JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2024, 25(10), 101–110
https://doi.org/10.12911/22998993/191784
ISSN 2299–8993, License CC-BY 4.0

Received: 2024.07.18
Accepted: 2024.08.21
Published: 2024.09.01

Establishing a Groundwater Quality and Quantity Monitoring System as a Prerequisite for the Determination of Protection Zones in Lipjan, Kosovo

Lavdim Osmanaj[1], Vlerë Krasniqi[2*], Laura Kusari[3], Venera Hajdari[3]

[1] Faculty of Civil Engineering, Department of Environmental Engineering and Hydrotechnical Engineering, University of Prishtina "Hasan Prishtina", St. Agim Ramadani, Prishtina, Kosovo

[2] Faculty of Civil Engineering, Department of Environmental Engineering, University of Prishtina "Hasan Prishtina", St. Agim Ramadani, Prishtina, Kosovo

[3] Faculty of Civil Engineering, Department of Hydrotechnical Engineering, University of Prishtina "Hasan Prishtina", St. Agim Ramadani, Prishtina, Kosovo

* Corresponding author's e-mail: vlere.krasniqi@uni-pr.edu

ABSTRACT

The scarcity of groundwater monitoring in Kosovo, particularly in Lipjan, underscores the urgency to assess and safeguard this vital resource amidst escalating water demands and mounting pollution. This study addresses the critical gap in groundwater data by proposing the establishment of a comprehensive monitoring system. The primary goal was to develop a system capable of providing real-time data on groundwater quality and quantity within the capture area. Specific research objectives include the daily real-time monitoring of groundwater quality, identification, and quantification of contaminants in the aquifer, as a basis for further work on delineation of contaminant sources impacting the capture area, and monitoring and quantifying water extraction rates from individual wells, therefore establishing the necessary protection zones. Seven divers have been installed in 7 monitoring wells in Lipjan to measure the water level and pressure, as well as a multiparameter sensor for water quality monitoring for pH, temperature, specific conductivity, total dissolved solids, and dissolved oxygen. The digital monitoring system has been set up to input and log the incoming data. The aim was to gather this data, analyze it and use it to create a model and calibrate it to match the observed data. Concurrently, a sensitivity analysis was performed to prioritize data collection and establish which parameters have the most significant impact on the model outcomes. This ensures the establishment of a model which will, in the future, be used to predict and forecast groundwater levels and quality and determine protection zones.

Keywords: groundwater monitoring, water quality assessment, real-time data, protection zones, groundwater modeling.

INTRODUCTION

The interaction between surface water and ground water is a crucial component of the hydrological cycle [Fetter, 2014; Hölting and Coldewey, 2019]. However, although surface water is monitored frequently, groundwater monitoring is still rare in Kosovo and there is no available data on the quality of groundwater. Groundwater is a vital component of water supply used for residential, industrial, and agricultural purposes [Hiscock and Bense, 2014; Sethi and Di Molfetta, 2019]. The growing water demand, as well as the increasing rate of pollution over the last decades emphasizes the need to undertake steps to evaluate the state of the environment, especially the water capture areas [Dassargues, 2019; Gilli et al., 2012]. Accordingly, this could be done through implementing a groundwater monitoring network which can provide data on the quantity and quality of the groundwater [Condon et al., 2021; Karamouz et al., 2011]. Groundwater monitoring is an essential step in characterizing groundwater systems which are being altered by anthropogenic and natural phenomena. A properly designed monitoring system provides a representative understanding of the state of the monitored area [Condon et al., 2021; Sethi and Di Molfetta, 2019]. The establishment of a monitoring system for groundwater will also bring the potential for research and management in the field of emerging organic pollutants and pharmaceuticals [Bunting et al., 2021; Rusiniak et al., 2021], assessment of groundwater vulnerability from climate change, or even assessment of pollution in specific sites such as landfills [Dąbrowska and Witkowski, 2022; Nistor, 2020], urban areas, and irrigated agricultural areas [Krogulec et al., 2020; Liu et al., 2021; Podlasek et al., 2021]. Kosovo is in need of research in all these fields, and this system will be a positive initial step in that direction.

The Municipality of Lipjan, being part of the District of Prishtina, is an industrial area in Kosovo, with potential pollution sources including the Paper production factory, the Industrial Park, agriculture as well as the damaged or inefficient septic tanks that are used for wastewater removal [Division for Industrial Policy, 2020; Gashi et al., 2016; Qeriqi, 2016]. Likewise, due to rapid urbanization, the increase in the percentage of impermeable surfaces and the effects of climate change, the Lipjan area is also prone to flooding [Affairs, 2023; Bublaku, 2021; Simeone and Mekolli, 2023]. Similarly, previous research in southwestern Europe [Spain, Portugal, France and Italy] shows that quite a lot of wells face potential decline in the future, with urban areas showing more anthropogenic influence and declining trends in water levels. That research has shown that groundwater monitoring is essential for sustainable water management [Silva et al., 2024; Quevauviller et al., 2009].

The general objective of this study was to develop a comprehensive monitoring system for real-time data on groundwater quality and quantity within the capture area upon which additional measures and analyses might be developed, specifically the determination of protection zones in Lipjan. The specific research objective of this study is establishing a daily real time monitoring of the groundwater quality of the capture area to be used for identifying and quantifying the contaminants present in the aquifer and finding the source of the contaminants polluting the capture area as well as monitoring and quantifying the volume of water extracted from each well. This will aid in generating reliable data on groundwater quality and quantity which is sorely lacking in Kosovo. This data will support Kosovo authorities and researchers in the planning and decision-making process, underlying the protection of this groundwater source as well as constructing future water monitoring institutions and ensure the establishment of a model which will, in the future, be used to predict and forecast groundwater levels and quality and determine protection zones. Additionally, the purpose of this data is to be used for the determination of protection zones in Lipjan. Protection zones are all catchment areas of water resources that are used for drinking, and therefore are subject to more stringent rules for contamination and quality control [Osmanaj et al., 2021]. This data is the first step that must be fulfilled in order to be able to create modeling simulations for the determination of protection zones.

METHODOLOGY

The first phase was establishing the wells that we aim to monitor and analyze and conduct field visits to these wells to see the situation before any equipment is installed. The second phase consisted of the setup of a groundwater quality monitoring network consisting of an MP1 submersible pump and a groundwater quantity monitoring network comprising of seven divers (water meters). The submersible pumps and the water meters have consistently monitored the water quality and the abstractions from the aquifer, respectively. The installed MP1 submersible pump' multiparameter sensors for monitoring pH, temperature, specific conductivity, total dissolved solids (TDS) and dissolved oxygen continuously monitored the water quality of the study area (Figure 1).

On the other hand, the installation of the water meter in each pump will provide information on the quantity of the abstracted water. The data was collected periodically on a daily timescale and through the implementation of a digital monitoring system for data input and logging, the monitored values of water quality and quantity were transmitted to base. The third phase consists of data analysis and reporting. This will aid in generating reliable data on groundwater quality and quantity which is sorely lacking in Kosovo.

Additionally, we have researched and established geological characteristics, hydrological factors, land use practices, and anthropogenic activities as a first step towards building the model.

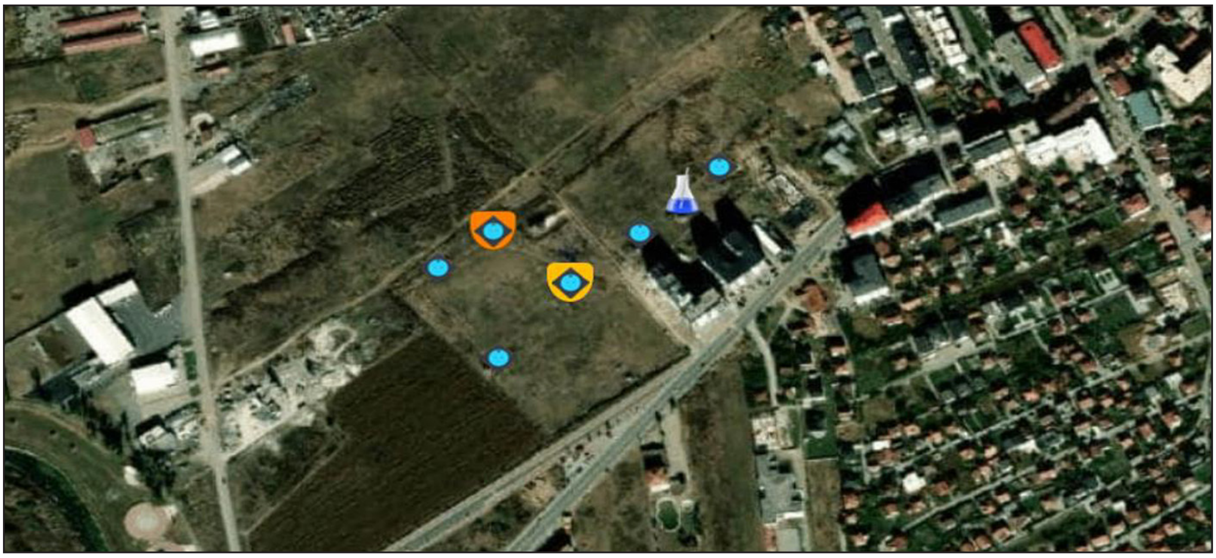

Figure 1. Map showcasing the positioning of 7 divers (blue dot) and the multiparameter sensor (beaker icon)

This monitoring system that has been established will aid in the collection of information such as precipitation, temperature, soil type, land use patterns, groundwater recharge rates, pollutant sources, etc. which will be used as input variables in your groundwater model.

The measurements are done in real-time, by the automatic systems, therefore potential errors may include connectivity issues between the equipment and the logging system, sporadic peaks in quantity data due to external factors such as pumps being turned on and off, and similar peaks in dissolved oxygen levels in areas close to the pumps (Figure 2). These issues have all been taken into account and noted when the data was analyzed. Peakes in quantity because of pumping were identified and excluded as outliers from final level analysis, and the same was done for dissolved oxygen peaks.

RESULTS AND DISCUSSION

Hydrogeological characteristics of the area

The topography of the target area is characterized by a plain in the northwest-south direction, with an average quota of 560 meters above sea level (Figure 3). The climate is of the continental type with average precipitation being 600–700 mm per year [Osmanaj et al., 2021]. According to the hydrogeological map of the area, the target zone is located on an intergranular aquifer with high porosity, and the groundwater flows from northeast to southwest [Osmanaj et al., 2021].

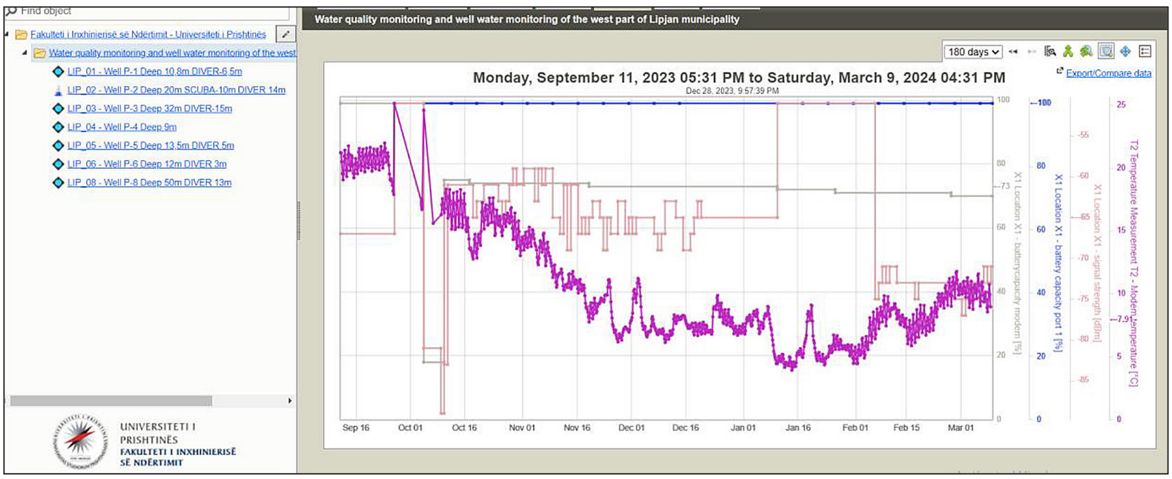

Figure 2. Snapshot of the data logging system

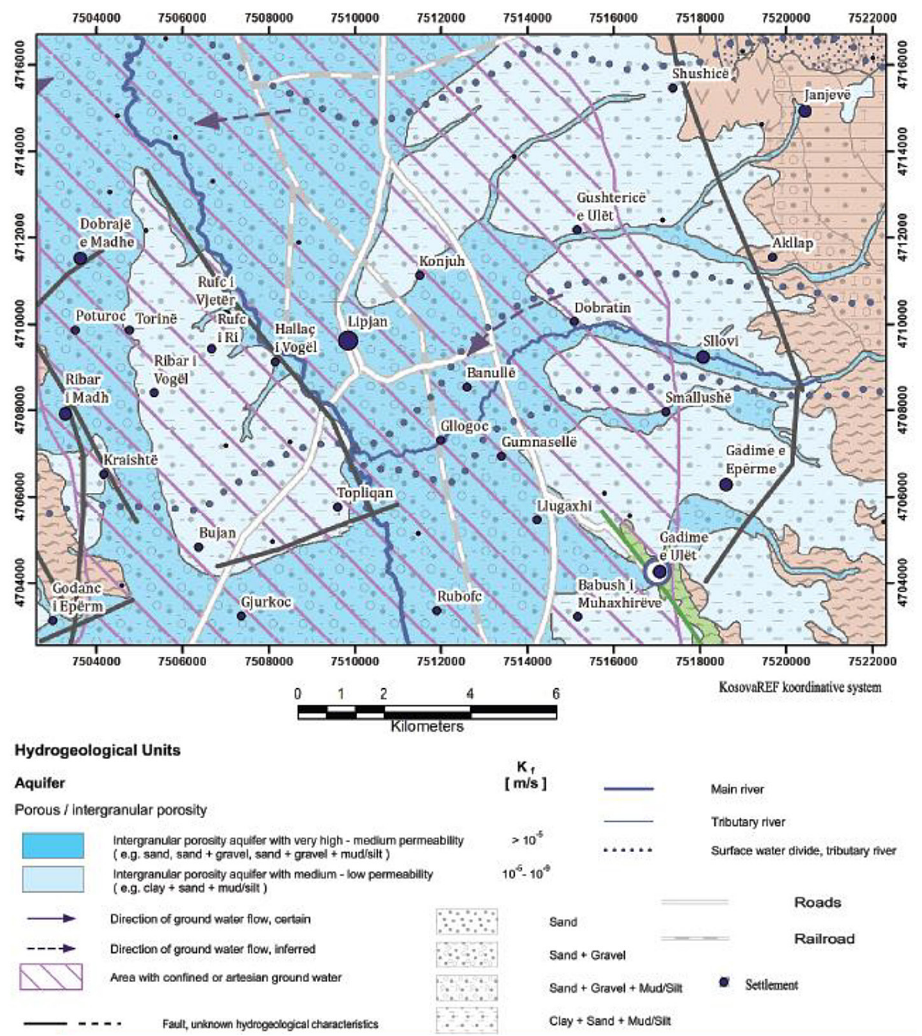

Figure 3. Hydrogeological map of the target area. Source: Osmanaj et al. (2021)

Water quantity data

The established monitoring system has been logging data for the past 7 months. The first diver (LIP_01) is installed at a depth of 6,5 meters from the top of the well. During the last seven months, monitoring data shows that the minimum water level recorded is 386.46 cmMSL, the maximum level recorded is 662.29 cmMSL, on average, the water level recorded is 521.6 cmMSL. The highest water level is observed in December 2023. The lowest water level is observed at the end of September 2023 when the pump was on. The second diver (LIP_03) is installed at a depth of 15 meters and the pump is at a depth of 17 meters. The minimum water level recorded is 739.38 cmMSL, the maximum level recorded is 1482.39 cmMSL, on average, the water level recorded is 1194.26 cmMSL (Figure 4). The water level recorded in LIP_03 is higher than LIP_02, and it is a more stable well with less fluctuations. The highest level was recorded in December 2023.

During pumping times big fluctuations can be observed, as shown in the graphs above. When the pumps are not active, the groundwater level rapidly grows and becomes stable, meaning the reservoirs of groundwater are opulent. The abrupt change that can be seen in the middle of the graph for LIP_03 is due to the sudden activation of the pump. The sporadic peaks that can be observed later are the result of sudden pump discontinuation.

The third diver (LIP_05) is installed at a depth of 5 meters and the pump is at a depth of 7 meters. The minimum water level recorded is 221.24 cmMSL, the maximum level recorded is 543.34 cmMSL, on average, the water level recorded is 355.74 cmMSL (Figure 4). The highest level was recorded in December 2023, and the lowest level in October 2023. The fourth diver (LIP_06) is installed at a depth of 3 meters and the pump is

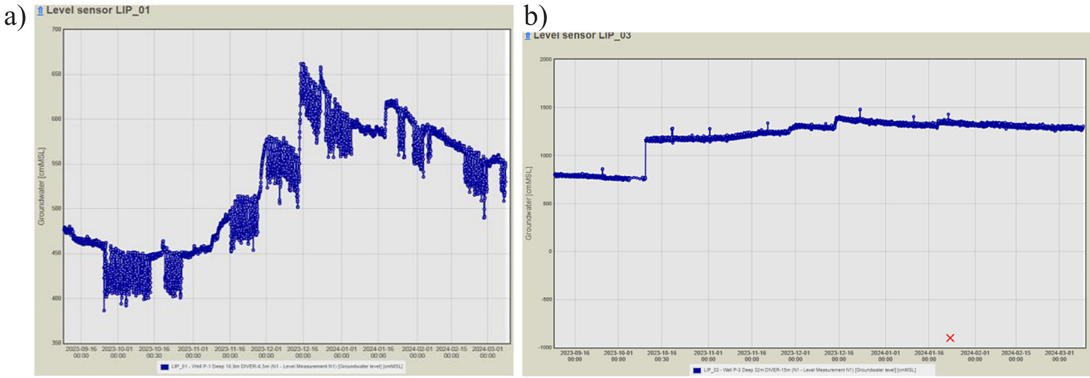

Figure 4. Graphical representation of the groundwater level for seven months for LIP_01 (left) and LIP_03 (right)

at a depth of 5 meters. The minimum water level recorded is 65.69 cmMSL, the maximum level recorded is 292.07 cmMSL, on average, the water level recorded is 182.59 cmMSL (Figure 5). The highest level was recorded in September 2023, and the lowest level in October 2023.

Again, during pumping times big fluctuations can be observed, as shown in the graphs above. The abrupt change that can be seen in both graphs is due to the sudden activation of the pump. The sporadic peaks that can be observed later for LIP_05 are the result of sudden pump discontinuation. For LIP_06, we can see that the groundwater level is close to the surface.

The fifth diver (LIP_08) is installed at a depth of 13 meters and the pump is at a depth of 33.5 meters. The minimum water level recorded is 734.09 cmMSL, the maximum level recorded is 1281.03 cmMSL, on average, the water level recorded is 902.19 cmMSL (Figure 6). The highest level was recorded in September 2023, and the lowest level in October 2023. The sixth diver (LIP_04) has

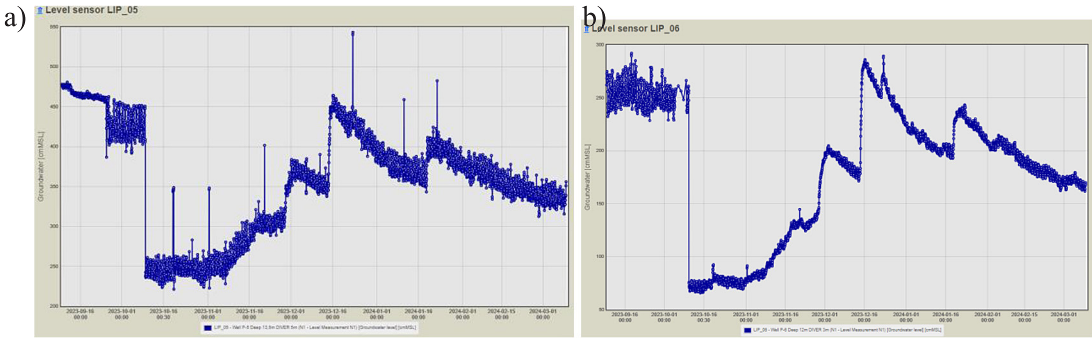

Figure 5. Graphical representation of the groundwater level for seven months for LIP_05 (left) and LIP_06 (right)

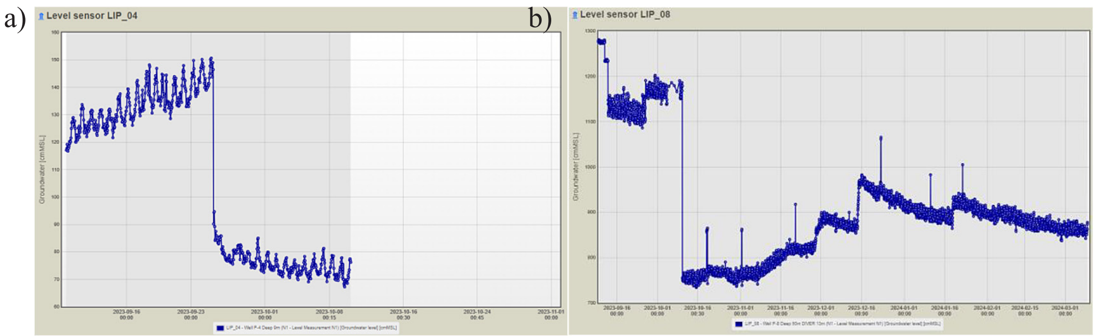

Figure 6. Graphical representation of the groundwater level for seven months for LIP_04 (left) and LIP_08 (right)

shown a severely low quantity of water present in the well. The highest level of water was observed in September 2023 with a maximum of 150.66 cmMSL, and the lowest level was observed in October 2023 with a minimum of 67.26 cmMSL, after which the sensor stopped logging data due to insufficient amount of water.

Water quality data

The installed MP1 submersible pump' multiparameter sensor measures pH, temperature, specific conductivity, TDS and DO and has collected data for the past seven months. National requirements for water quality are established by Law No. 04/L-147 for Kosovo waters and Law No. 08/L-048 on Public Health and the accompanying regulations and administrative instructions. Likewise, Kosovo aims to have its national legislation in line with EU Directives. According to these regulations, the allowed values for drinking water are [Government of the Republic of Kosovo, 2021]:

- EC of maximum 2500 µS/cm in 20 ºC;
- pH levels ≥ 6.5 and ≤ 9.5;
- DO of maximum 5.0 mg/l O_2.

pH has shown a steady increase since the beginning of the measurement period. Peak pH was recorded both in January and February at 7.24 (Figure 7). On average, the pH level for this groundwater well is 7.19. Typical pH for groundwater is from 6.5 to 8.5 [Ram et al., 2021], indicating a very good pH level for this well. The groundwater temperature has been shown to be relatively stable, in the range of 0.5 to 20 ºC (Figure 8). This groundwater tends to have a higher water temperature than typical. Groundwater with

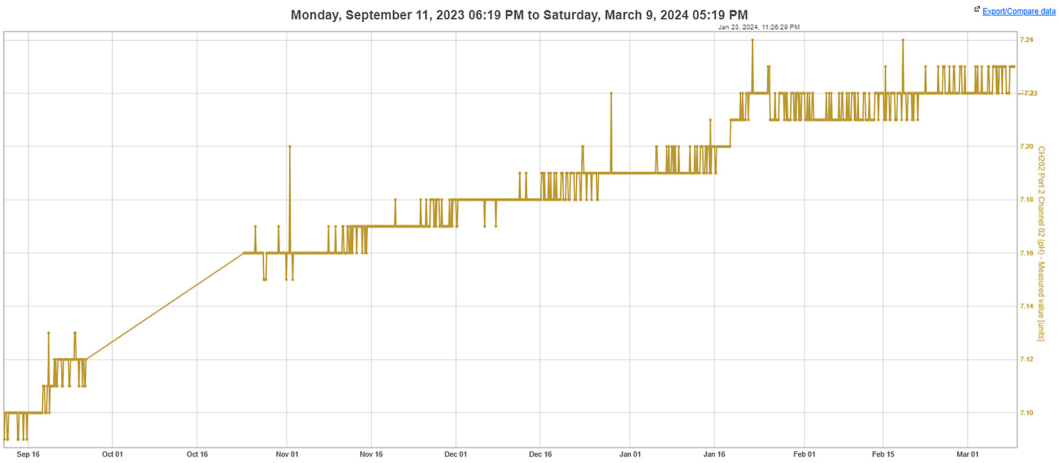

Figure 7. pH recorded levels for groundwater for the past seven months

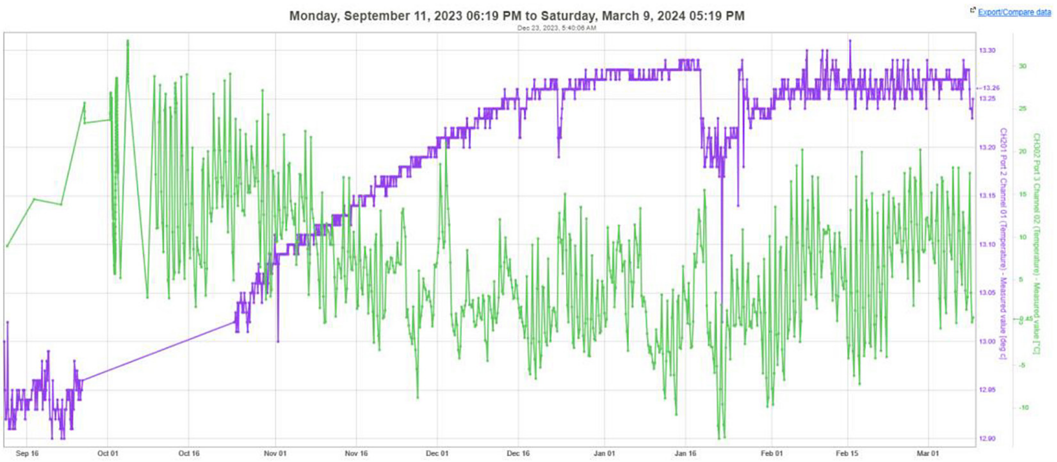

Figure 8. Recorded temperature of groundwater for the past seven months

higher temperatures can dissolve more minerals from the surrounding rock and will have a higher electrical conductivity, as shown in Figure 9.

The specific conductivity of this groundwater is, on average, 880 µS/cm. The threshold for drinking water is less than 1000 µS/cm according to the Environmental Protection Agency (EPA) [Domenico and Schwartz, 1998] which means that this well can be used for drinking water supply. On average, this groundwater well has a TDS level of 560 mg/L (Figure 10).

Typically, anything less than 1000 mg/L is classified as freshwater [Ram et al., 2021]. The optimal concentration for drinking is 500 mg/L [Ram et al., 2021]. Groundwater typically has a low DO level, mainly ranging from 1.75 to 19.40 mg/L [Zan et al., 2019]. This groundwater well has on average, a DO concentration of 1.8 mg/L, slightly

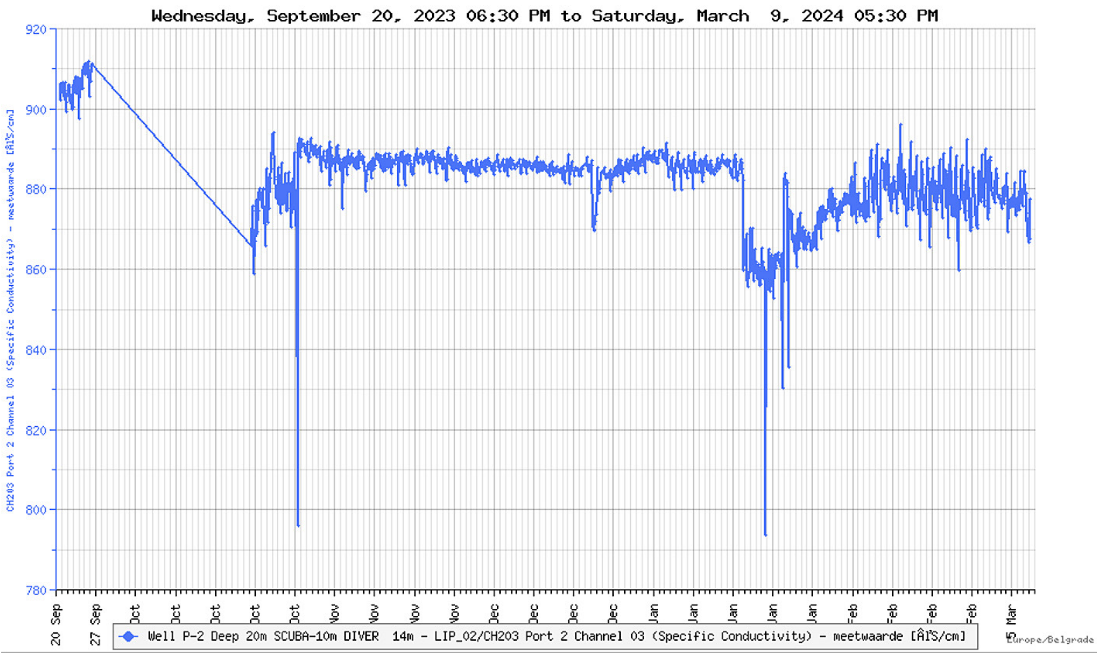

Figure 9. Recorded specific conductivity of groundwater for the past seven months

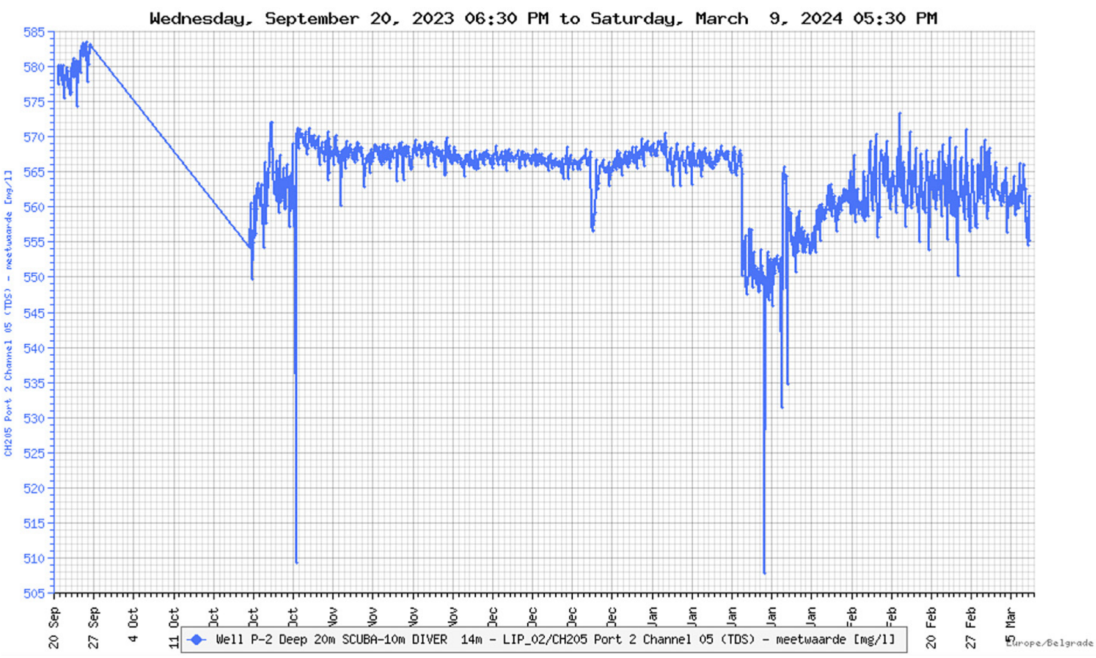

Figure 10. Recorded TDS of groundwater for the past seven months

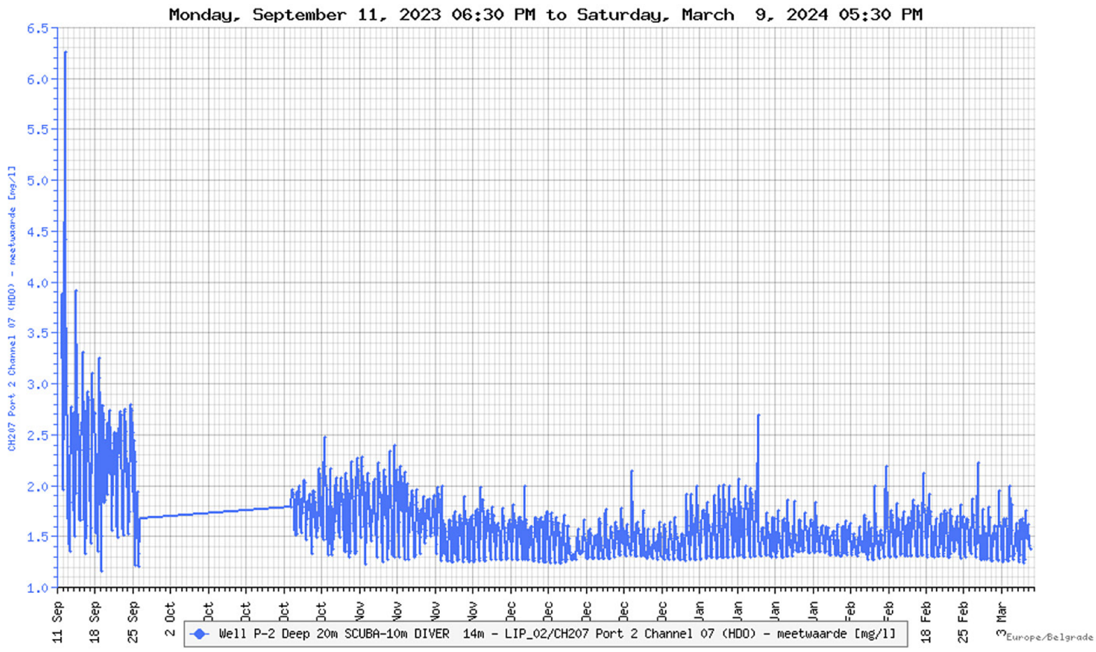

Figure 11. Recorded DO of groundwater for the past seven months

on the lower end of the spectrum. Additionally, it has been observed that pumping has an effect on the DO levels due to the aeration and mixing of air and water that happens every time the pump is turned on after being off. According to the data generated so far, this groundwater is acceptable for drinking and fulfills all the legal requirements on the measured parameters

CONCLUSIONS

In conclusion, the establishment of a comprehensive groundwater monitoring system in Lipjan, Kosovo, marks a significant step towards understanding and managing this vital resource. Despite the scarcity of groundwater data in the region, the implementation of real-time monitoring equipment has provided valuable insights into both the quantity and quality of the aquifer. The monitoring network, consisting of submersible pumps and water meters, has facilitated continuous data collection over the past seven months, revealing fluctuations in groundwater levels and variations in water quality parameters such as pH, temperature, conductivity, TDS, and DO. Analysis of the collected data has highlighted important trends, including seasonal variations in groundwater levels and the influence of pumping activities on water quality parameters. Despite fluctuations observed during pumping, the overall stability of groundwater levels suggests ample reserves within the aquifer.

Furthermore, the consistently favorable water quality indicators, such as pH within the acceptable range for drinking water and low levels of contaminants like TDS, indicate the potential suitability of this groundwater source for various purposes, including drinking water supply. Moving forward, the data obtained from this monitoring system will serve as a foundation for informed decision-making by Kosovo authorities and researchers. By identifying potential sources of contamination and understanding hydrological dynamics, this information can guide efforts to protect and sustainably manage the groundwater resources in Lipjan and beyond. Moreover, the establishment of this monitoring system sets a precedent for future groundwater management initiatives, paving the way for predictive modeling and the implementation of effective conservation measures.

Ultimately, the ongoing monitoring and analysis efforts underscore the importance of proactive measures in safeguarding this invaluable natural resource for present and future generations.

Acknowledgments

The authors would like to acknowledge the donation and contribution of the Swiss Agency for Development and Cooperation (SDC), Skat Consulting Ltd., St. Gallen Switzerland, and the

Environment Agency Austria. The equipment and necessary tools used for this research were procured as a grant from these agencies, as part of the 'Integrated Water Resources Management in Kosovo' (IWRM-K) Program.

REFERENCES

1. Government of the Republic of Kosovo. 2021. Administrative Instruction (Grk) No. 10/2021 on the Quality of Water Intended for Human Consumption. Prishtina, Kosovo.
2. Affairs, I.M.F.F. 2023. Republic of Kosovo: Technical Assistance Report-Public Investment Management Assessment Update and Climate PIMA. International Monetary Fund
3. Bublaku, S. 2021. Influencing factors in the occurrence of floods in the urban areas of Prishtina and Fushë Kosovë. In E. Hajrizi (Ed.), UBT International Conference. University for Business and Technology of Kosovo.
4. Bunting, S.Y., Lapworth, D.J., Crane, E.J., Grima-Olmedo, J., Koroša, A., Kuczyńska, A., Mali, N., Rosenqvist, L., van Vliet, M.E., Togola, A., Lopez, B. 2021. Emerging organic compounds in European groundwater. Environmental Pollution, 269, 115945. https://doi.org/https://doi.org/10.1016/j.envpol.2020.115945
5. Silva, R.C.G., Reinecke, R., Copty, N.K., Barry, D.A., Heggy, E., Labat, D., Roggero, P.P., Borchardt, D., Rode, M., Gómez-Hernández, J.J., Jomaa, S. 2024. Multi-decadal groundwater observations reveal surprisingly stable levels in southwestern Europe. Communications Earth & Environment, 5(1), 387. https://doi.org/10.1038/s43247-024-01554-w
6. Condon, L.E., Kollet, S., Bierkens, M.F.P., Fogg, G.E., Maxwell, R.M., Hill, M.C., Fransen, H.-J.H., Verhoef, A., Van Loon, A.F., Sulis, M., Abesser, C. 2021. Global groundwater modeling and monitoring: opportunities and challenges. Water Resources Research, 57(12), e2020WR029500. https://doi.org/https://doi.org/10.1029/2020WR029500
7. Dąbrowska, D., Witkowski, A.J. 2022. Groundwater and human health risk assessment in the vicinity of a municipal waste landfill in Tychy, Poland. Applied Sciences (Switzerland), 12(24). https://doi.org/10.3390/app122412898
8. Dassargues, A. 2019. Hydrogeology: Groundwater science and engineering (1st ed.). Taylor & Francis Group, LLC.
9. Division for Industrial Policy. 2020. Report 2019: Manufacturing Industry - Sector C.
10. Domenico, P.A., Patrick A., Schwartz, F.W., Franklin W. 1998. Physical and chemical hydrogeology. Wiley.
11. Fetter, C.W., Charles W. 2014. Applied Hydrogeology (4th ed.). Pearson Education Limited.
12. Gashi, F., Faiku, F., Hetemi, S., Bresa, F., Gashi, S. 2016. The effect of anthropogenic activity on the underground water quality in the territory of Lipjan (Kosovo). A Statistical Approach. Mor. J. Chem., 4, 187–196.
13. Gilli, É., Mangan, C., Mudry, J. 2012. Hydrogeology: Objectives, Methods, Applications (1st ed.). Taylor & Francis Group, LLC. www.taylorandfrancisgroup.com
14. Hiscock, K., Bense, V. 2014. Hydrogeology: Principles and Practice (2nd ed.). John Wiley & Sons Ltd.
15. Hölting, B., Coldewey, W.G. 2019. Hydrogeology (1st ed.). Springer-Verlag GmbH Germany. http://www.springer.com/series/15201
16. Karamouz, M., Ahmadi, A., Akhbari, M. 2011. Groundwater Hydrology: Engineering, Planning, and Management (1st ed.). Taylor & Francis Group, LLC.
17. Krogulec, E., Małecki, J.J., Porowska, D., Wojdalska, A. 2020. Assessment of causes and effects of groundwater level change in an urban area (Warsaw, Poland). Water (Switzerland), 12(11), 1–17. https://doi.org/10.3390/w12113107
18. Liu, C., Liu, H., Yu, Y., Zhao, W., Zhang, Z., Guo, L., Yetemen, O. 2021. Mapping groundwater-dependent ecosystems in arid Central Asia: Implications for controlling regional land degradation. Science of The Total Environment, 797, 149027. https://doi.org/https://doi.org/10.1016/j.scitotenv.2021.149027
19. Nistor, M.-M. 2020. Groundwater vulnerability in Europe under climate change. Quaternary International, 547, 185–196. https://doi.org/https://doi.org/10.1016/j.quaint.2019.04.012
20. Osmanaj, L., Hajra, A., Berisha, A. 2021. Determination of groundwater protection zones of the pozharan wellfield using hydrogeological modflow model. Journal of Ecological Engineering, 22(3), 73–81. https://doi.org/10.12911/22998993/132429
21. Osmanaj, L., Hajra, A., Berisha, A., de Beyer, T. 2021. The journey of establishing groundwater source protection zones in kosovo on the example of Lipjan municipality. Ecological Engineering and Environmental Technology, 22(3), 20–26. https://doi.org/10.12912/27197050/134753
22. Podlasek, A., Jakimiuk, A., Vaverková, M.D., Koda, E. 2021. Monitoring and assessment of groundwater quality at landfill sites: Selected case studies of poland and the czech republic. Sustainability (Switzerland), 13(14). https://doi.org/10.3390/su13147769
23. Qeriqi, M. 2016. Analiza e projektit te kanalizimi fekal fsh. Mirenë. https://knowledgecenter.ubt-uni.net/etd
24. Quevauviller, P., Fouillac, A.M., Grath, J., Ward, R. 2009. Groundwater monitoring. Wiley Chichester.
25. Ram, A., Tiwari, S.K., Pandey, H.K., Chaurasia,

A.K., Singh, S., Singh, Y.V. 2021. Groundwater quality assessment using water quality index (WQI) under GIS framework. Applied Water Science, 11(2), 46. https://doi.org/10.1007/s13201-021-01376-7

26. Rusiniak, P., Kmiecik, E., Wątor, K., Duda, R., Bugno, R. 2021. Pharmaceuticals and personal care products in the urban groundwater – preliminary monitoring (case study: Kraków, Southern Poland). Urban Water Journal, 18(5), 364–374. https://doi.org/10.1080/1573062X.2021.1893354
27. Sethi, R., Di Molfetta, A. 2019. Groundwater Engineering: A Technical Approach to Hydrogeology, Contaminant Transport and Groundwater Remediation (G. Solari, S.-H. Chen, M. Di Prisco, I. Vayas, Eds.; 1st ed.). Springer Nature Switzerland AG. http://www.springer.com/series/15088
28. Simeone, R.A., Mekolli, E. 2023. Hydraulic analysis of the Prishtina covered river under current conditions. UBT International Conference.
29. Zan, J., Dong, Y., Zhang, W., Xu, W., Li, J., Gao, B., Hu, F., Wang, Q. 2019. Distribution characteristics of dissolved oxygen and stable isotope compositions of shallow groundwater in the vicinity of an inland nuclear power plant, HK, China. E3S Web of Conferences, 98. https://doi.org/10.1051/e3sconf/20199809035