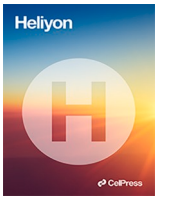
Heliyon 9 (2023) e18634

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



RSM optimization studies for cadmium ions adsorption onto pristine and acid-modified kaolinite clay

L.S. Mustapha [a,*], A.S. Yusuff [b], P.E. Dim [a]

[a] Department of Chemical Engineering, Federal University of Technology Minna Niger State, Nigeria
[b] Department of Chemical Engineering, College of Engineering, Afe-Babalola University Ado-Ekiti, Nigeria

ARTICLE INFO

Keywords:
Kaolinite clay
Cadmium ions
Adsorption
Optimization
Response surface methodology

ABSTRACT

Clay has been reported as an active absorbent for the removal of toxic heavy metals from aqueous medium. In this study, pristine and acid modified kaolinite clays (PKC and AMKC) were prepared, characterized using various analyses, and tested for Cd^{2+} ion adsorption from textile industry wastewater. After acid modification, the specific surface area of clay increased from 84.2 to 389.4 m^2/g. Adsorption isotherm, kinetics and thermodynamics behaviour process were examined. The pH at (pH_{pzc}) of 8.5 indicate that AMKC surface is positively charged for pH below the pH_{pzc} attracting anions. Response surface methodology was used to investigate the effect of adsorption process factors on Cd^{2+} ion removal uptake. At the optimum process conditions of 45.3 °C temperature, 0.63 g/L adsorbent dosage, and 120.9 min contact time, the percentages of Cd^{2+} adsorbed by PKC and AMKC were 77.82% and 99.19%, respectively. Various models were employed to analyzed the kinetic and equilibrium data. The Pseudo-first order, Pseudo-second order and Intra-particle diffusion were used to evaluate the kinetic data, while the Langmuir, Freundlich and Temkin isotherm models were applied to analyzed the equilibrium data. The sorption kinetics was found to be best described by Pseudo-second order considering the high correlation coefficient (R^2), smaller Chi-square ($_\chi 2$) and sum of square error (SSE). The Freundlich model was the most accurate in describing the equilibrium data followed by Langmuir and Temkin respectively. The thermodynamic reveal that the reaction is spontaneous and endothermic in nature, and increase in randomness between the adsorbent and adsorbate. The obtained activation energy (Ea) value suggest that the adsorption mechanism of Cd(II) is a physisorption dominated.

1. Introduction

Water pollution is identified as one of the social issues posing health risks to humans and their environment [1,2]. Water pollution caused by toxic heavy metal discharge from process industries and mining sites is a major concern [3]. Despite being an essential micronutrient, excessive heavy metal intake can have a variety of toxic effects [4]. Cadmium is one of the toxic heavy metals and longstanding environmental contaminants [5]. Numerous process industries such as electroplating, textile, metal plating and battery manufacturing generate huge quantities of wastewater contaminated by cadmium ions (Cd^{2+}) [6,7]. Over the years, the researchers' main focus has been on water, which contains heavy metals because of their negative effects on the environment and humans [8].

* Corresponding author.
E-mail address: mustaphalukman523@gmail.com (L.S. Mustapha).

https://doi.org/10.1016/j.heliyon.2023.e18634
Received 16 March 2023; Received in revised form 15 July 2023; Accepted 24 July 2023
Available online 27 July 2023