Physicochemical properties of clay minerals for cosmetic application

Murlanova T.[1], Paientko V.[2], Zabava L.[1], Mykhailovska I.[1], Pasko M.[1], Vovk O.[1], Zherdetska L.[1], Matkovsky O.[2], Nychyporuk Yu.[2], Pashchenko A.[3,4], Liedienov N.[3,4], Gun'ko V.[2]

[1] *National University of Kyiv-Mohyla Academy, Kyiv, Ukraine. Email: tanmurlanova@gmail.com*
[2] *Chuiko Institute of Surface Chemistry, NAS of Ukraine, Kyiv, Ukraine*
[3] *State Key Laboratory of Superhard Materials, International Center of Future Science of Jilin University, Changchun, China*
[4] *Galkin Donetsk Institute for Physics and Engineering, NAS of Ukraine, Kyiv, Ukraine*

Introduction

The clay minerals are widely used for practical applications due to their unique structure and mineral composition. Due to the simplicity of dispersion, clay minerals can be included in various compositions as fillers, carriers of active ingredients, sorbents, etc. The main characteristics of clays are: their mineral composition, structure and morphology of particles, adsorption and desorption properties. Research and application of clay minerals will allow to regulate and improve the characteristics of cosmetics, and the study of their adsorption capacity will allow the use of clay particles as carriers of bio-active substances and to create composite materials.

The aim of our research was to study the physicochemical properties of natural clay minerals: white (kaolin), black, yellow (Azov), and blue (Cambrian) clays.

Materials and methods

1) **Natural clay minerals:** white (kaolin), black, yellow (Azov), and blue (Cambrian) clays
2) **Methods and instruments:**

The morphology, phase and chemical compositions of the powders were studied using scanning electron microscope (SEM) FEI Magellan 400 with an energy-dispersive X-ray spectroscopy (EDS) module.

Dehydration of clays was studied using temperature-programmed desorption with mass spectrometry control (TPD MS) using mass spectrometr MX7304 (Sumy, Ukraine).

pH of aqueous suspensions of clay minerals were studied using pH meter MP 511 (Ulab, China).

It was also experimentally found that all samples of the studied natural clay minerals are capable of wetting, gel formation and swelling, and are also hygroscopic.

Results

The chemical composition and morphology of the surface of clay particles were studied by scanning electron microscopy (SEM) (Fig.1) with EDAX (Table 1).

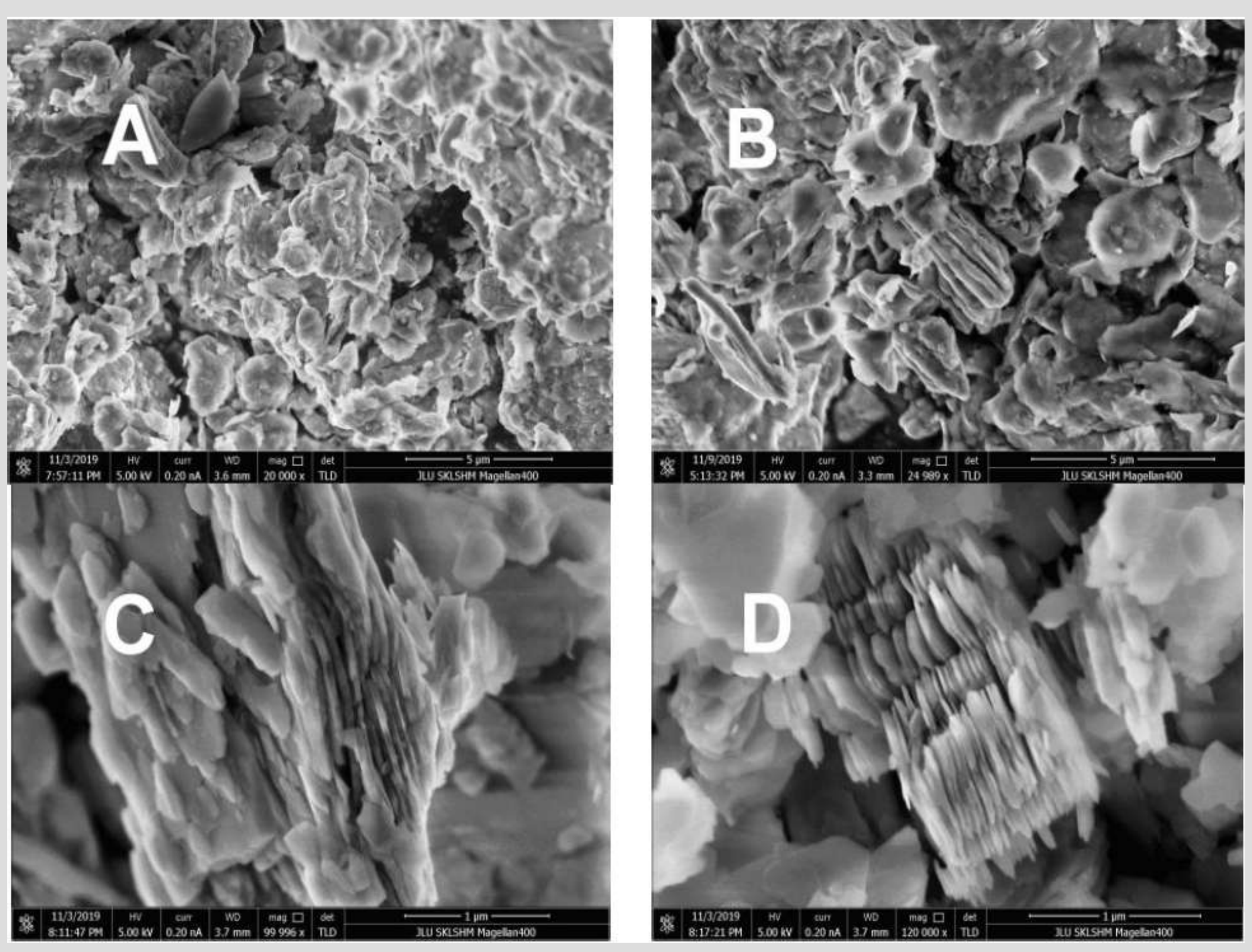


Fig. 1. SEM images of clay minerals: black clay (A), blue clay (B),yellow clay (C), white clay (kaolin) (D)

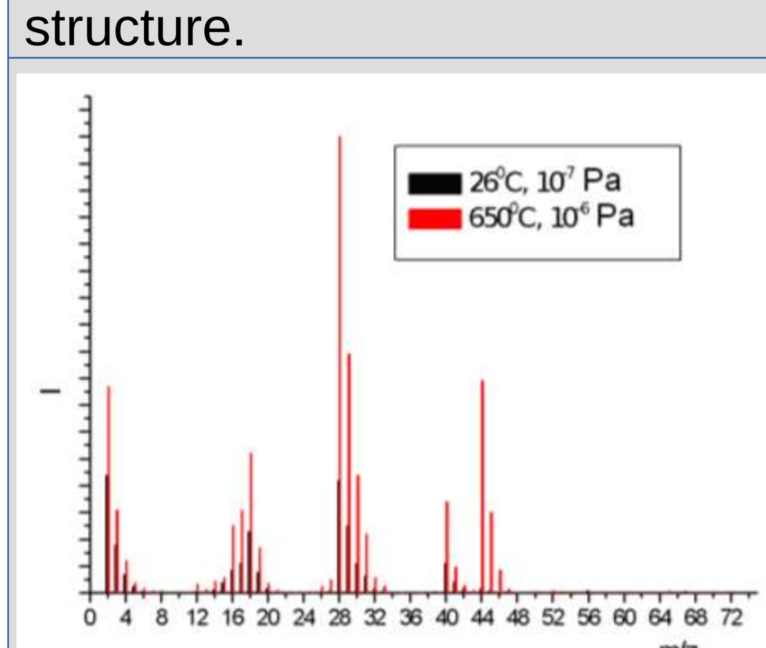
According to SEM images, it was found that the microstructure of black and blue clays contains aggregates and agglomerates of clay and calcite/quartz particles, while the microstructure of yellow clay and kaolin had a layered structure.

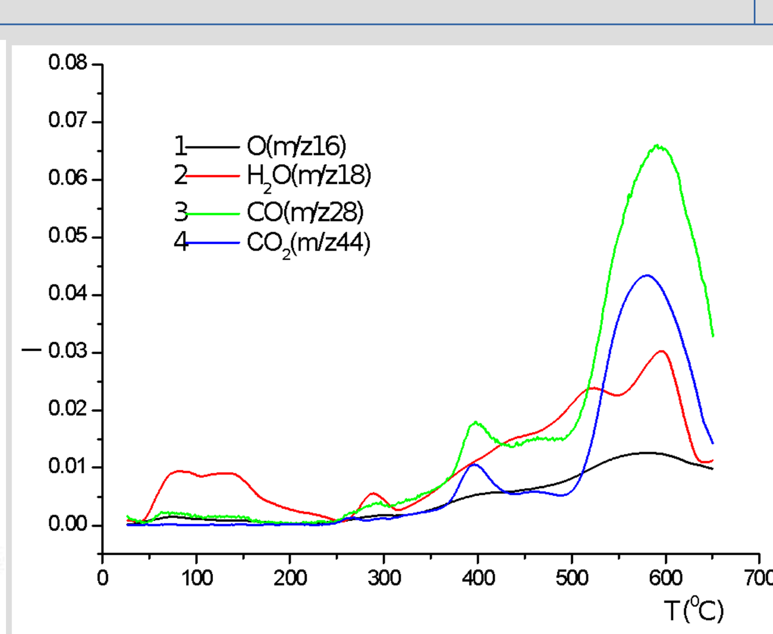
Table 1. Chemical composition of clay minerals in atomic percentages

Clay type	Elements, at. %									
	O	C	Si	Al	Fe	Ca	Mg	K	Na	Ti
White (kaolin)	48.61	36.24	7.32	7.73	-	-	-	0.10	-	-
Yellow	62.16	12.28	12.36	12.95	-	0.11	-	0.14	-	-
Black	52.88	20.12	16.47	6.41	1.56	0.64	0.80	0.50	0.47	0.16
Blue	50.38	20.69	15.40	6.78	1.77	1.52	1.27	1.45	0.58	0.17

White and yellow clays, according to their composition, belong to kaolinites, with impurities of Ca and K in yellow clay (Table 1). The layered structure of white and yellow clays is typical for kaolinite with high concentration of Al and Si in the layers. Blue and black clays have a high content of carbon (20.69 and 20.12 %, respectively), which causes their dark color, and they also contain Fe, Ca, Mg, K, Na, and Ti.

Analysis of 2 wt. % aqueous suspensions of the clays showed that the samples of kaolin suspension had a neutral medium with pH 7.24, while others were characterized by a slightly alkaline medium: yellow clay pH 9.3, black pH 9.55 and blue pH 9.94, due to impurities of alkali and alkaline earth metals.





Dehydration of clays was studied using temperature-programmed desorption with mass spectrometry control (TPD MS). The samples were heated linearly at a rate of 0.3 ºC/s between 26 ºC and 650 ºC, at a pressure of 10^{-7} Pa for 27 minutes.

The largest release of particles was detected for H_2 (m/z 2), H_2O (m/z 18), CO (m/z 28), and CO_2 (m/z 44). In the hydrated cover of clays, water is available in various forms. Therefore, desorption of intact water occurs at 100-175 ºC, and associative desorption of water (condensation of surface hydroxyls) is at 400-550 ºC.

Upon sample heating during pretreatment from 105 ºC to 150 ºC, there is a shift of O, H_2O, CO, CO_2 peaks toward high temperatures.

Conclusions

The physicochemical properties as well temperature dependent desorption of water from the clay minerals depend on their chemical structure, morphology and texture of the particles, type and concentration of surface hydroxyls, as well pretreatment temperature. The results suggest that the adsorption and other properties of natural clays could be varied due to appropriate selection of the materials and certain pretreatments, as well the use of composites.