INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 9, No. 4, p. 124-132, 2016
http://www.innspub.net

RESEARCH PAPER | OPEN ACCESS

Analysis of the aquifer vulnerability of a Miopliocene arid area using DRASTIC and SI models.

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Article published on October 30, 2016

Key words: DRASTIC, SI, GIS, Biskra sandy aquifer, Algeria

Abstract

Many methods in the groundwater vulnerability have been developed in the world (methods PRAST, DRIST, APRON/ARAA, PRASTCHIM, GOD). In this study, our choice dealt with two recent complementary methods using category mapping of index with weighting criteria (Point County Systems Model MSCP) namely the standard DRASTIC method and SI (Susceptibility Index). At present, these two methods are the most used for the mapping of the intrinsic vulnerability of groundwater. Two classes of groundwater vulnerability in the Biskra sandy aquifer were identified by the DRASTIC method (average and high) and the SI method (very high and high). Integrated analysis has revealed that the high class is predominant for the DRASTIC method whereas for that of SI the preponderance is for the very high class. Furthermore, we notice that the method SI estimates better the vulnerability for the pollution in nitrates, with a rate of 85% between the concentrations in nitrates of groundwater and the various established classes of vulnerability, against 75% for the DRASTIC method by including the land use parameter, the SI method produced more realistic results.

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Introduction

Both underground and surface freshwaters are a sensitive ecological heritage. It is important to manage and maintain them and are therefore an economic important issue (WHO, 2006). However, many authors find that the freshwater resources are under increasing pressure with multiple anthropogenic stresses that can perturb more and more these resources (Jourda *et al,* 2007; Ake *et al*, 2009; Djabri, 2012).

Groundwater contamination is a major concern for groundwater resource managers worldwide (Kaliraj and al, 2015; Sadat-Noori and Ebrahimi, 2016). In this context, the issue of water management appears essential, especially in some arid regions where rainfall is scarce: the case of northern Algerian Sahara. In this region, the surface water balance is more random; people must make use of the basement, through artesian wells (Mebarki, 2009). Since they are perennial, the management of groundwater resources is a real challenge for the future sustainable exploitation.

Vulnerability assessment to delineate areas that are more susceptible to contamination from anthropogenic sources has become an important element for sensible resource management and land use planning. The present study investigates sensitivity to pollution of the sandy aquifer of Biskra, using two complementary methods. We evaluated groundwater pollution potential by producing a vulnerability map of an aquifer using a modified Depth to water, Net recharge, Aquifer media, Soil media, Topography, Impact of vadose zone, and Hydraulic conductivity model (methods of DRASTIC and SI), integrated into the Geographic Information System (GIS). This approach allows mapping of the sensitive areas in order to increase protection measures and to provide best management capabilities.

Material and methods

Study area

The study area is the Miopliocene sandy aquifer located in the wilaya of Biskra (Fig. 1). This sedimentary reservoir of marine and continental origin (Cornet, 1964) exhibits various lithological facies (clay, sand, sandstone, sometimes with the presence of gypsum and some limestone beds). Its hydraulic system is also very heterogeneous; it shows variation in aquifer permeability and thicknesses (Chebbah, 2007). According to them, from the base to the top of the aquifer, we find the following sets:

- clay formation, with a thickness of a few tens of meters, which in the northern region is found in contact with limestone bedrock.
- sandstone outcrops with sandy clays at the base at very variable thickness by location that may exceed 150 m.
- A very thick clayey sandstone unit (over 500 m) in which there are two subsets : the first subset is consisting of an alternation of clays, sandy clay and sandstone, and the second one is composed of sandstone and clayey sandstone with gravel deposits.
- A set that contains conglomeratic sandstone lenses at the base. Its thickness is on average 250 m and forms the contours of the reliefs of Rhéliss.

The sandy aquifer of Biskra has an average depth of 120 m and an average flow of 10 l/s. It is heavily exploited especially in the plain of El Outaya (Located north of the city of Biskra), and in daïras: Tolga (Southwest Biskra), Sidi Uqba, Ain Naga Chetma and M'zirâa (South-East of Biskra).

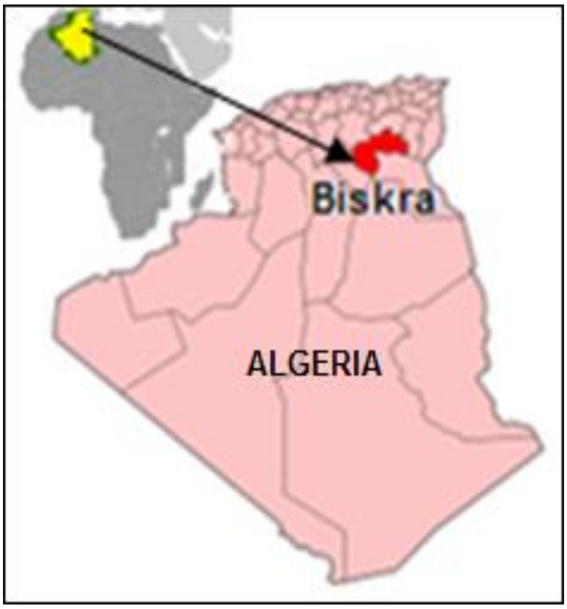

Fig. 1. Location of Biskra (Algeria).

Used equipment

An important collection of data was obtained from the National Agency for Water Resources (ANRH) relating to hydrogeology, geology, morphology, soil and topography of the environment in question. The compilation of these data with results from our fieldwork and laboratory (Piezometric surveys and chemical analyzes), has allowed us to acquire useful data, applied to different calculations of the used methods.

Method of the water vulnerability assessment

Two different but complementary methods were used in this study: one is assessing the intrinsic vulnerability (DRASTIC) and the other one the specific vulnerability (SI method).

Description of the DRASTIC method

The DRASTIC method was applied for the first time in 1985 in the United States of America, where it gave a very good result.

The acronym DRASTIC stands for the initials of seven factors determining the value of the vulnerability index (Bezelgues *et al.,* 2002): D: the depth of the water, A: effective recharge, A: materials of the aquifer; S: soil type, T: topography or slope, I: the impact of the non-saturated zone, C: permeability or hydraulic conductivity of the aquifer. The values of the weight parameters of the DRASTIC method defined by Aller *et al.,* 1987 are shown in Table 1.

Table 1. DRASTIC weight parameters as given by Aller *et al.,* (1987), applicable to ANRH data that are used for calculation and mapping.

Symbole	Properties	Type of information on the sandy aquifer of Biskra (ANRH, 2002)	Poids
D	Thickness of ZNS	- topographic curves - piezometric surveys	5
R	Net Recharge	- geological, Hydrogeological and geophysical studies; - Study of the hydro-agricultural development; - Rainfall data.	4
A	Lithology of the Aquifer	- sections of the lithologic drilling; - Hydrogeological map of the region	3
S	Soil	- Agro-pedologic study.	2
T	Topography	- topographic maps, scale 1/50 000.	1
I	Non-satured zone (Vadose)	- sections of the lithologic drillings ; - geophysical study - geologic map	5
C	Permeability	- geophysical and hydrogeological study.	3

For each parameter a rating scale is attributed with intervals corresponding to a rating dimension of the medium. Ratings are ranged from 1 to 10 (Tab.2, next).

Table 2. Notations according to the DRASTIC parameters (Lallemand-Barrès, 1994).

D : distance to the aquifer Thickness of ZNS		R : Recharge	
Values in m	rating	Values in cm	rating
0 à 2	10		
2 à 4	9		
4 à 6	8		
6 à 8	7	0 à 5	1
8 à 11	6	5 à 10	3
11 à 14	5	10 à 15	6
14 à 18	4	15 à 25	8
18 à 25	3	>à 25	9
25 à 33	2		
> à 33	1		

D : distance to the aquifer Thickness of ZNS		R : Recharge	
Values in m	rating	Values in cm	rating
A: Nature of the saturated zone		**S**: Type of soil	
Karstic limestone	10	Thin or absent	10
Sand and gravel	8	Sand	9
massive sandstone	6	Sandy loam	6
weathered Metamorphic rocks	4	Loams	4
Métamorphic rocks	3	Silty loams	3
Masive Shale	2	clay	1
T : Topography (slope)		**I** : Lithology of the vadose strata	
Value in %	rating		
0 à 2	10	Karstic limestone	10
2 à 6	9	Sand and gravel	9
6 à 8	8	Sand and gravel with silt and clay	8
8 à 10	7	sandstone	6
10 à 12	5	limestone	6
12 à 18	3	Silt/clay	1
>à 18	1		
C : hydraulic Conductivity			
Value (m/s)		Rating	
$>9,4\ 10^{-4}$		10	
$4,7.10^{-4}$ à $9,4\ 10^{-4}$		8	
$32,9.10^{-5}$ à $4,7.10^{-4}$		6	
$14,7.10^{-5}$ à $32,9.10^{-5}$		4	
$4,7.10^{-5}$ à $14,7.10^{-5}$		2	
4,7.10-7 à $4,7.10^{-5}$		1	

As soon as the different classes are defined with the assignment of their ratings, the method has determined the DRASTIC vulnerability index denoted ID, which allows characterizing the degree of vulnerability of a given sector of the aquifer. The vulnerability is more important when the calculated ID index is high. This index is defined as follows (Osborn *et al*, 1998):

ID = Dc x Dp x Rp + Rc + Ac + Ap x Sc x Sp x Tp + Tc + Ic x Ip + Cc Cp x.. (Where D, R, A, S, T, I, C are the seven parameters of the DRASTIC method, P is the weight parameter (Varying from 1 to 5); and c the associated rating dimension (ranging from 1 to 10).

The calculated index is as a measure of the level of contamination of the hydrogeological unit to which it relates. This risk increases with the value of the index. It can take a maximum value of 226 (100%) and a minimum value of 23 (0%). A classification was established by Engel *et al.* 1996, which allows to fix the limits of the intervals of the calculated indices and to match classes of vulnerability to these indices (Tab. 3).

For each of the seven parameters used by the DRASTIC method, a thematic map is performed. On each of these maps, areas are delineated, characterized by an index of a partial vulnerability of the corresponding parameter.

Table 3. Evaluation criteria of the vulnerability in the DRASTIC method (Engel *et al.*, 1996).

Level of vulnerability	Vulnerability index
low	< à 101
moderate	[101 à 140][
high	[140 à 200]
very high	>à 200

Description of the SI method

The SI (Susceptibility Index) method is a specific vertical vulnerability developed by Ribeiro (2000) to account for the behavior of agricultural pollutants, mainly the nitrates. The four common parameters (DSTI) in both methods, we can add a fifth parameter which is land use (OS) that takes into account the impact of human activities.

The index of sensitivity to water pollution (SI) is the product of the DRASTIC vulnerability index (IV) and the index of water quality (IQ) (Pusalti *et al*., 2009). It is given by the following expression: SI = IV x IQ.

It should be noted that the estimation of the final index (IV) needs first to assess the partial DRASTIC index for each of the seven parameters. This partial index is assigned a weight and a rating ranging from January to May and from 1 to 10 respectively; defining consequently the degree of vulnerability (Go *et al*., 1987). In addition, indexing the sensitivity of the quality of irrigation water (Neubert *et al.,* 2008) and drinking water (Pusalti *et al.,* 2009), takes into account the classification of these waters into five groups according to the concentration of ions, namely: I= water very good, II=good, III= usable, IV = to be used with caution, and V = harmful. The limits of each class used for the considered parameters are listed in Tables 4 and 5.

The quality index (QI) is calculated according to the following equation :

$$IQ = \sum_{i}^{n} (C_i)^2$$

We notice that the summation is generally considered as a quality parameter (ions). This is the class of the parameter i (ion) with an integer value between 1 and 5 at a given location. Using the square of the Ci concentration of each ion can strengthen the effect of classes with poor quality. Two sensitivity maps will be developed by the SI method: map of the sensitivity index related to irrigation, and that one intended for drinking water (Figs. 4 and 5).

Table 4. Classification of irrigation water use (Pusalti *et al.,* 2009).

Parameters	Classe I very good	Classe II good	Classe III usable	Classe IV Usable with caution	Classe V harmful
CE (µS/cm)	0 - 250	250 - 750	750 - 2000	2000 - 3000	> 3000
Cl (mg/l)	0 - 142	142 - 249	249 - 426	426 - 710	> 710
NO_3^- (mg/l)	0 - 10	10 - 30	30 - 50	50 - 100	> 100
SO_4^{2-} (mg/l)	0 - 192	192 - 336	336 - 575	576 - 960	> 960
Na^+ (mg/l)	0 - 69	69 - 200	200 - 252	------	> 252

Table 5. Classification of drinking water (Neubert *et al.,* 2008).

Paramètres	Classe I very good	Classe II good	Classe III usable	Classe IV Usable with caution	Classe V harmful
CE (µS/cm)	0 - 180	180 - 400	400 - 2000	2000 - 3000	> 3000
Cl (mg/l)	0 - 25	25 - 200	------	------	> 200
NO_3^- (mg/l)	0 - 10	10 - 25	25 - 50	------	> 50
SO_4^{2-} (mg/l)	0 - 25	25 - 250	------	------	> 250
Na^+ (mg/l)	0 - 20	20 - 200			> 200

The Geographic Information System (GIS)

The Geographic Information Systems (GIS) are tools used for data crossing, location issues, zoning overlays, spatial analysis and visualization of spatial indicators. The development of maps from a database allows us to analysis and to design a representation of a given space. Knowledge of hydrological models linked to GIS contributes to better management of aquifers to predict such flows and possible pollution of those aquifers (Previl *et al.*, 2003). This improvement is of course depending on the accuracy and uncertainty of the data used in these models.

Results and discussion

Level of vulnerability according to DRASTIC

Fig. 2 shows the distribution of the indexed zones to the vulnerability index obtained by the DRASTIC method. The values obtained are in the range of the theoretical values according to the classification of Engel *et al.,* 1996. This classification has identified four levels of hydrogeological aquifer vulnerability (low, moderate, high and very high).

Thus, there are 42 areas that have been defined: 38 areas having vulnerability index between 101 and 133 (light areas), considered as a moderate vulnerability and 4 areas with a vulnerability index ranging between 157 and 159, corresponding to a high vulnerability (Dark areas).

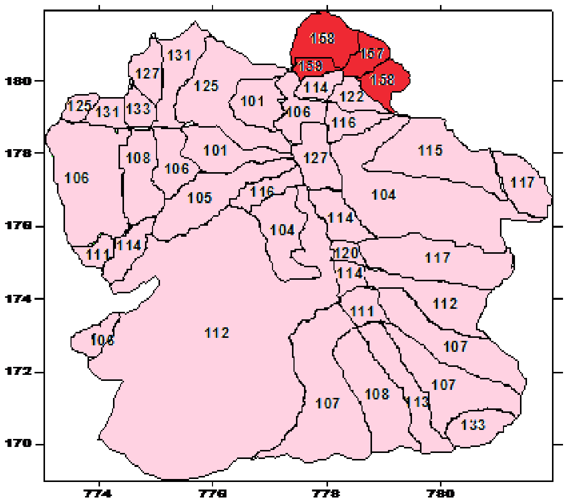

Fig. 2. Division of the study area into indexed areas according to the vulnerability index obtained from the DRASTIC method.

For each DRASTIC parameters, we have established a map on which are delineated areas according to intervals recommended by the DRASTIC rating system. The synthesis map (Fig. 3), is a result of the superposition of seven thematic maps related to the DRASTIC parameters.

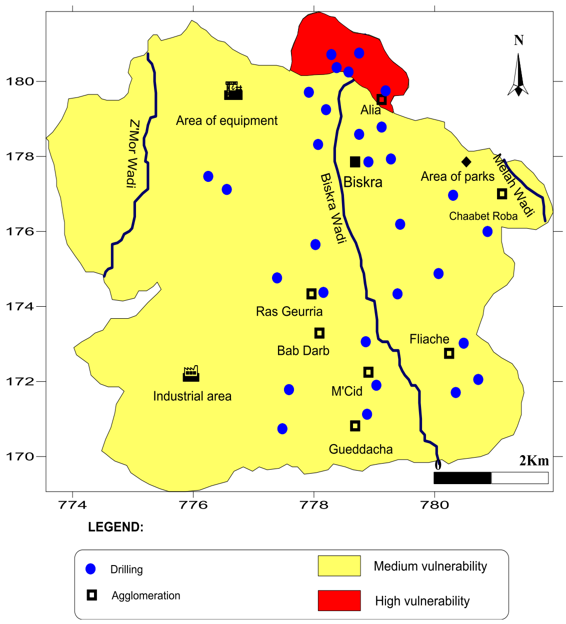

Fig. 3. Sensitivity mapping for water of the Biskra sandy aquifer pollution realized from data of the DRASTIC method.

Through this map, two levels of vulnerability to pollution were highlighted: moderate and high. The area of moderate vulnerability covers almost the entire territory of the aquifer (94%), while the area of high vulnerability (6%) is confined to the extreme north of the aquifer.

As a perspective, contamination of the aquifer due to surface pollution remains tolerable in the area of moderate vulnerability, because the pollutant will be difficult to cross the clayey sandy.

However, this will not be the case in the area of high vulnerability which should be subject to enhanced surveillance. Indeed, the relatively low depth of the aquifer and the non- saturated medium, composed of coarse sand, are conditions that promote infiltration of any contaminant present on the surface.

These findings require more protection of the aquifer located particularly in the area of high vulnerability from any pollution, mainly the one derived from agro-industrial plantations which are numerous in the study area. Nevertheless, Osborn *et al.*, (1998) have pointed out that even if the measure of the vulnerability of groundwater established by the DRASTIC method shows a low level, it is still considered as relative and therefore, the area is considered not so far away from contamination.

Level of vulnerability according to SI

The SI method differs from the DRASTIC method by its absence in taking into account the following parameters: hydraulic conductivity of the aquifer (C), impact of non-saturated conditions (I) and lithology of the aquifer (A). Indeed, Ribeiro (2000) has minimized these parameters because he considers that the hydraulic conductivity of the aquifer is difficult to assess in space, while the attenuation processes related to the parameter of "soil type" have no great effect on vulnerability.

These observations are also shared by other authors (Lobo-Ferreira and Oliveira, 2005; Stigter *et al.*, 2006. In addition, more recent studies (Hamza *et al*, 2007; Saidi *et al.*, 2009) show a good correlation between areas considered vulnerable by the SI method and the areas really contaminated after their exposure. In our study, two maps depicting the sensitivity level are developed : the sensitivity map of irrigation water use (Fig. 4), and that of water intended for drinking water (Fig. 5).

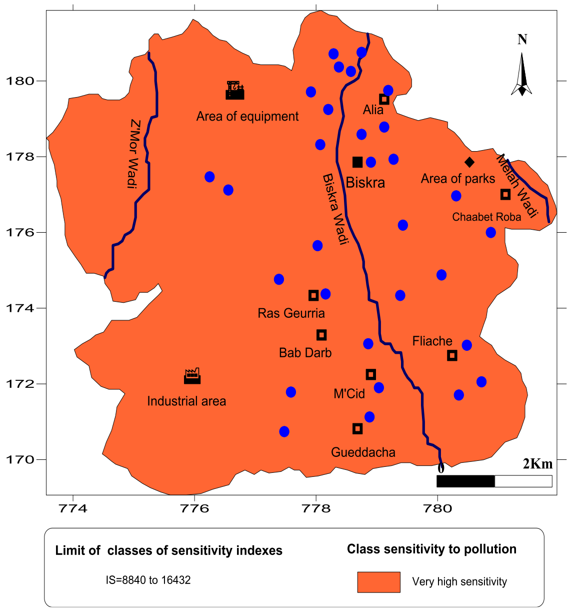

Fig. 4. shows that irrigation water, with a very high level of sensitivity to pollution, occupies the major part of the study area. However, we notice that the less sensitive area is spread over 3 km long and 500 m wide, located in the southeast of Biskra.

Fig. 5 shows that the entire study area has a very high level of sensitivity to pollution of the groundwater used for potable water. This is explained by the more restrictive criteria threshold of potable water quality.

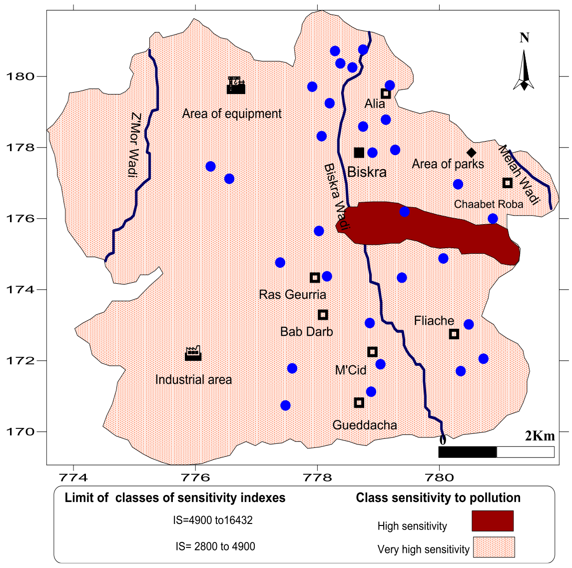

Fig. 5. Sensitivity map of water pollution in the sandy aquifer of Biskra, for the supply of drinking water.

Validation of the vulnerability maps

According to Hamza *et al.*, 2007; Ake *et al.*, 2009; Saidi *et al.*, (2009), the development of a vulnerability map is tested and validated by chemical analysis of groundwater. In the present study, this activity was carried out by a comparison between the distribution of nitrates in water of the aquifer and the distribution of vulnerability classes determined by the DRASTIC and SI methods. Analyzes of groundwater have been done on 20 samples from 12 drillings and 16 wells, evenly distributed over the study area.

Table 5 gives the distribution of values of nitrate concentration according to the degree of vulnerability through the application of DRASTIC and SI methods.

Table 6. Coincidence between nitrate concentrations and different vulnerability classes of DRASTIC and SI methods.

Vulnérability map	Degree of vulnerability	NO_3^- [0-10[(mg/l)	NO_3^- [10-30[(mg/l)	NO_3^- [30-50[(mg/l)	NO_3^- >50 (mg/l)	Rate of coincidence
DRASTIC	Moderate	8	3	1	2	75 %
	high	4	0	2	0	
Total		12	3	3	2	
SI	high	2	1	0	3	85 %
	very high	9	4	1	0	
Total		11	5	1	3	

This table shows on one hand the dominance of the vulnerability class 'moderate' in the DRASTIC method, on the other hand there is the predominance of the vulnerability class "very high" in the SI method. Moreover, it is shown that the rate of coincidence by the DRASTIC method is 75% less reliable than that of the SI method, which registers a rate of coincidence of 85%. The vulnerability map established using the later method reflects better the reality of the terrain.

This high rate of coincidence related to the SI method can be explained by the fact that the latter is specific to agricultural pollution from nitrates. The DRASTIC method in turn, is a method of intrinsic vulnerability that takes into account neither the nature of the pollutants or factors governing the specific vulnerability, such as land use. However, the rate of coincidence is satisfactory for both methods with at least 75%, which have proven their effectiveness in mapping water vulnerability to pollution.

Conclusion

Groundwater pollution risk mapping is carried out by overlay of layers representing the different parameters in the par metrics models. This overlay of the two models (DRASTIC and SI) by compiling hydro geological and hydro chemical sandy aquifer of Biskra data has allowed to index its vulnerability to water pollution. The integration of data from geographic information system (GIS) has defined risk areas with moderate and high indices. The region of moderate vulnerability covers almost the entire territory of the aquifer (94%). While the area of high vulnerability (6%), is confined to the extreme north of the aquifer, and which should be thus subject to special surveillance.

These results lead us to put a hypothesis of a pollution of the aquifer by infiltration of agricultural inputs (nitrates, etc..) into the soil surface. Regarding this situation, we shouldn't allow additional high risk activities in order to obtain economic advantage and to reduce environmental pollution hazard by taking necessary protection. Moreover, the validation test has allowed us to highlight more accurately the vulnerability to pollution of the groundwater by the SI method than that of the DRASTIC technique. Finally, we consider that the used methods of DRASTIC vulnerability, SI and Geographic Information System (GIS) are efficient methods to get a decision support and integrated planning tools to enable sustainable use of water resources. The results are a way to avoid possible contamination water.

References

Agence Nationale des Ressources Hydriques (ANRH). 2002. Carte d'inventaire des points d'eau dans la wilaya de Biskra Algérie.

Aké GE, Dongo K, Kouadio BH, Dibi B, Saley MB, Biemi J. 2009. Contribution des méthodes de vulnérabilité intrinsèque DRASTIC et GOD à l'étude de la pollution par les nitrates dans la région de Bonoua (Sud-Est de la Côte d'Ivoire). European Journal of Scientific Research **31(1),** 157-171.

Aller L, Bennet T, Lehr JH, Petty RJ, Hackett G. 1987. DRASTIC: a standardized system for evaluating groundwater pollution potential using hydrog-eological setting. EPA/600/2-87/035. US Env. Protection Agency 163 p.

Bézèlgues S, Des-Garets E, Mardhel V, Dörfliger N. 2002. Cartographie de la vulnérabilité de Grand-Terre et de Marie-Galatie (Guadeloupe). Phase 1: méthodologie de détermination de la vulnérabilité 45 p.

Chebbah M. 2007. Lithostratigraphie, Sédimentologie et modèles de bassins des dépôts néogènes de la région de Biskra, de part et d'autre de l'Accident Sud Atlasique. Thèse de Doctorat d'état, Université Mentouri, Constantine, Algérie 410 p.

Cornet A. 1964. Introduction à l'hydrogéologie saharienne, Revue de géographie physique et de géologie dynamique 2, Vol. VI, Fasc. 1, 5-72. *Djabri* L. 2012. Etats de la qualité des eaux en Algérie. XIIème Journée Nationale Génie Côtier – Génie Civil. Cherbourg, 12-14 juin 2012. France.

Engel BA, Navulur KCS, Cooper BS, Hahn L. 1996. Estimating groundwater vulnerability to non-point source pollution from nitrates and pesticides on a regional scale. Int. Assoc. Hydrol. Sci **235,** 521-526.

Hamza MH, Added A, Frances A, Rodriguez R. 2007. Validité de l'application des méthodes de vulnérabilité DRASTIC, SINTACS et SI à l'étude de la pollution par les nitrates dans la nappe phréatique de Metline-Ras Jebel-Raf Raf (Nord-Est Tunisien). Geoscience **339,** 493-505.

Jourda JP, Kouame KJ, Adja MG, Deh SK, Anani AT, Effini AT, Biemi J. 2007. Evaluation du degré de protection des eaux souterraines: vulnérabilité à la pollution de la nappe de Bonoua (Sud-Est de la Côte d'Ivoire) par la méthode DRASTIC. Actes de la Conférence Francophone. SIG 2007/10 au 11 Octobre 2007, Versailles-France 11p.

Kaliraj S, Chandrasekar N, Peter TS. Selvakumar S, Magesh NS. 2015. Mapping of coastal aquifer vulnerable zone in the south west coast of Kanyakumari, South India, using GIS-based DRASTIC model. Environnemental monitoring and sassement **187(1),** 1-27.

Lallemand-Barrès A. 1994. Normalisation des critères d'établissement des cartes de vulnérabilité aux pollutions. Etude documentaire préliminaire. Orléans BRGM (*édition*). France 128 p.

Mebarki A. 2009. Ressources en eau et aménagement en Algérie. Les bassins hydrographiques de l'Est. OPU, Alger 389 p.

Neubert S, Scheumann W, Kipping M. 2008. Water Politics, Policies and Development Cooperation: Local Power play and Global Governance, Springer, Geosciences 416 pages.

Oliveira M, Lobo-Ferreira JP. 2005. Análise de sensibilidade de aplicação de métodos indexados de avaliação da vulnerabilidade à poluição de águas subterrâneas no sul da península Ibérica, APRH (Édit-eurs), Lisbonne, Portugal 239-252.

Osborn NI, Eckenstein E, and Koon KQ. 1998. Vulnerability Assessment of Twelve Major Aquifers in Oklahoma: Oklahoma Water Resources Board Technical Report 98-5, 36 p.

Prévil C, Thériault M, Rouffignat J. 2003. Analyse multicritère et SIG pour faciliter la concertation en aménagement du territoire : vers une amélioration du processus décisionnel. Cahiers de géographie du Québec, vol **47, 130,** 35-61.

Pusatli TO, Camur ZM, Yazicigil H. 2009. Susceptibility indexing method for irrigation water management planning: applications to K. Menderes river basin, Turkey. Journal of Environmental Management, Vol **90, 1,** 341-347.

Ribeiro L. 2000. Desenvolvimento de um índice para avaliar a susceptibilidade dos aquíferos à contaminação. Nota interna, (Não publicada), ERSHA-CVRM 8 p.

Sadat-Noori M, Ebrahimi K. 2016. Groundwater vulnerability assessment in agricultural areas using a modified DRASTIC model. Environmental monitoring and assessment **188(1),** 1-18.

Saidi S, Bouri S, Ben Dhia H, Anselme B. 2009. A GIS-based susceptibility indexing method for irrigation and drinking water management planning: Application to Chebba–Mellouleche Aquifer, Tunisia. Agricultural Water Management **96,** 1683-1690.

Stigter TY, Ribeiro L, Carvalho-Dill AMM, 2006. Evaluation of an intrinsic and a specific vulnerability assessment method in comparison with groundwater salinisation and nitrate contamination levels in two agricultural regions in the south of Portugal, Hydrogeol J. **14,** 79-99.

Word Health Organisation (WHO). 2006. Guidelines for Drinking-water Quality. Recommendations, 3rd edition 595 p.