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Variation of groundwater quality in the poultry farming using cluster and multivariate factor analysis: a case study from middle atlas area, Morocco

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Abstract

The present study was carried out to assess the quality and the suitability of the wells waters used for drinking of poultry in Middle atlas area. The work was performed on 20 wells in June 2011 (rainy season) and February 2012 (dry season). Numerous monitoring data and water quality index obtained from 20 regional monitoring wells are simplified and classified by applying the multivariate statistical methods such as factor and cluster analysis to search for the interrelation between the water quality parameters, factors representing the characteristics as well as possible pollution sources of groundwater quality used as drinking water of poultry in Middle Atlas area, Morocco. Three principal factors were recognized in concerned area using principal component analysis (PCA) including salinization factor, mineralization factor and inorganic factor. All three factors can interpret 81.0% variances of the integrated groundwater characteristics. In addition three clusters were classified according to the similar and dissimilar characteristics of water quality of monitoring wells in the farming of poultry in Middle Atlas. The results showed that the groundwater quality in clusters G1 and G'1 is better as compared with the other clusters. Multivariate statistical methods provided by this study can not only reduce the harassment of the missing items of monitoring water quality, but also refer as a management alternative for groundwater resources.

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Introduction

The livestock production sector plays an important role in Morocco. Two out of three farms among the 1 million in the nation are involved in livestock production with 18% of the rural population.

depending exclusively on livestock as a source of income. This industry contributes, on average, 10 billion DH each year to the GDP, which represents 25% to 35% of agricultural GDP, depending on the production level. Moreover, this industry contributes significantly to food security with meat; milk and its by-products; and eggs, having self-sufficiency ratios of 98%, 88% and 100%, respectively (Azzouzi *et al.,* 2005).

Successful completion of a poultry farm depends in large part on the quality of drinking water distributed to poultry. In rearing conditions well mastered the adverse effects of poor water quality can go undetected, but the conditions just mastered, its effects are feel more and affect essentially at three levels: first on the health and and then on the production efficiency of antibiotic therapy in particular the effect of the hard water (Bengoumi *et al.,* 2004).

The main factors influencing the transport of the pollutants in the ground are: the underground water level, the quantity of pollutants, their type, and soil bedding (Bedient *et al.*, 1999). The ground water quality depends not only on natural factors such as the lithology of the aquifer, the quality of recharge water and the type of interaction between water and aquifer, but also on human activities, which can alter these groundwater systems either by polluting them or by changing the hydrological cycle (Farooq *et al.*, 2010).

The water element is the major and essential to every form of life, it is used for several purposes in poultry: Drinkers, Vector therapeutic (drugs and vaccines); Vehicle disinfectants. It was then that its quality takes a prominent place in the assurance of product quality and productivity of livestock, but unfortunately the breeder lends scant attention (Bengoumi *et al.,* 2004).

Poor water quality can not only cause many therapeutic failures, but also be a predisposing factor for a broad range of pathologies of the various etiology (chemical, bacterial, viral and parasitic (Mouhid *et al.,* 2001; Bengoumi *et al.,* 2004). Groundwater has been associated with water quality problems and the manure of poultry spilled near the wells used as drinking water for poultry.

In this context, the objective of this study is to utilize the factor and cluster analysis to understand the factors affecting the groundwater quality and discriminate their influence area. Multivariate statistical methods provided by this study can not only reduce the harassment of the missing items of monitoring water quality, but also refer as a management alternative for the groundwater resources.

Materials and methods

Study Area

Geology and Geographic Situation

The study area located between the coordinates 33°30 and 34° latitude north, 4°30 and 5° longitude south. It's the North-Est extension of the Middle Atlas Plateaus, consists mainly of dolomitic limestone's of the Lower Jurassic (Lower and multi-spectral radiometer, particularly Landsat images medium Lias), which overcome the series consisting of the Triassic red shale and basalt (Charriere, 1990; Fedan *et al.*, 1989; Lashkar *et al.,* 2000). It is characterized by a tabular structure, more faulted and folded as a monotone relief. It's a large karst plateaus variously staged, overlooking the plain of Sais, at altitudes above 1000 m. It's crossed by the Fault NE-SW of Tizi n'Tratten and separates, South East of Middle Atlas Pleated, by North Middle Atlasic Fault (ANMA). lithological contacts. The limit North and Northwest is determined by tertiary and quaternary overburden of the Rif south corridor (Ouarhache, 2002) (Fig.1).

The Middle Atlas Plateau consists mainly of Liassic limestones, which lie on argillaceous and basaltic Triassic layers (Fig. 2).

Field work

The study was performed on 20 wells on June 2011 (rainy season) and February 2012 (dry season). The water table and water quality are influenced by recharge or withdrawal of groundwater which can modify the physico-chemical characteristics of the water. Consequently, the physico-chemical parameters (pH, temperature, Total Hardness (TH), Chloride (Cl-),Chlorine free, Chlorine total, iron(Fe), Nitrate (NO3-), Nitrite (NO2-) and Salinity) were measured to assess water table fluctuation and groundwater quality (Rodier *et al.*, 2009) . All the samples, collected in tight capped high-quality polyethylene bottles, were immediately transported to the laboratory under low temperature conditions in the icebox and stored in the laboratory. The temperature, pH and salinity of the water were measured in situ.

Factor Analysis

The multivariate statistical process of environmental data is widely used to characterize and assess the surface water and groundwater quality, and it is useful for evidencing temporal and spatial variations caused by natural and human factors linked to seasonality (Huang *et al.,* 2005; Helena *et al.,* 2000).

With the aid of multivariate statistical techniques, the groundwater data can be simplified, organized and classified to bring about useful meanings (Wu T. N. and *al.,* 2005). Factor analysis such as principal component analysis (PCA) is known as a powerful technique for reduction of variables dimension by providing the correlation among measured chemical variables and their multivariate patterns based upon eigen analysis of the correlation or covariance matrix that may be help to classify the original large sets of data (Helena B and *al.,* 2000). The geochemical interpretation of determined factors gives insights into the dominant processes, which may command the distribution of hydrochemical variables (C.W., Liu, K. H. Lin and Y. M. Kuo. 2003).

Cluster Analysis

Cluster analysis is the method used for finding different classes and groups within the obtained data. A number of studies used this technique to successfully classify water samples (Alther, 1979; Williams, 1982; Farnham *et al.*, 2000; Alberto *et al.,* 2001; Meng and *al.,* 2001, Bengoumi D *et al.,* 2013 and El Moustaine R *et al.,* 2013). The cluster analysis is a group of multivariate techniques whose primary purpose is to assemble objects based on the characteristics they possess (Danielsson, 1999). The levels of similarity at which observations are merged are used to construct a dendrogram (Chen, 2007). The Euclidean distance usually gives the similarity between two samples, and the distance can be presented by the difference in analytical values from the samples (Otto, 1998).

Cluster analysis (CA) is a statistical tool to classify the true groups of data according to their similarities to each other. All variables were also standardized by score mode before being subjected to CA. A short Euclidean distant implies the high similarity between the measured objects (4, 5). Two types of CA methods, hierarchical cluster analysis and nonhierarchical cluster analysis, have been performed in two-step procedures in this study. In the present study statistical software STATISTICA version 10 is used to carry out the statistical analysis.

Results and discussion

Factor Analysis

The close inspection of the correlation matrix was useful because it can point out associations between variables that can show the overall coherence of the data set and indicate the participation of the individual chemical parameters in several influence factors, a fact which commonly occurred in hydrochemistry (Helena *et al.*, 2000). The Pearson correlation coefficient matrix is given in the Tables 1 and 2. The variables having coefficient value (r) >0.5 are considered significant. Inspection of these tables reveals that salinity is positively related with Cl-. The same matrix gives the maximum variance as shown in the principal component analysis-factor 1. This further substantiates the significance of the analysis. The variation in relationship indicates the complexity of the quality of groundwater.

In Tables 3 and 4, Factor 1 shows a strong positive correlation of the salinity with Cl-. Factor 1 explains for (rainy season: F1 (31.31%); dry season: F1 (24.27%)) of the total variance and is characterized by very strong positive loading. Even though calcium and magnesium were not measured in this study, these cations were expected to be present for the electro-neutrality of saline water and the TH. Therefore, Factor 1 is accordingly defined as the salinization factor and Cl-.

Table 1. Pearson correlation in dry season.

Variable	NO2-	Fer	NO3-	CL R	CL T	HT	Cl-	pH	SAL	T°C
NO2-	1,000000	-0,084677	0,012312	0,075761	-0,195299	0,105623	0,063603	0,231093	-0,054826	0,194045
Fer	-0,084677	1,000000	-0,039900	0,013533	0,221353	0,079090	-0,242223	0,116302	-0,240998	0,060881
NO3-	0,012312	-0,039900	1,000000	0,059100	0,421806	0,128406	0,219918	-0,060124	0,203552	-0,033014
CL R	0,075761	0,013533	0,059072	1,000000	0,059100	-0,184692	-0,145146	0,132983	0,012580	0,414799
CL T	-0,195299	0,221353	0,421806	0,059100	1,000000	-0,076814	-0,298071	0,054549	-0,369230	0,285107
HT	0,105623	0,079090	0,128406	-0,184692	0,076814	1,000000	-0,074466	0,352536	-0,266479	0,059350
Cl-	0,063603	-0,242223	0,219918	-0,145146	-0,298071	-0,074466	1,000000	0,079130	0,753897	-0,126170
pH	0,231093	0,116302	-0,060124	0,132983	0,054549	0,352536	0,079130	1,000000	-0,282276	0,284595
SAL	-0,054826	-0,240998	0,203552	0,012580	-0,369230	-0,266479	0,753897	-0,282276	1,000000	-0,273743
T°	0,194643	0,060881	-0,033014	0,414799	0,285107	0,059350	-0,126170	0,284595	-0,273743	1,000000

Factor 2 accounts for (dry season: F2 (15.73%); rainy season: F2 (19.46%)) of the total variance and is mainly associated with very high loadings of N-nitrogen and HT (Table 3 and 4). N-nitrogen is attributed to the infiltration from improper handle of pasturage and septic tank wastewater. High levels of HT in the groundwater are closely related to the dissolution processes of the geological features and formation in the study area. Therefore Factor 2 is characterized as the organic mineral factor. Fig. 3 demonstrates the PC score of each sampling data for APC 1 and APC 2.

Table 2. Pearson correlation in rainy season.

Variable	NO2-	Fer	NO3-	CL R	CL T	HT	Cl-	pH	SAL	T°C
NO2-	1,000000	0,58769	0,103382	0,479620	0,208368	-0,054387	0,467476	0,605186	0,526726	-0,364927
Fer	0,158769	1,000000	-0,162812	0,704358	-0,071809	0,134474	0,161728	-0,000874	0,526726	0,305054
NO3-	0,103382	-0,162812	1,000000	0,062141	0,553857	0,4851861	-0,169474	-0,064900	0,078502	-0,062570
CL R	0,479620	0,704358	0,062141	1,000000	-0,016222	0,094232	0,483172	0,151545	0,426890	0,119374
CL T	0,208368	-0,071809	0,553857	-0,016222	1,000000	0,155332	-0,070378	0,022127	-0,109704	0,040759
HT	-0,054387	0,134474	0,485186	0,094232	0,155332	1,000000	-0,521646	-0,145608	-0,551057	-0,003685
Cl-	0,467476	0,161728	-0,169474	0,483172	-0,070378	-0,521646	1,000000	0,098610	0,858864	0,061076
pH	0,605186	-0,000874	-0,064900	0,151545	0,022127	-0,145608	0,098610	1,000000	0,392019	-0,059201
SAL	0,526726	0,078502	-0,106890	0,426890	-0,109704	-0,551057	0,858864	0,392019	1,000000	-0,085808
T°	0,364927	0,305054	-0,062570	0,119374	0,040759	-0,003685	0,061076	0,059201	0,085808	1,000000

Factors 3 related to 17.58% (rainy season) and 14.52% (dry season) of the total variance of Cl-R and Cl-T, respectively (Tables 3 and 4). The single dominant variable, Cl- R and Cl-T, presented in Factor 3 is most likely contributed to the wells treatment by chlorination. Hence, Factor 3 is characterized as the inorganic.

Cluster analysis

The principal component analysis (PCA) applied to water samples allowed to highlight the mechanisms that govern the well water quality in Middel Atlas area taking into account the two seasons (dry and rainy season). For all of the two seasons (dry and rainy seasons), the first two factors F1 (rainy season: F1 (31.31%); dry season: F1 (24.27%)) and F2 (dry season: F2 (15.73%); rainy season: F2 (19.46%)). The indices G and G' characterized the groupings of the dry and the rainy season respectively.

Table 3. Showing result of principal component analysis in dry season.

Variable	Factor 1	Factor 2	Factor 3
No2-	0,032285	0,414675	-0,153048
Fer	0,177772	-0,158373	0,011758
NO3-	-0,027950	0,055558	0,589846
CL R	0,101478	0,230787	0,169998
CL T	0,231983	-0,155886	0,454809
HT	0,142906	0,149818	-0,040060
Cl-	-0,297083	0,282845	0,159080
pH	0,172854	0,389188	-0,085495
SAL	-0,355100	0,119761	0,178348
T°C	0,223316	0,299734	0,123919

The results of the cluster analysis are presented in figures 4 and 5. The data set were classified in three groups of the two seasons (dry and rainy seasons) named as G1, G2 and G3; G'1, G'2 and G'3 groupings of the dry and the rainy season respectively.

PCA reflects both common and unique variance of the variables and may be seen as a variance-focused approach that reproduces both the total variable variance with all components as well as the correlations. PCA is far more commonly used than principal factor analysis. In all the Principal component analysis generated tree significant factors (Table 4). Factor analysis is a multivariate analytical technique, which derives a subset of uncorrelated variables called factors that explain the variance observed in the original data set (Anazawa and Ohmori, 2005, Brown, 1998).

Table 4. Showing result of principal component analysis in rainy season.

Variable	Factor 1	Factor 2	Factor 3
No2-	-0,703601	0,489998	-0,314009
Fer	-0,310583	0,157503	0,836238
NO3-	0,244791	0,785279	-0,141707
CL R	-0,639046	0,392316	0,564852
CL T	0,118212	0,667651	0,180029
HT	0,511226	0,6221261	0,271221
Cl-	-0,856405	-0,116602	0,028689
pH	-0,856405	0,207857	-0,314326
SAL	-0,902538	-0,073222	-0,165199
T°C	0,059948	-0,128239	0,622946

Factor 1 exhibits 24.27 % during dry season and 31.31 % during rainy season of the total variance with correlation negative on pH, Salinity and Cl-, and the positive correlation on Fer and CL-T, there are only correlation positive one during dry season. Therefore, high level of salinity, Cl-, CL-T and Fe are observed in cluster G2 and G'2 whose groundwater quality was the saline in the study region. The relative position of each identified cluster is shown in Fig. 4 and 5.

Factor 2 exhibits 15.73 % during dry season and 19.46 % during rainy season with of the total variance with positive loading mostly on HT and N-nitrogen. This water is bicarbonate (expressed in total hardness) and chloride dominated. Main source of HCO3- ions in the groundwater of this region is due to dissolutionlimestone, dolomite and from anthropogenic activities.

Statistical units indicate that the groups G1 and G'1 characterize the well water with a low mineralization (Fig. 4 &5). Wells that characterize the group G1 (fig.4) are made up of P1, P2, P4,P8,P12, P13, P14, P16,P19,P20, while those of the group G'1 (fig.5) are composed of P1,P2, P4,P6,P7,P9,P10,P13, P14, P15, P18, P19, P20. The mechanism that governs the axis of factor F1 is therefore the mineralization of the well water. Indeed, during the rainy season, the groundwater recharge accelerated the mineralization of the wells P18. The groundwater quality in clusters G1 and G'1 is better as compared with the other clusters.

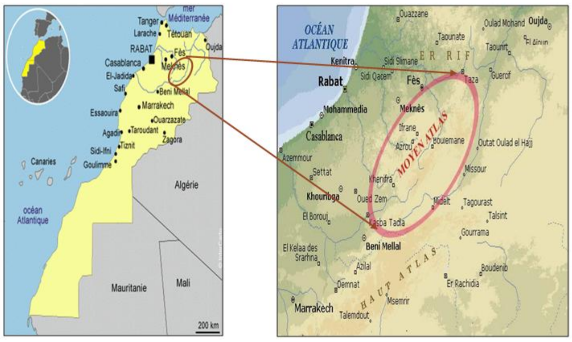

Fig. 1. Study area.

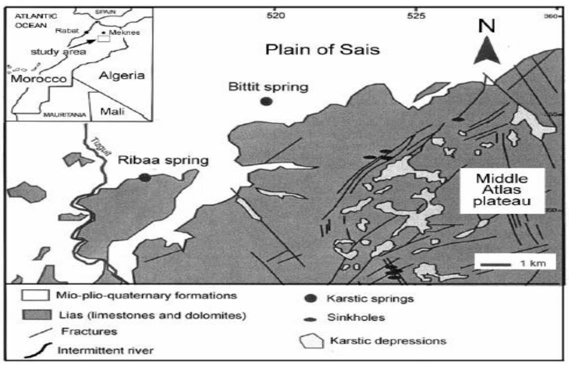

Fig. 2. Geological map of the Middle Atlas Plateau. adapted from F. AMRAOUI *et al.* (2003).

In the groups (G2 and G'2) (Fig.4 and 5), the water is characterized by high salinity and pH water compared to the water of the first groups (G1 and G'1). Higher recharges of wells water occur in rainy season. It's also observed that most of the wells of the group G2 (fig.4) such as P9, P15, P17 and P18 characterized by a high salinity during the dry season are absent from the group G'2 (Fig. 5) equivalent to G2 during the season rains. In addition, only the well P18 was recorded in the group G'2 during the rainy season. This means that the oxidation process of water in the study area is more intensive.

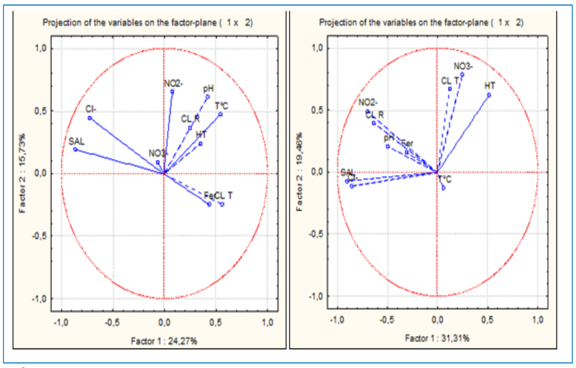

Fig. 3. Seasonal representation of different parameter groups of F1-F2 factorial plan: a - parameter groups in dry season; b - parameter groups in rainy season.

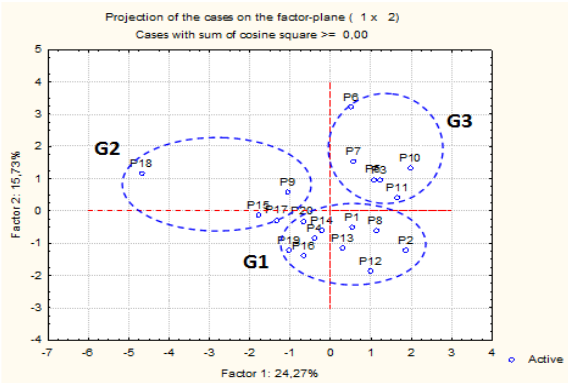

Fig. 4. Grouping of statistical units during the dry season.

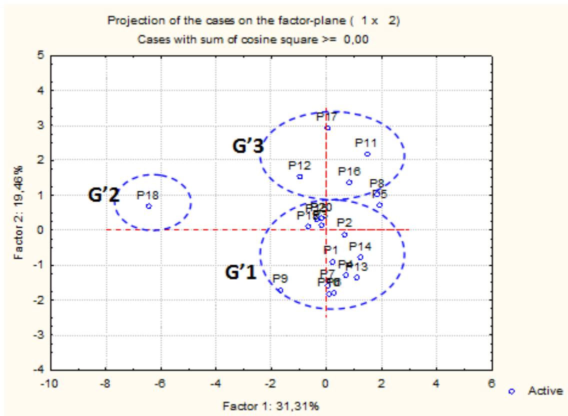

Fig. 5. Grouping of statistical units during the rainy season.

Well water from the groups G3 (Fig.4) and G'3 evolves therefore under reducing conditions (Fig.5) with pH close to neutrality during the rainy season. So the wells originally belonging to group G2 (P9, P15, P17) and to group G1 (P5, P8, P12, P16) during the dry season migrated to the group G'3 during the rainy season by a reduction process.

Conclusion

This study has successfully demonstrated the utility of multivariate statistical tools including factor and cluster analysis to characterize the groundwater quality used as drinking water of poultry of the Middel Atlas area during two companion of sampling in June 2011 (dry season) and February 2012 (rainy season).Two principal factors were recognized using PCA. The first salinization factor accounts for 24.27 % of the total variance during dry season and 31.31 % of the total variance during rainy season and includes the variables of salinity and Cl- . The second organic mineral factor specifies 15.73 % of the total variance during dry season and 19.46 % of the total variance during rainy season and contains the variables of pH, NO2-N, NO3-N and HT.

Three clusters of monitoring wells were classified according to the similar and dissimilar characteristics of groundwater quality in Middel Atlas area. With the aid of statistical techniques, it is predictable to be aware of the underlying processes and the distribution of sources that mightaffect the concerned groundwater quality. Furthermore, it can offer the requisite information for the stockbreeder to pursue the sustainable approaches on groundwater management and contamination prevention.

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