INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 14, No. 6, p. 114-125, 2019
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

On the use of GIS and DPSIR methods to analyse water quality in Seybouse Valley (North East of Algeria)

Aissam Ghrieb[1], Fethi Baali[2], Azzedine Hani[3], Larbi Djabri[3], Chemseddine Fehdi[2], Hicham Chaffai*[3]

[1]*Department of Earth Sciences, Faculty of Exact Sciences, Science of Nature and Life, University of Larbi Tebessi, Tébessa, Algeria*

[2]*Water and Environment Laboratory, Department of Earth Sciences, Faculty of Exact Sciences, Science of Nature and Life, University of Larbi Tebessi, Tébessa, Algeria*

[3]*Laboratory of Water Resource and Sustainable Development (REDD), Department of Geology, Faculty of Earth Sciences, Badji Mokhtar University, Annaba, Algeria*

Article published on June 30, 2019

Key words: Water quality, GIS, DPSIR model, ANN, Seybouse Valley, Algeria.

Abstract

Water sustainability in Seybouse Valley (North East of Algeria), must recognize the importance of water quantity and quality integration. So, there is a need for a better knowledge and understanding of the water quality determinants of groundwater abstraction to meet the municipal and agricultural uses. The quality of this ground water was determined by Water Abstraction from coastal aquifer (WAbs). This represents the amounts of water pumped by municipal wells in addition to the agricultural wells. It is measured by million cubic meters per year (hm3.y-1). The purposes of this investigation were to provide an overview of ground water quality and to determine spatial distribution of quality parameters in the study area using GIS tools. A new conceptual integrated water-management model has been developed, based on cause-effect relationships. The Driver-Pressure-State-Impact-Response was selected as a well-established framework to allocate the possible variables into five categories: namely socio-economic; pollution pressures; water quality; impacts; and management responses. In this paper, the artificial neural network (ANN) models were used to model and predict the relationship between groundwater abstraction and water quality determinants in the Seybouse Valley (North East of Algeria). The study area chosen is the Seybouse Valley and real data were collected from twenty-five wells for reference year 2006. Results indicate that the feed-forward multilayer perceptron models with back-propagation are useful tools to define and prioritize the important water quality parameters of groundwater abstraction and use. The model evaluation shows that the correlation coefficients are more than 97% for training, verification and testing data. The model aims to link the water quantity and quality with the objective to strengthen the Integrated Water Resources Management approach.

***Corresponding Author:** Hicham Chaffai ✉ hichamchaffai@yahoo.fr

Introduction

Lack of water resources and optimum management has been two recent challenges of water resources engineering. Population growth, decline of useable water resources, improvements in lifestyle, growing rate of consumption, climate change and several other parameters have caused useable water to be a noteworthy problem for the future. Economic and efficient use of water resources and its management have an increasingly important role.

The development of a model to predict understanding would help to manage water resources effectively. There are different methods for data analyses, such as statistic techniques. For Prediction of water quality parameters, first, accurate study of different processes which can affect water quality and developing statistical or deterministic models according to the obtained information is necessary. Second, developing Data Driven Models using information and collected data is an essential tool.

The study area climate is semi-arid Mediterranean; the annual rainfall is varies between 700 and 900mm. The potential evapotranspiration is closely linked to the temperatures. The annual average of the evapotranspiration range from 1000 to 2000mm (Djabri *et al.,* 2015).

The increasing population as well as industrial demands render the protection and preservation of these resources all the more important. The intensive agricultural activities in the plain of Annaba (Algeria) induce the increase of the risk of the fresh water degradation. In fact, uncontrolled high pumping rates of water causes modification of the natural flow system and induces seawater flow from the coast making the deterioration of the water table quality (Halimi *et al.*, 2016).

The principal purpose of the study is to develop ANN model studying the relation between Water abstraction from coastal aquifer (represented by WAbs ($hm^3.year^{-1}$) and some variables as: (Na) concentration mg/l, (Cl), (NO_3), (Ca), (Mg), (SO_4), (HCO_3), (K), (pH), (EC) and (RS). Understanding spatial relations between hydrological variables and salinity of groundwater can contribute in an integration of water resources management. Modeling groundwater salinity using traditional modelling software consume a lot of efforts and required huge quantity of data while ANN could provide an easy and efficient tool for modeling and prediction that help in water resources management. This research might be considered as one of the few contributions in quantitatively modeling of the relation between groundwater salinity and the hydrological variables in spatial scale using ANN.

The principal purpose of the study was to characterize the hydrochemistry of this coastal aquifer, identifying the main processes that occur in the system. Specifically, the aim of the work is to determine the extent of marine intrusion in the aquifer. From that, physical and chemical parameters were measured, such as electrical conductivity, pH, anions and cations concentrations.

Materials and methods

Study area

The Seybouse River basin is located in the northern east part of Algeria, and the coastal section is The Western part of the plain of Annaba.

The Seybouse is one of the most important rivers of Algeria by the length of its course, the number of its tributaries and the area of its basin. The Seybouse River basin has three parts: high plains (High Seybouse), Mean Seybouse and Maritime Seybouse. The latter represent the study area.

The study area is located in the North-East Algerian between the latitudes 36°30' and 37° North and longitudes 7°30' and 7°55' East.

The study area is an integral part of the Seybouse river watershed with an area of 103 km^2, its natural limits are: in the north by the Mediterranean Sea, in the south by the eastern extension of the Cheffia Numidian mountains, and is limited in the west by the Edough metamorphic complex and the Fetzara Lake, and finally in the east by the eastern prolongation of the Annaba-Bouteldja plain and Mounts of Nador N'bail.

The study area occupies the majority of Annaba city and the western part of El Taref city as shown in (Fig. 1).

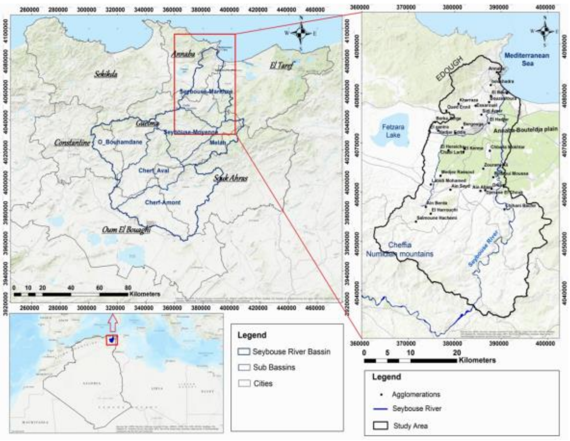

Fig. 1. Location of the study area.

The study area is divided into 25 main sectors: Annaba, El Bouni, Boukhadra, Bouzaaroura, Sidi Salem, Berka Zerga, Essarouel, Sidi Amar, Hadjar Eddis, Derradji Redjem, Bergouga, Merzoug Amar (El Gantra), El Hadjar, El Heraicha, Chabi Larbi, El Kerma, Ain Berda, El Harrouchi, Salmoune Hachemi, Drean, Djenane El Chouk, Fedaoui Moussa, Chbaita Mokhtar, Zourami Ali, Chihani Bachir.

Geological and Hydrogeological framework

The studies realized in the region show that there are two types of formations: metamorphic and sedimentary (Fig. 2). The geological formation dates back from the Palaeozoic to the Quaternary period.

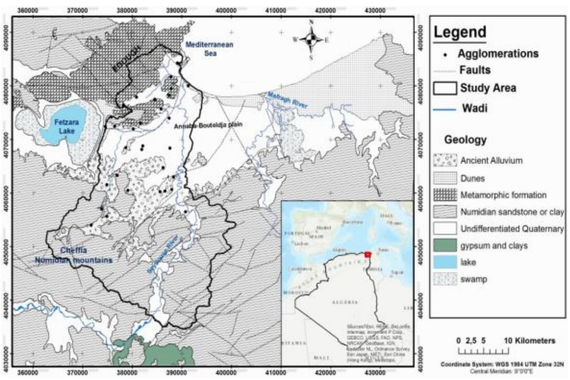

Fig. 2. Geological sketch map of the plain of the Annaba region.

The sediments are heterogeneous with numerous alternations of sandy clays, sands and gravels beds. Two main aquifers are distinguished (Lamouroux et Hani, 2006) shallow and deep aquifers:

- a surface aquifer that extends over the whole plain of Annaba and flows through the surface silts are represented by: gneiss altered; dune massif, the dunes and the water current and recent alluvium (Fig. 3).
- the deep aquifer is captive and made of gravel, its roof is formed by different textures (clay and clay loam, clay and sand) is the main aquifer of the basin is formed in the permeable sediments (Mio-Pliocène), is formed mainly of pebble, sand and clay along the wadis, which shows better hydraulic properties; and becomes free at the region Drean. At this point (Drean), the superficial layer overcomes gravel layer where there is the possibility of a phenomenon drainance between the two layers (Kherici, 1993).

These aquifers are separated by a semi-permeable and/or impermeable intermediate layer and, thus, constitute a single aquifer of two levels.

The aquifer is supplied by rainfall and infiltration of the Oued Seybouse water further south.

The need to conserve the reserves of this aquifer is very important since it is the main supplier of water intended for human consumption.

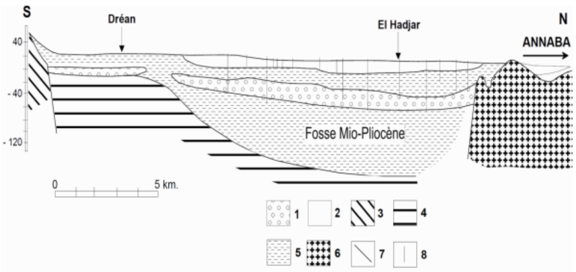

Fig. 3. Hydrogeological Cup through the plain of Annaba (Hani, 2003, amended, 2010).

1: pebbles and gravels, *2:* sand, *3:* Numidian clay, *4:* Cenomanian marl and marly limestone, *5:* Plio-Quaternary detrital clays, *6:* metamorphic formations, *7:* fault, *8:* drilling; source: own elaboration.

Spatial distribution map

The water samples were collected from municipal wells with in the study area and tested for physicochemical parameters were compared with drinking water guidelines of World Health Organization (WHO). The spatial and the attribute database generated are integrated for the generation of spatial variation maps of major water quality parameters like Water abstraction (WAbs), Chloride (Cl), Nitrate (NO_3), Sodium (Na), Calcium (Ca), Magnesium (Mg), Potassium (K), Sulfate (SO_4), hydrogen ion concentration (pH), Bicarbonate (HCO_3), Electrical Conductivity (EC) and Dry Residue (RS). Spatial represented symbology with column charts has been used in the present study to delineate the distribution of water chemical parameters (Fig. 4). The spatial variation of the ground water quality parameters were studied using GIS tools (ArcGIS version 10.3.1, 2015).

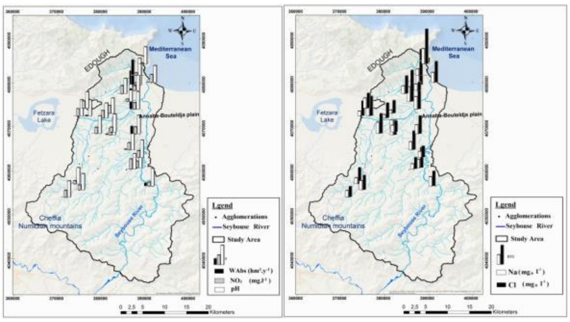

Fig. 4. Spatial distribution of Water Abstraction, Nitrates, pH, Sodium and Chloride for the upper part of the Seybouse River basin.

Sodium and Chloride

Increased concentration values of Soduim and Chloride were observed in northern side of the study area contents when approaching the sea, this result may therefore interpreted by a phenomenon of the influence of seawater (Aoun Sebaiti *et al*, 2013; Debièche, 2002; Djabri *et al*, 2003), and due to industrial activity are recorded at the northern part of the basin near Annaba, El Bouni, Sidi Amar and El Hadjar (Debièche *et al,* 2003; Attoui *et al,* 2014; Hamzaoui *et al,* 2017; Sayad *et al*, 2017; Toumi *et al,* 2017). The spatial distribution concentration of the groundwater spatial distribution values for soduim and chloride ranges from 123 and 625mg/l, and from 355 and 1622mg/l, respectively.

All of these wells exceed According to the standards of recommended by the World Health Organization (WHO) standards (World Health Organization, 2004), the maximum allowable concentrations for drinking water are: 250mg/l for chloride.

Nitrates

Map of spatial distribution of Nitrate ranges from 0.25 to 4.66mg/l, the amounts of Nitrates in the studied groundwater are in the first class according to WHO norms (World Health Organization, 2004). These values are attributed to agricultural and livestock activities.

Water Abstraction (WAbs)

Spatial variation map of water pumped by municipal wells is shown in (Fig. 4). It is measured by million cubic meters per year ($hm^3.y^{-1}$) with the highest value 17.97($hm^3.y^{-1}$) in El Hadjar and El Bouni 11.78($hm^3.y^{-1}$).

pH

Map of spatial distribution of pH (Hydrogen Ion Concentration) ranges from 6.9 to 8.6, which is within desirable limite spatial distribution of pH are shown in (Fig.4).

Calcium

The spatial variation in the calcium concentration of groundwater during the study area (Fig. 5) shows that calcium concentration varied from 34 and 394mg/l.

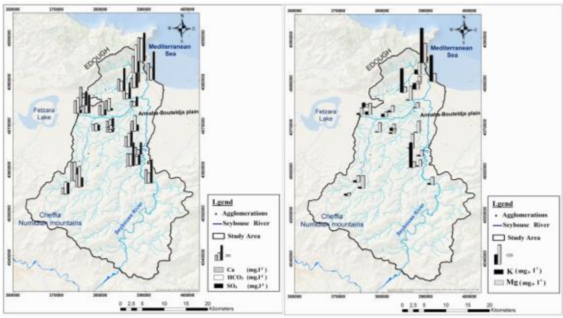

Fig. 5. Spatial distribution of Calcium, Sulphate, Bicarbonate, Magnesium and Potassium for the upper part of the Seybouse River basin.

Magnesium

The spatial variation in the Magnesium concentration of groundwater during the study area (Fig. 5) shows that Magnesium concentration varied from 11 and 124mg/l.

Relatively high concentrations of Ca and mg were also recorded, mainly due to the presence of carbonate rocks.

Potassium

The spatial variation in the Potassium concentration of groundwater during the study area (Fig. 5) shows that Potassium concentration varied from 2.3 and 248mg/l. Higher values of Potassium are were mainly attributed to the dissolution of minerals from the two-mica gneiss that prevails in the bedrock formations metamorphic, while crop fertilization might contribute to the phenomenon.

Sulphate

The map of spatial variation of sulphate (Fig. 5) shows that the sulphate concentration of groundwater in the study area ranges from 24mg/l and 517mg/l. In addition, the high values of sulphate ion are located in the North-East and in the South of the study area. The excessive sulphate concentration in the groundwater of study area, are due to the dissolution of the gypsum of study area.

Bicarbonate

The spatial variation in the Bicarbonate concentration of groundwater during the study area (Fig. 5) shows that Bicarbonate concentration varied from 66 and 486mg/l. Higher values of Bicarbonate are mainly due to the presence of carbonate rocks.

Electric Conductivity (EC)

Map the trend for spatial variation of electrical conductivity of groundwater in the study area. Electrical conductivity ranged from 725 to 2928mS/cm. Map of spatial distribution of electric conductivity show that the higher values of EC, corresponded to sites located in North-East and the centre of the study area (Fig. 6).

Dry Residue (RS)

Map the trend for spatial variation of dry residue of groundwater in the study area. RS ranged from 320 to 2512mg/l. Map of spatial distribution of RS show that the higher values along the wadis and in the centre of the study area (Fig. 6).

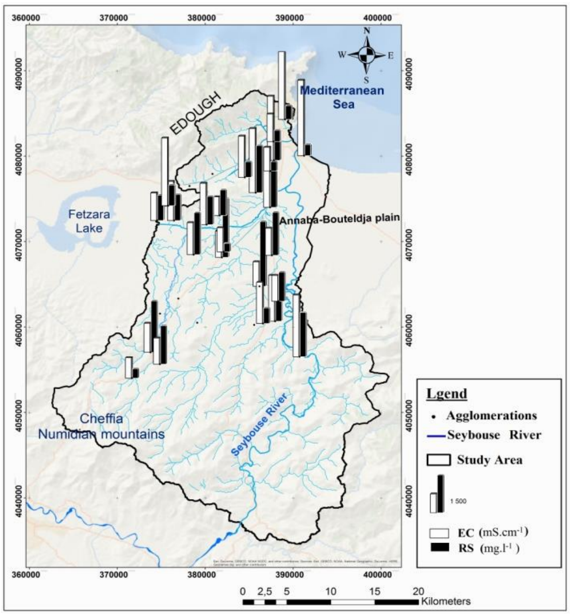

Fig. 6. Spatial distribution of Electrical Conductivity and dry residue for the upper part of the Seybouse River basin.

The Previous Figures also confirms the impact of geology on the water quality; Calcium, magnesium, sulphate and bicarbonates derived boundary formations, this mineralization comes from the dissolution-precipitation of the aquifer rock, evaporation and the Base Exchange (Halimi *et al.*, 2016). The chloride and sodium contents of the water are very high, over-exploitation of the aquifer has led to falling groundwater levels and deteriorated water quality due to seawater intrusion (Aoun Sebaiti *et al.* 2013; Debièche, 2002; Djabri *et al.*, 2003), while the nitrates are related to human activities.

DPSIR analysis approach

The Water Framework Directive (WFD) 2000/60/EC clearly sets the basis and principles for effective protection of groundwater, internal, transitional and coastal waters at the river basin scale.

Several techniques and methodologies have been proposed for the optimization of water resource management at this scale, and the Driver-Pressure-State-Impact-Response (DPSIR) methodology (European Environmental Agency, EEA, 2014), is one of the methods that is being extensively applied in the framework of integrated water resource management (Mattas *et al.*, 2014).

A new conceptual water integrated model has been developed based on cause-effect relationship tackling the life cycle of water resources management. The Driver-Pressure-State-Impact-Response (DPSIR) was selected as a well-established framework to develop the possible variables under five categories which are:
D: Driving forces are underlying socio-economic and sectoral factors influencing a variety of relevant variables;
P: Pressure indicators describe the variables which directly cause environmental problems;
S: State indicators illustrate the existing conditions and the observable changes of the environment;
I: Impact indicators describe the ultimate effects of changes of state on the human and ecosystems; and
R: Response indicators present the efforts of the administration and policy making level (Decision makers, management) to intervene and solve the problems.

The Driving force- Pressure- State- Impact- Response (DPSIR) framework has been selected to analyze all regional water catchments in the European research project, EUROCAT, which aims to achieve integrated catchment and coastal zone management. It will assist predict how future socio-economic changes in the water catchments might affect the water quality in order to formulate policy responses that will act to reduce the pressures created by certain drivers, and the impacts of certain pressures on water quality (Cave *et al.,* 2003). Also (Jeunesse *et al.,* 2003) introduced the DPSIR framework for environmental cause-effect relationship to develop indicators for integrated and operational decision support system for sustainable use of water resources at the catchment level.

The main objectives of the research were to:
- Characterize the effective variables of water sector management and define the geographical areas under water stresses;
- Establish prediction relationships between the water abstraction from the coastal aquifer and water quality state;
- Classify municipalities into clusters associated with their related water variables;
- Formulate recommendations for change including new concepts to sustain the natural water resources as sources of supply for both the present and future generations (IAHS, 2003).

Results and discussions

Statistical analysis

The statistical software (Statistica version 8, 2008) was utilized for the Tests of normality and multivariate statistical analyses-hierarchical cluster analysis (HCA) and principal component analysis (PCA) and neural networks to support the conventional hydrochemical techniques. Twelve hydrochemical variables (Ca^{2+},mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, HCO_3^{-}, NO_3^{-}, EC, pH, DR and Water Abstraction) were utilized in the statistical analyses.

Analysis with artificial neural networks (ANN)

Analysis with ANN models were used to characterize and prioritize the effective variable of water quality categories. Linearity and normality of data are not pre-requisites for using ANN models. Hence, there is no need for transformation of data (Jalala, 2005). Groundwater abstraction data and water quality parameters were applied to create the ANN model. The water quality parameters were: Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), Potassium (K^{+}), Chloride (Cl^{-}), Sulphate (SO_4^{2-}), Bicarbonate (HCO_3^{-}), Nitrate (NO_3^{-}), Electrical Conductivity (EC), Hydrogen ion concentration (pH), Dry Residue (RS).

Often in water quality management, understanding the relationship between input and output data might be a complicated process (Asadollahfardi, 2015). The water quality variables were considered as the possible input variables whilst the target output variable was the water abstraction (WAbstrac). The variables representing the water quality state were considered as the possible input variables whilst the target output variable was the water abstraction (Jalala, 2005).

The MLP network can be represented by the following compact form:
{WAbstrac}= ANN [Ca,mg, Na, K, Cl, SO_4, HCO_3, NO_3, EC, pH, RS]

A schematic diagram of this network is given in Fig. 7.

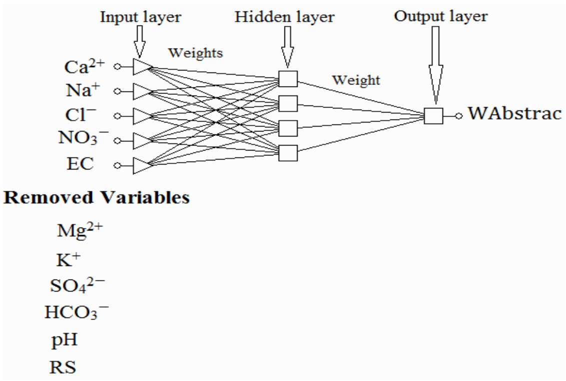

Fig. 7. MLP Network (three layers), water quality variables.

The types of networks considered are: MLP (3 and 4 layers), RBF, GRNN, and Linear. During the analysis several networks were tested. The best optimal ANN model found is MLP (3 layers) with 4 hidden nodes Fig. 7 and a minimal error of 0.0914258 compared with the other types of ANN networks Table 1. The model has very good performance in verification with regression ratio (S.D. ratio) of 0.2959572 and the correlation coefficient is higher than 97% for training, verification and testing Table 1 which shows an excellent agreement between the actual observed and predicted water abstraction (Fig. 8).

Table 1. Statistical regression parameters for the target output (WAbstrac)-Water quality variables.

	Tr. WAbstr	Ve. WAbstr	Te. WAbstr
Data mean	12.91034	4.884496	12.25741
Data S.D.	11.95233	0.9140903	8.577478
Error mean	-5.127481	-0.1374	0.691065
Error S.D.	8.253735	0.2705317	4.280636
Abs. error mean	7.127574	0.1716824	2.944339
RMS error	0.1166621	0.0914258	0.1273973
S.D. ratio	0.6905546	0.2959572	0.4990554
Correlation	0.9823898	0.9924537	0.9714513

Legend: Tr: Training, Ve: Verification, Te: Testing

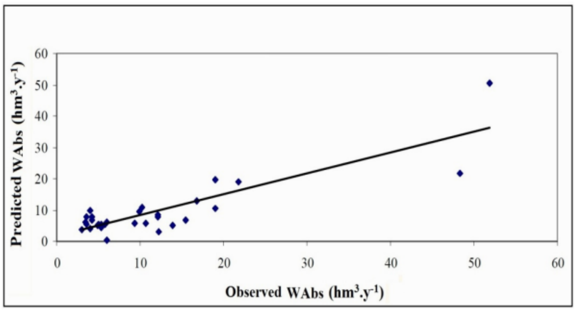

Fig. 8. Predicted QWAbs vs Observed QWAbs.

The ANN sensitivity analysis of water quality variables in both training and verification phases Table 2 indicates that Chloride and Electrical Conductivity, Nitrate, Calcium and Sodium are the most important and effective factors influencing the attractiveness of groundwater users. The ANN model removed six input variables due to their low sensitivity which are Magnesium, Potassium, Sulphate, Bicarbonate, Hydrogen ion concentration, Dry Residue.

Table 2. Sensitivity analysis of independent input variables-Water quality variables.

Ca^{2+}	Na^{+}	Cl^{-}	NO_3^{-}	EC
3	5	1	2	4
9.896936	9.714642	10.81463	10.20827	9.822055
1.027149	1.00823	1.122392	1.059461	1.019378
4	5	1	3	2
1.915556	1.824192	5.055606	3.073097	4.130911
0.9918232	0.9445173	2.617656	1.591166	2.138874

Verification phase are

Chloride, Electrical Conductivity, Nitrate, Calcium, Sodium. The ANN model removed six input variables - Magnesium, Potassium, Sulphate, Bicarbonate, Dry Residue, Hydrogen Ion Concentration (pH)- because of its low sensitivity. The results of the ANN model are shown in Table 3.

Table 3. Ranking of input variables via expert opinion and judgment-socio-economic variables.

	Cl^{-}	EC	NO_3^{-}	Ca^{2+}	Na^{+}
Rank	1	2	3	4	5

Tests of normality (Water Quality)

The normality tests are supplementary to the graphical assessment of normality (Elliott, Woodward, 2007). The main tests for the assessment of normality are Kolmogorov-Smirnov (K-S) test, Lilliefors corrected K-S test, Shapiro-Wilk test (Oztuna *et al.,* 2006). The Shapiro-Wilk test is the most powerful test (Yap, Sim, 2011). Some researchers recommend the Shapiro-Wilk test as the best choice for testing the normality of data (Thode, 2002).

Tests of normality of groundwater physicochemical parameters for the study area are summarized in Table 4. According to the Shapiro-Wilk test, that K^{+}, Cl^{-}, HCO_3^{-}, EC and WAbstra have non-normal distribution of data. Ca^{2+}, Na^{+}, mg^{2+}, SO_4^{2-}, pH, NO_3^{-}, DR, have reasonably normal data distribution.

Table 4. Tests of normality of water quality variables.

Variable	N	max D	K-S P	Lilliefors P	W	P
Ca^{2+}	25	0,130272	p > .20	p > .20	0,964572	0,512785
Mg^{2+}	25	0,180419	p > .20	**p < ,05**	0,941477	0,160121
Na^{+}	25	0,119707	p > .20	p > .20	0,932979	0,101839
K^{+}	25	0,367213	**p < ,01**	**p < ,01**	**0,579282**	**0,000000**
Cl^{-}	25	0,209884	p > .20	**p < ,01**	**0,820219**	**0,000504**
SO_4^{2-}	25	0,131742	p > .20	p > .20	0,960621	0,426986
HCO_3^{-}	25	0,155603	p > .20	p < ,15	**0,908343**	**0,027997**
NO_3^{-}	25	0,182421	p > .20	**p < ,05**	0,932800	0,100873
EC	25	0,208419	p > .20	**p < ,01**	**0,870186**	**0,004363**
pH	25	0,168674	p > .20	p < ,10	0,935031	0,113607
RS	25	0,128916	p > .20	p > .20	0,941383	0,159324
Wabstra	25	0,359676	**p < ,01**	**p < ,01**	**0,445049**	**0,000000**

Correlation matrix analysis

The Pearson's correlation coefficient was used to show the interrelationship and coherence pattern among groundwater quality parameters (Pearson, 1896). The correlation coefficient values of the analyzed water quality parameters are given in Table 5. Correlation matrix showed inter-parameter. Strong ($p < 0.01$) and significant correlation ($p < 0.05$) were observed in the groundwater samples. The NO_3^- showed a negatively significant correlation withmg^{2+} ($r = -0.52$), Na^+($r = -0.44$), Log Cl^-($r = -0.46$). The Log EC had a positive strong correlation with Na^+($r = 0.58$), Log Cl^-($r = 0.68$), SO_4^{2-}($r= 0.43$). It is found that the salinity load in groundwater are controlled first by Na^+, and then by $Cl^-$and SO_4^{2-}. The existence of strong positive correlation of Na^+ and Log Cl^- ($r = 0.73$) and weak positive correlation between Ca^{2+} andmg^{2+} ($r = 0.47$). A passively significant correlated was existed between Ca^{2+} with Log K^+($r = 0.54$), SO_4^{2-} ($r = 0.59$) and HCO_3^- ($r = 0.53$). Agricultural fertilizer and stagnant water may be attributed the main sources of this groundwater hydrochemical evolution in the study area.

Table 5. Pearson Correlation matrix of water quality variables.

	Ca^{2+}	Mg^{2+}	Na^+	LogK^+	LogCl^-	SO_4^{2-}	LogHCO_3^-	NO_3^-	LogEC	pH	RS	WAbs
Ca^{2+}	1,00											
Mg^{2+}	**0,47**	1,00										
Na^+	0,11	**0,48**	1,00									
LogK^+	**0,54**	0,00	-0,15	1,00								
LogCl^-	0,32	**0,59**	**0,73**	-0,08	1,00							
SO_4^{2-}	**0,59**	**0,44**	0,23	**0,56**	0,24	1,00						
LogHCO_3^-	**0,53**	0,38	-0,28	0,38	-0,21	0,37	1,00					
NO_3^-	-0,37	**-0,52**	**-0,44**	0,05	**-0,46**	-0,23	-0,05	1,00				
LogEC	0,38	0,15	**0,58**	0,25	**0,68**	**0,43**	-0,29	-0,21	1,00			
pH	-0,30	0,25	**0,54**	**-0,48**	0,24	-0,01	-0,29	-0,24	0,08	1,00		
RS	-0,09	0,32	0,30	**-0,69**	0,26	-0,15	-0,11	-0,03	-0,05	0,34	1,00	
WAbs	-0,35	-0,11	**0,40**	-0,38	0,31	-0,15	**-0,40**	-0,06	0,31	0,33	0,15	1,00

Note: Significant values (at *p*< 0.05) are in bold, n=25 (case wise deletion of missing data)

It can be said that common rock water interaction and anthropogenic activities are responsible for ionic alteration of groundwater in the study area and weak correlation between WAbstract and Na^+ ($r = 0.40$), Log HCO_3 ($r = -0.40$). The correlation matrix between the different analyzed parameters shows that certain variables (taken two by two) present correlation coefficients varying between 0.4 and 0.7 explaining the complexity of influences exercised over the chemistry of water.

Factor Analysis

The global PCCA of the set of data related to water demonstrate that the first two factors (F1 and F2) provide a justified inertia of 72,2 % that appears rather good, having an average inertia, a considerable number (25) of analyzed samples and (12) variables taken into consideration; knowing that the cumulated percentage goes gradually towards 100%.

Table 6 presents variances of factors and their loadings from variables.

The first factor corresponds to the largest eigenvalue (2,88) and accounts for approximately 47,96% of the total variance. It is most correlated with the variablesNa^+, Cl^-, EC (positive correlations) and NO_3^- (negative correlation). The second factor corresponding to the second eigenvalue (1,46) accounts for 24,27% of the total variance. It is highly correlated with Ca^{2+} (positive correlation) and WAbs (negative correlation). (Fig.9: a, b) displays coordinates for the two factors. The graph shows a unit circle with active variables that were used to compute the current factor solution and a supplementary variable that was only mapped into the coordinate system defined by the factors.

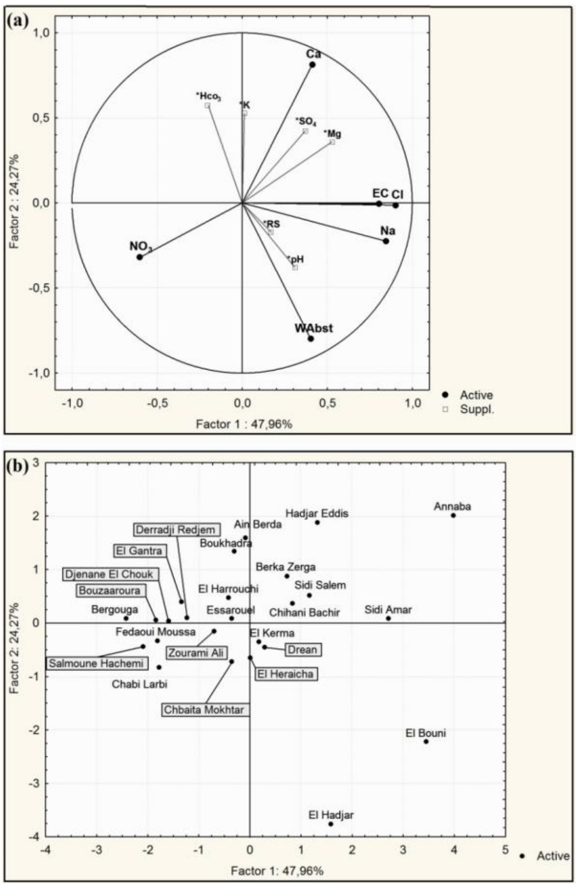

Fig. 9. (a) Projection of the variables on the factor-plane (I-II); (b) projection of the cases on the factor-plane (I-II).

Because the current analysis is based on correlations, the largest factor coordinate (variable-factor correlation) that can occur is equal to 1.0; also, the sum of all squared factor coordinates for a variable (squared correlations between the variable and all factors) cannot exceed 1.0. The circle can provide a visual indication (scale) of how well each variable is represented by the current set of factors (the closer a variable in this plot is located to the unit circle, the better is its representation by the current coordinate system). Based on the magnitudes of the factor coordinates (variable-factor correlations) for the variables in the analysis, the first factor can be labeled as Chloride. Factor two can be labeled as Calcium. (Fig.9: b) presents the factor coordinates for all municipalities. Matching (Fig.9:a, b) for the two factors shows that municipalities of El Bouni and El Hadjar are analogous in terms of water abstraction. Sidi Amar, El Bouni and Annaba are similar in the areas of Chloride, Sodium and Electric conductivity. Salmoune Hachemi, Fedaoui Moussa, Chabi Larbi, Chebaita Mokhtar and Zourami Ali is distinguished with Nirate, thus determining a pollution as a consequence of anthropogenic activities particularly agricultural knowing. Annaba and Hdjar Eddis with Calcium. Drean, El Kerma and El Heraicha are similar in terms of Dry Residue as a supplementary variable. Ain Berda, Boukhadra, El Harouchi and El Gantra are distinguished with Bicarbonate variable.

Table 6. Factor-variable correlations (factor loadings), water quality variables.

Variable	Factor 1	Factor 2
Ca^{2+}	0,411674	**0,814457**
Na^+	**0,847630**	-0,225899
Cl^-	**0,902884**	-0,012032
NO_3^-	-0,603454	-0,320443
EC	**0,804958**	-0,005327
Wabstra	0,402908	**-0,799272**
*Mg^{2+}	0,528869	0,359115
*K^+	0,012062	0,526744
*SO_4^{2-}	0,372576	0,425184
*HCO_3^-	-0,199760	0,573187
*pH	0,310536	-0,378939
*RS	0,170468	-0,171951

In bold: loadings are >.700000

Active and Supplementary variables

*Supplementary variable (Underlined loadings are >.700000)

The R-mode cluster analysis (CA) retained two major clusters for data sets of analyzed parameters. R-mode cluster analysis was applied to predict physicochemical groupings in the groundwater datasets, and the results are shown in (Fig. 10: a). Parameters belonging to the same cluster were likely to be found from a same source. Cluster 1 included different subgroups. Cl^-, EC and NO_3^- in one group with the same weight to WAbstract, it can be labeled as water abstraction. Cluster 2 contained only Na^+, it can be labeled as Sodium concentration.

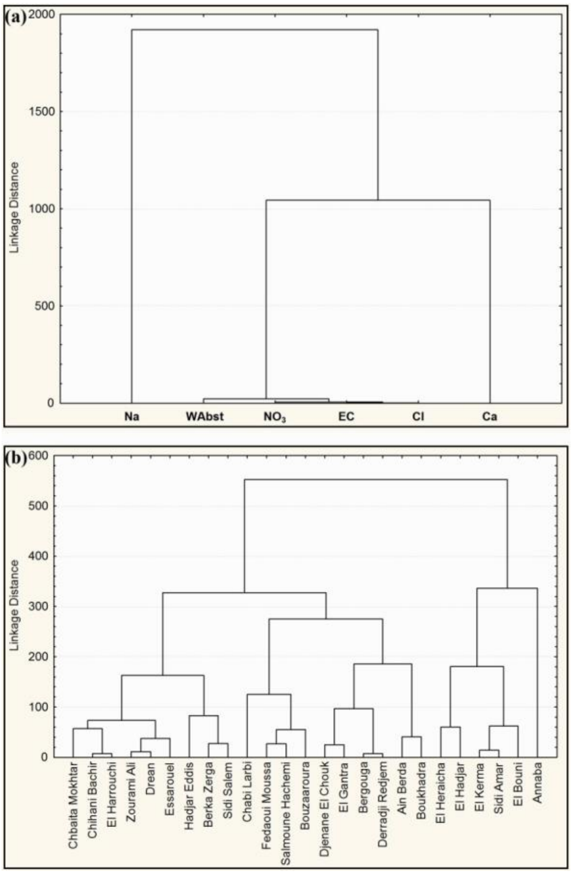

Fig. 10. (a) Cluster analysis results for variables - State of water quality; (b) hierarchical tree for cases- State of water quality Complete Linkage Euclidean distances.

Q-mode CA was used to recognize the spatial similarities and site grouping among the sampling points. Particular group/class shows similar characteristics with respect to the analyzed parameters in a samples cluster. The 25 sampling sites for ground water fall into two clusters (Fig. 10: b). The first cluster (right) consists 6 sampling of municipalities are Annaba, El Bouni, Sidi Amar, El Hadjar, El Kerma and El Heraicha. The second cluster of municipalities contains Chbaita Mokhtar, Chihani Bachir, Hdjar Eddis, Zourami Ali, Drean, El Harrouchi, Sidi Salem, Essarouel, Berka Zerga, Chabi Larbi, Salmoune Hachemi, Fedaoui Moussa, Bouzaaroura, Djenane El Chouk, Ain Berda, Derradji Redjem, Bergouga, El Gantra, and Boukhadra. The first cluster of municipalities is associated with the first group of variables whilst the second cluster of municipalities is associated with the second group of variables. Therefore, the first cluster of municipalities can be identified as "water abstraction" cluster whilst the second cluster of municipalities is labeled as "Sodium" cluster.

Conclusion

This paper presents integrated approaches for characterizing hydrochemistry and suitability of groundwater quality in the Seybouse Valley (North East of Algeria). Based on GIS and DPSIR methods; and the major objective of the study was to establish a modeling relationship between groundwater abstraction and water quality determinants, and characterize their priorities. To this end, the results obtained in this study indicate that MLP network proved to be the best ANN structure to model and predict the quantity-quality relationship of groundwater abstraction and use in the Annaba region. Besides, the effective water quality parameters were defined and prioritized. Thus, the ANN models can be recommended for independent data sets in water sciences.

This study comes as the first attempt in applying ANN models to assist water planners and managers in the Annaba region to better understand the water quality determinants influencing the attractiveness of groundwater users. The selection and prioritization of effective water quality parameters indicate that this model is a useful tool to devise priority interventions, optimizing the limited available financial resources, towards to provision of appropriate quantities of water of suitable quality. He model also, strengthens the Integrated Water Resources Management approach through addressing groundwater the parameter of nitrate stresses the need to remove nitrate from groundwater using appropriate techniques. The Chloride parameter demonstrates the need for desalination of brackish and sea waters.

Abbreviation

Ca^{2+}: Calcium,mg.l^{-1}
Mg^{2+}: Magnesium,mg.l^{-1}
Na^{+}: Sodium,mg.l^{-1}
K^{+}: Potassium,mg.l^{-1}
Cl^{-}: Chloride,mg.l^{-1}
RS: Dry Residue,mg.l^{-1}
SO_4^{2-}: Sulfate,mg.l^{-1}
HCO_3^{-} : Bicarbonate,mg.l^{-1}
NO_3^{-}: Nitrate, mg.l^{-1}
EC: Electrical Conductivity, mS.cm^{-1}
pH: Hydrogen Ion Concentration
WAbs: Water Abstraction, hm^3.y^{-1}

References

Aoun-Sebaiti B, Hani A, Djabri L, Chaffai H, Aichouri I, Bougherira N. 2013. Simulation of water supply and water demand in the valley of Seybouse (East Algeria). Desalination and Water Treatment. DOI: 10.1080/19443994, 855662, 1-6.

Asadollahfardi G. 2015. Water Quality Management. Assessment and Interpretation. SpringerBriefs in Water Science and Technology. DOI 10. 1007/978-3-662-44725-5.

Attoui B, Kherici N, Kherici-Bousnoubra H. 2014. Use of a new method for determining the vulnerability and risk of pollution of major groundwater reservoirs in the region of Annaba-Bouteldja (NE Algeria). Envron. Earth Sci **72,** 891-903.

Cave RR, Ledoux L, Turner K, Jickells T, Andrews JE, Davies H. 2003. The Humber catchment andits coastal area: from UK to European perspectives. The Science of the Total Environment **314-316,** 31-52.

Debièche TH. 2002. Evolution de la qualité des eaux (salinité, acidité et métaux lourds) sous l'effet de la pollution saline, agricole et industrielle : Application à la basse plaine de la Seybouse Nord-Est algérien. Thèse de Doct. Univ. de Franche-Comté 200 p.

Debièche TH, Mania J, and Mudry J. 2003. Pollution d'une nappe alluviale par le chrome et l'étain à partir d'un stockage de résidus métallurgiques: Application à la basse plaine de la Seybouse, Nord-Est Algérien. Africa Geosciences Review, Vol. **8**, **N°4,** 425-435.

Djabri L, Laouar R, Hani A, Mania J, Mudry J. 2003. The origin of water salinity on the Annaba coast (NE Algeria). Water Resources Systems, IAHS Publ. N°**280,** 229-235.

Djabri L, Fehdi Ch, Hani A, Bouhsina S, Nouiri I, Djouamaa MC, Boch AP, Baali F. 2015. Seasonal Hydrochemical Changes of Water from Alluvium Aquifers: Drean-Annaba Aquifer Case Study (NE Algeria). In: Lollino G., Manconi A., Clague J., Shan W., Chiarle M. (eds) Engineering Geology for Society and Territory- **V. 1.** Springer, Cham 89-93.

Elliott AC, Woodward WA. 2006. **Statistical Analysis Quick Reference Guidebook: With SPSS Examples**. SAGE Publications, Inc; 1 edition 280 p.

Eurpean Environmental Agency (EEA). 2014. The DPSIR framework used by the EEA. Available online: http://glossary.eea.europa.eu//terminology /sitesearch?term=DPSIR

Halimi S, Baali F, Kherici N, Zairi M, Bouhsina S. 2016. Irrigation and Risk of Saline Pollution. Example: Groundwater of Annaba plain (North East of Algeria). European Scientific Journal February 2016 edition, vol. **12, N°6,** 241-254.

Hamzaoui W, Hani S, Aoun-Sebaiti B, Harrat N, Chaffai H. 2017. Origin of water salinity in Annaba aquifer system, North-Eastern Algeria. J. Bio. & Env. Sci. **11 (6)**, 260-273. https://goo.gl/pfHEti

Hani A. 2003. Analyse méthodologique de la structure et des processus anthropiques : Application aux ressources en eau d'un bassin côtier méditerranéen. Thèse de Doctorat d'Etat en Sciences, Université Badji Mokhtar-Annaba 209 p.

Jalala S. 2005. Characterizing the Multi-criteria Parameters of Integrated Water Management Model in the Semi-arid Mediterranean Region: Application to Gaza Strip as a case study. PhD Thesis-univ of Lille 225 p.

Jeunesse I, Rounsevell M, Vanclooster M. 2003. Delivering a decision support system tool to a river contract: a way to implement the participatory approach principle at the catchment scale? Journal of physics and Chemistry of the Earth, **Volume 28, Issues 12-13,** 547-554.

Kherici N. 1993. Vulnérabilité à la pollution chimique des eaux souterraines d'un système de nappes superposées en milieu industriel et agricole (Annaba la Mafragh-nord-est algérien). Thèse de Doctorat d'Etat en Sciences, Université Badji Mokhtar-Annaba, 170 p.

Lamouroux C, Hani A. 2006. Identification of groundwater flow paths in complex aquifer systems, Hydrol. Processes **20(14),** 2971-2987.

Mattas C, Voudouris KS, Panagopoulos A. 2014. Integrated Groundwater Resources Management Using the DPSIR Approach in a GIS Environment Context: A Case Study from the Gallikos River Basin, North Greece. Water **6,** 1043-1068.

Oztuna D, Elhan AH, Tuccar E. 2006. Investigation of four different normality tests in terms of type 1 error rate and power un-der different distributions. Turkish Journal of Medical Sciences **36(3),** 171-176.

Pearson K. 1896. Mathematical contributions to the theory of evolution, III. Regression, heredity and panmixia. Phil. Trans. A 187, 253-318. Reprinted in K. Pearson **(1956),** pp. 113-178.

Sayad L, Djabri L, Drouiche N, Chaffai H, Hani A. 2017. Calculation and interpretation of effluent discharge objectives of metal industry - case of Protuil manufacturing - Annaba (Northeast Algeria). Desalination and Water Treatment, doi: 10.5004/dwt.2017.21749, **Vol. 99,** 338-343.

StatSoft Inc. 2008. STATISTICA (data analysis software system), version 6.1. www.statsoft.com

Thode HJ. 2002. Testing for normality. New York: Marcel Dekker.

Toumi F, Bougherira N, Hani A, Chaffai H, Djabri L. 2018. Impact of the Berka Zerga urban discharge on the Environment and Lake Fetzara (Annaba, Algeria). J. Bio. Env. Sci. **12 (4),** 176-184. https://goo.gl/QaxcDW

World Health Organization. 2004. *Guidelines for* Drinking-Water Quality, 3rd ed. Vol. **1**, Recommendations. WHO, Geneva, Switzerland, 494 p.

Yap BW, Sim CH. 2011. Comparisons of various types of normality tests. Journal of Statistical Computation and Simulation **81(12)**, 2141-2155.

Arc GIS. 2015. Version 10.3.1.