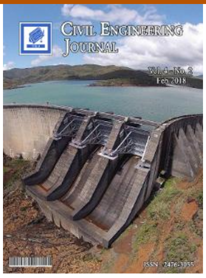
Available online at www.CivileJournal.org

Civil Engineering Journal

Vol. 4, No. 2, February, 2018



Assessment and Estimating Groundwater Vulnerability to Pollution Using a Modified DRASTIC and GODS Models (Case Study: Malayer Plain of Iran)

Maryam Hosseini [a], Ali Saremi [b*]

[a] *Faculty of Agriculture and Natural Resources, Islamic Azad University Science and Research Branch, Tehran, Iran*.

Received 01 December 2017; Accepted 22 February 2018

Abstract

This study deals with the intrinsic vulnerability of groundwater reservoirs to pollution, by the use of two models DRASTIC and GODS, this study is done by taking samples from 17 water resources of Malayer plain Aquifer area of southern Hamedan Province, Iran. 30 physicochemical parameters and heavy metals have been studied and vulnerability of this aquifer to the nitrate concentration, was determined. The study showed that results from DRASTIC were better than GODS in Assessment and Estimating groundwater vulnerability to pollution, also DRASTIC model has been corrected, and compared the ability of these two models in vulnerability zoning has been evaluated. According to high correlation between DRASTIC index and nitrate concentration, ranking and weighting of nitrate pollutant is inserted in the DRASTIC equation, and zoning map of DRASTIC method has been calibrated by nitrate concentration. By this method, vulnerability zoning is determined between very low to very high, which shows the increase of DRASTIC index by nitrate concentration. DRASTIC parameters uncertainty has affected the zoning results in this method, but its calibration with nitrate concentration, gives more accurate vulnerability results.

Keywords: Vulnerability; Sensitivity Analysis; Nitrate; DRASTIC; GODS.

1. Introduction

Water plays a vital role in every biological society in the globe. The socioeconomic development of a region predominantly depends on the availability of good quality water. Groundwater vulnerability assessment could be defined as the degree of assimilation capacity of the area to the contaminant from surrounding surface above the aquifer [1]. Groundwater pollution is a universal problem. Sometimes the nature is the cause of water quality decrease, but in the most cases, human is the main cause of water pollution [2]. The concept of aquifer vulnerability was first introduced by Marget. Vulnerability assessment has been conducted as an essential part of protection strategies for land use planning and groundwater protection zoning [3]. In fact, the term ‘‘vulnerability of groundwater to contamination was first used by [4]. This concept refers to the sensitivity of an aquifer to deterioration due to an external action and is based on the assumption that physical environment may provide some degrees of protection to groundwater against contaminants entering the subsurface zone. Consequently, some land areas are more vulnerable to groundwater contamination than others [5, 6]. Groundwater pollution vulnerability mapping is an important tool to identify areas that are more sensitive to contamination. GIS is an effective technique for the zone mapping and risk assessment on environmental health problems. GIS can be useful for taking quick decisions as graphical representation would be easy to take a policy decision by the makers [7]. GIS techniques have been becoming the most commonly

* Corresponding author: a-saremi@srbiau.ac.ir

http://dx.doi.org/10.28991/cej-0309103

used platform for assessment of groundwater vulnerability [1]. Several methods have been developed, throughout the world, to assess groundwater vulnerability. The NRC (1993) has classified these methods into three major classes: (1) the process-based simulation models; (2) the statistical methods; and (3) the overlay and index methods [8]. In hydrogeology, vulnerability assessment typically describes the susceptibility of a particular aquifer to contamination that can reduce the groundwater quality [9]. The National Research Council (1993) defined it as the tendency or likelihood for contaminants to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer. Two terms are used to describe groundwater vulnerability: intrinsic and specific. Intrinsic vulnerability is the natural susceptibility to contamination based on the physical characteristics of the environment while specific vulnerability is defined as an accounting for the transport properties of a particular contaminant or group of contaminants through the subsurface [10]. The first term refers to the intrinsic property of groundwater system to human or natural impacts. The most leading model of the intrinsic vulnerability is DRASTIC index [11].

The evaluation of vulnerability is a mean to gather complex hydrogeological data in a way that can be used by non-specialist people such as decision-makers. Vulnerability assessment of groundwater aquifers provides a basis for initially protective measures for important groundwater resources and will normally be the first step in a groundwater pollution hazard assessment and quality, when it interest [3]. In recent years, vulnerability assessment of groundwater aquifers considered as an essential part for putting suitable plans to protect groundwater aquifers around the world [9].

2. Materials and Methods

2.1. Study Area

About 90% of water demand across Malayer Plain is supplied by groundwater, deep and half-deep wells, aqueducts and fountains [12]. Annual groundwater resources discharge from deep and semi-deep wells, ghanats, and springs, is 495 million cubic meter. As can be seen in the Figure 1; the studied area is located between 48^o, 25' to 49^o, 05' longitudes east and 34^o, 05' to 34^o, 25' latitude north. And is a part of Malayer plain in the Hamedan province in Iran, approximately 922 km^2. Malayer height is 1760 m above sea level. The main river in this plain named Harm-Abad (Ab Malayer), which originates from Sarband Arak heights, after immerging with the branch streams from Borujerd heights (Kalan branch), flows to Malayer city. Average yearly rainfall is 313 mm and average temperature degree is 13o C. Meteoric rainfalls are caused by Mediterranean flows, mainly. The humidity and raining are caused by west weather fronts too (about 8 mounts (from December to July) is influenced by the system) [12]. Malayer Plain's alluvium comprises the erosion of schist, slate, phyllite, granite, granodiorite, limestone and sandstone and deposition of the destructive materials carried in valleys, where the size of particles tapers off from the brinks to the center. Thin gravelled sandy and silty layers are spread in the great part of the plain. Malayer plain is almost flat and its gradient is 0-6%.

Surface water, penetrates the aquifer and the rest of it flows in the Harm-Abad seasonal river, and at the end enters the Nahavand limit. Groundwater direction is as the same as the surface water, which flows to centre from all main entrances.

Metamorphic, igneous and sedimentary rocks across the region play an unimportant role in feeding the aquifer. However, they are significant in terms of forming the aquifer's rocky bed. The Plain's aquifer is composed of rubble, sand and clay with a thickness of 25 m in the brinks of the plain, expanding to 150 meters in the southwestern areas. According to the observed number of wells, the depth-to-water table in Malayer Plain ranged from 6 to maximum 30 meters during April 2007 (Figure 1). The overall direction of groundwater flow within Malayer Plain begins from East, North, West and South ends in the Center. The hydraulic gradient in the southeast and northwest brinks is higher than the center and outflow of the plain. The average transmissivity in Malayer Plain ranges from 1051 m^2/day to 8035 m^2/day. Over the 12-year span (1994-2006), the aquifer experienced a 15.48-meter drop in ground water. The summary of results indicated that the aquifer's balance in Malayer Plain is negative due to factors such as excess exploitation [13].

Malayer plain is located in the semi-pressurized zone of Sanandaj-Sirjan. This zone is south west margins of central Iran flat, actually. The oldest petrologic unit outcropped in Malayer plain is related to Triassic and the newest sediments are quaternary structures. Malayer plain alluvium is formed by schist, slate, phyllite, granite, granodiorite, limestone and sandstone of plain margins erosions and sedimentation of these sediments in the depression of region. Particles sizes decrease from margin to centre.

With a total of 217 zones registered, Malayer is one of the important plains in terms of agricultural and industrial growth. The quality downgrade in groundwater of Malayer Plain is mainly the outcome of human activities involving nitrate wastewater due to urban development and the sprawl of a few pollutant industries such as refining and packaging of raisins, dairy production and livestock slaughterhouses, which are released into the surrounding environment and then leaked into the aquifer. In addition, the contamination of groundwater has intensified by the excessive use of nitrate and animal fertilizers, pesticides, return water flow in agriculture, water passage through solid waste left from cowshed and poultry farms in rural areas and husbandry complexes especially in other areas in plain as well as inappropriate sanitation systems and Malayer's leachate from the urban landfill in plain. The contamination of drinking water refers to altered physical, chemical and biological properties of water, making it harmful for direct human consumption [14]. The quality downgrade of groundwater takes place slowly and is difficult to identify or even control. It might render the water unusable and dangerous for decades [15]. Therefore, it is crucial to preserve groundwater sources so as to guarantee health and reduce the risk of diseases caused by consumption of contaminated water.

Groundwater quality decrease in this plain is mainly due to nitrate sewage produced by some industries, such as raisin purification and packing, dairy products, and slaughters complexes, which widespread in the plain with no attention to environmental problems and diffuse to groundwater.

In addition, animal and chemical manure irregular use; accumulation of animal waste in villages' margins, animals' husbandry complexes and Malayer landfills, increase the probability of groundwater vulnerability in the plain. So, there are enough reasons to assess the vulnerability of this plain to pollutants. Vulnerability is not an absolute characteristic, but is a relative one, which can be propounded in the polluted area. The prognosis of groundwater vulnerability is similar to the weather forecasting [16]. This not only gives more data in order to decision-making, but also helps to detect and purify high risk and polluted areas. It will prevent more pollutant diffusion to groundwater and saves aquifer internal characteristic.

If possible, pollutants must be far from water resources, and if pollution occurred, it must be removed or compensated. And if complete removal is not feasible, at least the preferences must be distinct [17].

Hot spots, rainfall decrease and over-using causing the quality of groundwater getting worse, getting more information in order to increase groundwater protection strategies, information documentation in order to decision making in the area of groundwater pollutants, selecting special regions for rural and urban sewage management, groundwater quality protection [16] and saving public health [17] attract attention to Malayer plain aquifer vulnerability zoning.

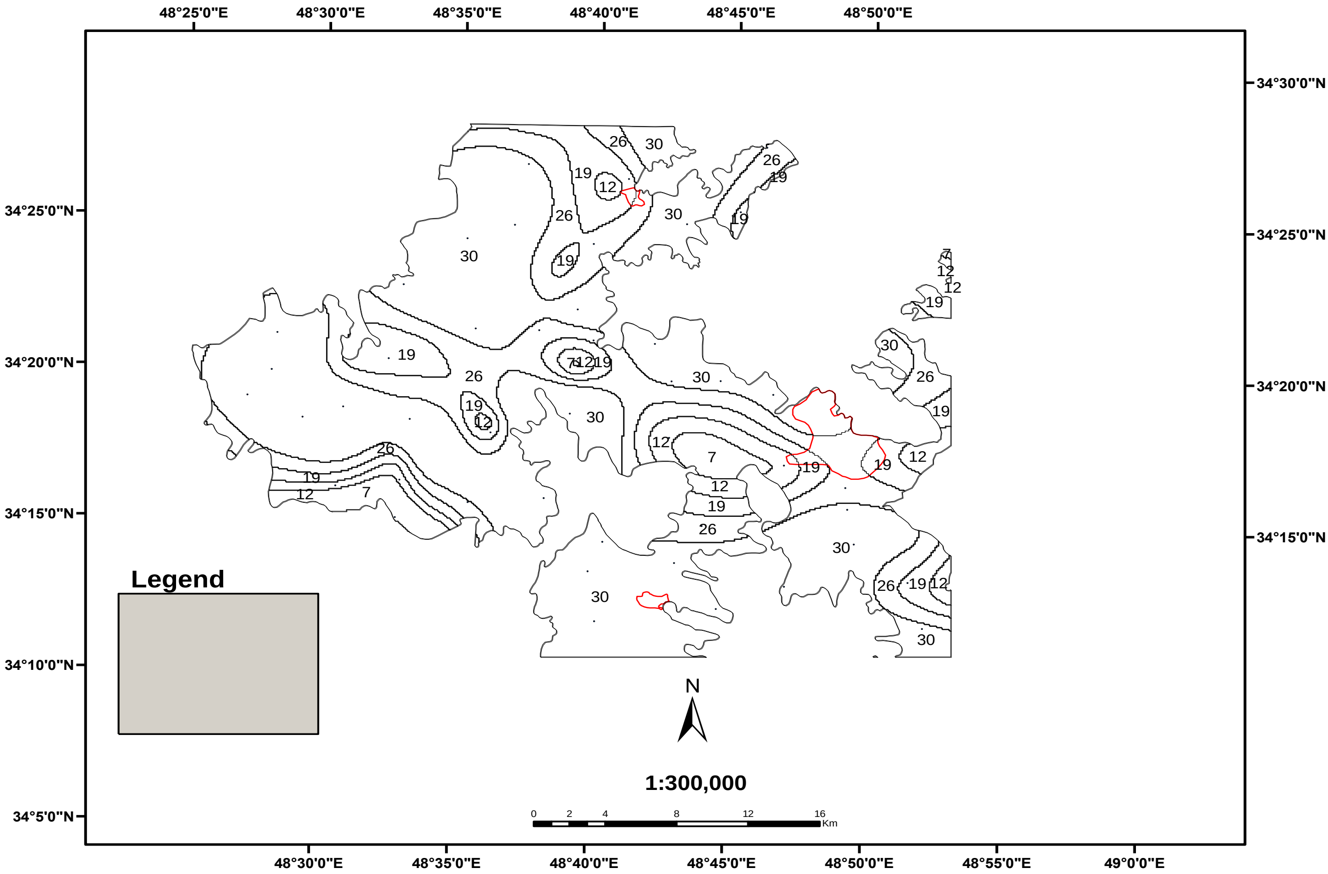


Figure 1. Depth-to-water table contour map for Malayer Plain (April 2007)

2.2. Methods

In this issue aquifer vulnerability of Malayer plain has been assessed by the use of DRASTIC and GODS methods. DRASTIC method was developed by EPA [18] in 1980, which estimates the groundwater vulnerability, empirically and the basis of hydro geologic data.

DRASTIC is a groundwater quality model for evaluating the pollution potential of large areas using the hydro geologic settings of the region [18]. Data needed for this method, are depth to water table, net recharge, aquifer media, soil media, topography slope, impact of vadose zone and hydraulic conductivity of aquifer formed material. Four dependent parameters (*D*, *A*, *S*, *I*) are gained from drilling and *T* parameter from topographic maps. There's an estimated value for R and C is calculated according to the aquifer characteristic.

Vulnerability index is obtained from the equation 1. The higher the DRASTIC index is the greater relative vulnerability potential. *r* and *w* refers to rating and assigned weighting, respectively. For areas with a lack of information about the sub surfaces and the groundwater, GODS method can be used [3]. GODS has four parameters. Groundwater existence (inexistent = 0 existent = 1), overlaying petrology (0.4-1), depth to groundwater (0-1) and soil type (0.5-1). Vulnerability index in this method is determined by multiplying these four parameters.

$$DRASTICindex = D_r \times D_w + R_r \times R_w + A_r \times A_w + S_r \times S_w + T_r \times T_w + I_r \times I_w + C_r \times C_w \quad (1)$$

The risk of biological contamination of Malayer Aquifer was determined by collecting samples from a total of 17 water sources and analysing the samples under laboratory standards from December 1, 2007 to December 23, 2007 (Figure 2). There were 30 physical-chemical parameters such as EC, TDS, Alkalinity, Hardness, Turbidity involving heavy metal samples such as Ca, Mg, Na, K, Cl, SO4, Si, NH3, NO3, NO2 Cr, Co, Cu, Pb, Ni, Zn and Fe. specified by Tehran Water and Sewage Company. The samples were collected from zones in vicinity of industrial plants, poultry, livestock slaughter facilities and landfill sites across Malayer (Table 1, 2).

Table 1. The results of chemical analysis of water samples (mg/lit)

Location	EC	PH	PHS	TDS	alkalinity	hard	turbidity	Ca mg/lit	Mg mg/lit	Na mg/lit	K mg/lit	Cl mg/lit	SO4 mg/lit
Behtak(Jurab)	677	7.16	7.1	462	332	352	0.2	97.60	25.92	28	1	17	51
Shabnam-e-Sahra	557	7.54	7.4	353	232	264	0.2	68.80	22.08	23	1	17	35
Kartil-Abad chicken farm	708	7.77	7.6	472	196	212	54	52.80	19.2	78	1	29	133
Khosh-Abad chicken farm	592	7.64	7.5	390	236	228	0.6	56	21.11	52	2	21	62
Tocheghaz dairy factory	1200	7.41	7.3	832	304	484	1.3	100.80	55.68	94	2	57	294
Haji-Abad cow-keep farm	1427	7.38	7.9	1140	172	764	0.4	214.40	54.72	50	1	35	634
Shirin-Abad slaughter	1273	6.47	6.9	870	592	516	4.6	132.8	44.16	112	1	41	87
Jokar cow-keep farm	578	7.69	7.6	385	220	204	0.2	46.40	21.11	54	3	19	68
Dehno bird slaughter	517	7.27	7.4	334	232	224	0.3	62.40	16.32	30	4	18	30
Pirmishan Cream and cheese	422	8.01	7.4	283	160	148	0.3	43.20	9.6	38	1	14	47
Aznav cow-keep farm	628	7.7	7.4	438	196	240	0.3	65.60	18.23	60	1	11	120
Varchigh chicken farm	585	7.61	7.6	407	204	196	0.3	52.80	15.36	62	1	9	100
Sahand industry	373	7.75	7.7	261	152	168	0.2	51.20	9.6	23	1	15	40
Kian Kordsa (Zanganeh Olia)	490	7.43	7.3	332	240	240	0.6	65.60	18.23	24	1	9	37
Nazul chicken farm	860	7.47	7.3	599	296	300	5.9	78.40	24.96	100	2	38	131
Sormak minary	320	8.07	7.7	203	140	156	1.3	38.40	14.39	11	1	4	34
Malayer city dumpsite	519	7.78	7.8	336	151	148	0.5	44.80	8.64	54	1	20	75

3. Results and Discussion

The results of chemical analysis on 17 samples collected from the study area based on the WHO standards (2000) and the Iranian standards indicated that groundwater across Malayer Plain mainly fall under facies Ca - Mg- HCO3 (71%) and Na - HCO3 (29%) and Bicarbonate calcic basic type as well as fresh and drinkable water according to the Piper and Stiff diagrams. In this regard, 94% of the fresh class, while 6% are in the brackish class. Moreover, 29% of the samples were averagely hard, 65% were hard and 6% were very hard. The location of the samples on the Schuler chart indicates that 94% of the samples were categorized as good quality, 4% were acceptable and 2% were average for drinking. In terms of agricultural potential, 76% of the samples fell under C3S1 while 24% fell under C2S1. In terms of industrial application, 76% of the samples inclined toward sedimentation and 88% were slightly corrosive. The majority of the samples collected from the Plain’s groundwater did not contain any suspended particles at constant temperature of 25 °C. Hence, they are preferred over surface water or general water supply and distribution.

However, the water turbidity is extremely high in Kartilabad Poultry Kartilabad (about 54%). In other areas, water turbidity was fine. As an indicator of biological contamination in Malayer Plain, the nitrate concentration varies from 9 to 61.3 mg/litre. Nitrate concentrations on the 17 sampling sites are shown in the Figure 3. The nitrate concentrations were over 20 mg/lit in about 65% of the samples. On the other hand, the increase in nitrate concentration at the wastewater outflow of raisin refining and packing plants and slaughterhouses is remarkable.

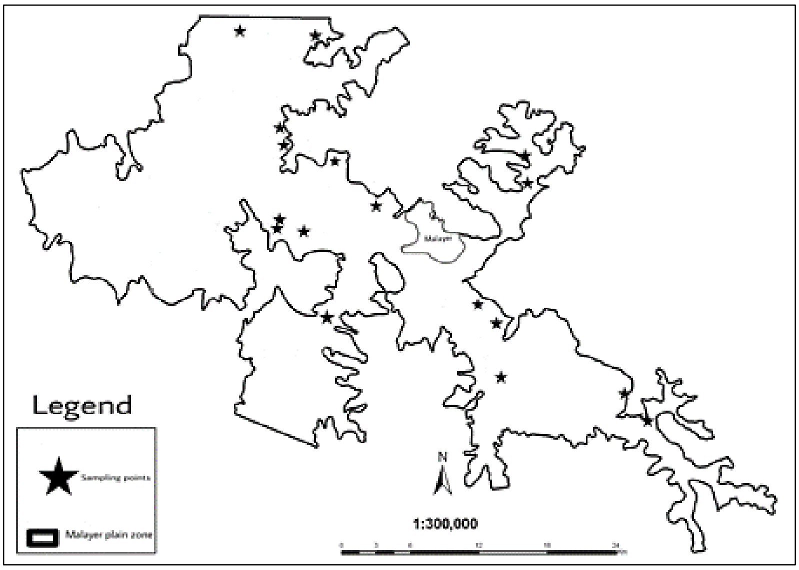


Figure 2. The scope of Malayer Plain and sample collection

Table 2. The results of chemical analysis of water samples (mg/lit)

Location	SiO2 mg/lit	NH3 mg/lit	NO3 mg/lit	NO2 mg/lit	Cr mg/lit	Co mg/lit	Cd mg/lit	Cu mg/lit	Pb mg/lit	Ni mg/lit	Zn mg/lit	Mn mg/lit	Fe mg/lit
Behtak(Jurab)	18	0.09	24.4	0.07	0.006	0.006	0.002	0.003	0.01	0.01	0.015	0.004	0.01
Shabnam-e-Sahra	16	0.1	30.8	0.07	0.006	0.005	0.002	0.003	0.01	0.01	0.013	0.002	0.011
Kartil-Abad chicken farm	15	0.13	26.1	0.240	0.01	0.005	0.002	0.003	0.01	0.01	0.005	0.013	0.376
Khosh-Abad chicken farm	19	0.16	15.2	0.100	0.006	0.005	0.002	0.003	0.01	0.01	0.024	0.003	0.024
Tocheghaz dairy factory	14	0.1	31.8	0.07	0.008	0.007	0.002	0.003	0.01	0.01	0.156	0.006	0.083
Haji-Abad cow-keep farm	19	0.04	28.5	0.07	0.006	0.005	0.002	0.005	0.01	0.01	0.024	0.003	0.058
Shirin-Abad slaughter	36	0.06	61.3	0.07	0.006	0.007	0.002	0.004	0.01	0.01	0.022	0.031	0.166
Jokar cow-keep farm	17	0.06	24.9	0.07	0.006	0.005	0.002	0.005	0.01	0.01	0.001	0.002	0.018
Dehno bird slaughter	16	0.05	17.7	0.07	0.006	0.005	0.002	0.003	0.01	0.01	0.014	0.002	0.025
Pirmishan Cream and cheese	20	0.03	14.6	0.07	0.006	0.005	0.002	0.003	0.01	0.01	0.033	0.002	0.013
Aznav cow-keep farm	15	0.03	29.8	0.07	0.006	0.005	0.002	0.003	0.01	0.01	0.005	0.002	0.014
Varchigh chicken farm	16	0.05	28	0.07	0.006	0.005	0.002	0.003	0.01	0.01	0.002	0.002	0.014
Sahand industry	15	0.03	14.9	0.07	0.006	0.005	0.002	0.003	0.01	0.01	0.009	0.002	0.006
Kian Kordsa (Zanganeh Olia)	16	0.04	17.3	0.07	0.006	0.005	0.002	0.003	0.01	0.01	0.015	0.037	0.06
Nazul chicken farm	16	0.09	30.9	0.07	0.006	0.005	0.002	0.003	0.01	0.01	0.013	0.004	0.123
Sormak minary	16	0.08	9	0.07	0.006	0.005	0.002	0.003	0.01	0.01	0.14	0.002	0.061
Malayer city dumpsite	21	0.03	20.8	0.07	0.006	0.005	0.002	0.003	0.01	0.01	0.009	0.011	0.107

Due to extreme blending with the wastewater outflow, the nitrate concentration is 61.3 mg/litre in the samples collected from the water well in Shirinabad Livestock Slaughterhouse. The maximum depth of the wells in the region is 90 meters. Hence, the impact of nitrate is limited to the depth of 90 meters. Since the bedrock of the alluvial plain is composed of schist, there is no chance of feeding. Therefore, the concentration of nitrate contaminants escalates over time by an increase in ammonium oxidation due to the leaching of inorganic fertilizers applied to farms.

The variations in nitrate concentration are normally proportionate to the hydrogeological regime. In fact, the nitrate flowing into the groundwater progresses like a plume in the direction of water towards greater depths as its concentration is curtailed. Based on the results of the tests, there is no contamination with heavy metals such as lead, copper, cadmium, chromium, nickel and zinc across Malayer Plain.

The iron concentration exceeded the standards at 0.376 mg/lit only in the water sample collected from Kartilabad Poultry. The intensity of variability is generally higher in zinc, manganese, iron, sulphate and chlorine than the average of ions, indicating erratic dispersion of data around the mean values.

In the case of nickel and lead ions, the intensity of variability is zero. Moreover, the intensity of variability for calcium, magnesium, sodium and potassium ions is higher than the average suggesting there are extreme alterations and dispersion of data in the constituent elements of different samples. Coexisting with humans, coliform bacteria decompose intestinal substances in the body. They tend to be highly resistant under temperature shift and variations in pH and eh. Moreover, they provide an indicator, measured based on E. coli. According to research conducted by the Health Department of Malayer, the E. coli test result in water well across the outskirts has been positive in recent years due to inadequate preservation measures taken to reinforce of walls and maintaining a distance from the sanitation network. However, this has not been resolved and the water contains little microbial load.

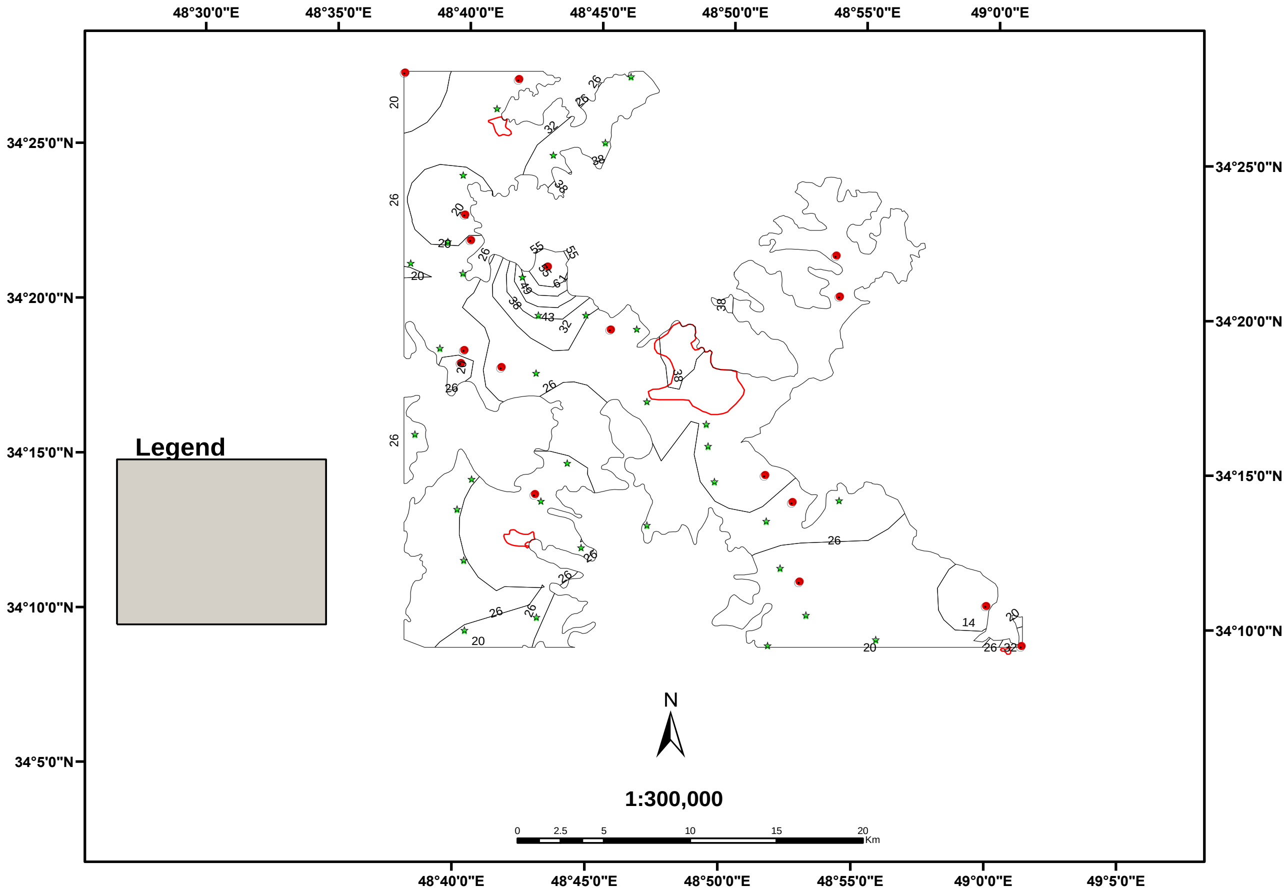


Figure 3. Nitrate-to-water table contour map across Malayer Plain

By the use of DRASTIC method and seven parameters gained in the studied area between 80 to 143. Final vulnerability mapping (Figure 4) shows that, the vulnerability potential of the studied region - Malayer plain- with the area of 922 km^2, is categorized in to very low, low and medium, which contains 51, 43, 6% of the area respectively.

Central parts have low to medium vulnerability, but northern, southern and margins have very low vulnerability. For DRASTIC method calibration, nitrate concentration of 17 water resources has been shown on the map.

Table 3. shows final DRASTIC index calculations. The greatest and the smallest vulnerability potential are due to D parameter and soil type, respectively. There is more changes index in depth to water table and impact of vadose zone, which indicates the important role of these parameters in vulnerability evaluation in this area. Because of samples biasing, which were taken of pollutant resources, nitrate concentration doesn't express the exact values in the aquifer and doesn't correspond with the vulnerability maps. Therefore, it is necessary to change weighting of seven parameters of DRASTIC, to gain better correspondence. Although DRASTIC method gets good relative information, in order to have a more accurate evaluation, not only must the exploiter drillings be increased, but also nitrate concentration data must be entered in the DRASTIC linear equation, and vulnerability must be assessed by changing in weights of parameters and finally calibrated by nitrate concentration, to increase the validity of this method.

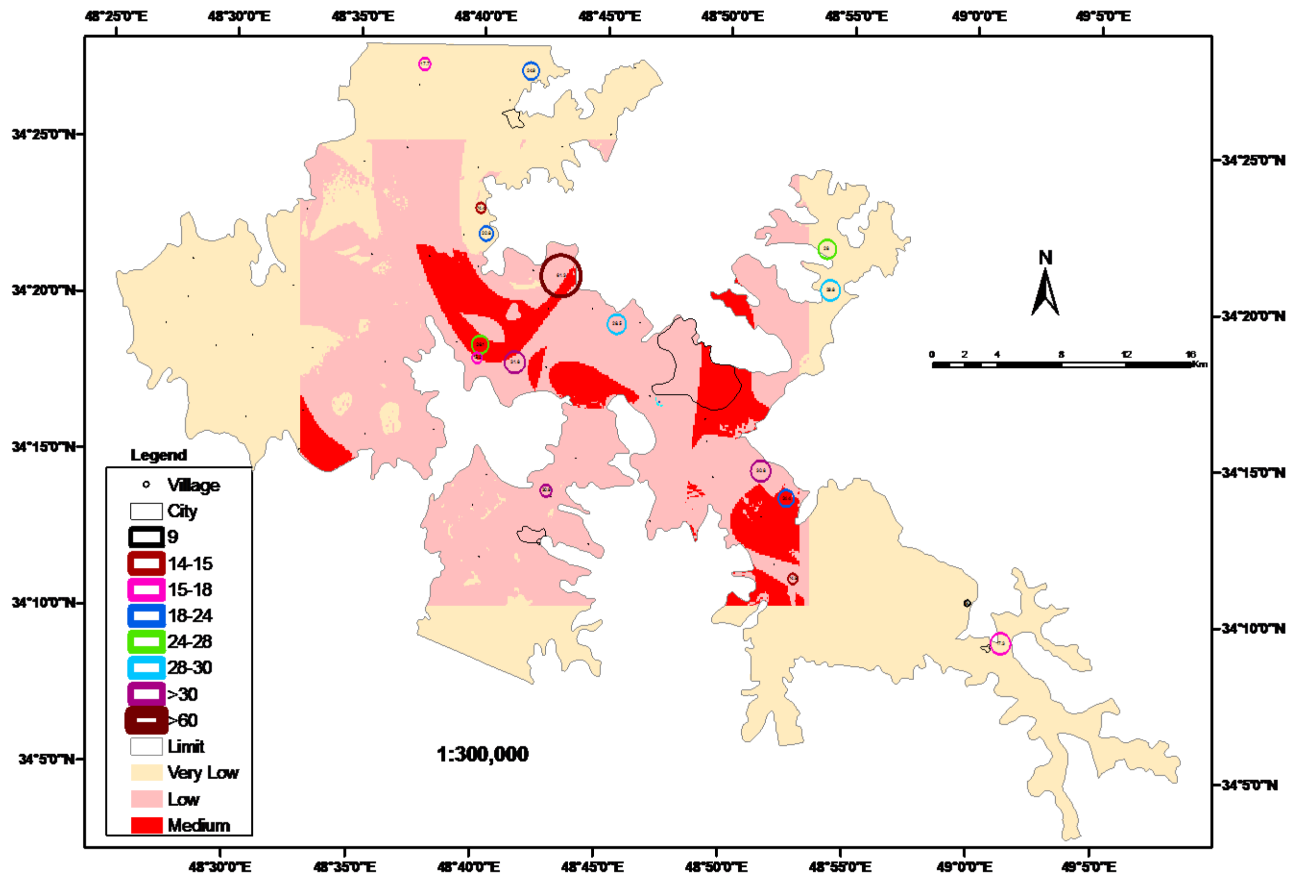


Figure 4. Aquifer vulnerability zoning in the Malayer plain by the use of DRASTIC

There's a high correlation between DRASTIC index and average nitrate concentration (r = 0.86). After some steps of changing the weighting of parameters of DARSTIC and using the results of nitrate concentration in the samples and rating and weighting of nitrate pollutants, *DI* gained 85-190 (heuristically). Thus, from the total area of 922 km^2 in 28% equals to 258 km^2, in 15% equals to 138 km^2, 16% equals 148 km^2, 38% equals to 350 km^2 and 3% equals to 28 km^2, the vulnerability assessed very low, low, medium, high and very high, respectively.

Table 3. DRASTIC index calculation in the exploiter wells

DI	C_wC_r	I_wI_r	T_wT_r	S_wS_r	A_wA_r	R_wR_r	D_wD_r	Site Name
80	24	15	10	6	12	12	10	Namazgah
130	30	15	10	6	12	12	45	Shomal-e-Gonbad
135	30	15	10	6	12	12	50	Hossein-Abad-e-Nazem
98	24	15	10	10	12	12	15	Mahdi-Abad
116	12	15	10	10	12	12	45	Kusanj-e-Khalij
106	12	15	10	8	24	12	25	Foruz
141	24	40	10	6	24	12	25	Jonub-e-Bizhan-Abad
143	12	40	10	10	24	12	35	Mehr-Abad-e-Karkan
97	18	15	10	8	24	12	10	Jonub-e-Gharb-e-Aznav

This estimation can be accepted because of expression the vulnerability zoning and increase of *DI* index related to nitrate concentration. Parameter deletion sensitivity analysis, expresses the sensitivity of vulnerability map to delete one or more parameters (Equations 2 and 3) [2].

$$S_i = \left| \frac{V_i}{N} - \frac{V_{xi}}{n} \right| \quad (2)$$

$$VX_i = \frac{V_i - V_{xi}}{V_i} \times 100 \quad (3)$$

In this equations *Si*= sensitivity analysis, *Vi*= vulnerability index in the i-th cell, *n*= number of parameters used in cell vulnerability determining, *Vxi*= vulnerability index sign of i-th cell without any notice to *xi*, *n*= number of parameters used in the sensitivity analysis, *VXi*= changes index due to parameter deletion, *Vi*= vulnerability index gained from seven parameters deletion and *Vxi*= vulnerability index with no parameter deletion. Uni-parameters sensitivity analysis evaluates the effect of each parameter on the vulnerability index. This sensitivity analysis must be done to comparison the actual and theoretic weighting of parameters (equation 4) [2]. Sensitivity analysis of DRASTIC model must be used in order to determine the effectiveness of each parameter on the aquifer vulnerability.

$$W_{xi} = \frac{X_{wi} \times X_{ri}}{V_i} \times 100 \quad (4)$$

In this equation *Wxi*= effective weighting of parameter, *Xwi*= x parameter weighting in the I area and *Xri*= numeric value of DRASTIC to *xi* parameter. The most changes in vulnerability index in the parameter deletion sensitivity analysis of DRASTIC method, occurs after deletion the groundwater depth parameter. The most effective weighting average in the uni-parameter sensitivity analysis relates to groundwater depth (23.8%). Vulnerability index in the Malayer plain, by the use of GODS method and four defined parameters, ranges from 0 to 0.34. Ultimate vulnerability mapping is shown in Figure 5.

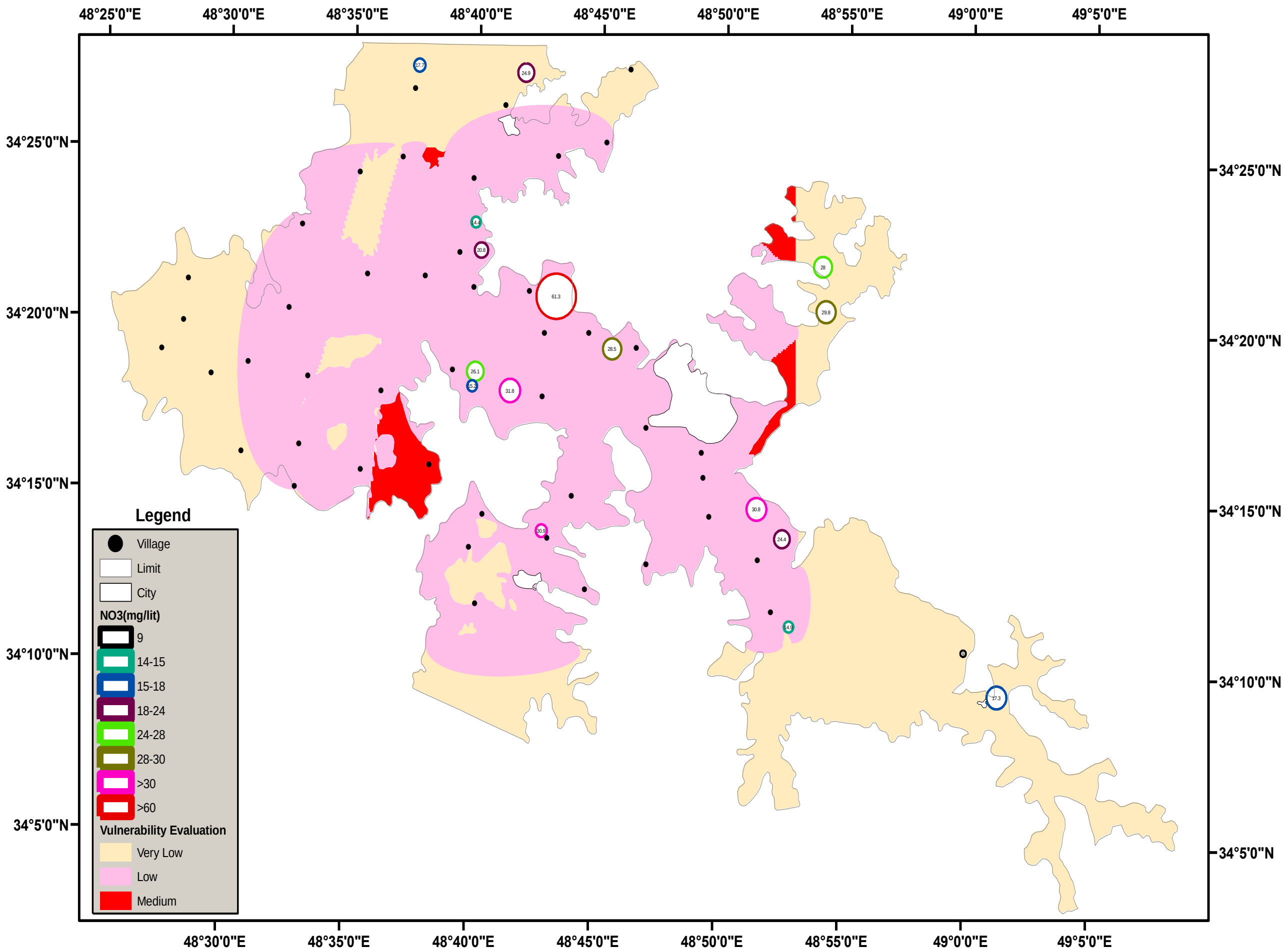


Figure 5. Aquifer vulnerability zoning in the Malayer plain by the use of GODS

In this way three groups of vulnerability very low, low and medium were obtained, which were 53%, 44% and 3% respectively. Central parts have medium vulnerability potential and northern and southern part and margins relate to very low vulnerability. In order to calibrate the GODS method.

The methods are compared in what follows:

- Vulnerability zoning by the use of DRASTIC method is more accurate than GODS method.
- Although vulnerability results are relatively equal in both methods, the vulnerability zoning using DRASTIC method is in accordance with pollutants sites, more. Vulnerability increases by the increasing of pollutants, gradually.
- There may be more faults for both methods in the margins, because the data collected from the margins are less than the centre, in number.
- Without calibration the DRASTIC method by the nitrate concentration, the vulnerability was very low. After calibration, due to high correlation between DRASTIC index and nitrate, vulnerability index increased. Also, the zoning results correlated with nitrate concentration, relatively.

- In both methods, vulnerability zoning categorized in three classes.
- Some points show medium vulnerability, but there's no pollution resource. Consequently, the pollution risk may be less. On the contrary, in some points vulnerability is low, but due to pollutants existence there, the risk of pollution may be more than other points.

Vulnerability zoning comparison is shown in Table 4.

Table 4. Comparison of two methods- DRASTIC and GODS- in vulnerability zoning

Vulnerability groups in DRASTIC method	Vulnerability groups in GODS method	Nitrate concentration mg/lit	Sample site
Medium	low	24.4	1
low	low	30.8	2
Medium	low	26.1	3
Medium	low	15.2	4
low	low	31.8	5
low	low	28.5	6
Medium	low	61.3	7
low	Very low	24.9	8
low	Very low	17.7	9
low	low	14.6	10
Very low	Very low	29.8	11
Very low	Very low	28	12
low	low	14.9	13
low	low	17.3	14
Very low	low	30.9	15
Very low	low	9	16
low	low	20.8	17

4. Conclusion

The results of chemical analysis on water samples according to the WHO and Iranian standards revealed that nitrate concentration as an indicator of biological contamination in Malayer Plain varies from 9 to 61.3 mg/lit. The nitrate concentrations were over 20 mg/lit in about 65% of the samples. Due to extreme blending with the wastewater outflow, the nitrate concentration is 61.3 mg/lit in the samples collected from the water well in Shirinabad Livestock Slaughterhouse. The increase in nitrate concentration at the wastewater outflow of raisin refining and packing plants and slaughterhouses is remarkable. In terms of heavy metals including lead, copper, cadmium, chromium, nickel and zinc, the aquifer in Malayer is not contaminated. The iron concentration exceeded the standards at 0.376 mg/lit only in the water sample collected from Kartilabad Poultry.

Vulnerability zoning by the use of DRASTIC method is more accurate than GODS method. Although vulnerability results are relatively equal in both methods, the vulnerability zoning using DRASTIC method is in accordance with pollutants sites, more. Vulnerability increases by the increasing of pollutants, gradually.

The most pollution potential relates to D parameter with the average of 20.88 m, and the list one relates to soil type. Changes indices in the parameter of depth to water table and vadose zone are more than other parameters and show the importance of these two parameters. In the parameter deletion sensitivity analysis of DRASTIC method, more changes occur with depth to water table deletion. In uni-parameters sensitivity analysis depth to water table has the most effective waiting in the parameters, nearly 23.8%.

DRASTIC method is more accurate in Malayer plain, and in this method sensitivity analysis is feasible. Uncertainties of some data are neutralized with certainty of other data (especially for I, T and C parameters which do not exist in the GODS method). DRASTIC method uses more parameters and rating and weighting in DRASTIC method are more precise than GODS method.

In order to reduce the environmental impact of contaminants such as nitrate, it is recommended that further investigation be conducted on how and why the relatively shallow wells are contaminated [19]. Since the urban waste has been amassed in Malayer's landfill, it is essential to insulate the site and prevent any leachate to water flows. Alternatively, the landfills can be relocated. Moreover, it is recommended that the outflow sewage at raisins refines and packing plants, slaughterhouses and poultry be continually sampled and examined. Furthermore, it is necessary to construct a refinery in highly pollutant factories. It is suggested that accumulation of biomass be prevented during rainy seasons, while restricting the application of pesticides with nitrate and livestock origins in the plain.

5. References

[1] Ghosh A, Tiwari AK, Das S. A GIS based DRASTIC model for assessing groundwater vulnerability of Katri Watershed, Dhanbad, India. Modeling Earth Systems and Environment [Internet]. Springer Nature; 2015 Jul 5;1(3). Available from: doi: 10.1007/s40808-015-0009-2.

[2] Belmonte-Jiménez SI, Campos-Enríquez JO, Zamora MA. Vulnerability to contamination of the Zaachila aquifer, Oaxaca, Mexico. Geofísica internacional. 2005;44(3):283-300.

[3] Foster SS. Fundamental Concepts in Aquifer Vulnerability, Pollution Risk and Protection Strategy: International Conference, 1987, Noordwijk Aan Zee, the Netherlands Vulnerability of Soil and Groundwater to Pollutants The Hague, Netherlands Organization for Applied Scientific Research. Netherlands Organization for Applied Scientific Research; 1987.

[4] Margat J. Vulnerabilite des nappes d'eau souterraine a la pollution: bases de la cartographie [Vulnerability of groundwater to pollution: database mapping]. BRGM Publication. 1968.

[5] Rahman A. A GIS based DRASTIC model for assessing groundwater vulnerability in shallow aquifer in Aligarh, India. Applied Geography [Internet]. Elsevier BV; 2008 Jan;28(1):32–53. doi: 10.1016/j.apgeog.2007.07.0085.

[6] Manos B, Papathanasiou J, Bournaris T. A multicriteria model for planning agricultural regions within a context of groundwater rational management. J Environ Manage. 2010; 91:1593 – 600.

[7] Singh, Prasoon Kumar, A. K. Tiwari, B. P. Panigarhy, and M. K. Mahato. "Water quality indices used for water resources vulnerability assessment using GIS technique: a review." Int J Earth Sci Eng 6, no. 6-1 (2013): 1594-1600.

[8] Boufekane A, Saighi O. Application of Groundwater Vulnerability Overlay and Index Methods to the Jijel Plain Area (Algeria). Groundwater [Internet]. Wiley-Blackwell; 2017 Aug 21;56(1):143–56. doi: 10.1111/gwat.12582.

[9] Al-Abadi AM, Al-Shamma'a AM, Aljabbari MH. A GIS-based DRASTIC model for assessing intrinsic groundwater vulnerability in northeastern Missan governorate, southern Iraq. Applied Water Science [Internet]. Springer Nature; 2014 Aug 3;7(1):89–101. doi: 10.1007/s13201-014-0221-7.

[10] Jessica EL, Sonia T. Groundwater vulnerability assessments and integrated water resource management. Watershed Manag Bull 13(1):18–29, (2009).

[11] Baghapour MA, Fadaei Nobandegani A, Talebbeydokhti N, Bagherzadeh S, Nadiri AA, Gharekhani M, et al. Optimization of DRASTIC method by artificial neural network, nitrate vulnerability index, and composite DRASTIC models to assess groundwater vulnerability for unconfined aquifer of Shiraz Plain, Iran. Journal of Environmental Health Science and Engineering [Internet]. Springer Nature; 2016 Aug 9;14(1). doi: 10.1186/s40201-016-0254-y.

[12] Hamedan Water Organization. "Malayer Groundwater Sources Balance Report", (1997-1998).

[13] Hamedan Water Organization. "Malayer Groundwater Sources Balance Report", (2005-2006).

[14] The Ministry of Energy of Iran. Water Sources Engineering Standards, Issue 3, PP. 116, (1992).

[15] Todd Keith and D., W. mays, L. "Groundwater hydrology" John Wiley & Sons, Inc, 636, (2005).

[16] Mato, Rubhera Rukumbuja Aloyce Mtani. "Groundwater pollution in urban Dar es Salaam, Tanzania: assessing vulnerability and protection priorities." (2002).

[17] Stokes SN. Mapping Ground water Vulnerability to contamination in Texas GIS for water resources CE 394K3 Term Project Presentation One. University of Texas at Austin. 2003:23-7.

[18] Aller L, Bennett T, Lehr JH, Petty R. DRASTIC: A System to Evaluate the Pollution Potential of Hydrogeologic Settings by Pesticides. Evaluation of Pesticides in Ground Water [Internet]. American Chemical Society; 1986 Jul 17;141–58. doi: 10.1021/bk-1986-0315.ch008.

[19] Godfrey S, Smith M. Improved microbial risk assessment of groundwater. Hydrogeology Journal [Internet]. Springer Nature; 2005 Feb 25;13(1):321–4. doi: 10.1007/s10040-004-0412-7.