Desalination and Water Treatment
www.deswater.com

doi: 10.5004/dwt.2021.27571

241 (2021) 230–235
November

The use of GIS technology-based water quality safety in environmental impact evaluation

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Received 25 June 2021; Accepted 23 September 2021

ABSTRACT

In order to solve the water environment problems in China, it is necessary to rely on the adjustment of policy and scientific evaluation and prediction technology. After empirical research, the practical operation content of the geographic information system (GIS) applied to regional surface water environmental impact evaluation has been pointed out. Based on the environmental monitoring data, the computer software ArcView is used to analyze the spatial distribution of monitoring values of two evaluation parameters, biochemical oxygen demand and chemical oxygen demand in the water area and generate the regional isopleth. According to the evaluation standards of surface water, the water quality is analyzed to determine the spatial distribution of different grades of water quality. Finally, the problems that should be paid attention to in the application of GIS technology are put forward.

Keywords: Environmental impact evaluation; Geographic information system; Water quality safety research; Water environment management

1. Introduction

Human reproduction and progress are closely related to the environment. Water, atmosphere and soil are the three essential conditions of the natural environment. In particular, the water environment plays a decisive role in the continuation and development of biology, industry and agriculture. The water environment includes all kinds of surface water bodies, such as oceans, lakes, reservoirs, rivers, and groundwater in the soil and rock pores. Water environment information reflects the distribution characteristics and variation rules of the quality and quantity of atmospheric precipitation, surface water and groundwater in a certain space [1]. Water is one of the necessary conditions for human survival. At present, with the rapid development of industrialization and urbanization in China, water quality safety has become a very important factor affecting economic and social development and threatening people's normal life. The continuous progress of the economy and society and the acceleration of the urbanization process, such as the increase of urban population density, lead to the resource shortage of energy, transportation, housing, and sewage; moreover, the increasingly acute contradiction between supply and demand of drinking water has become one of the main reasons for the decline of urban residents' living conditions and social satisfaction.

Meanwhile, with the rapid development of the social economy, a lot of industrial and agricultural domestic waste has been discharged into the water, and the water pollution caused by human production activities has seriously damaged the ecological environment. At present, more than 420 billion m^3 of sewage are discharged into rivers, lakes and oceans every year, polluting 5.5 trillion m^3 of freshwater, which is equivalent to more than 14% of the total global runoff [2]. Therefore, in order to solve the problem of the national water environment, it is necessary to rely on policy adjustment and scientific evaluation and prediction technology. Geographic information system (GIS) is an

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effective tool for water quality prediction, because it has the advantages of spatial data analysis and spatial data management. All the query and analysis results can be visualized in the form of map, text, chart and multimedia, and it can provide technical support for the data management function, change prediction function and visual display results of the model [3].

GIS is applied to the comprehensive evaluation of surface water environmental impact, which can combine a large number of spatial data, attribute data and regional geographical environment, quickly draw the thematic map of the environmental evaluation results of the evaluated area, and display the evaluation results in the form of figures to visually display the distribution, quantity and environmental impact of surface water environmental pollutants in the area.

2. Method

2.1. Basic introduction of GIS

GIS is a computer technology system that takes the spatial data with geographical location attributes as the research object, takes the spatial database as the main core, uses the spatial analysis method and spatial modeling method, and obtains various spatial and dynamic resources and environment-related information in time. In the 1960s, GIS technology was first proposed, which is the combination of traditional disciplines (such as geography, cartology, and geomatics) and modern science-related technologies (such as remote sensing technology and computer science). The statistics and calculation of a large number of spatial data is a common technology. GIS technology can be used for the dynamic analysis of spatial information, and it can simulate and show the development and change of things through space-time modeling, so as to provide a reference for future scientific research management and decision-making services. Its main feature is that it can effectively integrate all kinds of data in people's daily activities with the graphic data reflecting the geographical location, which makes it possible to effectively solve complex spatial problems. GIS is a new frontier subject integrating environmental science, management science, geomatics, remote sensing, computer science and geographic science. The system aims to support the collection, management, processing, analysis, modeling and display of spatial data, so as to solve complicated planning and management problems. GIS can timely and accurately provide geoscientists and production departments with reliable spatial data for regional analysis, scheme optimization and strategic decision-making. It becomes one of the driving forces for the spatial development of the IT industry. It is widely used in resource evaluation, environmental supervision, disaster early warning, land management, urban planning, communication engineering, transportation, military, public security, water conservancy, electric power, public facilities, agriculture, animal husbandry, forestry, statistics, finance and other fields [4].

2.2. Importance of water quality safety

At present, China is developing a well-off society in an all-around way. The safety of residents has become the focus of the government. Water quality safety is of great significance to the safety of residents. In the process of rural economic development, it will also become one of the important factors affecting its development [5]. Therefore, water quality safety has become an important problem to be solved by society and the public. According to the investigation report of water quality in recent years, the quality of rural water resources has declined seriously. First, it is due to the environmental problems caused by natural disasters in recent years. Moreover, the rapid development of industry has caused serious environmental pollution. Then, the sources of rural water resources are complex. The above-related reasons lead to the decline of rural water quality year by year. For the sake of national development, social progress and the improvement of residents' daily living standards, analyzing the causes of water pollution, strengthening water quality supervision, improving the quality of water resources and ensuring water quality safety has become one of the important issues in the current national development [6].

2.3. Application of GIS technology in water environment evaluation

The following analysis from four points shows the application status of GIS technology in water environment evaluation. The first is to analyze the current situation of the ecological environment and water quality characteristics in different areas. According to the monitoring data of different areas, the correct water environment evaluation factor is selected. The second is to decide the final water environment evaluation standard. The third is to use the professional model method of water environment evaluation, supplemented by a thematic map and distribution map to make an accurate evaluation of the water environment. Moreover, the analysis results are converted into quantitative data, which provides convenience for comparative analysis in the future. The fourth is to grade the results of the evaluation and analysis to more accurately determine the severity of water environmental pollution [7].

2.4. Application of GIS technology in water quality safety management

The application of GIS technology in water resources management can not only help professionals to develop and utilize water resources reasonably and effectively, but also effectively enhance the deep research and analysis of water resources and improve the effective supervision of water resources. In the actual work of water resources management, GIS technology can be effectively used to establish a reasonable water resources information management system, and a large number of water resources monitoring data can be used to realize the effective development and utilization of water resources. Meanwhile, in the application of GIS, the water resources management model is established, the effective development of water resources is improved, the invalid utilization of water resources is reduced, and the management efficiency of managers is improved, so that water resources can be effectively allocated and used [8].

2.5. Application of GIS technology in simulating surface water flow and groundwater flow

Generally, the implementation of surface water simulation is complex. It is not only necessary to clearly show the runoff relationship between surface water and rivers and lakes, but also need to use the corresponding surface runoff parameters to analyze the local geographical characteristics and geological conditions, so as to improve the effective use of land resources by relevant departments. In addition, GIS can also process and analyze data information, which can effectively complete the statistics and calculation of surface water flow parameters [9]. Furthermore, the importance of this method for groundwater flow simulation modeling cannot be ignored. It can not only improve the accuracy of input data, but also ensure the accuracy of modeling data [10].

2.6. Application of GIS technology in environmental impact evaluation of surface water

Because GIS has no data prediction function, it is in the process of environmental impact analysis. First, the environmental prediction model is used to predict and analyze the environment, and then the special spatial analysis function of GIS is used to complete the regional environmental evaluation and analysis [11].

2.6.1. Drawing electronic map of the evaluated area

According to the evaluation scope, the digitizer has the function of making an electronic map on the initial map; based on the scanned image, GIS graphics editing software and computer screen drawing method are used to make an electronic map of the evaluated area.

2.6.2. Build-up layer and database

The analysis results of surface water environmental impact are closely related to the social, economic, environmental and other aspects. To make the information effectively combined, a consistent data format should be adopted to standardize the data, and then store it in the relational database. When the database is established, the associated field and spatial index field must be set up to search information. The spatial database is related to the attribute database by specific fields, and the attribute database is managed by layer. In the design of the GIS spatial database, layers must be set up reasonably according to the evaluation object and environment characteristics.

2.6.3. Drawing single factor spatial isopleth

For the indexes of surface water environmental impact evaluation, based on the existing information or prediction data, the spatial interpolation method can be applied to make the spatial isopleth of each index, and then analyze the spatial distribution of each index. If there are many comprehensive isopleth indexes to be analyzed, the method of graph superposition can be used.

2.6.4. Single-factor evaluation

Gray or color grading is used, and the environmental information of existing spatial points is used to make a single factor spatial distribution map. Then, according to the environmental standards, the legend is adjusted to get the environmental quality grade map of each grade. On the graph, the environmental quality intervals of different grades in different regions can be known.

2.6.5. Comprehensive evaluation of the environmental impact of surface water

There are two different ways to complete the comprehensive evaluation of surface water environmental impact. First, the graph superposition analysis is completed on the basis of single-factor environmental evaluation. The stacking chart can be used as an evaluation map of environmental impact; second, the comprehensive analysis of the environmental impact of surface water is made by using the model, and then the spatial interpolation analysis is used to make a gray or color evaluation map for the calculation results of the model. Then, the comprehensive evaluation grade standard is compared to improve the evaluation chart, and the comprehensive evaluation is performed to obtain the impact evaluation results [12].

3. Results and discussion

Environmental supervision is a common way to get environmental information, which can quickly and quickly get the initial data information. Because of financial, human, material and other constraints, it is impossible to set up too many monitoring points. Therefore, it is difficult to determine the location and distribution of monitoring objects with common data analysis methods. GIS has a powerful spatial interpolation analysis function, which can make the spatial distribution isopleth of regional monitoring objects based on existing monitoring data, and realize regional environmental quality evaluation. It can be confirmed by many foreign research results [13]. In the use of GIS technology to complete environmental impact evaluation analysis, how to make the current data or forecast data associated with the geographical location and carry out the spatial analysis of environmental quality is the most important.

3.1. Application premise of the practical application of GIS technology

The specific calculation shows that GIS has strong spatial analysis ability. The essence of GIS is the computer program code of the algorithm, which does not have the ability of intelligent analysis and judgment. Therefore, the application of GIS technology in surface water environmental impact evaluation should have a certain application premise, that is, constraints [14]. If it is applied under the condition of not conforming to the restriction factors, although it can get the results, it does not have the opposite ability, and the information and data it provides are wrong.

- The gradual change of data. Spatial analysis data must have continuous spatial changes, but they are not scattered and abrupt spatial data, which is the primary condition for GIS application in spatial data analysis. For the distribution of pollutants in the water and air environment, the medium is single, and it is usually characterized by continuous change. Therefore, it can be statistically analyzed by GIS.

- The representativeness of the data. The information of spatial analysis is usually from environmental monitoring and prediction, remote sensing images and aerial photos of monitoring points. The research object is environmental monitoring. The basic data of spatial analysis must be representative, that is, the maximum and minimum value of the regional evaluation index must be included, and the monitoring point must be arranged on the representative data point. Otherwise, GIS will generate the data that is not in accordance with the actual situation independently, and provide the wrong index map for the results. In practice, this problem is very difficult. The solution is to divide the evaluation area into functional areas, and then arrange monitoring points at the core and edge of the functional area, or analyze them by remote sensing images.
- The accuracy of spatial position. When the monitoring points are associated with the regional electronic map, the spatial position must be accurate. If necessary, GPS can be used to determine the spatial position.

3.2. Establishing a spatial database

ArcView is used, based on the electronic map of a certain water area, through the biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD) monitoring data of 10 monitoring points in a certain water area (Table 1), a relatively perfect spatial database is established. BOD_5 and COD are taken as the research objects. In the process of setting up the spatial database, monitoring points and data can be modified at any time. According to the research requirements, the monitoring points can be added or deleted to dynamically achieve the purpose of data addition and deletion. In practical application, the number of parameters can be determined according to the research needs.

3.3. Regional digital analysis

The spatial database is set up to realize the association between the monitoring point and its geographical location (Fig. 1). In this way, according to the information of monitoring points, the spatial analysis ability of ArcView can be used for digital analysis of the regional water environment. In the analysis process, the software grid the research scope, and then calculate and count the data in each grid. The size of the grid will reflect the accuracy of regional digitization. If different grids have the same value, it will lead to the failure of regional digitization [15]. Therefore, the size of the grid must be set reasonably. According to the monitoring data of the existing monitoring points, the spatial interpolation analysis method is adopted to obtain the isopleth of BOD_5 and COD in the water area, as shown in Figs. 2 and 3. After spatial digital analysis, the query function of GIS is used to get any parameter value at any position in the water area. After the row spacing of the isopleth (the row spacing in Figs. 2 and 3 is 0.5 mg L^{-1}) is adjusted, the dynamic analysis of isopleth can be used to clarify the spatial distribution of pollution parameters, so as to formulate pollution control measures and optimize the decision-making scheme [16–19].

3.4. Evaluation of environmental quality

Based on the digitization of the regional water environment, the spatial distribution of the evaluation index values

Table 1
Monitoring data of monitoring points

Monitoring stations	BOD_5 (mg L^{-1})	COD (mg L^{-1})
1	2.18	14.19
2	3.26	15.58
3	3.18	16.27
4	2.39	15.09
5	2.61	16.27
6	3.38	17.58
7	1.99	14.79
8	1.95	14.51
9	2.16	15.48
10	3.59	16.79

Fig. 1. Spatial coding of monitoring points.

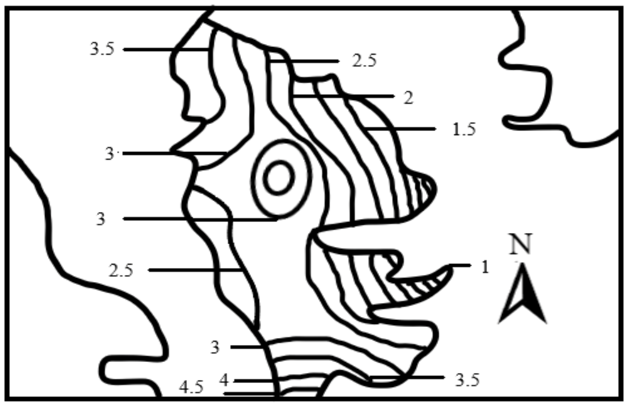

Fig. 2. Isopleth of BOD_5 evaluation parameters.

can be displayed on the map. The water quality grade of the area can be judged according to the environmental specifications.

ArcView can be used to get the spatial distribution map of different value segments of the single factor evaluation index in the evaluation area, and different gray levels are used to represent the different value range. Moreover, it can be explained in the legend. After the legend is improved, the spatial distribution map of any selected value range in the evaluation area can be made. During the environmental quality evaluation, the legend can be improved according to the evaluation standard, and the grade distribution map of any evaluation factor in the water area can be obtained, such as BOD_5 and COD environmental quality evaluation map, as shown in Figs. 4 and 5 [20–22].

In the comprehensive evaluation of environmental quality, the comprehensive evaluation model can be used to calculate the environmental comprehensive evaluation index, and associate the index value of different monitoring points with the geographical location. In this way, the spatial distribution map of the comprehensive evaluation index can be set up. After that, the legend is changed according to the grade value of the comprehensive index, and the comprehensive evaluation result chart is obtained. The operation process is consistent with the law of single factor environmental quality evaluation.

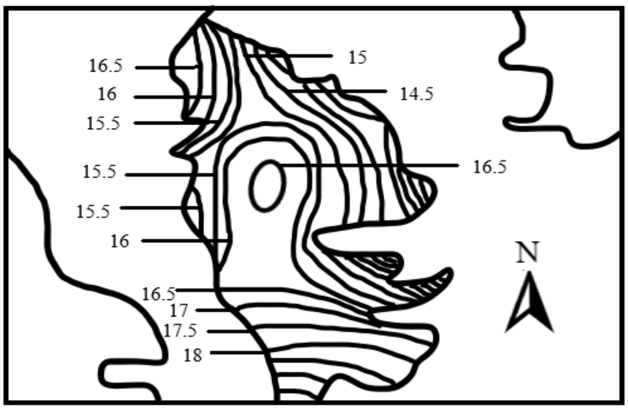

Fig. 3. Isopleth of COD evaluation parameters.

3.5. Query of evaluation results

ArcView can make the isopleth, evaluation results and comprehensive evaluation charts of all evaluation factors be stored in the independent thematic map. In the spatial query, the thematic map or isopleth of the evaluation index can be used to show and study its spatial distribution. In addition, it can also use the spatial measurement ability of GIS to calculate and statistics the different evaluation grade area, and get the proportion of the space pollution area in the total area of the evaluation water area, which is convenient for decision-making; moreover, it can also calculate the range between the edge line of a pollution level and the environmental sensitive point, so as to facilitate the rapid implementation of the solution to prevent environmental pollution accidents.

4. Conclusion

The water environmental impact evaluation based on GIS has the ability to analyze various environmental information and graphic data, improves the digital display of evaluation results, overcomes the problem of insufficient spatial digital ability to exist environmental impact evaluation methods, enriches the methodology of environmental impact evaluation, and has the characteristics of comprehensive evaluation method and graphic display function. However, in the spatial analysis, graphic display and other functions of GIS technology, it is necessary to comprehensively evaluate the characteristics and significance of data. For the evaluation results without temporal and spatial gradient and continuous distribution, the spatial analysis function cannot be applied to the spatial analysis of data. Otherwise, the result will deviate. In the research process, there may be a result deviation caused by data error. In future research, a more rigorous attitude will be adopted to reduce the error. Although some achievements have been made in water environmental impact evaluation, due to the constraints of time and actual working conditions, the above conclusions are only preliminary results. With the further deepening of the research and the continuous expansion of the actual scope, a series of new problems will inevitably appear. In future work, it is necessary to improve and carry out more in-depth research. This exploration is a broad

Fig. 4. BOD_5 environmental quality evaluation chart.

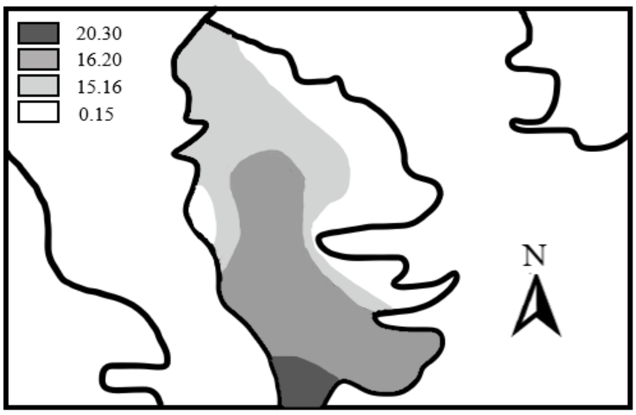

Fig. 5. COD environmental quality evaluation chart.

proposition involving the interdisciplinary and penetration of intelligent computing science, hydrogeology, environmental science and other disciplines. In terms of pollutant attenuation, precipitation and generation, it needs to be discussed in combination with chemical reaction dynamics, mechanics, biology, meteorology and other interdisciplinary directions. It is not easy to integrate the above knowledge in a short time, so some understanding is superficial. With the rapid development of computer science, object-oriented technology, three-dimensional technology, image processing technology, modeling technology and artificial intelligence technology can be directly applied to GIS. As a highly applied subject, GIS will promote the development of the national economy and the improvement of people's living standards. It will maintain the momentum of rapid development and become the core technology in the field of high technology.

References

[1] G. Pęczkowski, K. Szawernoga, T. Kowalczyk, W. Orzepowski, R. Pokładek, Runoff and water quality in the aspect of environmental impact assessment of experimental area of green roofs in Lower Silesia, Sustainability, 12 (2020) 4793, doi: 10.3390/su12114793.

[2] S. Lee, E. Lee, H.S. Yoo, M.-J. Lee, Analysis of trends in marine water quality using environmental impact assessment monitoring data: a case study of Busan New Port, J. Coastal Res., 102 (2020) 39–46.

[3] Y. Yang, Y.-q. Guo, W.-s. Zhu, J.-b. Huang, Environmental impact assessment of China's primary aluminum based on life cycle assessment, Trans. Nonferrous Met. Soc. China, 29 (2019) 1784–1792.

[4] P. Thaler, Comments on "Conceptualization, modeling and environmental impact assessment of a natural rubber techno-ecological system with nutrient, water and energy integration" by Martinez-Hernandez E and Hernandez JE (2018, 185: 707–722), J. Cleaner Prod., 210 (2019) 1063–1064.

[5] D. Abdissa, K. Beyecha, Sugarcane bagasse adsorption evaluation and application on BOD and COD removal from textile wastewater treatment, Water Conserv. Manage., 4 (2021) 30–34.

[6] A. Kadam, M. Rajasekhar, B. Umrikar, V. Bhagat, V. Wagh, R.N. Sankua, Land suitability analysis for afforestation in semi-arid watershed of Western Ghat, India: a groundwater recharge perspective, Geol. Ecol. Landscapes, 5 (2021) 136–148.

[7] H. Hc, S. Govindaiah, L. Srikanth, H.J. Surendra, Prioritization of sub-watersheds of the Kanakapura Watershed in the Arkavathi River Basin, Karnataka, India- using remote sensing and GIS, Geol. Ecol. Landscapes, 5 (2021) 149–160.

[8] M.A. Haque, M.K. Hossain, M.A.I. Molla, M. Sarker, S.C. Dey, M. Ashaduzzaman, Facile fabrication of copper oxide nanoparticles for antimicrobial activity, J. Clean WAS, 5 (2021) 27–30.

[9] P. Bhusal, B. Ghimire, S. Khanal, Assessing link between on farm agro-biodiversity and food self-sufficiency in two agro-ecological regions of Nepal, Environ. Ecosyst. Sci., 5 (2021) 78–84.

[10] B. Samuel, O. Temitope, D. Timothy, O. Olayinka, O. Olusegun, B. Emmanuel, Evaluation of the impacts of metals on soil samples, serum creatinine and blood urea nitrogen of residents in selected industrial communities in a developing country, Environ. Contam. Rev., 3 (2020) 40–47.

[11] N.S. Mohd, R.M. Mohamed, The initial ion effect of heavy metals adsorption by using hydrothermal carbonization banana peels, Environ. Contam. Rev., 3 (2021) 8–10.

[12] Z. Lyu, J. Chai, Z. Xu, Y. Qin, Environmental impact assessment of mining activities on groundwater: case study of copper mine in Jiangxi Province, China, J. Hydrol. Eng., 24 (2019) 05018027.

[13] A. Al-Kaabi, H. Al-Sulaiti, T. Al-Ansari, H.R. Mackey, Assessment of water quality variations on pretreatment and environmental impacts of SWRO desalination, Desalination, 500 (2020) 114831, doi: 10.1016/j.desal.2020.114831.

[14] M. Damiani, N. Lamouroux, H. Pella, P. Roux, E. Loiseau, R.K. Rosenbaum, Spatialized freshwater ecosystem life cycle impact assessment of water consumption based on instream habitat change modelling, Water Res., 163 (2019) 114884, doi: 10.1016/j.watres.2019.114884.

[15] L. Deng, B. Xu, X. Yang, A. Hu, Water quality and health risk assessment based on hydrochemical characteristics of tap and large-size bottled water from the main cities and towns in Guanzhong Basin, China, Environ. Earth Sci., 80 (2021) 1–15, doi: 10.1007/s12665-021-09415-x.

[16] R. Wang, Y. Luo, H. Chen, Y. Yuan, R.L. Bingner, D. Denton, M.Locke, M. Zhang, Environmental fate and impact assessment of thiobencarb application in California rice fields using RICEWQ, Sci. Total Environ., 664 (2019) 669–682.

[17] X. Tang, A. Zhai, X. Ding, Q. Zhu, Safety guarantee system of drinking water source in Three Gorges Reservoir Area and its application in Huangjuedu drinking water source area, Sustainability, 11 (2019) 7074, doi: 10.3390/su11247074.

[18] M. Redwan, A.O. Bamousa, Characterization and environmental impact assessment of gold mine tailings in arid regions: a case study of Barramiya gold mine area, Eastern Desert, Egypt, J. Afr. Earth Sci., 160 (2019) 103644, doi: 10.1016/j.jafrearsci.2019.103644.

[19] H. Khademi, M. Gabarrón, A. Abbaspour, S. Martínez-Martínez, A. Faz, J.A. Acostab, Environmental impact assessment of industrial activities on heavy metals distribution in street dust and soil, Chemosphere, 217 (2019) 695–705.

[20] Y. Zhang, F. Li, N. Peng, L. Peng, Environmental impact assessment of air-permeable plastic runway production in China, Sci. Total Environ., 730 (2020) 139073, doi: 10.1016/j.scitotenv.2020.139073.

[21] Z.F. Makki, A.A. Zuhaira, S.M. Al-Jubouri, R.Kh.S. Al-Hamd, L.S. Cunningham, GIS-based assessment of groundwater quality for drinking and irrigation purposes in central Iraq, Environ. Monit. Assess., 193 (2021) 1–27.

[22] A. Ram, S.K. Tiwari, H.K. Pandey, A.K. Chaurasia, S. Singh, Y.V. Singh, Groundwater quality assessment using water quality index (WQI) under GIS framework, Appl. Water Sci., 11 (2021) 1–20, doi: 10.1007/s13201-021-01376-7.