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EXAMINATION OF THE EFFECT OF THE RIVER IN RIVERBANK FILTRATED SYSTEM USING FIELD MEASUREMENTS

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Abstract

35-40% of Hungary's drinking water supply is based on riverbank filtered water bases. In addition, Budapest's water supply relies heavily on the riverbank filtered water bases located along the Danube. The research goal of the project " Drinking water: multidisciplinary assessment of secure supply from the source to the consumers" is the complex examination of two selected water bases, as well as the related water production structures and water distribution network from the Danube to the consumer. The two selected area was the Surány water base (east from Budapest), and the Ráckeve water base (south from Budapest). One of the sub-tasks of the project is the examination of the processes taking place between the Danube and the production wells, which is carried out by the staff of the Institute of Water Resources and Environmental Management of the University of Miskolc. In this study, we would like to present the results obtained during the field measurement campaign related to the Surány water base from the two selected project sample areas. With the help of field measurements, we can get an image of the subsurface flow conditions, and we can follow the effect of the Danube river. Our research can help us to build and calibrate a hydrodynamic model and to understand the operation of this natural purification system.

Keywords: *riverbank filtration, drinking water, water supply, field monitoring*

1. Introduction

The interaction of rivers and their environment can create favorable hydrogeological conditions that can greatly help water abstraction and drinking water supply. In the case of the so-called riverbank filtration systems, biological, chemical and physical processes take place during the production of water in the immediate vicinity of the river, as a result of which the produced water can even be purified to drinking water quality. The phenomenon of riverbank filtration is induced by the production of water with the help of water extraction structures installed on the riverbank. With the change in the hydraulic gradient during water production, leakage starts from the river and the background too (Figure 1). In the case of a suitable riverbed connection, the recharge flows in a larger proportion (more than 50%) from the river side, in which case we can speak of riverbank filtration (Ray et al., 2002). The factors of the natural cleaning process during coastal filtration are the hydrodynamic (dilution), mechanical (filtration), biological (activity of microorganisms), and physical-chemical (precipitation, adsorption, coagulation, etc.) cleaning process (Hiscock. Grischek, 2002). The combination of all these processes gives the natural drinking water procurement system that is used in many countries of the world, including Hungary. The database of Hungary's Watershed Management Plan records 94 riverbed filtered water bases, of which 37 are long-term water bases. 29.5% of our protected water resources are provided by the water bases under operation, while 25.5% are provided by long-term riverbed filtered water bases (VGT3 2021).

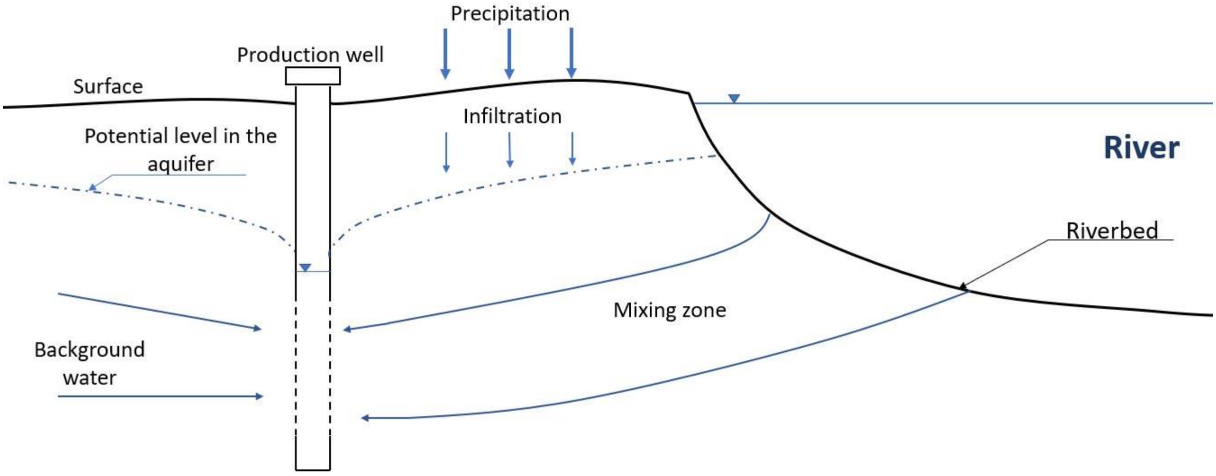

Figure 1. *The riverbank filtration process.*

In Hungary, we can find such aquifer types mainly along the Danube, along the Sajó and Hernád rivers, as well as along the Mura and Rába rivers. The importance of riverbank filtered drinking water bases is also shown by the fact that Budapest's water supply relies to a large extent on the water bases of Szentendre Island and Csepel Island. In the case of riverbank filtered water bases, the so-called horizontal collector well is a water extraction artefact often used. This well type consists of three larger structural units: the superstructure, the large-diameter well shaft, and the filter pipes extending horizontally and radially from it, the so-called arms (Székely et al, 2021). Their advantage is that in the case of thin aquifer layers typical of riverbank filtration systems, the horizontal arm arrangement increases the effective filter surface compared to the filter surface of vertical wells. In our work, we focused on the investigation of these water bases and well types. In our study, we describe the hydrogeological investigations designated by the project "Drinking Water: multidisciplinary assessment of secure supply from the source to the consumers ", as well as their results.

2. About the drinking water project

The aim of the project "Clean drinking water: multidisciplinary assessment of safe supply from the source to the consumers" is to explore the effects that threaten the safety of the drinking water supply in Budapest, from water extraction to the consumer. 5 consortium partners participate in the project:

- Centre for Ecological Research (consortium leader),
- Budapest University of Technology and Economics,
- Budapest Waterworks.,
- National Public Health Center,
- University of Miskolc.

In the framework of the project, two riverbank filtered water bases were selected, which are of great importance for Budapest's water supply. One is the Surány well group located on Szentendre Island, and the other is the Ráckeve well group located on Csepel Island. The criteria for selecting the test areas included the great importance of water bases in the capital's water supply, continuous operation and good accessibility. In the two areas, a detailed, complex hydrological, hydrogeological, water chemical, microbiological, ecological and health examination and evaluation was carried out, with the help of which potential risk points and intervention options that threaten the water supply are determined. A part of the complex research work is the hydrogeological investigations, with which we focus on the subsurface environment of the water-producing structures within the entire riverbank filtered drinking water supply. The hydrogeological investigations include biweekly and monthly sampling from production wells and observation wells in the area, during which the stable isotope composition of the produced raw water and groundwater was also examined. In addition to sampling, we continuously measured water level, temperature, and conductivity in the vicinity of each selected production well for more than a year. The goal of the project is to build a numerical flow model with different resolutions in space and time. Among the goals of the project is the connection of research results from different fields of science. In this study, field measurements related to the Surany water base and their results are presented.

3. The Surány water base

The group of wells with riverbank filtration in Surány is located on Szentendre Island, located north of Budapest, between the Danube branch of Vác and Szentendre. The length of the Szentendre Island is about 31 km, and its average width is about 3.5 km. The water production of a group of twenty wells located on the right bank of the Danube branch of Vác plays a very important role in Budapest's water supply. Its geology is characterized by the fact that it is basically formed by fluvial sediments. From the northern end of the island to Alsógöd, these fluvial sediments were deposited on oligocene clay, while to the south, sandy clay formations form the bed of the fluvial sediments (Góczán, 1955). These fluvial sediments appear stacked on top of each other in the geological data of the monitoring wells and production wells of the Szentendre Island. Figure 2 shows the cross section edited from the drilling data of the production wells.

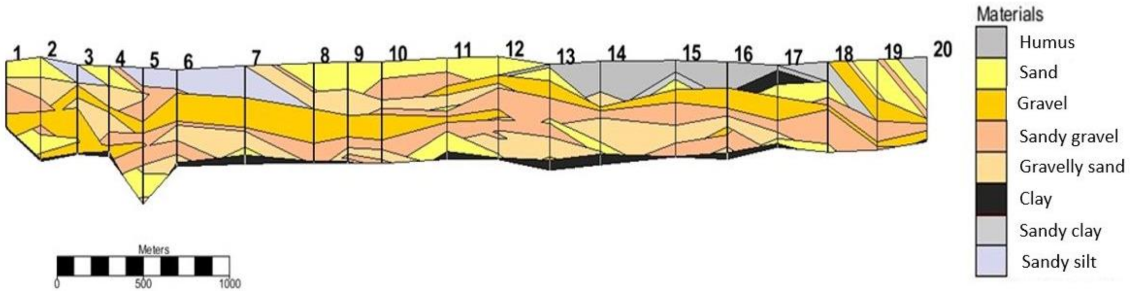

Figure 2. *Cross section of the surány well group.*

Water production at the water base is realized by twenty so-called horizontal collector wells. The production wells are evenly spaced along the banks of the Danube at an average distance of 300 m from each other. Their distance from the shore is characterized by the fact that the distance between the wells and the shore decreases from north to south. The distance of the southernmost well No. 1 from the Danube is approximately 65-70 m, depending on the water level, while the distance of the northernmost well No. 20 from the shore is 410-430 m, depending on the water level. The design of the wells can be said to be uniform except for the direction and depth of the extension of the arms. The superstructure visible on the surface continues in a well shaft, which has a mantle diameter of 2200 mm and the bottom of the shaft reaches its final depth of 15-17 meters on average (Tolnai, 2008). Except for well No. 2, the arms are located on two levels, forming two arm planes. Each production wells have 10 arms, except the well No 2, which have 5 arms. The arms have different lengths.

Within the framework of the Drinking Water project, three production wells were selected, in which water samples were taken. When selecting the wells on Szentendre Island, it was important to select wells at different distances from the Danube. This is how wells No 6., 15. and 17. were chosen, the locations of which are shown in Figure 4.

4. Field measurements at Surány water base

In the line of the production wells of the Surány well group, as well as on Szentendre Island, there are several monitoring wells in which we can take measurements. There are also many observation wells towards the Danube and towards the interior of Szentendre Island. The monitoring wells were filtered to the aquifer, so with their help, changes in potential levels can be easily followed, and sampling can also be easily carried out. The performed field measurements can be divided into three groups in terms of measurement frequency:

- hourly measurements,
- monthly measurements,
- bimonthly measurements.

The hourly measurements and the registration of the results of the measurements were carried out using continuous water level recording instruments. Continuous measurement and data registration was carried out in five wells with the help of these instruments. The five monitoring wells are located in the vicinity of production well No. 15, which is shown in Figure 3.

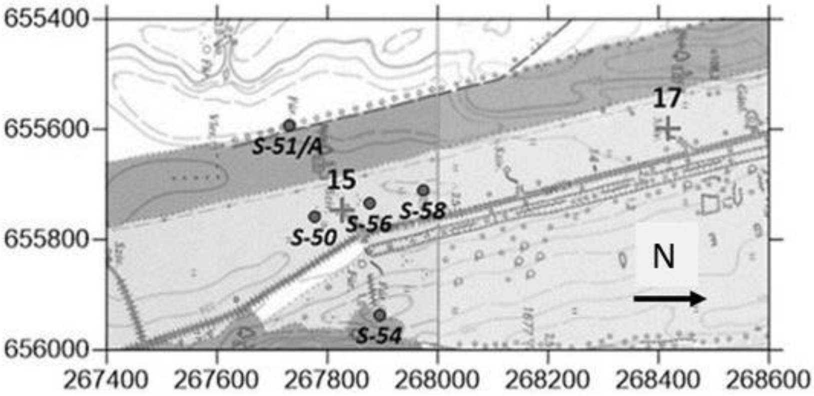

Figure 3. *Location of monitoring wells around the production well No 15.*

We tried to place the available water level recording instruments in such a way as to comply with the recommendations of Deák et al. (1992), Völgyesi (1993), so they were placed both perpendicular to the Danube coastline and parallel to the Danube coastline. water level recording instruments. During the measurement campaign, the following parameters were registered: water level, temperature, electrical conductivity.

The monthly measurements were aimed at examining the background and measuring the following parameters: water level, dissolved oxygen concentration, electrical conductivity, pH. Figure 4 shows the location of monitoring wells for monthly measurements compared to production wells. In parallel with the monthly measurements, water samples were also taken in order to be able to carry out isotope hydrogeological tests on them.

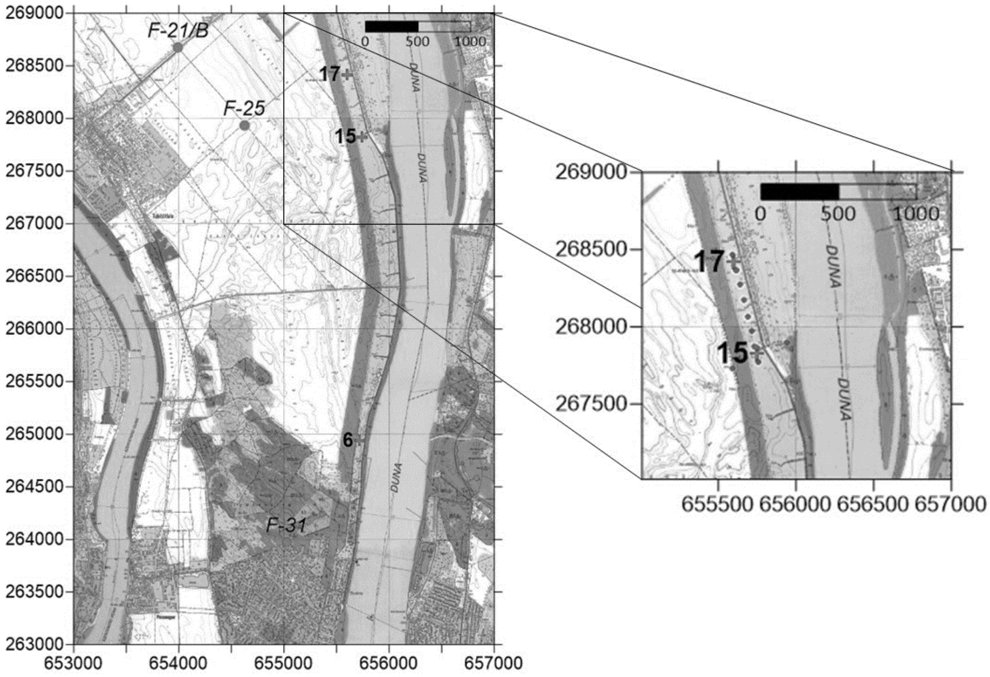

Figure 4. *Location of production, and monitoring wells on Szentendre island.*

The bimonthly measurements were carried out on the line of monitoring wells between the production wells and in the vicinity of the 15th production well. The measurements covered the water level, dissolved oxygen, temperature, and electrical conductivity. The aim of the tests was to be able to monitor the changes taking place in the environment of the Danube and the production well, as well as to be able to estimate the residence time in the aquifer.

5. Results of the field measurements

Regarding the change of the water level measured in the monitoring wells, it can be said that the behavior of the water level of the three zones typical of riverbank filtration systems (zone of the river, zone around production wells, zone in the background of production wells) can be easily followed. Figure 5 illustrates the development of water level changes. The curve marked in blue below the water level of the Danube shows the change in the water level of the observation well closest to the Danube. It can be seen from the curve that the water level of the S-54 observation well follows very well the change in the water level of the Danube, naturally with a lower water level. In the case of the well marked S-51/A, which characterizes the background of the production wells, the measured water level shows the change in the water level of the Danube only in a muted way. In some places, the water level measured in this observation well exceeds the water level of the Danube, which leads us to conclude that, even if for a short time, the situation arises that the groundwater flow direction is change from the background to the Danube. This phenomenon helps that the water from the background represents a larger proportion of the produced water. Under all these curves, the change in the water level of the monitoring wells created in the line of the production wells can be observed, which is illustrated by the data of the monitoring well marked S-50. The position of the curve marked in green shows the depression band caused by the production of water from the production wells, but the effect of the change in the water level of the Danube can also be observed here. The distance-dependent response to hydrological pressure can therefore be observed in the monitoring wells as expected. The closest monitoring well (S-54) reacts the fastest (~2 days) and to the greatest extent to changes in the Danube, while the reaction of the well located at a greater distance (S-51/A) is less pronounced. Moreover, this behavior can be influenced by the local lithology of the sediments.

During the measurement and sampling campaign, we had the opportunity to install recording instruments that are also suitable for measuring and registering electrical conductivity. These instruments were placed in the observation wells marked S-54 closest to the Danube and marked S-51/A in the background.

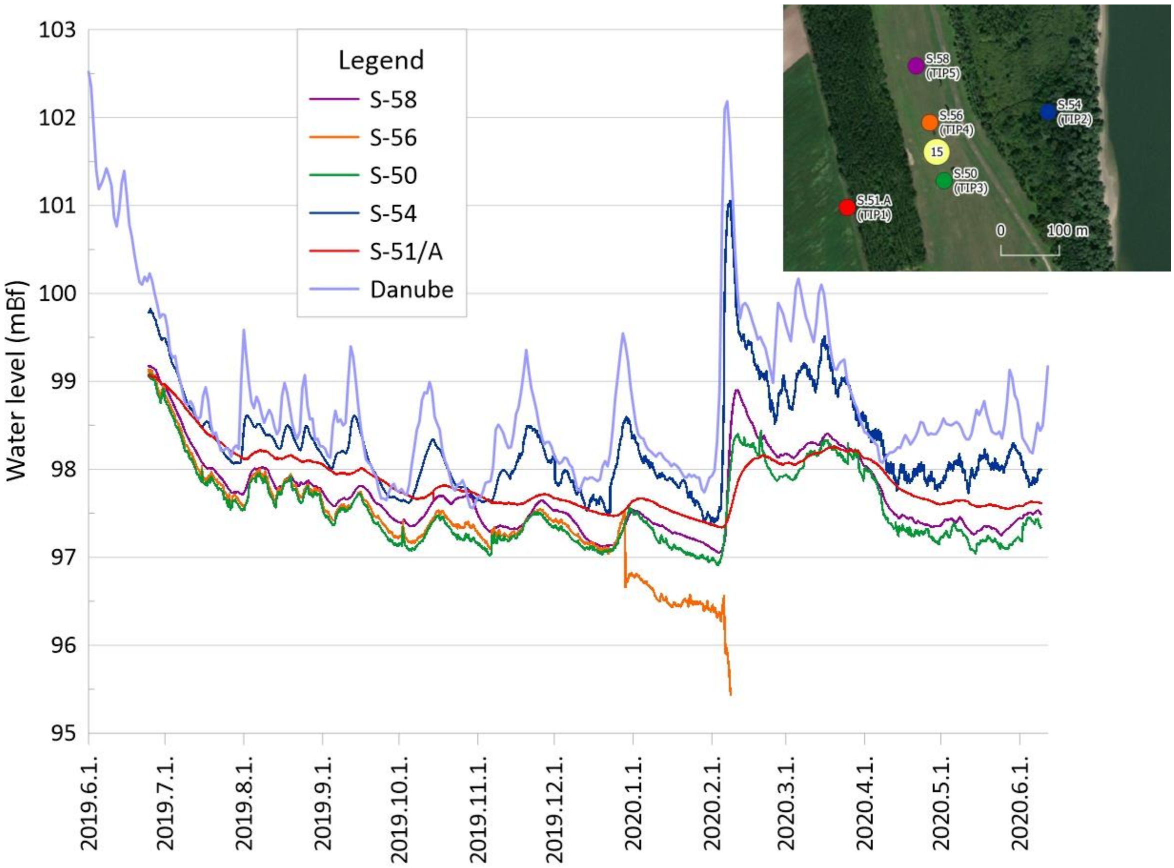

Figure 5. *Masured water levels around the production well No 15.*

It can be observed that the values belonging to the monitoring well marked S-54, which is closest to the Danube, do not show any significant changes from the beginning of the measurement to the end of January. Electrical conductivity values range between 0.7 and 0.8 mS/cm during this period. At the end of January, a marked drop in the change in electrical conductivity can be observed, followed by another, relatively steady period. At the same time as this fall, a sudden jump in the water level of the Danube can be observed, which can be the cause of a sudden large change in electrical conductivity. Regarding the monitoring well marked S-51/A in the background, it can be said that there is a continuous increase from the beginning of the measurement until the beginning of November, and then after a relatively balanced period, the shock that we have already presented at the well No S-54 appears here as well. The sudden decrease occurs with a shift in time, but it can also be attributed to the Danube's flood. In particular, the above-mentioned flood (February 7, 2020) caused a relatively large change in electrical conductivity in both tested wells. The well located closest to the Danube (S-54) is faster, while the farthest one (S-51/A) showed a slower, sharp change in both cases. We hypothesize that the flood changed the direction of flow in the aquifer, and that the two sharp changes in the electrical conductivity of S-51/A are the result of these changes in the flow pattern. The changing flow pattern can probably explain the phenomenon that the electrical conductivity of S-51/A was lower than that of S-54 at the beginning of the data collection, and later this phenomenon became the opposite.

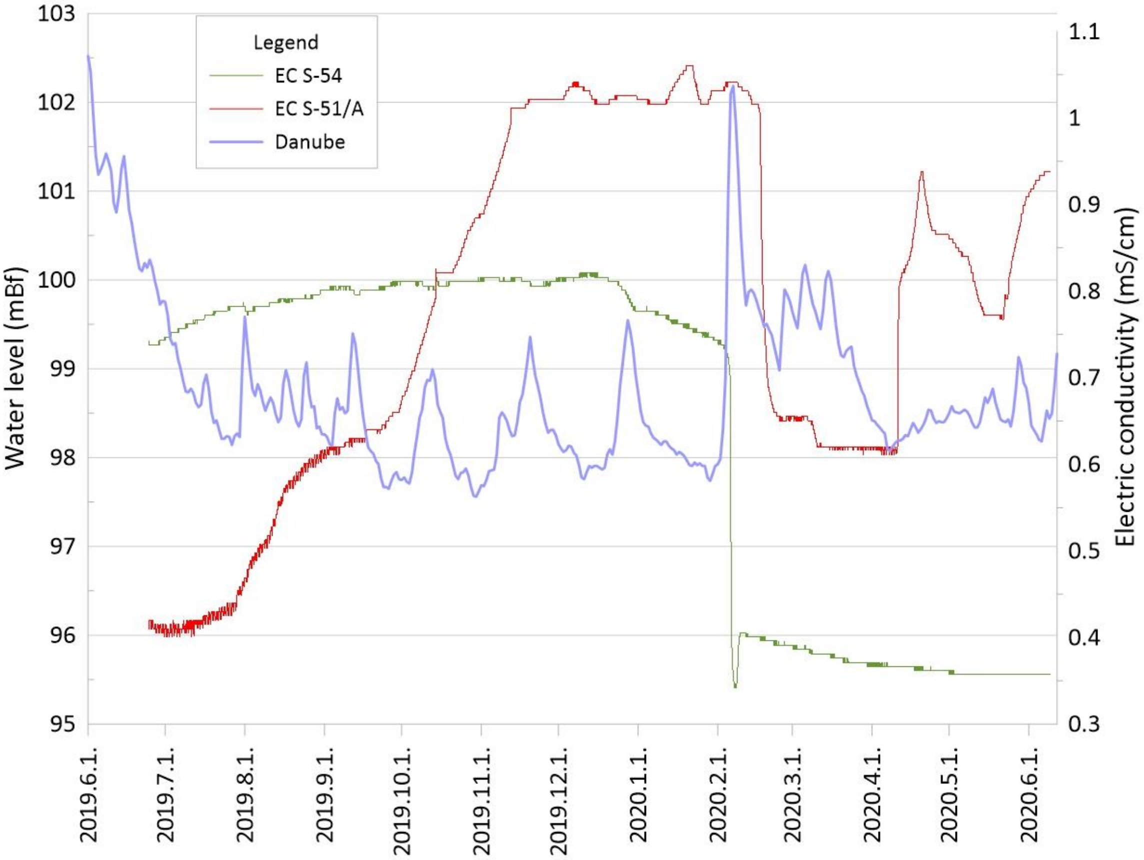

Figure 6. *Changes in electrical conductivity (EC) in the monitoring well No S-54 and S-51/A.*

The previously mentioned water level measuring and recording instruments were measured in the monitoring wells and the temperature changes were also recorded. The results of the measurement are illustrated in Figure 7. The temperature data of the observation well marked S-54 may be the most striking of its lines. Here you can see that the temperature shows a wave-like, large increase and then a large decrease during the measurement period. This trend is broken by the sudden temperature drop and rise at the beginning of February, which can be attributed to the Danube's flood that took place at that time. This is also surprising because the observation well marked S-54 is the closest observation well to the Danube. In the case of the S-51/A well, the temperature can be said to be relatively uniform, hovering around 12 °C. The undulating tendency of the temperature curve of the well marked S-50 with squares can be induced by the change in the water level of the Danube. It is interesting to note that the monitoring wells S-50 and S-56 are at the same distance from the production well and the Danube, yet they show different trends in temperature changes.

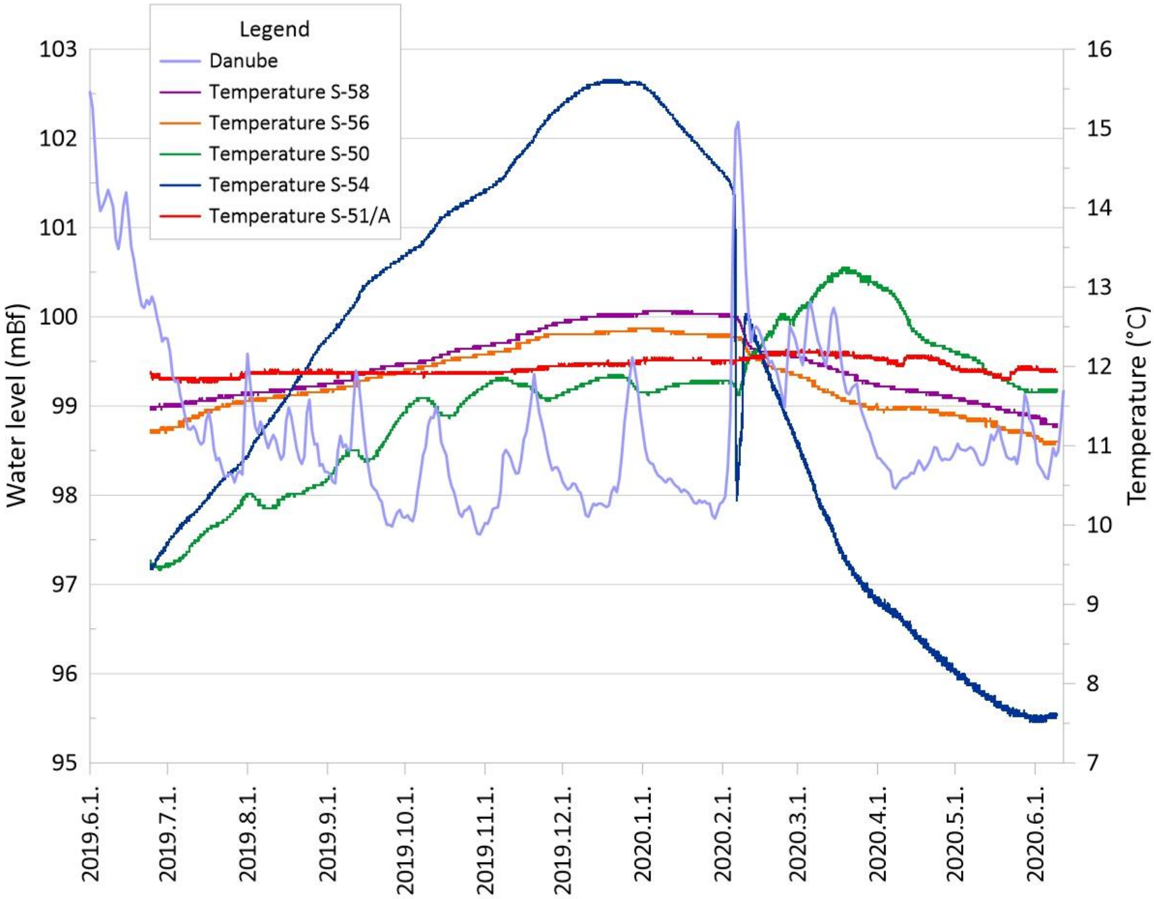

Figure 7. *Measured temperature data in the monitoring wells.*

6. Conclusion

In our work, we presented the field hydrogeological tasks carried out at the Surány water base related to the project "Drinking water: multidisciplinary assessment of secure supply from the source to the consumers". The measurement and sampling campaign took place over a year, with different frequencies. In addition to the water level, we also examined the temperature and specific electrical conductivity values. At some of the observation wells, water level measuring and recording instruments were used, which measured and recorded the above-mentioned parameters every hour.

The purpose of the measurements was to get to know the potential, temperature, and electrical conductivity conditions in the surroundings of the Surány well line in order to get an idea of the connection between the Danube and the aquifer. During the evaluation of our measurements, it can be concluded that the Danube plays a decisive role in the evolution of the water level of production wells and monitoring wells. The predominant water flow is basically from the Danube towards the producing wells, however, in case of low Danube water levels, this flow direction can be reversed. This phenomenon can induce a higher proportion of background water in the produced water. When examining the changes in temperature and electrical conductivity data, we came to the conclusion that there are probably distinct flow paths in the aquifer layer with basically good water conductivity, along which a stronger hydraulic connection can develop between the production well and the Danube.

Based on our investigations, it can be said that the water level measured in the monitoring wells and the parameters measured in them react with a delay to the changes occurring in the Danube. However, this delay is not the same as the time spent in the aquifer by the water molecules traveling from the river to the producing wells. The arrival time can be determined on the basis of the change over time in the stable isotope composition measured at the Danube and in the production wells. This can be achieved by cross-correlating the two time series, however the actual arrival time depends on hydraulic conditions such as river conditions, changes in water production and water level. A more accurate picture can therefore be obtained by examining stable isotopes and hydrodynamic modeling.

7. Acknowledgements

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