UNIVERSITY OF MISKOLC

MIKOVINY SÁMUEL DOCTORAL SCHOOL OF EARTH SCIENCES

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INVESTIGATION OF POROUS HYDROGEOLOGICAL SYSTEMS USING ENVIRONMENTAL ISOTOPES

THESES OF DOCTORAL (PHD) DISSERTATION

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Background and aims

Groundwater resources have growing strategic importance in the Earth's population water supply. Recently about 75% of public water demand has been ensured by groundwater in Europe, while in case of Hungary this value is more than 95%.

The justification of my research topic has been confirmed by the EU Water Framework Directive and the Kvassay Jeno Plan. Both of them highlight the groundwater recharge, as one of the most important hydrological element, which has a strategical importance in Hungary.

Special isotope hydrogeological researches were carried out via the cooperation of the University of Miskolc and the Institute for Nuclear Research, Hungarian Academy of Sciences.

The aim of my dissertation was developing innovative methods to investigate the groundwater recharge based on environmental isotopes and transport modeling on Hungarian research sites (*Figure 1*).

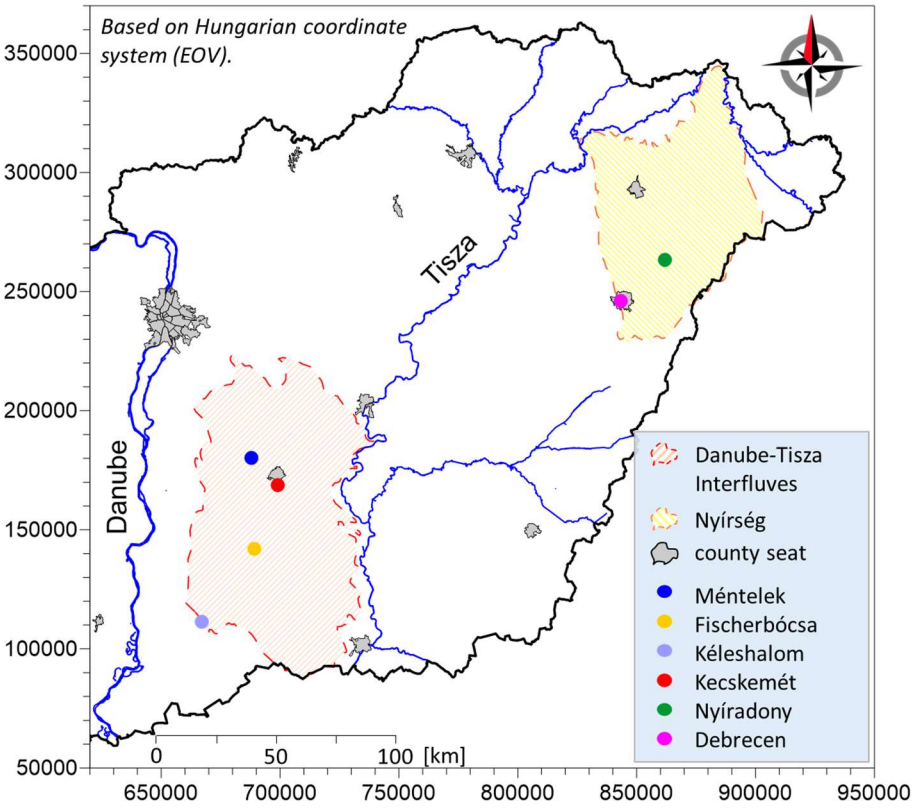

Figure 1 Location of the well-groups

New scientific results

Thesis 1

I proved the possibility of the ^{3}H transport modeling in the saturated zone due to recharge estimations on Hungarian shallow groundwater, furthermore the application of the ^{3}H concentrations to calibrate hydrogeological models.

I investigated 48, 62 and 27 mm/yr recharge rates with the combination of the ^{3}H-peak method and the transport modeling on multilevel wells in Méntelek, Fischerbócsa and Nyíradony, respectively. In these three research sites the recharge rates are 9, 11 and 4% of the annual precipitation in case of Danube-Tisza Interfluves and Nyírség. Based on the good defined geological model, the boundary conditions and also the parameters of the ^{3}H I have achieved good match between the modeled and the measured values during the modeling (*Figure 2*).

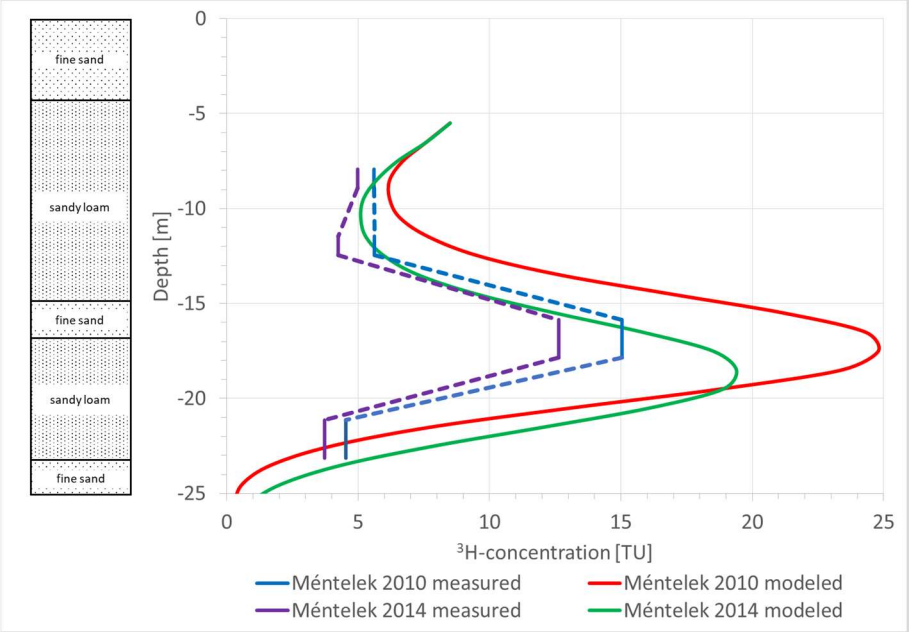

Figure 2 Measured and modeled ^{3}H-depth profiles in Méntelek from 2010 and 2014

Thesis 2

Comparing the results of ^{3}H-peak and ^{3}H/^{3}He methods I proved the efficiency of combination of the two separate methods.

In case of ^{3}H as an environmental isotope, we could not get accurate results to the groundwater recharge conditions. Groundwater with ^{3}H-concentration can be formed in a variety of ways while the initial ^{3}H-concentration decay to the measured values. The transport modeling based

on the ^{3}H-peak method has been confirmed by noble gas analysis; there is good match with the vertical changes in ^{3}H/^{3}He ages (*Figure 3*).

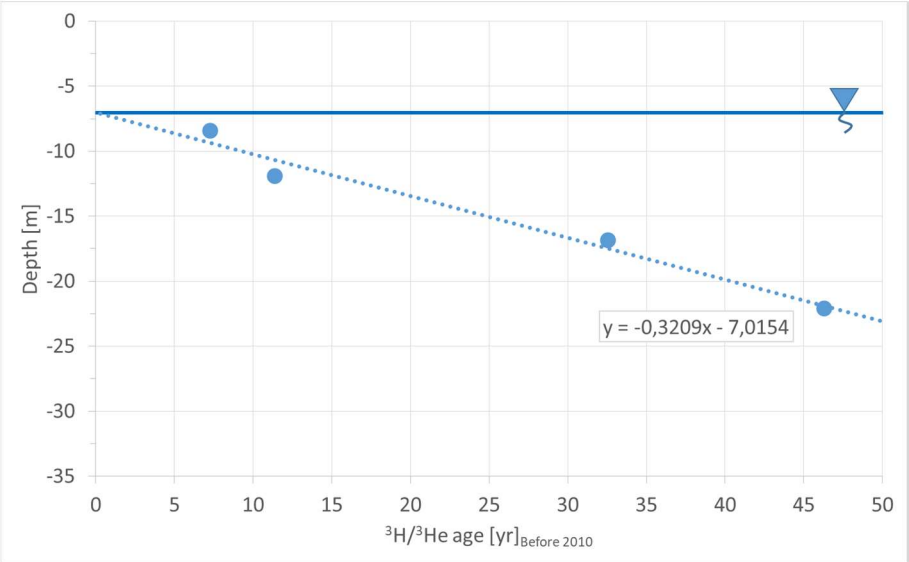

Figure 3 Calculated ^{3}H/^{3}He ages in Méntelek

Thesis 3

I determined the unsaturated resistance time of infiltrated precipitation with the help of δ^{18}O modeling of soil moisture. I also proved the seasonality of groundwater recharge and dynamics of winter and summer precipitation.

Based on the significant difference of δ^{18}O of winter and summer precipitation unsaturated resistance time of the infiltrated precipitation could be investigated. Measured and modeled δ^{18}O profiles of the soil moisture certify 1, 1.5 and 2 years unsaturated resistance time in Méntelek (*Figure 4*), Fischerbócsa and Nyíradony, respectively. Furthermore these profiles also illustrates the dynamics of infiltrating process. These resistance time also demonstrate the applicability of the ^{3}H/^{3}He method using for recharge estimation.

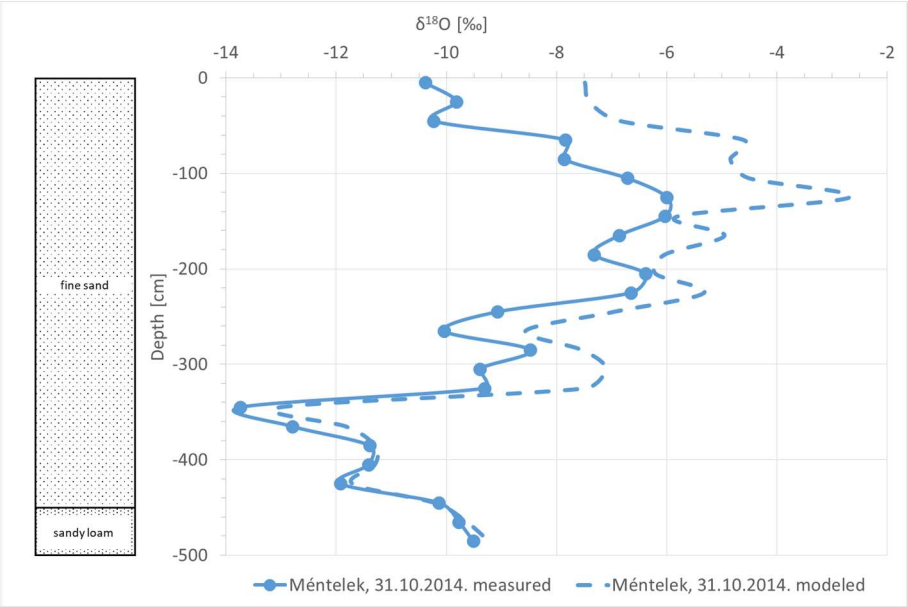

Figure 4 Measured and modeled $\delta^{18}O$-depth profiles in Méntelek

Thesis 4

I proved that the constructed special monitoring well-group in Nyíradony is suitable for determining vertical isotopic profile. The construction of these wells is much cheaper and faster than the traditional monitoring wells, otherwise the environmental impact is negligible.

Advantages of the constructed special monitoring well-group are as follows: (1) filtering depth can be identified accurately based on the microcarotage profile; (2) using a continuous tube coincidence of different layers can be avoid; (3) a very fast and cheap process to construct the monitoring well-group (in Nyíradony installation of 10 wells including microcarotage were carried out in two days).

The well-group was formed by direct-pushing of a steel pipe (OD = 37 mm) having been closed by a cone at the end. The steel pipe was pushed together with a KPE drill pipe (OD=25 mm) ensuring the closure of the well. In parallel with the pushing of the steel pipe, a continuous 25 mm diameter KPE liner was provided to ensure the closure of the well. The 0.5 m long filter section enabled the exact identifying of the origin of water samples. The novelty was granted with Utility Model Protection by the Hungarian Intellectual Property Office in 2015.

Thesis 5

Investigations carried out in Kecskemét and Debrecen have been the first Hungarian noble gas analytical researches when I proved degassing process in shallow groundwater. In this case the big differences in the $^{3}H/^{3}He$ ages are not explicable with the numerical transport modeling.

Dissolved noble gases can diffuse into gas lenses inside the geological media, gas-deficit can be established, making groundwater ageing uncertain. Hungarian hydrogeological researches do not mention gas-deficient groundwater, but I measured smaller amount of dissolved noble gases in Kecskemét and Debrecen than expected. In case of these research sites the majority of Ne and He have degassed from the groundwater (*Figure 5*).

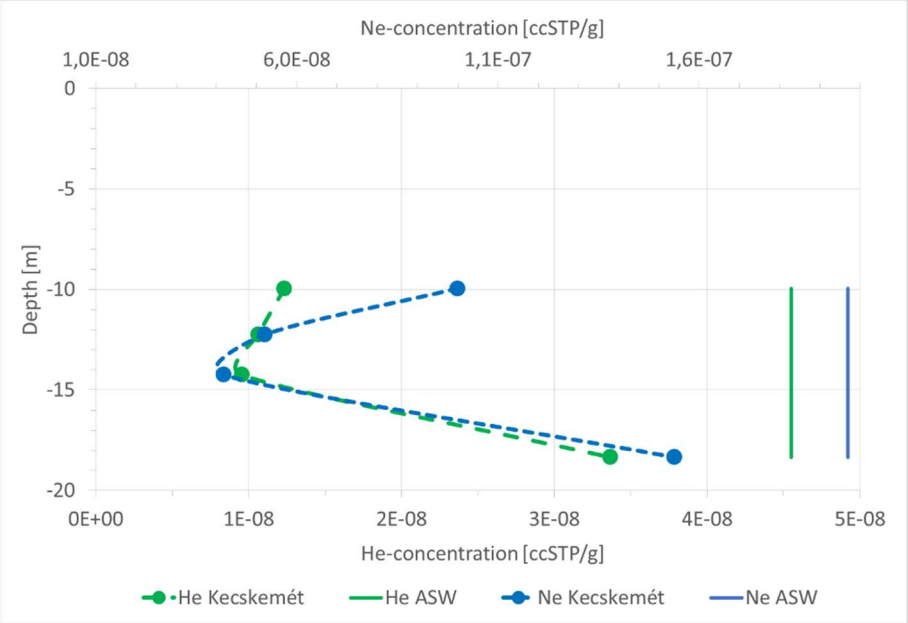

Figure 5 Measured He- and Ne-concentrations in Kecskemét

Thesis 6

Due to noble gas analytical experiments on shallow groundwater samples I proved that the applied method is suitable to identify deep-gas upcoming by the measured He-excess. Based on the $^{3}He/^{4}He$ isotopic ratio the mantle-origin component can be calculated.

I have detected more He in shallow groundwater near Kéleshalom than it can be expected based on air saturated water (ASW). These values mean 8.5 and nearly 20-fold He-excess in the

groundwater, and also higher than the other research wells on the Danube-Tisza Interfluves (*Table 1)*.

Previous Hungarian studies have already identified deep-He upcoming at hundreds and thousands meters, a big part of that is mantle-origin (similar to the Jánoshalma area near Kéleshalom). These results are the first Hungarian, measure-proved thesis which show this He-excess causes anomaly reaching shallow groundwater. Based on the $^{3}He/^{4}He$ isotope ratio I find that there is 11% mantle-origin He in shallow groundwater on the Southern Great Plain.

Table 1 Demonstration of the He-excess in Kéleshalom

Name of the well	He (ccSTP/g)	^{3}He (ccSTP/g)	R/Ra
Méntelek-1	4.96E-08	7.01E-14	1.02
Méntelek-2	4.52E-08	7.46E-14	1.19
Méntelek-3	4.38E-08	2.52E-13	4.15
Méntelek-4	5.44E-08	2.10E-13	2.79
Fischerbócsa-2	4.70E-08	7.32E-14	1.12
Fischerbócsa-3	4.52E-08	9.77E-14	1.56
Fischerbócsa-4	3.59E-08	1.17E-13	2.35
Kéleshalom-3	3.87E-07	8.06E-13	1.50
Kéleshalom-4	9.00E-07	1.78E-12	1.43

Thesis 7

Based on laboratory column tests I verified the formation of the excess air and also the degassing process. I proved the necessity of the CE and SD models during the isotope hydrogeological researches, when we calculate groundwater ages, but only minimum and maximum ages can be defined.

In some cases accurate groundwater age cannot be calculated based on noble gas concentrations, but only minimum and maximum ages. In order to clarify the validity of earlier assumptions, I proved the phenomena of excess air (*Figure 6*) and degassing by laboratory tests.

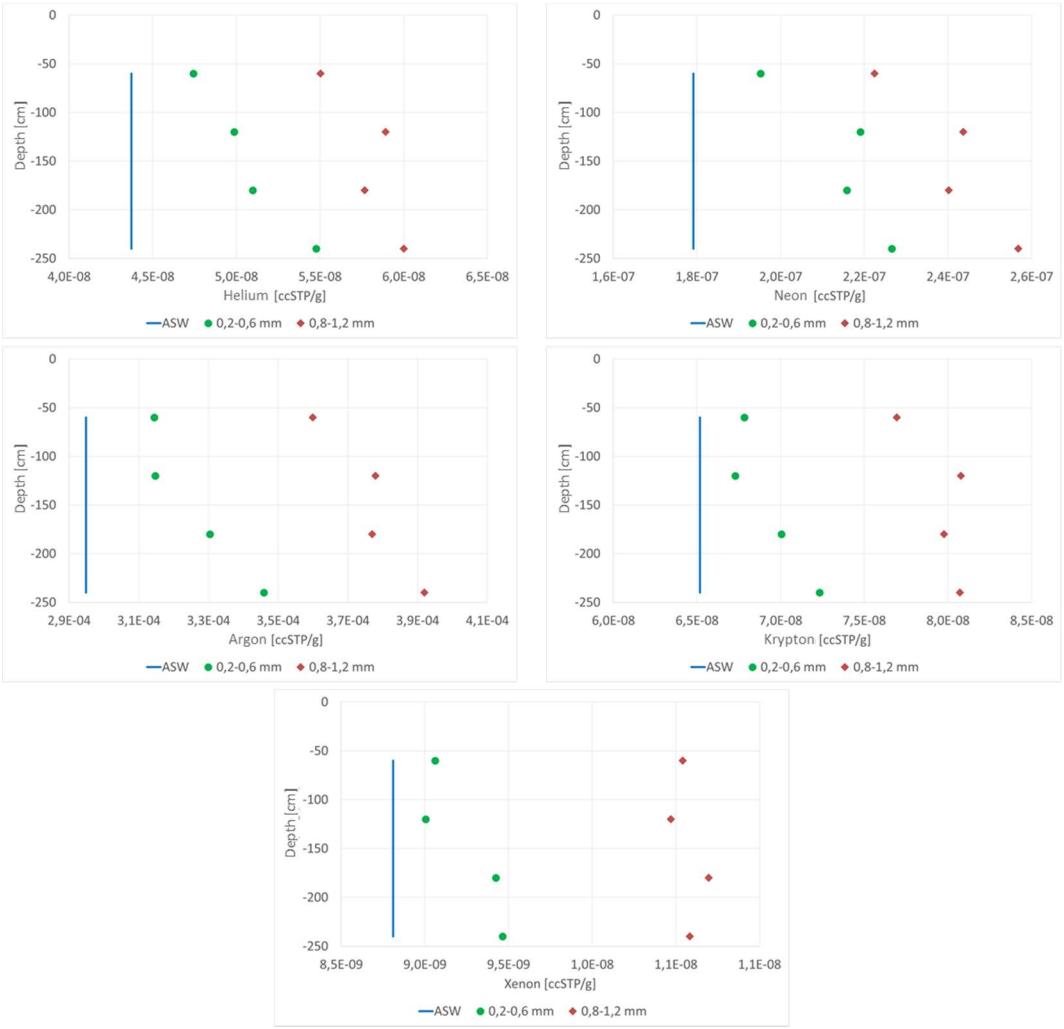

Figure 6 The noble gas analytical results of the formation of excess air

List of related publications and utility model protection

Kompár, L., Szűcs, P., Palcsu, L., Deák, J. (2012): *Impacts of Climate Change on Groundwater Recharge.* In: ELSEWAS, Landscape and Water. 11th Sanitary Constructions – Small waterworks – Landscape and Water Management Conference. Stará Lesna, Slovakia, Bratislava, Slovak University of Technology, pp. 173-178.

Kompár, L., Szűcs, P., Palcsu, L., Deák, J. (2012): *Determination of natural groundwater recharge with the help of groundwater modeling and tritium field measurements.* Geosciences and Engineering: A publication of the University of Miskolc, Vol. 1, No. 1, pp. 159-165.

Kompár, L., Szűcs, P., Fejes, Z., Palcsu, L., Deák, J. (2012): *Infiltration tests on irrigated agricultural areas.* Geosciences and Engineering: A publication of the University of Miskolc, Vol. 1, No. 2, pp. 99-104.

Kompár, L., Szűcs, P., Palcsu, L., Deák, J., Bernát, M. (2013): *A szélsőséges időjárási viszonyok hatása a felszín alatti vízkészletek utánpótlódási viszonyaira.* IX. Kárpát-medencei környezettudományi konferencia, Konferencia kiadvány. Miskolc, Miskolci Egyetem Műszaki Földtudományi Kar, pp. 420-425. *(in Hungarian)*

Kompár, L., Dobos, E., Szűcs, P. (2013): *The Estimation of Natural Groundwater Recharge on the Example of Two Research Sites on the Danube-Tisza Interfluves.* Geosciences and Engineering: A publication of the University of Miskolc, Vol. 2, No. 3, pp. 19-24.

Kompár, L., Szűcs, P., Deák, J., Palcsu, L., Cserny, T., Egyed, J., Gadóczi, M., Ilyés, Cs. (2014): *Izotóphidrogeológiai kutatások a Nyírségben.* Műszaki Tudomány az Észak-kelet Magyarországi Régióban 2014. MTA Debreceni Akadémiai Bizottság Műszaki Szakbizottsága, Elektronikus Műszaki Füzetek 14, pp. 328-334. *(in Hungarian)*

Kompar, L., Szucs, P., Deak, J., Palcsu, L., Egyed J., (2014): *Isotope Hydrogeological Researches On Regional Recharge Areas In Hungary.* In: International Association of Hydrogeologists, 41st IAH International Congress "Groundwater: Challenges and Strategies". Abstracts. Marrakesh, Morocco, Paper T7258.

Kompár, L., Szűcs, P., Deák, J., Palcsu, L., Braun, M. (2015): *Sekély víztartók utánpótlódásának meghatározása izotóp-vízkémiai vizsgálatokkal.* XXII. Konferencia a felszín alatti vizekről, Felszín Alatti Vizekért Alapítvány *(in Hungarian)*

Kompár, L., Szűcs, P., Palcsu, L., Braun, M. (2015): *Izotóphidrokémiai komplex módszer alkalmazása talajvizek utánpótlódásának vizsgálatánál.* microCAD 2015, A szekció: XXIX. International Scientific Conference. University of Miskolc, CD kiadvány *(in Hungarian)*

Kompár, L., Szűcs, P., Palcsu, L., Deák, J. (2015): *Tritium peak method and $^{3}H/^{3}He$ dating technique use for estimating shallow groundwater recharge.* microCAD 2015, A szekció: XXIX. International Scientific Conference. University of Miskolc, CD kiadvány

Kompár, L., Osváth, K., Ilyés, Cs., Szűcs, P., Palcsu, L. (2015): *Stabil vízizotópok alkalmazása ásvány- és gyógyvízkészletek utánpótlódásánál a Kárpát-medencében.* 11th International Scientific Conference on Mineral Waters of the Carpathian Basin. Institute of Environmental Management, University of Miskolc, Hungary, CD kiadvány *(in Hungarian)*

Madarász, T., Szűcs, P., Kovács, B., Lénárt, L., Fejes, Z., Kolencsik-Tóth, A., Székely, I., Kompár, L., Gombkötő, I. (2015): *Recent trends and activities in hydrogeologic reserach at the University of Miskolc, Hungary.* Central European Geology, Vol. 58, Iss. 1–2, pp. 171–185.

Palcsu, L., Kompár, L., Deák, J., Szűcs, P., Papp, L. (2017): *Estimation of the natural groundwater recharge using tritium-peak and tritium/helium-3 dating techniques in Hungary.* Geochemical Journal, Vol. 51, No. 5, pp. 439-448.

Szucs, P., Kompár L., Palcsu, L., Deák, J. (2012): *Estimation of Groundwater Recharge Change at a Hungarian Test Site Using Environmental Isotope Measurements.* 39th IAH Congress, Niagara Falls, Canada, Paper 447, pp. 1-5.

Szűcs, P., Kompár, L., Palcsu, L., Deák, J. (2015): *Estimation of the groundwater replenishment change at a Hungarian recharge area.* Carpathian Journal of Earth and Environmental Sciences, Vol. 10, No. 4, pp. 227-246.

Deák, J., Fekete, Zs., Kovács, B., Kompár, L., Szűcs, P., Vargay, Z. (2015): *Segédeszköz talajvizek vizsgálatának elvégzéséhez.* Használati Mintaoltalmi Okirat. Szellemi Tulajdon Nemzeti Hivatala, Budapest. Lajstromszám: 4 555, Ügyszám: U 15 00025 *(in Hungarian)*