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Modification of DRASTIC Model to Map Groundwater Vulnerability to Pollution Using Nitrate Measurements in Agricultural Areas

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ABSTRACT

DRASTIC model has been used to map groundwater vulnerability to pollution in many areas. Since this method is used in different places without any changes, it cannot consider the effects of pollution type and characteristics. Therefore, the method needs to be calibrated and corrected for a specific aquifer and pollution. In the present research, the rates of DRASTIC parameters have been corrected so that the vulnerability potential to pollution can be assessed more accurately. The new rates were computed using the relationships between each parameter and the nitrate concentration in the groundwater. The proposed methodology was applied to Astaneh aquifer located in north of Iran. Samples from groundwater wells were analyzed for nitrate content in thirteen locations. The measured nitrate concentration values were used to correlate the pollution potential in the aquifer to DRASTIC index. Pearson correlation was used to find the relationship between the index and the measured pollution in each point and, therefore, to modify the rates. The results showed that the modified DRASTIC is better than the original method for nonpoint source pollutions in agricultural areas. For the modified model, the correlation coefficient between vulnerability index and nitrate concentration was 68 percent that was substantially higher than 23 percent obtained for the original model

Keywords: Vulnerability, Modified DRASTIC, hydrogeology, Astaneh Aquifer, Nitrate pollution

INTRODUCTION

Groundwater is a valuable resource in most countries, especially in arid and semi-arid regions. Therefore, water quality is becoming increasingly important in groundwater management. Aquifers are usually unconfined, shallow, and highly permeable; therefore, they are extremely susceptible to contamination from surface sources. The potential for groundwater to become contaminated as a result of human activity at or near the surface has been recognized in recent years leading managers of this important resource to pursue a policy of prevention. The tendency or likelihood for contaminants to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer is called groundwater vulnerability (National Research Center, 1993). Today, groundwater vulnerability is one of the key elements in decision making and it is considered in multi-criteria decision making tools in river basins and wastewater management systems (Kholghi, 2001)

Vulnerability assessments must be specific, scientific, and based on accurate evidence. Different methods have been introduced to

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estimate groundwater vulnerability. In most cases, these methods are analytical tools that try to relate groundwater contamination to land use activities. These assessment methods may be divided into three general categories: Process-based simulation models, statistical methods (Harbugh *et al.*, 2000) and overlay and index methods.

Process-based models usually require large quantities of data and supplementary information necessary to run mathematical models that form the principal tool of the method. Clearly, such methods are more complicated and thus difficult to apply on a regional scale.

Statistical methods incorporate data on known areal contaminant distributions and provide characterizations of contamination potential for the specific geographic area by extrapolation from available data in the region of interest (NRC, 1993).

Overlay and index methods are based on combining different maps of the region by assigning a numerical index. Overlay and index methods are easy to apply, especially on a regional scale, and to use in Geographic Information Systems (GIS). They, therefore, constitute the most popular class of methods used in vulnerability assessment. Among the more popular of the overlay and index methods are GOD (Foster, 1987), IRISH (Daly and Drew, 1999), AVI (van Stemproot *et al.,* 1993) and DRASTIC (Aller *et al.,* 1987). DRASTIC has been used in several places including the USA (Plymale and Angle, 2002, Fritch *et al.* 2000, Shukla *et al.*, 2000), China (Yuan *et al.*, 2006), Jordan (Naqa *et al.*, 2006) and Morocco (Ettazarini 2006) and Iran (Mohammadi *et al.*, 2009).

Despite its popularity, the DRASTIC method does have some disadvantages. This method uses seven parameters in its calculation of a 'Vulnerability Index' with each parameter being assigned a specific weight and rating value as shown in Table 1 (Aller *et al.*, 1987). The influence of regional characteristics is not accounted for in the method and so the same weights and rating values are used everywhere. In addition, there is no standard algorithm to test and validate the method for an aquifer. Some researchers have tried to correlate the vulnerability index with chemical or contaminant parameters (Kalinski *et al.*, 1994; Rupert, 1999; Maclay *et al.*, 2001). Some other researchers have correlated land use to vulnerability (Secunda, 1998; Worrall and Koplin, 2004), but, they did not use it to correct the rates or weights of the DRASTIC model. Since nitrate is not normally present in groundwater under natural conditions, it may be selected as a good indicator of contaminant movement from surface to groundwater, especially in agricultural lands.

In the area under study,almost 10 percent of the irrigation water that is about 120 million cubic meters (MCM) infiltrates into the groundwater per year. In addition, part of the municipal wastewater i.e.about 7 MCM, from the cities of Rasht, Astaneh, and Kochesfahan, percolates into the groundwater annually. These factors have resulted in the groundwater in some parts of the aquifer being polluted, making it necessary to have an accurate plan to prevent more damage to the groundwater resources (Anonymous, 2006).

In the present study, rates of DRASTIC parameters were calibrated for the specific region. Using nitrate measurements in the groundwater, statistical analysis was applied to correlate nitrate concentration with vulnerability index and calibrate parameters rates. Astaneh aquifer located in the north of Iran, was selected as a case study to demonstrate the applicability of the proposed method. The selected study area is mostly comprised of agricultural lands and the use of fertilizers and pesticides are common practices.

MATERIALS AND METHODS

DRASTIC method

The Environmental Protection Agency (EPA) of the US has developed this method to classify the pollution potential of aquifers (Aller *et al.* 1987). Vulnerability to contamination is a dimensionless index function of hydrogeological factors,

Table 1. The original DRASTIC weights and rating systems (Aller *et al.* 1987).

Depth to Water (Meter)		Recharge (Milimeter)		Topography (Slope %)		Conductivity (Meter/Day)		Aquifer Media		Vadose Zone Material		Soil Media	
Range	Rating	Range	Rating	Range	Rating	Range	Rating	Range	Rating	Range	Rating	Range	Rating
(0-1.5)	10	(0-50.8)	1	(0-2)	10	(.04-4.1)	1	Massive Shale	2	Confining Layer	1	Thin or Absent	10
(1.5-4.6)	9	(50.8-101.6)	3	(2-6)	9	(4.1-12.3)	2	Metamorphic/Igneous	3	Silt/Clay	3	Gravel	10
(4.6-9.1)	7	(101.6-177.8)	6	(6-12)	5	(12.3-28.7)	4	Weathered Meta-	4	Shale	3	Sand	9
(9.1-15.2)	5	(177.8-254)	8	(12-18)	3	(28.7-41)	6	morphic Igneous		Limestone	3	Peat	8
(15.2-22.8)	3	(>254)	9	(>18)	1	(41-82)	8	Glacial Till	5	Sandstone	6	Shrinking Clay	7
(22.8-30.4)	2					(>82)	10	Bedded Sandstone,	6	Bedded Limestone,	6	Sandy Loam	6
(>30.4)	1							Limestone		Sandstone		Loam	5
								Massive sandstone	6	Sand and Gravel	6	Silty Loam	4
								Masive Limestone	8	W.Silt		Clay Loam	3
								Sand and Gravel	8	Sand and Gravel	8	Muck	2
								Basalt	9	Basalt	9	No shrinking Clay	1
								Karsts Limestone	10	Karsts Limestone	10		
DRASTIC Weight: 5		DRASTIC Weight: 4		DRASTIC Weight: 1		DRASTIC Weight: 3		DRASTIC Weight: 3		DRASTIC Weight: 5		DRASTIC Weight: 2	
Pesticide Weight: 5		Pesticide Weight: 4		Pesticide Weight: 3		Pesticide Weight: 2		Pesticide Weight: 3		Pesticide Weight: 3		Pesticide Weight: 5	

anthropogenic influences and sources of contamination in any given area (Plymale and Angle, 2002). The index consists of seven parameters with different weighting factors and is calculated based on Equation 1.

$$V = \sum_{i=1}^{7} (W_i \times R_i) \qquad (1$$

where V is the index value, W_i is the weighting coefficient for parameter i with an associated rating value of R_i. The seven physical parameters included in the DRASTIC method are:

D – Depth to water table from soil surface
R – Net recharge
A – Aquifer media
S – Soil media
T – Topography
I – Impact of the vadose zone media
C – Conductivity (hydraulic) of the aquifer

The DRASTIC parameters are weighted from 1 to 5 according to their relative importance in contributing to the contamination potential (Aller *et al.* 1987). The resulting index is a relative measure of vulnerability to contamination; areas with a higher index value are more vulnerable than those with a lower index. The weights and rates of the original DRASTIC model parameters are presented by Aller *et al.* (1987).

Study area

The Astaneh aquifer with an area of 1100 square kilometers is situated in northern Iran in the vicinity of the Caspian Sea. It is an alluvial aquifer filled by deposits from the Sefidrud River. The location of the aquifer is between 49° 32′ to 50° 05′ east longitude and 37° 07′ to 37° 25′ north latitude (Figure 1). The highest ground elevation in the area is 2705 m with the lowest point being 25 m below sea level.

Nitrate measurements

In order to calibrate the DRASTIC model, nitrate concentration was selected as the primary contamination parameter. Thirteen agricultural wells were selected for sampling and analysis. Two sets of samples in May and August of 2006 were taken. Figure 1 shows the location of the sampled wells. The exact position of each well was determined using GPS techniques.

Calibration method

For the purposes of this research, nitrate was selected as the primary (contaminant) control parameter used to modify the DRASTIC rates. Nitrate is not generally present in groundwater under natural conditions, it usually infiltrates from the surface layer. It can, therefore, be used as an indicator to show whether the vulnerability index correctly represents the actual situation in the study area. To use nitrate for optimizing the weights, Panagopoulos *et al.,* (2005) indicate that the following conditions should be satisfied:

The source of nitrate should be due to agricultural activities at the surface

The area distribution should be relatively uniform

Leaching of nitrate should be due to recharges from the surface over a long period of time to ensure the correlation between contamination and human activities

The combination of a relatively shallow depth of groundwater i.e.high water table elevation in the study area with agriculture being the main activity satisfies the necessary conditions to use nitrate as a calibration parameter.

Nitrate concentrations measured in May 2006 were used to calibrate the index and measurements in August 2006 were used to calculate the correlation factor. The nitrate concentrations were divided into 5 classes and the mean of every class was used to calculate the modified rate of each DRASTIC parameter based on the Wilcoxon rank-sum nonparametric statistical test (SAS, 2003).

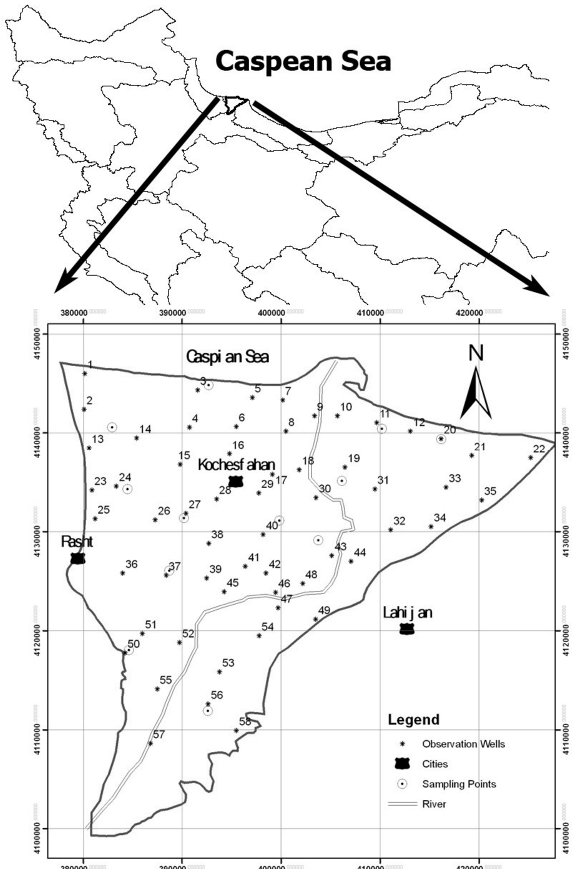

Figure 1. Study area and sampling locations.

RESULTS AND DISCUSSION

DRASTIC attribute layers

The attribute layers for the seven DRASTIC parameters were assembled within a GIS format, the commercially available ArcGIS 9.2 Software being used to execute the necessary computations in raster format.

The depths to water table were measured at 58 observation wells in May 2006 (Figure 1). Using the measurements at these points, the two-dimensional variation in water table elevation was constructed. Maximum water table levels occurred during the month of May, this month was therefore selected in order to consider the worst possible case scenario. The Geostatistical Analyst extension with Kriging interpolation algorithm in ArcGIS was used to interpolate the points and create the raster map with a pixel size of 100 m. Kriging has shown great success for interpolation in groundwater studies (Kumar, 2007; Gundogdu and Guney, 2007; Theodossiou, 1999). Figure 2 shows depth to water table in Astaneh aquifer. Using the created maps and based on the rating system recommended in the original DRASTIC model, the depths were divided into different classes.

Net recharge in the study area is the result of rainfall infiltration, river flow, irrigation return flow and absorption wells. Based on a water balance computation, the total net recharge for the study area was 341 MCM per year. Table 2 shows the water balance in the study area calculated by Guilan Water

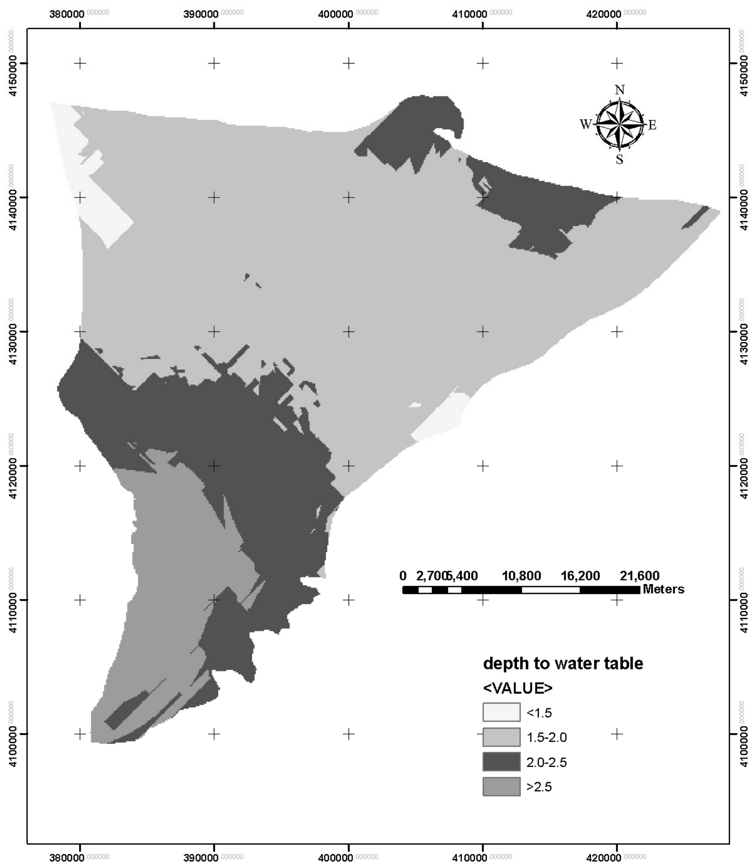

Figure 2. Depth to water table in Astaneh aquifer.

Authorities (Anonymous, 2006). Distribution of hydraulic conductivity in the study area was used to calculate the spatial distribution of the net recharge. Hydraulic conductivity distribution map was developed using the pumping test results and geo-electrical study in the region. Areas with a higher hydraulic conductivity have the higher potential for infiltration.

Three other layers, namely, the soil-, the vadose zone -, and the aquifer-media were classified based on the drilling logs for each well and Table 1. Using the topographic map of the study area prepared by the National Cartographic Center, a digital elevation model (DEM) with a pixel size of 100 m was created. The slope maps were obtained from the DEM model. The slopes varied between 0 near the coastline to 38 percent in close proximity to the mountains in the south.

Table 2. Groundwater Balance of Astaneh aquifer in 2006.

Inflow	Value (MCM/year[a])	Outflow	Value (MCM/year [a])
Underground inflow	74	Underground outflow	13
Recharge from rainfall	110	Discharge from wells	55
Recharge from river	104	Drainage from groundwater	330
Return flow from agriculture well	120	Evaporation from groundwater	17
Return flow from domestic wastewater	7		
Total	415		415

[a] Million cubic meters per year

Transmissivity was measured in the pumping wells and, based on these measurements, hydraulic conductivity was calculated. A geostatistical algorithm was used to interpolate the hydraulic conductivity and create the raster layer.

After creating all the necessary layers, each pixel was classified and rated, then, multiplied by its weighting factor and the DRASTIC index calculated. The resulted index was divided into 5 equal groups (Aller *et al.*, 1987). Small numbers indicate low vulnerability potential and large numbers are related to those areas that have high pollution potential (Figure 3).

Index calibration and evaluation

Using 13 sampled points in August 2006 and placing them on a DRASTIC map (Figure 4), the corresponding values for each point were extracted. The correlation between the DRASTIC values and nitrate concentrations were calculated based on Pearson's correlation factor (Table 3). The correlation factor was 23% that is relatively low. This means that the intrinsic vulnerability index needs to be modified in order to show a realistic assessment of the pollution potential in the area.

In this method, the highest mean of nitrate concentration was correlated with the highest rate and other weighting rates were modified linearly based on this relation. In this method, the rates of five attribute layers of DRASTIC model including depth to water table, net recharge, hydraulic conductivity, vadose zone, and soil media

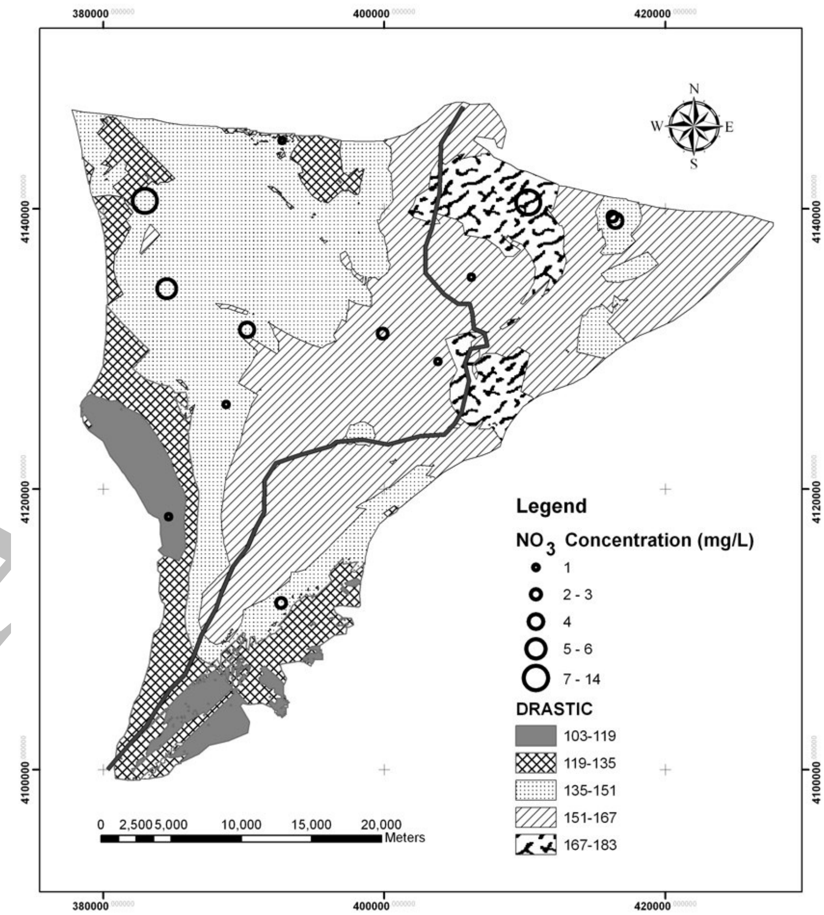

Figure 3. Original vulnerability map and nitrates concentrations for study area.

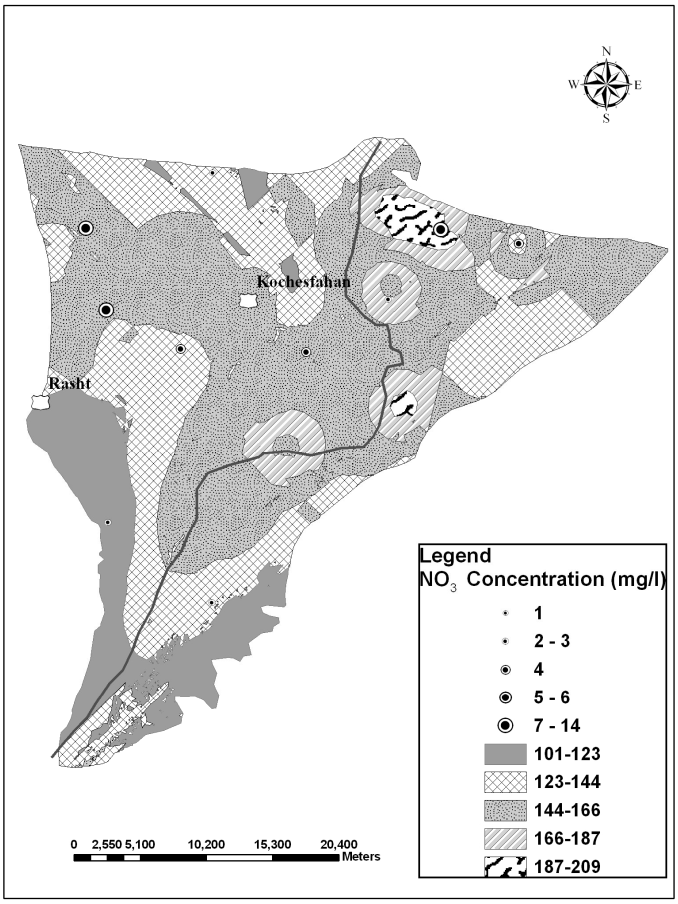

Figure 4. Modified (factor rating) vulnerability map and nitrates concentrations.

were changed according to the mean nitrate concentration. The higher was the mean concentration, the higher was the rate. The lowest mean concentration was selected for the lowest rate and the rest were modified linearly. Table 4 shows the results of this modification for each parameter.

The new DRASTIC map was calculated using the new rating system (Figure 5). Again, the Pearson's correlation factor was calculated (Table 5) and an increase in the factor up to 64 percent was noted. The correlation factor was now statistically significant at 95% confidence level.

Using the new rates, a new DRASTIC map was developed that shows that 9 percent of the area fall in high vulnerability class. This percentage was 48 before the modification. The calculated area was 46% and 33 % for moderate class and, for low vulnerability class, 19% and 45%, respectively, before and after application of the new rates. These results show a clear effect of the modification. In addition, in

Table 3. Correlation factors between nitrate concentration and the original vulnerability index.

Pearson's Correlation Coefficient	Number of Data	Factor
100 %	13	Nitrate Concentration
23 %		DRASTIC Index

Table 4. The Original and modified weighting rates based on nitrate concentrations.

Factor	Range	Original Rating	Mean NO_3 concentration (mgl^{-1})	Modified Rating
Depth to groundwater (m)	0 - 1.5	10	4.61	10
	1.5 – 4.6	9	1.51	2.3
Hydraulic conductivity (m/day)	0.4 – 4.1	1	1.66	1.67
	4.1 – 12.3	2	3.50	3.3
	12.3 – 28.7	4	4.16	6.7
	28.7 - 41	6	No Data	10
Recharge (mm)	0 – 50.8	1	1.12	2.54
	50.8 – 101.6	3	No Data	3
	101.6 – 177.8	6	2.98	6.8
	177.8 - 254	8	3.47	7.9
	> 254	9	4.40	10
Soil type	Clay Loam	3	No Data	3
	Silty Loam	4	4.45	4.2
	Loam	5	1.18	1.1
	Sandy Loam	6	No Data	6
	Shrinking Clay	7	2.61	2.5
	Peat	8	10.49	10
Impact of vadose zone	Silt/Clay	3	3.41	3.3
	Silty Sand Clay	4	5.55	5.3
	Sandstone	5	1.82	1.7
	Sand and Gravel w. Silt	6	3.26	3.1
	Coarse Sand	8	10.49	10

order to show the spatial distribution of the index before and after the modification, the two maps were compared. The result showed that 29 percent had similar class, but, 71 percent showed a difference of one class or more, indicating, again, the effectiveness of the proposed method.

CONCLUSION

The purpose of this research was to assess the vulnerability potential of the Astaneh aquifer using the original and modified DRASTIC index. Although the DRASTIC method usually gives satisfactory results in evaluation of groundwater intrinsic vulnerability to pollution, it cannot be used for accurate assessment of the groundwater pollution risk. Therefore, it is necessary to calibrate and modify the original algorithm in order to obtain more accurate results.

Results of this study showed that nitrate concentration could be used as a modifying parameter with considerable improvement in the resulting index that could lead to more realistic management of groundwater quality. The proposed method is suggested for agricultureal areas with extensive use of nitrates, where accumulation of nitrates in the groundwater is mainly due to its leaching from the soil surface layers.

REFERENCES

1. Aller, L.,Bennet, T.,, Lehr, J. H., Petty, R. J., Hackett, G. 1987. DRASTIC: A Standardized System for Evaluating

Table 5. Correlation factors between nitrate concentration and modified vulnerability index.

Pearson's Correlation Coefficient	Number of Data	Factor
100 %	13	Nitrate Index
68 %		DRASTIC Index

Groundwater Pollution Potential using Hydrogeological Settings. EPA/600/2–87/035. US Environmental Protection Agency, Ada, OK, USA.

2. Anonymous 2006. *Report on Hydro-climatological water balance in Astaneh aquifer*, Guilan Provincial Water Authority, Rasht, Iran.
3. Daly, D., Drew, D. 1999. Irish Methodologies for Karst Aquifer Protection. In: "*Hydrogeology and engineering geology of sinkholes and karst*" (ed): Beek B. Balkema, Rotterdam, 267-272.
4. Ettazarini, S. 2006. Groundwater Pollution Risk Mapping for the Eocene Aquifer of the Oum Er-Rabia Basin, Morocco. *Environ. Geol.*, **51(3)**: 341-347.
5. Foster, S.S. 1987. Fundamental Concepts in Aquifer Vulnerability, Pollution Risk and Protection Strategy. In: "*TNO Committee on Hydrological Research*", (Eds): Duijvenbooden W van, Waegeningh HG van The Hague Vulnerability of soil and groundwater to pollutants, Proceedings and Information, **38**: 69-86.
6. Fritch, T. G.; McKnight, C. L., Yelderman, J. C., Arnold, J. G. 2000. An Aquifer Vulnerability Assessment of the Paluxy Aquifer, Central Texas, USA, using GIS and a modified DRASTIC approach. *J. Environ. Manage.*, **25**: 337–345.
7. Gundogdu, K. S. and Guney, I. 2007. Spatial Analyses of Groundwater Level using Universal Kriging. *J. Earth Sys. Sci.*, **116**: 49-55.
8. Harbaugh, A. W., Banta, E. R., Hill, M. C., Mcdonald, M. G. 2000. MODFLOW-2000, The U. S. Geological Survey Modular Ground-water Model- Users Guide to Modularization Concepts and the Ground-Water Flow Process. U. S. Geological Survey Open-File Report 00-92, 121.
9. Kalinski, R. J., Kelly, W. E., Bogardi, I., Ehrman, R. L., Yamamoto, P. O. 1994. Correlation between DRASTIC Vulnerabilities and Incidents of VOC Contamination of Municipal Wells in Nebraska. Ground Water, **32(1)**: 31–34.
10. Kholghi, M. 2001. Multi-criterion Decision-Making Tools for Wastewater Planning Management, *J. Agr. Sci. Tech.*, **3**: 281-286.
11. Kumar, V. 2007. Optimal Contour Mapping of Groundwater Levels using Universal Kriging- a Case Study. *Hydrol. Sci. J.*, **52**: 1038-1050.
12. McLay, C. D. A., Dragden, R., Sparling, G., Selvarajah, N. 2001. Predicting Groundwater Nitrate Concentrations in a Region of Mixed Agricultural Land use: A Comparison of Three Approaches. *Environ. Pollut.*, **115**: 191–204.
13. Mohammadi, K., Niknam, R. Majd, V. J. 2009. Aquifer Vulnerability Assessment Using GIS and Fuzzy System: A Case Study in Tehran-Karaj Aquifer, Iran, *J. Environ. Geo.*, **58**: 437-446.
14. Naqa, A., Hammouri, N., Kuisi, M. 2006. GIS-based Evaluation of Groundwater Vulnerability in the Russeifa Area, Jordan. *Revista Mexicana de Ciencias Geológicas*, **23(3)**: 277-287.
15. National Research Council 1993. Groundwater Vulnerability Assessment: Predicting Relative Contamination Potential under Conditions of Uncertainty. Committee for Assessing Ground Water Vulnerability, National Academy Press, Washington, D. C. 210p.
16. Panagopoulos, G. P., Antonakos, A. K., and Lambrakis, N. J. 2006. Optimization of the DRASTIC Method for Groundwater Vulnerability Assessment Via the use of Simple Statistical Methods and GIS. *Hydrol. J.*, 14: 894-911.
17. Plymale, C. L., Angle, M. P. 2002. Groundwater pollution potential of Fulton County, Ohio. Ohio Department of Natural Resources Division of Water, Water Resources Section. Groundwater Pollution Potential, Report No 45.
18. Rupert, M. G. 1999. Improvements to the DRASTIC Groundwater Vulnerability Mapping Method. U. S. Geological Survey Fact Sheet FS-066-99, USGS, Reston, VA., USA.
19. SAS 2003. SAS OnlineDoc, Version 8, SAS Institute, Inc., Cary, NC, USA.
20. Shukla, S., Mostaghimi, S., Shanholt,V. O., Collins, M. C., Ross, B. B. 2000. A County-Level Assessment of Ground Water Contamination by Pesticides. *Ground Water Monit. Rev.*, **20(1)**: 104– 119.
21. Secunda, S., Collin, M. L., Melloul, A. J. 1998. Groundwater Vulnerability Assessment Using a Composite Model Combining DRASTIC with Extensive Agricultural Land Use in Israel's Sharon Region. *J. Environ. Manage.*, **54**: 39–57.
22. Theodossiou, N. 1999. Evaluation of the Distribution of Hydraulic Head in an

Aquifer using the Kriging Method, *Scientific Journal of the Hellenic Hydrotechnical Association – Hydrotechnika*. **9**: 3–14.

23. van Stemproot, D., Evert, L., Wassenaar, L. 1993. Aquifer Vulnerability Index: A GIS Compatible Method for Groundwater Vulnerability Mapping. *Can. Water Res. J.*, **18**: 25-37.
24. Worrall, F., Koplin, D. 2004. Aquifer Vulnerability to Pesticide Pollution Combining Soil, Land-use and Aquifer Properties with Molecular Descriptors. *J. Hydrol.*, **293**: 191-204.
25. Yuan, M., Zhang, X., Wang, L. 2006 Fuzzy Pattern Recognition Method for Assessing Groundwater Vulnerability to Pollution in the Zhangji Area. *J. Zhejiang Univ. Sci. A*, **7(11)**: 1917-1922.

اصلاح روش DRASTIC برای تعیین مناطق آسیب پذیر آب زیرزمینی نسبت به آلودگی با استفاده از اندازه گیری‌های نیترات در مناطق کشاورزی

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چکیده

مدل DRASTIC برای طبقه بندی آسیب پذیری آب زیرزمینی در بسیاری از مناطق استفاده شده است. از آنجا که این روش در مناطق مختلف بدون هیچ تغییری استفاده می‌شود، امکان در نظر گرفتن تأثیر نوع آلودگی و مشخصات آن وجود ندارد. بنابراین، این روش نیاز به واسنجی و اصلاح در یک آبخوان به خصوص و برای یک آلودگی مشخص دارد. در این تحقیق، با استفاده از اصلاح رتبه‌های پارامترهای روش DRASTIC، می‌توان به یک نقشه آسیب‌پذیری دقیق‌تر دست یافت. رتبه‌های جدید با استفاده از رابطه بین هر پارامتر و غلظت نیترات در آب زیرزمینی اصلاح شد. روش معرفی شده، در آبخوان آستانه واقع در شمال کشور به کار رفت. با نمونه‌برداری و آنالیز ۱۳ حلقه چاه کشاورزی، غلظت نیترات در آب زیرزمینی به دست آمد. مقادیر غلظت به دست آمده با مقادیر پتانسیل آلوده شدن آبخوان که از روش DRASTIC به دست آمده بود، همبستگی داده شد و برای اینکار از روش همبستگی پیرسون استفاده گردید. نتایج نشان داد که DRASTIC اصلاح شده بهتر از روش استاندارد می‌تواند در مناطق کشاورزی با آلودگی غیرنقطه‌ای به کار رود. ضریب همبستگی به‌دست آمده در حالت اصلاح شده برابر ۶۸ درصد بود که نسبت به مقدار این ضریب در حالت استاندارد که ۲۳ درصد بود، بهبود چشمگیری را نشان داد.