INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 13, No. 3, p. 109-116, 2018
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Groundwater vulnerability assessment using GOD method in Boulimat coastal District of Bejaia area North east Algeria

Khemmoudj Kaddour*[1], Balla El Hacen[1], Djenadi Hlima[2], Djerroud Yasmina[2]

[1]*Faculty of Life and Nature Sciences, University of Bejaia, Bejaia, Algeria*

[2]*Ecology and Environmental Department, Faculty of Life and Nature Sciences, University of Bejaia, Bejaia, Algeria*

Article published on September 30, 2018

Key words: GOD, Groundwater, Vulnerability, Boulimat coastal District, Algeria

Abstract

This study constitutes the diagnosis of groundwater assessment vulnerability of the Boulimat coastal district. It has been carried out identify the area at high risk of contamination either by sources of pollution (traffic road, wastewater, pesticides, fungicides, tourist and intrusion of saline waters, for this we used the method of GOD to draw a map of vulnerability, interpretation of this map revealed that the vulnerability represented by four classes: The index of GOD is high between which (0.5 to 0.7) represents 55% of the study area is located to the centre, generally the sources of the pollution is the intensive use of pesticides and fungicides; on the other hand the east side, the west side and the south side the GOD index is average between (0.3 to 0.5) which represents about 20% of the study area. In the coastal zone the index is ranged between (0.7 to1) which represent about 10%. The low vulnerability characterized by the GOD index is ranged between (0.1 to 0.3) which represent 15% localized in south study area. This study is a valuable tool for local authorities for managing groundwater resources, monitoring these problems closely and the act accordingly.

***Corresponding Author:** Khemmoudj Kaddour ✉ kaddour_khemmoudj@yahoo.fr

Introduction

Groundwater is one of the major sources of replenish-able water on the earth and constitutes approximately 30% of fresh water from the total water of which only 0.86% is fresh water and total available water is 0.022%. The groundwater is comparatively safe and reliable source as compared to surface water. Though not easily polluted, but once it is polluted it's exhaustively expensive, time consuming and extremely difficult to remediate this precious source of the contaminants it has been polluted with and replenish the lost integrity and sometimes it's impossible to restore. Due to increasing population, other anthropogenic activity (like agriculture, industrial, domestic waste etc.) changes in topography and relief, and land use land cover deteriorated it and its been over exploited and stressed due to ever increasing water demand and less availability of surface water (Gupta N. 2014). The socioeconomic development of a region depends on the availability of good quality water. Recent decades have seen a global increase in demand for freshwater, mainly satisfied by groundwater abstracted from aquifers via numerous wells and boreholes. Groundwater is under intense anthropogenic pressure in the Mediterranean basin, from sources such as changes in land use, urbanization, a lack of proper sewerage, intensive agriculture and a general increase demand. This factor can cause severe degradation of both the quality and quantity of groundwater resources (Civita, 1994; Polemio, 2005; Polomio *et al.*, 2008). Vulnerability is an ever changing concept; it was first introduced in France in 1960s to create awareness among the people and scholars towards groundwater health (Vrba and Zoporozec, 1994). Literal definition of vulnerability assessment means that it is a system that can identify the problem, the weakness that might make the system to succumb at the time of crisis or destabilization or any system which is sensitive to damage by one or the other or combination of factors. It analyzes all the available means by which the systems might get harmed and locates the most vulnerable or weak point and thereafter, measures can be taken to prevent, protect and avoid further damage of the ground water system. However, scientists have given various definitions to groundwater vulnerability. The main aim of the project is to assess the most vulnerable areas of the study area that are susceptible to the exploitation and overall contamination owing to their geological setting and other anthropogenic factors.

The identification of the vulnerable area would help in the managing the local groundwater resources from over exploitation and further deterioration and measure can be taken to improve the aquifer quantity and quality. Groundwater vulnerability assessment is done on the idea that the aquifer is not of same feature at all the locations and that some specific land area more vulnerable to deterioration in terms of quantity and quality (Gogu and Dassargues, 2000). Hence, it delineates the area which are more vulnerable or susceptible to contamination, and can help scientists to remediate (if contaminated), protect and prevent (if highly vulnerable) and policy makers to manage the resource in sustainable manner so as to assure the sustainable use of this precious resource, therefore leading to sustainability which is now the core aim of all the economies' of the world. The aquifer vulnerability is of two types. The first is intrinsic vulnerability which is due to the geology of the aquifer like clay layer thickness, overlaying media, lateritic layer thickness ect.

Several vulnerability assessment techniques have been developed. The most exhaustively exploited methods used are: The DRASTIC system (Aller al. 1987), the GOD system (Foster 1987), GLA (Holting *et al.*, 1995), KAVI (Beynen *et al*, 2012) the AVI ranting system (Van Stempvoort *et al.* 1993), the SINTACS method (Civita 1994), PI (Goldscheider *et al.*, 2000), the ISIS method (Civita and De Regibus 1995), the Irish perspective (Daly *et al.* 2002), RISK (Pitelet-Giraut 2000), the German method (Von Hoyer and Sofner 1998) and EPIK (Doerflinger *et al.* 1999).

Groundwater resources protection requires knowledge of groundwater to pollution vulnerability and any vulnerability information is essential to facilitate groundwater planning and management.

In Algeria several study of groundwater vulnerability to contamination by (khemmoudj *et al* 2014; Boulabaiz Mahrez *et al.*, 2017; Saadali and kherici., 2018) this study was undertaken with the aim of identifying area of high risk of contamination regardless of the type of pollutant by GOD (vulnerability) method and to know the effect of pollution on sustainable development of agricultural and tourism in the district and we will purpose some solicitations for this problem.

Materials and methods

Study area

Boulimat district has an area of around 45 km² (Fig.1.). It is located on the coastal strip on the western side of the town of Bejaia city North east (Algeria). It is surrounded by the Mediterranean Sea the north, the city of Bejaia from the east , the town of Oued Ghir from the south and the city of Beni Ksila from the west.

Boulimat Discrict is characterized by an irregular morphology. Two different zones are distinguished: a very broken part and another point which corresponds to the embouchure of Boulimat and Saket wadis (Fig. 1).

The culminating point is located at Djebel Gouraya (672m) (Fig.2), which overhangs the city in north and forms cape Carbon in the east. Up to Aghbalou mount which culminates upon (1316 m), extends a series of hills of variable altitude between 100 m and 500 m, in the north of Soummam up to Sidi Bou Drahem (490m) and of Manchar Trilast (681 m), the slopes varying among 0 to more than 45% (Fig 1). The Boulimat district known by a multiple pollution: the intensive use of chemical fertilizers in agriculture (pesticides and fungicides), the rise of sewage ,the waste discharge , the road traffic ,the touristic activity, salt water invasion and anthropogenic activity.

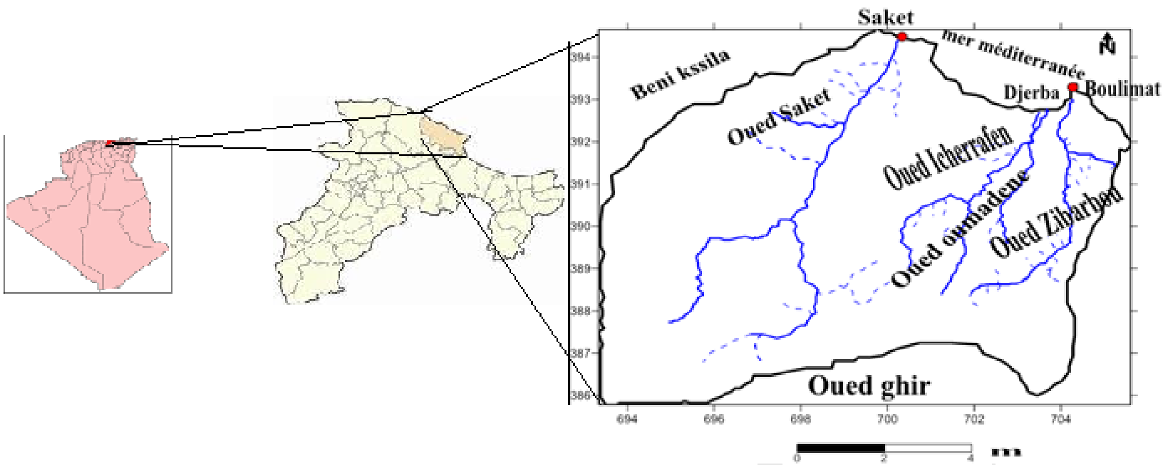

Fig. 1. Location map of the study area.

Geology

The Tellian atlas of Algeria consists of mountains ranges and valleys parallel to coastline, and showing diverse morphological aspect. Indeed this zone is made of young Mountain formed during Tertiary time by alpine orogeny, which consists of sedimentary units from north to south. The Tellian atlas is the nape domain with mountain basin and sedimentary column ranging from the Jurassic to Miocene. North Kabylia belongs to geological whole of Tellian Atlas; it corresponds to the internal zones of Maghrebides. It is represented by two massifs, small Kabylia and large Kabylia . These two massifs have crystalline base, and the Paleozoic which is an metamorphic, the kabylian ridge or calcareous range. Northern and southern kabylian flysch form a large band between internal and external zones. The southern part of kabylian domain corresponds to external zone of Maghrebides range. Kabylia belongs to the Tellian atlas, which is characterized by a lithological and structural complexity, which made this zone the object of several works. Indeed, it is one of the old solid masses of the internal zones of Maghrebides, with a Mesozoic and Tertiary cover.

The sector of the study corresponds to the oriental part of Babors, located at the west of Bejaia's golf axis. In Bejaia's area, several formations are distinguished , the Quaternary one with slopes unconsolidated, solifluctions, dunes and beaches sands, recent alluvia, muddy deposits of Oumaden, Ichrafenne, Ziberbou and Saket wadis and torrential alluvial cones, marshy alluvia, old alluvia, low terraces, muddy deposits, sandy and stony. Miocene superior-Pliocene, at the base, breaches re-cemented slopes passing under grey-bluish clays of Srir wadi. Lower Miocene, with facies Sea which are not very deep, limestones, sandy marl and conglomerates. Nummulitic beds are represented by Bouhattem conglomerates. Two series of flysch are distinguished: missylien flysch and the Mauritanian and an intermediate series. Moreover, the Cretaceous is composed of two sedimentary cycles, one Cenomanian-Turonian and second upper Senonian. The Jurassic one is presented by red and green schists, and limestones. The Lias is represented by calcareous marl and marl on cape Carbon and Djebel Oufarnou. Inter alia; several authors reported the presence of Trias in Gouraya-Aghbalou link (Hassissen 1989; Lilouche *et al.* 2018)

Hydrogeology

The different geological formations of the Boulimat coastal District, to better understand the system aquifer of the study area. Four aquifers identified ,aquifer of coastal sand , alluvium aquifer localized in Oumaden, Ichrafenne, Ziberbou and Saket wadis, the flysh aquifer localized in limitroph area and limestone aquifer localized in the south area. The geological sections we have summarized them in the. The tablecloth receives, in addition a lateral feeding from the aquifer in the flow of the Boulimat and saket wadis. In times of flood, these two wadis participate ,moreover, fully, in the supply of the aquifer of the Boulimat coastal district. In general, the piezometric map observes the direction of flow from south to north at the level of the littoral zone. The latter are related to the exploitation of the tablecloth. At the level of the littoral zone it has a contribution of marine water; the variation in the spacing of the piezometric curves is due mainly to the heterogeneity of the aquifer lithology (Saadali and kherici 2018; Gouadia *et al.*, 2011).

Table 1. Hydrogeological interest of geological formation.

Leasing	Formations	Thickness	Hydrogeology interest
South part	Karstic limestone	30m	Large underground water reservoir
Limitroph part	flyschs	25m	Low hydro geological interests
Midfielder	recent alluvia, muddy deposits	6m	Low hydro geological interests
Northern part	Fine Sand	1.5-5m	Large underground water reservoir

GOD method

The GOD method was developed in Foster (1987) and Foster and Hirata (1993). The GOD method is a simple and systematic method used exploratory approach towards determination of groundwater contamination risk, being the acronym for three attenuator parameters: G (groundwater hydraulic confinement) represents the hydraulic confinement of groundwater in the aquifer and is meant to attribute different vulnerabilities to water table, semi-confined or confined aquifers; O (Overlying strata) describes the type of materials present in the unsaturated zone above the aquifer, in keeping with their ability to neutralize contaminants; and D (Depth to groundwater table) measures the depth to groundwater level, being a proxy to the time that contaminants require to reach the aquifer. In the evaluation of GOD vulnerability, each composing parameter is assigned a value between 0 and 1, where 0 represents minimum vulnerability and 1 represents maximum vulnerability. For example parameter will approach 1 if the aquifer is unconfined and will decreases. Parameters O will be low when the unsaturated zone is composed of impermeable or consolidated materials (clays, fresh granites) and high when that horizon is made of permeable or loose sediments (clean sands, gravels, karstic limestone's). The GOD index which is used to evaluate and map the aquifer vulnerability caused by the pollution, was calculated by multiplication of the influence of the three parameters using the equation (1).

GOD Index = Cl × Ca × Cd

Where: Ca is the type of aquifer, Cl is the lithology of the unsaturated zone and Cd is the depth to aquifer.

Groundwater occurrence

None Over flowing Confined Semi confined Unconfined covered Unconfind 0 0.2 0.4 0.6 1

Overlying lithology

Unconsolited

Residuel soils loess alluvial site aeolien sand sand +gravels collovial gravels

Consolidated (porous rocks)

Mudstones shales siltstones volcanic sandstones tuffs chalky limestones calcarenites

Consolidated (dense rocks)

Igneous/Metamorphic Recent volcanic laves Calceretes+Limestones

0.4 0.5 0.6 0.7 0.8 0.9 1.0

Depth to Groundwater

Sup 100m	50–100m	20–50m	10–20m	5–10m	Inf 5m
0.4	0.5	0.6	0.7	0.8	0.95

Output Intrinsic Aquifer Vulnerability

C .Vuln	Very Low	Low	Average	High	Very High
Index	0 0.1	0.1 0.3	0.3 0.5	0.5 0.7	0.7 1

Results and discussion

Groundwater occurrence

In the natural context, groundwater generally takes place within geological formations that give rise to confined, Unconfined and semi confined aquifer.

The geological context of coastal aquifers (geometry, organization of permeable and impermeable formation has an undeniable influence on the presence of underground pollution (Saadali and kherici, 2018).

The aquifer type of Boulimat coastal district is a unconfined and confined aquifer (Fig 2), thus exposed more underground pollution. The index of groundwater occurrence is ranged in 0.1, 0.6 and 1.

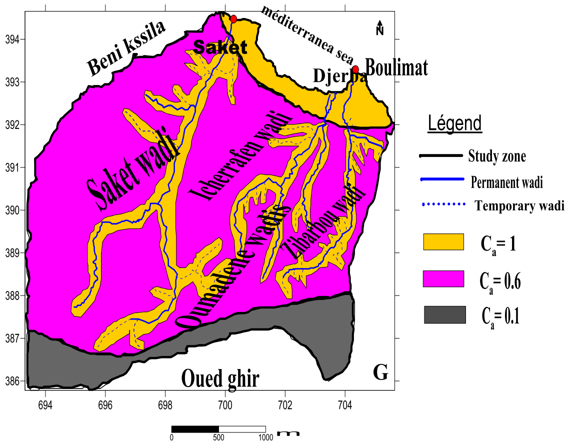

Fig. 2. Groundwater occurrence map.

Overall lithology of aquifer

It is a very important parameter and from it on can know if there is a protective layer or not and the thickness of the aquifer or of the saturated zone and also. Boulimat district (Fig 3) it is formed by fine sand, recent alluvial, muddy deposits, flyschs and karstic limestone. Depth to water table shows the map of the depth, in the study area the water level is weak, it does not exceed 30 meters, because of the measured depth in a very rainy period, which implies that the tablecloth more exposed to pollution generally the depth of the water between 0 and 5 meters to the north and 5 to 10 in the centre and 10 to 30 meters in the south. The index of overall lithology of aquifer ranged in 0.5, 0.6 and 0.9

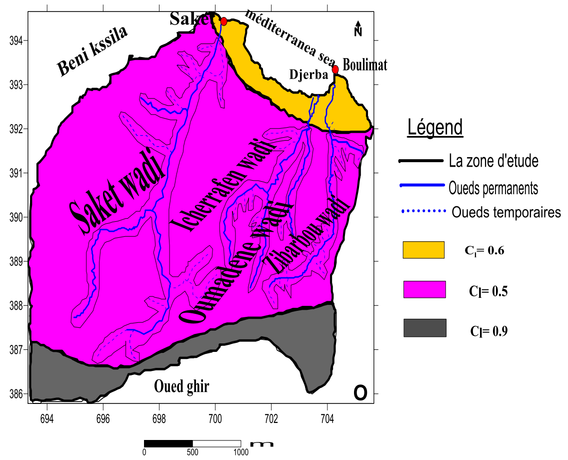

Fig. 3. Overral lithology of aquifer

Depth of groundwater

Depth to water table shows the map of the depth (Fig 4), in the study area the water level is weak, it does not exceed 30 meters, because of the measured depth in a very rainy period, which implies that the tablecloth more exposed to pollution generally the depth of the water between 0 and 5 meters to the north and 5 to 10 in the centre and 10 to 30 meters in the south. The index of overall lithology of aquifer ranged in 0.9, 0.6 and 0.5.

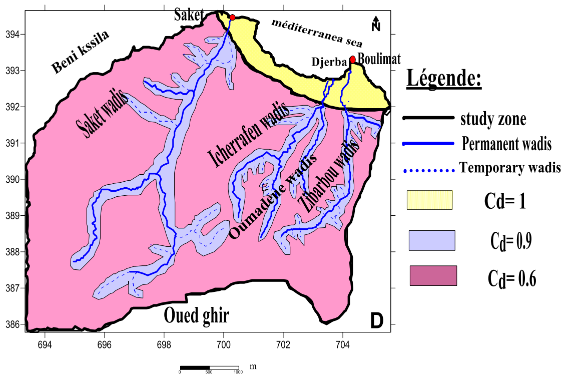

Fig. 4. Depth of groundwater map.

Discussion

Applying the multiplicative formula of GOD methodology to composing parameters (G,O,D), one gets the final vulnerability map (Fig.). The Boulimat district displays all classes of vulnerability, except the very low. The dominant class describes area of high vulnerability (0.5 to 0.7) which coincides with spots where geology is characterized by alluvial deposits rocks. Following the dominant class in the study area, the moderate vulnerability (0.3 to 0.5) coincide with the limitrophe zone represented by the flychs geological formations, very high vulnerability (0.7 to 1) coincide in the coastal zone is characterized by fine sandstone rocks. Finally, Fig. shows that classes low vulnerability coincide the south zone is characterized by karstic limestone rocks.

Hazard is potential sources of groundwater contamination, comprising point (e.g septic tank), linear (roads) and diffuse hazard (spreading of fertilizer and pesticides) (Goldscheider *et al.*, 2005). The index of GOD is high between which (0.5 to 0.7) represents 55% of the study area is located to the centre, generally the sources of the pollution is the intensive use of pesticides and fungicides; on the other hand the east side, the west side and the south side the GOD index is average between (0.3 to 0.5) which represents about 20% of the study area. In the coastal zone the index is ranged between (0.7 to1) which represent about 10%. The low vulnerability characterized by the GOD index is ranged between (0.1 to 0.3) which represent 15% localized in south study area (Fig 5).

Urbanization significantly affects the natural cycle of water, both quantitatively and qualitatively. It usually results in a regression of wetland, the waterproofing of soils not to allow water to dilute against pollution, disturbance of flow systems by foundations, pollutions problems cause by point or diffuse sources in the urban zones (absence of a sanitation network) and a strong increase in salinity, flooding problems. Durant the period tourisms activities the numbers of tourists decrease the wastes in study area. Practical agricultural activity and use the pesticides fertilizing.

Another problems of pollution in study area, the saline water intrusion fall into three causes: reduction or reversal of groundwater gradients, which permits denser saline water to displace fresh water. the situation commonly occurs in coastal aquifers in hydraulic continuity with the sea when pumping of wells disturbs the natural hydrodynamic balance. Destruction of natural barriers that separate fresh and saline waters by overexploitations of the coastal sand used in construction. An important source of salinity in groundwater in coastal regions is airborne salts originating from air-water interface over the sea.

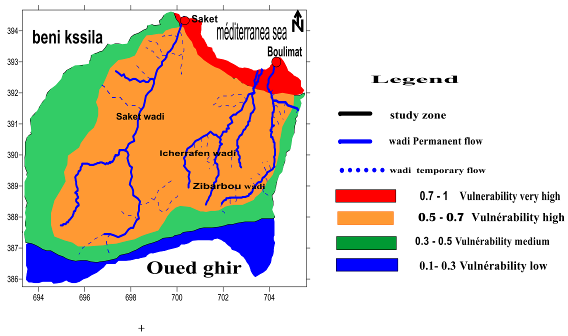

Fig. 5. Vulnerability map of study area.

Conclusion

The assessment of the vulnerability of the Boulimat coastal district by the method of GOD index**.** The repartition of the index GOD is high between which (0.5 to 0.7) represents 55% of the study area is located to the centre, generally the sources of the pollution is the intensive use of pesticides and fungicides; on the other hand the east side, the west side and the south side the GOD index is average between (0.3 to 0.5) which represents about 20% of the study area. In the coastal zone the index is ranged between (0.7 to1) which represent about 10%. The low vulnerability characterized by the GOD index is ranged between (0.1 to 0.3) which represent 15% localized in south study area. This study is a valuable tool for local authorities for managing groundwater resources, monitoring these problems closely and the act accordingly.

References

Aller L, Bennet T, Lehre JH, Petty RJ. 1987. DRASTIC : A Standardized system for Evaluating Groundwater Pollution Potential Using Hydrogeologic Setting. US EPA. Robert S Kerr environmental Research Laboratory. Ada . OK. EPA/600/2-85/0108 pp. 163.

Bekesi G, Mc Conchie J. 2002. The use of aquifer-media characteristics Manawatu region, New Zealand. Hydrogeol. J. **10,** 322-331.

Boulabeiz M, Houha B, Bousnoubra H, Agaguenia S. 2017. AGIS based DRASTIC model for assessing groundwater vulnerability in the coastal plain of Collo, Northeastern Algeria, Journal of biodiversity and Environmental Sciences (JBES), Vol. 10 , N, 4 p. 81-89, 2017.

Civita M. 1994. Le carte della vulnerability a degli acquiferi all inquinamiento teoria e pratica (Contamination vulnerabilty mapping of the aquifer theory and pratic) Quaderni di techich di Protezione Ambiental, Pitagora, Italy.

Daly D, Dassargues A, Drew D, Dunne S, Goldscheider N, Neale S, Popescu I, Zwahlen F. 2002. Main concepts of the "European approach" to karst-groundwater vulnerability assessment and mapping. Hydrogeol. J. **10,** 340-345?

Dixon B, Scott HD, Dixon JC, Steele KF. 2002. Prediction of aquifer vulnerability to pesticides using fuzzy rule-based models at the regional scale. Phys. Geogr **23,** 130-153.

Foster S. 1987. Fundamental concept in aquifer vulnerability pollution risk and protection strategy. Proc. Intl. Conf. Vulnerability of soil and groundwater pollution. The Netherland. April.

Gemitzi A, Petalas C, Tsihrintzis VA, Pisinaras V. 2006. Assessment of groundwater vulnerability to pollution: a combination of GIS, fuzzy logic and decision making techniques. Environ. Geol **49(3),** 653-673.

Gogu RC, Dassargues A. 2000. Current trends and future challenges in groundwater vulnerability assessment using overlay and index method. Environmental Geology **39(6),** 549-559.

Gogu RC, Hallet V, Dassargues A. 2003. Comparison of aquifer vulnerability assessment techniques. Application to the Néblon River basin (Belgium). Environ. Geol **44,** 881-892.

Gouadia L, Boudoukha A, Djabri L, Guefaifia O. 2011. Evaluation de la vulnerability d une nappe en milieu semi aride et comparaison des methodes appliquees: cas de la nappe de meskiana (Est Algerian) Secheresse, N 22 pp. 35-42.

Kalantari N, Faryabi M, RahimiM H. 2008. Assessment of Groundwater Vulnerability with AVI Method and GOD and DRASTIC model by GIS. Journal of Engineering Geology. **2(2),** 431-445.

Khemmoudj K, Bendadouche H, Merabet S. 2014. Assessment of the vulnerability of an aquifer by DRASTIC and SYNTACS methods: Aquifer of Bazer-Guelt Zerga (Northeast Algeria) E3 journal of environmental research and Management N 5/9 pp. 169-179.

Khodai K, Shahsavari A, Etebari A. 2006. Join Plain Aquifer Vulnerability Assessment Using GOD and DRASTIC Models. Journal of Iran Geology **4,** 73-87.

Saadali R, Kherici N. 2018. Groundwater pollution and sustainable development of the Collo plain; Northeastern Algeria, Journal of Biodiversity and Environmental Sciences (JBES), vol. **12,** N°6 pp. 160-165.

Vrba J, Zoporozec A. 1994. Guidebook on mapping groundwater vulnerability. IAH International Contribution for Hydrogeology, vol. **16,** Hannover: Heise.

Wang L, Yang YS. 2008. An approach for catchment-scale groundwater nitrate risk assessment from diffuse agricultural sources: a case study in the Upper Bann, Northern Ireland. Hydrol. Processes **22,** 4274-4286.

Yang YS, Wang L. 2010. A Review of Modelling Tools for Implementation of the EU Water Framework Directive in Handling Diffuse Water Pollution. Water Resource Management.