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Evaluation of physico-chemical and bacteriological quality of water springs by using a principal component analysis (PCA): A case study of Tingitane Peninsula (Morocco)

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Abstract

Water is a renewable resource constantly threatened by pollution, among others, demographic backgrounds, agricultural and industrial factors. Access to safe drinking water is a prerequisite for health, a basic human right and a key component of effective health protection policy. Hence, comes the need to consider a physico-chemical and bacteriological study to assess the quality of these sources using a principal components analysis (PCA). Analysis of 25 sources at the level of the groundwater table of Tingitane peninsula was performed in those sources located in rural areas; after a monthly sampling and selection of specimen during the whole year 2014. The principal component analysis (PCA) carried out, using the medium values for each parameter, showed highly differentiated source groups: groups gather sources with moderate to good water quality and others contain contaminated sources. The results of our study are divided into two types:
The physicochemical results show that most studied sources are considered acceptable to good quality according to Standard 03.7.001 Moroccan, 2006. Bacteriological results showed microbial contamination observed for the majority of sources from runoff and domestic and industrial wastewater. The use of this water resource could be risky for the health of people who use these sources for their needs of water.

Keywords: Contamination, Tingitane Peninsula, Quality, PCA, Sources and Pollution.

Introduction

Water is nowadays an increasingly sensitive issue. It is essential for human life, but this vital need may be associated with a variety of risks and dangers which people must be aware of so as it can be better controlled [1]. The spring water is a vital resource for the economy of the region. They are the primordial water resources for drinking water supply of much of the rural population and for the irrigation of agricultural land [2]. Pollution of groundwater is one of the most disturbing aspects and the use of these waters for food is dangerous for the health of people [3]. Consuming contaminated water by the microorganisms is the main cause of epidemics [4, 5]. The physico-chemical and bacteriological quality of the drinking water, served to the population, has been the subject of numerous studies that have shown the impact of the consumption of uncertain water quality on human health ([6]; [7] and [8]).
The aim of our study is to evaluate the physico-chemical and microbiological quality of water sources exploited by the local population, through the use of multivariate statistical method corresponding to the Principal Component Analysis (PCA). The correlations of variables and the reduction of the number of characters make the relationships between individuals and between variables possible. Also, it makes the least redundant information. It is simply the optimistic assumption but reasonable directions as Principal Component larger

sample dispersions are the most interesting directions and the variability associated with these directions corresponding to information [9, 10].

2. Material and methods

2.1. Study Area

The region of Tangier-Tetouan (Figure 1), the capital city of Tangier covers an area of 11,570 km ², representing 1.6% of the total area of the Moroccan Kingdom. It is bordered by the Mediterranean Sea to the north, the Atlantic Ocean to the west, the region of Taza-Al Hoceima-Taounate to the east and the Gharb-Chrarda-Beni Hssen South.

From the geographical point of view, the Tingitane Peninsula is characterized by a structural entity that is the Rif area according to [11].

Indeed, and outside the coastal plains areas geomorphology steep or heavily corrugated cover more than 80% of the region.

❖ Tangiers, located in the Strait of Gibraltar between the Mediterranean and the Atlantic Ocean, approximately coincides with the basin of the river M'harhar and presents an alternation of valleys, covered mainly Quaternary alluvium, marl and sandstone hills.

❖ Lower Basin Loukkos constituting the countryside the most developed in the region, thanks to good soils and abundant water and covering the clay alluvial plains and the sandy plateau of Larache.

Tangiers Peninsula is characterized by a dense hydrographic network in the form of Oueds with low and unsteady flow [12].

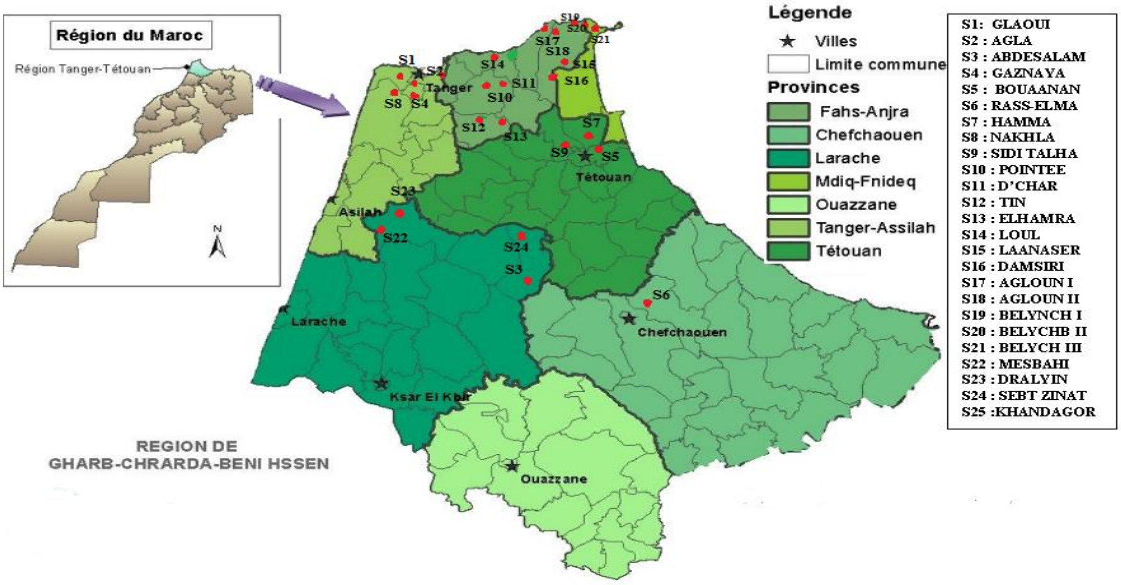

Figure 1: Map of the Tangier-Tetouan Region (source: 1/50000 topographic map)

2.2. Methods of sampling and analysis

In our region sources have been selected to have a representation on the spaced Tingitane peninsula. We conducted a total of 150 samples during the year 2014 for physico-chemical and bacteriological analysis:

- *Physico-chemical analysis*

The physicochemical analysis of the water is assessed using several parameters of varying importance. Temperature, pH, electric conductivity, dissolved oxygen, turbidity, hardness, chlorides, nitrates, and ammonium sulfate [13].

Temperature (T), the potential of hydrogen (pH) and conductivity (Cs) were measured by immersing a thermometer, a pH meter, turbidity and conductivity of all types EUTECH in 50 ml of water taken from each sample. After 4 minutes of immersion, each of these devices has been removed for reading the results. Ares sample bottles are kept in a cooler at 4°C and transported to the laboratory for physical and chemical analysis within the following 24 hours. For other physicochemical parameters: volume is the method used for the determination of chlorides, dissolved oxygen, calcium and magnesium, total hardness; the molecular absorption spectrophotometry for sulfates, nitrates, ammonium [14].

- *Microbiological analyzes*

For microbiological analysis, samples were collected using sterile Pyrex glass bottles (120°/20) fitted with screw caps: the submerged bottle filled and then closed before being returned. The samples were immediately placed in an insulated cooler where the temperature is kept between 2°C and 8°C; they are sent to the laboratory to be analyzed immediately on selective media according to FAS_NF T 90-414.2000.
Germs test of fecal contamination (GTFC) chosen according to Normalizes Moroccan 03.7.001 are:
- Escherichia coli (E. coli) is the most significant species of faecal contamination.
- Coliform bacteria (CB).
- Intestinal enterococci (IE).
- Viable microorganisms at 22°C and 37°C: Sprouts Totals (GT) at 22°C and 37°C.

2.3. *Statistical tool*
The physico-chemical and bacteriological parameters were analyzed by Principal Component Analysis (PCA) means values of samples. The software used is the version 10 of STATISTICA software.

3. Results and discussion

We performed physicochemical and bacteriological analysis for 25 sources and we have chosen the average results for each parameter express.
3.1. Results of physico-chemical analysis of water sources and the Principal Component Analysis (PCA)
Principal Component Analysis (PCA) was performed on a data matrix consisting of 25 lines representing the prospected sources and 13 columns representing the physicochemical variables measured or analyzed (Table 1).

Table 1: Results of physicochemical Analyzes of water sources surveyed (average values).

Source	T °C	PH	EC µs/c	O_2 mg/l	TR NTU	NO_3^- mg/l	NH_4^+ mg/l	Ca^{2+} meq/l	Mg^{2+} meq/l	TH meq/l	TAC meq/l	Cl^- mg/l	SO_4^{2-} mg/l
S1	17,5	7,25	4,32	6,7	2,63	9,9	0	0,323	0,466	0,94	0,12	118	17
S2	17,2	6,60	331	7,333	3,74	0,793	0,23	0,383	0,346	0,73	0,126	165	80
S3	16	7,42	49,66	7,83	0,71	0,436	0,08	0,096	0,073	0,17	0,05	7,30	133,3
S4	15,5	6,72	271,3	7,6	3,78	1,34	0	0,73	0,52	1,25	0,5	4,35	28,67
S5	17	7,59	555	8,3	4,32	2,653	0,03	3,42	2,833	3,25	4,4	36,67	138,3
S6	16	7,75	356,6	8,43	0,38	2,943	0,06	2,723	1,74	4,463	4,08	24,43	12,23
S7	16,4	7,67	501,6	6,63	1,06	2,733	0	3,27	1,78	5,3	4,2	43,20	22,44
S8	17	6,52	439,3	4,43	2,75	7,773	0,02	0,58	0,753	1,333	0,526	75	120,6
S9	17,2	7,40	985	6,81	3,73	16,8	0,02	6,8	3,646	10,36	4,36	91,70	128,8
S10	16,3	6,58	105,6	4,13	1,3	6,72	0	0,38	0,513	1,2	0,313	29,13	58,33
S11	16	6,69	256,6	6,68	3,60	3,76	0,01	0,35	0,86	0,316	0,2	78	41,67
S12	15	6,98	270	5,60	1,1	0,555	0,15	2,4	0,15	2,7	2,14	160	67
S13	14,5	6,99	250	6,70	1,2	5,23	0,23	4,6	0,67	1,6	2,67	98	89
S14	17	6,52	130	5,6	2,9	1,20	0,01	2,8	0,78	1,09	3,89	67	123
S15	16,3	6,52	340	5,9	1,5	0,274	0,08	1,4	0,6	0,89	3,78	5,98	78
S16	15,8	6,25	190	4,8	1,6	0,957	0,06	0,22	1,9	1,89	2,34	9,87	145
S17	16,4	7,5	256	6,7	1,1	3,81	0,67	0,88	2,9	3,01	2,78	220	96
S18	16,5	6,88	109	6,3	2,7	3,23	0,55	1,89	3,0	2,23	1,89	100	45,9
S19	17	7,71	230	4,2	1,8	2,35	0,31	2,77	2,9	2,89	1,34	156	230
S20	16	7,41	170	5,8	1,5	1,67	0,08	3,8	1,69	0,89	0,45	123	76
S21	17	8,1	200	7,2	0,9	1,23	0,37	1,8	1,8	0,45	0,67	90	189
S22	16	6,37	300	7,8	2,9	1,83	0,04	0,9	1,9	0,23	0,89	67	77
S23	17	6,3	340	7,6	1,8	1,67	0,02	2,8	2,87	1,9	1,93	98	287
S24	17,5	6,25	300	6,5	1,6	13,67	0,09	1,5	1,9	1,2	2,13	129	31
S25	16	7,23	570	5,3	1,5	2,23	0,02	0,89	0,22	0,98	1,34	222	98,6

T = Temperature ; EC= electrical conductivity ; O_2 = dissolved Oxygen ; TR= Turbidity ; NO_3^-= Nitrates ; NH_4^+= Ammonium ; TH= total Hardness ; Mg^{2+}= Magnesium ; Ca^{2+}= Calcium ; SO_4^{2-}= Sulfates ; TAC= Complete Alkalimetric Titre ; Cl^-= Chloride.

Figure 3 shows the projection of the 25 sources on the first factor-plan (F1-F2). Examination of the numerical results of this PCA shows that the first component, which combines 29.83% of the variability captured, objects (Mg^{2+}, TAC and the TH) in negative coordinates. The second component, with 17.34% of the variability captured especially opposes the SO_4^{2-} ions, NH_4^+ and Cl^-, positively contributes to expressing this axis. Unlike, Turbidity (TR) and dissolved Oxygen (O_2) that are negatively correlated with this axis (Figure 2).

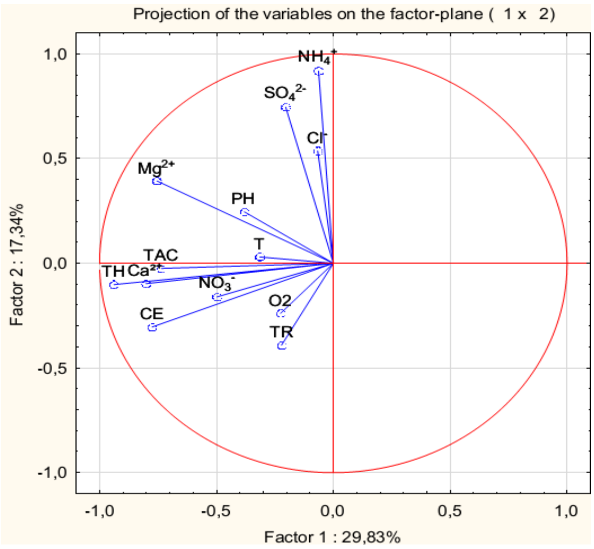

Figure 2: Screening of physical-chemical factors of water sources in the factorial design F1-F2 PCA

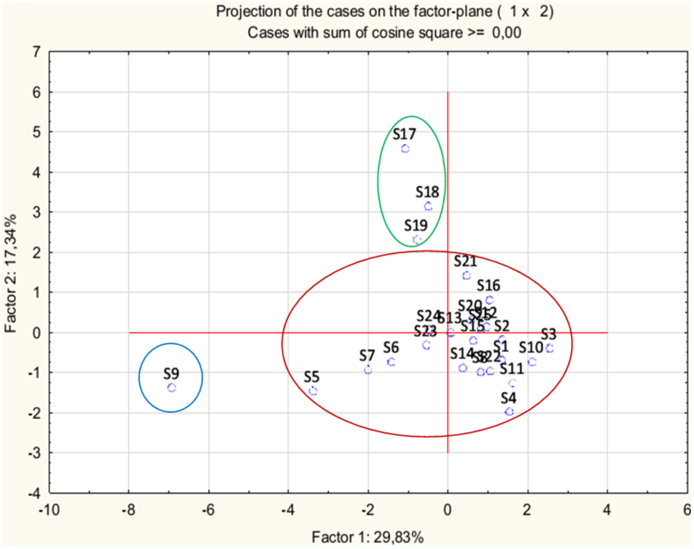

Figure 3: Projected surveyed 25 sources in the factorial F1-F2 PCA

The hierarchical classification of the 25 sources on the basis of the physico-chemical water quality has allowed us to distinguish three groups:

Group 1: characterized the water medium quality, high mineralization, as they are rich in Ca^{2+}, Mg^{2+} and nitrates. This class includes the source S9.

Group 2: For waters with high mineralization as S17, S18 and S19 where ion contents NH_4^+, Cl^- and SO_4^{2-} are high and which also have a water medium physicochemical quality.

Group 3: represents good quality waters with low mineralization as S1, S2, S3, S4, S5, S6, S7, S8, S10, S11, S12, S13, S14, S15, S16, S20, S21, S22, S23, S24 and S25 with low levels of NO_3^- and SO_4^{2-} ions.

3.2 Bacteriological results in water sources and Principal Component Analysis (PCA)

The principal component analysis performed on a data matrix consisting of 25 lines representing the sampled stations and 5 columns representing the bacteriological parameters measured or analyzed (Table 2).

The PCA showed Intestinal Enterococci (SF); Fecal coliform (FC); total germ (WG) at 22°C and 37°C and coliform bacteria (BC) negatively contribute to the expression of the F1-axis, which combines 54.77% of the captured variability. The second component (axis-F2), with the captured variability 18.11%, shows Intestinal Enterococci (SF) and Fecal coliforms (FC) which positively contribute to expressing this axis. Unlike total germs (GT) at 22°C and 37°C and coliform bacteria (BC) that negatively contribute to expressing the axis F2 (Figure 4).

The hierarchical classification of the 25 sources, on the basis of their contamination by germs, allowed to distinguish five different groups (Figure 5):

Group 1: it contains the S23 source which has very poor water bacteriological quality. This spring is characterized by very high rate in contamination of germs indicators of faecal pollution including Intestinal Enterococci.

Group 2: it isolates the source S18 which shows water very poor bacteriological quality, characterized by very high concentration rate indicator of faecal pollution germs including total germs.

Group 3: This group brings together the sources S2 and S17; the waters are of mediocre to bad quality. They are indeed highly polluted by germs of fecal pollution indicators, the contents of which often exceed the standards.

Group 4: This group brings together the sources S3, S6, S21 and S22, whose waters are of good enough quality with bacterial pollution, not exceeding Moroccan standards.
Group 5: This group brings together all of the following sources S1, S4, S5, S7, S8, S9, S10, S11, S12, S13, S14, S15, S16, S19, S20, S24 and S25, which also have a poor bacteriological quality water.

Table 2: Bacteriological results of water sources surveyed (average values).

Sources	S.T à 22°C (UFC/1ml)	S.T à 37°C (UFC/1ml)	C.B (UFC/100ml)	F.C (E.Coli) (UFC/100m)	I.E UFC/100ml)
S1	7890	3567	518	378	231
S2	3567	4389	1780	431	349
S3	0	0	0	0	0
S4	150	89,5	231	139	29,5
S5	1219	1012	789,5	30	0
S6	0	0	0	0	0
S7	2718	1348	780	389	123
S8	12678	890	289	98	70
S9	9889	3789	450	241	71
S10	2348	890	934	312,5	7
S11	1078	7890	780	230	0
S12	45	70	0	0	9
S13	780	560	1045	780	67
S14	8230	2389	980	200	120
S15	679	6579	245	50	0
S16	9802	150	150	80	120
S17	7890	5789	560	971	67
S18	15761	6789	2789	719	3
S19	762	60	780	78	230
S20	98	20,5	89	34	12,5
S21	54	9	0	0	0
S22	79	0	0	0	0
S23	5657	4678	1021	870	789
S24	679	541	580	234	67
S25	10	9	89	34	101

S.T= Sprouts Totals; F.C= Fecal Coliforms; B.C= Coliform Bacteria; I.E= Intestinal Enterococci.

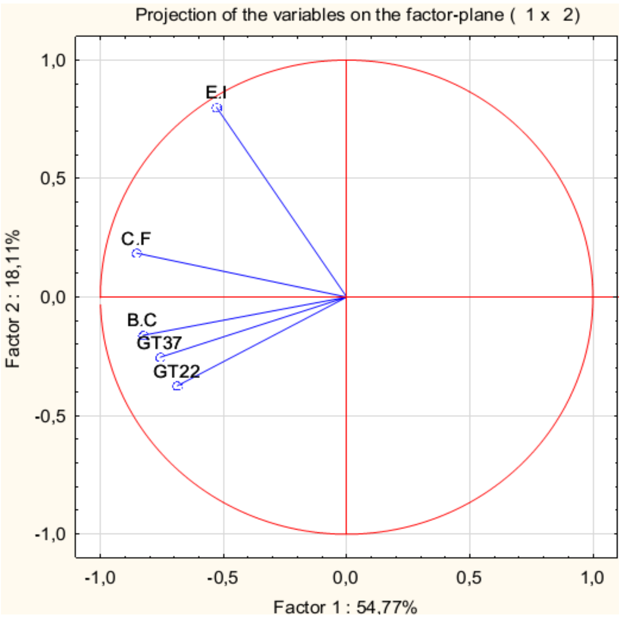

Figure 4: Projection of the 5 germs in the water of 25 studied sources on the F1-F2 factor-plane.

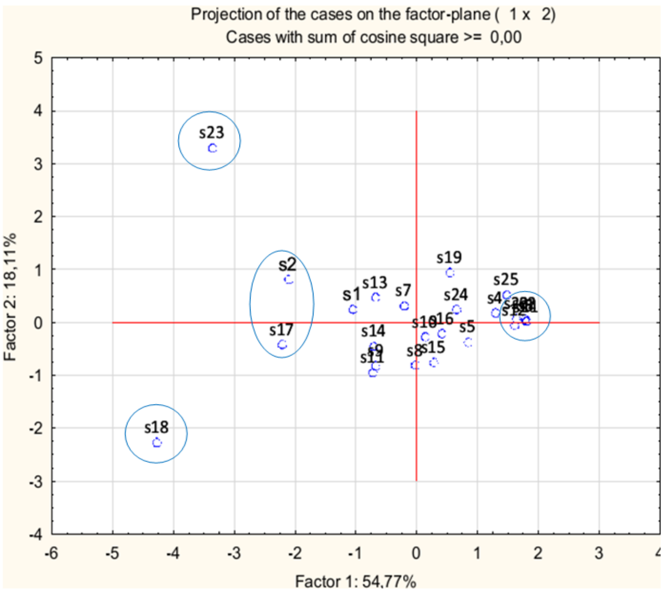

Figure 5: Projection of the 25 sources examined on factor-plane F1-F2.

The bacteriological water quality of the sources surveyed reveals contamination of the water table in some most sources of pollution. The latter could be due to domestic human activities and agriculture, to the existence of any kind of waste and uncontrolled public landfills. Moreover, the sources of our study area experiencing heavy pollution in indicators of faecal contamination, in agreement with those found by [15, 16] for the sheet of Fez, and those registered for the surface water table in Marrakech [17]. The results [18] have also shown that the water from a groundwater is more vulnerable when the top of the water table is close to the ground surface, knowing that the lands which overcome the aquifer are permeable and that the superficial pollution sources are important.

Conclusion

It is clear from this qualitative study that human activities present a potential risk to the environment, including water resources. This study demonstrates the utility of multivariate analysis techniques to obtain better information on water quality and prevent pollution caused by human factors.
The results for *physico-chemical* analysis showed that the region of Tangier-Tetouan, generally, has a good quality within the parameters examined during the period of the study, since the results obtained comply with the limits of quality (Standard Morocco: Quality of water for human consumption). The results for *bacteriological* analysis showed that the region of Tangier-Tetouan, generally, has a bad quality within the germs examined during the study period. Bacteriological point view, the sources studied have very high concentrations of fecal contamination in almost all sources studied, which is undoubtedly a threat to residents who obtain water from these sources for most of their needs. In general, Microbiological seeds were more directly related to human activities that took place in the area (agriculture, domestic waste, septic systems and application of deicing salts).
The results of this study will help managers to develop a water strategy for good governance of water resources in accordance with the requirements of sustainable development.

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