J. Black Sea/Mediterranean Environment
Vol. 19, No. 2: 268-273 (2013)

REVIEW ARTICLE

Assessing the vulnerability to pollution in the aquifer's Charf El Akab (Tangier, Morocco)

Laila Achagra[1], Jamal Stitou El Messari[1*], Mohamed Draoui[1]

Faculty of Science, University of Abdelmalek Essaadi, BP 2121 Tetouan, MOROCCO

[*]**Corresponding author:** stitoumessari@yahoo.fr

Abstract

The application of the DRASTIC's method on Charf El Akab's aquifer situated in the northwest of Morocco, precisely in the coastal plain between Tangiers and Asila, was made in this study. The mapping of the index DRASTIC allows us to delineate zones with various degrees of pollution vulnerability. The obtained results show that: i) the high-vulnerability zones extend over the entire free part of the lower ground-water (in the South of the aquifer), and ii) These zones lack natural protection of the ground-water. Precisely, the pollution vulnerability becomes very high in the southeast part of the studied sector, mostly in the quarry areas where the exploited biosandstones play the reloading role with respect to the lower ground-water. The zone with moderate vulnerability extends over the north part, where the ground-water is covered by the upper, and the middle, fine-grained to marly lithological formations. In the same zone, the vulnerability becomes low at the level of wetlands. As a conclusion, it is important to carry out strict control and follow-up of the ground-water to optimize its role as a strategic reserve in the Tangier's region.

Key words: DRASTIC model, groundwater, vulnerability mapping.

Introduction

The aquifer of Charf El Akab is situated 20 km south of the city of Tangier, in the northeast of Morocco. It extends over 17 km² and derived from a Tortonian-Pliocene estuarian basin that was linked to the Atlantic Ocean. Now it is separated from this ocean by a big anticline structure made up of the impermeable Tangier pelites. It is characterized by a generally flat relief. In the southeast part of the aquifer we note the predominance of altitudes less than 60 m. This is an isolated basin without hydrographic network and surrounded by pelitic successions with very low or no permeability (Achagra *et al.* 1998) (Figure 1).

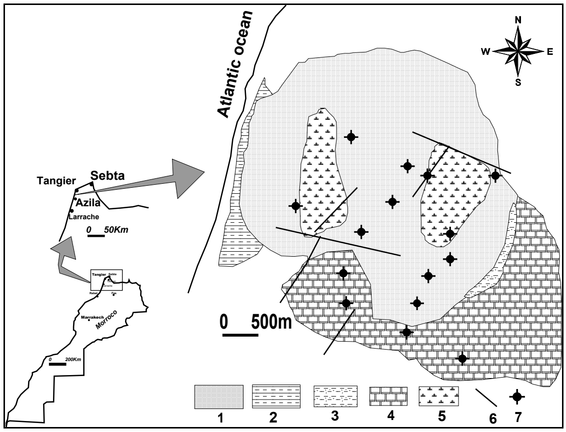

Figure 1. Geografic location and hydrogeological schema of the study area
1: sands and sandstones; 2: lithified gray marls; 3: gray marls *e.g.*sandy marls; 4: biocalcarenites; 5: wetland; 6: fault and 7: well.

The Charf El Akab's aquifer system is a strategic hydrogeologic reserve, which can be used as a valuable help for exceptional drought, as well as in case of unavailability of drinking water for the cities of Tangier and Asila. For a long time, the ground-water constituted the unique source of drinking water for the city of Tangier: since 1920, only springs were exploited, but the increasing request constrained the expansion of the harnessing field and at the same time, the artificial injection, in the ground-water, to gain a surplus in the treated waters. Besides, the unceasing development of the touristic activities, and the linked coastal infrastructure, the numerous extraction-quarries cut within the highly porous biocalcarénites, imply for the Charf El Akab water resources to run imminent risks in a short term. Hence, protecting measures are highly needed before all irreversible pollution. To restore the natural balance, disturbed today by the implementation of the artificial hydrological works, and to allow the ground-water to play its long-term strategic role (as it was the rule during the last decades), its protection has become absolutely essential. For this purpose, the evaluation and the mapping of the vulnerability to pollution represents a first and reliable step towards the restoration of the hydrological balance of the Charf El Akab's aquifer.

Structurally, the Charf El Akab (ChAb) aquifer is hosted in a late Tortonian-early Pliocene subsiding basin of ca 6 km long, ca 3, 2 km wide and 17 km^2 in surface. It came into being in the middle-to-late Tortonian as a semi-elongated post structure, the basement of which is made up of the widespread late Cretaceous Tangier pelites. To the northeast and the south, this same basement supports the large-scale holoquartzous Numidian nappe, the relieves of which played during the late Tortonian-Pliocene the role of continental detrital source. Thus, the ubiquist sandy fraction within the sedimentary filling of ChAb basin was likely to have been supplied from this nappe. Internally the main axis of this basin is oriented NW-SE and materialize a huge-syncline structure gently deepening towards the NW. By virtue of this structure the massive and porous carbonate formations (the so-called biocalcarnites of late Tortonian-Messinian in age) outcrop along its southern and southeastern borders and progressively disappear towards the NW, i.e. under the Charf El Akab plain. Poorly permeable marly Pliocene strata conformably rest on the biocalcarenites and chiefly occur in its central and NW areas. These Pliocene marls result in the two present-day lagoonal depocenters (the so-called Daya): the Daya Srhira, and the Daya Dhi Dhat. Internally, the whole sedimentary carbonate pile can exceed 500 m thick as far as shown by several wells drilled for hydrological purposes (Medioni and Wernli 1978). According to this lithological and structural setting, the direct rain-water infiltration proved to mostly occur in the southern and southeastern calcarenitic borders, whereas a more or less stagnation phase can precede the infiltration in the large-scale lagoon areas (Figure 2).

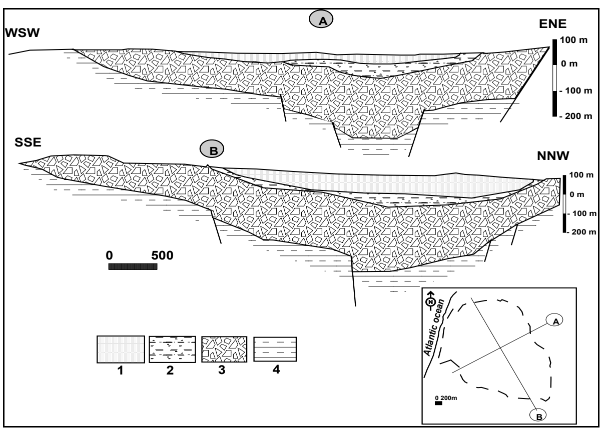

Figure 2. Geological location and hydrogeological cross sections of the Charaf El Akab
1: Upper formation; 2: Middle formation; 3: Lower formation; 4: Tangier pelites substratum

Stratigraphically, three silico and calci-clastic materials consist the main part of Charf El Akab's aquifer (Lamarti Sefiani 1999), namely (from the base onwards):

- the lower Formation made up as follows : ***i)*** gray sandy marls rich in bioclastic material in its basal levels (10-50 m) ; ***ii***) yellow bryozoan-dominated sandy biocalcarenites (200-350 m); ***iii)*** alternation of rust-colored pebbly conglomerates and wood debris–bearing sandy calcarenites (ca 100 m);
- the middle Formation dominated by metric to decametric marly sequences separated by decimetric near-holoquartzous beds (ca 50 m);

- the upper Formation made up of yellow homogenous sandy marls with frequent intercalations of oyster and lumachellic beds (50-100 m). This Formation extends over 10 km^2 and includes Dhidhat-Daya Sghira lagoons as well as the Charf El Akab plain. It and was dated strictly as early Pliocene.

Methodology of Evaluation

The method DRASTIC, was first developed by "The U.S Environmental Protection Agency (US EPA)" and "National Water Well Association (NWWA)", to estimate the vulnerability of subterranean waters at the pollution (Aller *et al.* 1987). Several authors have adopted the drastic method in the same context of climate (Draoui *et al.* 2008). This methodology is used to estimate the degree of vulnerability of the ground-water according to its physical characteristics. The method consists in assigning a digital indication to certain physical parameters of the aquifer, when they are considered susceptible to exert a degree of protection of the groundwater quality. Every parameter is balanced according to its relative importance. In DRASTIC model, seven parameters which influence and control groundwater flow and contaminant transport are listed for comprehensive evaluation of groundwater vulnerability. They are depth to water, net recharge, aquifer media, soil media, topography, impact of the vadose zone; conductivity of the aquifer. The warning of the weighted indexes of the parameters gives a quantitative evaluation of the vulnerability of the aquifer. Based on this information, the rate and weight of each hydrological unit is determined and then be put together by the seven factors to calculate the vulnerability index. The formula is as follows:

DRASTIC vulnerability index: $VI = D_rD_w + R_rR_w + A_rA_w + S_rS_w + T_rT_w + I_rI_w + C_rC_w$

In the formula, the subscript ***w*** is weight, ***r*** is rate, and the vulnerability index is weighted sums of rate of all the evaluation factors. Once the DRASTIC vulnerability index is calculated, relative vulnerability of groundwater of each unit can be determined. The regional vulnerability index is larger, its groundwater is relatively more susceptible to pollution, and vulnerability is relatively higher. It should be specially noted that the DRASTIC index does not mean the absolute value of groundwater pollution; it is only means the relative vulnerability of groundwater in different regions. The spatial distribution of the vulnerability is so calculated for the whole territory of the aquifer in this precise place. Possible values of the DRASTIC index are divided into five intervals of five classes of vulnerability. They are summarized in Table 1.

The synthesis map results from overlapping seven thematic maps of parameters DRASTIC. By examining the map of vulnerability of Charf El Akab's aquifer and indexed maps, we note that the parameters having conditioned the index of vulnerabilities are essentially distance to the water level or depth groundwater **D**, the impact of the vadose zone media **I,** as well as the soil media **S**. Four classes of vulnerability emanate from this synthesis map.

Table 1. Intervals of the values of the index DRASTIC and the corresponding classes

Interval	DRASTIC class
23-64	Very low
65-104	Low
105-124	Moderate
125-154	High
>155	Very high

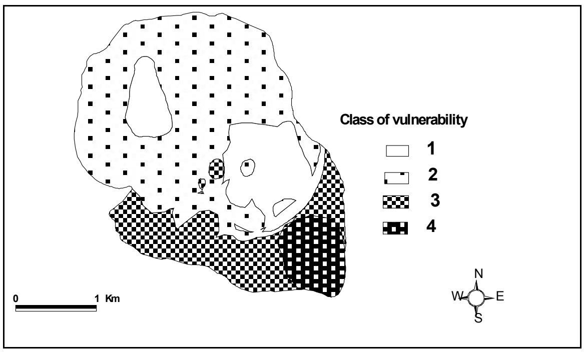

Figure 3. Groundwater vulnerability map of the Charf El Akab basin generated through DRASTIC. 1: low, 2: moderate, 3: high and 4: very high

The class of low vulnerability zone coincides both with the localization of wetland (Figure 3), and the zone where the intermediate formation outcrops. This result can additionally be supported by the fact that at the level of wetland the distance in the groundwater is maximal, the ground is waterproof (impervious) and the lithologic nature of the non-saturated zone upper and middle Formations) would limit the infiltration of pollutants down to the groundwater to a certain extent. The zone of moderate vulnerability corresponds to the northern half of the aquifer dominated by the upper Formation outcrops. The level of the groundwater shows values exceeding 30 m, except for some points where inverse faults cause subterranean basement horsts. The permeability of the ground, as well as the upper Formations lithologies, would influence slightly the vulnerability to pollutants. The zone of high vulnerability represents the free part of the groundwater where we note the predominance of sandy soil, and the vadose zone, the lithology of which is favorable to the penetration of pollutants. Importantly, the values of the depths to the groundwater are relatively low in this zone. Hence, the presence of faults in the massive biocalcarenite succession, (particularly in the vicinity of the artificially reloaded basin in the southeast side of the aquifer), would favor this high degree of vulnerability. The zone of very high vulnerability corresponds to the sites of the extracting quarries entirely cut in the massive biocalcarenites. In these places the groundwater occurs in the shallowest levels compared to the rest of the Charf el Akab ones. The ground is absent there and the natural topography is completely disturbed by the abolition of the primitive centripetal slopes, particularly in zones intensely quarried.

Conclusion

The use of the method DRASTIC for the evaluation of the vulnerability to the pollution of Charf El Akab's groudwater allows us to identify zones with degree of variable vulnerability. The southern zone exhibits high to very high vulnerability. This zone is characterized by shallow depths of the water level and by the absence of natural protection of the groundwater particularly in the extensively quarried areas. The zones of moderate proceed vulnerability are characterized by low-permeability lithologies and by deep-water levels; it mainly occurs in the northern parts of the basin. Grounds in the wetland are the least vulnerable.

Acknowledgments

This paper was carried out with the assistance of Projects RS/2011/6 CNRST of Morocco.

References

Achagra, L., Sarroukh, M., Benjbara, M., Stitou El Messari, J., Ceron., J. C. (1998) Relación estadisticas entre las propriedades hidodinámicas y geoelectricas del acuífero de Charaf El Akab (Marruecos). *Geogaceta* 25: 3-6.

Aller, L., Bennett, T., Lehr, J. H., Pretty, R., Hacket, G. (1987) DRASTIC: A standardized system for evaluating groundwater pollution in potential using hydogeologic settings. United States Environmental Protection Agency, 662 pp.

Draoui M., Vias, J., Andreo, B., Targuisti, K., Stitou El Messari, J. E. (2008) A comparative study of four vulnerability mapping methods in detritic aquifers under Mediterranean climatic conditions. *Environmental Geology* 54: 455-463.

Durand Delga, M., Didon, J., Médioni, R., Wernli, R., Suter, G. (1985) Carte géologique du Rif, feuille Tanger-Al Manzla, notes et Mém. Serv. Geol. Maroc, No: 294.

Lamarti Sefian, N. (1999) Une plate-forme ouverte à faciès bryomol: le bassin de Charf El Akab (NO Maroc). Sédimentologie, Paléontologie et Paléoenvironnements. Thèse Univ. Tétouan, 227 pp.

Médioni, R., Wernli, R. (1978) Etude géologique du bassin post-nappe de Charf El Akab (Province Tanger, Maroc). *Notes Serv. Géol. Maroc.* 40 (275): 107-133.

Received: 01.10.2012
Accepted: 19.10.2012