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Assessment of groundwater vulnerability to pollution using the Kherici's method in the Talezza plain, Collo region (NE Algeria)

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Abstract

The intrinsic vulnerability of groundwater aquifers refers to their sensitivity to all contamination coming from soil surface irrespective of the nature of the polluting. In order to improve the protection of groundwater, there must be a reduction in the infiltration of contaminants towards the reservoir through the impacting factors determination of this phenomenon by means of research. There are collected models that include particular number of factors which allow the determination of a sign of groundwater vulnerability of all superficial pollutions.

The goal of the study centers on ascertaining the state of vulnerability and the risk of groundwater pollution of the Collo region with a new proposed method by Kherici. Generally, assessment methods of vulnerability and the danger of groundwater pollution employ parametric systems with numerical quotation, cartographic superposition where the analytical methods are based on equations. In this study, we consider the combination of criteria dependent on natural factors (thickness of the unsaturated zone, geologic facies, degree of auto-purification) and the causes of groundwater vulnerability to man-made pollution (anthropogenic factors).

Key words: *risk of pollution, self-purification, Talezza plain, unsaturated zone, vulnerability to pollution*

INTRODUCTION

The water quality in the world has experienced in recent years a deterioration, because uncontrolled industrial discharges, intensive use of chemical fertilizers in agriculture well as disorderly exploitation of water resources [GEMITZI *et al.* 2006]. They produce a chemical modification of the water and make it unsuitable for desired uses [MEDDEB 1989]. Among these cases of pollution include the aquifer of Collo (NE Algeria). In addition to the expansion of the agglomeration of the village of Ouled Mazouz, and Dr Toukla, a proliferation of the building appeared all along the road and at the foot of Koudiat Talezza (upstream of the aquifer). Indeed, a large population settled gradually in the plain with the creation of activi-

ties, generating discharges with negative effects on the environment. These anthropogenic activities result in serious imbalances in ecosystems. So, the Talezza plain known by multiple pollution caused by liquid wastes (domestic and industrial waste water), solid (public landfills) and overexploitation of groundwater [CHABOUR 2004].

DESCRIPTION OF STUDY AREA

The Collo plain is part of the sub-watershed of the wadi and a Gueblie shape of an elongated the quadrilateral with a length of 8 km and a width of 5 km along the sea (Fig. 1). The plain is for agricultural use, which requires the mobilization a large amount of water as well for potable water supply as

for irrigation [BOULABEIZ, NEGHRA 2002]. The geological and geophysical study of the area reveal the existence of three lithostratigraphic formations of unequal importance [BOUILLIN 1979; MARRE 1983]. The first formation is that of Mio-Pliocene-Quaternary formed by surface alluvion with dominance of sandy-loam silt loam and clay below this formation is encountered a layer be the sand and gravel forming the reservoir of the aquifer with an average thickness of 15 to 25 m [BOULABAIZ 2006]. These formations based on a layer formed by an alternation of marl and sandstone of Pliocene which constitutes the substratum (Fig. 2). Concerning the climate, the region is among the wettest ones in Algeria. With a Mediterranean climate, mild and wet in winter; hot and dry in summer. The annual average rainfall varies between 800 and 1200 mm under an annual average temperature of 23.35°C, and can reach 2000 mm·year⁻¹ over the massifs of Zitouna and with evapotranspiration of between 485 and 581 mm·year⁻¹.

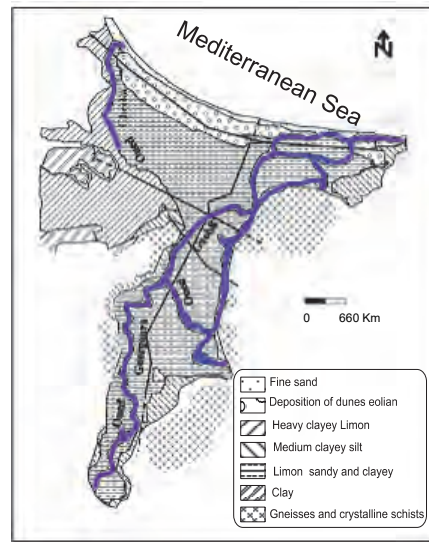


Fig. 1. Geologic map of the Talezza plain; source: KAHAL [2011]

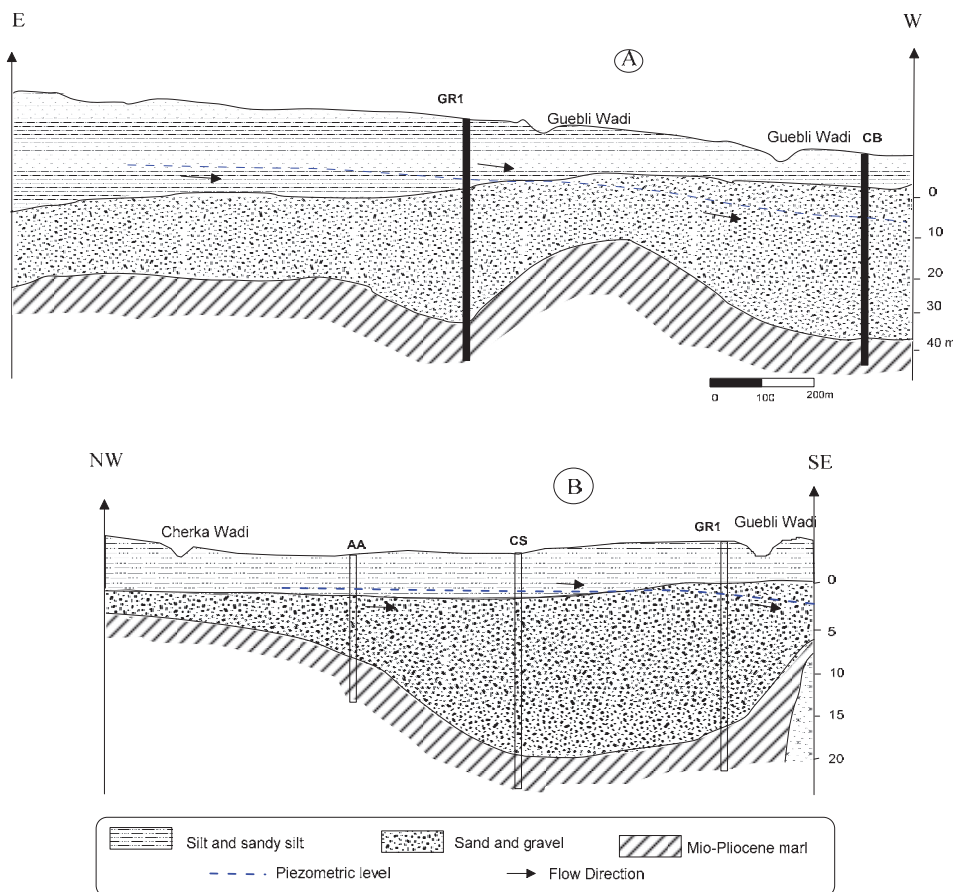


Fig. 2. Hydrogeological cup through of Talezza plain; source: own elaboration

MATERIALS AND METHODS

PRINCIPLE OF THE KHÉRICI'S METHOD

To highlight the state of vulnerability to pollution we apply a new method proposed by Kherici [KHÉRICI *et al.* 2010] from which it is represented by an abacus supported on the factors (natural: thickness of the

unsaturated zone, geological facies, degree of self-purification) and on the causes of vulnerability of the aquifers to pollution (anthropic factors caused by man).

The abacus is essentially formed of two triangles and a rectangle, the first triangle A represents the natural factors identified by a semi-logarithmic scale (depth of the water surface that sometimes out passes

hundreds of meters lithological type of the ground crossed the product of these factors) ascertains the total self-purification index of the unsaturated zone representing the Rehse1977 [DETAY 1996] (Tab. 1) calculation method (Ex: P1: $Md = h \cdot i = 4.15 \text{ m} \cdot 0.5 = 2.07 \text{ m}$). The second triangle B represents the organic contamination index of a side the mineral contamination index on the second side [ATTOUI *et al.* 2012], and the sum of the two indexes represents the total contamination index identified by the third side Exp ($ICO = \text{NO}_3 \text{ class} + \text{NO}_2 \text{ class}$, $ICO = 2 + 2 = 4$), ($ICM = \text{Pb class} + \text{Fe class} = 3 + 2 = 5$) so, ($ICT = ICO + ICM = 4 + 5 = 9$). The projection of the preceding two triangles ($Md = 2.07$ and $ICT = 9$) (Fig. 3) over the rectangle identifies the state of vulnerability and of the risk pollution of the studied water points of the aquifers of Talezza [KHERICI *et al.* 2010].

Table 1. Power scrubber ground in coverage (unsaturated zone)

Description	H, m	$i=1/H$
Humus, 5–10% humus, 5–10% clay	1.2	0.80
Clay, clay loam, clayey sand	2.0	0.50
Clayey silt to silt	2.5	0.40
Silt, silica sand, siliceous little sand and some clay	3.0–4.5	0.33–0.22
Fine to medium sand	6	0.17
Medium to coarse sand	10	0.10
Coarse sand	15	0.07
Gravel siliceous rich sand and clay	8	0.13
Gravel slightly silty, lots of sand	12	0.08
Gravel fine to medium rich of sand	25	0.04
Medium to coarse gravel, some sand	35	0.03
Pebbles	50	0.02

Explanations: H = thickness of layer of soil needed for complete purification.
 Source: DETAY [1997], modified.

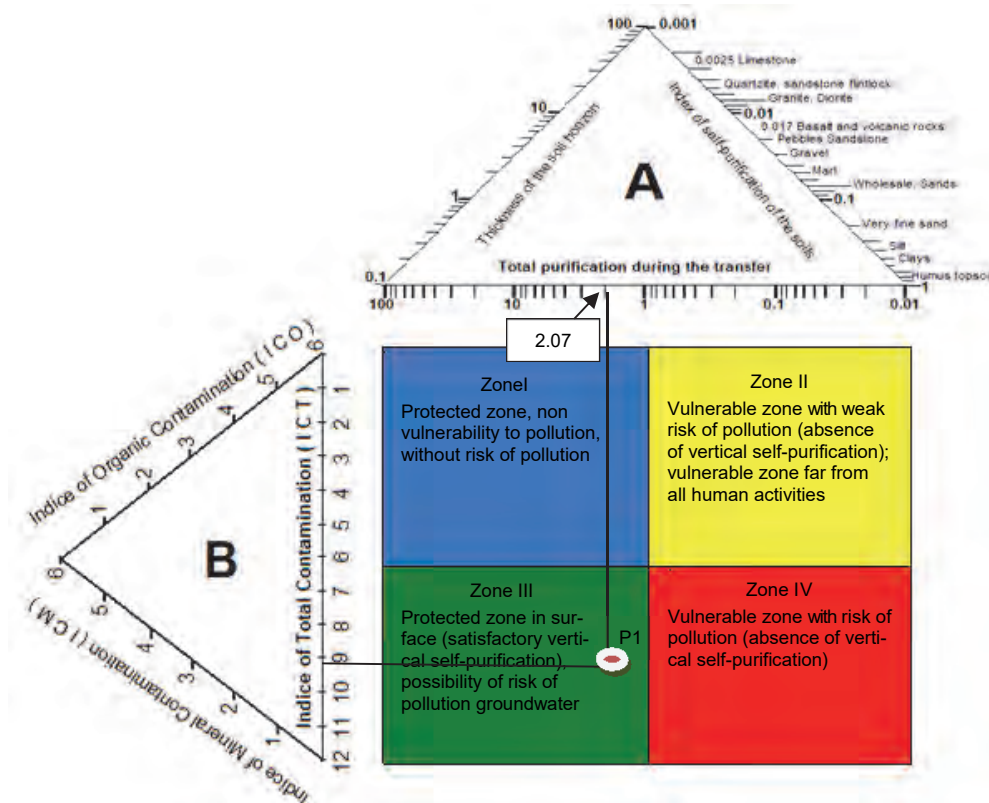


Fig. 3. Determination of vulnerability and risk of waters pollution zones; source: KHERICI *et al.* [2010], modified

MATERIAL

The work consists of evaluating the vulnerability and the pollution risk of some number of water points that represent Talezza region (Fig. 4). The water samples have been taken from domestic wells and drillings during a period of more than 10 years and completed by the actual analyses, but the most pessimistic period is selected in 5 years. The flame spectrophotometric absorption has been used for heavy metals, the atomic absorption spectrophotometer for all the nutrients (NO_3 , NO_2).

RESULTS AND DISCUSSION

CALCULATION OF CLEANER POWER

Calculating the purifying effects Talezza collo region is brought to the Table 2.

From the data of Table 2, we note that the purifying depends much more of the groundwater level than the coverage of the aquifer. The self-purification is insufficient across the surface of the web right to drilling wells and P9, P10, P11, P14 and mediocre P15 and to places that contain (FB, FG). However, at cer-

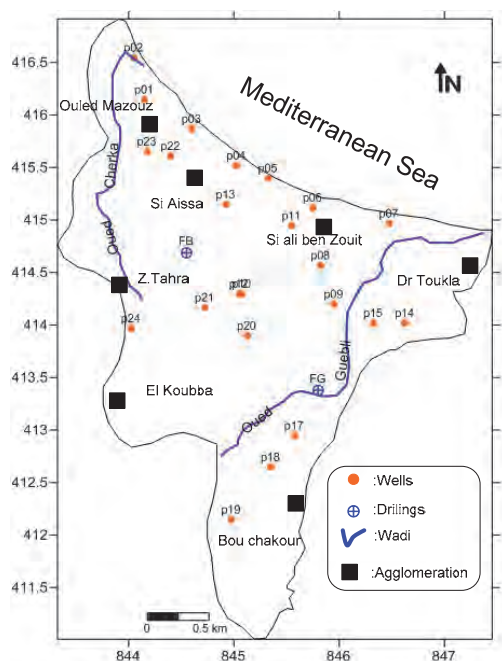


Fig. 4. Map inventory of water points in the region of Talezza plain; source: own elaboration

tain points, boreholes and wells show good purifying powers due to the importance of the depth of the groundwater level (P3, P22, F TE1, FTE2), this fails to protect groundwater because it is continuous.

CLASSIFICATION OF ORGANIC ELEMENTS AND MINERALS

The index of organic contamination (ICO)

It is the sum of the two classes of elements from organic pollution of the same sample. The choice is made by the element that had the highest class.

In this case the $ICO = \text{class of nitrate} + \text{nitrite class or ammonia nitrogen (NH}_4^+)$.

Classification organic elements

Nitrate (NO₃). Nitrates (NO₃) are an essential source of nitrogen (N) for plants. When nitrogen fertilizers are used to enrich soils, nitrates may be carried by rain, irrigation and other surface waters through the soil into ground water. Human and animal wastes can also contribute to nitrate contamination of ground water. According to the Table 3 the aquifer is affected by pollution with this element. The alluvial aquifer

Table 2. Power and cleaner area Talezza collo

Well and drilling	Lithology of the coverage	<i>E</i> m	<i>H</i> _{ENS} m	<i>NP</i> m	<i>Md = h·i</i>	<i>Md</i> m	<i>Mr</i> m
2	3	4	5	6	7	8	9
P1	clay	7	4.15	4.15	4.15·0.5	2.07	
P2	clay	7	4.52	4.52	4.52·0.5	2.26	
P3	clay	7	5.5	5.5	5.5·0.5	2.75	
P4	clay	7	4.8	4.8	4.8·0.5	2.4	
P5	clay	7	2.2	2.2	2.2·0.5	1.1	
P6	clay	7	4.35	4.35	4.35·0.5	2.17	
P7	clay	7	5	5	5·0.5	2.5	
P8	brown clay sand and gravel	5 0.1	5 0.1	5.1	5·0.5+0.1·0.04	2.504	
P9	fine sand sand	5 0.1	5 0.1	5.1	0.17·5+0.1·0.17	0.86	0.14
P10	fine sand medium sand	5 1	5 1	6	5·0.17+1·0.1	0.95	0.05
P11	fine sand medium sand	5 0.47	5 0.47	5.47	5·0.17+0.47·0.1	0.89	0.11
P12	fine sand medium sand	5 1.24	5 1.24	6.24	5·0.17+1.24·0.1	0.97	0.03
P13	clay	6	5.33	5.33	5·0.5	2.66	
P14	fine sand medium sand	5 0.47	5.47	5.47	5·0.17+0.47·0.1	0.89	0.11
P15	fine sand	5	3.6	3.6	3.6·0.17	0.61	0.39
P16	fine sand medium sand	5 1.5	6.5	6.5	5·0.17+1.5·0.1	1.0	
P17	fine sand medium sand	5 1	6	6	5·0.17+1·0.1	0.95	0.05
P18	fine sand medium sand	5 1.14	6.14	6.14	5·0.17+1.14·0.1	0.96	0.04
P19	fine sand medium sand	5 1.44	6.44	6.44	5·0.17+1.44·0.1	0.99	0.01
P20	brown clay sand and gravel	5 1.37	6.37	6.37	5·0.5+1.37·0.04	2.55	
P21	brown clay sand and gravel	5 2	7	7	5·0.5+2·0.04	2.58	
P22	brown clay sand and gravel	5 2.24	7.24	7.24	5·0.5+2.24·0.04	2.58	

cont. Table 2

2	3	4	5	6	7	8	9
P23	brown clay sand and gravel	5 2.24	7.24	7.24	5·0.5+2.24·0.04	2.58	
P24	brown clay sand and gravel	5 1.17	6.17	6.17	5·0.5+1.17·0.04	3.71	
P25	brown clay sand and gravel	5 1.8	6.8	6.8	5·0.5+1.8·0.04	2.57	
F AA	fine sand	5	3	3	3·0.17	0.51	0.49
F GR1	brown clay sand and gravel	5 0.2	5.2	5.2	5·0.5+0.2·0.04	2.50	
F TE1	clay	6	4.4	4.4	4.4·0.5	2.2	
F TE2	clay	6	4.8	4.8	4.8·0.5	2.4	

Explanations: *Md* = purifying power on the vertical path; *E* = thickness of the layer (m); *H_{ENS}* = thickness of unsaturated area of the aquifer (m); *NP* = piezometric ground water level (m); *Mr* = purifying power on the horizontal path.
 Source: ATTOUI [2010].

Table 3. Organic and mineral elements classification according to the WHO

Element	Trace amount mg·dm ⁻³	Class	Wells' number	Natural amount mg·dm ⁻³	Class	Wells' number	WHO limit mg·dm ⁻³	Class	Wells' number
NO ₃	0–10	1	14	10–50	2	6	>50	3	9
NO ₂	0–0.05	1	20	0.05–0.1	2	3	>0.1	3	4
Lead	0–0.05	1	21	0.05–0.1	2	0	>0.1	3	4
Iron	0–0.05	1	19	0.05–0.3	2	20	>0.3	3	0

Source: own study based on the WHO's classification.

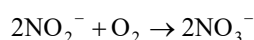
of Collo includes the 14/29 samples belonging to the first class there are also 6 samples are in the second class just 9 sample are largely over the norms WHO standards, are localized either besides a pollution source (polluted wadis Charka and Guebli by urban wastes affecting the aquifers).

Nitrite (NO₂). Considered a toxic element, NO₂ is the least stable in the nitrogen cycle.

It comes from the reduction of ammonium NH₄⁺. Its origin is linked to agriculture or urban and industrial discharges.



The transformation of the nitrite in the presence of oxygen gives rise of the nitrates:



As shown Table 3 the levels of nitrites are low in the aquifer of Talezza in 20 samples, there are three samples in the second class, there are some four samples that are classified in the 3rd class are largely exceeded the standards, due to the presence of domestic and agricultural and industrial discharges (presence of ammonium in industrial discharges).

Mineral contamination index (MCI)

It represents the sum of the classes of the two elements with the most significant concentration that is issued from mineral pollution of a same sample. In the studied region we have chosen lead and Iron.

From the projection of the two indexes (organics and mineral) we obtain the total contamination index (ICT).

Classification of mineral elements

Lead (Pb⁺⁺). Lead is a toxic metal that is harmful to human health. In rare instances lead gets into water as a result of pesticides that were used decades ago or industrial activity that contaminated soil and groundwater, as shown in Table 3, where there are 4 samples that exceeds the standards, they are located north and south of the alluvial plain of Talezza at the side the Charka Wadi and Guebli Wadi, and other samples 21 are belong to the first class, they can far from these wadis.

Iron. Iron occurs naturally in soil, sediments and groundwater and can be found in many types of rocks. Iron can be present in water in two forms; the soluble ferrous iron or the insoluble ferric iron. Water containing ferrous iron is clear and colourless, and when exposed to air the water turns cloudy causing a reddish brown precipitate of ferric iron appears. The presence of iron in water can have different origins: natural by leaching from clay soils, artificially by industries (metallurgical, steel). In the case of the Collo plain we found 20 samples of the class 2 and 19 samples in the first class where the concentration are low (Tab. 3).

According to data processing (Figs 5 and 6), the Talezza plain presents 4 states of vulnerability and risk to pollution:

- The vulnerability and the risk of pollution occupies the coloured area in red at south east of the Talezza plain, and the reason remains in the presence of the terrain composed of permeable formations essentially find to average to fine sands, and sands with gravel, where the purifying capacity on the vertical

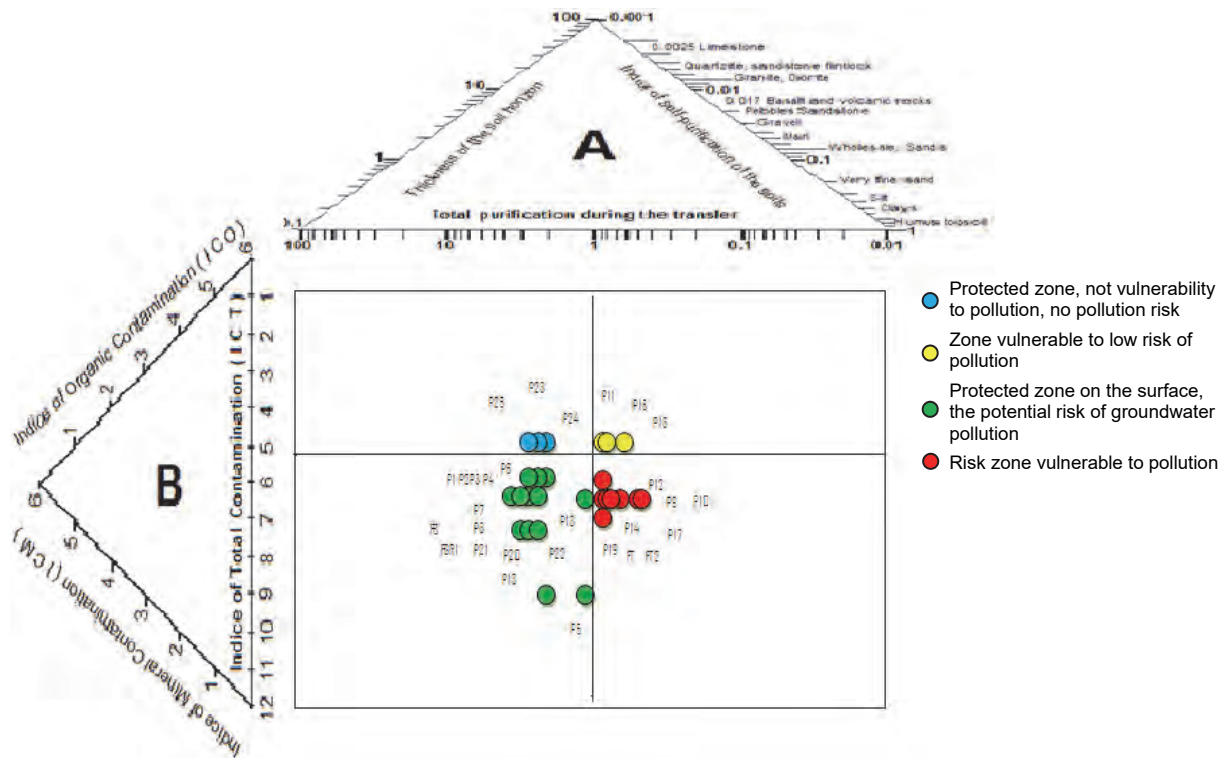


Fig. 5. Determination of vulnerability and pollution risk of water pollution zones acc. to KHERICI *et al.* [2010] – the aquifer of the Talezza; source: own study

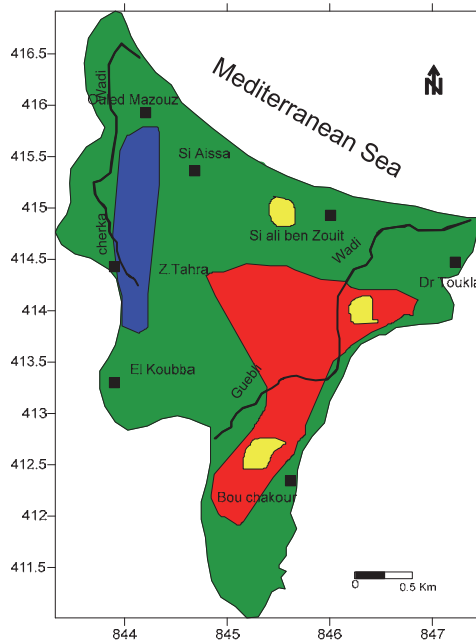


Fig. 6. Map of vulnerability and risk of pollution of the aquifer of Talezza; source: own elaboration

Way M_d is less than 1; so the self-purification is not complete. The contamination if it exists, must continue in the aquifer (saturated zone). At this location the index of mineral contamination (ICM) is high in some drillings of about 5, the same for organic contamination index (ICO) is high up to 6 in the vicinity agglomerations. This area is the

most accessible to pollution with a high risk of contamination [CHAOUÏ *et al.* 2015].

- The vulnerability of the terrain with a weak risk of pollution occupies the coloured area in yellow situated in the north part and the south east of the Talezza plain where the lithology presents the clay to coarse sands and sands with gravels and where the purification capacity of the soil over the vertical way M_d is less than one 1 due to the piezometric level which is very near the surface of the soil and which gives an insufficient and incomplete self-purification. Thus, it should be continued in the aquifer layer (the saturated zone).
- The green almost occupies all the part of the Talezza plain indicating a protected terrain and the possibility of risk of groundwater pollution. The lithology of this terrain is composed of fine sands and clay and gravel where we note a high purification capacity of the soil over the vertical path M_d is superior to 1, associated with a relatively important thickness of the unsaturated zone (and the importance piezometric level compared to soil).
- The protected zone with a weak risk of pollution occupies a very limited surface in the aquifer of Talezza at the west and the south of Cherka Wadi (coloured in blue). At that place the purification capacity of the soil over the vertical path M_d is superior to 1 because of the importance of the piezometric level compared with the surface of the soil [ATTOUI *et al.* 2012].

CONCLUSION

According to the Kherici's method used for the first time in recognition of the situation of vulnerability and risk of groundwater pollution in the Talezza region can be defined that the vulnerable terrain with risk of pollution occupies the northeastern part and can optionally siege pollution risk at the time court, the north and west part of the plain of Talezza has a low risk of pollution, the protected terrain with possible risk of groundwater pollution occupies almost all the plain of Talezza. The protected area and no risk of pollution has a very limited area in the plain of Talezza.

Highlighting of the states of vulnerability to pollution of the groundwater of Talezza suggests collect all the wastewater to a single collector and conduct a preliminary actual treatment by installing a water treatment plant.

Purification stations of used water in the urbanized localities must be constructed.

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Ocena podatności wód gruntowych na zanieczyszczenia przy użyciu metody Kherici w regionie Collo na równinie Talezza (NE Algeria)

STRESZCZENIE

Podatność podziemnych poziomów wodonośnych odnosi się do ich wrażliwości na zanieczyszczenia pochodzące z powierzchni gleby, niezależnie od ich charakteru. Dla ochrony wód gruntowych konieczne jest ograniczenie infiltracji zanieczyszczeń po ustaleniu czynników wpływu metodami badawczymi. Istnieją modele obejmujące szereg czynników, które umożliwiają określenie podatności wód gruntowych na zanieczyszczenia powierzchniowe.

Celem badań było określenie stanu podatności i ryzyka zanieczyszczenia wód gruntowych w regionie Collo za pomocą nowej metody zaproponowanej przez Kherici. W metodach oceny podatności i zagrożenia zanie-

czyszczeniem wód gruntowych stosowane są zwykle parametryczny system numeryczny i kartograficzne nałożenia, w których metody analityczne bazują na równaniach. W pracy rozważano kombinację kryteriów zależnych od czynników naturalnych (miąższość strefy nienasyconej, facje geologiczne i stopień samooczyszczania) oraz przyczyny podatności wód gruntowych na zanieczyszczenia antropogeniczne.

Słowa kluczowe: *podatność na zanieczyszczenia, równina Talezza, ryzyko zanieczyszczenia, samooczyszczanie, strefa nienasycona*