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New approach to obtain the geopolymers based on the metakaolin for heavy metal ions removal from water

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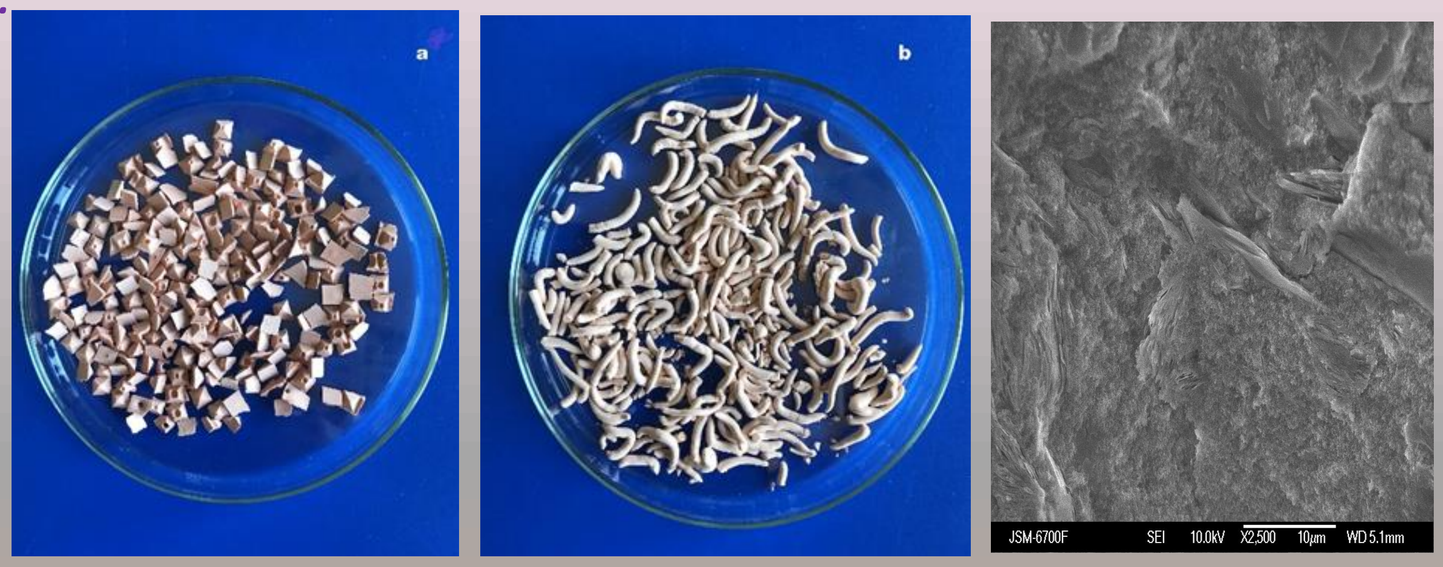
Geopolymers are three-dimensional amorphous inorganic polymers formed by the activation of aluminosilicate precursors with an alkali silicate solution. The main advantages of geopolymers that caused the great interest of researchers are: their synthesis held at low temperatures 20-100 ^{0}C, high compressive strength, thermal stability at temperatures up to 1300–1400 ^{0}C and durability against various acids and salts. The application of geopolymers as construction materials (concrete manufacturing and soil stabilization) has been studied in the past, while the new step of their investigation has begun in the field of ecology, first of all as the membranes or powder sorbents for removing the hazardous ions from water.

New approach to the synthesis of geopolymers is approved in this work on the last stage of reaction. Mixture of reagents NaOH/Na_2SiO_3 and metakaolin is placed in an oven to cure for 24 h at 60 ^{0}C (polycondensation reaction), due to using the special forms it could be obtained the sorbents in the form of ***pyramids*** (GP 1). For producing the ***spherical rods*** (GP 2) solution of reagents after heated up to 60 ^{0}C is extruded to NH_4Cl solution for neutralization of NaOH. This step significant diminishes the time of washing the final material up to neutral pH.

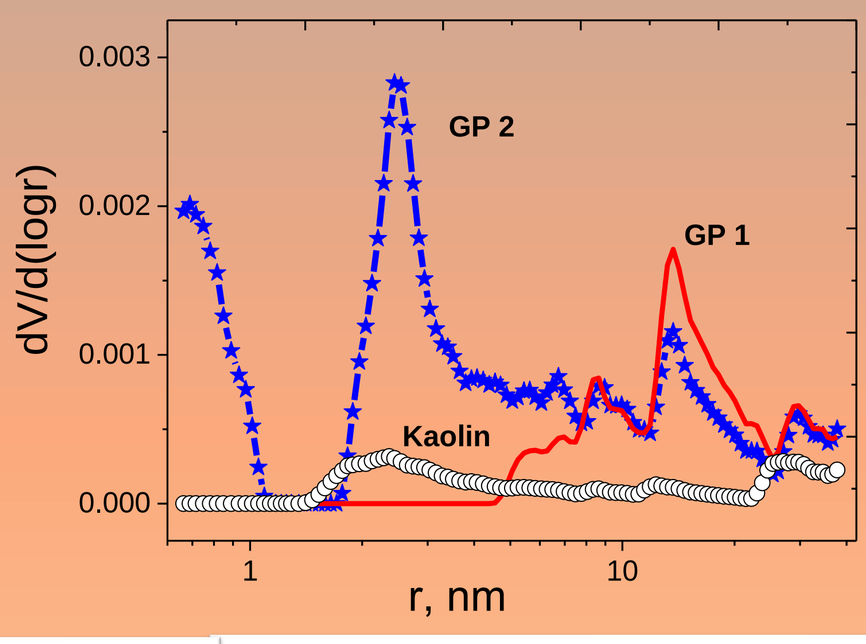


Geopolymers based on the metakaolin obtained as pyramids (a) and spherical rods (b), SEM micrographs for pyramids (x 2500 times magnification).

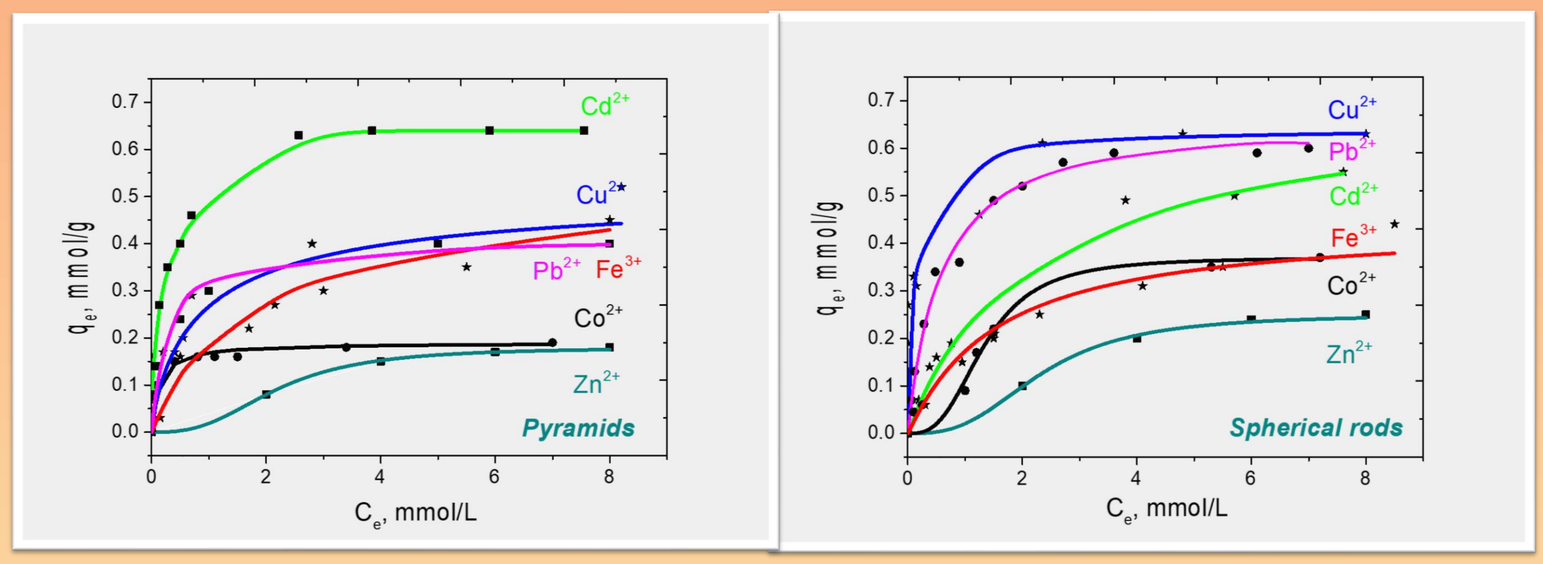
Morphology of geopolymers obtained are analyzed via XRD, XRF, SEM and low-temperature nitrogen adsorption techniques. It is found that porous structure of materials depends from the method used. Surface area of geopolymers increase from 9 (kaolin) up to 26 (pyramids) and 88 m^2/g (rods). As seen from pore size distributions structure of rods consist from a great number of micro- and mesopores those are absent in the pyramids structure.

Porosity data and pore size distribution obtained in term of DFT method for initial kaolin and geopolymers obtained

Samples	Kaolin	GP 1	GP 2
BET surface area, S_{total} (m^2 /g)	*9*	*26*	*88*
Total pore volume, V_{total} (cm^3/g)	*0.12*	*0.25*	*0.29*
Mesopore volume, V_{meso} (cm^3/g)	*0.12*	*0.25*	*0.28*
Micropore volume, V_{micro} (cm^3/g)	*0*	*0*	*0.01*
Average pore radius, R_{pore} (nm)	*28*	*19.2*	*6.6*



The ion exchange capacities of geopolymers for Zn (II), Cu (II), Co(II), Pb(II), Cd(II) and Fe (III) removal from the aqueous solution are determined. The adsorption capacities accounted by Langmuir model reach to 138 for Pb^{2+}, 77.3 (Cd^{2+}) and 41 mg/g (Cu^{2+}) by sample GP 2 that could be compared with values obtained for powder materials. The adsorption capacities of the geopolymer samples in the form of pyramids for heavy metal ions decreases in the order **Cd^{2+} > Cu^{2+} > *Fe^{3+}*> Pb^{2+} > Co^{2+}> Zn^{2+}. For comparison the adsorption capacity of initial kaolin equals 0.2 mmol/g for copper removal.**



Sorption isotherms for Zn^{2+} Cu^{2+} Co^{2+} Cd^{2+} Pb^{2+} and Fe^{3+} adsorbed onto the samples GP 1 (pyramids) and GP 2 (rods)

Conclusions:

New approach is used for obtaining low-cost sorbents based on the kaolin produced by Ukrainian enterprises in technologically convenient forms. It is found that porous structure of spherical rods include a great number of micro- and mesopores that caused the great adsorption capacities of these materials towards cadmium, lead and copper ions.