Acceptability for injury assessment of groundwater resources in plain of Ardakan-Yazd using Drastic Model And GIS

[1.] **S.A.Mirhosseini**, [2.] H. Zarei Mahmoodabady, [3.] Mohsen Bemani

[1.] Department of Environment, MaybodBranch, Islamic Azad University, Maybod, Iran (Corresponding author)
Tel: 00989132552059 E-mail: mirhosseinid@yahoo.com
[2.] Department of Environment, Maybod Branch, Islamic Azad University, Maybod, Iran
[3.] M.Scgraduated of Groundwater Hydrology, University of Sistan and Baluchestan, Zahedan, Iran

Abstract: Yazd-Ardakan plain was placed at Yazd province center and regarding its structure is a part of Iran central plateau, according to the weather conditions, there is not any kind of permanent river in the region and also other regions of province are dependent to the underground waters and due to the development of industries and importance of aforementioned water resource in the supply of required water of industries agriculture and drinking water in this study using the drastic model, aquifer acceptability for injury of Yazd–Ardakan was compared to the pollution. Since the removal of pollution from underground aquifers is a very expensive affaire and somewhat is impossible, preventing from their pollution is a most important work in order to protect the water resources. Main goal of doing this work is to evaluate the Yazd-Ardakan aquifer acceptability for injury in presence of pollution. In this research after classification and weighting for each one of the effective parameters, the drastic index is calculated per region and according to it the various degrees of vulnerability is identified and acceptability for injury plan is drawn based on the drastic method. Then we used of GIS technique to prepare the vulnerability plan. according to the results, 10 % of all region area in our study was in a negligible range, 75 % in a low range and 15 % in a medium range.According to the *medium* acceptability for injury of aquifer and lack of wastewater treatment system in the region, strategies such as prevention from *contaminant* units establishment and designing of waste water treatment in the regions with lower acceptability for injury is offered.

[S.A. Mirhosseini, H. Zarei Mahmoodabady, Mohsen Bemani. **Acceptability for injury assessment of groundwater resources in plain of Ardakan-Yazd using Drastic Model And GIS.** *Life Sci J* 2013;10(2):1186-1194] (ISSN:1097-8135). http://www.lifesciencesite.com. 163

Keywords: Acceptability for injury, aquifer, Yazd-Ardakan, Drastic model, GIS

Introduction:

Underground water resources are one of the main water resources of any country. Unfortunately, negligibility to it causes to distribute and transfer of various polluting materials to this regions. human activities creates a vulnerable environment such that the underground water was placed as a natural resource in front of the industrial and agricultural pollutants. (Thapinta, and Hudak, 2003) underground waters in the dry regions where the access to the surface waters were restricted have the main importance. (Todd. 1980) By increasing the urbanization and industry development and increase of agricultural activities, underground waters quality were reduced severely and converted to one of the main ecological problems. (Aller.L et a1985) one of the preventive strategies from the water pollution in the future is the identification of vulnerable areas of underground waters systems and management of land use (B-Thirumalaivasan-2003). The concept of Acceptability for injury of underground waters was offered for the first time in end of decade 60 about the water pollution and defined the Acceptability for injury as a protective degrade that the nature provides for the protection of pollution entrance to the underground waters (Vrba & Zaporozec, 1994). Acceptability for injury is a kind of relative feature, without dimension, and un-measurable and depend upon the aquifer's features, geological and hydrological environment. (Antonakos, and Lambrakis 2007). Aquifer Acceptability for injury, indicates its power for penetrations and spread of pollutants from the surface to the underground waters systems. such that the created pollution can reach to the underground water and spread among it. (Worrall, and Besien,. 2004; Babiker, et al., 2005). Now, use of the Acceptability for injury maps for ecological management of underground waters was converted as the main useful tools in the worlds (Connell & Van den Daele 2003). the concept of underground waters was based on this hypothesis that " the physical environment may imply the underground waters facing with some unsuitable natural effects especially cases that the pollution enter the underground surface".

Evaluation of Acceptability for injury of underground waters were done based on the various methods (Vrba, and Zoporozec, 1994), the aquifer's Acceptability for injury was estimated based on the pollution transfer from earth surface to the hydrated layer in all methods. One of the common methods to evaluate the aquifer's Acceptability for injury is the drastic model. this method was used in the various regions of world such as South Korea (Kim, and Hamm, 1999), UAE ((Zabet, 2002), India (Rahman, 2007), Algeria (Samey and Gang 2008), Iran (Mirzaei ;2009) and America (Plymale & Angle, 2002), China (Kabera & Zhaohui 2008), and Egypt (EI-Naqa et al,2006).

In the recent years, estimation of Acceptability for injury of underground waters is one of the main important methods for planning and decision making regarding the underground water protection. Taherefore, zonation of underground water systems Acceptability for injury is considered important for prevention of future pollutions. Also, GIS and RS are used successfully in the preparation of Acceptability for injury map.

In this research, investigation of underground waters Acceptability for injury of Yazd –Ardakan plain was based on drastic model and was used of GIS environment to prepare the map. according to the importance and shortage of water resources in our studied region and long term effects of dry climatic conditions of Iran including the studied region which is of the desert regions and also lack of safe and reliable surface water resources causes the dependence to the aquifers in order to supply the required water of agricultural, industrial and drinking sections, to be increased, then most f aquifers are faced with crisis in out under study zone.

On the other hand, quality of existed water in the cities of Yazd Ardakan plain due to the lack of collecting network, urban waste water treatment system, development of industries and waste water producer centers have been reduced. (Zareyi, 2011). with the development of industry and population growth, waste water production in region of our study was faced with an enormous increase that in mostly are discharged to the environment and by penetration to the underground waters along with the pollutions produced by the agricultural section causes the underground waters to be more polluted.

The aim of this study is to provide the map of Acceptability for injury and determination of regions with high power of undergrounds waters pollution in the our under studied regions, therefore the identification of hydrologic and hydro-geologic structure of an aquifer and zonation of aquifers' sensitivity compared to the pollution can help to the managers of water resources with providing the suitable appropriate strategies for controlling the pollutions caused by the human activities in the vulnerable regions. Regarding to this issue, according to the importance of Yazd-Ardakan aquifer as one of the main aquifers in water supply in the study region, we began to determine the various levels of Acceptability for injury of this aquifer compared to the presence of pollution.

2- Methods and Materials

In this research, initially the information and required data including the whole geological, hydrological and hydro geological data and topographic maps were collected and derived via the organizational referrals and basic maps were prepared from the research scope.

The existing layers in this the drastic model that include a set of line, point and polygon, including the layers of water surface (D), aquifer net recharge (R), Aquifer environment (A), Soil type (S), Topography (T), effect of unsaturated zone (I), hydraulic conductivity (C), and all information related to them must be digitized in GIS environment. Therefore, in line with the preparation of intrinsic Acceptability for injury of Yazd-Ardakan plain using the drastic model, the whole data of zone were digitized in the GIS environment and a rank and appropriate weight were assigned per layer and layers were gathered together and drastic index was calculated per point.

2.1 Drastic model introduction

The drastic model is an empirical and standardized model to evaluate the Acceptability for injury of underground water using the hydrogeological factors that play an important role in the transfer of water pollution. the final purpose is to estimate the Acceptability for injury using the 7 hydrogeological parameters and mapping of vulnerable areas. In a drastic model to determine each parameter and also applying the effect of each environment in the existing zone, we used of 3 factors including weight, range and rating. to determine the Acceptability for injury index by the drastic model was used of PCSM and weighting and valuation method. the drastic model determination is obtained from the equation (1) per zone.

$$I_d = D_r D_w + R_r R_w + A_r A_w + S_r S_w + T_r T_w + I_r I_w + C_r C_w \quad [1]$$

In the equation.1, r and w are related respectively to the parameters of rank and weight. In the combination of these layers, weight and values related to each parameter are going to be multiplied to each other and layers will be summed with each other and finally will be expressed in a map form that the Acceptability for injury index will be achieved separately per cell as a value.

Then, according to the table (1), the achieved values are expressed as the various grades of Acceptability for injury and map. In this index, high value indicate the high Acceptability for injury and low value indicates the low Acceptability for injury of underground water to the pollution.

Drastic modeling method based on GIS

Finally using this indices, we began to determine the various grades of Acceptability for injury and preparation of Acceptability for injury map of our studied zone

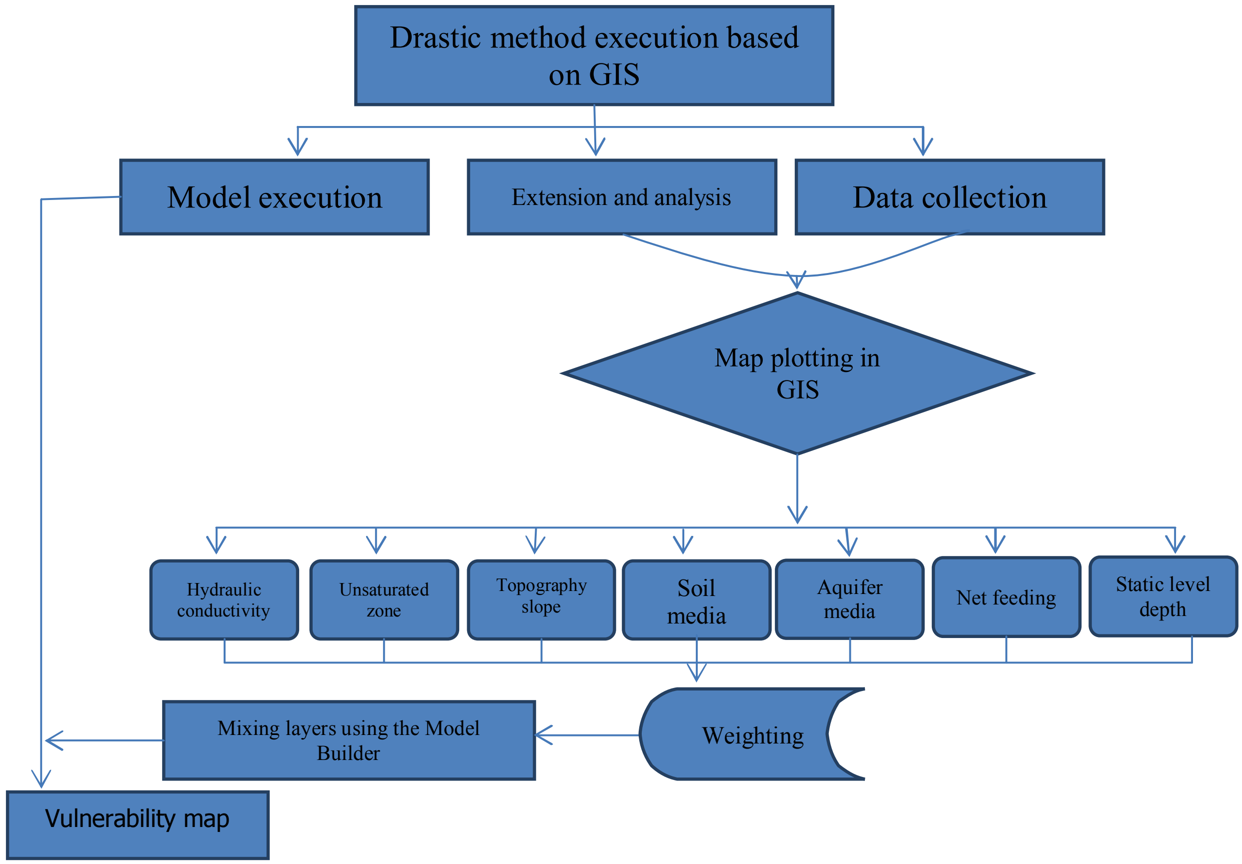

Table 1: Acceptability for injury index value and practical description of its grades

Practical description of Acceptability for injury	Acceptability for injury	Acceptability for injury index
When the confiner layers that current's vertical components of them is tiny to be in the environment.	negligible	46-23
When the recharge of aquifer to be continuously and extensively and pollutants have not the ability to react in the environment.	low	92-47
When the recharge of aquifer to be continuously done, Acceptability for injury to be created compared to some of pollutants.	medium	136-93
Acceptability for injury on most of cases is created compared to the most of pollutants (except than the pollutants which have a high ability of transfer.	high	184-137
Acceptability for injury is created compared to the most of pollutants with the effect of velocity in most cases.	Very high	230-184

3. Research findings

3.1. Region geographical location

Ardakan-Yaz aquifer zone has been a part of Siah Kooh region with 8050 km ² of area where has been placed at the geographical position between the longitudes of 53°*45′* - 55° and latitudes of 31°*49′* - 32°*55 ′* approximately at the center of province and in terms of its structure is a part of the central plateau of Iran. This region is restricted from the north toward the Siahkooh desert and down of Aghda region, from the east toward the down of Khazanagh region and downof Bahadaran region (Anjeer valley desert), from the south toward the ridge of heights of Shirkooh (under the Ali Abad region, Nir and Dehshir) and from the west under the Taghestan region and Nadooshan and Aghda. The highest point of region of Shirkooh with 4075 meters from sea level and deepest point is the margin of Siahkooh with height of 970 meters. The average height of region is 1565 meters. According to the distribution table of area, in terms of the height approximately 60 % of region area is placed at the height lower than 1500 meters and the rest 40 % has a height higher than 1500 meters.

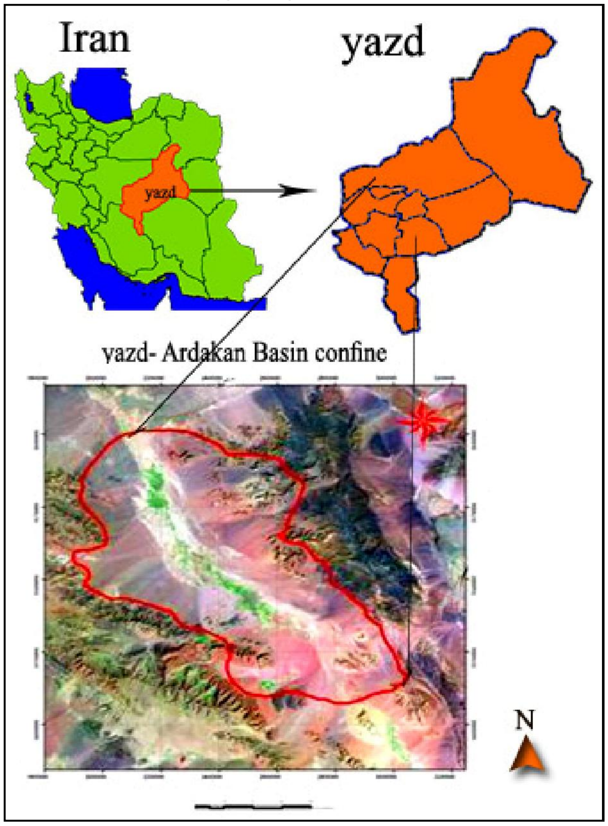

Fig. 1: Geographical position and satellite image of our studied region

3.2 Layers of drastic model

Since, to determine the Acceptability for injury of Yazd-Ardakan aquifer, it is required to estimate the drastic index of this region, therefore we are going to explain the our studied region's layers structure and their weighting in the following:

3.2.1: Depth of underground water

This parameter is determining the length of path that the pollutant must travel to reach the underground water level. Of course during this path, loss of pollution will be done and whatever the depth is more, then the possibility of reaching to the pollution is low and the potential of pollution will be reduced.

To prepare this layer was used of water level piezometeric data obtained from the years 1990-2000. According to this that Yazd Ardakan Plain regarding to UTM system is placed at two zones of 39 and 40 and also maximum placement of existing piezometers in zone of 40, the whole data was converted to the zone of 40. A map with the depth same as the water using the data related to the water level and ***Surfer*** software, was plotted and interpolated using the Kriging method. After the preparation of TIN map and its conversion to Raster and its classification, layer of the underground water depth was obtained and shown in the Fig.2.

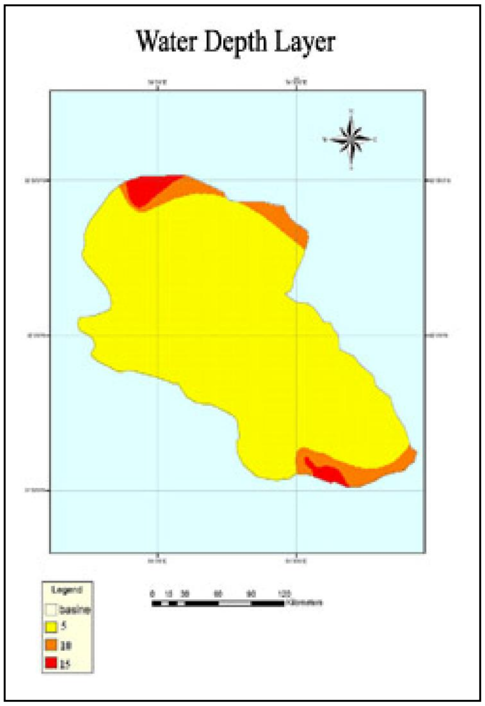

Fig.2 Underground water depth

3.2.2 Aquifer media

Aquifer media is said to a part of layer which all porosity of it to be saturated of water and to be able to store and transfer the water, and particle size, sorting, hardening and cementation are from very important factors. Because, they can affect the transfer rate of contaminant materials within the layer. of course layer materials by affecting the hydraulic conductivity causes the contaminant velocity rate to be increased or decreased. To prepare the aquifer layer from log of drilling wells that were prepared by the water supply company. In these logs, stratigraphic column of unsaturated zone and saturated zone are shown. after the preparation of logs related to each wells and changing the geographical coordination system to determine the ranges, was used of a part which were related to the saturated zone. first of all according to the materials type and table.2, ranges related to each type was identified and rank of each range was diagnosed and then using the information obtained from the layers related to aquifer media, Fig.3 was prepared.

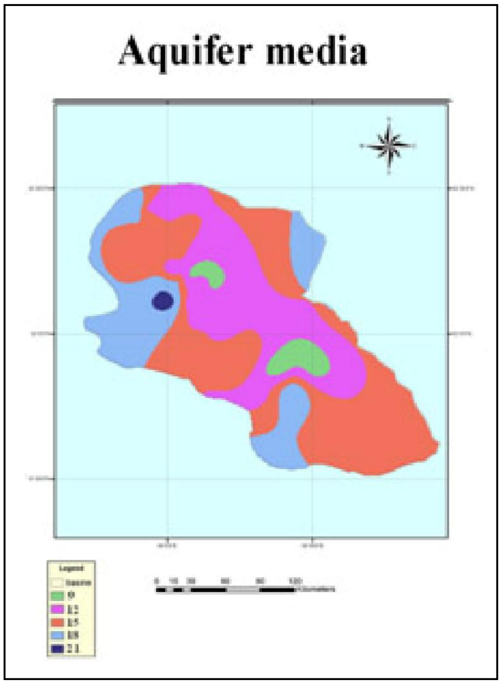

Fig.3: Aquifer media layer

Table.2 Ranges and ranking of aquifer media

(Aquifer media)		
(Range)	(Rating)	Typical ratings
A massive shale		
Igneous / metamorphic	1-3	2
Igneous / metamorphic	2-3	3
Weathered	3-5	4
glacial sediments	4-6	5
Sandstone layers		
Layers of limestone	5-9	6
And sequence of Shales	4-9	6
A massive sandstone	4-9	6
A massive limestone	4-9	8
Sand	2-10	9
Basalt	9-10	10
Karstic limestone		
Assigned weight: 3		

3.2.3 Soil Media

0.5 to 2m thickness from the upper layers of unsaturated zone is called the soil layer where is the upper part of the saturated zone. The top layer due to the presence of plant roots is important in reducing the pollution. This study aimed to determine the soil type and geologic maps of the used soil. In Yazd – Ardakan plain Unfortunately, due to the existence of the extensive and comprehensive zone, an applied map to determine the soil type is not provided by any of the concerned agencies. The drilling well logs were used for preparation of the soil layer. Thickness of 2m above the log has been known as the soil type and then the rank is given for each soil type according to Table 3. To generalize these values to the region, Tyson network, was plotted and value was considered per log for polygon to the same piezometer and by classifying the raster maps, layers of soil material were obtained which is shown in the form (4).

Table (3): the scope and rating of the soil media [1]

(Soil media)	
(Range)	(Rating)
Thin soil layer or non-thin soil layer	10
sand	9
(peat)	8
Compacted clay	7
Sandy loam	6
loam	5
Silty loam	4
Clayey loam	3
(muck)	2
Non-compacted clay	1
Assigned weight:2	

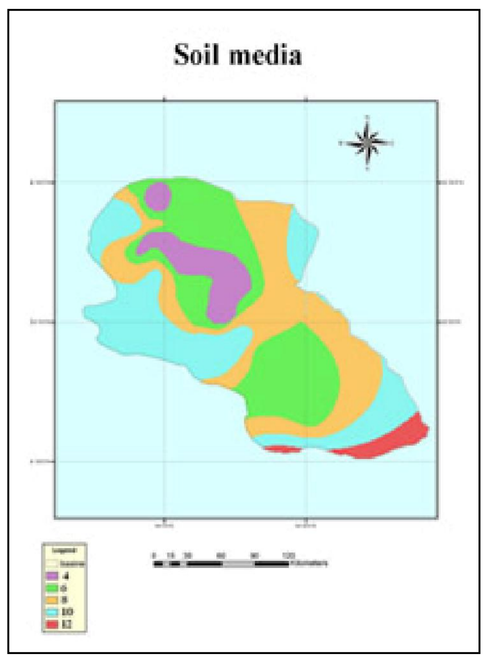

Fig. (4) layers of soil material

3.2.4 Topography

Topography has two roles in drastic model, on the one hand, will determine the movement and survival rate of pollution and on the other hand, affect the creation of soil layers. Digital topographic maps of the area to provide the topographic layer (1:50000) is used. To prepare this layer must first of these maps based on the height, DEM be prepared that this map in ArcGIS using the map TIN and slope percent map was prepared by TIN mapping. The rating and valuation of percentages of the calculated slope in the ArcGIS software, the rating using Table.4 was done and the topographic layer was obtained. In Fig. 5, the produced topographic layer is shown.

Table.4: Ranges and topographic ratings [1]

(Topography)	
(Range)	(Rating)
0-2	10
2-6	9
6-12	5
12-18	3
>18	1
Assigned weight:1	

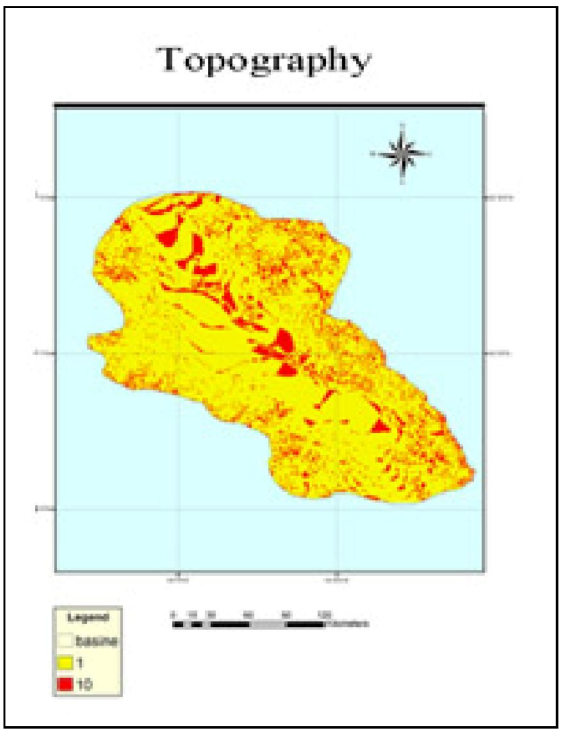

Fig. (5) Topographic Layer

3.2.5. Effects of unsaturated zone

Unsaturated zone has a significant role in reducing pollution, because the contaminants moving into the environment are affected by a series of mechanisms, such as absorption, distribution, filtering,... and then, their concentration will be reduced. to generalize the given value for area, was used of Tyson network and based on the assigned weight, the classification was done and the concerned layer was obtained which is shown in Figure 6.

Table 5. Ranges and Ratings of the impact of vadose zone

(Impact of the vadose zone)		
(Range)	(Rating)	Typical ratings
Confining layer		
Silt, clay	1	1
Shale	2-6	3
Limestone	2-5	3
Sandstone	2-7	6
Sandstone, limestone, and	4-8	6
shales layers	4-8	6
Sand with large amounts of clay	4-8	6
and silt	2-8	4
Igneous, metamorphic stones	6-9	8
sand	2-10	9
basalt	8-10	10
Karstic limestone		
Assigned weight:5		

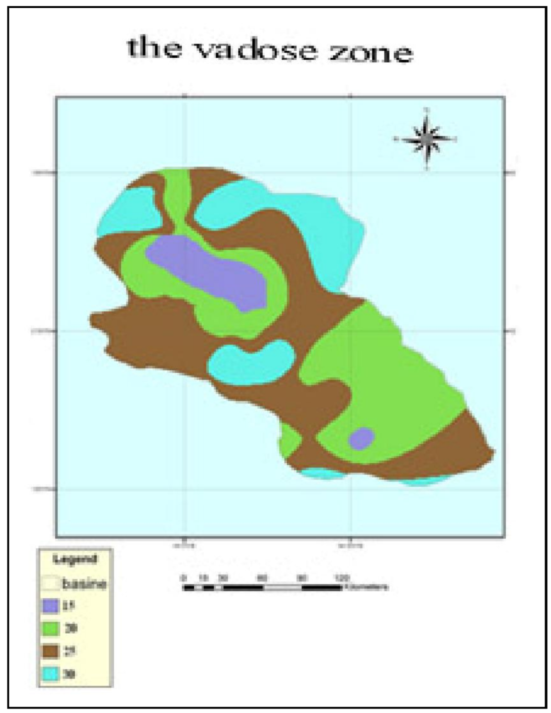

Fig.6 Vadose zone layer

3.2.7 Hydraulic conductivity

The hydraulic conductivity indicates the rate of water infiltration and its movement within the earth and also reaching the contaminations to the underground water level. The information related to the hydraulic conductivity is calculated based upon the pumping test designed for one region. to calculate the hydraulic conductivity was used of the Eq.2.

$$T = Kb \qquad [2]$$

In which, the hydraulic conductivity according to the transfer ability and the thickness aqueous layer are calculated. in this research, due to the shortage of the pumping data and also being non-uniform of these data, one hydraulic conductivity is assigned per log and then these data entered the software based on the drilling logs. According to the Table.6, a determined hydraulic conductivity was assigned per range and the classification also was done and the weight related to these later was multiplied and finally the hydraulic conductivity layer was prepared. Fig.7.

Table 6. ranges and ratings of the hydraulic conductivity

(Hydraulic conductivity)	
(Range)	(Rating)
0-5.5	1
5-15	2
15-35	4
35-50	6
50-100	8
>100	10
	Assigned weight:3

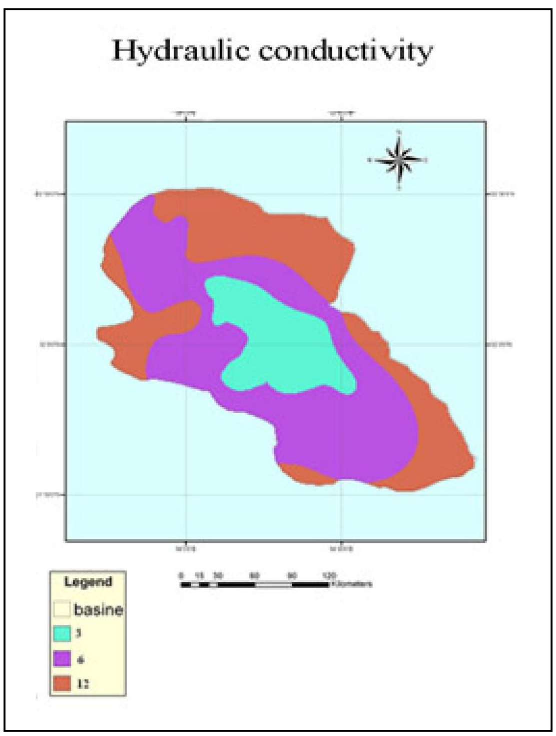

Fig. Hydraulic conductivity layers

3.3 Direction of underground water

To draw the line with the same potential and determine the general direction of the region was used of the average groundwater level related to the years 2001 -2010. we used of absolute height of wells and water level height that the water absolute height within wells is obtained from them. According to the map of current direction, water level at the entry point of plain (Shirkouh heights) is 1383.8 m and at the output point of Yazd-Ardakan plain (Siahkooh basin) is 973 m above sea level. Height difference between the entry and output point of plain is equal to 410.8 m and hydraulic gradient is various at the different points of plain. In the southern parts and entry point of plain, the inclination is variable between 10-14m per k, and in center of plain changes between 2-2.69 m per k and at the entry point has an inclination equal to 4.5 -6.24 m per k.the direction of general water current is from South West to the North East. the layer of Yazd-Ardakan aquifer current direction is indicated In the Fig.8.

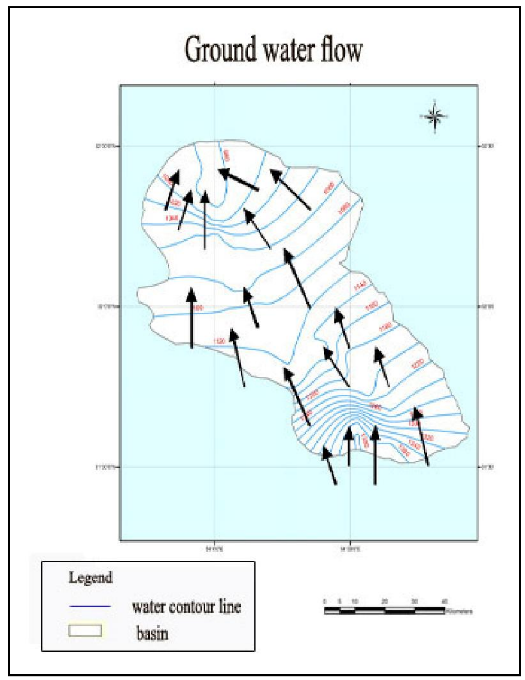

Fig.8 Map of the local general current of region

3.4 Determining the Acceptability for injury index of drastic model

According to the results and layers achieved here, the Acceptability for injury index and/or in the other words, the index of contamination potential of drastic mode per cell, is going to be calculated from Eq.1 and the related values to each parameter, in the combination of these layers, will be gathered each other and finally will be introduced in form of a map that the Acceptability for injury map of Yazd – Ardakan is shown in Fig. 9. in table 7, the efficient parameters in the drastic model and the related weights per parameter are indicated.

The Acceptability for injury index is achieved per part as a value for the related cell that these values are separated from each other. to show the achieved indices, was used of the various levels of Acceptability for injury from Table.1.

According to this table, Acceptability for injury index is divided into 5 parts including the negligible part of Acceptability for injury from 23-46, low from 47-92, intermediate from 93-136, high from 137-184, and very high from 184-230. According to the Acceptability for injury index map, the studied region is placed between 49-163. 15 percent of region area has the intermediate Acceptability for injury where often are placed at the southern and eastern section and 10 % has the negligible Acceptability for injury and is placed at the center ofplain. more than 75 % of region has the low Acceptability for injury that has the maximum area.

Table 7. the weights related to the seven parameters of Drastic model

parameter	weight
(D)Underground water depth	5
(R)Net recharge	4
The ingredients of aquifer(A)	3
(S) Soil material	2
(T)topography	1
(I)Unsaturated zone substance	5
(C)Hydraulic conductivity	3

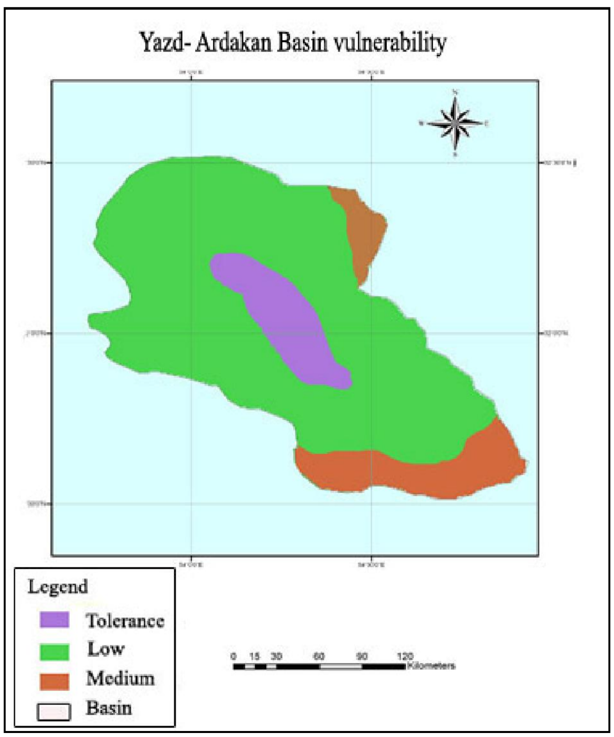

Fig.9 map of acceptability for injury of Yazd-Ardakan plain using the drastic model

4- Discussion and Conclusion

In this research, Acceptability for injury map of Yazd-Ardakan plain using the seven prepared layers was planned and according to the table-1, the achieved indices were converted to the various levels of Acceptability for injury. we conclude based on the prepared map of Yazd-Ardakan from Fig.9 that a wide range of region i.e, more than 75 % has the low potential of Acceptability for injury, and 15 % of plain area has the intermediate potential of Acceptability for injury that a development is observed in the eastern and southern part of plain where is placed at the central part of plain.

By investigations and also observation of satellite pictures was determined that the size of sediments is reduced from the boundaries of plain toward the central part of plain that these variation of size in sediments directly affect the parameters of vadose zone, aquifer media, soil media and hydraulic conductivity and causes the rating of these parameters to be reduced in center of plain that this effect is observed in the final result and Acceptability for injury map clearly.

We can say about the southern and eastern part placed at the medium Acceptability for injury region that the drastic index was calculated for the eastern section was around 92-98 and for the southern sections was 92-106 that according to this intermediate range has an index of 92-136, therefore these two sections have the intermediate Acceptability for injury that in most of layers, the higher value is considered for this section and its effect is observed in the final map wityh higher index. In the valuation and classification of Yazd-Ardakan plain according to the Fig.2, 90.6 percent of plain area has a depth more than 30 m where the least value is assigned to it, 6.8 percent of region area has a depth between 23 -30 m where has a value of 2 and 2.6 percent also has a depth between 15-23 and value of 3 that are placed at the southern part in the entry point of plain and in the northern part which indicating the potential of contamination in the northern and southern section of plain. After calculation of the rate of net rainfall and rate of retuned water, there was area under rain about 12.1 percent which was composed of southern section and in place of plain entry point, 5-100 mm rainfall was observed and then the southern region has a potential of Acceptability for injury compared to the other points. According to n the hydrograph map of this plain, average medium loss of plain during these years is equal to 2 m. Finally, and with regards to this that the entrance of plain of Shirkouh has the medium Acceptability for injury and aquifer entrance is placed at this location, it is suggested to be prevented from establishment of the polluting units in this region and also removal of pollutants to be avoided in such regions with medium sensibility. Also according to this that the cities of Yazd suffer from the proper sewerage treatment system and mostly waste directly enter the wells as well as Qanats, it is suggested that a proper sewerage system to be designated and wastes in the regions with least Acceptability for injury and specially in the central part of plain where has a negligible Acceptability for injury to be removed.

References

1. Bemani et al, (2009), Comparison of GODS AND DRASTIC models in determining the Acceptability for injury of groundwater aquifers of Yazd - Ardakan, 8th International Congress on Civil Engineering, Shiraz University.
2. Moaddab, M., (2005), the evaluation of Iranshahr aquifer using the drastic models in GIS, M.Sc. Thesis, University of Sistan and Baluchestan.
3. Khodayi, K, SHAHSAVARI, A., (2003), Zonation of groundwater susceptibility of Behbahan aquifer against the pollution using the DRASTIC model, the twenty-second meeting of Earth Sciences, Organization of Geology and Mineral Explorations.
4. Zare'ee Mahmud Abadee, E., Mirhosseini, A., Munawari, M., (1390), and review and prediction of the role of industry in the underground aquifer pollution using a conceptual model (Case Study: Yazd - Ardakan), Water Journal of Iran.
5. Antonakos,A.K., N.J.,Lambrakis.2007. Development and testing of three hybrid methods for the assessment of aquifer Acceptability for injury to nitrates, based on the drastic model, an example from NE Korinthia, Greece. Journal of Hydrology 333, 288– 304.

6- Aller L, Bennet T, Lehr JH, and Petty RJ, DRASTIC: standardized system for evaluating ground water pollution potential using hydrogeologic settings. Office of Research Development, US EPA, Ada, Oklahoma, 1985

6. B. Thirumalaivasan, M. Karmegam, K. Venugopal, AHP-DRASTIC: software for specific aquifer Acceptability for injury assessment using DRASTIC model and GIS, Environmental Modeling & Software 18 645-656,2003
7. Committee for Assessing Ground Water Acceptability for injury, National Research Council, Ground Water Acceptability for injury Assessment: Predicting Relative Contamination Potential under Conditions of Uncertainty, 224 pages
8. **Connell, L. D. & Van den Daele, G., 2003,** "Aquantitative approach to aquifer Acceptability for injury mapping",*Journal of Hydrology, Vol. 276(1-4): 71-88*.
9. **El–Naqa, A., Hammouri, N. & Kioso, M., 2006,** "GIS–based evaluation of groundwater Acceptability for injury in the Russeifa area"**,** *Jordan: Revista Mexicana de CienciasGeológicas, Vol. 23(3), 277–287*
10. Kim,Y.J., S.Y.,Hamm.1999. Assessment of the potential for ground water contamination using the DRASTIC/EGIS technique, Cheongju area, South Korea: Hydrogeol. J., 7 (2): 227-235.
11. **Kabera, T. & Zhaohui L., 2008,** "A GIS Based DRASTIC Model for Assessing Groundwater in Shallow Aquifer in Yuncheng Basin, Shanxi, China", *Research Journal of Applied Sciences, Vol. 3(3): 195-205*.
12. Rahman,A. 2007. A GIS based model for assessing groundwater Acceptability for injury in shallow aquifer in Algarh, India. Applied Geogr., 28 (1): 32-53.
13. Samey,A.A., C.,Gang.2008. A GIS based DRASTIC model for the assessment of groundwater Acceptability for injury to pollution in west Mitidja: Blida city, Algeria. Research Journal of Applied Sciences 3 (7): 500-507.
14. **Todd, D. K., 1980,** "Groundwater Hydrology",*2nd edition, John Wiley, New York, 535 pp.*
15. Thapinta,A., P.,Hudak.2003. Use of geographic information systems for assessing groundwater pollution potential by pesticides in Central Thailand. Environmental International 29, 87–93.
16. *Vrba,J., A.,Zoporozec.1994. Guidebook on mapping groundwater Acceptability for injury. International Contributions to Hydrogeology. Verlag Heinz Heise GmbH and Co. KG.*
17. Worrall,F., T.,Besien.2004. The Acceptability for injury of groundwater to pesticide contamination estimated directly from observations of presence or absence in wells. Journal of Hydrology 303 (1-4), 92–107.
18. Zabet,T.A. 2002. Evaluation of aquifer Acceptability for injury to contaminant potential using DRASTIC method. Environ. Geol., 43(1-2): 203-208.
19. **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.*

10/20/2012