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Evaluation of the adsorption efficiency of dolomite from Taza (Morocco) for cadmium removal in aqueous solution: Kinetic and isotherm analysis

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ABSTRACT

The shortage and contamination of water by heavy metals represent a major risk to environment and human health. Many natural adsorbents have been the subject of detailed studies for heavy metal adsorption, thanks to their profitability and high efficiency. In this context, this study aims to evaluate the effectiveness of a material produced from natural dolomite rocks collected around the city of Taza (Morocco) in removing cadmium (Cd) by adsorption, in order to contribute to reducing heavy metal contamination in water. The method is based on the production of an adsorbent from dolomite, whose characteristics were analyzed before and after adsorption using structural methods involving scanning electron microscopy (SEM), X-ray diffraction (XRD), and Fourier transform infrared spectroscopy (FTIR). Moreover, contact time, Cd concentration, temperature, and adsorbent dose were used to evaluate the adsorption efficiency, using kinetic models and adsorption isotherms models. A removal rate (R%) of Cd of 58% was obtained after 80 minutes of adsorption, at an optimal pH of 6, a dose of 5 g/l and an initial Cd concentration of 25 mg/l. The adsorption process was modeled according to the pseudo-second order model, while the adsorption isotherm was more effectively described by the Langmuir model, with a maximum adsorption capacity of 16.60 mg/g. Although the study was carried out under controlled conditions, and the material's long-term stability, its capacity for regeneration and reuse, remain to be determined; this material constitutes practically a sustainable, economical, and environmentally friendly alternative exploiting local natural resources for treating contaminated water. Finally, the geochemical approach and the use of regional resources give these results significant importance for the development of innovative and sustainable decontamination solutions.

Keywords: adsorption, cadmium, dolomite, kinetic, isotherm.

INTRODUCTION

The environment represents the essential basis for the preservation of existence, providing the natural resources, ecosystem services and physical conditions required for the progress of human societies. However, the gradual depletion of non-renewable resources, the increasing pressure from anthropogenic activities, urbanization, mining and growing requirements for sustainability are causing a significant degradation in the quality of natural environments (Sophia and Devi, 2020).

This delicate balance is now threatened by various forms of pollution, notably chemical due to its often invisible impacts that disrupt natural cycles and affect ecosystems and human health (Weldeslassie et al., 2017; Alloway, 2012). Among the pollutants of most concern are heavy metals, substances particularly persistent in the environment.

Heavy metals represent a particular category of inorganic pollutants that are distinguished by their persistence in the environment. Unlike organic pollutants, they do not naturally degrade and accumulate in soils, waters, and food chains (Pujari and Kapoor, 2021). The main heavy metals of concern include lead, mercury, cadmium, arsenic, chromium and zinc. These contaminants mainly come from various natural and anthropogenic sources (industrial discharges, fossil fuel combustion, mineral processing, agricultural emissions) (Jadaa and Mohammed, 2023; Masindi et al., 2021), these elements, such as lead, mercury, arsenic, cadmium and chromium have multiple toxic effects, ranging from physiological disturbances to severe damage to the nervous, renal, and immune systems (Tchounwou et al., 2012).

Among these metals, cadmium (Cd) attracts particular attention due to its high toxicity even at low levels and its dispersion in the environment. The main sectors of its use are nickel-cadmium batteries, pigments, electroplating, and stabilizers (Chiffoleau, 2001). Cadmium enters aquatic environments, soils and the atmosphere (Jaishankar et al., 2014). It can then accumulate in the food chain, notably via agricultural products and fisheries resources. Chronic exposure to cadmium is associated with renal, bone and cardiovascular pathologies, as well as proven carcinogenic effects (Aftab and Waseem, 2025). Moreover, its mobility in the environment and its transfer to living organisms make it a contaminant of priority interest for prevention and depollution policies (WHO, 2025). Cadmium can remain present in the system for several years and has been classified as the seventh most lethal metal (Bayuo, 2021). It is therefore now a real challenge to eliminate this by using ecological and sustainable technologies in order to preserve human and environmental health.

As part of this challenge, heavy metal treatment techniques have progressed, combining efficiency and environmental protection. Among these techniques, physicochemical processes play a crucial role, they encompass various processes based on physical and chemical phenomena to reduce or eliminate these contaminants. These techniques include: coagulation-flocculation, ion exchange, oxidation and reduction, filtration as well as adsorption (Rafique et al., 2022). These techniques are frequently combined in order to optimize the overall treatment performance. Adsorption remains a preferred and most commonly used technique due to its ability to handle a wide variety of pollutants, ease of use, and also efficiency (Baari et al., 2025). This process involves the fixation of molecules or ions (adsorbates) on the surface of a solid material (adsorbent) through physical or chemical interactions (Aljamali et al., 2021). The search for innovative, economical, high-performance and simple to develop materials for the adsorption of various pollutants such as heavy metals has been intensively conducted recently. The heavy metals adsorption on natural mineral surfaces is a fundamental geochemical process. This approach is based on the theory of surface complexation between metals and surface functional groups. The choice of geological rocks, such as limestones, clays, zeolites, and bentonite, proves to be natural materials that perform well for the adsorption of several organic and inorganic pollutants (Ahamad and Nasar, 2024; Aljabarin, 2023; Trach et al., 2022; Hussain and Ali, 2021). The use of geological rocks as natural adsorbents offers a sustainable and economical solution for decontamination, particularly for cadmium.

In this context, the present study aims to evaluate and explore the potential of a natural geological adsorbent prepared from dolomite from the region of Taza (Morocco), on the removal of Cd, in order to offer a sustainable and inexpensive alternative to commercial adsorbents. Indeed, these rocks are widely available in nature and constitute sustainable sources for the environment. This study also aims to improve understanding of the molecular mechanisms of adsorption by characterizing the material before and after treatment using SEM, XRD, and FTIR, in order to explain its potential for reducing Cd. In addition, the study seeks to develop a predictive model based on kinetic and adsorption isotherm models to anticipate the performance of the material under various conditions. By filling a gap in the field concerning the efficiency, sustainability, and regeneration of natural adsorbents derived from local resources, this research contributes to offering an environmentally friendly, inexpensive, and potentially renewable alternative to commercial materials. The

underlying assumptions are that this material can offer significant adsorption capacity, that it can be effectively regenerated, and that it is a sustainable solution for treating contaminated water, with performance that can be optimized through in-depth analysis of operating parameters.

MATERIALS AND METHODS

Preparation of materials

The dolomite rock used in this study was collected around Taza city, Morocco [X (-4.10637); Y (34.0891); Z (1383.3)]. The preparation of material from this rock by physical processes involves several steps.

The collected dolomite was first cleaned and dried, then crushed using a Fritsch Pluverisette 1 jaw crusher. After being ground in a ball mill, the material obtained was sieved into particles of less than 100 µm and dried at 60 °C for several hours. The material produced from dolomite was named DM-1 (Figure 1). The characterization of DM-1 was carried out using: SEM identified by the SEM Quanta 200 equipped with a tungsten filament electron gun; the XRD method realized by the XPERT-type XRD-PRO in a scanning area ranging from 5 to 120° 2θ and the FTIR spectroscopy achieved in the mid-infrared domain using a Vertex 70 spectrometer, at the "Cité d'Innovation" of the University of Sidi Mohamed Ben Abdellah (USMBA) - Fez.

Adsorbate preparation

The Cd stock solution was obtained by dissolving 10 g of cadmium sulfate octahydrate ($3CdSO_4.8H_2O$) in 1 liter of distilled water (Touzani et al., 2024). The preparation of a cadmium (Cd) daughter solution (25, 50 and 100 mg/l) consists of precisely diluting the stock solution with distilled water until the desired final volume is reached.

Experimental adsorption of Cd

In order to evaluate the effectiveness and performance of DM-1 material for Cd removal, in a closed reactor, 50 ml of the Cd solution (50 mg/l) was brought into contact with 5 g/l of DM-1, the solution was stirred at 300 rpm. After 300 minutes of contact, the suspension was centrifuged at 5000 rpm for 10 minutes. The Cd concentration was determined by inductively coupled plasma mass spectrometry (ICP-AES) at the "Cite d'Innovation" in Fez.

Contact time's effect

The contact time effect of Cd removal was investigated for 20–300 min of contact for each of the initial concentrations (25, 50, and 100 mg/l) in the presence of 5 g/l of DM-1 at room temperature under stirring at 300 rpm. After every 20 min of contact, the suspension was centrifuged 5 min at 5000 rpm. The removal efficiency R (%) and adsorption capacity q_e (mg/g) were calculated using the following Equations 1 and 2.

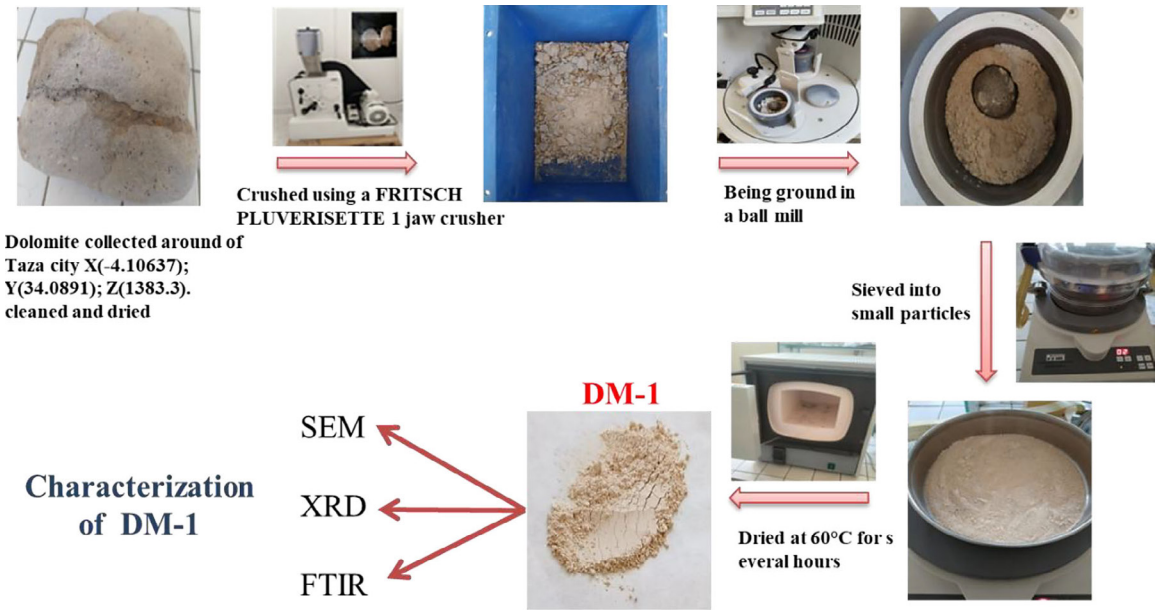

Figure 1. Prototype for preparation and characterization of the DM-1 material

$$R(\%) = \frac{Ci-Ce}{Ci} \times 100 \quad (1)$$

$$qe = \frac{(Ci-Ce)}{m} \times V \quad (2)$$

where: C_i and C_e are the initial and equilibrium concentrations of Cd in the liquid phase, respectively (mg/l), V is the solution volume (l) and m is the mass of dry adsorbent (g).

Effect of Cd initial concentration – Cd solutions at initial concentrations of 25, 50, and 100 mg/l were prepared. Each solution was added to DM-1 (5 g/l), in a flask, then stirred at a constant speed of 300 rpm for 60 minutes.

Effect of pH

pH is an important factor affecting the adsorption process. The pH of the solutions was adjusted between 2 and 10 with HCl (0.1 M) or NaOH (0.1 M) solutions. A Jenco Microcomputer PH/MV/TEMP pH meter (meter MOD 6171) was used to determine the pH values. A quantity of 5 g/l of DM-1 was added to a 50 mg/l Cd solution and stirred for 60 minutes.

Effect of DM-1 dosage

In order to evaluate the effect of the DM-1 dose on the Cd adsorption process. Different quantities varying between 1 and 10 g were carried out, each being individually mixed containing Cd (50 mg/l) pH at a 6 and temperature of 25 °C for a duration of 60 minutes. After this period, the mixture was separated, and the Cd concentration was measured by the above methods.

Effect of temperature

The effect of temperature on cadmium adsorption by DM-1 material was examined by performing the same experiments at different temperatures (25, 30, and 40 °C). The temperature varied while keeping the other parameters constant (pH at 6, Cd concentration at 50 mg/l, DM-1 dose at 5 g/L, contact time at 60 minutes and stirring speed at 300 rpm). These studies make it possible to determine if the adsorption is endothermic or exothermic, which is essential for understanding the nature of the interaction mechanism between cadmium and the adsorbent material.

Adsorption kinetic and isotherm models

In the aim to optimize the design and deepen understanding of the Cd removal process by DM-1, it is important to understand the adsorption's kinetics and dynamics. Adsorption kinetics aims to determine the rate at which Cd is removed from the solution and to identify the dominant mechanism (physisorption or chemisorption) through models such as pseudo-first-order or pseudo-second-order models. Table 1, summarizes the expression of the pseudo-first-order and pseudo-second order linear equations used in this work (Fayoud et al., 2015; Achak et al., 2014). On the other hand, the adsorption isotherm describes the relationship between the quantity of Cd adsorbed per unit mass of material and its concentration in solution when the adsorption process reaches a state equilibrium. This makes it possible to determine the maximum adsorption capacity of the material and to evaluate the nature of the interaction between the adsorbent and the adsorbate (Amrutha et al., 2023). In this work, the Langmuir and Freundlich isotherms are used according to their mathematical model (Table 1) (El Khomri et al., 2020; Nourmoradi et al., 2016).

The parameters of the kinetic models: q_e and q_t are the adsorbed quantities (mg/g) and k_1 is the pseudo-first order equilibrium rate constant (min^{-1}), k_2 is the pseudo-second order adsorption rate constant (g/mg.min).

The parameters of the isotherm models were: C_e (mg/l) the adsorbate concentration in the liquid phase at equilibrium; q_e (mg/g) the adsorption capacity at equilibrium; q_{max} (mg/g) maximum

Table 1. Linear equations and plot representation for kinetic and isotherm models

Model	Equation	Representation plot
Kinetic		
Pseudo-first order	$log\ (q_e - q_t) = log\ q_e - K_1\ t$ (3)	Log (qe – qt) versus t
Pseudo-second order	$\frac{t}{q_t} = \frac{1}{K_2 q_e^2} + \frac{t}{q_e}$ (4)	Log qe versus log Ce
Isotherm		
Langmuir	$\frac{C_e}{q_e} = \frac{1}{K_L q_{max}} + \frac{C_e}{q_{max}}$ (5)	Ce/qe versus Ce
Freundlich	$log\ q_e = log\ k_f + \frac{1}{n} log\ C_e$ (6)	Log qe versus log Ce

adsorption capacity; K_L, K_f and n are constants of Langmuir and Freundlich model.

The adsorption characteristics of the Langmuir isotherm can be explained in terms of a non-dimensional constant R_L (Harrache et al., 2019), which is defined as follows:

$$R_L = \frac{1}{1 + K_L.C_e} \quad (7)$$

The R_L factor indicates whether the adsorption process is favored or not. Hence, when $0 < R_L < 1$, adsorption is considered favorable. It is irreversible for $R_L = 0$, unfavorable for $R_L > 1$, and linear when $R_L = 1$ (Ayawei et al., 2017).

RESULTS AND DISCUSSION

Characterization results

Scanning electron microscopy (SEM)

The SEM analysis is used to determine the external pore structure and morphological changes in the material studied before and after the adsorption process (Figure 2). Before adsorption process, as shown in Figure 2 (A, B), the DM-1 material has a partially heterogeneous surface with a microporous structure of different sizes and rhombohedral shapes, as well as the appearance of partitions and dolomite crystals due to the presence of calcite inclusions. These results are consistent with previous studies (Sackiran and Esen, 2024; Leng et al., 2021). In addition, the presence of various pore diameters that can be identified as transparent areas clearly highlights the multitude of micropores on the dolomite surface. This essential textural feature provides a large surface area for adsorption (Leng et al., 2021). After adsorption, the DM-1 material underwent a modification of surface after interaction with Cd. Figure 2 (C, D) reveals an increase in roughness or the formation of thickened deposits on the surface of the sample, indicating the fixation of Cd. However, these results show a structural and chemical transformation after the adsorption process, confirming the removal efficiency of Cd on DM-1.

X-ray diffraction

X-ray diffraction (XRD) is used to identify the crystalline or amorphous structure of materials. Before adsorption, Figure 3.A, DM-1 allows the identification of the dominant crystalline peaks of dolomite $CaMg(CO_3)_2$, accompanied by secondary minerals such as calcite ($CaCO_3$) and possibly quartz (SiO_2) (Sackiran and Esen, 2024; Diwan et al., 2020; Baali, 1998). This identification is supported by the high intensity at 26.65°

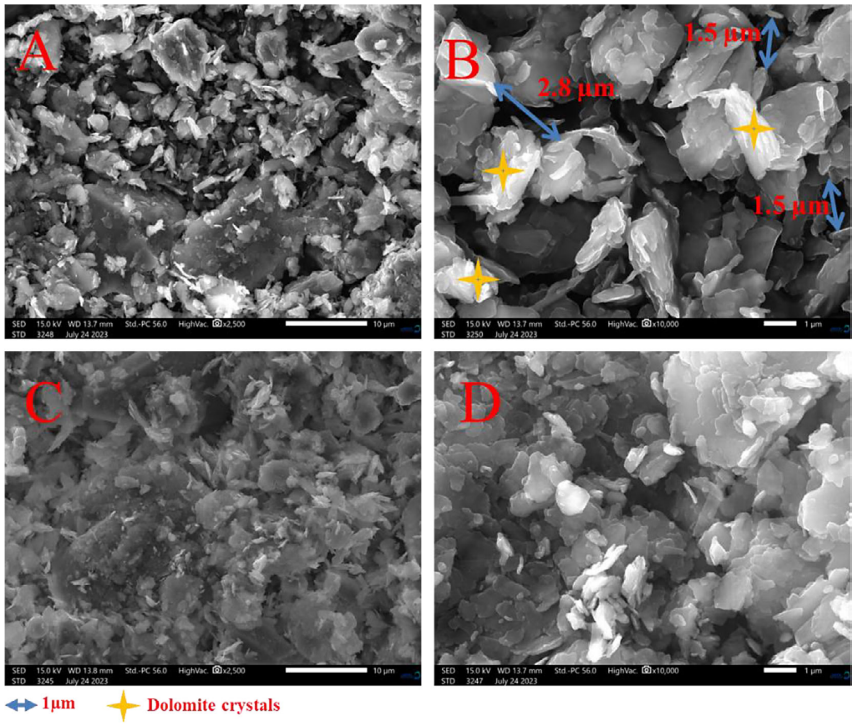

Figure 2. Image of DM-1 observed by scanning electron microscopy (SEM) before (A, B) and after (C, D) Cd adsorption

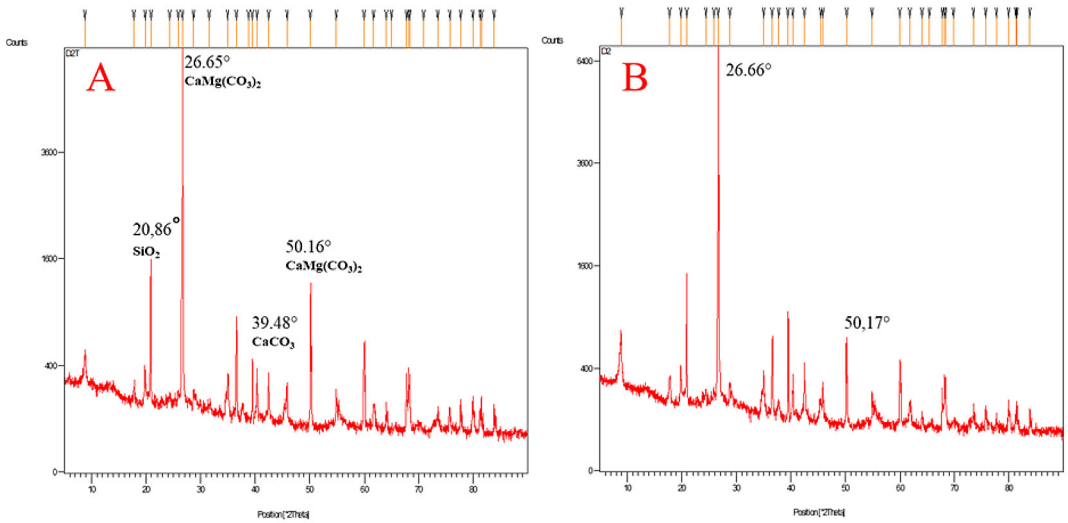

Figure 3. Image of DM-1 observed by DRX before (A) and after (B) Cd adsorption

and the presence of a marked secondary peak at 50.16°, which are attributed to dolomite. Furthermore, weak to moderate peaks at 39.48° and 40.30° suggest the presence of calcite ($CaCO_3$). This result also indicates the minor presence of quartz SiO_2, justified by the low intensity of the 20.86° peak. After adsorption, Figure 3.B shows a slight attenuation or displacement of certain peaks, indicating a chemical or physical interaction with Cd. The main peak is always located at 26.66°, indicating that DM-1 retains its structural dominance after interaction with Cd. In addition, certain peaks have undergone an increased variation in intensity, particularly the 39.49° peak. On the other hand, the increase in peaks at 36.57° and 50.17° and the appearance of other minor peaks indicate possible adsorption or interaction with Cd, partially modifying the mineral surface. In some cases, a reduction of crystalline order or partial amorphization may also be observed due to metal fixation and alteration of the initial DM-1 structure. However, these results reveal that DM-1 material produced from dolomite rock acts as an adsorbent capable of effectively trapping Cd ions present in the solution.

FT-IR analysis

Fourier transform infrared spectroscopy (FTIR) is a standard analytical method for identifying and characterizing carbonate minerals. The adsorption spectra of the two samples, before and after adsorption, are presented in Figure 4. Before

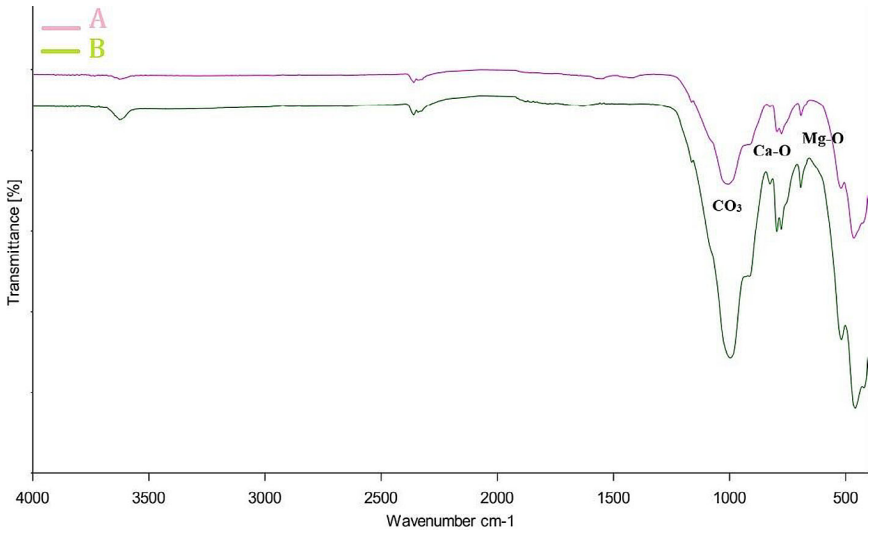

Figure 4. Image of DM-1 observed by FTIR spectrum before (A) and after (B) Cd adsorption

adsorption, the FTIR spectrum of DM-1 (Figure 4-A) shows a broad band between 1050–950 cm^{-1} corresponding to the elongation vibration of the carbonate group CO_3^{2-}. The low to medium intensity peaks observed between 800–500 cm^{-1} fit with vibrations of the Ca-O and Mg-O bonds. These results are similar to previous studies (Sočo et al., 2023; Stanienda-Pilecki, 2019; De Lorenzi et al., 2017). After Cd adsorption (Figure 4-B), the spectrum reveals the displacement and intense variations of certain peaks, indicating chemical or physical interactions between Cd and the functional groups present. These variations observed both on the intense and wide peak at 1000 cm^{-1} and between 800–500 cm^{-1}, suggest that other bonds are formed at the reactive sites of the DM-1 material produced from dolomite during the adsorption process. However, this analysis provides evidence of chemical modifications within the material, confirming the interaction mechanisms that are essential for understanding the nature of Cd adsorption by DM-1.

Results of experimental absorption

Contact time's effect

The effect of contact time on the adsorption of cadmium (Cd) by a dolomite-based material is a crucial parameter for optimizing the adsorption process. This effect time was analyzed using an aqueous solution of different Cd concentrations (25, 50 and 100 mg/l) in the presence of 5 g/l of DM-1 over a period of 300 min (Figure 5). The results show that after 80 minutes of adsorption on DM-1, the Cd reduction rate (R %) is between 42 and 52%. Moreover, the adsorption curves show similar patterns for the different concentrations, starting with an initial phase of about 60 minutes, where the removal efficiency is about 30 to 47%, during which a rapid adsorption rate was observed. This is attributed to the existence of a pronounced concentration gradient between Cd ions in solution and available adsorption sites on the surface (Bayuo, 2021). This phase is followed by a gradual slowdown phase as the available sites become saturated. Then an equilibrium phase was reached after about 80 minutes, with final efficiencies of 53 to 58%. This kinetics suggests a physicochemical adsorption mechanism involving first the occupation of the most energetic sites, followed by intraparticulate diffusion. On the other hand, it is crucial to examine the adsorption's dynamics and equilibrium to understand the transfer mechanism between liquid and solid.

Effect of Cd initial concentration

The initial concentration is considered one of the most important parameters that can affect the adsorption process. Figure 6, shows that when the initial concentration increases from 25 to 100 mg/l, the adsorption capacity by DM-1 tends to increase proportionally due to the availability of adsorption sites, facilitating effective Cd fixation. Similarly, the abatement rate (R%) varies from 53% to 58% in the Cd concentration range studied. However, as the initial concentration increases, the gradual saturation of available sites reduces the adsorption efficiency, which may lead to a lower percentage removal capacity, even if the adsorption capacity continues to increase. This phenomenon highlights the need to further study adsorption isotherms, such as Langmuir or Freundlich, which describe

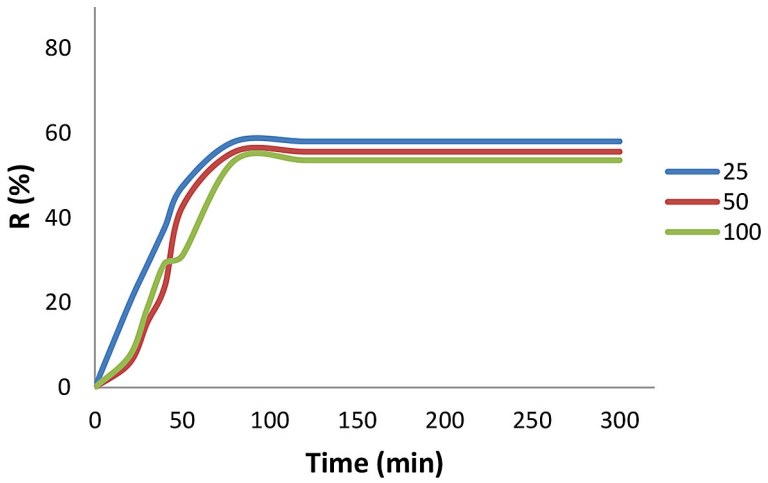

Figure 5. Effect of contact time on Cd adsorption to DM-1

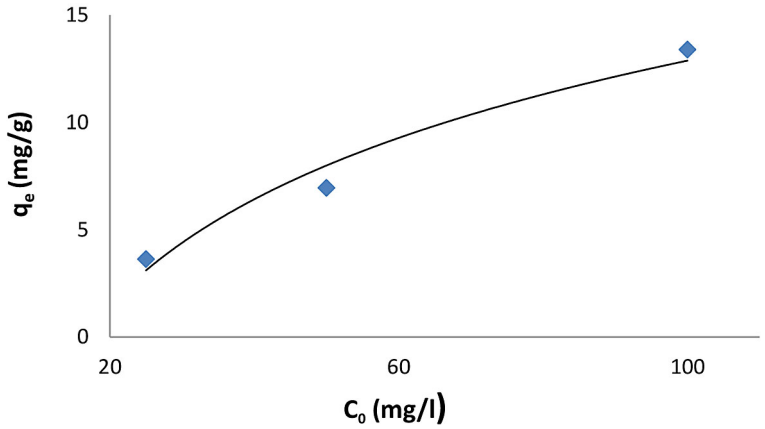

Figure 6. Effect of concentartion intial C_0 on Cd adsorption to DM-1

adsorption processes and optimal conditions conducive to ideal adsorption. In addition, interaction with other ions present, the solution pH and the potential for Cd precipitation must be taken into account to perfect the reduction process. Thus, a concentration of 50 mg/l of Cd was chosen for the subsequent experiments.

Effect of pH

The solution's pH significantly affects heavy metal removal processes. The effect of pH, from 2 to 10, on the adsorption mechanism was examined at room temperature. Figure 7 shows the effect of pH on Cd adsorption by DM-1. These results reveal that the adsorption capacity (q_e) of Cd increases significantly as the pH increases. In an acidic medium, the Cd adsorption capacity has decreased because the surface of DM-1, which is mainly composed of negatively charged $CaMg(CO_3)_2$, favors the fixation of hydronium ions H^+ compared to Cd ions through the effect of electronegativity. However, when pH increases the electrostatic attraction towards depleted hydronium ions H^+, which makes cadmium ions more attracted to the surface of the material and allows them to bind to the active sites of the adsorbent (Chen et al., 2011). However, the highest adsorption capacity (8.14 mg/g) was observed at a pH between 6 and 8, and this value was selected as an optimal pH condition for subsequent experiments.

Effect of DM-1 dosage

The effect of the adsorbent dose, in this case a dolomite-based material, on cadmium (Cd) removal is a key parameter to optimize the adsorption process. Figure 8, shows the effect of the amount of adsorbent varying from 1 to 10 g/l, for a contact time of 60 minutes, a pH of 6 and a temperature of 25 °C. The Cd removal rate (R%) was increased by 12% to 48%, with the increase in the dosage of DM-1 from 1 to 5 g/l. A gradual increase in the dose of DM-1 results in an increase

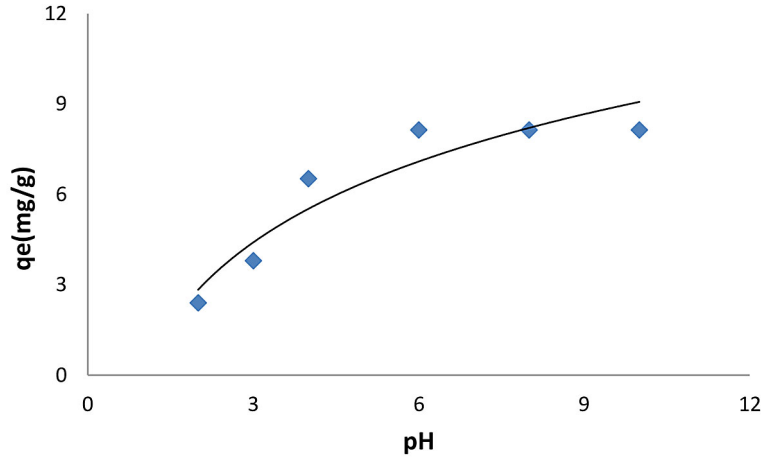

Figure 7. pH effect on Cd adsorption on to DM-1 (Ci = 50 mg/l; m = 5 g/l; t = 60 min)

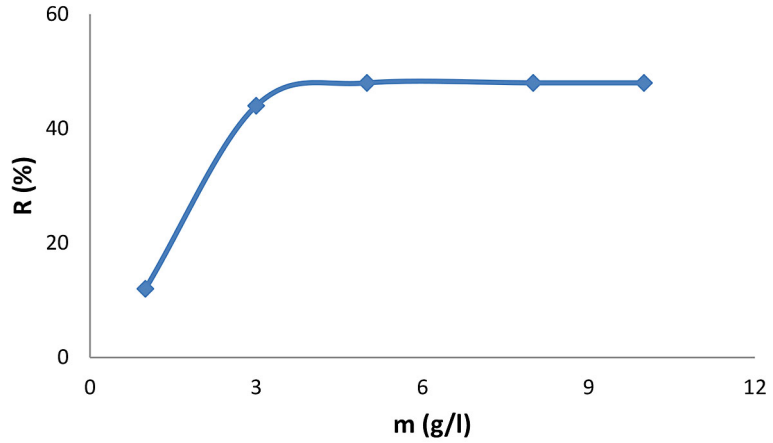

Figure 8. Effect of adsorbent dosage on Cd adsorption on to DM-1. (Ci = 50 mg/l; pH = 6; T = 25 °C; contact time = 60 min)

in the total amount of Cd adsorbed, due to the increase in the number of available adsorption sites (Burham and Sayed, 2016). However, above 5 g/l, the dose effect tends to stabilize, indicating a saturation of available adsorption sites (Dim and Termtanun, 2021). Moreover, a significant adsorbent amount can also cause problems during the material separation, without providing a significant increase in efficiency. In addition, too much adsorbent can cause particles to clump together, thereby reducing the surface area available for adsorption. Thus, an optimal dosage of 5 g/l of adsorbent was selected for further research.

Effect of temperature

The temperature of the solution influences both the adsorption capacity and the rate of fixation of the adsorbate on the adsorbent. The effect of temperature on Cd removal was examined at different temperatures (25, 30 and 40 °C), while keeping other parameters constant. Figure 9, shows a slight increase in Cd removal rate from 60% to 70%, when the temperature increases from 25 °C to 40 °C. This increase in Cd removal efficiency suggests that the adsorption process is endothermic, where thermal energy promotes ion dispersion and accessibility of adsorption sites (Abbou et al., 2021; Ozdes et al., 2011). Moreover, a higher temperature can also accelerate the adsorption kinetics, thereby reducing the time required to reach equilibrium.

Adsorption kinetic and isotherm models

The kinetic study of adsorption delivers information on the adsorption mechanism and the transfer mode between liquid/solid. Different models can be operated to test the kinetics of

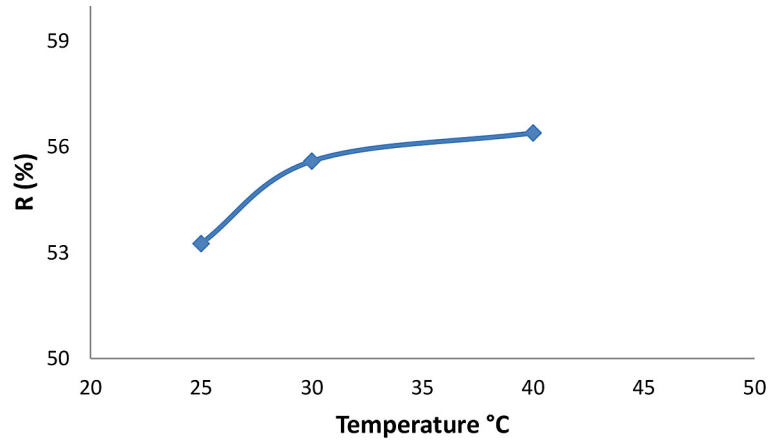

Figure 9. Effect of temperature on adsorption of Cd on to DM-1. (Ci = 50 mg/l, pH = 6, m = 5 g/l, contact time = 60 min)

adsorbent interactions. The pseudo-first order and the pseudo-second order equations (Table 1) were used to understand the mechanism of kinetic data as a function of time. As shown in Table 2, the coefficient of determination R^2 for the second-order model of 0.95 is higher than that of the pseudo-first order model of 0.91, this indicates that the pseudo-second order model more precisely describes the Cd adsorption kinetics on dolomite-based DM-1 material. Indeed, a higher R^2 value indicates that the relationship predicted by the model better corresponds to the experimental data, which suggests that the adsorption process could be regulated by chemically controlled mechanisms, such as the formation of covalent bonds or specific complexes with the adsorbent sites. These results are consistent with subsequent studies for the adsorption of Cd on natural materials (Li et al., 2023; Bayuo, 2021). However, the q_e calculated by the pseudo-first order model is further at the q_{max} of the experimental data with 6.95 mg/g compared to 8.13 mg/g. Similarly, the adsorption process cannot be fitted to the pseudo-first order model if there is a significant deviation between the predicted qe and the experimental q_{max}, even if it has a high R^2 coefficient (Febrianto et al., 2009). This also indicates that chemisorption is the best mechanism that determines the steps of kinetic adsorption reactions. These results have corroborated that the pseudo-second order model is the most appropriate and consistent for Cd adsorption on DM-1.

Table 2. Kinetics models for adsorption Cd on to DM-1

Pseudo-first order				
Metal	qe exp (mg/g)	qe cal (mg/g)	K1 (min^{-1})	R^2
Cd	6.95	8.13	0.013	0.91
Pseudo-second order				
Metal	qe exp (mg/g)	qe cal (mg/g)	K2 (g/mg.min)	R^2
Cd	6.95	7.25	0.010	0.95

Table 3. Isotherm parameters for Cd adsorption on to DM-1

Model	Parameters	Value of parameters
Langmuir	q_{max} (mg/g)	16.60
	K_L (l/mg)	0.021
	R^2	0.99
Freundlich	K_F	2.14
	1/n	0.87
	R^2	0.94

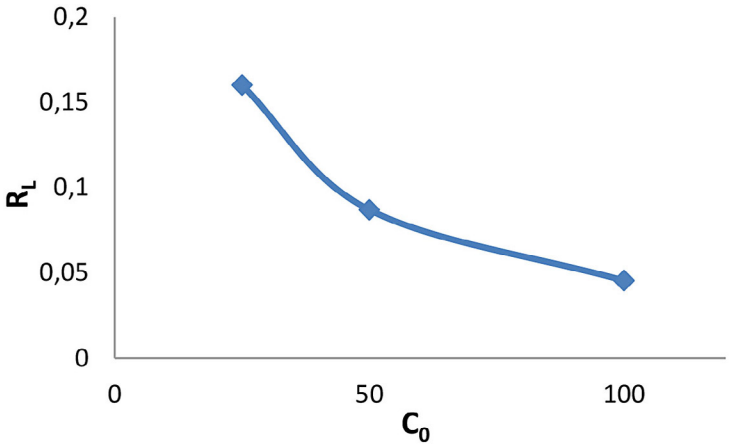

Figure 10. Separation factor (R_L) of the Langmuir isotherm

The Langmuir and Freundlich adsorption isotherms are used to evaluate the adsorption efficiency and performance of the DM-1 studied material. Table 3, presents the experimental K_l, K_f and R^2 data for the Langmuir and Freundlich adsorption models. The correlation coefficient obtained from the Langmuir model (R^2 = 0.99) shows that adsorption occurs preferentially in homogeneous and monolayer active sites with uniform energy levels (Yang et al., 2018), which gives this model a better representativeness of Cd adsorption on DM-1. Similarly, the maximum adsorption capacity q_{max} of 16.6 mg/g reflects the maximum number of sites available for metal fixation on the adsorbent surface. This high value indicates a large adsorption capacity, which suggests that the material is effective for Cd adsorption. Furthermore, the separation factor (R_L) was employed to appraise the adsorption process in the studied system (Figure 10). The data indicate that the R_L values, for the analyzed concentrations, are between 0 and 1, which means a favorable adsorption (Ayawei et al., 2017). The reduction of R_L, linked to an initial Cd concentration raise, suggests that adsorption is more conducive to higher concentrations.

CONCLUSIONS

This study focused on the evaluation of removal using a natural material made from dolomite rock from the region of Taza (Morocco). The rock used for the preparation of the material was crushed, sieved and heated to 60 °C. Characterization by SEM revealed a partially heterogeneous surface, exhibiting a microporous structure of different sizes and shapes. Similarly, these results proved that the cadmium adsorption process was influenced by several factors, including pH, adsorbent dose, contact time, initial Cd concentration and temperature. Kinetic analysis and adsorption isotherms showed that the pseudo-second order model and the Langmuir model best fit the results, respectively. These data indicate that the dolomite based product material possesses both high adsorption capacity and a strong affinity for cadmium, making it a promising option for water treatment applications. Overall, these results confirm the relevance of using natural dolomite-based materials for environmental remediation, especially in contexts requiring efficient and economical cadmium removal.

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