

Optimization of DRASTIC and SINTACS Models According to Geographical Information System with the Use of Analytical Hierarchy Process (AHP) (Case Study: Andimeshk Plain)

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Introduction

Because of expansion of agricultural activities, of excessive use of chemical fertilizers, and of location of the municipal and industrial wastewater of Andimeshk, it is possible for this aquifer to be polluted. Therefore, the aim of the present study is to assess the aquifer vulnerability of Andimeshk plain and to recognize the sensitive areas against pollution. This work can be conducted using the DRASTIC and SINTACS models. Although, these models are among the most used models for the assessment of aquifer vulnerability, these models should be corrected on the basis of local hydrological conditions to obtain correct results. Therefore, the main aim of this study is correction of the DRASTIC and SINTACS models according to the local hydrological conditions and finally determining the best aquifer vulnerable model for the plain.

Materials and methods

Study area

The Andimeshk plain is located in the north west of Khuzestan province with an area of 295 km² and its geographical coordinates is in north latitude, 32° 15' to 32° 35' and east longitude 48° 29' to 48° XX'.

DRASTIC and SINTACS models

Generally, parameters used in these models consist of depth to water table, net recharge (effective infiltration), aquifer media (aquifer hydrogeologic characteristics), soil media, topography (slope), impact of vadose zone (unsaturated condition), and hydraulic conductivity.

Analytical Hierarchy Process (AHP)

The AHP method is based upon the construction of some series of Pair-Wise comparison matrices (PCMs) which compare all the criteria to one other. Saaty (1980) suggests a scale of 1-9 for the PCM elements, wherein the value of 1 suggests that the criteria are equally important and the value of 9 shows that the priority of this one is extremely more than the other one in this comparison.

Data acquisition

Based on the collected data and required information, a database in the GIS environment was prepared for calculation of final vulnerability index in the methods. So the ArcGIS9.3 software has been used. The main aim of the criteria maps preparation is its modulation using overlaying technique and finally after that the preparation of aquifer vulnerability maps by the models. Finally to identify the accuracy of specific weights for parameters, the models have been analyzed according to their sensitivity to the real conditions. In the present research, the entered parameters according to the DRASTIC and SINTACS model theories the corrected weights by the AHP method for the preparation of maps indices were used as well. To determine the optimized weight of each parameter, the correlation coefficient calculated vulnerability indices by the methods and nitrate concentration have been calculated using Simple Linear Regression Analysis (SLRA). Finally according to a high correlation

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coefficient of each index with the nitrate concentration, the optimized model has been determined for the assessment of aquifer vulnerability. It is necessary to mention that for reduction of decision making errors and correct choice of the weight, many expert views were used. Therefore, many models were executed for the calculation of the aquifer vulnerability index.

Sensitivity analysis

In the present research single parameter analysis method has been used to analyze the sensitivity of used models.

Specific vulnerability to nitrate pollution

The Composite DRASTIC index (CD index) is an adaptation of the DRASTIC index based on the addition of a new parameter defining the potential risk associated with land use (L). The risk potential map related to land use using the same methodology applied for other parameters of DRASTIC index will be prepared. It is necessary to mention that calculation of specific vulnerability of SINTACS method was performed according to the same methodology used in the Composite DRASTIC index calculation (Composite SINTACS index or CS index). To prepare specific aquifer vulnerability map of the plain using the DRASTICS and SINTACS models at the first step because of the importance of parameters of this area in the transfer of pollution into the aquifer. These parameters with the weight of 5 will be added to both parameters in a normal way. For correction of the weight given to this parameter in the real condition using Simple Linear Regression Analysis (SLRA), the correlation of specific vulnerability indices has been determined using both aquifer models and the Nitrate concentration. In this type of vulnerability also the method of weighting based on the AHP method has been used for determination of optimized weight according to the real condition of the area.

Results and discussion

The results obtained from overlaying of criteria maps of the DRASTIC and SINTACS models show that the final intrinsic vulnerability index for the DRASTIC model is between 73 and 157 and for the SINTACS model is between 90 and 171. To check the accuracy of specific weight of both model parameters, the single parameter sensitivity analysis has been done based on local condition. The statistical results obtained from the single parameter sensitivity analysis of the models show that the most effective parameter in the calculation of intrinsic vulnerability of the studied aquifer is the unsaturated area parameter (with the average effective weight of 28.59 and 29.32 percent respectively) and topography (with average effective weight of 8.83 and 7.04 percent respectively) have the minimum effect in the calculation of this index. Comparison of the effective and theoretical weights for the DRASTIC and SINTACS parameters models are not fully matched with each other. Considering this inconsistency, the parameter weights for both models have been corrected by the AHP method according to hydrological conditions. The results obtained from this method show that among the models executed for the DRASTIC model, the best correlation coefficient is 0.752, and it has been chosen as the optimized model; because it has better correlation coefficient compared to the normal DRASTIC (0.741). The SINTACS model has been determined as the optimal one after determining the correlation coefficient in different corrected SINTACS models and finding that the greatest correlation coefficient was 0.659 due to having a greater correlation coefficient against the normal SINTACS model (0.636). Finally between two determined optimized model, the corrected DRASTIC model has been determined which is because of having more correlation with the Nitrate concentration as the optimized model for the assessment of final aquifer intrinsic vulnerability of Andimeshk plain. The results obtained from Simple Linear Regression Analysis (SLRA) between CD and CS indices with aquifer Nitrate concentration show that the correlation coefficients for both of the indices are 0.651 and 0.529, respectively. After execution of different models by the AHP weighting method and determination of their correlation coefficients with the Nitrate concentration, the best model of specific aquifer vulnerability model for the plain have been determined according to the most correlation coefficient for both of the methods. Specific vulnerability map obtained from the corrected CD index has been used for the evaluation of the possibility for the studied aquifer, because of its greater correlation coefficient (0.749 and 0.657 respectively for CD and CS indices). Generally, the optimized weight of the composite DRASTIC and DRASTIC model according to hydrological condition of the Andimeshk plain has been presented in Table 1.

Table 1. The optimized weights of the DRASTIC and Composite DRASTIC model parameters

Parameter	Primary weight	Optimized weight	
		DRASTIC	Composite DRASTIC
Depth to watertable	5	3.86	3.93
Net recharge	4	2.03	2.28
Aquifer media	3	1.22	1.35
Soil media	2	2.55	2.84
Topography	1	1	1
Impact of vadose zone	5	5	5
Hydraulic conductivity	3	1.59	1.72
Land use	5	—	1.1
Inconsistency Rate	—	0.035	0.052

Conclusions

Increasing the correlation coefficient of the optimized DRASTIC, SINTACS indices, and the corrected CD and CS indices by the AHP method with the nitrate concentration of the studied aquifer show that optimization of the vulnerability models according to the hydrological condition of the area is more compatible with the aquifer real conditions. The vulnerability index of the corrected DRASTIC model is between 51.81 and 122.69. According to the obtained results from the corrected CD index, the specific vulnerability index for the studied aquifer is between 65.83 and 135.85. Although the nitrate pollution's risk for the Andimeshk plain is not evaluated as a high value, a crucial environmental management should be conducted in this area due to this area's condition, urbanization growth, agricultural development, and increasing disposal of municipal, industrial, and agricultural wastewater. This is also possible by cooperation of society members, experts, and authorities and by correcting of land use planning.

Keywords: analytical hierarchy process (AHP), Andimeshk plain, DRASTIC, SINTACS, vulnerability.