Evaluation of slay composition in the sediments of the Mohamed Ben Abdelkrim El Khattabi Dam, Beni Bouayach, Northern Morocco

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Abstract. This research analyses and identifies clays from the Mohamed Ben Abdelkrim El Khattabi dam in Beni Bouayach, northern Morocco, to assess their suitability for various applications. The study employed X-ray diffraction (XRD), X-ray fluorescence, infrared spectroscopy, and physicochemical methods. Elemental analysis revealed high silicon and calcium levels alongside iron, aluminum, potassium, titanium, sulfur, manganese, and trace amounts of zinc, nickel, and chromium. These components suggest a clay composed mainly of montmorillonite, calcite, and quartz. The physicochemical characteristics included a neutral pH of 7.6, an average density of 2.04 g/cm³, a 16.01% moisture content, a swelling index above 0.65%, and a 0.64% loss on ignition. The XRD results support these findings. Infrared spectroscopy shows two prominent absorption bands: one at 3620 cm^{-1}, linked to the -OH group, and another indicative of SiO_4 and AlO4 tetrahedral units at approximately 400 cm^{-1} and 600 cm^{-1}, respectively. The comprehensive analysis of this study reveals the clay composition and provides valuable insights into its potential industrial applications. Various elements and specific physicochemical properties suggest that these clays could be valuable in industries requiring specific mineral compositions and characteristics. This work lays the groundwork for future exploration and exploitation of these natural resources, highlighting their potential in diverse fields. **Keywords:** Clay, Valorization, characterization, Dam's Sediments, X-ray diffraction

1 Introduction

The risk of siltation of dams is a global problem [1-3]. The sedimentation of sludge in the Mohamed Ben Abdelkrim El Khattabi dam in Morocco has become a crucial issue in recent years. Due to irregular rainfall and soil erosion in the area, the dam gradually accumulates large amounts of sludge, mainly composed of clays. This accumulation threatens the dam's useful storage capacity, which can negatively impact the drinking water supply and agricultural irrigation. In addition, the clays present in the mud are rich in potentially valuable minerals, such as kaolinite and montmorillonite, which can be recovered [4,5] and used in several fields, thus offering economic and environmental opportunities. Among the areas of the valorization and use of clays are the ceramics industry, the construction industry, the cosmetic and pharmaceutical industry, the oil drilling institute, agriculture, wastewater treatment, the composite materials industry, and the chemical industry. Before proceeding to the valorization or use of these clays, characterization is necessary to determine the favorable conditions in which we will have a better use. In this context, these clays have been characterized by adopting the parameters, such as (i) Physicochemical parameters: temperature, acidity, humidity level, fire loss, and swelling index; and (ii) IR-spectroscopy, X-ray diffraction (XRD), and X-ray fluorescence were used to determine the mineralogical composition of our clay sample.

2 Sampling of adsorbent materials

The study area is situated in the northern central region of Morocco, along the Mediterranean coast, encompassing an area of approximately 3,550 km^2. This region is predominantly marked by varied topography, with slopes ranging between 10% and 40%, alongside 12,000 hectares of plains. Geographically, it is bounded to the west by Chefchaouen and Taounate, to the east by Nador, and the south by Taza. This area's northern boundary extends 120 kilometers from the Mediterranean coastline [6-8].

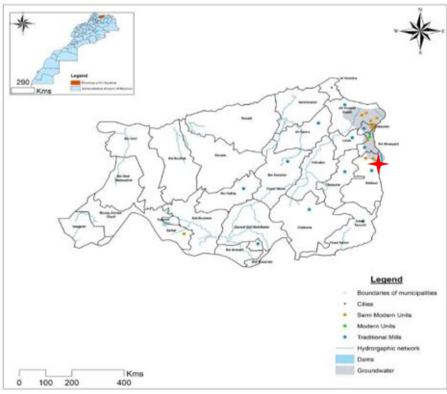

Fig. 1. Location of Mohamed Ben Abdelkarim El Khattabi Dam [6].

The samples were immediately transported to the laboratory, decontaminated with HNO_3 in 24 hours, and

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stored in a refrigerator (04°C). Within the laboratory, the samples were divided into two parts according to the analyses to be adopted: one part was in a fresh state, and the other was dried and preserved. The clay sample was dried at 80 °C for 24 h, crushed, and sieved. The sampling was carried out at the Mohamed Ben Abdelkarim El Khattabi dam, located southeast of Bled Nekkor and north of Chaabat Imoula in Beni Bouayache in Morocco. Initially, we set five different sampling points since, in this work, we tested the adsorption capacity of Mohammed Ben Abdel Karim el Khattabi dam sediments (clay) for removing organic matter from olive oil wastewater. After the particle size, the station mentioned in Figure 1 was fixed, located downstream of the Mohamed Ben Abdelkarim AL Khattabi dam near gate number 1 because of the quantity of clays it contains.

3 Results and discussion

3.1 Physicochemical Parameters

The physicochemical results are presented in Table 1.

Table 1. Characterization of the adsorbent material.

Parameter	Value
Temperature (°C)	17
Acidity	7.6
Humidity (%)	16.01
Density (g/cm^3)	2.04
Swelling index (%)	0.65
Loss to fire (%)	0.64

For this physicochemical analysis, a pH equal to 7.6 was obtained, with an average density of 2.04 (g/cm^3), a humidity of 16.01%, a swelling index exceeding 0.65%, and a fire loss percentage of 0.64%.

3.2 X-ray Diffraction Analysis

X-ray diffraction (XRD) allowed us to identify the different components present in our clay sample. The diffractogram obtained is shown in Figure 2.

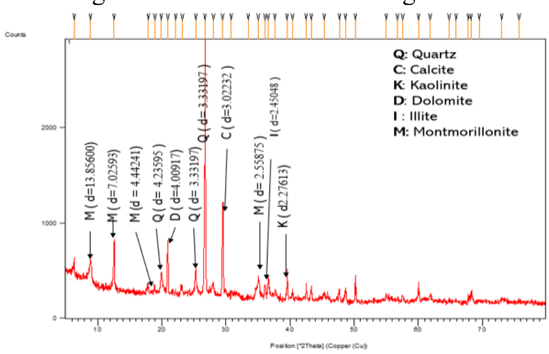

Fig. 2. The diffractograms of the clays studied.

The diagram shows peaks at 2θ~6.5, 2θ~13.5, 2θ~20, and 2θ~2θ~36, which may be due to reflections of the Montmorillonite phase [9], and the peaks at 2θ~30 and 2θ~37 may reflect the presence of the calcite phase. The peaks at 2θ~21 and 2θ~27 may be due to the quartz phase [10]. Other clay groups may be present in our sample, such as dolomite at 2θ~22° and kaolinite at 2θ~38° [11].

Table 2. The table of remarkable peaks in our sample.

Position [°2Th.]	Peak intensity	d- [Å]	Rel. Int. [%]	Phase
6.3791	161.80	13.8560	6.76	Montmorillonite
12.5887	444.55	7.02593	18.56	Montmorillonite
19.9708	173.27	4.44241	7.24	Montmorillonite
20.9549	481.36	4.23595	20.10	Quartz
22.1951	43.45	4.00197	1.81	Dolomite
23.1948	94.07	3.83170	3.93	Montmorillonite
26.7336	2394.65	3.33197	100.0	Quartz
29.5318	944.67	3.02232	39.45	Calcite
33.5344	28.80	2.67017	1.20	Montmorillonite
35.0408	189.49	2.55875	7.91	Montmorillonite
36.1173	140.61	2.48491	5.87	Calcite
36.6427	185.64	2.45048	7.75	Illite
37.6131	76.24	2.38946	3.18	Kaolinite
39.5620	290.85	2.27613	12.15	Kaolinite

Our clay sample contains a large proportion of quartz, montmorillonite, illite, and calcite. It is fine and soft to the touch. Montmorillonite is a clay mineral that has unique bulking properties that allow it to expand significantly in the presence of water. The presence of quartz, illite, and calcite in our clay sample can influence its physical and chemical properties, including porosity, permeability, strength, and reactivity.

3.3 Fourier Transform Infrared Spectroscopy Analysis

Infrared spectroscopy is a method that allows us to detect the different chemical bonds that make up our sample. The following spectrum represents the different bands obtained, and there are two remarkable adsorption bands in the spectrum: the first band is centered at 3620 cm^{-1}, which is linked to the -OH group, and the second band corresponds to the tetrahedral units SiO_4 and AlO_4 (approximately 400 cm^{-1} and 600 cm^{-1}). The spectrum examination allows us to distinguish the following adsorption bands (Figure 3):

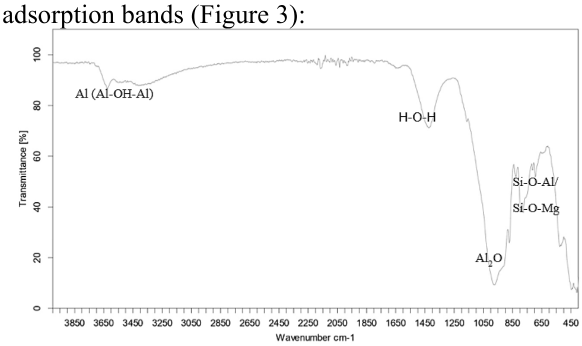

Fig. 3. IR-TF spectrum of the clay studied.

- The absorption band corresponds to the chemical bond valence vibration of OH bound to the octahedral cation Al (Al-OH-Al) (3650-3450 cm^{-1} centered at 3620 cm^{-1} [11]).
- The low-intensity absorption band centered at 1641 cm^{-1} corresponds to the H-O-H valence vibration of water molecules [12].
- The band observed at 1440 cm^{-1} corresponded to the chemical bond of C-O-C.
- The band corresponding to the deformation of the Al_2O bond is centered at 953 cm^{-1} [12,13].
- The bands centered at 857, 782, 634, 524, and 434 cm^{-1} correspond to the valence vibrations of the Si-O-Al/Al-OH-Mg, Si-O-Al, Si-O-Mg, Si-O-Al and Si-O-Si bonds, respectively [12].

Table 3. The bands in the IR spectrum of the clays studied.

Bands in cm^{-1}	Probable groupings
3650-3450	Vibrations of the Al_2OH bond.
1640	OH bond vibration
1420	Vibrations of the O-C-C bond
953	Vibrations of the Al-OH-Al bond
857	Vibrations of the Si-O-Al/Al-OH-Mg bond
782- 424	Vibrations of the Si-O bond

3.4 X-ray Fluorescence Analysis of Clays

Elemental chemical analysis was also adopted to determine the chemical constituents of our sample. The results obtained indicate that the predominant constituents are silica, iron, calcium and aluminum. The following table represents the percentages found for each chemical element.

Table 4. Elemental chemical composition of the clay sample.

Element	Si	Ca	Fe	Al
% by weight	33.87	25.83	18.77	13.22
Element	**K**	**Ti**	**S**	**Sr**
% by weight	5.47	1.81	0.36	0.14
Element	Mn	Rb	Cu	V
% by weight	0.12	0.08	0.07	0.06
Element	**Cr**	**Zn**	**Ni**	**Y**
% by weight	0.05	0.04	0.02	0.01

The percentages of silica and aluminum are significant at 33.873% and 13.227%, respectively. This explains the presence of quartz. Thus, a high rate of calcium is 25.837%, so our clay is rich in calcite ($CaCO_3$), with the presence of a few other substances, namely, Zn, Cr, and Ni, with percentages of 0.04%, 0.05%, and 0.03%, respectively.

4 Conclusion

The analyses revealed that this clay essentially consists of quartz, montmorillonite, and calcite as associated clay minerals. These results also highlighted the richness of this clay in quartz, resulting in a high proportion of silica. Therefore, this study was essential before applying this type of clay in treatment and valorization. In addition, applying clays from sedimentation sludge from the Mohamed Ben Abdelkrim El Khattabi dam can contribute to various industries and economic sectors, representing an interesting economic opportunity for the region. However, developing effective management strategies for sludge reprocessing while minimizing environmental impacts is essential.

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