IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 13, Issue 7 Ser. I (July. 2019), PP 39-44
www.iosrjournals.org

Assessing Groundwater Vulnerability to Contamination in A Semi-Arid Environment Using DRASTIC And GOD Models, Case Of F'kirina Plain, North Of Algeria.

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Abstract: *Groundwater is vulnerable to contamination by anthropological activities. Vulnerability mapping is considered as a fundamental aspect of groundwater management. The aim of this study was to estimate aquifer vulnerability by applying the DRASTIC and GOD models in F'kirina agricultural plain northern Algeria. The DRASTIC model uses seven environmental parameters (depth to water, net recharge, aquifer media, soil media, topography, impact of vadose zone, and hydraulic conductivity) to characterize the hydrogeological setting and evaluate aquifer vulnerability. GOD is an overlay and index method designed to map groundwater vulnerability over large regions based on three parameters (groundwater confinement, overlying strata, and depth to groundwater). The information layers for models were provided via geographic information system. The results showed that the DRASTIC model is better than GOD model to estimate groundwater vulnerability to pollution in the measured wells. For DRASTIC model, the correlation coefficient between vulnerability index and nitrate concentration was 68 % that was substantially higher than 28 % obtained for the GOD model. We can conclude that nitrate concentration should be a suitable parameter to investigate the accuracy of the DRASTIC and GOD models.*

Keywords: *F'kirina plain; DRASTIC; GOD; Groundwater contamination; Nitrate.*

Date of Submission: 27-06-2019 Date of acceptance: 13-07-2019

I. Introduction

In the arid and semiarid regions of the world, water resources are limited and are under pressure due to pollution, population growth, increasing per capita water use, and irrigation. The management of water resources, especially groundwater, has become an increasingly pressing issue in these areas [1]. With the scarcity of surface water, groundwater instead is considered to be one of the most important water sources of various regions. F'kirina plain that is situated in the northeast part of Algeria as explained in Figure 1 is a typical example where grounds water is the main source for all humans' activities. In this region groundwater quality is usually subject to contamination because it's an agriculture-dominated area having intensive activity involving the use of fertilizers among which and pesticides. Vulnerability assessment has been recognized for its ability to delineate areas which are more easily contaminated than others as a result of anthropogenic activity on/or near the earth's surface. The vulnerability of groundwater needs to be assessed as it is not only a function of the intrinsic properties of groundwater flow system (hydraulic conductivity, porosity), but also of the proximity of contaminant sources and their particular characteristics (location, chemical interaction with surface water) that could potentially increase the load of specific contaminants to aquifer systems However, the estimation of groundwater vulnerability is a complex procedure and depends on the temporal and spatial variability of contamination sources [2]Different methods have been introduced to estimate groundwater vulnerability. These methods may be divided into three general categories: process-based simulation models, statistical methods, and overlay and index methods [3]. Overlay and index methods are based on combining different maps of the region. The more popular types of the overlay and index methods are GOD [4]and DRASTIC [5]The DRASTIC model uses seven environmental parameters (depth to water, net recharge, aquifer media, soil media, topography, impact of vadose zone, and hydraulic conductivity). GOD model is based on three parameters (groundwater confinement, overlying strata, and depth to groundwater). The objectives of this study were: (1) assessing groundwater vulnerability of F'kirina plain to contamination using DRASTIC and GOD models and (2) performance comparison of DRASTIC and GOD models for the evaluation of groundwater contamination.

II. Materials And Methods

2.1 Study site

The study area is located in the North of Algeria between 35 ° 39′ 50″ N and 7 ° 17′ 55″ E in the Figure 1. This region covers an area of approximately 540 km². It is limited to the North by the line of water formed by Djebel El Galaa Kebira (1246 m) and Djebel Ammamrat El Kebira (1203 m). on the South by the line of water formed by Djebel Boutekhma (1291 m) and Djebel Amer (1259 m) to the East by the watershed line formed by Djebel El Medjifla (1174 m) and Djebel Fedjidjet (1291 m) and to the West by a large area flat limit the high constantinoises plain and by the Garaet Tarf. The area has a mean annual rainfall of 400 mm, and a mean annual air temperature of 15°C. The average elevation of the study area is 1300 m above sea level. Low annual rainfall and an extremely hot weather during spring and summer give the semi-arid characteristic of the study area. The direction of the regional groundwater flow over the whole basin is from the carbonate formation to the lake of GarâatTarf.

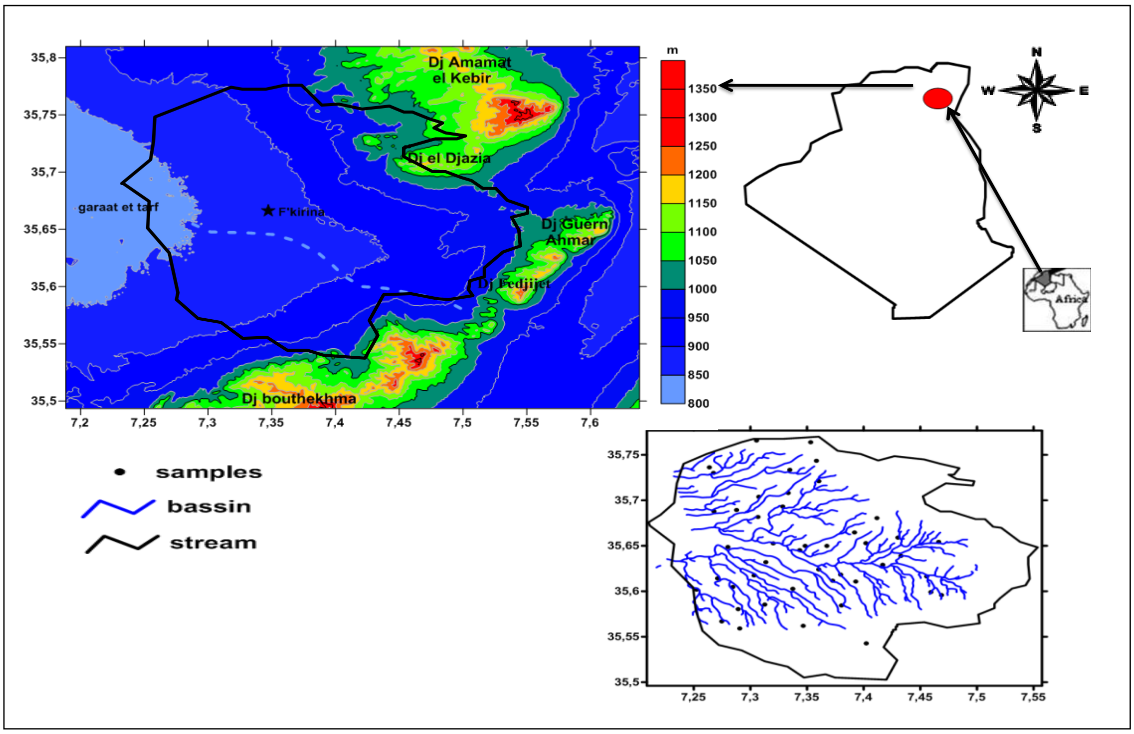

Figure 1: Localization of study area.

2.2 Geology

In the study area in the Figure 2 the Triassic outcrop was observed in the Northeast and South West of Ain Delâa and F'kirina. Cretaceous formations are represented by marly-limestones with platelet limestone at the base. It also shows on the surface in the northern margin of Ain Beïda where it ishighly fractured.The Eocene formations show a marly and a carbonate sequence separated by a slightly sandstone. Outcrops of Miocene are of small dimensions and are distributed in the southern part of the plain. So, it's a series composed by a set of marly-limestone at the top, a set of thick limestones at the center of the series.

The Pliocene is made up of sand continental detrital deposits, conglomerates, marls and clays reddish. Quaternary deposits have covered most of the plains; these deposits are very varied however sedimentation is much clay and marly.

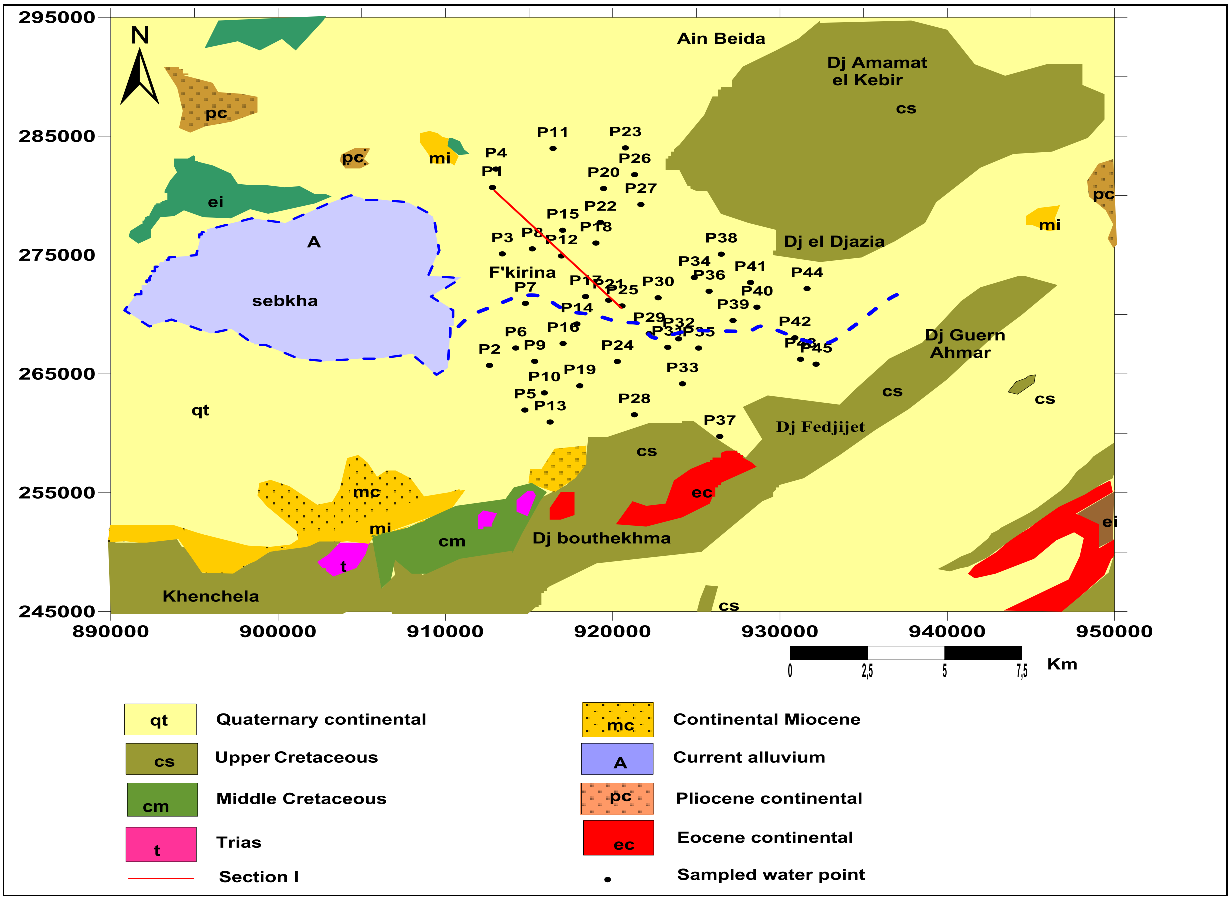

Figure 2. Geological map of study area.

III. Methodology

In order to assess the aquifer vulnerability to pollution in F'kirina plain, two models were used: GOD and DRASTIC. The information about the layers for each model was provided via geographic information system (GIS). ArcGIS 10 software was used to create an interactive geodatabase, compile the geospatial data, compute the GOD and DRASTIC indexes, and to generate the final vulnerability maps.

3.1 Description of the DRASTIC method

This method was developed in the 1980 by the National Water Well Association, in order to assess the risks of groundwater pollution. It was developed by the Environmental Protection Agency (EPA) in the United States in 1985, and by Aller et al., in 1987, to estimate the groundwater pollution potential. This method is supposed to assess the vertical vulnerability, based on seven parameters. Each first letter of a parameter is part of the name of this method, and each one of the seven parameters is assigned a multiplicative factor (Dp), which increases from 1 to 5 (table.2), depending on its importance in assessing the vulnerability [4]. These parameters are classified by categories that are associated with ratings, ranging from 1 to 10. The lowest rating represents the lowest conditions of vulnerability to contamination. A numerical value, called DRASTIC vulnerability index, denoted DI is determined; it describes the vulnerability level of each hydrogeological unit. The DRASTIC vulnerability index is calculated as the sum of products of ratings and weights assigned to each corresponding parameter.

$$DI = Dp*Dn + Rp*Rn + Ap*An + Sp*Sn + Tp*Tn + Ip*In + Cp*Cn$$

- D_n, R_n, A_n, S_n, T_n, I_n, C_n are the ratingsfor DRASTICparameters.
- D_p , R_p, A_p, S_p, T_p, I_p, C_p are the weightsfor DRASTICparameters.

Parameters	Weights	Parameters	Weights	Parameters	Weights
D : Depth of water	5	A : Material of Aquifer	3	T : Land slope	1
R : Effective recharge	4	S : Type of soil	2	I : Impact of unsaturated zone	5
C: Hydraulic conductivity	3				

Table 2. Weights of DRASTIC parameters [5].

3.2 Description of the GOD method

This method was developed in England by Foster, in 1987. It determines the vulnerability of the aquifer, with regard to the vertical percolation of contaminants, through the unsaturated zone. The principle of this method is based on the identification of three criteria, namely the Type of aquifer (Groundwater occurrence), Type of aquifer in terms of lithological factors (Overall aquifer class), and aquifer depth (Depth of aquifer) [6]. Calculation of the GOD vulnerability index: Iv (GOD) = CA * CL * CD Where CA is the rating of the type of aquifer, CL is the lithography rating of the unsaturated zone of the aquifer, and CD the rating of depth at the aquifer surface. The ratings used for the parameters range from 0 to 1..

Aquifertype	Note	Lithology(X-m)	Note	Depth to aquifer (m)	Note
Non-aquifer	0	<60	0,4	<2	1
Artesian	0,1	100	0,5	2-5	0,9
Confined	0,2	100-300	0,7	5-10	0,8
Semi-confined	0,3-0,5	300-600	0,8	10-20	0,7
Unconfined	0,6	>600	0,6	20-50	0,6

Table 1: Attribution of notes for GOD model parameters [6].

Once the indices of the two methods are calculated, the vulnerability classes, corresponding to the intervals of indices obtained, should be determined. Generally, these indices are distributed between five vulnerability classes, ranging from "very low" to "very high"(Table.3).

Vulnerability indices with DRASTICmethod	Vulnerability indices with GOD method	Corresponding vulnerability class
50-75	00-0.1	Very low
75-100	0.1-0.3	Low
100-125	0.3-0.5	Medium
125-150	0.5-0.7	High
150-200	0.7-1	Veryhigh

Table 3. Interval of vulnerability index and corresponding class.

IV. Results and discussion

The vulnerability maps, obtained from the DRASTIC and GOD methods in the Figures 3 and 4, for the Mio-Plio-Quaternary aquifer in the F'kirina plain, show that the most predominant class with the DRASTIC method, corresponds to a medium degree of vulnerability. However, the GOD method indicates that most of the valley has a low degree of vulnerability.

4.1 Vulnerability map using the DRASTIC method

- Class "Low" covers 30% of the land in the Ouest part of study area near the sabkha of Garaet tarf. This low index is due the lithological nature of the terrain in the Figure 3.
- Class "Medium" extends from south to north; it covers the largest portion of the plain (74.30%). The medium degree of vulnerability is related to the average depth of the aquifer, and also to the semi-permeable geological formations (sand with clay or gypsum passages), reflecting an average permeability.

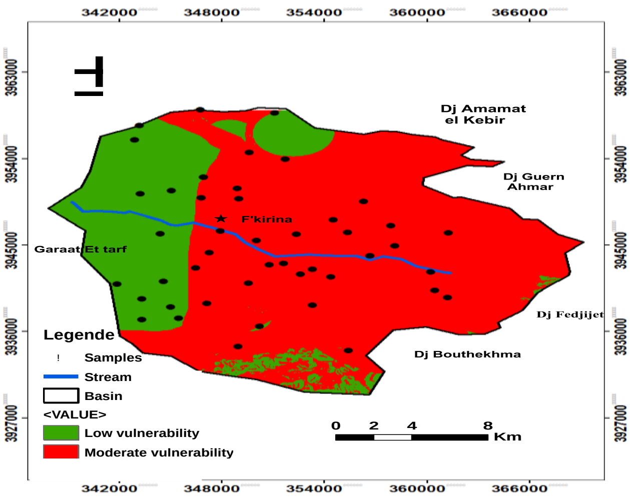

Figure 3. Map of vulnerability to pollution, according to the DRASTIC method.

4.2 Vulnerability map using the GOD method

- Class "Low" around the sabkha of Garaet et tarf it covers 45% of the mapped area in the Figure 4. This level of vulnerability is due to the average depth of the aquifer and to lithology of the unsaturated zone.
- Class "Medium" covers the largest portion of the plain (55%). This low degree can be explained by the significant piezometric height .

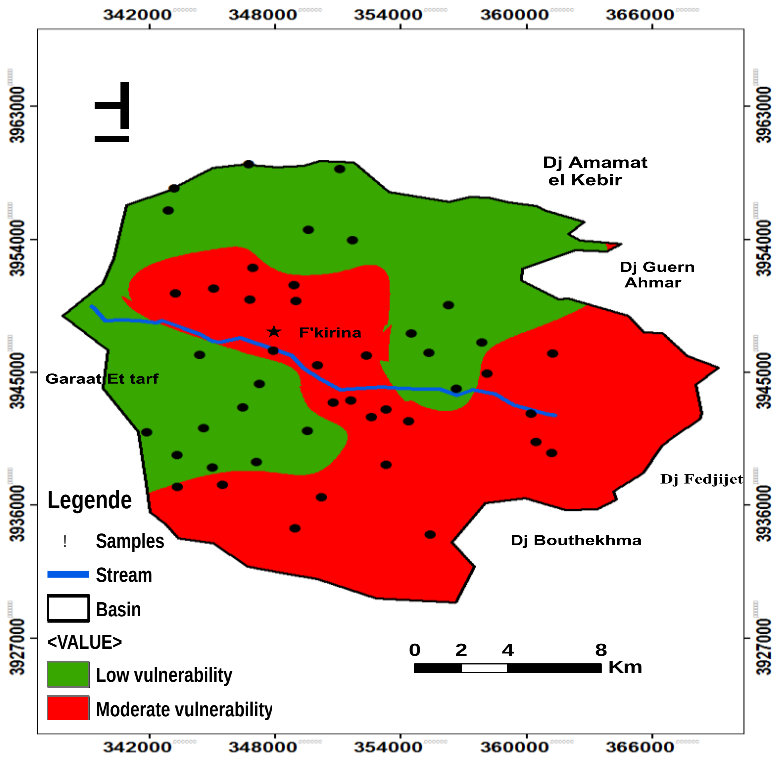

Figure 4. Map ofvulnerability to pollution, according to theGODmethod.

V. Vulnerability Maps Validation To Nitrate Pollution

5.1 Nitrate spatial distribution into groundwater

Nitrate spatialvariation concentrations nitrate concentration into groundwater in the Figure 5 depends on agricultural activities, covering soil lithology and airy area thickness. Recorded contents in 45 samples collected in Mai 2015 show the following:

- The highest values are observed in the northeast corner of the plain. These values frequently exceed the threshold of 50 mg/l tolerated by the WHO (World Health Organization) for drinking water. Nitrate high-concentration in this corner is attributed to the highly fertilized agricultural fields.
- In the rest of the plain, nitrate concentrations are close to 20 mg/ thanks to traditional soil fertilization practices and clay covering soil, allow protection of groundwater against pollution.

The comparative study, conducted by the DRASTIC and GOD methods, showed that the first method (DRASTIC) gives more detailed information for the representation of vulnerability, another point worth noting is that the GOD method uses only three parameters, against seven parameters for the DRASTIC method. Therefore, it seems that the amount of information acquired in assessing the vulnerability by the GOD method is not sufficient enough to understand the functioning of the Mio-Plio-Quaternary aquifer system, in F'kirina plain, since the nitrate map obtained is relatively uniform as compared to the DRASTIC method which provides a very diversified vulnerability index map,

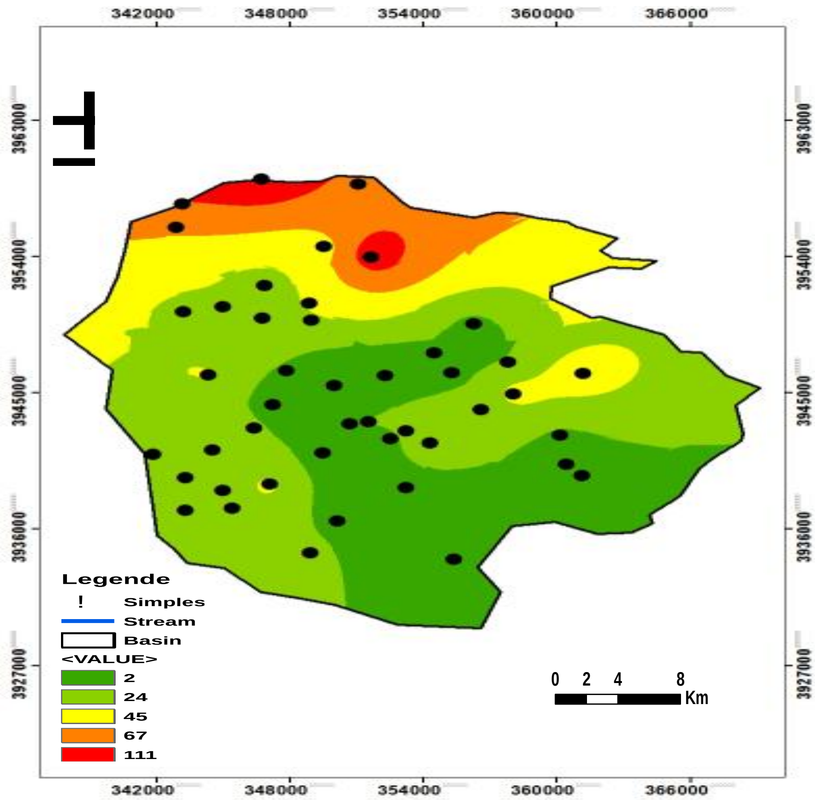

Figure 5. Nitrate distribution map.

VI. Conclusion

Mapping the intrinsic vulnerability of the Mio-Plio-Quaternary aquifer in F'kirina plain using the DRASTIC and GOD methods, showed a trend towards medium vulnerability for the DRASTIC method (70 %) and low vulnerability for the GOD method (50%). Comparing the two vulnerability maps, obtained with the two methods (DRASTIC and GOD), showed that the first method (DRASTIC method) best represents the distribution of degrees of vulnerability to pollution in the Mio-Plio-Quaternary aquifer, in in F'kirina plain. The results obtained are relative values of the assessed area only; they do not represent an absolute vulnerability. Moreover, these vulnerability maps use the characteristics of the environment only; they do not consider the nature of the pollutant. They are valid only for the periods considered. Then, it would be interesting to validate the results obtained by the DRASTIC method, and to the nitrate map that could be based on the time necessary for the infiltration and conservation of pollutant concentrations. The discussed groundwater vulnerability map can be a useful tool for land-use planners, hydrogeologists and water managers. Based on the results of the project, it is possible to determine the location of the land. Comparing the vulnerability map and land-use map, it is possible to identify the areas where there is significant risk of groundwater contamination [7].

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