Treatment, characterization and Pb^{2+}, Cu^{2+}, Ni^{2+} and Zn^{2+} adsorption behaviour of chemically treated bentonite clay: a comparative study

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A sample of bentonite from Mostaganem (N.W. Algeria) was characterized by powder X-ray diffraction, FT-IR spectroscopy and elemental analysis. The acid-activated bentonite was employed as adsorbent for four heavy metal ions from aqueous solutions by mean of batch experiments. The effect of shaking time, pH of aqueous solution, metal concentration and adsorbent amount was studied. The effective pH range was found to be in the range 4 to 6, in which Algerian bentonite showed significant removing potential for Pb^{2+}, Cu^{2+}, Zn^{2+} and Ni^{2+} ions from aqueous solutions.

Keywords: acid-activated bentonite, removal, toxic, heavy metals

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1. Introduction

Due to their remarkable properties as adsorbents (high specific surface area, chemical stability, tendency to hold water in the interlayer sites, availability and low cost, material clays have received great attention for the removal of hazardous organic and inorganic pollutants from water (Bereket et al., 1997; Bailey et al., 1999; Gupta and Bhattacharyya, 2005; Okada et al., 2005; Boufatit et al., 2007a, b; Khazali et al., 2007; Dib et al., 2008). Attempts have been made to further improve their surface properties by chemical treatment and by intercalation with inorganic or organic molecules (Bhattacharyya and Gupta, 2008; Boufatit et al., 2008; Kwon et al., 2001; Pérez-Quintanilla et al., 2007; Uribe et al., 2002; Yapar, 2009). However, the sorbing properties of acid-activated clays for heavy metal ions must be characterized in order to predict the behaviour and removal of toxic heavy metals such as chromium, lead, cadmium, copper, nickel, and zinc from industrial wastewaters is still remains a technological challenge (Xu et al., 2008; Khazali et al., 2007; Al-Qunaibit et al., 2005; Donat et al., 2005; Yaruza et al., 2003). In this work, we report new data on the efficiency of native Algerian bentonite in removing Pb^{2+}, Cu^{2+}, Zn^{2+} and Ni^{2+} ions from aqueous systems.

2. Materials and experimental methods

2.1. Reagents and solutions

All chemicals were purchased in analytical reagent grade and were used as delivered. These were obtained from Carlo Erba (NaOH, 98%), Fluka (KOH, 99.5%; $CuCl_2$, 97%), Merck (HCl, 37%; $NiSO_4.6H_2O$, 99%) and Panreac ($Pb(NO_3)_2$; $ZnSO_4H_2O$). The elements standard solutions used were prepared with distilled water.

2.2. Preparation of bentonite

In this study, we used bentonite samples from Mostaganem (N.W. Algeria). The commercial clay was purified using a sedimentation method (Van Olphen, 1963). In this method, 5 g of clay were dispersed in 500 ml distilled water and shaken overnight on mechanical shaker (Janke type, Hunkel Ika. Werk, KS 500). The resulting clay slurry was then left to stand for 2 h to allow sedimentation of silica and other heavy impurities. The suspension was then centrifuged and the supernatant water discarded. The restrained sample was air dried (*Fig. 1.*). The purified bentonite was reacted with a 0.05 M, 0.1 M, 0.2 M, 0.5 M or 1 M HCl solution. The suspension composed of purified clay (5 g) and a HCl solution (500 ml) was shaken for 24 h. The acid-activated bentonite was centrifuged, air dried and ground to fine powder then stored for further use (*Fig. 2.*).

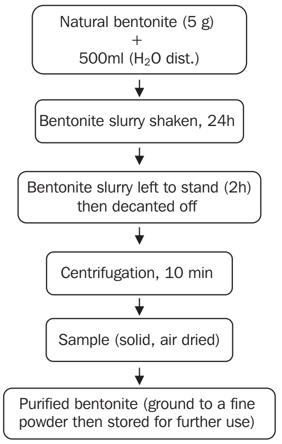

Fig. 1. Procedure for purification of bentonite clay
1. ábra A bentonittisztítás vázlata

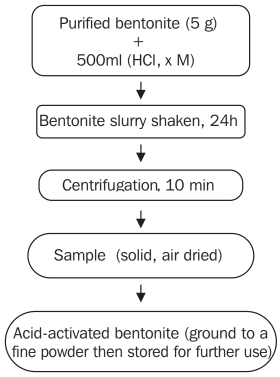

Fig. 2. Treatment of bentonite with HCl solution: x M= 0.05, 0.1, 0.2, 0.5 or 1 M HCl
2. ábra A bentonit kezelése sósavval: x M= 0.05, 0.1, 0.2, 0.5 or 1 M HCl

Figs. 1–2. Schematic diagrams for the procedure of purification and acid-treatment of bentonite (adapted from Van Olphen, 1963)
1–2. ábra A bentonit tisztításának és savval történő kezelésének sematikus diagramjai

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2.3. Adsorption experiments

1g of acid-activated bentonite, with HCl solution, was added to 100 ml aqueous solution containing separately Pb^{2+}, Cu^{2+}, Zn^{2+} and Ni^{2+} ions into 200 ml conical flasks and shaken to achieve the desired concentrations of different components. The pH values of the solution were adjusted by adding negligible volumes of 0.1 mol/l HCl or NaOH solution. After stirring the suspensions for 2h (Cu^{2+}, Ni^{2+}, Pb^{2+}) and 1h (Zn^{2+}), the solid and liquid phases were separated by centrifugation at room temperature.

2.4. Analytical method

The surface properties of raw and acid-activated bentonite were characterized by Fourier Transform Infrared spectra (FT-IR) and X-ray diffraction (XRD).

XRD patterns were obtained from Philips PW 1730 diffractometer equipped with anode using Cu-Kα. radiation (40 kV, 30 mA). The sample for the FT-IR measurement of raw and acid-activated bentonite was obtained on a FT-IR Spectrometer, type Perkin Elmer Spectrum one model in KBr pellet at room temperature.

The specific surface analysis of the raw and acid-activated bentonite was obtained with an analyzer (Micromeritics ASAP 2020 equipment), using N_2 as adsorbate.

The concentrations of Pb^{2+}, Cu^{2+}, Zn^{2+} and Ni^{2+} were analyzed by Varian type SAA-110 flame atomic absorption spectrometer equipped with deuterium background corrector. All measurements were carried out in air/acetylene flame. The removal of metal ions was calculated as:

$$\text{Removal \%} = \left(\frac{C_i - C_e}{C_i}\right).100 \qquad (1)$$

where C_i and C_e are the initial and equilibrium metal ions concentrations, respectively.

3. Results and discussion

3.1. Characterization of bentonite

The specific surface analysis of the raw bentonite was found to be 52 m^2/g, (Boufatit and Ait-Amar, 2007b). The chemical composition was (55–65)% SiO_2; (12–19)% Al_2O_3; (0.5–1.8)% K_2O; (2–3)% MgO; (0–2)% Fe_2O_3 (1.5–5.5)% CaO; (1–3)% Na_2O, (Dib and Boufatit, 2009). The chemical composition of this natural clay mineral indicates the presence of important quantity of silica (SiO_2) with traces of calcium and potassium oxides in the form of impurities (CaO and K_2O).The ignition loss of the clay at 1000 °C was found to be 7.5%, humidity 15%, and swell 0.8%.

3.1.1. XRD analysis

XRD analysis (*Fig. 3.*) showed that there was no obvious difference in the crystal structure of the raw and acid-activated bentonite (which was used in the experiments). The reflexions of all samples were exactly the same except the disappearance of the reflexion centred at $2\theta = 9°$ in the acid-activated bentonite (0.2M HCl) spectrum. In addition, associated montmorillonite and quartz impurities were also found in both materials.

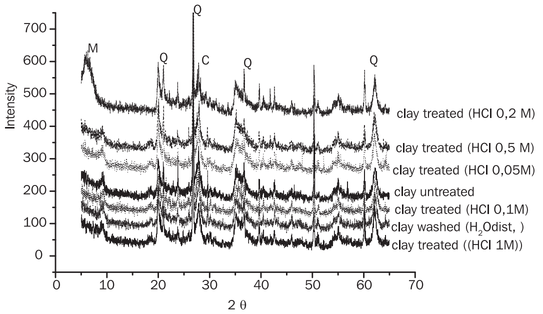

Fig. 3. X-ray diffractograms of raw and acid-activated bentonite with HCl
3. ábra A nyers és a sósavval aktivált bentonitminták röntgen diffraktogramjai

3.1.2. Infrared Spectroscopy Study

The characteristic bands of bentonite and the detailed vibrational frequencies with possible assignments being given are obtained from studies reported earlier (Boufatit et al., 2007b, 2008; Ledoux et al., 1964; Slosiarikova et al., 1992; Van der Marcel et al., 1979). All products (*Fig. 4.*) exhibit a moderately intense band at 3451 cm^{-1}, which might be ascribed to the stretching frequencies of the OH functional group of co-ordination water and of the hydration OH stretching. The absorption band at 1638 cm^{-1} can be attributed to both OH stretching vibration and $\delta(H_2O)$ deformation. The rest of the bands between 1043 and 500 cm^{-1} in all samples are due to stretching vibrations of Si-O, Si-O-Si, OH attached to (Al^{3+}, Fe^{3+} and Mg^{2+}) groups and the Silica Quartz impurities. The main change of spectra found after the acid treatment is the disappearance of the absorption bands centred at 1109 cm^{-1} and 500 cm^{-1} in the acid-activated bentonite (0.05, 0.5 and 1M HCl).

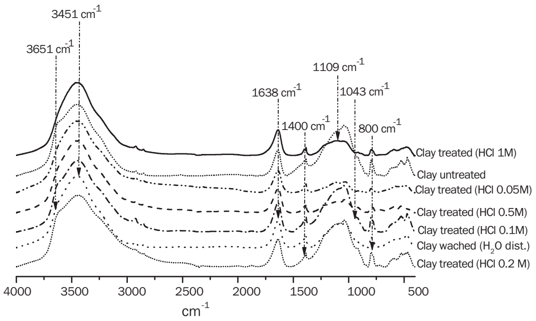

Fig. 4. Compared Infrared Spectra of raw and acid-activated bentonite with HCl
4. ábra A nyers és a sósavval aktivált bentonitminták FT-IR spektrumai

3.2. Effect of shaking time

The effect of shaking time on the removal of Pb^{2+}, Cu^{2+}, Zn^{2+} and Ni^{2+} ions is shown in *Fig. 5.* According to this figure, the removal increases with the increasing of shaking time, in the range of 5–120 min, to reach a highest value at the contact time of 15 min. Then, it decreases when shaking time exceeds 20 min to reach equilibrium within 60 min in the case of Pb^{2+}. Similar behaviour was reported elsewhere (Dib and Boufatit, 2009; Xu et al., 2008). However, the removal of Zn^{2+} ions increases with time and attains saturation within 60 min. In contrast, the removal of both Cu^{2+} and Ni^{2+} ions was slightly decreasing to reach equilibrium within 90 min. Maxima adsorptions were: 94% (Pb^{2+}); 96% (Cu^{2+}); 91% (Ni^{2+}) and 91.7% (Zn^{2+}).

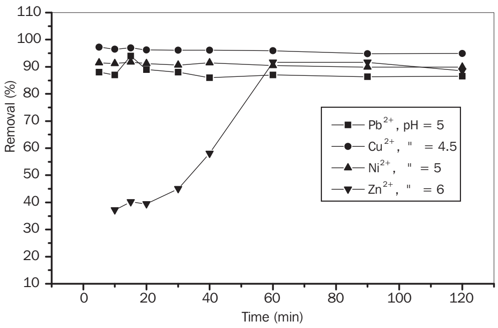

Fig. 5. Removal of Pb^{2+}, Cu^{2+}, Zn^{2+} and Ni^{2+} onto acid-activated bentonite (0.05M HCl) as a function of shaking time (initial metal concentration: 10 mg.l^{-1}; mass of acid-activated bentonite: 1g, T: 25°C)

5. ábra Az Pb^{2+}, Cu^{2+}, Ni^{2+} és Zn^{2+} ionok megkötése sósavval aktivált bentoniton (0.05M HCl) az érintkezési idő függvényében (kezdeti fémkoncentráció 10 mg.l^{-1}, sósavval aktivált bentonit tömege 1 g, hőmérséklet 25°C)

3.3. Effect of pH

The removal of Pb^{2+}, Cu^{2+}, Zn^{2+} and Ni^{2+} ions strongly depended on pH values (*Fig. 6.*). The pH effect was investigated within the range from 1 to 7 in order to avoid any possibility of metal hydroxide precipitates. In fact, adsorption of these ions on bentonite could be masked and difficult to quantify at pH values slightly higher than 6. It is found that the removal of these ions increased gradually in acidic solutions within the pH range of 1–4 and then becomes constant within the pH range of 4–7. Taking into account the effect of H_3O^+ at low pH values on surface of bentonite, this surface would be closely associated with hydronium ions (H_3O^+) which hinder the access of metal ions, by repulsive forces, to the surface functional groups (Bhattacharyya and Gupta, 2008). However, with the increasing pH, the concentration of H_3O^+ decreases and more of the metal ions could reach the clay surface and adsorb on it. The percentage removals of the metal ions reach the following maxima: 95% at pH = 4 for Cu^{2+} ions; 90% at pH = 5 for Ni^{2+}; 98% at pH = 5 for Pb^{2+} ions and 85% at pH = 6 for Zn^{2+} ions.

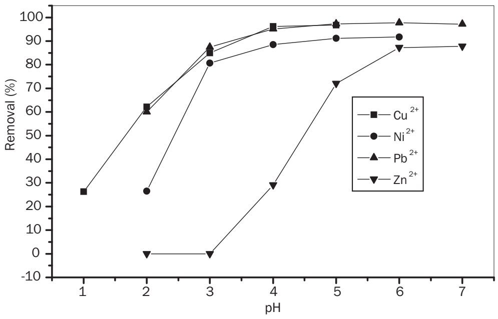

Fig. 6. Removal of Pb^{2+}, Cu^{2+}, Zn^{2+} and Ni^{2+} onto acid-activated bentonite (0.05M HCl) as a function of pH (initial metal concentration: 10 mg.l^{-1}; mass of acid-activated bentonite: 1 g, T: 25 °C)

6. ábra Az Pb^{2+}, Cu^{2+}, Ni^{2+} és Zn^{2+} ionok megkötése sósavval aktivált bentoniton (0.05M HCl) a pH függvényében (kezdeti fémkoncentráció 10 mg.l^{-1}, sósavval aktivált bentonit tömege 1 g, hőmérséklet 25 °C)

3.4. Effect of mass of bentonite

The removal of Pb^{2+}, Cu^{2+}, Zn^{2+} and Ni^{2+} increased with the bentonite amount (*Fig. 7.*). This removal became constant beyond masses greater than 1 g for the three metals ions Cu^{2+}, Pb^{2+} and Zn^{2+} and 2g for Ni^{2+} ions. This increase may be associated with the increase of available sites on the bentonite surface upon increasing the amount of bentonite. The optimazed removal was 91% (Cu^{2+}), 74% (Ni^{2+}), 99% (Pb^{2+}) and 36% (Zn^{2+}).

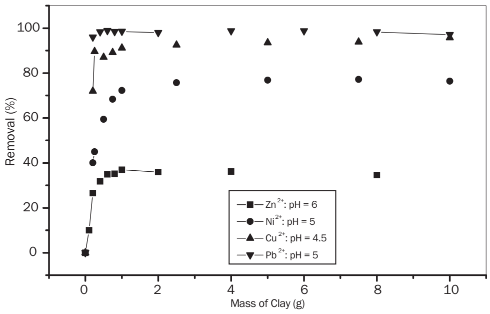

Fig. 7. Removal of Zn^{2+}, Ni^{2+}, Cu^{2+} and Pb^{2+} as a function of acid-activated bentonite (0.05M HCl) mass (initial metal concentration: 10 mg.l^{-1}; T: 25 °C)

7. ábra Az Pb^{2+}, Cu^{2+}, Ni^{2+} és Zn^{2+} ionok megkötése sósavval aktivált bentoniton (0.05M HCl) a bentonit tömegének függvényében (kezdeti fémkoncentráció 10 mg.l^{-1}, hőmérséklet 25 °C)

3.5. Effect of initial concentration of Pb^{2+}, Cu^{2+}, Zn^{2+} and Ni^{2+} ions

The removal of Pb^{2+}, Cu^{2+}, Zn^{2+} and Ni^{2+} ions on bentonite as a function of initial concentration in the range 5–100 mg/l was investigated at pH = 5 (*Fig. 8.*). As seen in this figure, the removal was constant for initial concentration exceeding 30 mg. L^{-1} for Pb^{2+} ions, while the extent of the removal decreased continuously for $Cu^{2+}$and Ni^{2+} ions. This behaviour observed for $Cu^{2+}$and Ni^{2+} ions might be explained by the availability of sites.

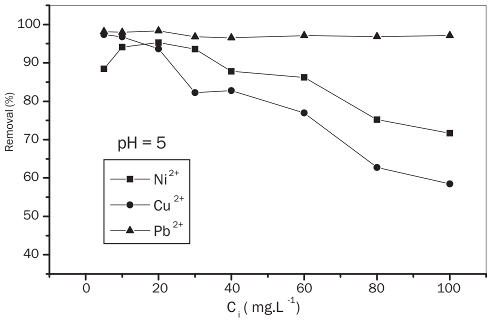

Fig. 8. Removal of Cu^{2+}, Ni^{2+} and Pb^{2+} ions as a function of initial metal concentration (pH of the aqueous solution: 5; mass of acid-activated bentonite: 1 g; T: 25 °C)

8. ábra Az Pb^{2+}, Cu^{2+} és Ni^{2+} ionok megkötése sósavval aktivált bentoniton a fémkoncentráció függvényében (vizes oldat pH-ja 5, bentonit tömege 1 g, hőmérséklet 25 °C)

4. Conclusion

Acid-activated bentonite from Mostaganem (N.W. Algeria) can be used as an effective adsorbent for the removal of Pb^{2+}, Cu^{2+}, Zn^{2+} and Ni^{2+} from aqueous solutions.

The effective solution pH for the removal was: 4 for Cu^{2+}, 5 for (Pb^{2+}, Ni^{2+}) and 6 for Zn^{2+}.

The contact time for the maximum removal required was 90 min for $Cu^{2+}$and Ni^{2+} and 60 min for $Pb^{2+}$and Zn^{2+}.

The availability and the low cost of this bentonite make it a good candidate in adsorption processes for use in water treatment and purification.

Aknowledgements

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References

[1] Al-Qunaibit, M. H. – Mekhemer, W. K. – Zaghloul, A. A.: *The adsorption of Cu(II) 152. ions onto bentonite-a kinetic study*. J. Colloid Interface Sci. 283, 2005. 316–321.

[2] Bailey, E.S. – Olin, T.J. – Bricka, R.M. – Adrian, D.D.: *A review of potentially low-154. cost sorbents for heavy metals.* Water Res. 33(11), 1999. 2469–2479.

[3] Bereket, G. – Aroguz, A.Z. – Ozel, M.Z.: *Removal of Pb(II), Cd(II), Cu(II) and Zn(II) from aqueous solutions by adsorption on bentonite.* J. Colloid Interface Sci.187, 1997. 338–343.

[4] Bhattacharyya, K.G. – Gupta, S.S.: *Adsorption of Fe(III), Co(II) and Ni(II) on ZrO-kaolinite and ZrO-montmorillonite surfaces in aqueous medium*. Colloids and Surfaces A: Physicochem. Eng. Aspects 317, 2008. 71–79.

[5] Boufatit, M. – Ait-Amar, H. – McWhinnie, W. R.: *Development of Algerian material montmorillonite clay. Adsorption of phenol, 2-dichlorophenol and 2, 4, 6- trichlorophenol from aqueous solutions onto montmorillonite exchanged with transition metal complexes*. Desalination, 206, 2007a. 394–406.

[6] Boufatit, M. – Ait-Amar, H.: *Removal of N, N-dimethylaniline from dilute aqueous solution by* Na^+*/* K^+ *saturated montmorillonite*. Desalination, 206, 2007b. 300–310.

[7] Boufatit, M. – Ait-Amar, H. – McWhinnie, W. R.: *Development of Algerian material montmorillonite clay - Intercalation with selective long chain alkylammonium cations (Octadecytrimethylammonium, Cetylpyridium and Tetrabutylammonium) and with tellerium complexes.* Desalination 223, 2008. 366–374.

[8] Dib. S. – Khouider, A. – Boufatit, M.: *Removal of* Cu^{2+} *and* Ni^{2+} *from aqueous solution by Algerian clay materials*. Proceedings of the Global Conference on Global Warming-2008 (GCGW-08), 6-10 July 2008, Istanbul, Turkey. pp.737–744.

[9] Dib. S. – Boufatit, M.: *Equilibrium study of adsorption of* Pb^{2+} *from aqueous solution onto Algerian bentonite clay.* Desalination and Water Treatment, 5, 2009. 106-110.

[10] Donat, R. – Akdogan, A. – Erden, Cetisli, H.: *Thermodynamics of* Pb^{2+} *and* Ni^{2+} *adsorption onto natural bentonite from aqueous solutions.* J. Colloid Interface Sci. 286, 2005. 43–52.

[11] Findon A. – Mckay O. – Blair H. S.: *Transport studies for the sorption of copper ions by chitosan*. J. Environ. Sci. Healt, 1993. A28: 173–185.

[12] Gupta, S. S. – Bhattacharyya, K. G.: *Interaction of metal ions with clays: I, A case study with Pb(II).* Appl. Clay Sci. 30, 2005. 199–208.

[13] Khazali, O. – Abu-El-Halawa, R. – Al-Sou'od, K.: *Removal of copper (II) from aqueous solution by Jordanian pottery materials.* J. of Hazardous Materials, 139(1), 2007. 67–71.

[14] Kocaoba, S. – Orhan, Y. – Akyüz, T.: *Kinetics and equilibrium studies of heavy metal ions removal by use of natural zeolite.* Desalination 214, 2007. 1–10.

[15] Kwon, O.Y. – Park, K.W. – Jeong, S. Y.: *Preparation of porous silica-pillared montmorillonite: simultaneous intercalation of amine-tetraethylorthosilicate into H-Montmorillonite and intra-gallery amine-catalyzed hydrolysis of tetraethylorthosilicate.* Bulletin Korean of Chemical Society 22 (7) 2001. 678–684.

[16] Ledoux, R. L. – White, J. L.: *Infrared study of selective deutertion of kaolinite and halloysite at room temperature.* Science 145 1964. 47–49.

[17] Marcel, Van der H.W. – Spacher, H. B.: *Atlas of infrared spectroscopy of clay minerals and their admixtures.* Elsevier, Amsterdam. 1979.

[18] Okada, T. – Morita, T. – Ogawa, M.: *Tris(2,2'-bipyridine)ruthenium(II)-clays as adsorbents for phenol and chlorinated phenols from aqueous solution.* Applied Clay Science 29, 2005. 45–53.

[19] Olphen, H. V.: *An introduction to clay colloid chemistry. App. I: Preparation of clay suspensions*. Interscience Publishers, John Wiley and Sons. N.Y, London, 1963. pp 239–243.

[20] Pérez-Quintanilla, D. – Sanchez, A. – Del Hierro, I. – Fajardo, M. – Sierra, I.: *Preparation, characterization, and* Zn^{2+} *adsorption behavior of chemically modified MCM-41 with 5-mercapto-1-methyltetrazole.* J. Colloid Interface Sci. 313(2), 2007. 551–562.

[21] Slosiarikova. H. – Bujdak, J. – Hlauaty, V.: *IR spectra of octadecylammonium-montmorillonite in the range of Si-O vibrations.* The Journal of inclusion phenomena and molecular recognition in chemistry 13(3) 1992. 267–272.

[22] Uribe, A. – Bishop, P. L. – Neville, G. P.: *The influence of pH and temperature changes on the adsorption behaviour of organophilic clays used in the stabilisation/solidification of hazardous wastes.* Journal of Environmental and Engineering Science 1: 2002. 123–133.

[23] Xu, D. – Tan, X. L. – Chen, C. L. – Wang, X. K.: *Adsorption of Pb(II) from aqueous solution to MX-80 bent: Effect of pH, ionic strength, foreign ions and temperature.* Applied Clay Science, 41, 2008. 37–46.

[24] Yapar, S.: *Physicochemical study of microwave-synthesized organoclays*. Colloids and Surfaces A: Physicochem. Eng. Aspects 345, 2009. 75–81.

[25] Yaruza, Ö. – Altunkaynaklo, Y. – Güzel, F.: *Removal of copper, nickel, cobalt and manganese from aqueous solution by kaolinite.* Water Res. 37, 2003. 948–952.

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Makhlouf **Boufatit** – Fettouma **Mohammed-Azizi** – Saroya **Dib:** *Treatment, characterization and* Pb^{2+}*,* Cu^{2+}*,* Ni^{2+} *and* Zn^{2+} *adsorption behaviour of chemically treated bentonite clay: a comparative study.* Építőanyag, 63. évf. 1–2. szám (2011), 24–27. p.

Összehasonlító vizsgálatok egy bentonitos agyag kémiai kezeléséről, jellemzéséről, valamint Pb^{2+}, Cu^{2+}, Ni^{2+} és Zn^{2+} adszorpciójáról

Mostaganem-ből (Délnyugat-Algéria) származó bentonitmintát vizsgáltunk pordiffrakciós, FT-IR spektroszkópiai módszerekkel, és meghatároztuk kémiai összetételét is. A savval aktivált bentonitot adszorbensként használtuk nehézfémek vizes oldatból való megkötéséhez, szakaszos körülmények között. Tanulmányoztuk az érintkezési idő, az oldat pH-ja, a fémkoncentráció és az adszorbens mennyiségének hatását a fémmegkötő képességre. A legmegfelelőbb pH tartomány 4–6 közé esik. Ekkor az adott bentonit jelentős mennyiségű Pb2+, Cu2+, Ni2+ és Zn2+ iont köt meg vizes oldatokból.

Kulcsszavak: savval aktivált bentonit, toxikus nehézfémek eltávolítása

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