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Characterising the Physicochemical Properties of Selected Geophagic Clay from the Democratic Republic of Congo (DRC) to Investigate Their Potential Applications

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Abstract: Clay and clay composite have been used for numerous applications around the world including as construction materials, cosmetics, and absorbents. As easy to find, abundant, and sustainable, the knowledge of the quality of clay is crucial. This study focuses on the characterization of geophagic clay samples from various locations in the Democratic Republic of Congo (DRC) to investigate their potential use in various sectors. The geophagic clays have different colors, different morphology, and properties. Many characterizations were carried out including X-ray diffraction, and X-ray fluorescence spectroscopy. The microstructure and chemical analysis were carried out using scanning electron microscopy combined with energy dispersive spectroscopy (SEM/EDS). UV-Vis spectroscopy was also carried out to investigate the reflectance. XRD revealed the presence of Muscovite, Kaolinite, Illite, and Quartz. On the other hand, XRF showed the presence of SiO_2, Al_2O_3, TiO_2, and Fe_2O_3 as major chemical compounds. A flake-like surface morphology was observed in all the samples and the EDS analyses exhibited similar results as the XRF. The XRF, XRD, and EDS results were in agreement. The Zeta potential was negative for all the clay samples. The properties exhibited by the selected geophagic clay were compared with the properties of various samples used for different applications. It was concluded that the selected geophagic clays demonstrated properties that could lead to their use for water and wastewater treatment and other applications including as a sunblock (cosmetic industry) due to their mineralogical/chemical composition, and UV-Vis reflectance.

Keywords: clay; Geophagia; Chemical properties; Mineralogy; Zeta potential

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1. Introduction

Around the world, there is a substantial amount of raw clay materials which is considered a sustainable material. Clay and clay materials have numerous applications in a number of sectors including construction, cosmetic, ceramics and water treatment [1–8]. To be able to investigate the suitability of specific clay and clay materials for specific applications, proper characterizations are required.

Geophagia is globally known and recognized as universally recognized as a deliberate habit of consuming earthy materials including clays, soils, and sediments [11]. There are not many studies on the characteristics of geophagic clay [9–17]. Choquenaira-Quispe et al. [16] carried out a study on the characterization and health risks of geophagic clay. They indicated that a weekly intake of clay represented an appreciable health risk. The characterized clay contained mainly silica and alumina, iron, sodium, magnesium, calcium, and potassium were present in smaller quantities [16]. Ekosse and Jumbam [13] also investigated the health risks of consuming clay. They concluded that people consuming clays may benefit from the possible medicinal and nutritional values of the chemical elements contained in those clays, even though there are possibilities of human health risks. Most studies on geophagic clay are focused on the health risk of consumers, therefore it is important to also look at other usages of geophagic clay materials.

This study presents the characteristics of selected Geophagic clay samples from the Democratic Republic of Congo (DRC) to evaluate their suitability for various applications besides being consumed by human beings. A number of properties including the surface morphology and physicochemical properties are presented.

2. Materials and Methods

2.1. Materials

The clay samples were collected in three different locations and exhibited different morphology and color as depicted in Figure 1. The colors displayed by the samples were light grey/yellow, reddish, and dark grey for BUK, LUB, and KIN respectively. The reddish and yellowish colors are mostly associated with the presence of iron oxide. Those locations are Lubumbashi (11°39′51″ S 27°28′58″ E), Bukavu (2°30′S 28°52′ E) and Kinshasa (4°19′30″ S 15°19′20″ E). The samples were coded as LUB, BUK, and KIN for Lubumbashi, Bukuvu, and Kinshasa respectively.

Figure 1. BUK, LUB, and KIN geophagic clay samples.

2.2. Methods

A Rigaku, ZSX Primus II X-ray Fluorescence spectrometer was used for chemical composition while the phases were identified using a Rigaku, Ultima IV X-Ray Diffractometer. The surface morphology and the sample mapping were conducted using scanning electron microscopy combined with energy dispersive spectroscopy (SEM/EDS) a JEOL JSM-IT300 was utilized. A UV-Vis (Lambda 650S, Perkin Elmer) spectrometer was used to analyze the UV-visible spectrophotometric of the clay samples. The Zeta potential was measured using a Malvern Zetasizer Nano series (Malvern, UK). The zeta potential measurements were carried out at neutral pH.

3. Results and Discussion

3.1. X-ray Fluorescence and X-ray Diffraction Analyses

The chemical composition using X-ray fluorescence (XRF) depicted in Table 1 indicates that SiO_2 and Al_2O_3 are the major compounds in all three samples. K_2O was present with the BUK sample having the highest percentage (8.1733 wt%) followed by KIN (2.8707 wt%) and LUB (1.5754 wt%). Furthermore, the highest percentage of TiO_2 was found in the LUB sample (4.0406 wt%). This shows that the LUB sample will exhibit good photocatalytic properties [8] and can be used for the removal of pollutants in water and wastewater. The XRD results showed the presence of Muscovite, Kaolinite, Illite, and Quartz (BUK), quartz, Dickite, Kaolinite, and Montmorillonite (KIN), and Quartz, Kaolinite, Muscovite and Calcium Iron Aluminum Oxide (LUB) (Figure 2).

Table 1. Chemical composition (wt%) of the geophagic samples.

Component	LUB	KIN	BUK
Na_2O	0.0334	1.0855	0.0821
MgO	0.554	1.0703	1.1812
Al_2O_3	29.8908	29.9264	30.389
SiO_2	60.2544	59.3893	52.2636
P_2O_5	0.0411	0.0999	0.05
SO_3	0.0381	0.072	0.327
Cl	0.0214	1.4382	0.0134
K_2O	1.5754	2.8707	8.1733
CaO	0.0361	0.1615	0.1024
TiO_2	4.0406	1.4217	1.5949
Cr_2O_3	0.0312	0.0161	0.0366
MnO	0.0102	0.0127	0.028
Fe_2O_3	3.0454	2.2351	5.4643
NiO	0.0204	0.0064	0.0155
CuO	0.0116	0.0038	0.0097
ZnO	0.0048	0.0073	0.0102
Ga_2O_3	0.0066	0.0063	0.0091
GeO_2	0.0031	-	-
As_2O_3	0.0021	-	0.0027
Rb_2O	0.0202	0.0199	0.0517
SrO	0.004	0.0069	0.0055
Y_2O_3	0.0889	-	0.0008
ZrO_2	0.1235	0.062	0.0544
BaO	0.0811	0.0746	0.1312
ThO_2	0.0034	-	0.0035
Nb_2O_5	-	0.0053	-
PbO	-	0.0079	-

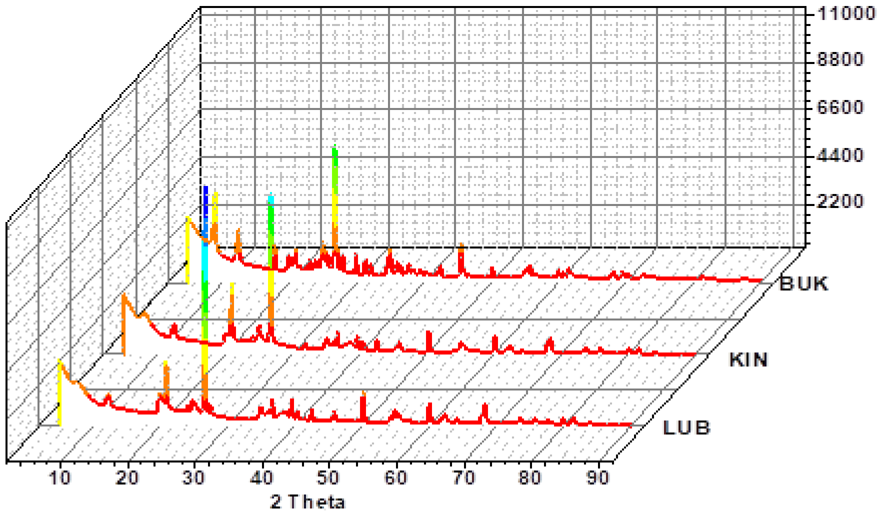

Figure 2. XRD patterns of BUK, LUB, and KIN geophagic clay samples.

3.2. Surface Morphology and Chemical Composition Mapping

The surface morphology of the three samples was analyzed and it was observed that the clay samples had similar surface morphology as other clay materials investigated in other studies [12]. The surface morphology of all the clay samples exhibited a flake-like morphology and that could be due to the presence of amorphous materials present in the samples (Figure 3). EDS mapping analysis was carried out and it was observed that Si, Al, K, and Fe are present on the analyzed spot (Figure 4). The obtained result was in agreement with the XRF and the XRD results. Furthermore, the chemical content of the examined geaophagic clay samples was similar to those presented in the open literature [10].

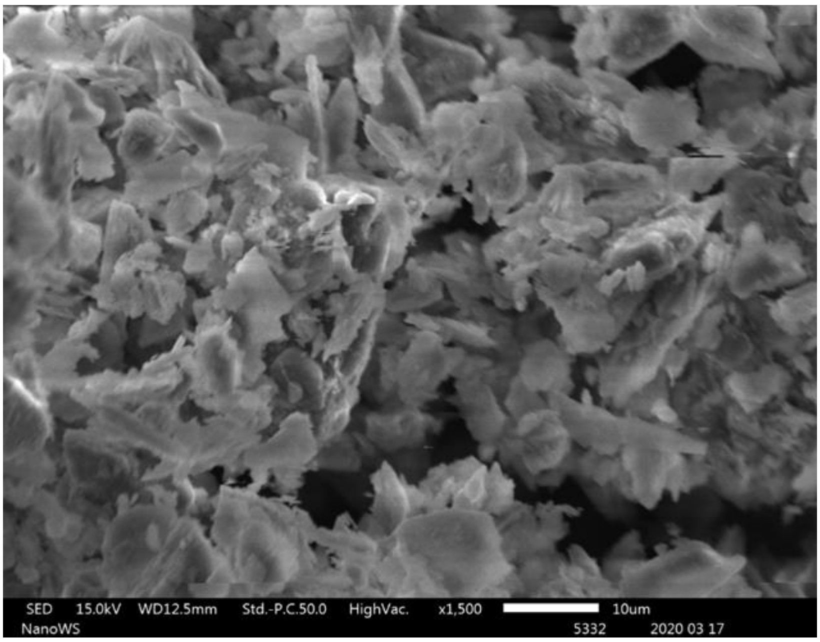

Figure 3. SEM micrograph of the BUK sample.

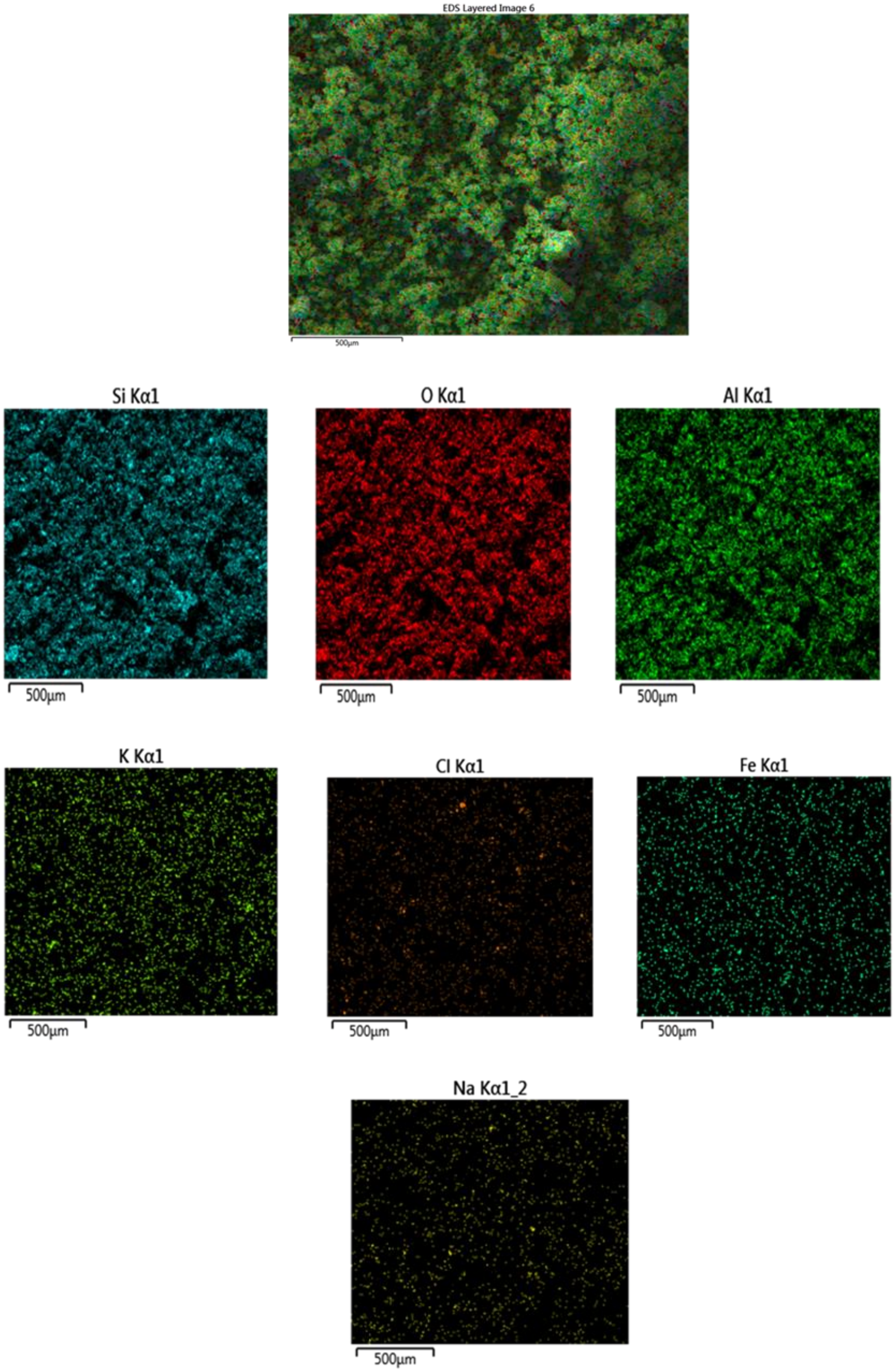

Figure 4. EDS mapping for the KIN sample.

3.3. Zeta Potential and UV-Vis Spectroscopy Analyses

The Zeta potential values of all three geophagic clay sample are negative which indicate good absorbance capacity with more negative zeta potential linked to higher absorbance capacity [18]. Zeta potential analysis has been proven to be a helpful indicator of the surface charge of particles and is directly associated with the composition. The zeta potential of the BUK, KIN, and LUB were −11.20, −23.60, and −15.00 respectively. It can be said that the KIN sample would have a higher absorbance capacity when compared with BUK and LUB. The UV-Vis spectroscopy analyses were carried out to study the usage of clay materials in the cosmetic industry as sunblock (Figure 5). It was observed that the three samples contained TiO_2 which is used in sunscreen products, acts as a physical ultraviolet filter, and could block sunlight and reflect the ultraviolet light.

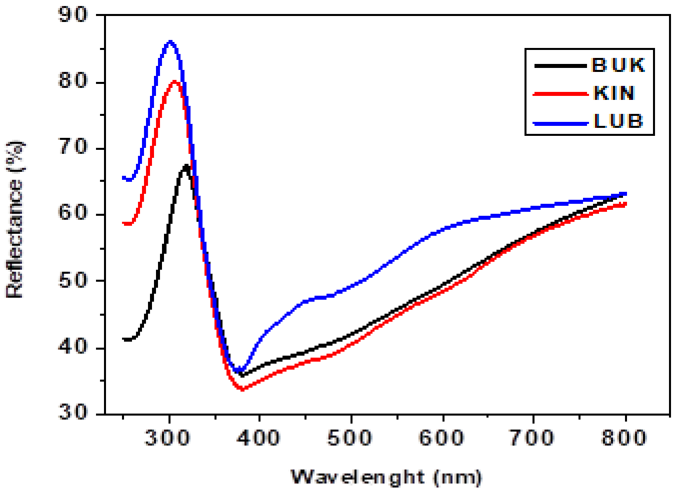

Figure 5. Ultraviolet reflectance percentage variation of the BUK, KIN and LUB geophagic clay samples.

4. Conclusions

Three geophagic clay samples were collected in three different locations in the Democratic Republic of Congo (DRC). The clay samples were analyzed to assess their potential uses for various applications. The samples contained SiO_2 and Al_2O_3 mainly and the XRF, XRD, and EDS results were in agreement. The UV-Vis results indicated that these clay materials can block and reflect light. It was concluded that the geophagic clay samples analyzed can be used in the cosmetic industry and for water/wastewater treatment. The analyzed clay samples showed the potential of being used as a substitute in cosmetic creams such as sunblock. Furthermore, those clay samples can also be used for water and wastewater treatments in various forms including ceramic filters. Further studies need to be conducted to analyze more properties and further investigate their applications.

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