic evaluation showed that the adsorption was exothermic, spontaneous and possible within the temperature range. Based on the range of metals removed, Gure modified clay has shown to be good adsorbent for heavy metal removal in contaminated borehole water.

Capsule Summary: Gure modified clay-based material was prepared and employed for the adsorption of heavy and at optimum condition, the modified clay showed a promising efficiency for the removal of metals form contaminated water.

Cite This Article As: K. Dagde, P. Ikenyiri and P. Yorpah. Application of Gure modified clay for adsorption of heavy metals in polluted underground water. Chemistry International 9(3) (2023) 94-103.
https://doi.org/10.5281/zenodo.8117938

INTRODUCTION

Water pollution is a global challenge, and it is made worse by lots of human's activities. Hundreds of organic and inorganic pollutants originating from natural or anthropogenic sources are released every day into the environment from numerous branches of industries (Abdolahnejad et al., 2014). Most water contaminants, be it groundwater or surface water, are entrained with wastewater. Some of the industries that release greater amount of wastewater with complex pollutant load include the mining and extractive industry, electroplating and metal surface treatment processes, metallurgy, metal coating and plastics. Particularly, wastewaters from metal plating facilities, production of paints and pigments, ammunition, ceramic and glass industries contain high concentration of heavy metals (Adebowale et al., 2008). These chemical substances can be highly problematic to the ecosystem and human health (Ademiluyi and Ujile, 2013). Also, oil and gas exploration and production activities are other sources that can discharge pollutants, especially heavy metals and organic contaminants into soil and water environment (Agbo et al., 2015; Argun and Dursum, 2008).

To reduce the impact of water contaminants on flora, fauna, plants and human health, discharge limits and regulations are set, but these precautions are often not enough, therefore wastewater is required to be treated (Chie-Amadi et al., 2020). There are several treatment methods that can be used in the removal of water contaminants, but some of these techniques are very expensive with reduced efficiency (Chowdhury et al., 2012). Conventionally, the most common and widely used methods for advanced heavy metal removal include chemical precipitation, flotation, flocculation, sedimentation, solvent extraction, oxidation/reduction and dialysis/electro-dialysis, reverse osmosis, ultra-filtration, electrochemical deposition, ion exchange and adsorption (Chowdhury et al., 2012). The choice of method is dependent on efficiency and cost effectiveness of the technology (Grassi et al., 2012). However, adsorption technology has several advantages such as the ease of operation, inexpensive nature of the equipment, less sludge production, and reusability of adsorbent after desorption (Gu et al., 2019). Adsorption technology is a surface phenomenon (that is, the removal of contaminants in solution takes place on the adsorbent surface), whereby contaminated solution comes into contact with a solid material called adsorbent, and through the porous surface structure, the solute (contaminant or adsorbate) molecules in the solution adhered onto the adsorbent surface (Hamadi et al., 2001).

In addition, adsorption technologies have been studied with various models in order to evaluate the capacity of adsorbent and thermodynamic relations of the process. Some of adsorption models include the Langmuir, Temkin and Freundlich isotherm, the pseudo first and second order adsorption kinetics. Hence, this study would investigate the adsorption capacity of Nigerian zeolite in the removal of heavy metals and organic components in crude oil contaminated groundwater in Ogoni land of Rivers State. The aim of this research is to evaluate the performance of clay minerals as adsorbent for the treatment of heavy metal contaminated hand dug well water in Gure Community of Ogoni Ethic Nationality, Rivers State.

MATERIAL AND METHODS

Chemical and reagents

Clay, well water, graduated beaker, sieve, funnels, distilled water, test tubes, desiccators, weighing balance, bucket, crusher, filter papers, conical flasks, magnetic stirrer, oven, measuring cylinder, crucibles, thermometer, pH meter, stop watch, Atomic Absorption spectrophotometer (AAS), capillary tubes, sodium hydroxide (NaOH), hydrochloric acid (HCl), sulphuric acid (H_2SO_4), barium chloride ($BaCl_2$), zinc(II) chloride ($ZnCl_2$), copper(II) nitrate ($Cu(NO_3)_2$) and potassium dichromate ($K_2Cr_2O_7$).

Sample collection and preparation

Well water and clay used as adsorbent were the two major samples collected far away from the laboratory. Reagents and apparatus were provided by the laboratory technologist.

Well water collection and preparation

Well water sample was collected from hand dug well close to crude oil polluted swamp in Gure Community, Khana Local Government Area of Rivers State within the morning hours. A small bucket tied with rope was lowered down the well to fetch water from the well. The fetched well water was transferred into 20 litre plastic can and transported to the chemical/petrochemical Engineering Laboratory in Port Harcourt for analysis. 200 ml of the well water sample, upon arrival to the laboratory, was collected and immediately analyzed of heavy metal presence using the AAS. This initial water analysis was to identify and determine the level of each heavy metal concentration in the well water sample. The remaining water sample was stored in refrigerator to be collected in batches for the main adsorption experiments.

Clay collection and preparation

The clay was also collected from Gure Community in swampy area at depth not below 100 cm and put in polythene bag to protect it against external contamination. The collected bagged clay sample was transported to Port Harcourt and prepared for laboratory analysis. The method described by was used to prepare the clay sample as adsorbent (Burham and Sayed, 2016). 2kg of clay sample was weighed into distilled water and dissolved using hand. The clay was dispersed in the water, and allowed to settle for a while.

Suspended solid particles were separated via decantation. More water was poured into the container to remove more particulate maters.

Thermal modification of clay sample

The method described by (Kentsa et al., 2019) for modification of natural clay was adopted in this study. The clay was synthesized to metakaolin. This was done by heating the prepared clay sample. Thus, 1000 g of the prepared clay sample was placed in the oven, and heated gradually to a temperature of 750°C at increasing rate of 10°C/min. The heating was allowed for three hours.

After heating, the metakaolin was dealuminated by mixing 900 g of the metakaolin with 1500ml of 10M sulphuric acid. The mixture was agitated under reflux at temperature of 90 °C for 10 hours. The resulting product was cooled and separated from water via sedimentation. The sulphate ion in the obtained product was removed by washing with distilled water until the sulphate ion was removed. This process was stopped when there was no presence of white precipitate in the supernatant mixture after addition of 0.1M $BaCl_2$. The modified clay was oven dried at 80 ºC for 8 hours. After drying, the sample was grinded via electric blender to fine particles, and then, sieved through grain sizes between 300μm and 2.3mm, ready for adsorption experiment (Dagde and Ndaka, 2019).

Chemical characterization of clay sample

The elemental composition of the modified clay sample was analyzed using AAS. Thus, the modified product obtained before drying was collected and analysed for the presence of chemical composition. Also, the surface functional groups of the clay sample were analysed using Fourier Transform Infrared (FTIR) spectroscopy analysis. The Satellite FTIR spectrometer model 2000 (Mattson Instruments Inc., Madison, WI, USA) was used. The wave number ranged from 4000–750cm^{-1}. The FTIR analysis was performed using clay sample compressed into pellet with KBr powder. To obtain FTIR spectrum for the modified clay sample, the background spectrum was subtracted.

Adsorption experiment

Based on the concentration level of the identified heavy metals from the initial well water analysis, series of adsorptions were carried out in batches to investigate the effects of adsorbent dosage, contact time, pH and temperature. Though, several heavy metals were identified, but to reduce cost and for the purpose of investigating the capacity of the modified clay adsorbent, only zinc (II), chromium (VI) and copper (II) ions were selected for the adsorption study.

Estimation of adsorption capacity

The percentage and adsorption capacity adsorbed onto the adsorbent was calculated using Eqs. 1-2, respectively.

$$\text{Adsorbed metal}(\%) = \frac{C_i - C_f}{C_i} \times 100\% \quad (1)$$

$$Q_t = (C_i - C_t)\frac{V}{w} \quad (2)$$

Where, Q_t is the Concentration of contaminant adsorbed by the clay at time, t (mg/g), C_f is the Final concentration of contaminant in the liquid mixture (mg/l), C_i is the Initial concentration of contaminant in the solution (mg/l), C_t is the Concentration of contaminant in the solution at time, t (mg/l), V is the Volume of liquid mixture (l) and w is the Weight of adsorbent (g)

Adsorption isotherms

The adsorption capacity of the clay was investigated by fitting experimental data into Langmuir, Freundlich and Redlich–Peterson isotherm models. The capacity of the clay to adsorb the metals at equilibrium was calculated using Eq. 3.

$$Q_e = (C_i - C_e)\frac{V}{w} \quad (3)$$

Where, Q_e = Concentration of metal ions adsorbed by clay at equilibrium (mg/g), C_i = Initial concentration of metal ions in the solution (mg/l), C_e = Concentration of metal ions in the solution at equilibrium (mg/l), V =Volume of liquid mixture (l), w =Weight of clay particle or dosage (g).

Langmuir isotherm

The Langmuir isotherm model has been used by many researchers as expressed in Eq. 4 (Dagde and Ndaka, 2019). Linearization of equation 4 is shown in Eq. 5.

$$Q_e = \frac{Q_m K_L C_e}{1 + K_L C_e} \quad (4)$$

$$\frac{C_e}{Q_e} = \frac{C_e}{Q_m} + \frac{1}{K_L Q_m} \quad (5)$$

A plot of $\frac{C_e}{Q_e}$versus C_e would give a slope equivalent to $\frac{1}{Q_m}$and the intercept as$\frac{1}{K_L Q_m}$. Where, Q_m = Maximum adsorption capacity (mg/g), K_L = Energy of adsorption (l/mg), to further investigate adsorption system, the Langmuir isotherm was further expressed as a dimensionless parameter called separation factor R_L, which is used to indicate the favorability of contaminant adsorption from a solution. In the work of [3], the adsorption separation factor was expressed as shown in Eq. 6.

$$R_L = \frac{1}{1 + K_L C_i} \quad (6)$$

If, $0 < R_L < 1$ indicates that the adsorption is favorable; $R_L > 1$ indicates that the adsorption is not favorable; $R_L = 1$ indicates that the adsorption is linear; and when $R_L = 0$ indicates that the adsorption is irreversible (Ademiluyi and Ujile, 2013).

Freundlich isotherm

The Freundlich isotherm is another widely used adsorption isotherm, which is expressed in Eq. 7.

$$q_e = K_f C_e^{1/n} \tag{7}$$

To obtain the constants, the logarithm of both sides of equation (7) was taken to obtain Eq. 8.

$$\log q_e = \log K_f + \frac{1}{n} \log C_e \tag{8}$$

A plot of $\log q_e$ versus $\log C_e$ gives the slope of the graph as $\frac{1}{n}$ and the intercept as $\log K_f$. Where, $K_f =$ Freundlich constant $n =$ Heterogeneity of the adsorption energy across the adsorbent surface.

Redlich–Peterson isotherm

The Redlich-Peterson isotherm model can be used over a wide range of concentration either in homogeneous or heterogeneous systems to describe adsorption at equilibrium, due to its versatility. The Redlich–Peterson isotherm is expressed in Eq. 9 and the linearization of equation (9) gives Eq. 10.

$$Q_e = \frac{k_R C_e}{1 + a_R C_e^{b_R}} \tag{9}$$

$$\ln\left(K_R \frac{C_e}{Q_e} - 1\right) = \ln(a_R) + b_R \ln(C_e) \tag{10}$$

Where, $K_R =$ Redlich–Peterson constant (l/g), $a_R =$ Redlich–Peterson constant (l/mg), $b_R =$ Exponent, which lies between 0 and 1. If $b_R = 1$, this model simplifies to Langmuir model, and if $a_R >> 1$, the Freundlich model is obtained. Also, at low and high concentrations this model approximates to Henry's law and Freundlich isotherm, respectively. A plot of $\ln\left(K_R \frac{C_e}{Q_e} - 1\right)$ versus $\ln(C_e)$ for obtaining the isotherm constants is not applicable because of the three unknowns: K_R, a_R and b_R (Piccin et al., 2011). Therefore, a maximization procedure of the coefficient of correlation was adopted for

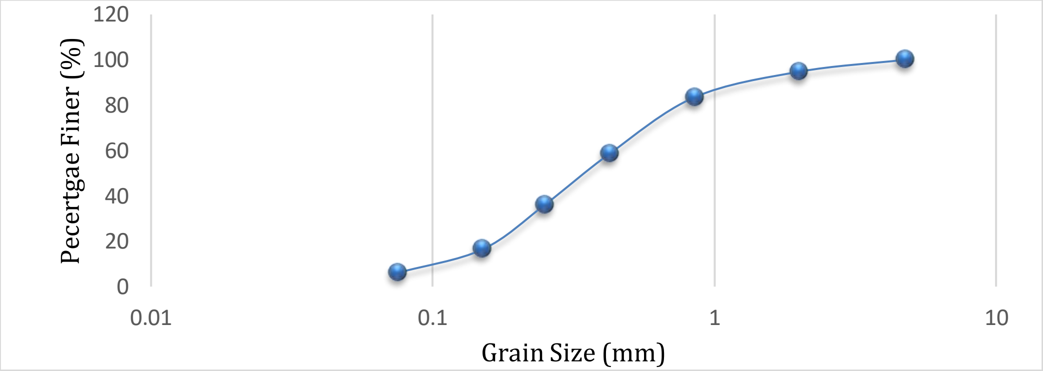

Fig. 1: Particle size distribution of modified clay

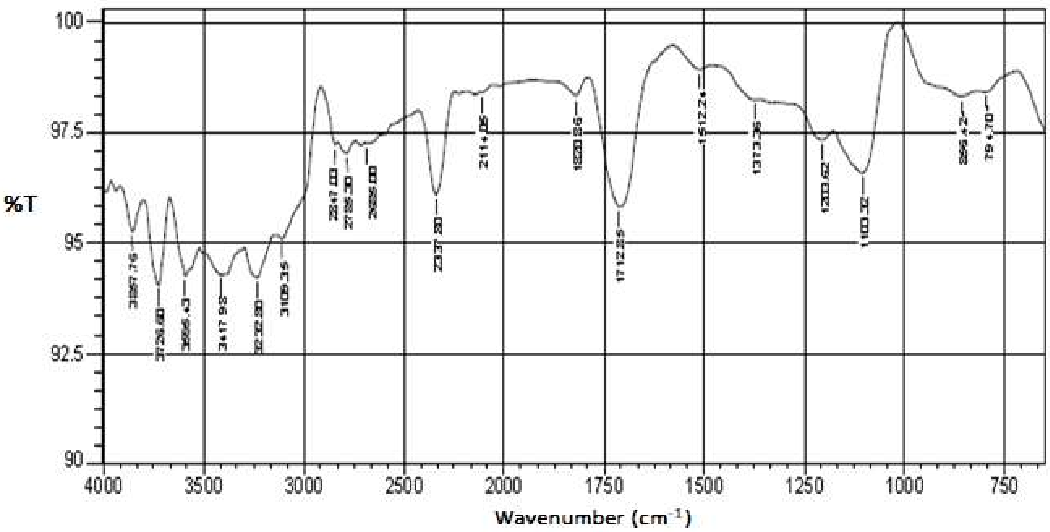

Fig. 2: FTIR spectrum of clay particles

solving Equation (10) by minimizing the distance between experimental data points and theoretical model predictions, through the *solver* add-in function of Microsoft Excel.

Adsorption Kinetics

The pseudo first order and pseudo second order kinetic models were used to study the kinetics of the adsorption and to determine the nature of the adsorption (Ho, 2004).

Pseudo first order kinetics

The Lagergren's pseudo first order equation would be used to describe the adsorption rate of contaminants onto the clay adsorbent (Eq. 11).

$$\frac{dQ_t}{dt} = k_1(Q_e - Q_t) \qquad (11)$$

Where, k_1 =Pseudo first order rate constant (min^{-1}), Q_e = Concentration of heavy metal adsorbed by the adsorbent at equilibrium (mg/g), Q_t = Concentration of heavy metal adsorbed by the adsorbent with time (mg/g), t = Contact time (min). The adsorption rate constant and the adsorption capacity can be obtained by integrating equation (11) to give Eq. 12. The plot of $ln(Q_e - Q_t)$ versus t would give a slope equivalent to k_1 and intercept equivalent to $ln\, Q_e$.

$$ln(Q_e - Q_t) = ln\, Q_e - k_1 t \qquad (12)$$

Pseudo second order kinetics

The pseudo second order model (Dagde and Ndaka, 2013) would be adopted to also describe the adsorption rate of contaminants onto the adsorbent (13).

$$\frac{dQ_t}{dt} = k_2(Q_e - Q_t)^2 \qquad (13)$$

Where: k_2 = Pseudo second order adsorption rate constant (g/gm.min). Every other parameter remained as defined previously. Again, the adsorption rate constant and the adsorption capacity can be obtained by integration to give Eq. 14-15.

$$\int_{Q_{to}}^{Q_t} \frac{dQ_t}{(Q_e - Q_t)^2} = k_2 \int_0^t dt \qquad (14)$$

$$\frac{1}{(Q_e - Q_t)} = k_2 t + C \qquad (15)$$

Initial condition, $t = 0, Q = 0, t = t, Q = 0$. Substituting into equation (17) gives Eq. 16 and further simplification yields Eq. 17.

$$\frac{1}{Q_e - Q_t} = k_2 t + \frac{1}{Q_e} \qquad (16)$$

$$\frac{1}{Q_e - Q_t} - \frac{1}{Q_e} = k_2 t$$

$$\frac{Q_e - Q_e + Q_t}{Q_e(Q_e - Q_t)} = k_2 t$$

$$\frac{Q_t}{Q_e(Q_e - Q_t)} = k_2 t \qquad (17)$$

The constants can be obtained by linearization of equation (17) as shown Eq. 18 to 20. The plot of $\frac{t}{Q_t}$ against t would give a slope equivalent to $\frac{1}{Q_e}$ and intercept equivalent to $\frac{1}{Q_e^2 k_2}$.

$$Q_t = k_2 t Q_e^2 - Q_t Q_e k_2 t \qquad (18)$$

$$\frac{1}{Q_e^2 k_2} = \frac{t}{Q_t} - \frac{t}{Q_e} \qquad (19)$$

$$\frac{t}{Q_t} = \frac{t}{Q_e} + \frac{1}{Q_e^2 k_2} \qquad (20)$$

Thermodynamic analysis

The thermodynamics of the adsorption was at temperatures of 29, 40, 50 and 60 ºC. The thermodynamic parameters were determined using Van't Hoff equation stated in Eq. 21.

$$ln\, K_e = -\frac{\Delta H^o}{RT} + \frac{\Delta S^o}{R} \qquad (21)$$

Where, ΔH^o is the change in enthalpy (kJ/mol), ΔS^o is the change in entropy (kJ/mol.K), R is gas constant (8.314 J/mol.K), T the absolute temperature (K) and K_e is equilibrium constant, which from the Langmuir isotherm (L/mol). The plot of $ln\, K_e$ versus $\frac{1}{T}$ will give the slope as $\frac{\Delta H^o}{R}$ and the intercept as $\frac{\Delta S^o}{R}$, where upon ΔH^o and ΔS^o are determined. Similarly, the Gibbs free energy change, ΔG^o of the adsorption was obtained from the Eq. 22.

$$\Delta G^o = -RT\, ln\, K_e \qquad (22)$$

The equilibrium constant, K_e, is expressed as the ratio of heavy metal adsorbed onto the clay particles to the concentration left in the liquid solution at equilibrium. This is expressed in Eq. 23.

$$K_e = \frac{C_{ad}}{C_s} \qquad (23)$$

Where, C_{ad} = Concentration of metal adsorbed by the clay at equilibrium (mg/L), C_S = Concentration of metal left in the solution at equilibrium (mg/L).

RESULTS AND DISCUSSION

The modified clay particle size distribution is shown in Figure 1 and grain size was observed in the range of 0.075-4.75 mm. The cumulative percentage fines (*f*) ranged between 6.04% for sieve number 200 (0.075 mm particle size) to 100% for sieve number 4 (4.75 mm particle size). The highest mass of particles retained on the sieved was 124.16 g in sieve number 40 (0.425 mm grain size), while the least was 26.25 g in sieve number 10 (2.00 mm grain size).

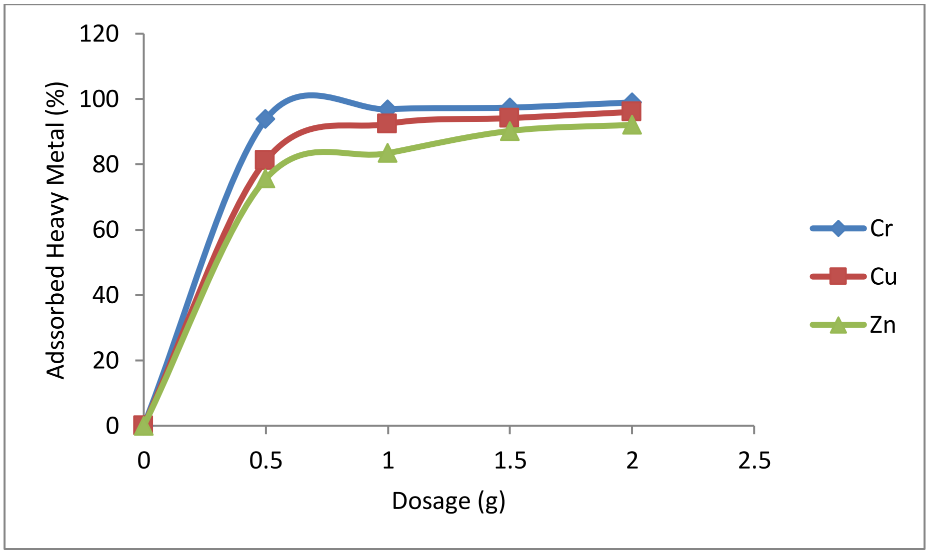

Fig. 3: Heavy metal removal at various doses of clay minerals

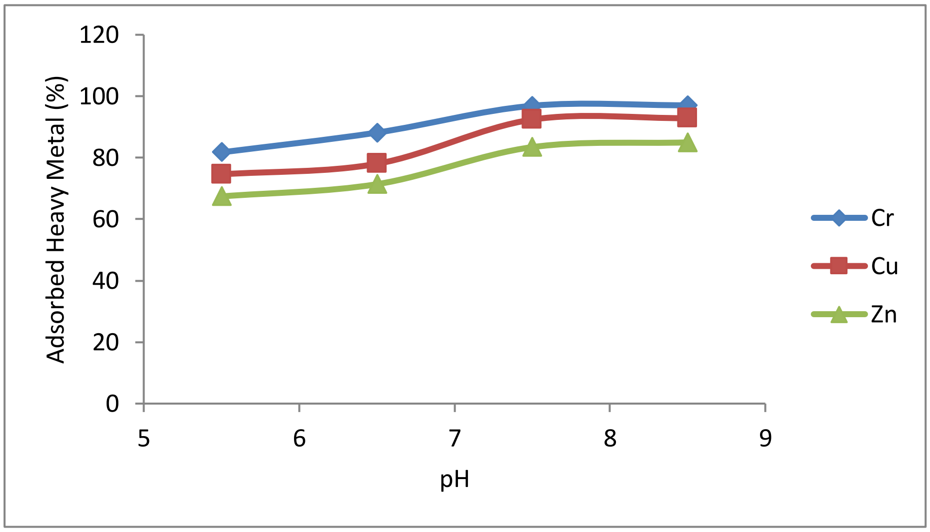

Fig. 4: Heavy metal ion removed at various solution pH

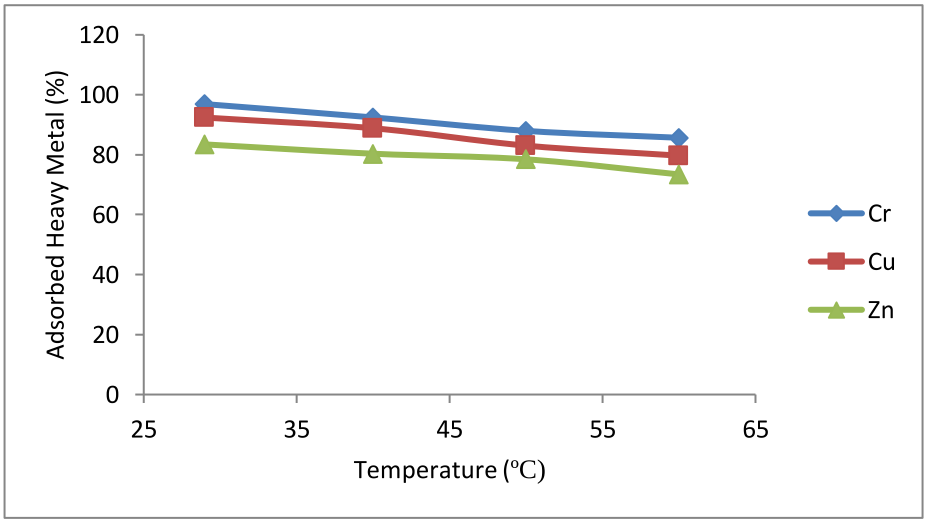

Fig. 5: Heavy metal removal at various temperatures

Figure 2 shows the FTIR spectra of modified clay sample. Various number of adsorption bands are displayed, which signified the presence of several functional groups on the clay surface. From the spectra analysis, bands at 3726.60 cm^{-1} represent medium and sharp absorption bands that are freely bonded; 3595.43 cm^{-1} and 3232.80 cm^{-1} represent strong and broad absorption bands that were inter-molecularly bonded; and 3109.35 cm^{-1} and 2847.03cm^{-1} represent strong and broad absorption bands that were intra-molecularly bonded respectively.

The percentage of chromate (VI) ion (Cr^{6+}), copper (II) ion (Cu^{2+}) and zinc (II) ion (Zn^{2+}) removed from the natural well water by the modified clay particles (adsorbent) are shown in Figure 3. From the profiles, increase in adsorbent dosage increased the percentage of the heavy metal ions removed. The percentages of the selected heavy metal ions adsorbed onto the modified clay after 60 minutes, from 0.5 to 2.0g adsorbent dosage, ranged from 93.79 to 98.98% for Cr^{6+}, 81.21 to 96.06% for Cu^{2+} and 75.60 to 92.12% for Zn^{2+}. From the amount of heavy metals removed, it showed that Cr^{6+} was the most adsorbed onto the modified clay particles, and it was followed by Cu^{2+} and least in Zn^{2+}. This implied that chromium ion has more affinity to the modified clay adsorbent than the other two metal ions.

The profiles of pH effect on the removal of Cr^{6+}, Cu^{2+} and Zn^{2+} are shown in Figure 4. From the profiles, increasing the solution pH equally increased the percentage of the heavy metal ion removed. Thus, the percentage of Cr^{6+} adsorbed from the well water onto the clay particles at pH of 5.5 to 8.5 ranged from 81.74 to 97.05%, that of Cu^{2+} increased from 74.58 to 92.87%. Also, from pH of 5.5 to 8.5, the percentage of Zn^{2+} adsorbed from the well water onto the clay particles increased from 67.40 to 84.99%. It was observed that there was no significant increase in the percentage of the metals adsorbed from the solution after pH of 7.5.

The effect of temperature on Cr^{6+}, Cu^{2+} and Zn^{2+} adsorption onto the clay particles is shown in Figure 5. Experimental analysis showed that the percentage of Cr^{6+},

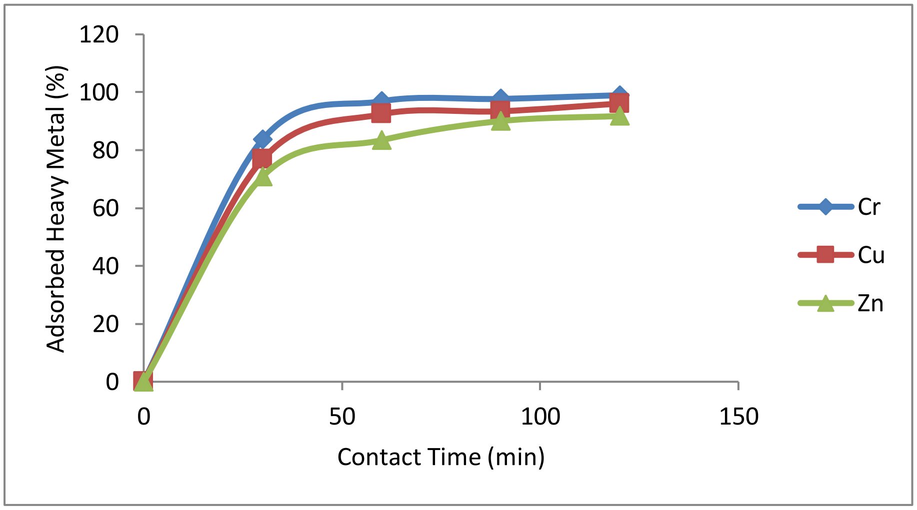

Fig. 6: Heavy metal removal at various contact times

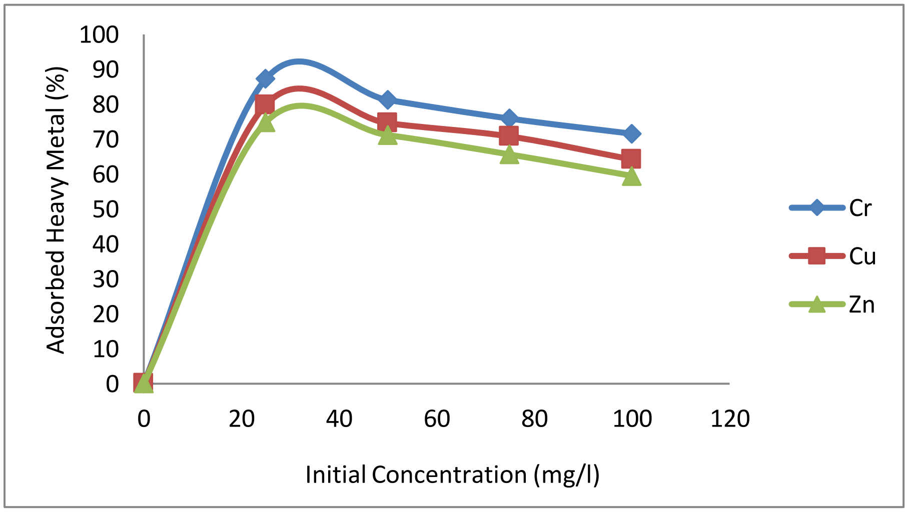

Fig. 7: Heavy metal removal at various initial concentrations

Cu^{2+} and Zn^{2+} adsorbed slightly decreased as temperature was increased from 29 to 60 ºC. Thus, increase in well water temperature from room temperature to 60ºC resulted to decrease in the percentage of Cr^{6+}, Cu^{2+} and Zn^{2+} adsorbed onto the clay particles from 96.89–85.66%, 92.40–79.70% and 83.44–73.44%, respectively.

The profiles indicating the effect of contact time on the adsorption of Cr^{6+}, Cu^{2+} and Zn^{2+} from the well water onto the clay particles is shown in Figures 6. As indicated in the figure, the percentage of Cr^{6+}, Cu^{2+} and Zn^{2+} adsorbed by the clay particles increased with increase in contact time, which was rapid within the first 30–40 minutes. The percentages of metal adsorbed as contact time was increased from 30 to 120 minutes ranged from 83.6998.98% for Cr^{6+}, 76.79–96.10% for Cu^{2+} and 70.89–91.80% for Zn^{2+}. From the study analysis, the adsorption of Cr^{6+} and Cu^{2+} onto the clay mineral reached equilibrium at about 60 minutes, while that of Zn^{2+} reached equilibrium at about 90 minutes.

The profiles of percentage removal of Cr^{6+}, Cu^{2+} and Zn^{2+} at initial metals concentration of 25 to 100mg/l is shown in Figure 7. From the profiles, increase in initial concentration of the metals decreased the percentage Cr^{6+}, Cu^{2+} and Zn^{2+} removed from the aqueous solution. The results showed that percentages of metal adsorbed as initial concentration increased from 25 to 100mg/l, decreased from 87.24 to 71.57% for Cr^{6+}, 79.84–64.19% for Cu^{2+}, and 74.87–59.50% for Zn^{2+}. The specific adsorption decreased at 25 mg/l initial concentration, after 120 minutes, are 3.19 mg/l, 5.04 mg/l and 6.28 mg/l, while at 100 mg/l initial concentration the specific adsorption decreased to 28.43 mg/l, 35.81 mg/l and 40.50 mg/l for Cr^{6+}, Cu^{2+} and Zn^{2+}, respectively.

Modified clay is a type of clay that has been chemically or physically altered to enhance its adsorption properties, particularly for the removal of heavy metals from various environmental sources. The modification process involves treating the clay with specific compounds or techniques to increase its surface area, porosity, and affinity for heavy metal ions (Kausar et al., 2019; Kausar et al., 2022; Kausar et al., 2020; Nausheen et al., 2020). The modified clay materials obtained through this technique exhibit enhanced adsorption capabilities, selectivity, and stability, making them effective for the removal of heavy metals from contaminated water, soil, or industrial effluents. The choice of modification method depends on the target heavy metal contaminants, their concentration, and the specific application requirements (Awwad et al., 2020; Awwad et al., 2021; Chikwe et al., 2018; Jennifer and Ifedi, 2019). Modified clay has gained significant attention for its potential in wastewater treatment due to its excellent adsorption properties and low cost. Modified clay can effectively adsorb heavy metal ions present in wastewater. The modified clay's increased surface area and enhanced affinity for heavy metals enable it to trap and immobilize the contaminants. Common modifications, such as acid treatment or ion exchange, enhance the clay's adsorption capacity, making it suitable for treating industrial wastewater containing heavy metals like lead, cadmium, mercury, and chromium. Modified clay-based adsorbents offer several advantages in wastewater treatment, including high adsorption capacity, low cost, and ease of regeneration. However, the specific choice of modified clay and its modification method depends on the target pollutants, wastewater characteristics, and treatment objectives. Extensive research is ongoing to develop and optimize modified clay materials for efficient and sustainable wastewater treatment processes (Hacıosmanoğlu et al., 2022; Hnamte and Pulikkal, 2022; Najafi et al., 2021; Sanavada et al., 2023; Sharifian et al., 2023).

CONCLUSIONS

The pollution of well water used for domestic purpose can be detrimental to human health. Hence, protection of such waters against contamination is crucial, though, seemed difficult due week monitoring. Therefore, this study investigated the performance of modified clay sample, obtained from Gure Community in Khana Local Government Area of Rivers State, as adsorbent for treatment of heavy metals polluted well water. The study equally fitted experimental data into some adsorption isotherms and kinetics to explain the adsorption of Cr^{6+}, Cu^{2+} and Zn^{2+} ions onto the clay mineral. Preliminary analysis on the water sample showed that the well water was highly contaminated by heavy metals above the maximum limit for drinking water quality. Thereby, justifying the need to be treated and reduced the impact it could cause to innocent rural dwellers.
Also, the modified clay contains several elemental compounds, with 47.16% silicon oxide (SiO_2) as the highest composition and 0.16 % copper oxide (CuO) as the least composition. The particle size distribution analysis showed that the grain size of the clay ranged between 0.075mm and 4.75mm, and the highest mass of particles (124.16g) was retained on sieve no 40 (0.425 mm grain size) representing 58.64% cumulative percent, while the least mass (26.25 g) was retained on sieve no 10 (2.00 mm grain size) with 6.04% cumulative percent. Also, FTIR spectra analysis showed various number of absorption bands signifying the presence of several functional groups on the clay surface that aided its uptake capacity.

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