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Towards a dynamic index of water quality for a given site Case study of the Taanzoulte plain (Aguelmam Sidi Ali RAMSAR site), Draa Tafilalt region, Morocco

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Abstract

The present study aims to develop a dynamic model water quality index of a given site (DWQI-S). Based on the principal component analysis, the potential indicators were calculated. This model has been applied to determine the surface water quality of Taanzoult plain (Aguelmam Sidi Ali RAMSAR site), using physicochemical (13 parameters) and bacteriological analysis results (2 parameters), which are monitored of 7 stations during 12 months (January to December 2017). The compilation of the DWQI-S allowed assessing the quality of the waters in Taanzoult plain with precision compared to the empirical approach of the evaluation grid according to Moroccan standards. Water quality varies with the seasons and kind of use. It can be mainly considered good to medium for spring water of drink and medium to poor for surface water, flowing in the meadow, exclusively used for livestock watering. The strength of DWQI-S lies in its ability to integrate a reduced parameters number deemed relevant for the assessment of water quality in each particular case. It might, therefore, maximize accuracy in determining water quality at lower cost and permit to the regulation authorities the opportunity to maximize the cost-effectiveness of water pollution monitoring missions over time according to standards set.

1. Introduction

Monitoring of water quality is one of the major concerns of scientists and regulatory agencies responsible for protecting water resources, human and animal health. It is based on the individual comparison of each pollution indicator with water quality standards and limit values (physicochemical and bacteriological parameters) according to the different water sources and fields of use. In this context, several water quality indices (WQIs) have been developed to simplify the interpretation of water quality data by a single value. It has been compiled from indicators deemed relevant and is understandable by a wide range of stakeholders including non-experts and decision-makers. Horton suggested that the various water quality data could be aggregated into a global index [1]. This index was developed by [2] and improved by Deininger for the Department of Scottish Development in 1975. Thus, several indices have been developed wide world. They were based on different indicators and matrices of aggregates for special purposes. Among the best water quality indices, we cite the US National Sanitation Foundation Water Quality Index for Sanitation Quality (NSFWQI); the Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI); the British Columbia Water Quality Index (BCWQI) and the Oregon Water Quality Index (OWQI). Many scientists i.e. [3-10] have adopted these indices using the most commonly measured water quality variables. Despite the efforts made through several studies to compare several indices of water quality i.e. [11-19] no one of them has been universally able to be generalized to all sources and plans of water. Thus, research is continually improved to develop a common and simplified index so that international organizations, in different countries, can adopt this model taking in to account specific characteristics. Furthermore, international and national agencies and departments, responsible to regulate and monitoring water quality in its various uses, adopt grids setting of water quality standards and limit values for each considerate relevant physicochemical and bacteriological parameter in function of water sources and use fields (drink, agricultural, livestock watering, aquatic life …etc.) [20].

In Morocco, water department has highlighted a legal-political legislation (Law 36-15, Decree 2-97-787 and 2-97-785, Joint Decrees 1277-01; 1276-01 of 17/10/2012) and National Strategy for Water Management to regulate and set water quality standards and limit values for each pollution indicator. Also, a static monitoring system has been introduced in a recurrent and extended way by adopting a simplified grid to quantify and determine water quality of different water plans. Nevertheless, decision taken still insufficient and the conventional approach, based on simplified indicators, excludes the relevance of the final assessment of water quality. Hence the need to modernize Moroccan legislation to implement an approach to water quality assessment based on statistical evidence.

Our approach seeks first to determine, through principal component analysis, the aggregate of potential indicators influencing water quality and secondly to compile them for computing a dynamic WQI of a given site or water plan (DWQI-S). In this study, the above-mentioned approach will be tested to determine the water quality in Taanzoult plain, belonging to the Aguelmam Sidi Ali RAMSAR site, which envelop several permanent and intermittent spring and a network of streams in the studied area.

The studied area was selected based on intrinsic fragility level due to the anarchic frequentation and use of springs (semi-transhumant, neighboring community, truck drivers, campers and summer visitors). It constitutes an in-situ use aggregate water resource whose water withdrawal is done without any preliminary pre-treatment either hygiene measures.

2. Material and Methods

2.1. Study area

Studied area is located at the extreme northern part of the Draa Tafilalt region, belonging of the territory of Itzer rural commune of the province of Midelt and at 55 km far from Azrou city (figure 1). Geographically, the site takes part of the Middle Atlas pleated north of which most of it is located at 33.0568 N latitude and 5.0244 W longitude. Precisely, it’s an enclave of Aghbalou Larbi forest and coinciding with the upstream part of sub-watershed High Guigou. The Taanzoult plain is an integrated part of the Aguelmam Sidi Ali wetland, classified RAMSAR site since 2005.

Its location at an average altitude of 2100 m, significantly influences rainfall intensity and duration. In fact, the swampy area and streams freeze with water flow temporary decline during the winter at very low temperatures.

The average monthly rainfall variability during the period 1975-2017 reveals that the site receives precipitations throughout the year even in summer with lower rates. Annual temperature evolution analysis of the studied area shows that there is a slight annually average increase, maximum and minimum. As for the seasonal evolution temperature analysis, Continental climate is clearly noticed and characterized by a cold season, going from December to March with minima below 0°C justifying the Taanzoult grassland glaciations and a hot season from July to September.

Geologically, study area takes part in the Meso-Cenozoic litho-stratigraphic series, which ranges from the Upper Triassic to the Quaternary [21-22]. Taanzoult plain is located in a vast depression surrounded by mountains and furrowed by brooks network emerging from permanent and temporary water springs. It looks like an icy pond in winter, seasonal swamp in spring and pastoral meadow in summer and autumn. In fact, Taanzoult plain vegetation cover consists mainly of (i) aquatic plants that proliferate in brooks-bed and banks, (ii) herbaceous pastoral plants, of high forage productivity, grazed by livestock; and (iii) medicinal plants (*Anacyclus pyrethrum*, *Taracsacum officinalis*, *Plantago major*) hand-picked by site users.

This surface waters (lakes, marshes, streams, water springs) makes the site a feeder and water privileged destination for several wild vertebrates. Nevertheless, anthropogenic activity harms to wild fauna habitat [23] and might decrease water quality. Thus, permanent water springs is frequented for drink and it’s presumed to have therapeutic virtues and the brooks network is trampled by cattle more than 9 months per year for grazing and watering.

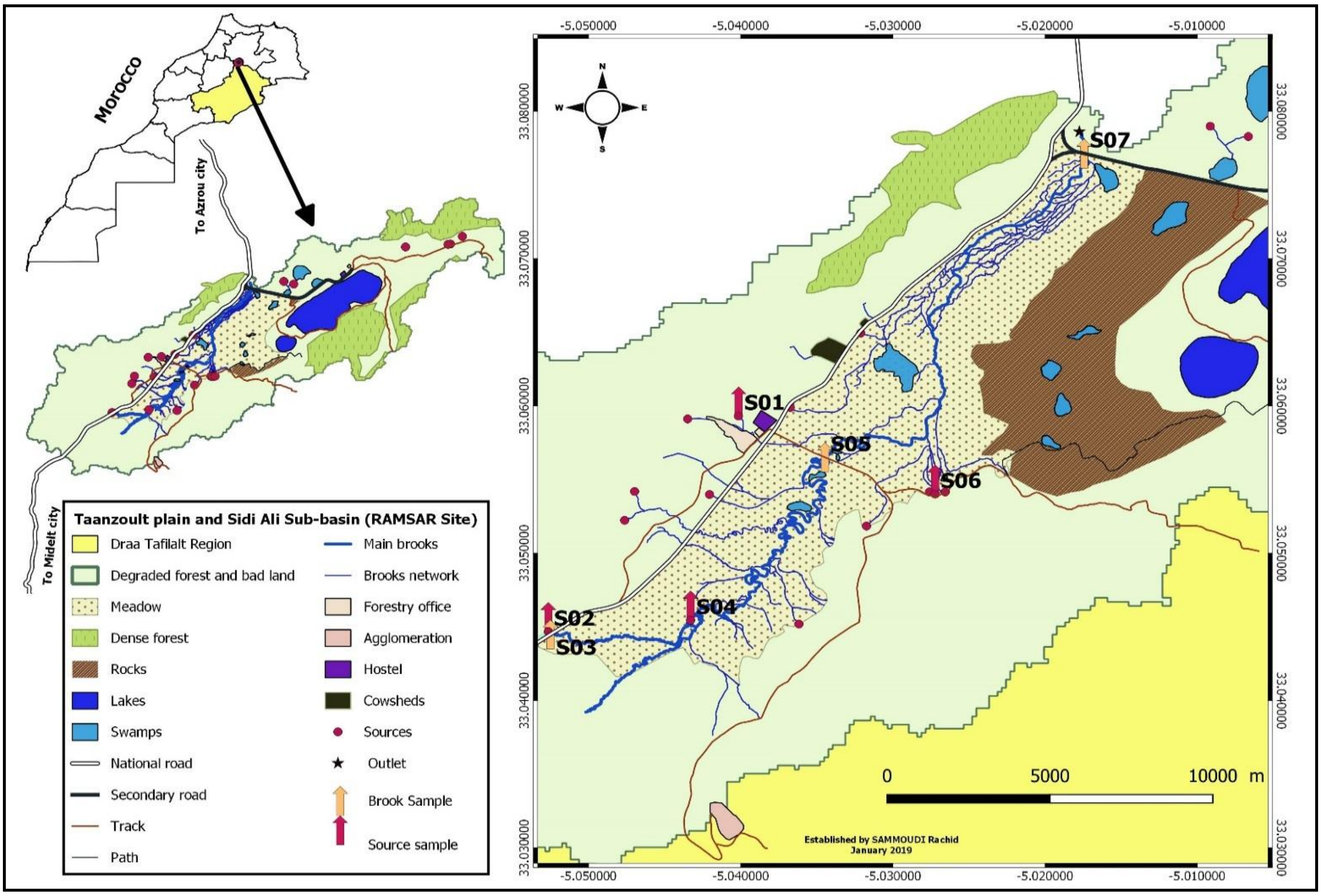

Figure 1: Location of the study area.

2.2. Sampling plan

In order to determine the DWQI-S of the Taanzoult plain, by succession of principal component analysis and dynamic compilation of the potential water quality indicators, a physicochemical and bacteriological study was carried out according to a spatiotemporal sampling plan. Representative stations choice was based on water resources abundance, hydrological properties, topographic and geographic accessibility. For this purpose, the selection concerned seven sampling stations (table 1).

Twelve samples were collected monthly and simultaneously during the one-year hydrological and biological cycle (January to December 2017). The experimental setup, thus adapted to this research work, is defined according to the following sampling plan: seven space stations and twelve temporal sampling. In fact, sampling number is of the order of 84 observations.

2.3 Monitored parameters

In order to evaluate the quality of water resources in the Taanzoult plain, physicochemical and bacteriological studies were carried out. The physicochemical parameters such as: pH, temperature (Tw), electrical conductivity (Ec), total suspended solids (TDS), chlorides (Cl^-), sulphates (SO_4^{2-}), nitrates (NO_3^-), ammonium (NH_4^+), orthophosphates (PO_4^{3-}), oxidizability in $KMnO_4$ (MO), dissolved oxygen (DO), biochemical demand in oxygen (BOD) and chemical oxygen demand (COD) were measured using normalized methods [24]. The enumeration of total coliforms (TC) and fecal coliforms (FC) is carried out by membrane filtration (0.45µm porosity) in accordance with AFNOR NF EN ISO 9308-1 standards [24].

2.4 Development process of DWQI-S

Development process of the DWQI-S is based on 5 steps:

a- Identification of potential indicators for measuring water quality integrates the Principal Component Analysis (PCA) of physicochemical and bacteriological study results using SPSS.20 software. This analysis based on the specific variance of the variables (parameters) and consists of extracting a minimum of factors to explain the maximum possible of specific variance. According to the Kaiser criterion, the PCA can only be significant if the number of factorial axes retained, having an initial eigen value greater than 1, is less than or equal to 4 [25].

Table 1: Description of sampling stations

Station	Coordinates	Description
Forest post office of Aguelmam Sidi Ali (S01)	33.059324N -5.040141W	- Permanent medium-flow spring, fitted out to meet the water needs of neighboring residents and livestock watering; - Located in herds passage, - Supplying brooks network from outside the Taanzoult plain grassland.
Aghbalou Dkhiss (S02)	33.04468N -5.052645W	- Permanent high-flow spring, fitted out to provide fresh drink water for truckers and passengers using the National road n°13 connecting the cities of Meknes and Errachidia; - Located in the rest area on the outskirts of Taanzoult plain, where a mobile trade of local products settled in summer and autumn; - Permanent supplying water of brooks network from outside the Taanzoult plain grassland.
Upstream(S03)	33.044466N -5.052479W	- Located downstream from the rest area and the source of Aghbalou Dkhiss; - Main brook starting point of the Taanzoult plain grassland; - Accumulation place of waste from the rest area.
Aghbalou Ouhili(S04)	33.045459N -5.0433W	- Permanent low-flow spring, located in the pasture of Taanzoult plain; -Mostly frequented by cattle and wild fauna; - Water main supply of the brooks network.
Bridge (S05)	33.056518N -5.034463W	- Located at the median level of the main brook; - Boundary of grazing land sharing between user tribes; - Middle flow rate station; -Mostly frequented by cattle and wild fauna.
Aghbalou Aberchane (S06)	33.054038N -5.027228W	- Permanent medium-flow spring, located in the pasture of Taanzoult plain; - Water main supply of the brooks network; - Complex of springs providing fresh drinking water for residents and transhumant; - Frequented by residents and by regional visitors for its alleged therapeutic virtues.
Downstream (S07)	33.077053N -5.017511W	- Located downstream of the brooks network and the grassland; - Mostly frequented by cattle and wild fauna.

To redistribute the variance as fairly as possible is primordial to explain and simplify the correlation matrix between the factorial axes and the variables, an orthogonal rotation (varimax) is envisaged to virtually rotate these axes around their origin in the case of 3 to 4 significant axes. In the case where only one to two axes are significant, it would be wise to take only projection without rotation [26]. In order to facilitate the interpretation of the results in both cases, only two factorial axes were taken into account to represent the total variance explained. Thus, the potential parameters (variables), which will part of the DWQI-S indicators aggregate, are those significantly correlated (weight> 0.3) with a single axis among the selected axes whose maximum weight in absolute value is greater than or equal to the sum of inertia of the two factorial axes retained (main components) and that their residual variances with the other axis retained hardly exceed 0.3.

b- Identification of the subindex rating (Vr) is defined for 5 classes of water quality taking in to account Moroccan standards (Table 2). It varies from 0 to 100 according to the modified version by [27]

c- Weighted unit value estimate (Wi) of each parameter, identified for the DWQI-S calculation, is calculated on the basis of the allowable limit value of each indicator according the formula: $Wi = \mathrm{K/Xi}$

whith:

K: proportionality constant calculated using the equation $K = 1/(\sum_{i=1}^{n} 1/\mathrm{Xi})$

n: number of indicators taken into account for DWQI-S calculation

Xi: the permissible limit value to be considered for each indicator. It is equal to the optimal value of one of the World Health Organization (WHO-S) and Moroccan standards (MS) [28-31]. This limit value considered (LVC) is equal to the smallest limit value (LV) of the tow standards (MS or WHO-S). If not, it is equal to the lowest guide value (GV) of both standards (Table 3).

Table 2: Moroccan standards of physicochemical and bacteriological parameters for the assessment of surface water quality

Parameters	Unit	CLASS 1 Excellent	CLASS 2 Good	CLASS 3 Medium	CLASS 4 Poor	CLASS 5 Very poor
Tw	°C	≤20	20-25	25-30	30-35	>35
pH		6.5-8.5	6.5-8.5	6.5-9.2	<6.5ou>9.2	<6.5ou>9.2
Ec	µs/cm	≤750	750-1300	1300-2700	2700-3000	>3000
DO	mg/l	>7	7-5	5-3	3-1	<1
BOD	mg/l	≤3	3-5	5-10	10-25	>25
COD	mg/l	≤30	30-35	35-40	40-80	>80
Cl^-	mg/l	≤200	200-300	300 -750	750 -1000	>1000
TDS	mg/l	≤50	50-200	200-1000	1000-2000	>2000
MO	mg/l	≤2	2-5	5-10	>10	-
NO_3^-	mg/l	≤10	10-25	25-50	>50	-
NH_4^+	mg/l	≤0.1	0.1-0.5	0.5-2	2-8	>8
SO_4^{2-}	mg/l	≤100	100-200	200-250	250-400	>400
PO_4^{3-}	mg/l	≤0.2	0.2-0.5	0.5-1	1-5	>5
FC	UFC/100ml	≤20	20-2000	2000-20000	>20000	
TC	UFC/100ml	≤50	50-5000	5000-50000	>50000	
Vr		**100**	**80**	**60**	**40**	**0**

Table 3: Permissible limit values for physicochemical and bacteriological parameters according to Moroccan and WHO standards

Indicator	Unit	MS		WHO-S		Limit Value considered (LVC)
		GV	**LV**	**GV**	**LV**	
Tw	°C	20				<20
pH		6.5-8.5			6.5-9.5	6.5-8.5
Ec	µs/cm	1300	2700			<2700
DO	mg/l	7				>7
BOD	mg/l	3				<3
COD	mg/l	25				< 25
Cl^-	mg/l	300	750		250	<250
TDS	mg/l	50				<50
MO	mg/l	2				<2
NO_3^-	mg/l		50		50	<50
NH_4^+	mg/l	0.05	0.50	0.20		<0.5
SO_4^{2-}	mg/l	200			500	<500
PO_4^{3-}	mg/l	0.4				<0.4
FC	UFC/100ml	20				<20
TC	UFC/100ml	50				<50

d- Determining the sub-index (Wi * Vr) by multiplying the weighted unit value (Wi) of the indicator considered et sub-index rating (Vr) of the water quality class corresponding to the value of the i^{th} parameter considered.

e- Compilation of DWQI-S is computed by the formula: $DWQS = \sum_{i=1}^{n} \text{Wi} * Vr$, whose water quality rating scale is identical to that of the National Sanitation Foundation Water Quality Index (NSFWQI) (Table 4).

Table 4: NSF water quality rating scale

WQI Value	Water quality assessment
91-100	Excellent
71-90	Good
51-70	Medium
26-50	Poor
0-25	Very poor

3. Results and discussion

The average values of physicochemical and bacteriological parameters recording in the study area are summarized in the table 4. The average pH value varies between 8.64 and 7.63 with values higher than LVC (8.5) in the brooks network (S05 and S07). All of the assessment stations have an average Ec value less than LVC (2700 µs/cm) with a values interval between 309.75 and 503.09 µs/cm. The oxygenation rate is higher at stations with a significant flow rate throughout the year (S06, S02, S03, S05 and S01) with an average DO content greater than LVC (>7mg/l) and lower at stations S04 and S07 (<7mg/l) where the flow is low or intermittent. The BOD content recorded at the S02 and S06 stations is more significant, with average values being lower than the LVC (<3mg/l), the rest of the stations have mean values between 3.63 and 8.82mg/l. The COD content of all stations is higher than LVC (25 mg/l) with average values between 86.67 and 287.27 mg/l, the maximum value of which was recorded at the downstream of the brooks network (S07). The Cl^- content recorded at all stations is lower than that of LVC (250 mg/l) with a maximum recorded at brooks network (45.5 mg/l at S07) and a minimum recorded at springs water (13.46mg/l at S02). The average TDS values of springs water (S01, S02 and S06) are lower than VLC (<50mg/l), whereas those of the brooks network (S03, S05 and S07) and S04 are higher. The MO recorded at all stations is greater than VLC (2mg/l of O_2) with a maximum recorded at station S07 (17.71mg/l of O_2). Nitrogen compounds (NO_3^- and NH_4^+) are more significant in the brooks network (S03, S05 and S07) compared to springs water (S01, S02, S04 and S06) whose NO_3^- levels are lower than LVC (<50mg/l) at all stations, whereas only S01, S02 and S06 stations with average NH_4^+ content lower than LVC (<0.5mg/l).The SO_4^{2-} and PO_4^{3-} levels are higher in brooks network water (S03, S05 and S07) than in springs water (S01, S02, S04 and S06) with SO_4^{2-} levels lower than VLC (<500mg/l) and those of PO_4^{3-} are greater than VLC (<0.4 mg/l).

Regarding bacteriology, the TC and FC levels recorded at all stations exceed LVC successively (<50 UFC/100ml and <20 UFC/100ml), of which those in the brooks network are higher than those in the spring's water.

Table 5: Physicochemical and bacteriological results by sampling site among January – December 2017

Parameters	Unit	S03	S05	S07	S01	S02	S04	S06
Tw	°C	10.74	12.13	14.37	12.38	9.83	11.78	10.11
pH		8.15	8.46	8.64	7.63	7.89	7.87	7.87
Ec	µs/cm	357.67	463.75	503.09	399.50	339.75	397.58	309.75
DO	mg/l	8.82	8.72	6.17	7.99	12.41	6.93	10.93
BOD	mg/l	5.78	6.23	4.88	3.63	1.98	3.92	2.49
COD	mg/l	261.67	266.67	287.27	146.67	115.00	175.00	86.67
Cl^-	mg/l	16.12	36.54	45.50	13.90	13.46	25.74	14.79
TDS	mg/l	53.83	122.58	92.45	36.92	17.00	51.25	21.75
MO	mg/l	13.69	16.57	17.71	9.66	7.75	11.33	8.30
NO_3^-	mg/l	18.54	25.82	25.27	9.22	5.16	14.29	7.17
NH_4^+	mg/l	1.23	1.72	2.64	0.47	0.33	0.64	0.26
SO_4^{2-}	mg/l	2.73	4.10	4.77	1.80	1.04	2.25	0.84
PO_4^{3-}	mg/l	1.34	1.72	2.06	0.68	0.41	0.92	0.47
TC	UFC/100ml	12 585	6 952	6 628	2 385	1 954	5 226	2 185
FC	UFC/100ml	559	458	525	66	35	110	48

In accordance with Moroccan standards for the quality of surface water, the evaluation remains subjective. It is based on the 95% of the measurements of the combined parameters and the 90% of the measurements for a given parameter presenting values in the range of the class I [29]. In fact, the highest water quality ratio of all stations is recorded at class I (Excellent Quality) with a maximum of 60% (S02 and S06) and a minimum of 33% (S04 and S07). The cumulative ratio, exceeding 90%, is recorded at class III (medium quality) for stations S01, S02 and S06 and at class IV (poor quality) for stations S04, S03, S05 and S07(Table 6). Overall, the stations S01, S02 and S06 are of medium quality and the others are of poor quality.

The principal component analysis of the physicochemical and bacteriological results of the 15 parameters highlighted two factorial axes (PC) having the initial eigen value> 1 that can explain 71.35% of the total variance of the results of the parameters studied (Table 7). Factorial axes with initial eigen values less than 1 are neglected because of their non-significance[32].

Table 6: Assessment of the water quality of Taanzoult plain according to Moroccan standards

Stations	Class I Excellent	Class II Good	Class III Medium	Class IV Poor	Class V Very poor
S01	53%	27%	13%	0%	7%
S02	60%	27%	13%	0%	7%
S04	33%	47%	7%	7%	7%
S06	60%	27%	7%	0%	7%
S03	40%	20%	20%	13%	7%
S05	40%	13%	27%	13%	7%
S07	33%	27%	13%	20%	7%

Table 7: Total variance explained

Axes (PC)	Initial eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Total variance	% of total cumulative variance	Total	% of Total variance	% of total cumulative variance	Total	% of Total variance	% of total cumulative variance
1	9.237	61.580	61.580	9.237	61.580	61.580	7.066	47.109	47.109
2	1.466	9.771	71.351	1.466	9.771	71.351	3.636	24.242	71.351
3	0.993	6.622	77.973						
4	0.795	5.301	83.274						
5	0.543	3.620	86.894						
6	0.442	2.944	89.839						
7	0.362	2.414	92.252						
8	0.269	1.790	94.043						
9	0.215	1.435	95.478						
10	0.178	1.188	96.666						
11	0.156	1.039	97.704						
12	0.116	0.770	98.475						
13	0.099	0.659	99.133						
14	0.073	0.486	99.619						
15	0.057	0.381	100.000						

In this study, the non-rotational PCA matrix showed that 61.58% of the total variance of studied parameters are explained by the first factorial axis (PC1) and 9.77% are explained by the factorial axis (PC2) with inertia (in absolute value) greater than 0.3[26]. Thus, exclusively, the SO_4^{2-}, PO_4^{3-}, NO_3^-, TDS, MO, COD, NH_4^+, pH, BOD and Tw parameters are positively correlated with PC1 which is correlated negatively with DO parameter. The Ec and Cl^- parameters are positively correlated with the PC1 and negatively with the PC2 and the TC and FC parameters are positively correlated with the two axes (Table 8 and figure 2).

Table 8: Matrix of principal component analysis without rotation

	SO_4^{2-}	PO_4^{3-}	NO_3^-	TDS	MO	COD	NH_4^+	Ec	Cl^-	pH	BOD	FC	Tw	TC	DO
PC1	.934	.928	.911	.896	.873	.859	.831	.793	.761	.748	.724	.704	.518	.487	-.626
PC2	-.085	.079	.027	-.056	.083	.240	-.061	-.420	-.357	-.271	.020	.597	-.159	.766	.185

The dispersion analysis of the parameters and the individuals (observations) represented by the PCA in two dimensions made it possible to identify three groups of individuals (figure 3): (i) the first shows the causality of the pollution of the Taanzoult plain, particularly at the level of S07 and S05, through pastoral activity and the long stay of the livestock, trampling in the brooks network, during more than 9 months, (ii) the second represents the impact of the anarchistic use of the other area, upstream of the S03 station, by truckers and street vendors, particularly in summer and autumn, and (iii) the third explains that the springs reserved for drink (S02 and S06) are relatively less polluted. In contrast, the PCA will not be able to comment on the influence of human activity at the S03 station, especially in winter and spring, and that S04 whose dispersal of individuals is located near the origin of two factorial axes.

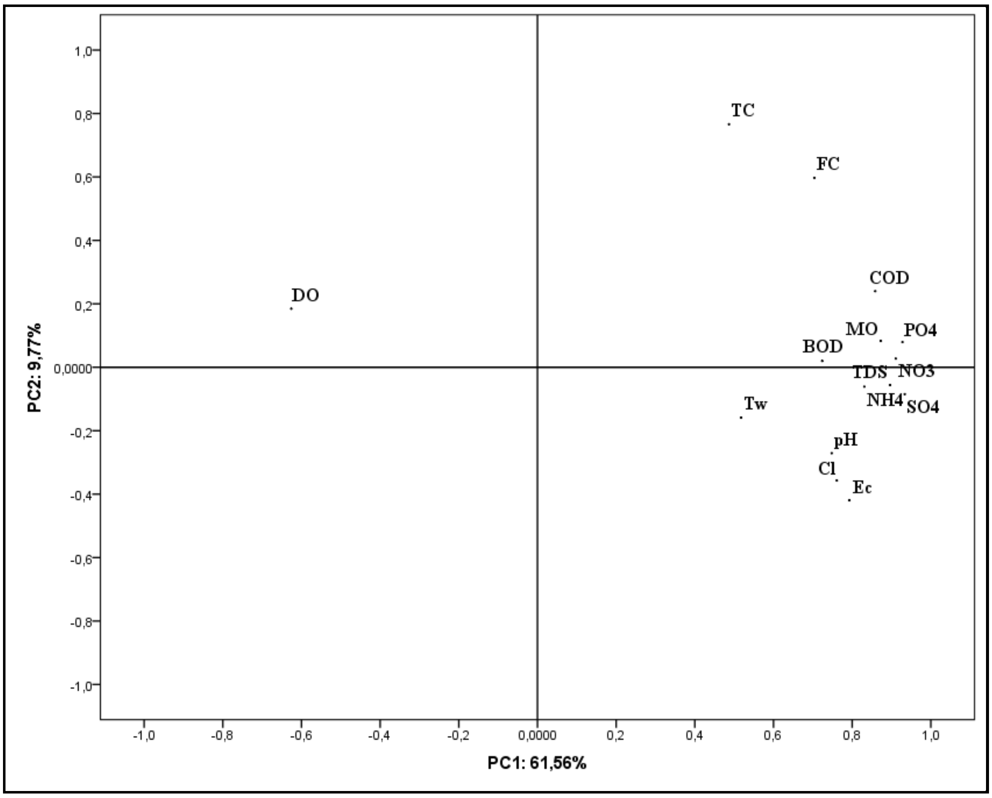

Figure 2: Graphical Representation of Variables by Factorial Axes of the PCA

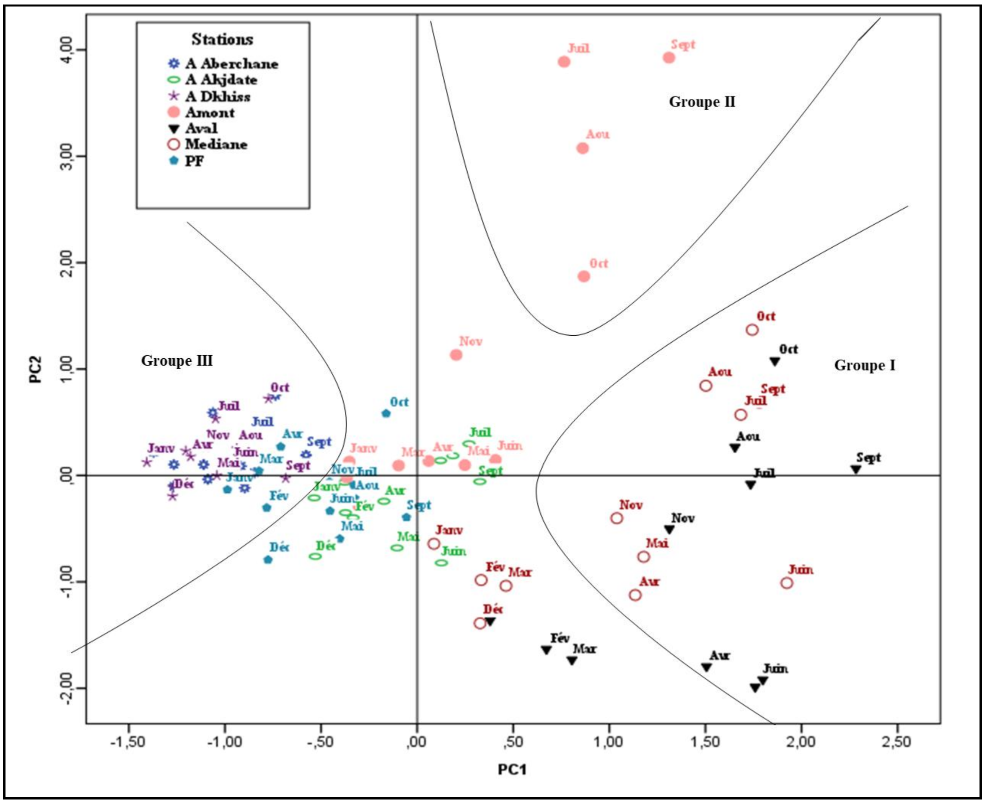

Figure 3: Graphical Representation of Individuals by Factorial Axes of the PCA

In accordance with the conditions for selecting the parameters, mentioned in the methodological approach followed in this study, only 9 parameters (pH, SO_4^{2-}, TDS, BOD, COD, MO, NO_3^-, NH_4^{3-} and PO_4^{3-}) are included within the calculation aggregate of the DWQI-S, which represent 60% of the parameters studied (Table 8).

The Table 9 shows the weighted unit value (Wi = K/Xi) of each indicator which included in the DWQI-S calculation aggregate whose constant $K = 1/(\sum_{i=1}^{n} 1/Xi)$ = 0,18 and ∑Wi = 1.

Table 9: Calculation of the weighted unit value of selected indicators

Indicators	Permissible Value Xi	1/Xi	Wi
pH	8.50	0.1176	0.0213
SO_4^{2-}	500.00	0.0020	0.0004
TDS	50.00	0.0200	0.0036
BOD	3.00	0.3333	0.0603
COD	30.00	0.0333	0.0060
MO	2.00	0.5000	0.0904
NO_3^-	50.00	0.0200	0.0036
NH_4^+	0.50	2.0000	0.3617
PO_4^{3-}	0.40	2.5000	0.4521
Total		**5.53**	**1.00**

Following the aforementioned protocol for the calculation of the individual sub-index (Wi * Vr) values for each parameter per station and per period, the final compilation of the DWQI-S, relating to the water quality assessment period from January to December 2017 of the Taanzoult Plain, made it possible to conclude that there is spatiotemporal variability (table 10). The maximum annual score of 89 is recorded at Station S06 (December-January) and Station S02 (April-May) but the minimum of 42 is recorded at S05 (April-May) and S07 (may June). The water quality of S01 source is good in winter and spring with a maximum score of 76 and the medium in summer and autumn with a minimum score of 61. The S02 Source is characterized by a good quality in winter (DWQI-S = 83) and in spring (DWQI-S = 89) and a medium quality in summer and autumn with respective average values of DWQI-S in the order of 69 and 70. However, the Source S06 is characterized by a good quality in all seasons with a maximum score of 89 in winter and a minimum of 73 in summer and autumn. The water quality at source S04 is medium along the year with a maximum DWQI-S score of 70 in winter and minimum of 55 in summer. The Station S03 is characterized by a medium quality in winter and spring with successive DWQI-S scores of 60 and 54 and a poor quality in summer and spring with successive scores in the order of 48 and 47. In contrast, the water quality of S05 and S07 stations is medium in winter with a respective score of 56 and 51 and poor during the other three seasons with a minimum score of 43 in summer.

Table 10: Distribution of DWQI-S by station and sampling period (January-December 2017)

Sampling period	Water springs				Brooks network			Average
	S01	S02	S04	S06	S03	S05	S07	
December	72	81	69	89	60	51	51	68
January	78	81	69	89	59	59		73
February	78	87	70	87	60	58	50	70
Winter	**76**	**83**	**70**	**88**	**60**	**56**	**51**	**69**
March	78	88	62	80	59	49	50	67
April	76	89	60	87	59	42	43	65
Mai	60	89	60	80	44	42	42	59
Spring	**72**	**89**	**61**	**82**	**54**	**44**	**45**	**64**
June	78	79	60	79	44	43	42	61
July	54	63	53	70	50	43	43	54
August	52	63	51	70	50	44	44	53
Summer	**61**	**69**	**55**	**73**	**48**	**43**	**43**	**56**
September	51	61	51	69	43	44	44	52
October	67	70	60	79	50	51	43	60
November	71	78	69	71	50	51	51	63
Autumn	**63**	**70**	**60**	**73**	**47**	**48**	**46**	**58**
Annual average	**68**	**78**	**61**	**79**	**52**	**48**	**46**	**62**
DV-S	9.54	9.74	6.49	7.13	6.23	5.66	3.58	
Mean by category	**72**				**49**			

Overall, the average annual water quality is good at the stations (S02 and S06) with respective DWQI-S scores of 78 and 79; medium at the stations (S01, S04 and S03) with 68 , 61 and 52 respective DWQI-S scores and poor at the stations (S05 and S07) with 48 and 46 respective DWQI-S scores (Figure 4).

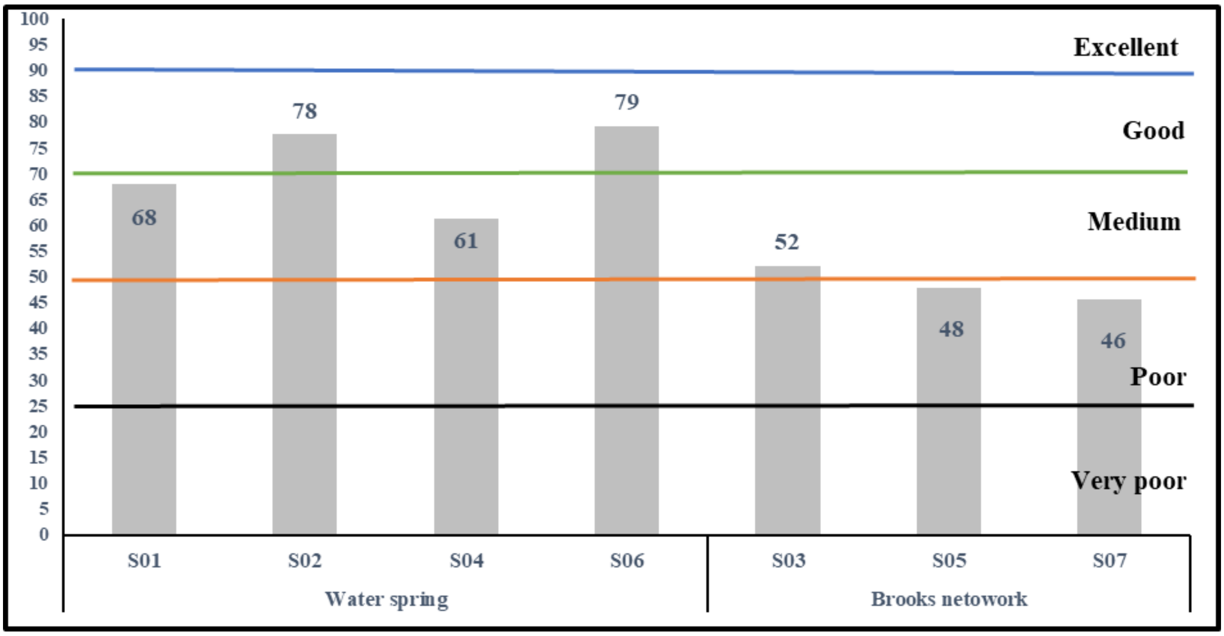

Figure 4: Distribution of DWQI-S per station

According to water classification, the quality of the source water (S01, S02, S04 and S06) is good with a DWQI-S of 72 at two steps higher than the lower limit of the good quality class. The overall water quality of the brooks network (S03, S05 and S07) is poor with a DWQI-S of 49 at one step less than the upper limit of the poor-quality class. These results demonstrate the evolution and the dynamism of the anthropogenic activity in the time that RAMSAR site enveloping Taanzoult plain undergoes. In fact, during the winter, especially after the snowfall (mid-December to mid-March), Taanzoult plain becomes an icy platform with water streaming in all directions and inaccessible neither by livestock nor by transhumant pastoralists and space users. Also, the other area (located between S02 and S03 stations) is less frequented by truckers and passengers to get fresh water. Thus, the quality of the water reaches its optimum both for spring's water (S01, S02 and S06), used for drink water, with good quality both for the brooks network (S03, S05 and S07) and S04 source, intended for livestock watering, with medium quality.

After the Taanzoult plain thaw and resumption of its lawn (pastoral plants), the anthropogenic activity is amplified by the advent of herds in overload (exceeding the burden of pastoral balance), over the spring until autumn, and by the encampments of transhumant in the periphery. In fact, the quality of the runoff (S03, S05 and SO7) and of S04 spring water is affected by trampling, urination and abundance of livestock feces in shallow brooks and their surroundings. Although the quality of the spring water (S06) is good throughout the year, it is widely dependent on human activity, especially during the summering period, where attendance is intense from all horizons (local, regional and national) for looking water with presumed therapeutic virtues whose DWQI-S reaches the upper limit of the average quality class, with a score of 69 in September and 70 in July and August. Thus, the water quality of the source (S02) has deteriorated particularly from good to medium in summer and autumn because of the intensity of human activity. In fact, during these two seasons, the resting air is highly frequented by users of the national road 13 to rest, get fresh water, defecate and urinate upstream. At the same time, the installation of itinerant sales of local produce generates excess waste, especially from seasonal fruits, which are emptied upstream and downstream of the resting air. Being located in the corridor of passage, the quality of spring water (S01) is negatively impacted especially in summer and autumn when the water resources decrease in the region (drying of intermittent sources). It is very frequented by flocks of livestock for watering, at least twice a day at each entry and exit to the meadow.

Conclusion

This study was carried out to develop a dynamic water quality index for a given site. It's based on the PCA to identify the potential indicators used for its calculation. The approach was applied to determine the surface water quality of the Taanzoult plain (part of the Aguelmam Sidi Ali RAMSAR site), based on results of physicochemical (13 parameters) and bacteriological analysis (2 parameters), which are monitored of 7 stations during 12 months (January to December 2017). According to the methodological approach adopted, the PCA was able to identify, for this study, only 9 geochemical indicators (pH, SO_4^{2-}, TDS, BOD, COD, MO, NO_3^-, NH_4^+ and PO_4^{3-}) forming part of the aggregate of the calculation of the DWQI-S, meaning a reduction of 40% of the parameters studied initially. The compilation of the DWQI-S made it possible to assess the water quality of the Taanzoult plain with precision compared to the empirical approach of the grid evaluation dictated by the decree n ° 1275-01 of October 17th, 2002 [30]. Water quality is relatively good to medium for spring water of drink (S01, S02 and S06) and medium to poor for surface water flowing in the meadow (S03, S05 and S07) and source (S04) which is exclusively used for livestock watering. The interest of the DWQI-S is summed up in the ability to aggregate several water quality assessment parameters into a reduced number. It could also maximize accuracy in determining water quality at lower cost by providing regulator authorities the ability to maximize the cost-effectiveness of water pollution monitoring missions at time, accordance with established standards. Due to its dynamic aspect, it is recommended that the update of the DWQI-S be periodic (maximum every 3 years) and this depending on the use of the water resources and the site's surrounding environment.

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