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Editörler / *Editors*
Prof. Dr. İbrahim KÜRTÜL
Prof. Dr. Fatih GÜLTEKİN
Doç.Dr. Can TÜRK

Katkı Sunanlar / *Contributors*
Fatma Betül TELLİOĞLU
Arş.Gör. Hasan Tahsin ŞEN
Ercan KURT

Grafik & Tasarım / *Graphics & Design*
Savaş Güler

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CONTENTS

(S-52) COMPARATIVE STUDY OF KAOLIN AND BENTONITE CLAY AS POTENTIAL MATERIALS FOR HALAL SERTU IN HEALTHCARE APPLICATIONS

Aminudin Che-Ahmad[2,3], Abdul Rahman Al-Azmi[3], Zuraida Ahmad[1], Noorasikin Samat[1], Norshahida Sarifuddin[1], Mohd Shukrimi Awang[2]

1. Department of Manufacturing and Materials, Kulliyyah of Engineering, IIUM, Selangor, Malaysia, fatmakat94@gmail.com
2. Department of Orthopedics, Kulliyyah of Medicine, IIUM, Kuantan, Malaysia
3. Department of Shariah Compliance, SASMEC @IIUM, Kuantan, Malaysia

Abstract

This study explores the suitability of kaolin and bentonite clays for halal Sertu solutions in healthcare applications, specifically for equipment cleansing using the spraying technique. Addressing challenges arising from dog and wild boar bites, the research emphasizes adherence to Islamic jurisprudence, utilizing water and specific soils for formulation. Structural properties of kaolin, with its ordered crystal lattice, and bentonite, known for its swelling capabilities, are analyzed through Fourier Transform Infrared Spectroscopy (FTIR) and X-ray Diffraction (XRD). The study also investigates their morphology using Scanning Electron Microscopy (SEM). Results indicate that kaolin, with its higher crystallinity and organized structure, exhibits enhanced homogeneity and stability in healthcare-relevant solutions. In contrast, bentonite's more disordered structure may pose challenges in achieving uniform dispersion. The findings contribute crucial insights for developing a standardized, halal-compliant Sertu product, aligning with healthcare standards, equipment specifications, and regulatory guidelines for safe and quality industrial applications.

1. INTRODUCTION

The multifaceted issue of dog and wild boar bites requires careful attention in hospitals, addressing both wound treatment challenges and healthcare equipment decontamination. Saliva impurity (*mughallazah najs*) in Islamic jurisprudence necessitates adherence to Halal "*Sertu*" methods, incorporating healthcare principles. *Sertu* (ritual cleansing) means cleansing something from *mughallazah najs* such as dogs, pigs and their descendants. In Shafi'ie Mazhab, *mughallazah najs* should be cleansed by 7 times of washing which consists of using one time of clean water mixed with clay and followed by six times of clean water. Formulating a Halal *Sertu* involves water and specific soils, such as clay or earth, with considerations for soil type, purity, and the soil-to-water ratio to meet healthcare standards. [1]

There are, however, many negative effects of using soil in the *Sertu* process, especially when it involves cleaning machines or instruments that are sensitive to the soil. Therefore, several literature [2-4] explained the suitable soil used in the *Sertu* process. The use of clay has been proven effective as a tanning agent in this *Sertu* industry because clay is used as an active ingredient in cosmetics because of the high level of absorption of substances such as oil, toxins, and others [5] Four types of physic-chemical properties of clays that need to be considered before using the clay in the halal industry includes; First, the pH must be at an acidic at natural level. Second, the particle size distribution (PSD) of clay must be small and contain no other particles that can cause blockages or scratches to the equipment. Lastly, toxic metals and microbial load must be at a low level and meet the limits allowed in the Malaysian Food Regulations 1985 to ensure it is safe to use [6]. Apart from these properties, most importantly, it must comply with the safety and quality of the products manufactured as well as the regulations and guidelines practiced. Therefore, a specific *Sertu* clay standard for industrial application is needed to meet the halal requirement as well as meet the specifications of the equipment and machines. The conditions of the soil must be free from *najs*; and not *mustakmal* (soil that had been used for dry ablution) [7]

Types of soil ordinarily used in *sertu* purification include Kaolin Clay, Bentonite Clay, Fuller's Earth, Red Clay, White Clay (China clay), and local clays based on traditions [8 – 10]. Among all, local clay, kaolin clay and bentonite clay are the three materials that are easily available. For commercialization purposes and controlling the properties of the sertu product to be produced, the focus of the study is only on kaolin and bentonite.

Kaolin, or China clay, is a soft and white clay mineral primarily composed of kaolinite, a type of alumina silicate. Its presence in various industrial sectors, such as paper, ceramics, and pharmaceuticals, highlights its versatility and safety profile. This type of clay, known for its distinctive white colour and fine particle size, is primarily composed of a composite of kaolinite. The crystal structure of kaolinite is a layered arrangement of tetrahedral silica and octahedral alumina sheets. These layers are held together by weak van der Waals forces and hydrogen bonding, resulting in a relatively low cation exchange capacity. The presence of hydroxyl groups on the surface of kaolinite provides sites for potential interactions with water and other molecules, making it an excellent adsorbent material. This unique structure contributes to its stable and non-swelling nature, making it particularly suitable for applications where controlled stability is required, such as in pharmaceutical formulations and cosmetic products [11].

On the other hand, Bentonite is a porous clay with a high percentage of montmorillonite, endowing it with exceptional swelling and absorbing capabilities. These properties make Bentonite an essential component in various applications, including drilling fluids, adsorbents, and even cosmetics. Bentonite, characterized by its high content of montmorillonite, exhibits a more complex and expandable crystal structure. Montmorillonite belongs to the smectite group of clay minerals, featuring a three-layered structure consisting of two tetrahedral silica sheets sandwiching an octahedral alumina sheet. The layered structure of montmorillonite is responsible for its exceptional swelling capacity when exposed to water, allowing it to expand several times its original volume. The interlayer spaces between the layers provide sites for the absorption of water molecules and other cations, resulting in a higher cation exchange capacity compared to Kaolin. This unique structural feature gives Bentonite its remarkable water-absorbing properties, making it valuable for applications requiring high moisture retention, such as in drilling fluids and cat litter [10].

In the context of the spraying technique for clay solutions, it is imperative to consider specific solution characteristics to prevent nozzle clogging and adhere to the Sertu standard, which stipulates a 2.5% composition of clay from the total mixture of clay and liquid. To ensure optimal performance, the solution should exhibit a homogeneous consistency that avoids the formation of clumps or blockages in the spraying mechanism. Furthermore, the selected clay concentration needs to align with the Sertu standard, striking a balance between effective cleansing properties and compliance with the specified percentage. This meticulous approach ensures that the sprayed clay solution remains uniform, user-friendly, and meets the stringent standards set by Sertu for healthcare applications.

Therefore, the research seeks to compare the suitability of kaolin and bentonite soils in a sertu process, specifically in a spraying application adhering to sertu standards. The primary goal is to formulate a sertu product that ensures effective equipment cleansing while prioritizing user-friendliness and compliance with halal standards. Given machinery sensitivity to soil, selecting an appropriate soil type is crucial. The proposed spraying application necessitates a comprehensive study of the homogeneity and stability of the solution. Additionally, it is imperative to maintain a clay composition of more than 2.5% in the solution to meet sertu standards. This research aims to contribute insights for developing a standardized, halal-compliant sertu product that aligns with equipment specifications and regulatory guidelines, ensuring safety and quality in its industrial application

2. MATERIALS

Kaolin and bentonite clays were obtained from Morning Prestige Trading. The clays were in the form of a fine powder, and its purity was verified using X-ray diffraction (XRD) analysis. Analytical grade solvents, such as Sodium Lauryl Ether Sulfate (SLES), paraben, deionized water and ethanol were also obtained from Morning Prestige Trading and were used for the preparation of clay pastes.

3. METHODOLOGY

3.1 Characterisation

The mineralogical composition and crystalline structure of both Kaolin and Bentonite clays were determined using an X-ray diffractomer (XRD) (D2 Phaser, Bruker). The clays were subjected to X-ray diffraction, and the resulting diffraction patterns were analyzed to identify the crystal phases present in each clay. Scanning Electron Microscopy (SEM) (JSM 5600, JEOL) was used to analyze the particle size distribution and surface morphology of the clays. Zeta potential measurements were carried out by the Nano-ZS model (Malvern) zetasizer instrument. Fourier Transform Infra-Red (FTIR) spectroscopy (Perkin Elmer 100 Series), characterized by a 4 cm^{-1} resolution and 32 scans within the spectral range of 1000 – 4000 cm^{-1}.

3.2 Preparation

Kaolin and Bentonite clays were mixed with deionized water to form a homogenous paste. The water-to-clay ratio was optimized based on initial rheological studies to achieve a stable and workable consistency.

3.3 Paste Stability Evaluation

The homogeneity of each paste was visually inspected, looking for any signs of phase separation or agglomeration of particles and the consistency of the pastes. The stability of each paste was evaluated over a designated period, and changes in consistency and other physical properties were monitored at regular intervals.

4. RESULTS AND DISCUSSION

4.1 Physical Properties

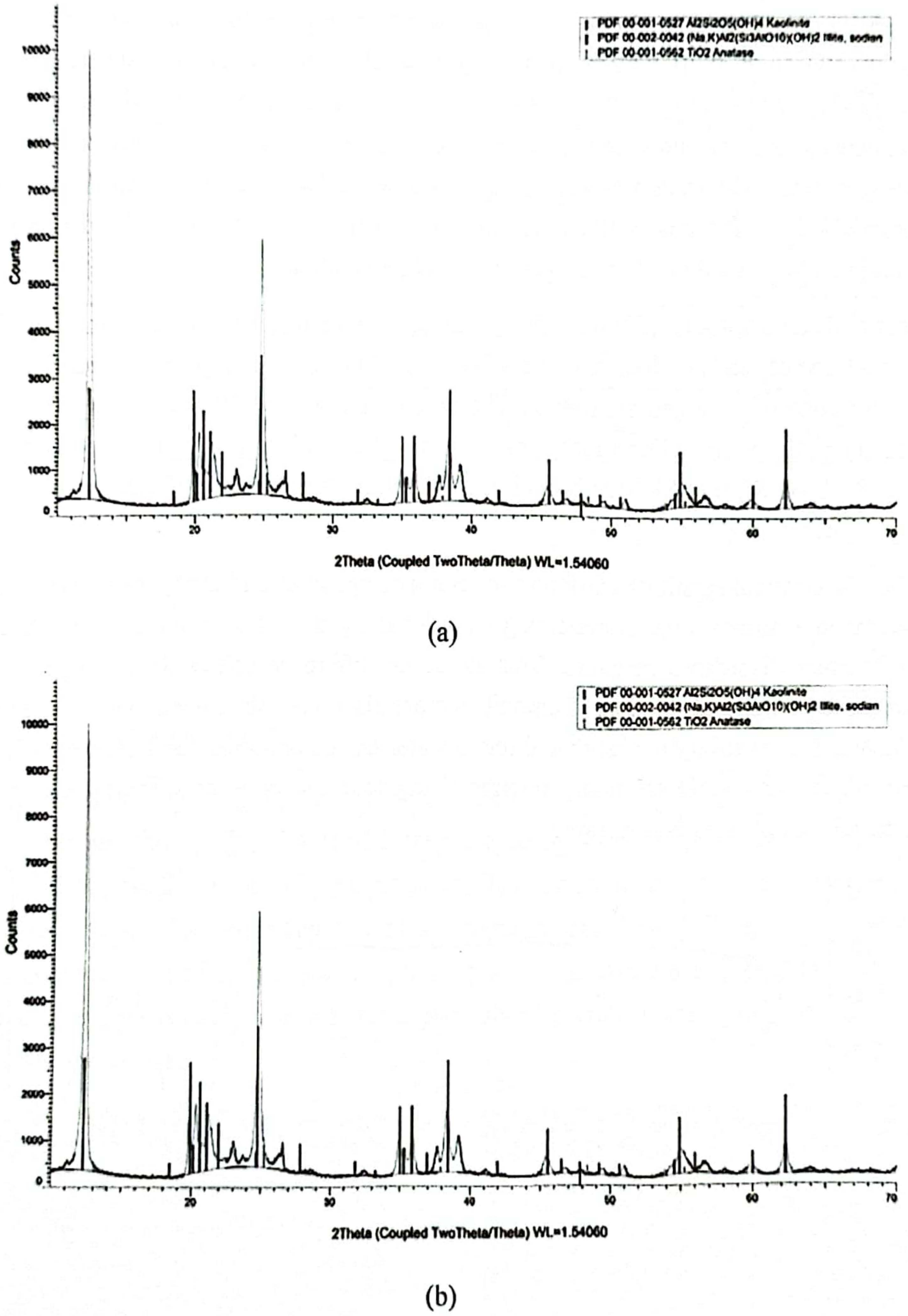
The kaolin and bentonite clay in powder form. Upon visual inspection and tactile examination, bentonite and kaolin exhibit distinct physical properties discernible to the naked eye when it is touched. Bentonite typically presents itself in light grey, featuring a smooth and slightly slippery texture. In its dry form, bentonite manifests as a fine powder, while in a wet state, it transforms into a sticky, mouldable consistency. The visual appearance is granular and powdery, with a glossy sheen when wet. Conversely, kaolin is characterized by its pure white, offering a soft and silky texture akin to chalk. In its dry state, kaolin appears as a fine powder, transforming into a smooth paste when wet. The visual presentation of kaolin is velvety and smooth, providing a matte finish when wet.

4.2 Characterisation

4.2.1 X-ray Diffraction (XRD) Analyses

X-ray Diffraction (XRD) analysis unveils the distinct mineral composition of kaolin and bentonite by emphasizing critical peaks in their respective patterns. Figure 2(a) for the kaolin diffraction pattern exhibits a well-defined peak at specific angles, notably around 12.4° and 24.8° (2θ). These peaks signify the presence of kaolinite, emphasizing the dominant mineral in kaolin. Conversely, bentonite, in Figure 2(b), enriched displays key peaks around 5.2°, 19.2°, and 29.6° (2θ). These peaks highlight the mineral composition, especially the prevalence of montmorillonite. The broader and less intense nature of these peaks reflects the more disordered crystal structure inherent in bentonite. Variability in peak shapes and positions underscores the diverse minerals contributing to bentonite's composition. The XRD analyses provide insights into the mineral composition and crystalline structure of kaolin and bentonite. This information is crucial in ensuring the absence of prohibited substances, as it allows for the identification and confirmation of the specific minerals present.

It can be seen from Figure 2(a), that the characteristic of the peak for kaolin is sharper, more intense, and narrower, suggesting a well-ordered crystal lattice compared to bentonite in Figure 2(b) signifying greater crystallinity. An increased number of symmetric peaks at specific angles, along with their distinct shapes add up to confirm it.



(a)

(b)

Figure 3: X-ray Diffraction pattern for (a) Kaolin (b) Bentonite

In general, kaolin tends to exhibit higher crystallinity compared to bentonite. Crystallinity refers to the degree of organization and order within the crystal lattice structure of a mineral. Kaolin, composed mainly of kaolinite, often features a well-organized, ordered crystal lattice, contributing to its high crystallinity [8-9]. Bentonite, on the other hand, is a group of clay minerals, primarily composed of montmorillonite, which has a more complex structure. Bentonite minerals can have variable crystallinity, but they generally exhibit a more disordered structure compared to kaolin. The presence of additional minerals and the unique layering characteristics of bentonite contribute to its lower overall crystallinity compared to kaolin [10].

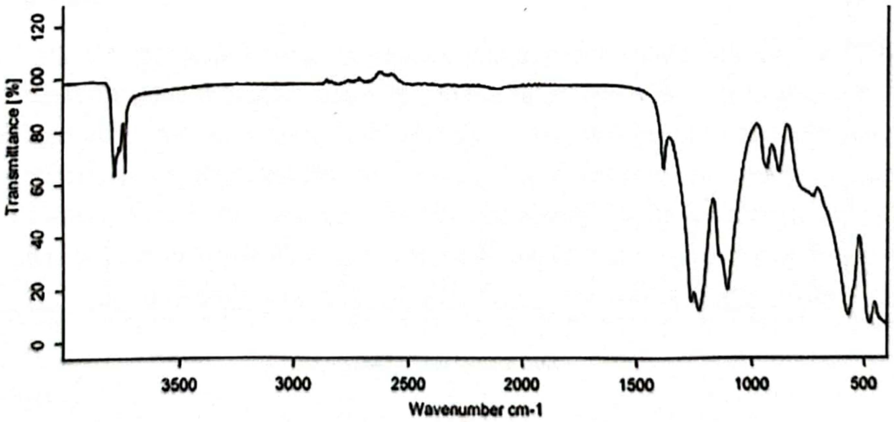
This high crystallinity in kaolin promotes uniform dispersion, enhancing homogeneity and solution stability over time. In contrast, bentonite, primarily composed of montmorillonite, exhibits lower crystallinity due to its complex and disordered structure. This structural variability can lead to less uniform dispersion, potentially impacting homogeneity and solution stability.

4.2.2 Fourier Transformation Infra-Red (FTIR)

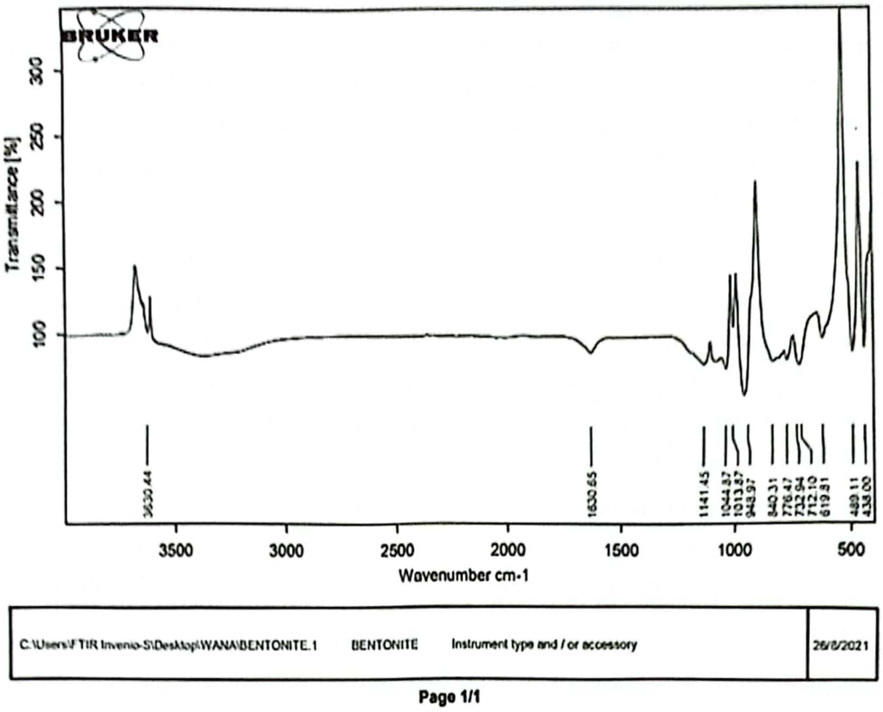
In the presented Fourier Transform Infrared (FTIR) spectrum (Figure 3(a)), characteristic absorption bands corresponding to OH (hydroxyl) groups in the kaolinite clay showed distinct appearance. Notably, four well-defined bands at 3700, 3670, 3650, and 3620 cm-1 indicate an ordered kaolinite structure. This ordered arrangement enhances stability and unique properties. Conversely, a disordered structure lacks the 3670 cm-1 band, suggesting higher dehydration susceptibility. P0 index calculations (3620 cm-1 to 3700 cm-1 ratio) confirm the ordered nature of the kaolinite structure (P0 = 1.121 > 1). This structural order promises enhanced homogeneity and solution stability when integrated into other solutions.

The FTIR spectra of raw bentonite (Figure 3(b)) reveal key mineral phases present in the clay. The absorption band at 3657 cm-1 corresponds to the stretching vibrations of structural OH groups coordinated to Al-Al pairs, indicating the presence of hydrated aluminum. The broad band around 1030 cm-1 signifies Si-O stretching vibrations, characteristic of the silica framework in bentonite. Additionally, bands at 520 and 468 cm-1 are related to Al-O-Si, Si-O-Si, and Si-O deformations, suggesting the presence of aluminum and silicon bonds within the clay structure.

Compared to kaolin, bentonite exhibits a different structural composition and arrangement. While kaolin typically features well-defined absorption bands indicating an ordered crystal lattice, bentonite tends to exhibit broader bands due to its more disordered structure. This structural difference affects the homogeneity and solution stability of bentonite-containing solutions. Bentonite's more disordered structure allows for greater surface area and porosity, enhancing its ability to absorb and retain water and other molecules. However, this can also result in less uniform dispersion within solutions, potentially impacting homogeneity. Therefore, for the purpose of producing Sertu solution, kaolin is preferable.



(a)



(b)

Figure 3: FTIR spectra of (a) Kaolin and (b) Bentonite

4.2.3 Scanning Electron Microscope

Scanning Electron Microscopy (SEM) serves as a valuable tool in corroborating and enhancing the characterization obtained through Fourier Transform Infrared Spectroscopy (FTIR) and X-ray Diffraction (XRD) analyses. FTIR provides insights into molecular vibrations and chemical compositions, while XRD reveals crystalline structures within materials. SEM complements these techniques by offering a high-resolution visual examination of the surface morphology and microstructure to enables us to validate and further understand the physical attributes and arrangements of particles, confirming the outcomes derived from FTIR and XRD analyses.

(a) (b)

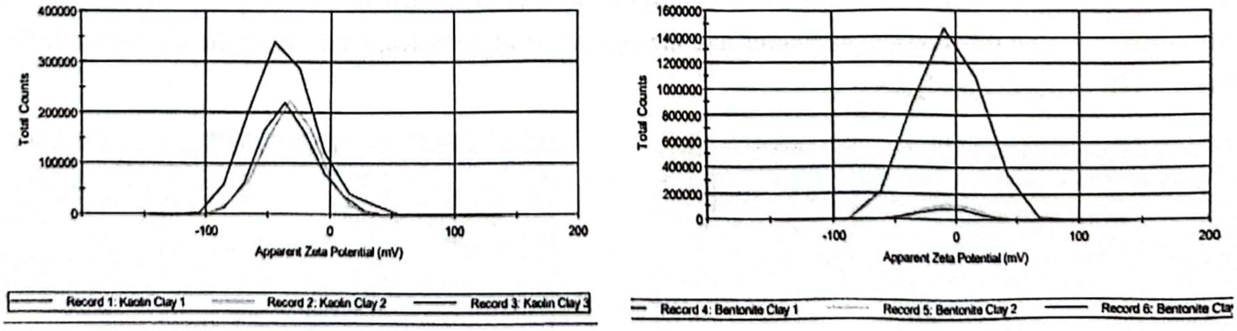
Figure 4: Scanning Electron Micrograph for (a) Kaolin (b) Bentonite

Figures 4(a) and 4(b) reveal the microstructure of kaolin and bentonite showing intricate details that define their unique characteristics. Kaolin (Figure 4(a)) exhibits a smooth surface with fine particles, showcasing its well-ordered hexagonal crystal structure. The micrographs capture the organized arrangement layers, providing insights into its compact and uniform composition. In contrast, bentonite (Figure 4(b)) displays a more granular and layered appearance. The SEM images unveil the stacked, plate-like layers, showcasing the characteristic "house of cards" arrangement.

These visualizations allow for a closer examination of the microstructural intricacies that underlie the diverse properties and applications of kaolin and bentonite that affect the stability and homogeneity once they are in solution. The organized arrangement of particles in Kaolin allows for uniform dispersion, promoting stability over time. While the layered structure in bentonite enhances the material's swelling and adsorption capacities, it can also lead to challenges in achieving uniform dispersion. The plate-like particles may tend to stack or aggregate, potentially influencing the stability and homogeneity of the solution. Therefore, the microstructural differences between kaolin and bentonite play a crucial role in dictating the behavior of these clays within the sertu solution. Since focus of the study is to produce sprayed sertu solution, stability and homogeneity of the solution is vital to ensure the percentage of clay in the solution is maintained to not less than 2.5% from the total mixture of soil and liquid.

4.2.4 Zeta Potential

The zeta potential is a key parameter in understanding the stability and behavior of colloidal particles, including clay minerals like kaolin and bentonite. Zeta potential represents the electric charge at the slipping plane of the particle and influences the particle's dispersion and interactions in a solution. In the context of kaolin and bentonite, measuring their zeta potential provides insights into their stability, dispersibility, and potential agglomeration. For kaolin, a high negative zeta potential is often observed due to the presence of hydroxyl groups on its surface, contributing to repulsion between particles. This repulsion helps maintain the dispersion of kaolin particles, resulting in a more stable solution. Bentonite, on the other hand, may exhibit a more variable zeta potential depending on factors like pH and the presence of ions in the solution. The high surface area and charged sites on bentonite particles can lead to interactions that influence the zeta potential. Understanding the zeta potential of bentonite is crucial for predicting its behaviour in various applications, including sertu processes.



(a) (b)

Figure 5: Zeta potential distribution of (a) Kaolin and (b) Bentonite

Zeta potential measurements offer valuable insights into the colloidal stability of kaolin and bentonite, aiding in the optimization of formulations and processes where these clay minerals are utilized. From Figures 5(a) and (b), the average zeta potential value for kaolin is -34.3 mV (-33.8 mV, -32.2 mV, and -37.3 mV for the red, green, and blue lines, respectively) and bentonite is -6.96 mV (-6.49 mV, -6.40 mV, and -8.00 mV for the red, green, and blue lines, respectively). According to Naval et al. (2019), [12], stable nanoparticles without the formation of aggregation in a colloidal suspension system could be achieved if the nanoparticles have a zeta potential of more than +30 mV or less than -30 mV. In contrast, the nanoparticles that possess values between -30 mV and +30 mV will show flocculation, agglomeration, or aggregation. Therefore, from the zeta potential values, the kaolin exhibited better colloidal stability than the kaolin.

4.2.5 Solution Stability

We demonstrate the solution stability of kaolin and bentonite over six months. In the case of kaolin, the stability is evident, showcasing a consistent and uniform dispersion of particles without significant changes in properties. The well-ordered crystal lattice structure of kaolin contributes to this stability, preventing agglomeration or settling of particles. On the other hand, it indicates a less stable solution for bentonite after the same duration. The more disordered structure of bentonite, coupled with its higher swelling capacity, may lead to uneven dispersion and settling of plate-like particles. This difference in stability highlights the distinct behaviors of kaolin and bentonite in solutions over an extended period, emphasizing the importance of choosing the right clay for specific applications, such as Shariah-compliant *Sertu* solutions.

5. CONCLUSION

In summary, the study extensively compared kaolin and bentonite for potential use in halal sertu solutions for equipment cleansing in the healthcare industry. Physical examinations revealed distinct appearances, with bentonite presenting a light grey, smooth texture, and moldable consistency, while kaolin exhibited a pure white color and a soft, chalk-like texture. Advanced characterizations through FTIR, XRD, SEM, and zeta potential emphasized the ordered structure of kaolin (kaolinite) promoting stability, in contrast to bentonite's disordered structure affecting homogeneity differently. Kaolin demonstrated higher crystallinity, finer particle size distribution, and better solution stability over six months, showcasing its suitability for sertu applications. These findings offer crucial insights for selecting the appropriate clay for Shariah-compliant healthcare solutions, ensuring optimal performance and stability over time.

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