INFILTRATION TESTS ON IRRIGATED AGRICULTURAL AREAS

LÁSZLÓ KOMPÁR [1], *PÉTER SZŰCS* [2], *ZOLTÁN FEJES* [3], *LÁSZLÓ PALCSU* [4], *JÓZSEF DEÁK* [5]

1. Introduction

The Duna-Tisza ridge is one of the largest recharge areas in Europe. There is an international project, which is coordinated by the International Atomic Energy Agency (IAEA) to investigate the natural groundwater recharge at some test sites in Europe. In Hungary a special research group carries out this interesting research program at two sampling sites named Méntelek and Kecskemét Szv II. The aim of the research is to build flow and transport models for the sample sites, which are based and calibrated on tritium isotope measurements in order to derive local recharge values. In earlier papers the research work at Méntelek has been presented [1]; we showed our model simulations and the results. Now in this work another test site, which was irrigated for agricultural purposes earlier, has been investigated close to Kecskemét.

2. Materials and method

^3H is the radioactive isotope of hydrogen. The only difference between the ^3H and the hydrogen is the number of the neutrons. Tritium is formed in the upper atmosphere during – β decay. It has a half life of 12.4 years, during which tritium decays to ^3He.

The main aspects of selection of sample area were the followings:

- on the site there was sewage disposal for at least 5 years,
- the site was used for agriculture ,
- the sites must be on the Hungarian Great Plain,
- the depth and the quality of the groundwater must be suitable to model the movement of sewage components.

The choice was based on these parameters, so for a test site Kecskemét was chosen [2]. Kecskemét can be found near Méntelek in the Duna-Tisza ridge (Méntelek was the base of the previous studies (Figure 1)). The test site in Méntelek operates just for research; only a meteorological station works on the site. This test site in Kecskemét was installed in 1944 for research purposes on an agricultural area. At that time there was a plan to join the Danube and the Tisza rivers through a canal. At the station in Méntelek the decreasing of groundwater level would have been monitored, but this plan was never realised.

The wells in Kecskemét were installed in loess and sand bedrock on the Duna-Tisza ridge. This area has a moderately warm and arid climate. The average annual precipitation was about 550 mm/year in the last 70 years. The soils of the site were investigated before the study began. The test site is physiologically heterogeneous; there are several soil types on the area [3].

[1] Ph.D student;MTA-ME Research Group of Geoengineering, Department of Hydrogeology and Engineering Geology; 3515 Miskolc, University of Miskolc; hgkompar@uni-miskolc.hu

[2] Head of department, professor; MTA-ME Research Group of Geoengineering, Department of Hydrogeology and Engineering Geology; 3515 Miskolc, University of Miskolc; hgszucs@uni-miskolc.hu

[3] Pre-Ph.D student; Department of Hydrogeology and Engineering Geology; 3515 Miskolc, University of Miskolc; fzolee14@gmail.com

[4] Head of departement; Institute of Nuclear Research of the Hungarian Academy of Sciences; 18/C Bem tér 4026 Debrecen; palcsu@atomki.hu

[5] Managing director, GWIS Ltd ; 45 Alkotmány u. 2120 Dunakeszi; deak47jozsef@gmail.com

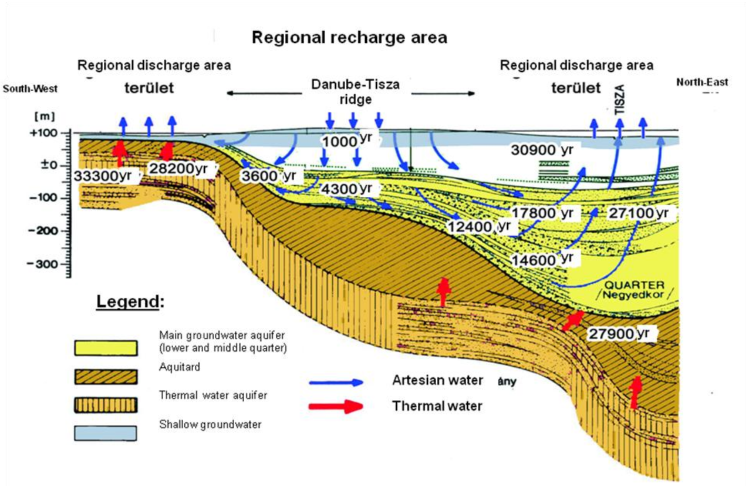

Figure 1. The Duna-Tisza ridge is the main recharge area of Hungary

The test site, as in Méntelek, is a typical recharge area. The groundwater flow is nearly vertical. This is the reason for its selection as a test site. The tritium profile was measured in 2001 at 6 different depths under the surface from groundwater, because at that time 6 wells were drilled (Figure 2). A numerical transport model was created covering the period between 1951 and 2010, like for Méntelek. The tritium content of the Hungarian precipitation was estimated for this period using precipitation data since 1972, wine samples of 1960 to 1977 and GNIP data of Vienna and Ottawa.

The framework of the model is the same as in the model of Méntelek: a column model was built, which works with just vertical flow involving recharge. The hydrodynamic model is similar to the other model; while the groundwater level is different, the geological parameters are the same. These geological parameters were determined from the boreholes from 2001.

Figure 2. The 6 wells near Kecskemét

MODFLOW is a U.S. Geological Survey modular finite-difference flow model. This computer code can solve the groundwater flow equation. The governing partial differential equation solved numerically in MODFLOW is given in the following form:

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)+W=S_S\frac{\partial h}{\partial t}$$

where K_{xx}, K_{yy}, and K_{zz} are the values of the hydraulic conductivity along the x, y, and z coordinate axes (L/T), h is the hydraulic head (L), W is the volumetric flux per unit volume representing the sources and sinks of groundwater, for which the negative values mean extractions while the positive values mean injections (T^{-1}), S_S is the specific storage of the investigated aquifer (L^{-1}), and t is time (T). This program is widely used throughout the world by hydrogeologists to simulate the flow of groundwater through aquifers. The code is a free software, written in the FORTRAN language, and can be compiled and run on the DOS, Windows, or UNIX operating systems. Since its original development in the early 1980s [4], the USGS have released four major versions of this code, and it is now considered to be the de facto standard industrial code among groundwater specialists for aquifer simulation. Currently, there are many actively developed commercial and non-commercial graphical user interfaces for MODFLOW.

Commercial MODFLOW programs are typically used by governments and consultants for practical applications of MODFLOW to real-world groundwater problems. The applied PMWIN-Pro may be considered as a professional commercial version of MODFLOW. A three-dimensional flow model considering 44 layers was implemented with the help of the MODFLOW-2000 module in the current project work. This model was used to characterise the nearly vertical groundwater flow of the investigated area in Kecskemét, which is a main recharge region on the Hungarian Great Plain. The required input data for the flow model were readily available from an earlier geological and hydrogeological prospecting activity.

Besides the flow model, a transport model was also built to investigate tritium concentration distribution under the surface due to the groundwater recharge from precipitation. The tritium transport movement investigations were carried out in the field-study by the module MT3DMS, where MT3D means Modular 3-dimensional transport model, and MS means the multi-species structure to model several components simultaneously. MT3DMS has a comprehensive set of options and capabilities for simulating the advection, dispersion, diffusion, radioactive decay and chemical reactions of contaminants in groundwater flow systems under general hydrogeologic conditions. MT3DMS was developed for use with any finite-difference flow model such as MODFLOW, and is based on the assumption that changes in the concentration field (Figure 3) will not affect the flow field appreciably.

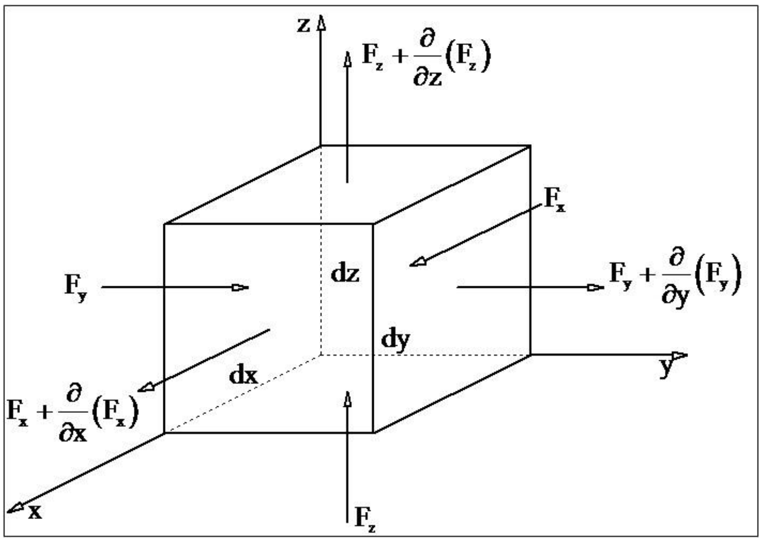

Figure 3. The balance of tracer of elementary space

The partial differential equation describing the fate and transport of chemical components or contaminants of the species k in a three-dimensional space in transient groundwater flow systems can be written as follows:

$$\frac{\partial\left(\phi C^k\right)}{\partial t} = \frac{\partial}{\partial x_i}\left(\phi D_{ij}\frac{\partial C^k}{\partial x_j}\right) - \frac{\partial}{\partial x_i}\left(\phi v_i C^k\right) + q_s C_s^k + \sum R_n$$

where ϕ means porosity of the aquifer, dimensionless, (fraction), C_k is the dissolved concentration of species k, (M/L^3), t is time (T), $x_{i,j}$ is distance along the respective Cartesian coordinate axis (L), $D_{i,j}$ is the hydrodynamic dispersion coefficient tensor (L^2/T), v_i is the seepage or linear pore water velocity based on the Darcy equation (L/T), q_s is the volumetric flow rate per unit volume of aquifer representing fluid sources and sinks (1/T), C_s^k is the concentration of the source or sink flux for species k (M/L^3), and $\sum R_n$ is the chemical reaction term ($M/L^3/T$).

Figure 4. Water sampling for tritium measurement

3. Results

Water samples were collected on the test site close to Kecskemét in 2012 (Figure 4). The model of Kecskemét shows the same results as the model of Méntelek. We obtained a tritium profile from the transport model (Figure 5). The red line was constructed from data of 2001, when the wells were drilled, and the groundwater was sampled during drilling. From these drillings the largest TU value was established at 9.5 m. The figure simulates 2 peaks, which is an interesting thing: the researches started in 1971 on this site, during 10 years of sewage disposal, when the splashed water had a TU value, which was 0 TU (the deep groundwater has 0 TU tritium content). After the research work the tritium content of the precipitation appeared in the shallow groundwater, this look likes the second peak at 13.6 m below the surface. The blue line shows the calculated values. These model values need to be clarified and calibrated, as the obtained line is an adducing result. However, it can be seen that the model works in an acceptable manner, and it shows the character of the red curve.

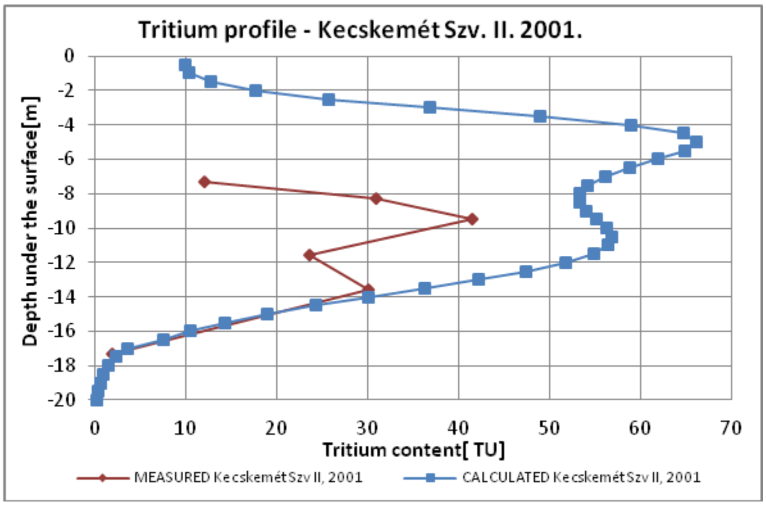

Figure 5. The tritium profiles of Kecskemét

4. Conclusion

Nowadays isotopes are very important tools for hydrogeology. Numerical transport modeling is also a useable tool for defining some problems in earth science and engineering. In this case study we determined that isotope hydrology and transport modeling applied together is a possible tool for investigating the natural recharge from precipitation.

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