

Assessment of Aquifer Vulnerability in Baghmalek Plain in Khuzestan, Iran using GIS DRASTIC Model



ABSTRACT

The purpose of this study was to assess the vulnerability of groundwater in Baghmalek aquifer to pollution. The groundwater vulnerability was simulated in Geographical Information System (GIS) using DRASTIC model. Indeed, GIS clarifies the results of a complicated model through visual representation, which provided an applicable tool for decision makers. The vulnerability map of Baghmalek basin shows four classes including no risk to pollution, very low vulnerability, low vulnerability, and low to moderate vulnerability depending on the intrinsic characteristics. The results of the model indicate that the northern parts of the plain are more vulnerable than the southern parts.

Key words: Baghmalek groundwater, GIS system, DRASTIC model, Vulnerability, Pollution, Aquifer

Reihany Glareh¹
Heydar Ali Kashkuli²
Narges Zohrabi^{*}

¹ Department of Water Sciences and Engineering, Khuzestan Science and Research Branch, Islamic Azad University, Ahvaz, Iran

² Department of Water Sciences and Engineering, Ahvaz branch, Islamic Azad University

*Corresponding author:
n.zohrabi@khouzestan.srbiau.ac.ir

INTRODUCTION

Groundwater is a natural fresh water resource that is often subjected to severe human impacts. Several programs and models are required to preserve the optimum groundwater quality. Therefore, the management of this vital natural resource has become a worldwide priority. The increasing use of chemical fertilizers and the overexploitation of Baghmalek aquifer during the last decades were the main causes of the groundwater pollution. Thus, the pollution vulnerability map of Baghmalek aquifer is highly required. The assessment of groundwater vulnerability to pollution has intensively studied during the past years and a variety of methods have been developed. (Saidi *et al.* 2010) Focusing on Baghmalek area, this paper attempts to elaborate groundwater vulnerability zonation. This research aimed to show areas with greatest potential of groundwater pollution based on hydrogeological conditions and human impacts. GIS software is used to create the groundwater vulnerability map through overlaying the available hydrogeological data. The word DRASTIC is an abbreviation of seven hydrogeological parameters, which helps defining the groundwater regime and its vulnerability towards pollution. The seven thematic parameters are depth to water (D), recharge (R), aquifer media (A), soil type (S), topography (T), impact of vadose zone (I), and hydraulic conductivity (C), generated in GIS environment.

Different weights and rating values have been assigned to each parameter proportional to their behaviour towards groundwater pollution. Their rating value varied from 1 to 10 (Aller *et al.* 1987). The DRASTIC concept was first used in France towards the end of the 1960s to develop the awareness of groundwater contamination. The model delineates the zones, which are more prone to contamination from anthropogenic activity (Verba and Zaporozec 1994). It was developed by the United States Environmental Protection Agency. Chitsazan *et al.* (2011), evaluated potential for groundwater pollution in pelly-mianrudan plain that is located in northern lali city in Khuzestan province. Resulted map obtained in GIS environment shows that the study area has DRASTIC index of 71-150 that is divided to five vulnerable zones namely no significance, very low, low, low to moderate, moderate to high. Maximum groundwater vulnerability correspondent low to medium zone that approximately covers 45 percentage of the study area and other parts on the northwest and centre of the study area has high vulnerability.

Lathamani *et al.* (2015), determined the aquifer vulnerability using DRASTIC method which correlated well with the physico-chemical characteristics of groundwater in Mysore city in India. The main objective was to determine the susceptible zone for groundwater

pollution by integrating hydrogeologic layers in Global Information System (GIS) environment. It was found that, when the net recharge is high, the vulnerability was also found very high. A positive correlation was observed between groundwater vulnerability and concentration of nitrate in groundwater. GIS application of the DRASTIC model was found to be a suitable method for analyzing the groundwater vulnerability in a city environment like Mysore.

Malik Muhammad *et al.* (2015) evaluated of local groundwater vulnerability based on DRASTIC index method in Lahore, Pakistan. Central regions within this study area showed low vulnerability due to dense human settlement and low water level. Pasture type lands and agricultural areas recorded high risk. They reported that Lahore's environmental and socio-economic development is dependent on policy makers and planner's ability to use information effectively for decision making.

Vulnerability assessment is a basis for initiating protective measures for important groundwater resources and will normally be the first step in groundwater pollution assessment (Foster *et al.* 2002). The purpose of this study was to assess the potential of groundwater pollution in Baghmalek plain.

METHODOLOGY

Study Area

The study area is located between latitude $31^{\circ} 30' - 31^{\circ} 38'$ and longitude $49^{\circ} 49' - 49^{\circ} 56'$, which is in the southwest of Iran, more specifically in the Khuzestan province, northeast of Ahwaz city, (**Figure 1**). The elevation ranges from 700 to 800 m above the sea level. In terms of climate, the study area belongs to a dry climate and according to systematic classification, it falls in semi-arid climate with annual average rainfall of 620.3mm and temperature of 21.1°C . The geomorphology map of the study area was prepared based on the lithological units, recent sediments, landform, and landscapes (*Reihany 2011*). The main geomorphologic units of the study area are mountains, plains, and streams. The recharge from precipitation is the main input to the aquifer and pumping is the main output.

The study area is located in the folded Zagros belt. This zone is one of the most active zones of Zagros tectonic. The various geological structures including anticlines, thrust faults and other linear and earthquake structures show the intensity of tectonic activities of the region (**Figure 2**).

DRASTIC model

DRASTIC is an empirical method developed by US EPA for the evaluation of the groundwater pollution potential of an area in USA (*Aller *et al.* 1987*). The

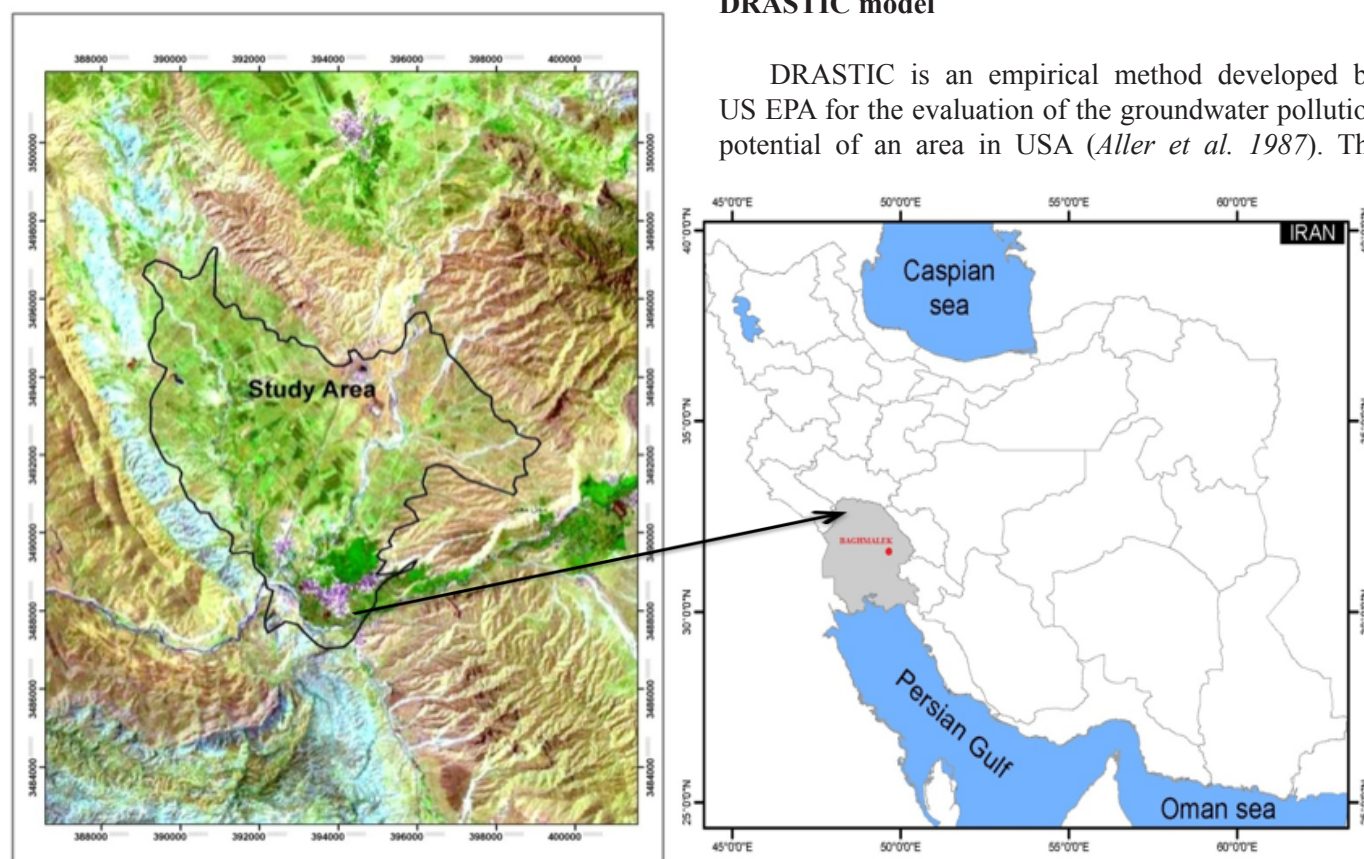


Figure 1. Location of the study area.

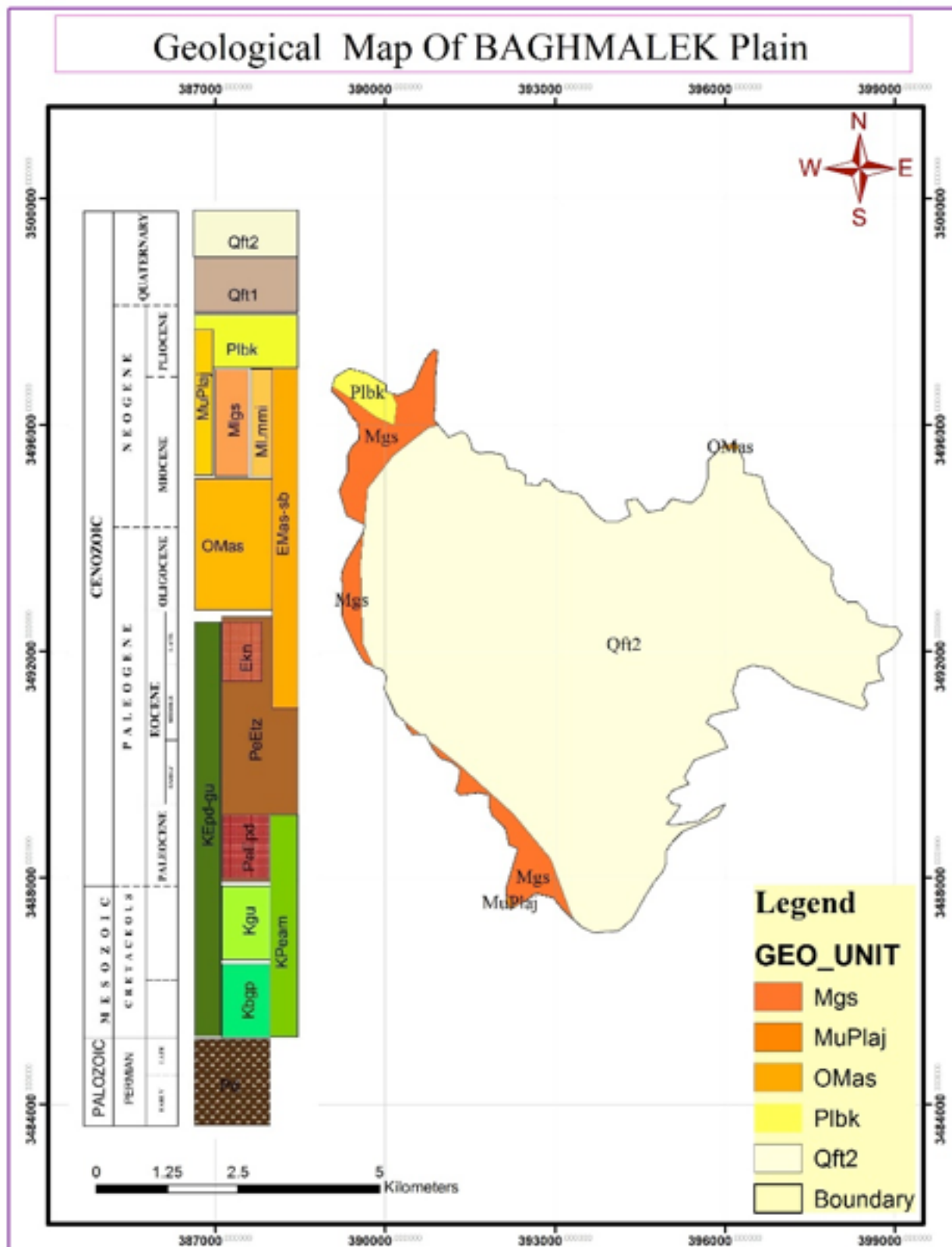


Figure 2. Geological section of Baghmalek plain.

DRASTIC model applied in the GIS environment was used to evaluate the vulnerability of the Baghmalek plain. It was based on the concept of the hydrogeological setting that is defined as “a composite description of all the major geologic and hydrologic factors that affect and

control the groundwater movement into, through and out of an area”(Aller *et al.* 1987). The DRASTIC model has been applied in the present basin to determine the degree of susceptible zone for groundwater pollution from anthropogenic activity using the “Spatial Analyst Tool”

(extension tools of Arc catalog) of the GIS environment. This method covers all important geological such as the hydrogeological parameters, which govern the occurrence and movement of groundwater into the system. Each letter from the word DRASTIC constitute one thematic layer for vulnerable pollution study (**Table 1**). In this system, the nature of vulnerability to pollution in groundwater is based on numerical index value. The index numbers are derived from the rating and weights assigned to every thematic layer. The class of each thematic layer has been rated between 1 to 10 based on the susceptibility towards pollution and the weights have been ranged from 1 to 5. The calculation of DRASTIC index is based on the simple arithmetic formula where the multiplication of rating assigned to each class of thematic layer is done by weight and finally the results are added together (*Aller et al. 1987*). The higher the DRASTIC index number, the higher is the susceptibility to groundwater pollution. The general formula is shown below:

$$\text{DRASTIC INDEX} = D_r D_w + R_r R_w + A_r A_w + S_r S_w + T_r T_w + I_r I_w + C_r C_w \quad (1)$$

where:

r rating assign to each class of thematic layer

w weight assign to thematic layer

D Depth to water

R Recharge

A Aquifer media

S Soil type

T Topography

I Impact of vadose zone

C Hydraulic conductivity

GIS is used to obtain the DRASTIC INDEX value for groundwater vulnerability to get more reliable

and fast results. It requires mainly three steps namely spatial database building, spatial data analysis, and data integration (*Prasad et al. 2011*). In the spatial database building, various vector layers such as depth to water, recharge, aquifer media, soil type, topography, impact of vadose zone, and hydraulic conductivity are generated from the available model parameters.

These layers are made after digitization of maps, editing for errors dangle etc., topology building, attribute assignment, projection, and buffering. The spatial data analyses are the analytical techniques associated with the study of geographic phenomena locations together with their spatial dimension and their associated attributes (like table analysis, classification, polygon classification, and weight classification). Furthermore, various thematic maps as described above have been converted into raster form considering 100 mas cell size to achieve considerable accuracy. These were then reclassified and assigned suitable rating based on their class (**Table 2**) (*Prasad et al. 2011*). Each model parameter provides certain indication on groundwater pollution zone. These layers are unified together by applying DRASTIC equation. Although, it is possible to superimpose these information manually, but it is time consuming and errors may occur. Therefore, these information are numerically integrated through GIS. The DRASTIC index are generated by bringing all the reclassified model parameters by assigning appropriate rate and weight into the “Raster Calculator and Math” function of Spatial Analysis tool for integration. The final map (**Figure 10**) has been categorized into four zones from no risk up to, low to moderate zone from groundwater pollution point of view. The extent of various zones (**Table 4**) in terms of area are presented in km² and percentage.

Table 1. The DRASTIC model parameters (*Aller et al. 1987*).

Factor	Description	Relative weight
Depth to water	Represents the depth from the ground surface to the water table, deeper water table levels imply lesser chance for contamination to occur.	5
Recharge	Represents the amount of water that penetrates the ground surface and reaches the water table, recharge water represents the vehicle for transporting pollutants.	4
Aquifer media	Refers to the saturated zone material properties, it controls the pollutant attenuation processes.	3
Soil type	Represents the uppermost weathered portion of the unsaturated zone and controls the amount of recharge that can infiltrate downward.	2
Topography	Refers to the slope of the land surface, it dictates whether the runoff will remain on the surface to allow contaminant percolation to the saturated zone.	1
Impact of vadose zone	Is defined as the unsaturated zone material, it controls the passage and attenuation of the contaminated material to the saturated zone.	5
Hydraulic Conductivity	Indicates the ability of the aquifer to transmit water, hence determines the rate of flow of contaminant material with in the groundwater system.	3

RESULTS AND DISCUSSION

Preparation of DRASTIC maps

Depth to water. It is the distance of water level from the ground surface. The depth of water level is inversely correlated with groundwater pollution. If water level is very shallow then the chances of pollutants intermingling with groundwater will be higher. Whereas, if the water level is deeper, the travel time will be longer and as a result, the chances of contamination will be reduced (**Figure 3** and **Table 2**).

Recharge. It is the total quantity of water (in cm),

Table 2. Rate of the seven DRASTIC parameters.

Parameter	Rating
Depth to water (m)	
1.5–4.6	9
4.6–9.1	7
9.1–15.2	5
15.2–22.9	3
22.9–30.5	2
>30.5	1
Recharge (mm. yr⁻¹) mm yr⁻¹	
178–254	8
102–178	5
51–102	3
<51	1
Aquifer media	
Sand and gravel	8
Sand with some clay/silt	6
Clay and silt with some sand/gravel	4
Clay and silt	2
Soil type	
Sand dunes	9
Loamy sand to sandy loam	6
Silty-clayey loam to clay loam	3
Topography (slope %)	
0–2	10
2–6	9
6–12	5
12–18	3
>18	1
Impact of vadose zone	
Sand	8
Silty sand	7
Clayey sand	6
Sandy silt	5
Sandy clay	4
Silty clay	3
Confined aquifer or compact clay	1
Hydraulic conductivity (m. day⁻¹)	
12.2–28.5	4
4.1–12.2	2
<4.1	1

which infiltrates from the ground surface to the aquifer on an annual basis. This recharge water is available to transport a contaminant vertically to the water table

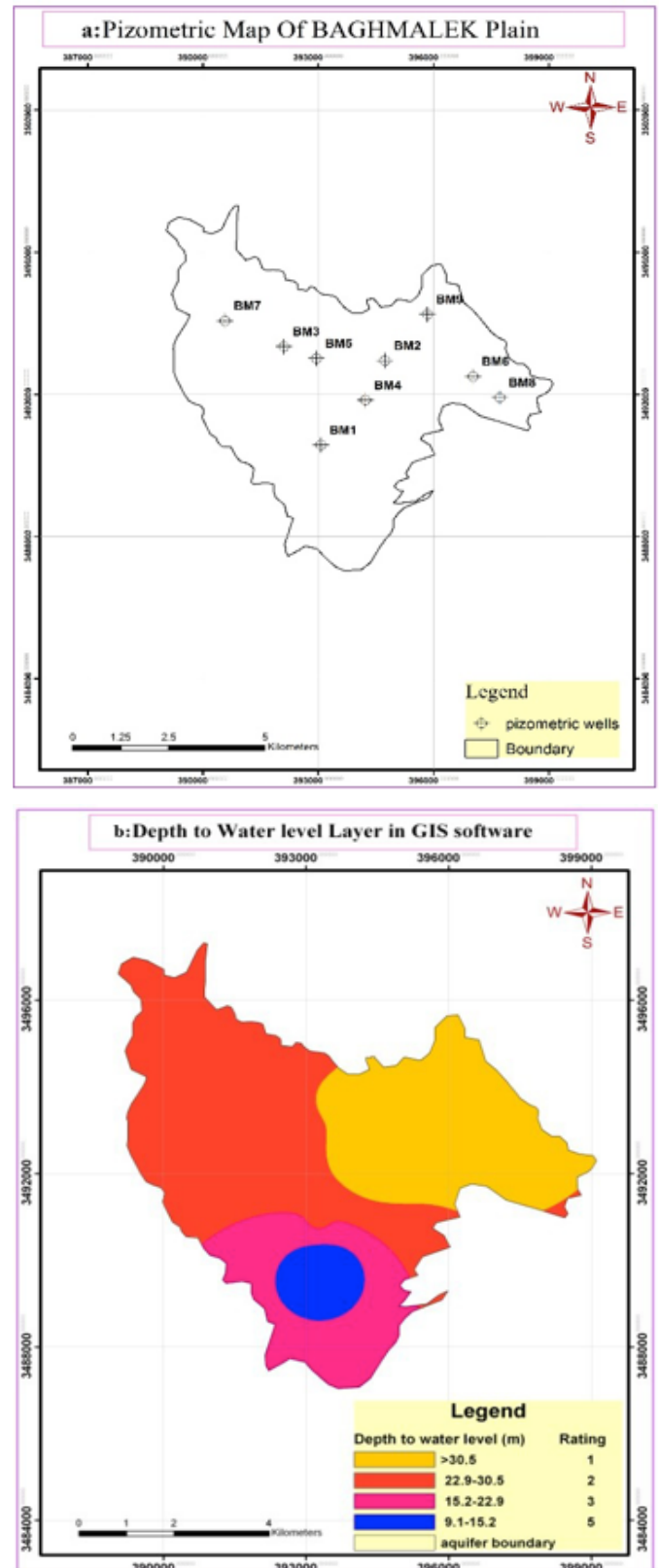


Figure 3. a: Pizometric map of BAGHMALEK plain, b: Depth to water level layer.

and horizontally within the aquifer (Saro 2003). To prepare the recharge layer, Piscopo method (Piscopo 2001) was used:

$$\text{Net Recharge Index} = \text{Slope} + \text{Rainfall} + \text{Soil Permeability} \quad (2)$$

Initially, a digital elevation model (DEM) of the study area was generated from the topographic map. Then, the derived slopes were reclassified according to the criteria (Table 3) (Slope). The resulting slope map was converted into grid coverage, considering that the pixel values in the grid coverage are based on the slope ratings. The soil map was classified into two classes based on the criteria and was then converted into grid coverage (Table 3). This process was essential in order to perform arithmetic operations within the GIS (Al-Adamat, Foster, and Baban 2003).

Finally, both grids added together with the rating value of the rainfall, which is equal to 2 in the study area (Table 3). The recharge index then calculated from Equation 2. The resulting map was classified according to the criteria given in (Table 3). According to this table the maximum recharge value is 13 and the minimum recharge value is 3. The most rechargeable zone belongs to sand dunes area (with rating of 8), while the central and northern part of the study area has moderate recharge (with rating of 5). In addition, the southern parts of the study area has low recharge rate (with rating of one and three) (Figure 4).

Aquifer media. It is a descriptive layer, which depends on the components of the aquifer. The log of exploitation wells has been applied in order to capture the layer of aquifer media. The aquifer media layer of the study area has been divided into four ranks of 6 (51% of the region), 7 (28.2% of the region), 8 (17.9% of the region) and 9 (2.9% of the region) based on the criteria of DRASTIC model (Table 2) (Figure 5). According to DRASTIC theory, the smaller the size of sediments, the less the vulnerability. An aquifer is defined as “a subsurface rock unit, which will yield the sufficient quantities of water for use.” The aquifer media describes consolidated and unconsolidated rock in where the water is contained. This

will include the pore spaces and fractures of the media in where the water is held. The aquifer media therefore affects the flow within the aquifer. This flow path controls the contaminant contact rate within the aquifer (Aller et al.1987).

Soil type. It has a significant impact on the amount of recharge that can infiltrate into the ground, and hence it affects the ability of a contaminant to move vertically into the vadose zone. The presence of fine-textured materials such as silts and clays can decrease relative soil permeability and restrict contaminant migration. The soil map of the study area (1:50000) prepared by the Environmental Source Office of Khuzestan Province, was scanned to prepare the soil media layer. Initially, the

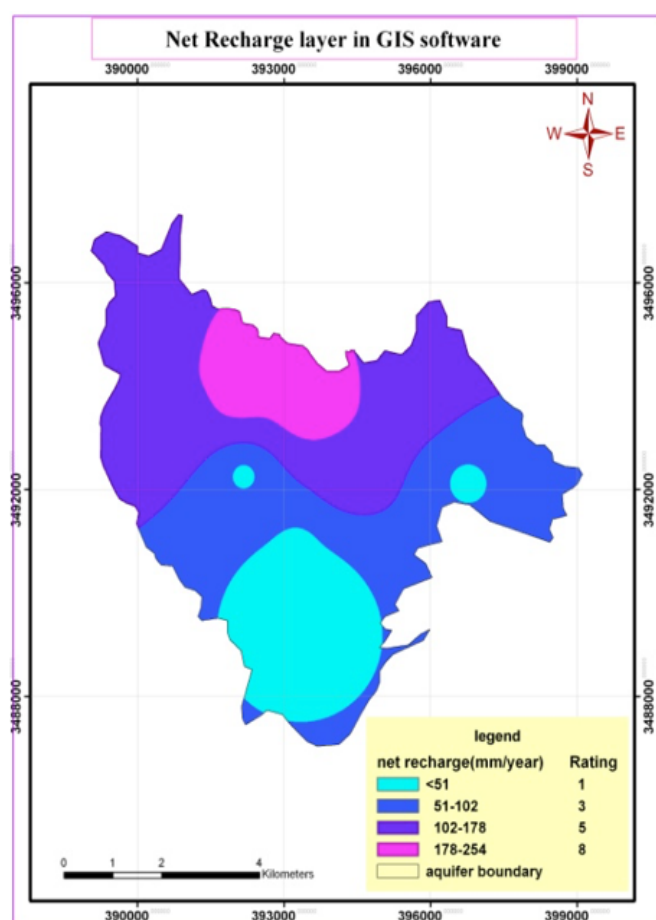


Figure 4. The net recharge of the area.

Table 3. Recharge is generated according to Equation 2.

Slope		Rainfall		Soil permeability		Recharge value	
Slope %	Factor	Rainfall (mm yr ⁻¹)	Factor	Range	Factor	Range	Rating
<2	4	850<	4	High	5	11-13	10
2-10	3	700-850	3	Moderate to high	4	9-11	8
10-33	2	500-700	2	Moderate	3	7-9	5
>33	1	500>	1	Low	2	5-7	3
				Very low	1	3-5	1

hard copy of this map was scanned and digitized through the “software” and then, the vector file of soil map was prepared in ArcView of GIS software. Finally, the rating of three to ten was assigned to different soil media types according to their permeability. The coarse soil media have high rates compared to fine soil media. In general, the majority of the study area surface has the moderate to heavy soil texture (ranks 3, 4), which is mostly influential in the south and east of the plain, which has the heavy soil (rank 3) and reduce the potential vulnerability (**Figure 6**).

Topography. It describes the slope in DRASTIC. This factor influences the flow rate at the surface, and accordingly influences biodegradation and attenuation. Areas with low slope tend to hold water longer. It allows a greater infiltration of recharge water and a greater possibility for contaminant migration (*Chitsazan and Akhtari 2009*).

In the Baghmalek plain, there is relatively little variation in slope. In order to prepare the topography layer, a digital elevation model (DEM) of the study area was generated from the topographic map. The slopes in the study area were then derived from the DEM and classified according to the criteria of DRASTIC model (**Figure 7**).

Impact of vadose zone. It is defined as the zone above

the water table that is unsaturated or discontinuously saturated. The type of vadose zone media determines the attenuation characteristics of the material below the typical soil horizon and above the water table. Furthermore, this zone controls the path of contaminant particles to the aquifer system. (*Chitsazan and Akhtari 2009*). The vadose zone media was defined from lithologic data of wells and logs of 9 piezometers. However, the locations of these wells were too sparse to create an interpolated map, Denny method (*Denny et al. 2006*) was used, and hydraulic conductivity values were assigned to the thiessen polygons. The sediments of vadose zone in the northern part of the study area contains coarse gravel and sand sediments. The main part of the vadose zone in Baghmalek zone contains tiny sediments like silt clay, which play an important role in reducing the potential ground water pollution (**Figure 8**).

Hydraulic Conductivity. This is the final component of the DRASTIC model. It is described in terms of aquifer material, which is able to transmit water for a given hydraulic gradient. Contamination is controlled by the rate at which groundwater flows. Hydraulic conductivity is a measure by which voids, fracturing, and bedding planes are the controlling elements. Higher hydraulic conductivity increases the greater potential for pollution

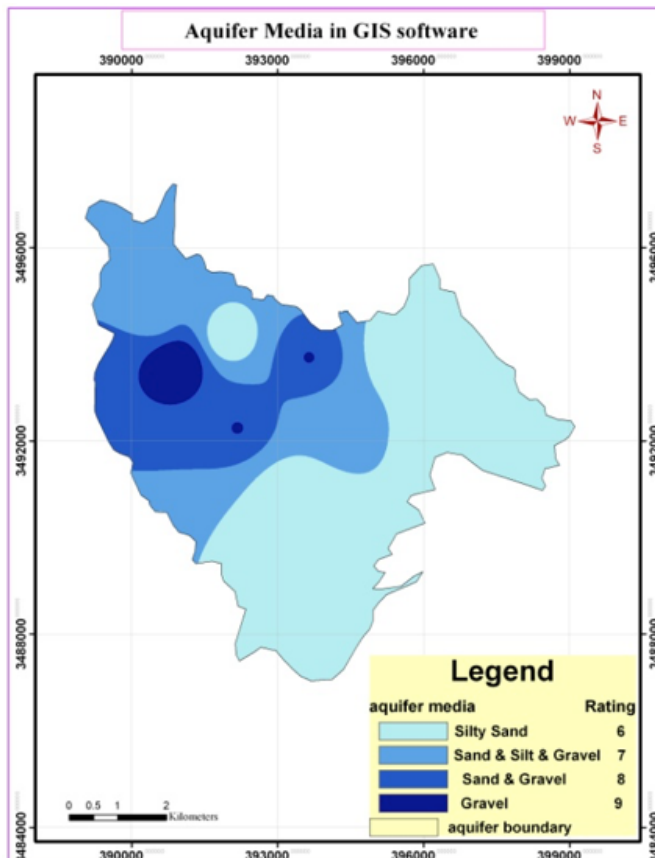


Figure 5. The aquifer media of the area.

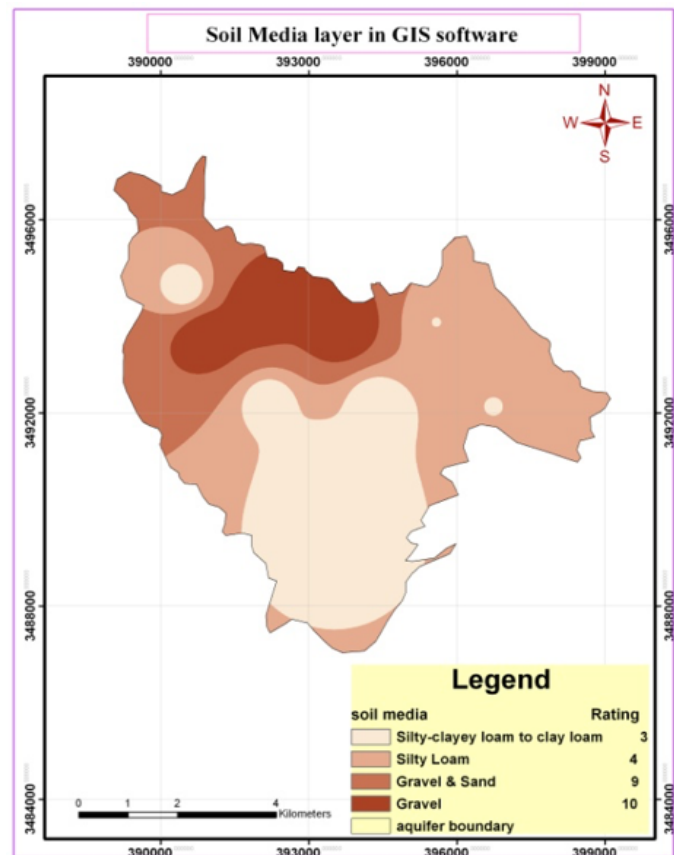


Figure 6. The soil media of the area.

(Aller *et al.* 1987). According to the pumping tests data of wells in the study area and transmissibility values obtained from specific capacity data by using Mace method (Mace 1996), the conductivity values were interpolated. Then, the interpolated layer was reclassified according to the criteria of DRASTIC model. The most parts of the study area (60.1%) have hydraulic conductivity values from 4 to 12 (m day^{-1}) with rating value of 2. The hydraulic conductivity of the remaining parts of the study area is less than four (m day^{-1}) and rating value of one (Figure 9).

The DRASTIC Vulnerability Index

The GIS coverage was all in raster format. Each overlay values were summed in ArcView in GIS according to the pixel value of each area that resulted from multiplying the ratings with its appropriate DRASTIC weight (Table 2) (Chitsazan and Akhtari 2009). Since the minimum possible DRASTIC index for using these parameters is 23 and the maximum is 230, this range is divided into four classes (Aller *et al.* 1987). The resulting DRASTIC values in this application lay between 62 to 129. Thus, the range was classified as:

- Low to moderate groundwater pollution potential (120–139)

- Low groundwater pollution potential (100–119)
- Very Low groundwater pollution potential (80–99)
- No risk groundwater pollution potential (0–79)

The DRASTIC aquifer vulnerability map (Figure 10) classifies 4, 53.5 percent of the study area with very low pollution potential, 34.2 percent with no risk to groundwater pollution, 11.2 percent with low pollution potential, and the rest (1.1 percent) with low to moderate pollution potential (Table 4). The DRASTIC aquifer vulnerability map (Figure 10) clearly shows that only very small parts of the study area (northern) have low and low to moderate vulnerability to pollution and most parts of the study area have very low vulnerability to pollution. The southern parts of the study area are characterized by no risk vulnerability. According to the condition of component layers of DRASTIC model final index, it could be concluded that depth to water table and impact of vadose zone for their high ranks (weight 5) have the most effect on the final map of vulnerability. Aquifer media, net recharge, and soil media have some effects. Topography layers and hydraulic conductivity for their relative uniformity in the study area have no effect on the final map of vulnerability (Table 4).

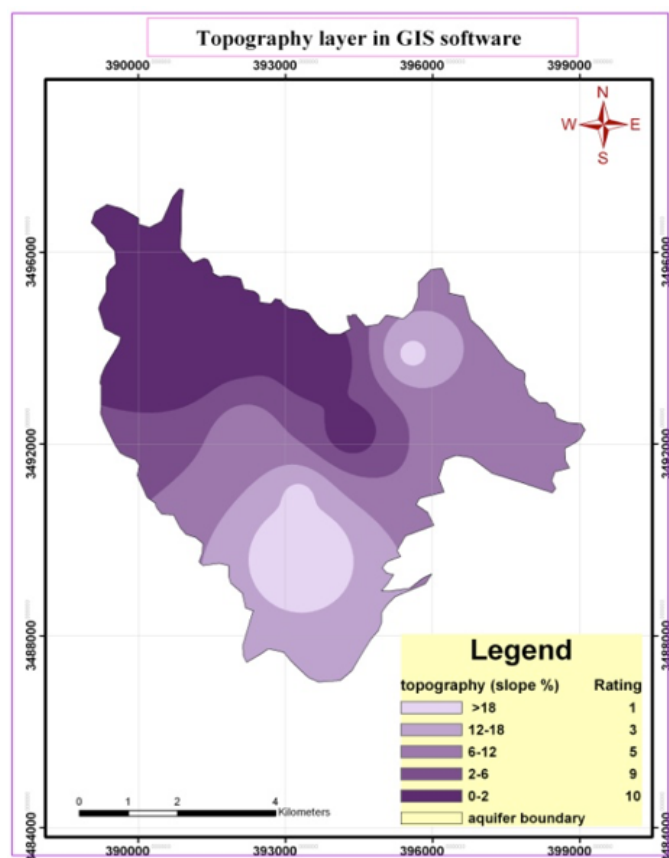


Figure 7. The topography pattern of the area.

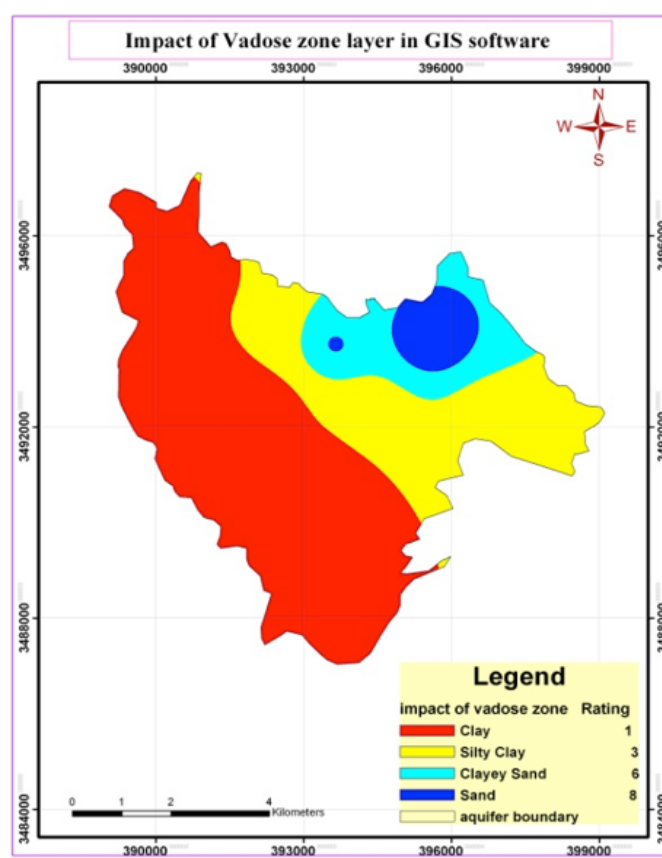


Figure 8. The layer of vadose zone of the area.

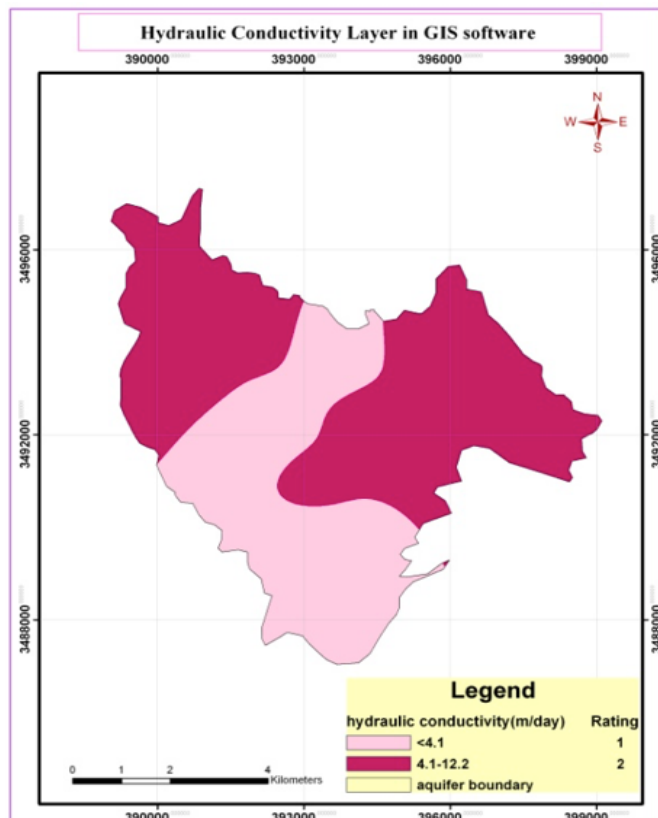


Figure 9. The hydraulic conductivity layer of the area.

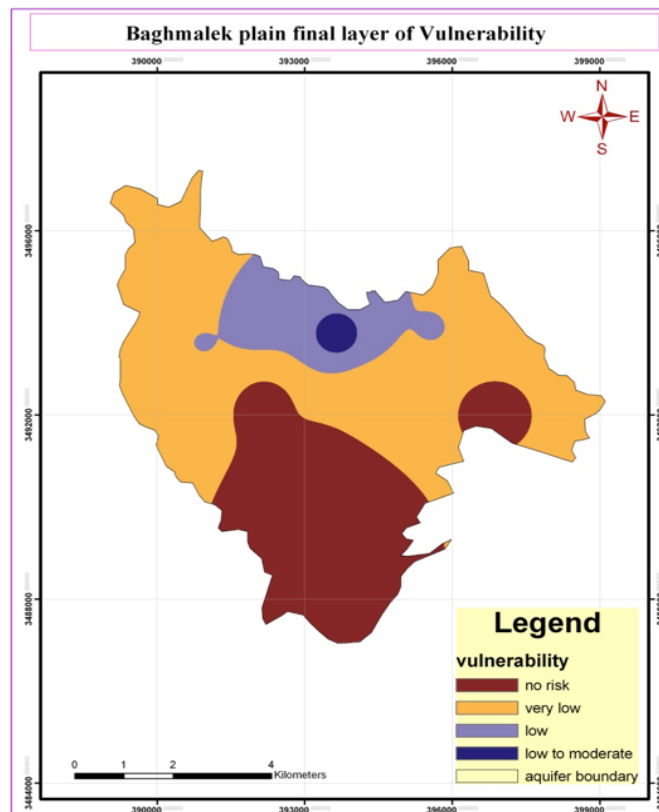


Figure 10. Vulnerability map of Baghmalek plain.

Table 4. The DRASTIC index for the study area.

DRASTIC index	DRASTIC Range	Area (km ²)	Percent of the total area
No risk to pollution	<79	16.9	34.20%
Very low vulnerability	80-99	26.4	53.50%
Low vulnerability	100-119	5.5	11.20%
Low to moderate vulnerability	120-139	0.5	1.10%
total		49.30	100%

CONCLUSION

In this paper, it has been attempted to assess the aquifer vulnerability of Baghmalek groundwater basin employing the empirical index of DRASTIC model of the U.S. Environmental Protection Agency (EPA). Seven environmental parameters were applied to represent the natural hydrogeological setting of Baghmalek aquifer; Depth to water, recharge, aquifer media, soil type, topography, impact of vadose zone, and hydraulic conductivity.

According to the integrated vulnerability map, the areas that have been classified as low vulnerable represent 11.2 percent of the study area (northern areas). Low to Moderately vulnerable zones only comprise 1.1 percent of the study area (northern areas). Very low vulnerable regions comprise 53.5 percent of the area, and the no risk to pollution areas make up the remaining 34.2 percent of

the total area.

Aquifer vulnerability maps are a useful tool for managing and protecting the groundwater resource. The GIS technique has provided an efficient environment for analyzing and high capabilities in handling a large quantity of spatial data. The seven model parameters were constructed, classified, and encoded using various maps and attributing GIS functions. (Babikeri and Mohamed 2005)

The DRASTIC model was applied to assess the groundwater vulnerability of the study area. The model has provided a basic of information, which helps further defining the classification system and its potential role in groundwater management in aquifer basin. In addition, it has significantly improved the knowledge of the characteristics of aquifers. The vulnerability index can assist in the implementation of groundwater management

strategies to prevent the degradation of the groundwater quality. The operational policies for groundwater assessment activities should be developed for the different aquifer classes including the types of investigations, monitoring programs, and other initiatives that support management. The role of the classification system and how it is integrated with other environmental and resource management activities should be further defined. Finally, the classification results should be explored.

REFERENCES

- Al-Adamat, R.A.N., Foster, I.D.L. and Baban, S.M.J. 2003."Groundwater vulnerability and risk mapping for the basaltic aquifer of the Azraq Basin of Jordan using GIS, remote sensing and DRASTIC." *Applied Geography* 23:303–324.
- Aller, L., Bennet, T., Leher, J. H., Petty, R. J. and Hackett, G. 1987. DRASTIC: A standardized system for evaluating ground water pollution potential using hydro geologic settings. EPA 600/2-87-035.622 pp.
- Babiker, I.S. and Mohamed, M.A.A. 2005."A GIS based DRASTIC model for assessing aquifer vulnerability in Kakamigahara Heights, Gifu Prefecture, Central Japan." *Science of the Total Environment* 345:127–140.
- Chitsazan, M. and Akhtari, Y.. 2009. "AGIS based DRASTIC model for assessing aquifer vulnerability in Kherran Plain, Khuzestan Iran." *Water Resource Management* 23: 1137–1155.
- Chitsazan, M., Rahimi, Z. and Mirzaee, Y. 2011." Assessment of Groundwater Pollution Potential through GIS Technique: A Case Study for Pelly-Mianrudan Plain, Lali Urban District, Iran." *Environmental Science and Engineering* 5:1350-1362
- Denny, S.C., Allen, D.M. and Journeay, J.M. 2006." DRASTIC-Fm: a modified vulnerability mapping method for structurally controlled aquifers in the southern Gulf Islands, British Columbia, Canada." *Hydrogeol J* 15:483–493.
- Foster, S., Hirata, R., Gomes, D., Delia, M. and Paris, M. 2002."Groundwater quality protection: a guide for water utilities, municipal authorities, and environment agencies. "The World Bank, Washington, DC. pp. 1–116.
- Lathamani, Ra., Janardhanab, M.R., Mahalingam, B. and Sureshad, S. 2015." Evaluation of Aquifer Vulnerability Using Drastic Model and GIS: A Case Study of Mysore City, Karnataka, India." *Aquatic Procedia* 4:1031 – 1038
- Mace, R.E. 1996." Determination of transmissivity from specific capacity tests in karst aquifers. " *Ground Water* 35(5):733–742.
- Malik Muhammad, A., Zhonghua, T., Salman Dawood, A. and Earl, B. .2015." Evaluation of local groundwater vulnerability based on DRASTIC index method in Lahore, Pakistan." *Geofisica Internacional* 54-1: 67-81
- Piscopo, G. 2001. Groundwater vulnerability map explanatory notes: Lachlan Catchment', NSW - Department of Land and Water Conservation, Parramatta, New South Wales, Australia.
- Prasad, R.k., Singh, V. S., Krishnamacharyulu, S. K. G. and Banerjee, P. 2011." Application of drastic model and GIS: for assessing vulnerability in hard rock granitic aquifer." *Environ Monit Assess* 176:143–155.
- Reihany, G. 2011. Assessment of potential pollution vulnerability of Baghmalek plain aquifer using DRASTIC model in GIS environment. Ms Dissertation, Science and Research Branch, University of Ahvaz Islamic Azad Khuzestan, Iran.(162p)
- Saidi, S., Bouri, S. and Ben Dhia, H. 2010."Groundwater vulnerability and risk mapping of the Hajeb-jelma aquifer (Central Tunisia) using a GIS-based DRASTIC model. " *Environ Earth Sci* 59:1579–1588.
- Saro, L. 2003. "Evaluation of waste disposal site using the DRASTIC system in the Southern Korea." *Environmental Geology* 44: 654–664.
- Verba, J. and Zoporozec, A. 1994. Guidebook on mapping groundwater vulnerability. IAH International Contribution for Hydrogeology, vol. 16. Hannover 7 Heise. 131 pp.

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