Assessment of Groundwater Quality for Drinking Water Using by Water Quality Index in Mnasra Region (Morocco)

Nadia Aghrib [*], Sarra EL-Haji [**], Imane Bedoui [**], Mustpha Lebkiri [***] , Hefdhallah Alaizari [****], Abdelaziz Chaouch[*], Mohamed Fadli [**]

[*]laboratory of Biotechnology, Environment and Quality - UFR of process engineering, Faculty of Sciences, Ibn Tofail University

[**]Laboratory of Plant, Animal and Agro-Industry Productions, Faculty of Sciences Kenitra, Ibn Tofail University, Kenitra, Morocco.

[***]Laboratoire des matériaux avancés et génie des procédés Faculté des sciences de kenitra

[****]Department of Chemistry, Faculty of Education, University of Dhamar, Yemen.

Abstract

The Water Quality Index (WQI) is a method used to assess the overall water quality from data of analyze for understood by managers and decision-makers. In this study, the WQI with twelve physicochemical parameters were used to evaluate the overall sixty eleven wells of the groundwater of Mnasra in the northeastern of Morocco, is about 488 km^2. The results of WQI showed a difference from 35.45 to 660.22. According of standards the WQI values, it is observed that only one location study is found unsuitable for drinking (WQI > 300). Where, the results show that the highest values effective weight value belong to the $NO3^-$, Cl^-, Na^+ and K^+ parameters compared with the other parameters. Consequently, environmental pollutants negatively affect the Mnasra groundwater. Therefore, necessary protection measures should be taken as related to planned usage of the groundwater.

Keywords: Water samples, Correlation, WQI, Mnasra region, Morocco.

I. Introduction

The water is the basic element of life, it has been known that the quality of water directly influences of human health. In the last century, the demand for water was very large due to the increase in population growth. The preferred drinking sources are groundwater, because it is more protected from pollution compared to surface water. In addition, there are factors influence on quality of groundwater. Such as urbanization, industrialization, and environmental pollution. Soon all these factors were responsible for water quality and the source of many pollutants[1, 2– 4].

Water Quality has become an important concern especially in rural areas where the population is large depend on ground water for drinking purposes[5]. Unwanted Groundwater quality reduces economy and restrictions improving the living conditions of the rural population. Therefore, it became necessary to conduct a systematic evaluation and monitor the quality of groundwater for drinking and to adopt appropriate measures for protection[2].

The Water Quality Index (WQI) is a valuable and unique assessment to describe the general condition of water quality in a single term, which is helpful in choosing an appropriate treatment technique to meet to the problems encountered[6– 9].

However, the WQI describes the combined effect of different water quality standards and conveys information on water quality to the public and to decision makers. Although there is no universally accepted composite water quality index, some countries have used aggregate water quality data and use them to generate water quality indicators[6].

The study area is a rural where residents depend on groundwater for drinking and domestic purposes. The objective of this work is to discuss the suitability of groundwater for human consumption based on computed WQI values in Mnasra region.

II. Materiel and Method

Study area

The study area between the city of Kenitra in the south, the Oued Sebou extended by the parallel line passing through Sidi Allal Tazi in the east, Merja Zerga near Moulay Bouselham in the north it is located around the geographic coordinates 34°21′37″N 6°33′03″W, the rural commune of Manasr extends approximately 488 km^2. The climate is Mediterranean with oceanic influence. It receives an average annual rainfall of about 566, 4 mm. The rainfall period extends from October to the end of April, with a maximum for November, December and January. Mean temperatures range from 12°C in winter to 23°C in summer. Potential evaporation exceeds 150 mm during the dry months of June to September and is less than 80 mm during the months of December to February.

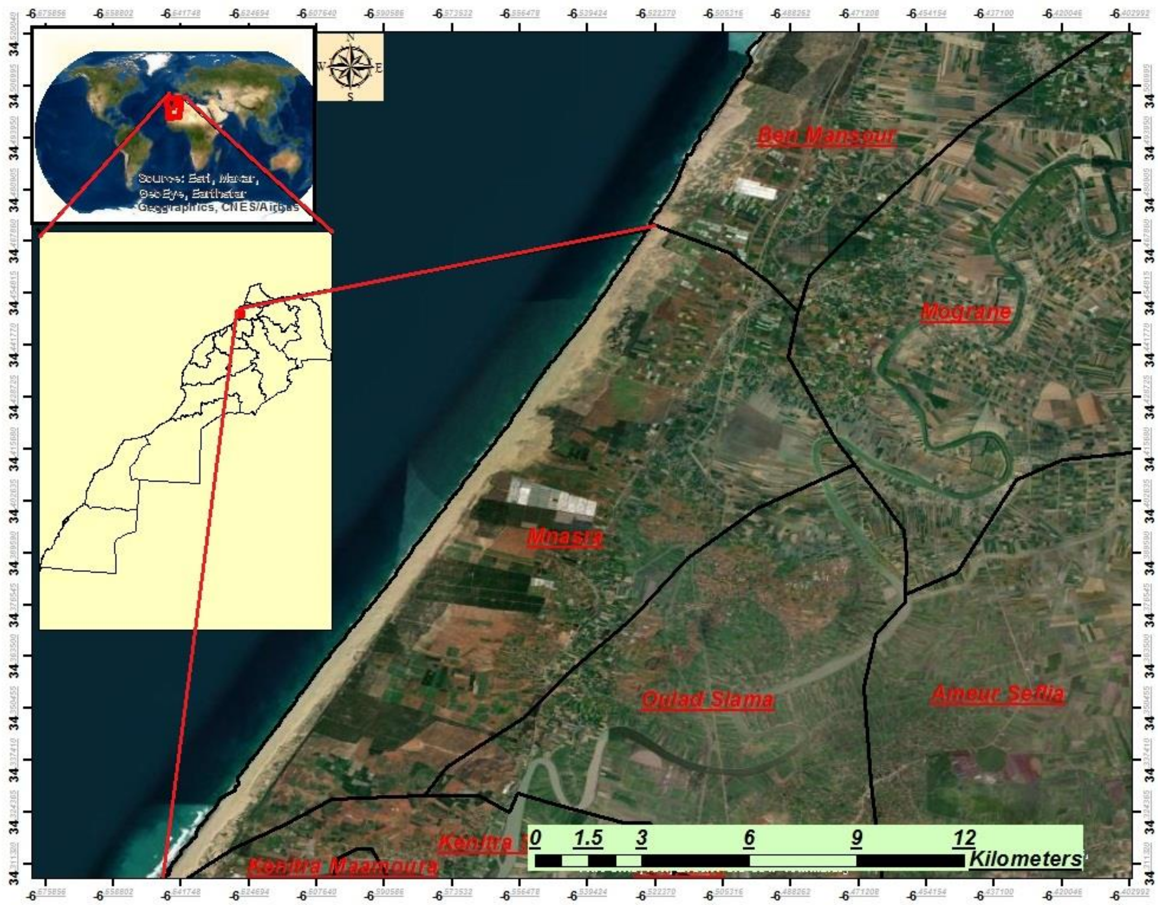

Figure 1: Study area

Samples of study

We have selected 70 wells belonging to the commune of Mnasra. The depth of its wells varies between 20 to 40m, where, were selected that to use for drinking according to personal interviews with well owners, on a daily basis, irrigation and animal feeding (Fig.1).The wells are located in the Manasra region, which is adjacent to the agricultural lands.

The samples of study were collected from different region in Mnasra, where were taken in 2010. and then transported in a cooler at 4°C to the laboratory for analysis. all samples were analyzed for twelve physicochemical parameters, physic parameters are temperature, pH, and electrical conductivity (EC), and chemical parameter are Cations (Ca^{2+}, Mg^{2+}, Na^{+}, k^{+} & $NH3^{+}$)and anions (Cl^{-}, HCO_3^{-}, SO_4^{2-}& NO_3^{-}) which were all parameters using standard procedures recommended by [10]. The samples were measured in the lab, the Table 1, summarizes the whole physic-chemical parameters measured as well as the Detail methodology followed.

Table 1: Summarizes the physic-chemical parameters measured as well as the Detail methodology

Parameters	**Methods used**
Electrical Conductivity EC(µs/cm)	Conductive meter
Hydrogen Potential pH	pH-meter
Calcium $Ca^{2+(}$meq/l)	Titrimetric methods
Magnesium $Mg^{2+(}$meq/l)	Titrimetric methods
Sodium Na^{+} (meq/l)	Photometry a flame
Potassium K^{+}(meq/l)	Photometry aflame
Chloride Cl^{-} (meq/l)	Mohr's method
Bicarbonate $HCO3^{-}$ (meq/l)	Titrimetric methods
Sulfate $SO4^{2-}$ (meq/l)	Titrimetric methods

The quality of analytical data was examined by computing the balance of positive and negative ions. Almost all groundwater samples showed good charge balance, typically less than 5%. The analytical data obtained were processed for statistical analyses using Minitab 17, Excel 2013 ArcGIS13.3 software. The hydrochemistry of groundwater was analyzed by major cation and anion concentrations, correlation analysis among various physiochemical parameters and water quality index.The suitability of groundwater of the study area was examined based on percent compliance of the measured data with respect to Moroccans Standard. In order to assess groundwater quality, it was used the Moroccans Standard for drinking Water for to calculate WQI. WQI is computed through three steps. First, each of the 12 parameters (pH, EC, TDS, TH, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, HCO_3^{-}, SO_4^{2-}& NO_3^{-}), it was assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes (Table 2). The values of weights were between 1 and 5 based on their relative significance in the water quality evaluation. Second and Third, Computed the relative weight (*Wi) & (Qi)* of the chemical parameter and calculi WQI were using the following[11], [12]:

$$\boldsymbol{WQI} = \sum \boldsymbol{W_i Q_i} = \sum \left[\left(\frac{\boldsymbol{w_i}}{\sum_{n}^{i=1} \boldsymbol{w_i}}\right) * \left(\frac{\boldsymbol{C_i}}{\boldsymbol{S_i}} * \boldsymbol{100}\right)\right]$$

Where,

w_i is the relative weight, $\boldsymbol{w_i} = \frac{\boldsymbol{w_i}}{\sum_{n}^{i=1} \boldsymbol{w_i}}$

w_i is the weight of each parameter, and n is the number of parameters.`

Q_i is the quality rating, $\boldsymbol{Q_i} = \left(\frac{\boldsymbol{C_i}}{\boldsymbol{S_i}} * \boldsymbol{100}\right)$

C_i is the concentration of each chemical parameter in each water sample in mg/L, and

S_i is the Moroccan drinking water standard for each chemical parameter in mg/L.

Table 2: The relative weight of the physicochemical parameter.

Number	Parameters	Parameter Weight(Gorchev and Ozolins 2011)	Si	Relative weight (Wi)
1	pH	4	9.5	0.0952381
2	EC	3	2700	0.07142857
3	TDS	5	1500	0.11904762
4	Ca^{2+}	3	100	0.07142857
5	Mg^{2+}	3	100	0.07142857
6	Na^{+}	4	15	0.0952381
7	K^{+}	2	12	0.04761905
8	SO_4^{2-}	5	250	0.11904762
9	HCO_3^{-}	1	500	0.02380952
10	Cl^{-}	5	750	0.11904762
11	NO_3^{-}	5	50	0.11904762
12	TH	2	500	0.04761905
		Σwi =42		**1**

The range for WQI for drinking purpose is tabulate in Table 3[13].

Table 3: Classification of water by WQI

WQI range	Water quality
<50	Excellent water
50-100	Goodwater
100-200	Poor water
200-300	Very Poor water
>300	Water unsuitable for drinking purpose

III. Result and Dissection

The results of basic statistics of groundwater chemistry are presented in Table 4. In this Table 4, we expressed the levels in means ± standard deviations.

Table 4: Basic statistics of the physicochemical parameters of wells samples.

Variable	Mini	Max	Mean	StDev
pH	6.91	8.65	7.4943	0.332
CE(µs/cm)	267	9870	1567	1496
TH(mg)	109.7	529.9	246	93.2
Ca2+(meq/l)	0.4	7.204	3.012	1.292
Mg2+(meq/l)	0.2	5.396	1.908	1.115
Na+(meq/l)	0.71	71.16	4.71	8.93
K+(meq/l)	0.005	6.4	0.2079	0.774
Cl-(meq/l)	0.5	68.88	5.47	8.74
HCO3-(meq/l)	1	9.998	2.884	1.634
NO3-(meq/l)	0.2	5.199	1.835	1.105
SO42- (meq/l)	0.01	0.9915	0.5398	0.2704

Physiochemical parameters

The pH shows slightly acidic to alkaline nature 6.91 to 8.65 with mean 7.4943 ±0.332 of groundwater in the study area. The value electrical conductivity of the study samples was between 267 to 9870 (µs/cm) with mean 1567±1496, the maximum values of electrical conductivity is 9870 µs/cm indicating high to moderate mineralization in the area. In addition, the value of TDS was between 170.88 to 6316.8 mg/l with mean 1003±1130.Where, 82.1% of TDS sites within permissible limit at maximum. The concentration of Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} varied from 0.4 to 7.2, 0.2 to 5.4, 0.7 to 71.16 and 0.005 to 6.4 meq/l with an average value of 3.012, 1.908, 4.71 and 0.21meq/l respectively in groundwater of Mnasra. And anion concentration of ground water samples the concentration of Cl^{-} , $HCO3^{-}$, $SO4^{2-}$ and $NO3^{-}$ varied from 0.5 to 68.88 , 1 to 9.998 , 0.01to 0.9915 meq/l and 0.2 to 5.199 respectively with mean 5.47, 2.88, 1.884 and 0.54 respectively. The major ion chemic reveals that Na^{+} is the most leading cation, and Cl^{-} is the most dominant anion in study samples . All the major cations and anions show values within the permissible and safe limits with respect to Moroccan standards.

Correlation Analysis.

The criterion of correlation a widely used between two variables, it indicates the sufficiency of one variable to predict the other [14].wich is used to determine the relation between tow variables dependent and independents. In this study, the correlation matrix of 10 variables for study area was computed using Minitab 17 software and is presented in Table 5. The value of correlation coefficient (r) ranges from -1 to +1, which indicates strongest negative and positive linear correlation[15]. The correlation among parameters in the study area has shown approximately an analogous trend. Strong (r >0.9) to good (r = < 0.9 to >0.5) correlations between the various physicochemical parameters have been observed: Electrical conductivity and Na^+ & Cl^- are strongly (r= 0.90& 0.91) respectively, also the sodium and chloride is 0.99. This correlation indicates that all of them have originated from the same source.

Table 3: Correlation of physicochemical parameters

Parameters	pH	CE	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	HCO_3^-	NO_3^-	SO_4^{2-}	WQI
pH	1.00										
CE	0.14	1.00									
Ca^{2+}	-0.21	0.48	1.00								
Mg^{2+}	-0.01	0.54	0.20	1.00							
Na^+	0.10	**0.90**	0.23	0.54	1.00						
K^+	0.36	0.60	0.33	0.33	0.33	1.00					
Cl^-	0.07	**0.91**	0.29	0.59	**0.99**	0.35	1.00				
HCO_3^-	0.09	0.82	0.48	0.57	0.74	0.52	0.73	1.00			
NO_3^-	-0.01	0.39	0.47	0.10	0.17	0.41	0.15	0.26	1.00		
SO_4^{2-}	-0.07	-0.08	0.05	-0.03	-0.05	-0.07	-0.03	-0.25	0.03	1.00	
WQI	0.35	0.65	0.38	0.35	0.37	**0.99**	0.40	0.56	0.50	-0.07	1.00

Water quality index

The WQI value and water type of the individual samples are presented in Table 8 and Figure 2 The WQI ranges from 36.45 to 660.22. 54.3 % of groundwater samples were ''excellent''; 37.1 % were ''good''; and 7.1% were ''poor'' In addition, 1.5 % of samples were ''unsuitable for drinking' The dissolved ions in groundwater affected WQI values, particularly K^+, Mg^{2+}, $HCO3^-$, Cl^-, $NO3^-$, $SO4^{2-}$, . High K^- and $HCO3^-$ concentrations in groundwater caused high WQI values; These affects are evident from the correlation coefficients of WQI with respect to K^+ and$HCO3^-$ (Table and Table). K shows strong correlation with WQI values (r = 0.99). This may be explained by the observed higher values mainly of Potasium in many samples. The WQI values (Table-8) show that the quality of groundwater at some locations (sample numbers).

Table 8: Computation of water quality index (WQI) for individual groundwater samples

N	WQI	Water type		N	WQI	Water type
W1	36.45	Excellent water		W36	49.41	Excellent water
W2	38.04	Excellent water		W37	49.54	Excellent water
W3	39.07	Good water		W38	49.97	Excellent water
W4	39.41	Poor water		W39	50.44	Excellent water
W5	39.62	Good water		W40	50.99	Excellent water
W6	40.97	Excellent water		W41	51.65	Excellent water
W7	41.08	Good water		W42	52.42	Excellent water
W8	41.12	Excellent water		W43	53.02	Excellent water
W9	41.28	Good water		W44	53.09	Good water
W10	41.55	Excellent water		W45	54.73	Excellent water
W11	41.57	Excellent water		W46	55.09	Good water
W12	41.59	Excellent water		W47	55.50	Good water
W13	42.43	Excellent water		W48	56.12	Excellent water
W14	42.51	Excellent water		W49	56.49	Excellent water
W15	42.56	Excellent water		W50	57.56	Excellent water
W16	43.22	Excellent water		W51	58.75	Good water
W17	43.43	Excellent water		W52	59.13	Good water
W18	43.53	Excellent water		W53	59.51	Poor water
W19	44.05	Excellent water		W54	59.76	Good water
W20	44.66	Excellent water		W55	69.48	Good water
W21	44.88	Good water		W56	69.98	Good water
W22	45.17	Poor water		W57	71.25	Poor water
W23	45.40	Good water		W58	75.60	Good water
W24	45.46	Excellent water		W59	78.15	Good water
W25	45.77	Excellent water		W60	78.30	Excellent water
W26	45.98	Water unsuitable for drinking		W61	79.09	Good water
W27	46.03	Excellent water		W62	80.62	Excellent water
W28	46.26	Excellent water		W63	88.94	Good water
W29	47.17	Excellent water		W64	92.19	Excellent water
W30	47.17	Good water		W65	100.78	Good water
W31	47.44	Good water		W66	104.06	Good water
W32	48.04	Excellent water		W67	116.18	Excellent water
W33	48.18	Good water		W68	127.26	Good water
W34	48.83	Good water		W69	137.47	Poor water
W35	48.83	Excellent water		W70	660.22	Excellent water

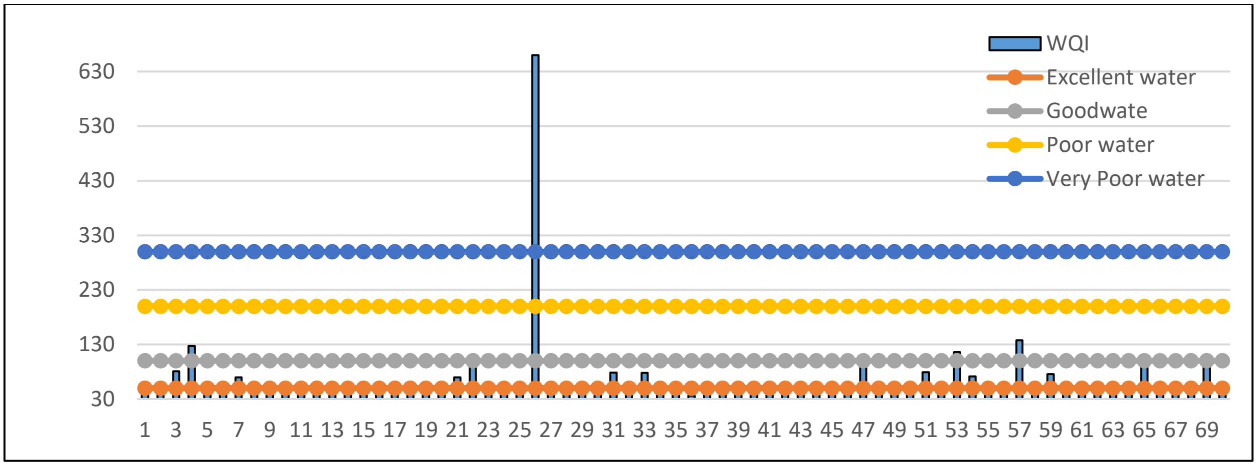

Figure 2: Water quality index (WQI) of groundwater at different Wells of the study

IV. Conclusion

In this study, water quality of Mnasra region and its suitability as drinking water were evaluated to evaluate water quality of the Mnasra region. 71 sampling sites were determined and 10 water quality parameters were selected for seasonal monitoring and analysis. Physicochemical analysis results indicate that, the Mnasra region water samples have alkaline properties, EC values of water samples varied in the range 260 and 9860 µS/cm. The order of anion and cation $Cl^- > HCO3^- > SO4^{2-}$ and, $Na^+ > Ca^{2+} > Mg^{2+} > K^+$, in water samples. In general, the major ion contents of water samples are related to water-rock interaction. The anthropogenic pollutants dominate some locations. Water quality parameters pH, EC, TDS, TH, Ca^{2+}, Mg^{2+}, Na^+, k^+, Cl^-, HCO_3^-, SO_4^{2-} and NO_3^- were used to calculate WQI values to evaluate Mnasra region water quality. The computed values of WQI vary from 35.45 to 660.22. According to the WQI values, groundwater at only one location study were found unsuitable for drinking (WQI > 300). The effects of water quality parameters on the WQI were investigated, and the obtained results show that the highest values effective weight value belong to the NO_3^-, Cl^-, Na^+ and K^+ parameters compared with the other parameters. Consequently, environmental pollutants negatively affect the Mnasra groundwater. Therefore, necessary protection measures should be taken as related to planned usage of the groundwater.

References

[1] H. Al-Aizari, A. Achaouch, M. Fadli, and F. Al-Kadasi, "Study of groundwater quality in Wadi Almawaheb and Qa'Asawad in Dhamar City (Yemen) its validity for

agricultural use," *J Chem Pharm Sci*, vol. 11, pp. 40–44, 2018.

[2] D. V. Chapman, *Water quality assessments: a guide to the use of biota, sediments and water in environmental monitoring*. CRC Press, 1996.

[3] N. R. Council, *Water reuse: potential for expanding the nation's water supply through reuse of municipal wastewater*. National Academies Press, 2012.

[4] R. Helmer, I. Hespanhol, and W. H. Organization, "Water pollution control: a guide to the use of water quality management principles," 1997.

[5] S. Water and W. H. Organization, "Guidelines for drinking-water quality [electronic resource]: incorporating first addendum. Vol. 1, Recommendations," 2006.

[6] N. Adimalla and H. Qian, "Groundwater quality evaluation using water quality index (WQI) for drinking purposes and human health risk (HHR) assessment in an agricultural region of Nanganur, south India," *Ecotoxicol. Environ. Saf.*, vol. 176, pp. 153–161, 2019.

[7] A. Gibrilla *et al.*, "Application of water quality index (WQI) and multivariate analysis for groundwater quality assessment of the Birimian and Cape Coast Granitoid Complex: Densu River Basin of Ghana," *Water Qual. Expo. Health*, vol. 3, no. 2, p. 63, 2011.

[8] T. Poonam, B. Tanushree, and C. Sukalyan, "WATER QUALITY INDICES- IMPORTANT TOOLS FOR WATER QUALITY ASSESSMENT: A REVIEW," *Int. J. Adv. Chem.*, p. 14, 2013.

[9] S. Varol and A. Davraz, "Evaluation of the groundwater quality with WQI (Water Quality Index) and multivariate analysis: a case study of the Tefenni plain (Burdur/Turkey)," *Environ. Earth Sci.*, vol. 73, no. 4, pp. 1725–1744, 2015.

[10] APHA/AWWA/WEF, "Standard methods for the examination of water and waste water, 20th edition. American Public Health Association/American Water Works association, Water Environment Federation, Washington DC, USA, pp 235-237. -," 1998.

[11] N. I. McClelland, *Water quality index application in the Kansas River Basin*, vol. 74. US Environmental Protection Agency-Region VII, 1974.

[12] K. Srinivasamoorthy, S. Chidambaram, M. V. Prasanna, M. Vasanthavihar, J. Peter, and P. Anandhan, "Identification of major sources controlling

groundwater chemistry from a hard rock terrain—a case study from Mettur taluk, Salem district, Tamil Nadu, India," *J. Earth Syst. Sci.*, vol. 117, no. 1, p. 49, 2008.

[13] C. R. Ramakrishnaiah, C. Sadashivaiah, and G. Ranganna, "Assessment of water quality index for the groundwater in Tumkur Taluk, Karnataka State, India," *E-J. Chem.*, vol. 6, no. 2, pp. 523–530, 2009.

[14] J. C. Davis and R. J. Sampson, *Statistics and data analysis in geology*, vol. 646. Wiley New York, 1986.

[15] I. Morell, E. Giménez, and M. V. Esteller, "Application of principal components analysis to the study of salinization on the Castellon Plain (Spain)," *Sci. Total Environ.*, vol. 177, no. 1–3, pp. 161–171, 1996.