

THESES FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (PHD)

Preparation, structural and surface characterization of
lanthanoid bentonites

by Eszter Mária Kovács

Supervisor: Professor Dr. Noémi M. Nagy



UNIVERSITY OF DEBRECEN
DOCTORAL SCHOOL OF CHEMISTRY
DEBRECEN, 2019

Introduction and objectives

Interfacial reactions of clay rocks play an essential role in describing the interfacial processes in the rocks and in mapping the consequences of environmental pollution. During this work, bentonite clay rock was used, main mineral of which is montmorillonite. Montmorillonite is a 2:1 layered (TOT type) dioctahedral clay mineral of the silicate class in the layersilicate subclass. Due to its permanent negative charge, it can bind cations in its interlayer space. Montmorillonite is particularly suitable for the study of interfacial processes because of its well-known properties and high cation exchange capacity.

Lanthanoide ions are often used as geochemical tracers for surface processes. Lanthanoide ions are also geological indicators, but their nature and binding strength are not fully known. Moreover, lanthanoide ions are models in the interactions between soil and transuranium ions and lanthanide ions are also found in fission products. Considering the complexity of surface processes, it is important to understand the mechanisms that may influence the system. Clay minerals are extremely important for sorption studies, due to their large specific surface area and abundance in the natural environmental surface. The interaction

between clay minerals and lanthanides have been investigated in the past 40 years. These studies focused on different aspects of sorption mechanisms, e.g. the irreversibility of sorption mechanisms or their relation to cation exchange ability.

However, the published data often differ and it is difficult to compare the results of different experimental protocols. In addition, experiments are usually done with a single lanthanoide ion. The available data on lanthanoide sorption do not allow us to draw conclusions. Little is known about the nature of the chemical bonds between the metal cations and the clay structure or the possible changes in the clay structure.

Thus, it is essential to study structural changes before using bentonite clay rock. Therefore, in the main part of my dissertation, structural determination examinations were used for studying the structure of bentonite.

Sorption and migration experiments were carried out on lanthanoide bentonites with different ions by radioactive tracer method, monitoring the relationship between lanthanoide clay and radionuclide clay.

Experimental methods

Lanthanoide bentonites were prepared from Ca-bentonite by cation exchange procedure. XRF, XRD, SEM and Mössbauer spectroscopy were used to study the structure of the prepared lanthanoide bentonites.

The calcium, iron and lanthanoide ion contents of the modified bentonites were examined by XRF method. The surface of the lanthanoide bentonites was observed by SEM (EDX) method and the elemental distribution map of the Ln^{3+} and Fe^{3+} ions were recorded.

The change in mineral composition and in the basal spacing (d) of the clay mineral depending on the size of the cation was observed by XRD measurement.

Mössbauer spectroscopy measurements of bentonite samples were also performed to determine the oxidation state, coordination and chemical environment of iron.

Gamma spectrometry method was used to investigate the sorption of ^{137}Cs isotope and the migration of the ^{36}Cl isotope which can be used to determine the amount of the sorption of cesium and chloride in the bentonite and how it goes forward during the migration.

Liquid scintillation spectrometry method was used to follow the ^{36}Cl isotope and ^{137}Cs isotope migration to track the location by the time in the bentonite.

Abbreviations

XRF: X-ray fluorescent spectroscopy

XRD: X-ray diffraction

SEM (EDX): Scanning electronmicroscopy (with energy dispersive detector)

Ln^{3+} : Lanthanoides

TOT type: tetrahedral-octahedral-tetrahedral structural unit

New scientific results

1. Lanthanoide bentonites were prepared from lanthanum to lutetium (except for promethium) by cation exchange procedure. The sorbed amount of Y^{3+} , La^{3+} , Ce^{3+} and Gd^{3+} ions was higher than the cation exchange capacity while the structural iron content released.

1.1 The cation exchange was successful between the Ca^{2+} and Ln^{3+} ions as detected by XRF measurements. The concentration

of Ca^{2+} ion in the bentonite was under 10%. The concentration of Ln^{3+} ion in the bentonite was mostly 70-80%, or over the cation exchange capacity. The Fe^{3+} content decreased by 20-50%.

1.2 XRD measurements show no changes in crystal structure. The $d(001)$ basal spacing of the montmorillonite increases as the radius of the lanthanoide ions increases, indicating successful cation exchange.

1.3 The morphology is characteristic of the montmorillonite and the Ln^{3+} ions are homogenously distributed on the surface.

2. As the temperature increases, more and more lanthanoide ions are sorbed on the bentonite. Sorption is slightly influenced by the pH, but it is significantly influenced by the concentration of lanthanoide ions (yttrium and lanthanum).

3. The Y^{3+} , La^{3+} , Ce^{3+} and Gd^{3+} ions cause the release of the octahedral iron ions from the montmorillonite lattice in aqueous media at room temperature which was observed and proved firstly by me. Even at low concentration of lanthanoide ion ($1 \cdot 10^{-4} \text{ mol/dm}^3$) a slightly decrease in iron concentration can be detected in the bentonite.

3.1 ^{57}Fe Mössbauer spectroscopic measurements showed the presence of the interlayer Fe^{3+} ions, which did not occur on the calcium bentonite spectra. A part of the octahedral iron in the

montmorillonite was entered into the interlayer phase using high concentration of lanthanoide ion during cation exchange procedure.

3.2 Another part of the octahedral iron enters to the aqueous phase then hydrolyzed and present as FeO-OH using high concentration of lanthanoide ion during cation exchange procedure.

4. The concentration of lanthanoide, calcium and iron ions go through a three-step change during the sorption kinetic studies of lanthanum ion. The three steps were separately evaluated for the three ions using pseudo-second-order kinetic model. It was assumed that beside the ion exchange between the calcium and lanthanum ions, the iron ion leaves the crystal lattice in the very beginning of the kinetic study which is due to the high concentration of lanthanum ion. The lanthanoide ion creates new sorption site for itself by diffusing the iron ion from the octahedral layer, which increases the negative layer charge and the cation exchange capacity of the clay mineral. This explains the sorption of lanthanoide ions over the cation exchange capacity and the decrease in structural iron concentration.

5. $^{137}\text{Cs}^+$ ion can exchange lanthanoide ions during the sorption on Pr-, Dy- and Nd-bentonites. The exchange isotherm derived

by us can be used to determine the number of active sites of the surface in heterogeneous system. However, the equilibrium constants of the cation exchange can only be evaluated with large error; thus, it can be used for comparing the relative preference of the cations.

6. The migration coefficients of the $^{36}\text{Cl}^-$, $^{137}\text{Cs}^+$ ions were determined in La- and Pr- bentonites. It was concluded that the bentonites modified with lanthanoid ions are also suitable as engineering barrier for radioactive waste storage based on the evaluation.

Acknowledgments

I am grateful to my supervisor Dr. Noémi M. Nagy professor for my guidance, advices and patience during my work. I thank Prof. Dr. József Kónya for his help and valuable advices.

I am thankful to my former colleague Zoltán Nemes for his practical advices and to Éva Gombosné Németh, chemist technician for her experimental assistance. Furthermore, I am grateful to Dóra Buzetzký, research assistant for her encouragement words. I would like to thank to my BSc., MSc. students for their work.

I am grateful to my loving family and my partner for their uninterrupted encouragement.

I am grateful to Dr. Péter Kovács-Pálffy, Dr. Péter Kónya and Dr. Ferenc Kristály for X-ray diffraction measurements.

I am grateful to Dr. Erdélyiné Dr. Eszter Baradács and Dr. Csaba Cserhádi for the scanning electron microscopy measurements.

I am also grateful to Prof. Dr. Ernő Kuzmann and Prof. Dr. Zoltán Homonnay for the Mössbauer-spectroscopic measurements.

I am grateful to Dr. Edina Baranyai and Sándor Harangi for the ICP-OES measurements.

This research was supported by the EU and co-financed by the European Regional Development Fund under the project GINOP-2.3.2.-15-2016-00008 and the Hungarian National Research, Development, and Innovation Office under the project NKFIH K 120265.

Publications

List of publications related to the dissertation

1. Nagy N., Kovács E.M., Kónya J.: Ion exchange isotherms in solid: electrolyte solution systems. J. Radioanal. Nucl. Chem 308 (3), 1017-1026., **2015**. IF: 1,186 (2018)

2. Kuzmann, E., Singh, L., Garg, V., Oliveira, d., Kovács, E., Molnár, Á., Homonnay, Z., Kónya, P., Nagy, N., Kónya, J.: Mössbauer study of the effect of rare earth substitution into montmorillonite. *Hyperfine Interact* 237 (2), 1-8., **2016**. IF: 0,92 (2015)
3. Kovács, E., Baradács, E., Kónya, P., Kovács-Pálffy, P., Harangi, S., Kuzmann, E., Kónya, J., Nagy, N.: Preparation and structure's analyses of lanthanide (Ln) -exchanged bentonites. *Colloid Surf. A-Physicochem. Eng. Asp* 522 287-294., **2017**. IF: 2,829 (2016)
4. Kovács E., Kónya J., M. Nagy N.: Structural curiosities of lanthanide (Ln)-modified bentonites analyzed by radioanalytical methods. *J. Radioanal. Nucl. Chem.* DOI: 10.1007/s10967-019-06765-6 (Accepted **2019.09.10.**) IF: 1,186 (2018)

List of other publications

1. Kuzmann, E., Garg, V., Singh, H., Oliveira, d., Pati, S., Homonnay, Z., Rudolf, M., Molnár, Á., Kovács, E., Fehérné Baranyai, E., Kubuki, S., Nagy, N., Kónya, J.: Mössbauer study of pH dependence of iron-intercalation in montmorillonite. *Hyperfine Interact* 237 (1), 106. **2016**. IF: 0,92 (2015)

2. Kuzmann E., Kovács E. M., Homonnay Z., Csákvári Sz., Klencsár Z., Kónya P., Nagy N. M. and Kónya J.: Fe microenvironments in heat treated rare earth exchanged montmorillonites. *Hyperfine Interact* 240,87, **2019**. DOI: 10.1007/s10751-019-1622-7 IF: 0,45 (2018)
3. Nagy M. N., Buzetky D., Kovács E.M., Kovács A. B., Kátai J., Vágó I., Kónya J. Study of phosphate species of chernozem and sand soils by heterogeneous isotope exchange with ³²P radioactive tracer. *Appl. Radiat. Isotopes*. 152, 64-71. **2019**. IF: 1,123 (2017)

Conference participation

Presentations related to the PhD dissertation

1. Kovács, E., Kónya, J., Nagy, N.: Ritkaföldfém montmorillonitok előállítása és szerkezetük vizsgálata. In: Őszi Radiokémiai Napok 2013. Szerk.: Szentmiklósi László, Magyar Kémikusok Egyesülete, Budapest, 71-75, **2013**. ISBN: 9789639970427
2. Kovács, E., Molnár, Á., Nagy, N., Kónya, J.: Háromértékű kationcserélt montmorillonitok néhány tulajdonsága. In: Őszi Radiokémiai Napok 2014: Balatonszárszó, **2014**. október 13-

15.:a konferencia programja és előadás kivonatai. Szerk.: Szentmiklósi László, Magyar Kémikusok Egyesülete, Budapest, 33-38, 2014. ISBN: 9789639970502

3. Kovács E.M., Kónya J., M. Nagy N.: Ritkaföldfém-bentonitok előállítására és szerkezetük vizsgálata környezetvédelmi szempontból. 3. Környezetkémiai Szimpózium. Lajosmizse. **2014.**

4. Kovács E. M., M. Nagy N., Kónya J.: Bentonit szerkezetének vizsgálata kationcserét követően. Geológus ülés. Debrecen. **2014.**

5. Kovács, E., Nagy, N., Kónya, J., Kuzmann, E., Homonnay, Z., Singh, L., Garg, V.: Lantanoid-bentonitok ioncserés előállítása kalcium-bentonitból. In: Őszi Radiokémiai Napok 2015: Balatonszárszó, 2015. október 19-21. : a konferencia programja és előadás kivonatai. Szerk.: Szentmiklósi László, Magyar Kémikusok Egyesülete, Budapest, 69-74, **2015.** ISBN: 9789639970595

6. Kovács, E., Kuzmann, E., Kónya, J., Nagy, N.: Surface species of lanthanum ion on montmorillonite. In: 8th Mid-European Clay Conference (MECC 2016) : Book of Abstracts. Ed.: Jana Valúchová, Equilibra, Košice, Slovakia, 41, **2016.** ISBN: 9788097228804

7. Kovács E.M., Kónya J., M. Nagy N.: La-bentonit szerkezeti érdekességei. Geológus ülés. Debrecen. **2016**.
8. Kovács, E., Harangi, S., Kuzmann, E., Kónya, J., Nagy, N.: Environmental importance of preparation and structure's analyzes of trivalent clays. In: Proceedings the 6th International Conference on Carpathian Euroregion ECOLOGY CERECO. Ed.: Bárány Sándor, Buczkó István, Kohut Erzsébet, Csoma Zoltán, Komonyi Éva, Szabó Marján, Filep Mihály, II. Rákóczi Ferenc Kárpátaljai Magyar Főiskola, Beregszász, Ukrajna, 45-57, **2017**. ISBN: 9786177404285
9. Kovács E.M., Buzetzy Dóra, Kónya J., M. Nagy N.: La-, Ce-, Y- és Fe- bentonitok előállítás környezetvédelmi felhasználás céljából. 6. Környezetkémiai Szimpózium. Bakonybél. **2017**.
10. Kovács, E., Kónya, J., Nagy, N.: Ca(II)-Y(III) cserefolyamat vizsgálata bentoniton. In: Őszi Radiokémiai Napok 2017. Szerk.: Szentmiklósi László, Magyar Kémikusok Egyesülete, Budapest, 72, **2017**. ISBN: 9789639970809
11. Kovács, E., Kónya, J., Nagy, N.: Structural iron release from bentonite by Y³⁺ and La³⁺ ions. In: 9th Mid-European Clay Conference MECC 2018: Conference Book. Ed.: by Darko Tibljaš, Marija Horvat, Nenad Tomašić, Marta Mileusnić, Anita

Grizelj, Croatiaoan Geological Society, Zagreb, 66, **2018**. ISBN: 9789536907717

12. Kovács, E., Kónya, J., Nagy, N.: Structural curiosities of lanthanide (Ln)-modified bentonites analyzed by radioanalytical methods. In: International Conference on Radioanalytical and Nuclear Chemistry : Book of abstracts, Akadémiai Kiadó, Budapest, 62, **2019**. ISBN: 978963454369

Other presentations, posters

1. Buzetzký D., Kovács E.M., M. Nagy N., Kónya J.: Foszfátionok megkötése módosított bentonitokon. PhD hallgatók 2. Környezettudományi Konferenciája. Budapest, **2016**.
2. Nagy, N., Buzetzký, D., Földvári, A., Kormány, Z., Kovács, E., Nemes, Z., Kónya, J.: Talajok foszfortápanyag-forgalmának vizsgálata heterogén izotópcserével. In: Őszi Radiokémiai Napok **2017**. Szerk.: Szentmiklósi László, Magyar Kémikusok Egyesülete, Budapest, 70, 2017. ISBN: 9789639970809
3. Buzetzký, D., Kovács, E., Nagy, N., Kónya, J.: Eutrofizációs folyamatok csökkentésére irányuló vizsgálatok módosított bentonitokkal. Talajvédelem. 205-214, **2017**.

4. Nagy, N., Buzetzky, D., Földvári, A., Kormány, Z., Kovács, E., Nemes, Z., Balláné Kovács, A., Kátai, J., Vágó, I., Kónya, J.: Study of phosphate species in soils by radioisotopic labeling. Czech Chemical Society Symposium Series. 16 (2), 151-152, **2018**.
5. Kovács, E., Balogh, M., Kónya, J., Nagy, N.: Réteges kettőshidroxidok megkötő-képességének vizsgálata ^{131}I -, ^{36}Cl - és $^{99\text{m}}\text{TcO}_4^-$ anionok segítségével. In: Őszi Radiokémiai Napok **2018** / Homlok Renáta, Kovácsné Tóth Zita, Kasztovszky Zsolt, Magyar Kémikusok Egyesülete, Budapest, 22-26, **2018**. ISBN: 9789639970933
6. Nagy, N., Buzetzky, D., Kovács, E., Kónya, J.: Gyors és lassú konzekutív folyamatok vizsgálata heterogén izotópcserével egyetlen rövid életű radionuklid segítségével. In: Őszi Radiokémiai Napok 2018 / Homlok Renáta, Kovácsné Tóth Zita, Kasztovszky Zsolt, Magyar Kémikusok Egyesülete, Budapest, 90, **2018**. ISBN: 9789639970939
7. Kónya, J., Buzetzky, D., Kovács, E., Nagy, N.: Study of phosphate sorption of soils by radioactive tracer method. In: International Conference on Radioanalytical and Nuclear Chemistry : Book of abstracts, Akadémiai Kiadó, Budapest, 369, **2019**. ISBN: 9789634543695

8. Kovács, E., Balogh, M., Kónya, J., Nagy, N.: Sorption of $^{131}\text{I}^-$, $^{36}\text{Cl}^-$ and $^{99\text{m}}\text{TcO}_4^-$ Anions by ZnAl and MgAl Layered Double Hydroxides. In: Euroclay International conference on clay science and technology: Book of abstracts, Sorbonne Université, Paris, 354, **2019**.
9. Nagy, N., Kovács, E., Buzetzky, D., Kónya, J.: Phosphate sorption of soils with different clay content. In: Euroclay: International conference on clay science and technology 2019.07.01-2019.07.05. Paris, Sorbonne Université : Book of abstracts, Sorbonne Université, Paris, 461, **2019**.



Registry number: DEENK/345/2019.PL
Subject: PhD Publikációs Lista

Candidate: Eszter Mária Kovács
Neptun ID: VP6830
Doctoral School: Doctoral School of Chemistry
MTMT ID: 10054387

List of publications related to the dissertation

Foreign language scientific articles in international journals (4)

1. **Kovács, E. M.**, Kónya, J., Nagy, N. M.: Structural curiosities of lanthanide (Ln)-modified bentonites analyzed by radioanalytical methods.
J. Radioanal. Nucl. Chem. [Epub ahead of print], 1-8, 2019. ISSN: 0236-5731.
DOI: <https://doi.org/10.1007/s10967-019-06765-6>
IF: 1.186 (2018)
2. **Kovács, E. M.**, Baradács, E., Kónya, P., Kovács-Pálffy, P., Harangi, S., Kuzmann, E., Kónya, J., Nagy, N. M.: Preparation and structure's analyses of lanthanide (Ln)-exchanged bentonites.
Colloid Surf. A-Physicochem. Eng. Asp. 522, 287-294, 2017. ISSN: 0927-7757.
DOI: <http://dx.doi.org/10.1016/j.colsurfa.2017.02.085>
IF: 2.829
3. Kuzmann, E., Singh, L. H., Garg, V. K., Oliveira, d. A. C., **Kovács, E. M.**, Molnár, Á. M., Homonnay, Z., Kónya, P., Nagy, N. M., Kónya, J.: Mössbauer study of the effect of rare earth substitution into montmorillonite.
Hyperfine Interact. 237 (2), 1-8, 2016. ISSN: 0304-3843.
DOI: <http://dx.doi.org/10.1007/s10751-016-1225-5>
4. Nagy, N. M., **Kovács, E. M.**, Kónya, J.: Ion exchange isotherms in solid: electrolyte solution systems.
J. Radioanal. Nucl. Chem. 308 (3), 1017-1026, 2015. ISSN: 0236-5731.
DOI: <http://dx.doi.org/10.1007/s10967-015-4536-0>
IF: 0.983

Hungarian conference proceedings (3)

5. **Kovács, E. M.**, Nagy, N. M., Kónya, J., Kuzmann, E., Homonnay, Z., Singh, L. H., **Garg, V.**.: Lantanoid-bentonitok ioncserés előállítására kalcium-bentonitból.
In: Őszi Radiokémiai Napok 2015 : Balatonszárszó, 2015. október 19-21. : a konferencia programja és előadás kivonatai. Szerk.: Szentmiklósi László, Magyar Kémikusok Egyesülete, Budapest, 69-74, 2015. ISBN: 9789639970595





6. **Kovács, E. M.**, Molnár, Á. M., Nagy, N. M., Kónya, J.: Háromértékű kationcserélt montmorillonitok néhány tulajdonsága.
In: Őszi Radiokémiai Napok 2014 : Balatonszárszó, 2014. október 13-15. : a konferencia programja és előadás kivonatai. Szerk.: Szentmiklósi László, Magyar Kémikusok Egyesülete, Budapest, 33-38, 2014. ISBN: 9789639970502
7. **Kovács, E. M.**, Kónya, J., Nagy, N. M.: Ritkaföldfém montmorillonitok előállítása és szerkezetük vizsgálata.
In: Őszi Radiokémiai Napok 2013. Szerk.: Szentmiklósi László, Magyar Kémikusok Egyesülete, Budapest, 71-75, 2013. ISBN: 9789639970427

Foreign language conference proceedings (1)

8. **Kovács, E. M.**, Harangi, S., Kuzmann, E., Kónya, J., Nagy, N. M.: Environmental importance of preparation and structure's analyzes of trivalent clays.
In: Proceedings the 6th International Conference on Carpathian Euroregion ECOLOGY CERECO. Ed.: Bárány Sándor, Buczkó István, Kohut Erzsébet, Csoma Zoltán, Komonyi Éva, Szabó Marján, Filep Mihály, II. Rákóczi Ferenc Kárpátaljai Magyar Főiskola, Beregszász, Ukrajna, 45-57, 2017. ISBN: 9786177404285

Hungarian abstracts (1)

9. **Kovács, E. M.**, Kónya, J., Nagy, N. M.: Ca(II)-Y(III) cserefolyamat vizsgálata bentoniton.
In: Őszi Radiokémiai Napok 2017. Szerk.: Szentmiklósi László, Magyar Kémikusok Egyesülete, Budapest, 72, 2017. ISBN: 9789639970809

Foreign language abstracts (3)

10. **Kovács, E. M.**, Kónya, J., Nagy, N. M.: Structural curiosities of lanthanide (Ln)-modified bentonites analyzed by radioanalytical methods.
In: International Conference on Radioanalytical and Nuclear Chemistry : Book of abstracts, Akadémiai Kiadó, Budapest, 62, 2019. ISBN: 9789634543695
11. **Kovács, E. M.**, Kónya, J., Nagy, N. M.: Structural iron release from bentonite by Y3+ and La3+ ions.
In: 9th Mid-European Clay Conference MECC 2018 : Conference Book. Ed.: by Darko Tibljaš, Marija Horvat, Nenad Tomašić, Marta Mileusnić, Anita Grizelj, Croatian Geological Society, Zagreb, 66, 2018. ISBN: 9789536907717
12. **Kovács, E. M.**, Kuzmann, E., Kónya, J., Nagy, N. M.: Surface species of lanthanum ion on montmorillonite.
In: 8th Mid-European Clay Conference (MECC 2016) : Book of Abstracts. Ed.: Jana Valúchová, Equilibra, Košice, Slovakia, 41, 2016. ISBN: 9788097228804





List of other publications

Foreign language scientific articles in international journals (3)

13. Kuzmann, E., **Kovács, E. M.**, Homonnay, Z., Csákvári, S., Klencsár, Z., Kónya, P., Nagy, N. M., Kónya, J.: Fe microenvironments in heat treated rare-earth exchanged montmorillonites. *Hyperfine Interact.* 240 (B7), 1-7, 2019. ISSN: 0304-3843.
DOI: <http://dx.doi.org/10.1007/s10751-019-1622-7>
14. Nagy, N. M., Buzetzy, D. B., **Kovács, E. M.**, Balláné Kovács, A., Kátai, J., Vágó, I., Kónya, J.: Study of phosphate species of chernozem and sand soils by heterogeneous isotope exchange with ³²P radioactive tracer. *Appl. Radiat. Isot.* 152, 64-71, 2019. ISSN: 0969-8043.
DOI: <http://dx.doi.org/10.1016/j.apradiso.2019.06.038>
IF: 1.343 (2018)
15. Kuzmann, E., Garg, V. K., Singh, H., Oliveira, d. A. C., Pati, S. S., Homonnay, Z., Rudolf, M., Molnár, Á. M., **Kovács, E. M.**, Fehérmé Baranyai, E., Kubuki, S., Nagy, N. M., Kónya, J.: Mössbauer study of pH dependence of iron-intercalation in montmorillonite. *Hyperfine Interact.* 237 (106), 1-6, 2016. ISSN: 0304-3843.
DOI: <http://dx.doi.org/10.1007/s10751-016-1314-5>

Hungarian conference proceedings (2)

16. **Kovács, E. M.**, Balogh, M., Kónya, J., Nagy, N. M.: Réteges kettőshidroxidok megkötő-képességének vizsgálata ¹³¹I-, ³⁶Cl- és ^{99m}TcO₄- anionok segítségével. In: Őszi Radiokémiai Napok 2018 / Homlok Renáta, Kovácsné Tóth Zita, Kasztovszky Zsolt, Magyar Kémikusok Egyesülete, Budapest, 22-26, 2018. ISBN: 9789639970933
17. Buzetzy, D. B., **Kovács, E. M.**, Nagy, N. M., Kónya, J.: Eutrofizációs folyamatok csökkentésére irányuló vizsgálatok módosított bentonitokkal. *Talajvédelem. Kisz.*, 205-214, 2017. ISSN: 1216-9560.

Hungarian abstracts (2)

18. Nagy, N. M., Buzetzy, D. B., **Kovács, E. M.**, Kónya, J.: Gyors és lassú konszekutív folyamatok vizsgálata heterogén izotópcserével egyetlen rövid életű radionuklid segítségével. In: Őszi Radiokémiai Napok 2018 / Homlok Renáta, Kovácsné Tóth Zita, Kasztovszky Zsolt, Magyar Kémikusok Egyesülete, Budapest, 90, 2018. ISBN: 9789639970933
19. Nagy, N. M., Buzetzy, D. B., Földvári, A. C., Kormány, Z., **Kovács, E. M.**, Nemes, Z., Kónya, J.: Talajok foszfortápanyag-forgalmának vizsgálata heterogén izotópcserével. In: Őszi Radiokémiai Napok 2017. Szerk.: Szentmiklósi László, Magyar Kémikusok Egyesülete, Budapest, 70, 2017. ISBN: 9789639970809



Foreign language abstracts (4)

20. Nagy, N. M., **Kovács, E. M.**, Buzetcky, D. B., Kónya, J.: Phosphate sorption of soils with different clay content.
In: Euroclay : International conference on clay science and technology 2019 .07.01-2019.07.05. Paris, Sorbonne Université : Book of abstracts, Sorbonne Université, Paris, 461, 2019.
21. **Kovács, E. M.**, Balogh, M., Kónya, J., Nagy, N. M.: Sorption of 131I-, 36Cl- and 99mTcO4- Anions by ZnAl and MgAl Layered Double Hydroxides.
In: Euroclay International conference on clay science and technology : Book of abstracts, Sorbonne Université, Paris, 354, 2019.
22. Kónya, J., Buzetcky, D. B., **Kovács, E. M.**, Nagy, N. M.: Study of phosphate sorption of soils by radioactive tracer method.
In: International Conference on Radioanalytical and Nuclear Chemistry : Book of abstracts, Akadémiai Kiadó, Budapest, 369, 2019. ISBN: 9789634543695
23. Nagy, N. M., Buzetcky, D. B., Földvári, A. C., Kormány, Z., **Kovács, E. M.**, Nemes, Z., Balláné Kovács, A., Kátai, J., Vágó, I., Kónya, J.: Study of phosphate species in soils by radioisotopic labeling.
Czech Chemical Society Symposium Series. 16 (2), 151-152, 2018. ISSN: 2336-7202.

Total IF of journals (all publications): 6,341

Total IF of journals (publications related to the dissertation): 4,998

The Candidate's publication data submitted to the iDEa Tudóstér have been validated by DEENK on the basis of the Journal Citation Report (Impact Factor) database.

15 October, 2019

