

Groundwater Vulnerability Assessment Using GIS-Based DRASTIC Model in the Bazargan and Poldasht Plains

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Extended Abstract

The groundwater system responds slowly to contamination events and the travel times to reach the groundwater zone are often long. Cleaning and restoring contaminated groundwater is often technically problematic and expensive. Moreover, finding alternative sources for water supply is not always possible. Therefore, the most effective and realistic solution is to prevent the contamination of groundwater through. Groundwater vulnerability is considered an intrinsic property of groundwater and can be defined as the possibility of percolation and diffusion of contaminants from the ground surface into the groundwater system (Babiker et al. 2005). Groundwater vulnerability is a relative, dimensionless and characteristic that cannot be directly measured in the field and depends on aquifer characteristics, geology and hydrogeology. Many different methods have been developed for assessing this vulnerability (Vrba and Zaporozec 1994). One of the most commonly used of method of groundwater vulnerability assessment is the DRASTIC method. In the present study, vulnerability assessment was carried out to evaluate the potential for groundwater contamination through the construction of a map for groundwater aquifer system in the study area. For this purpose the combined use of the DRASTIC and geographical information system (GIS) demonstrated as an effective method for groundwater pollution risk assessment.

Study area

Study area is situated in the north of West Azarbaijan province, northwest of Iran, on the foot hills of Ararat Mountain. The study area lies between longitudes 44°21' and 45°10' and latitudes 39°13' and 39°34'. It is bounded to the west by Turkish territories, to the east by Aras River and to the south and southeast by Zangmar River. The area of the sector is approximately 1000 km² that up to 330 km² covered with basaltic lavas. Maku, Poldasht and Bazargan are the main cities of this area. The study area has a cold and arid climate. In the county, groundwater supplies main water demands for different purposes such as drinking, agriculture and industry.

Geological and Hydrogeological setting

From the hydrogeological point of view, there are two main formations that dominantly covered the study area: (a) Lava flows that mainly consist of basaltic rocks and (b) limestones of Qom formation (Oligo-Miocene) and massive limestone and Dolomites of Rute formation (Permian). Furthermore, the other formations such as Shale, Marl and Conglomerate are also covered small parts of the area. The basaltic lava flows are erupted from Ararat Mountain volcanoes. Most of these lavas are flowed from east and southeast flanks of Ararat and covered the lowlands of the study area. Based on the geophysical data, the thickness of basalts in Bazargan and Poldasht Plains are more than 54m and 40m respectively. The average values of transmissivity and hydraulic conductivity for the aquifers of the area are reported 116 m²d⁻¹ and 3×10⁻³ md⁻¹ respectively (Asghari Moghaddam and Fijani 2009).

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Methodology

The assessment of groundwater vulnerability to pollution has been subject to intensive research during the past years and a variety of methods have been developed. The simplest to apply – and for that reason the most widely used – are the Rating Models. These methods classify each parameter, which potentially influences the probability of pollution of the aquifer, in a scale and lead to a score, which designates the vulnerability of the groundwater (LeGrand, 1964). An evolution of these methods is the Point Count System Models (PCSM) or Parameter Weighting and Rating Methods, which – apart from classifying the various parameters – also introduce relative weight coefficients for each factor. The most widespread PCSM method of evaluation of the intrinsic vulnerability is the DRASTIC method (Aller et al., 1987). This method allows seven parameters of the geological and hydrological environments to be considered. These seven elements are combined in the model are Depth to Water (D), Net Recharge (R), Aquifer Media (A), Soil Media (S), Topography (T), Impact of the Vadose Zone (I), and Hydraulic Conductivity (C). These elements are evaluated in reference to a numeric rating system that is weighted according to its relative importance within the model. The rating scales are values that range from 1 to 10 and weights from 1 to 5. This model was not originally designed for use in a GIS, although it has been shown that such an implementation provides substantial benefits (Merchant 1994). By using the spatial analysis tools available within a GIS, data layers are developed based on the seven DRASTIC components. This methodology creates a spatial database which is divided into contamination vulnerability categories for evaluation over the selected area. When the DRASTIC score is displayed via a GIS, the spatial relationship between land management practices and groundwater vulnerability is illustrated. All DRASTIC data elements are incorporated, manipulated, interpreted, and displayed using a GIS. The resulting output is a spatially-oriented dataset showing the hydrogeologic setting and areas of groundwater vulnerability to contamination. The particular GIS software tool used in this analysis is the ArcView software package.

Result and Discussion

Information collected is either in a raw format that requires extraction or is available in a digital format that can be tailored to the specific requirement of the model parameters. From this point forward, GIS tools are used almost exclusively to integrate model elements for analysis and display. In the case of well locations that exist as GIS point files, the Kriging spatial interpolation technique is used to transform depth to water information into a continuous surface. The Spatial Analyst extension within the ArcView software package provides many of the operation selections for manipulating the elements within the DRASTIC model. In addition to the Kriging functionality, a surface analysis tool is available for calculating the percent slope from a Digital Elevation Model (DEM) of the study area. To generate the remaining model elements, topological integration using various data management, analysis and conversion tools (e.g., Clip, Merge, and Overlay) provide the mechanisms for creating the desired data structures. Data manipulation occurs based on the description of the geologic formation or soil textural information acquired. Conversion to a raster format for all vector formatted data is necessary for integration of the model elements within the GIS. The data layers representing each DRASTIC element will be combined based on the Pollution Potential equation using the raster calculator functionality within the ArcView Spatial Analyst extension. The resulting raster file will be the layer used to evaluate groundwater vulnerability.

In addition to investigating where there is potential for contamination of groundwater within the study area, an application of this research is to understand if the DRASTIC model output, in the form of a vulnerability map, correlates with existing measured patterns of contaminant data. Combining the hydrogeological setting elements results in a range of numerical values termed the DRASTIC Index. Derived by combining the seven DRASTIC element index values, a range of values are developed that have been classified to represent groundwater vulnerability. These numbers are relative and have no intrinsic meaning other than in comparison with other like DRASTIC indices. As the methodology indicates, statistical data grouping has been implemented in order to differentiate three categorical index ranges (High, Moderate, and Low). Index values for this integrated model range from 71 to 175 and the distribution of the data in this model indicates

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that over 60 percent of the study area has high vulnerability. Moderately vulnerable areas comprise nearly 37 percent of the area, and the least vulnerable areas make up the remaining 3 percent of the total area.

For verification of final vulnerability map, correlation carried out with existing measured patterns of fluoride contaminant data that confirmed the precision of the model (Fig. 1).

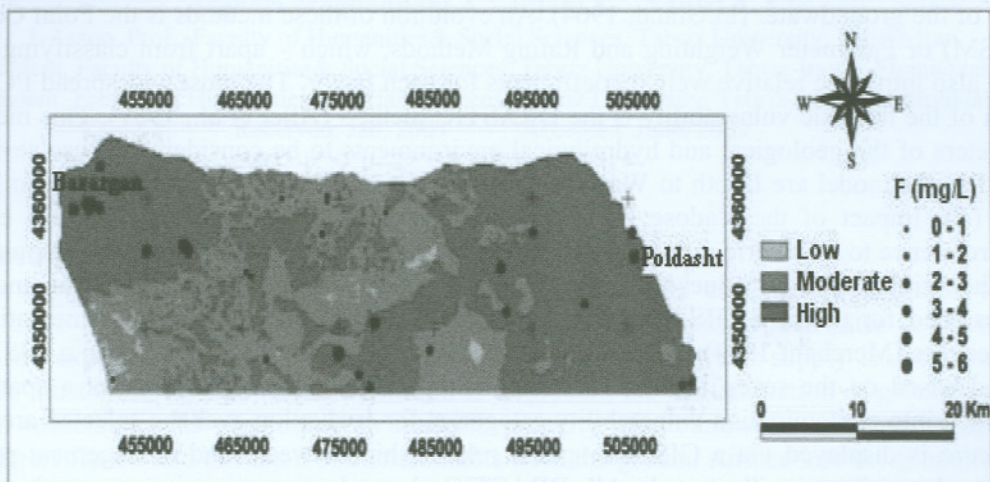


Fig. 1: Final vulnerability map and correlation with existing fluoride contamination

Conclusion

In order to assess the aquifer vulnerability for contamination potential, the combined use of the DRASTIC and geographical information system (GIS) demonstrated as an effective method for groundwater pollution risk assessment. DRASTIC index value was evaluated 71 to 175 for study area. Around 3% of the study area was classified as being at low risk, 37% as moderate risk while the remainder was classified as high risk that covered large parts of the east, west and central portion of the area. The final DRASTIC model was tested using fluoride concentration data from the aquifer. High fluoride concentrations coincide with the high pollution risk area. This can confirm the precision of the model.

Key words

Bazargan and Poldasht plains, Groundwater vulnerability, DRASTIC model, GIS