Assessment of Geostatistical Methods in Groundwater Quality Evaluation of Mashginshahr Plain Using WQI Index

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ABSTRACT

In this study, the groundwater quality of the Meshgin Plain was investigated based on the WQI index and using geostatistical methods. As the results and evaluation statistics of the cokriging method showed, the variogram of the random variable WQI index from the exponential model had a nugget effect (0.02) for the WQI index and (0.05) for the auxiliary variable electrical conductivity. the sill of the variogram for the WQI variable was (0.7) and for the auxiliary variable electrical conductivity was (0.77), which indicates that the role of the structured component of the variogram is greater than the role of its unstructured component, and this indicates the strength of the spatial structure of the region for both the random variables WQI index and electrical conductivity at the regional level. The results showed that geostatistical methods and simple cokriging model, with a coefficient of determination of 0.85 and a root mean square error of 3.27, has an accurate estimate of the WQI random variable. In general, it can be said that the evaluation using the kriging method shows that the WQI index at the regional level is generally at the level of 0-100 and is in the "Excelent" and "Good" quality range, and more than 96 percent of the studied area has good quality for drinking purposes. The results of this study showed that geostatistical estimates are of great importance in determining the WQI index at the regional level, especially in areas where water is withdrawn for drinking purposes, due to the high accuracy of this method.

KEYWORDS :

Groundwater quality, geostatistics, WQI index, GIS, plain

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Introduction

Groundwater is a critical water source in arid and semi-arid regions, particularly in northwestern Iran, where precipitation is limited and surface water resources are scarce. Mashgin Plain, covering 1705 km², exhibits elevations from 357 to 2541 m above sea level and experiences a semi-humid temperate climate according to Ambriz classification and semi-arid conditions according to De Martonne. Monitoring groundwater quality is essential to ensure safe drinking water and sustainable agricultural practices.

The Water Quality Index (WQI) provides a quantitative measure for overall water quality by integrating multiple physico-chemical parameters into a single value. It simplifies complex datasets, allowing for spatial and temporal comparisons, and has been widely applied in groundwater studies globally. Obeidavi and Houshmand (2021) investigated the spatial distribution of the water quality index based on World Health Organization (WHO) standards using Geographic Information System (GIS) in the Firoozabad region of Khuzestan Province. The results showed that in certain parts of the region, the concentrations of four parameters, calcium, chloride, turbidity, and total hardness,exceeded permissible limits, while the values of other parameters complied with WHO standards.

Heshmati and Beigi Harchgani (2012) assessed groundwater quality in Shahrekord for agricultural use using geostatistical methods and applied Ordinary Kriging for spatial interpolation of variables. The results indicated consistency and correlation among the observations, suggesting the high accuracy of semivariogram models and the Ordinary Kriging estimator in estimating groundwater quality indices in Shahrekord. In another study, Nakhaei and Vediati (2013) evaluated the water quality of 23 qanats in Tehran Province for various drinking and agricultural uses using fuzzy logic. The results demonstrated that the fuzzy inference model is an appropriate tool for assessing qanat water quality. Hassanalipour et al. (2022) assessed the effects of urban development in Ardabil city on surface and groundwater quality in the Ardabil Plain. They reported that in the northern, northeastern, and eastern sections toward the central, southern, and southeastern areas, the concentrations of water quality parameters increased, attributing this to the deterioration of water quality resulting from urban development

Coupling WQI with geostatistical techniques such as co-kriging enhances spatial predictions by accounting for the correlation between water quality parameters and auxiliary variables.

Methodology

Groundwater samples were collected from 42 wells distributed across Mashgin Plain. In situ measurements included pH, temperature, and EC, while laboratory analyses determined TDS, major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), and major anions (HCO_3^{-}, CO_3^{2-}, Cl^{-}, SO_4^{2-}) using standard methods. Data normalization and trend analysis were performed before geostatistical modeling to minimize spatial bias.

The WQI was calculated using the weighted sum method, assigning higher weights to parameters with greater health impacts, such as nitrate and EC. Each parameter was normalized against its standard drinking water guideline value. The WQI values were then classified into five categories: Excellent (<50), Good (50–100), Poor (100–200), Very Poor (200–300), and Unsuitable (>300).

Geostatistical analysis involved ordinary kriging and simple co-kriging, using EC as an auxiliary variable due to its strong correlation with other ions. Model validation was performed using cross-validation metrics including R^2, RMSE, MAE, EF, and relative error percentage (ε). Figure 1 illustrates the Mashgin Plain study area and well locationsThe basic elements of the extended abstract are listed below in the order in which they should appear:

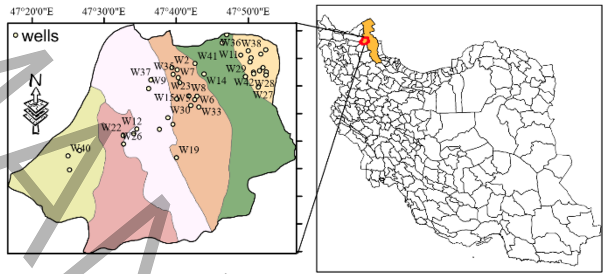

Figure 1 illustrates the Mashgin Plain study area and well locations.

Results and Discussion

The co-kriging approach using EC as an auxiliary variable provided the highest prediction accuracy, outperforming ordinary kriging and other univariate methods. Cross-validation yielded $R^2 = 0.85$ and RMSE = 3.27, indicating a strong agreement between observed and predicted WQI values.

Spatial mapping revealed that most of Mashgin Plain exhibits high groundwater quality. Table 1 summarizes the WQI classification and the area coverage of each class. Over 44% of the plain falls into the “excellent” category, and an additional 52% into the “good” category, totaling more than 96% suitable for drinking purposes. Only a small fraction (4%) falls into the “poor” or “very poor” categories.

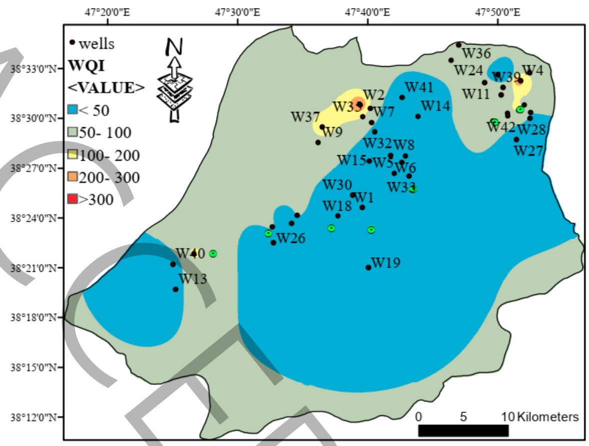

Figure 2 shows the spatial distribution of WQI values across the plain.

The map highlights areas of relatively higher EC and TDS, corresponding to zones with lower water quality. These results suggest that groundwater in Mashgin Plain is largely suitable for consumption but requires regular monitoring in localized areas where salinity may increase due to agricultural or natural factors.

Conclusions

This study demonstrates the effectiveness of combining WQI and geostatistical methods for groundwater quality assessment. Simple co-kriging with EC as an auxiliary variable provides high-resolution predictions of water quality, outperforming univariate methods. More than 96% of Mashgin Plain is classified as having "excellent" or "good" water quality, confirming the suitability of its groundwater for drinking purposes. These findings provide a reliable framework for future groundwater monitoring and sustainable resource management in semi-arid regions

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