Characterization and Classification of Different Aquaculture Tunisian Water using an Electronic Tongue

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ABSTRACT
In this report we present a comparative study realized on different aquaculture water samples collected from several fish farms in Tunisia. For each water sample, significant physiochemical parameters such as conductivity, pH, NH_4^+, Na^+, Ca^{2+}, F^- and NO_3^- were determined using a potentiometric multi-sensor system named "electronic tongue". Experimental analysis data were standardized and subjected to principal components analysis (PCA) in order to classify, to control and to maintain the quality of water needed for aquaculture purposes. In particular, our study has been profoundly interested to Hergla farm comparing the quality of its aquaculture reject water to other wastewater resources. It is meant by this procedure to elucidate the impacts of aquaculture on its surrounding environment. This leads to a better opportunity to give the objective elements used for the comparative judgement of the polluted aquaculture.

Keywords ***-Multivariate analysis, Principal components analysis, Aquaculture, Water quality, Electronic tongue.***

INTRODUCTION
Aquaculture represents a quick growing food production sector in the world. Tunisia is among the countries that gives a great interest to aquaculture according to its significant and particular place occupied in agriculture. Indeed, aquaculture can generate similar products (fish, crustaceans, mollusks, minnows, algues,….) as those obtained with fishing from the natural sources. However, the aquaculture industry is based on water resources, and typically requires from 200 – 600 m^3 of water for every kilogramme of fish produced [1]. Actually, the quality and the quantity of the aquatic product can be influenced by the aquaculture water quality. For this reason aquaculture water needs a high control potential to provide acceptable aquatic products and consequently leads to a good environmental field even human health.

During the development of aquaculture many problems are raised affecting the durability of this activity. The technology development added to the increase of the demand on the aquaculture products implies a prosperous future for aquaculture. This fact should achieve the challenge of durability.

Recently, we have witnessed a considerable decrease in fishing production not only in Tunisia but in all Mediterranean towns [2]. Aquaculture was the original solution in order to fill up this deficiency. In addition, Tunisia has some good favourite sites for developing the aquaculture activity and profits from the European market for the exportation.

To maintain a good production in terms of quality and quantity aquaculture requires the management of parasitic problems and the control of some parameters [3]. In addition to the technical and economic parameters which are very important, water quality is becoming more and more dependent on the quality of the aquatic products. So, qualitative control (observation parameters) of water quality based on the change of colour or odour will be defined and become efficient when it is coupled to quantitative study (numerical parameters). In fact, high temperature, pH variation, nitrate accumulation or CO_2 decrease due to a high photosynthetic activity leads to a bad water quality and consequently to a risk of high mortality rate. All these disagreeable effects based on the change in the physiochemical parameters of water induce a strong decrease in the aquaculture production. In addition there is a strong interaction between the farm and its environment. For this reason it is very important to first evaluate the impact of aquaculture activity on the environment and then the impact of environment on the aquaculture farm.

In the present work principal component analysis was employed to investigate the classification of different aquaculture water samples collected from several fish farms in Tunisia. The quantitative analysis of aquaculture water was obtained using an electrochemical system composed of several potentiometric sensors named "electronic tongue". The correlation between experimental data and the multivariate analysis demonstrate the usefulness of

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the technique in the analysis of aquaculture water quality data. The evaluation of the activity of the aquaculture wastewater impact on the environment was investigated in comparison with other rejected water resources.

1. MATERIALS AND METHODS

1.1. Study area

Tunisia with 1250 Km of coast occupies a particular and a favourable position in the Mediterranean for aquaculture development. In addition the Tunisian coast presents a great number of lakes and lagoons that facilitate, enhance and vary the aquaculture activities.

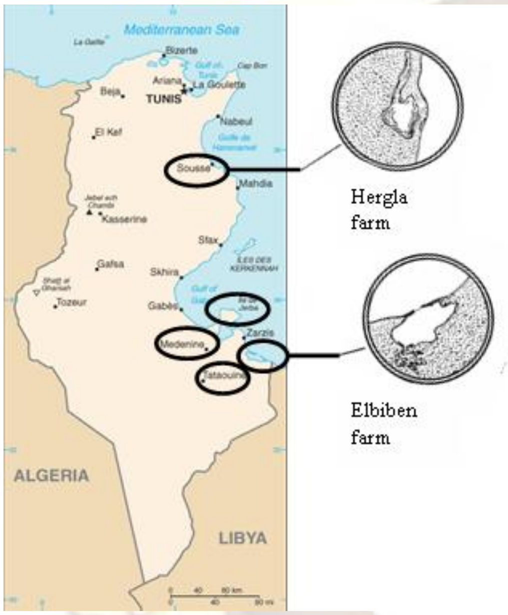

Fig. 1: Study area and sampling stations of five farms located in the centre and the south of Tunisia

Aquaculture water samples were collected from different sites in Tunisia in the same period. In fig.1 are located the five farms studied in this work, such as Hergla (Sousse Governorate), Tuni-peche (in Ajim near Jerba Governorate), Seapat (Mednine Governorate), Ebiben (ben Gardane) and SAT (Mednine Governirate) farm.

1.2. Sampling site and sample analysis

The collected water samples from the different aquaculture farms were immediately preserved in polyethylene sampling bottles at 4°C in darkness to be analysed in within no more than 48h. The parameters of water quality included conductivity (χ), pH, nitrate (NO_3^-), ammonium (NH_4^+), sodium (Na^+), calcium (Ca^{2+}) and fluoride (F^-). The conductivity was measured with YSI meter Model 33 (YSI, USA). The pH and other ions concentration were determined using commercialized ion specific electrodes (working electrodes) taken in network form and connected to a multiplexor system for potential or concentration measurements as shown in Fig. 2. All other reagents for solution calibration were analytical grade.

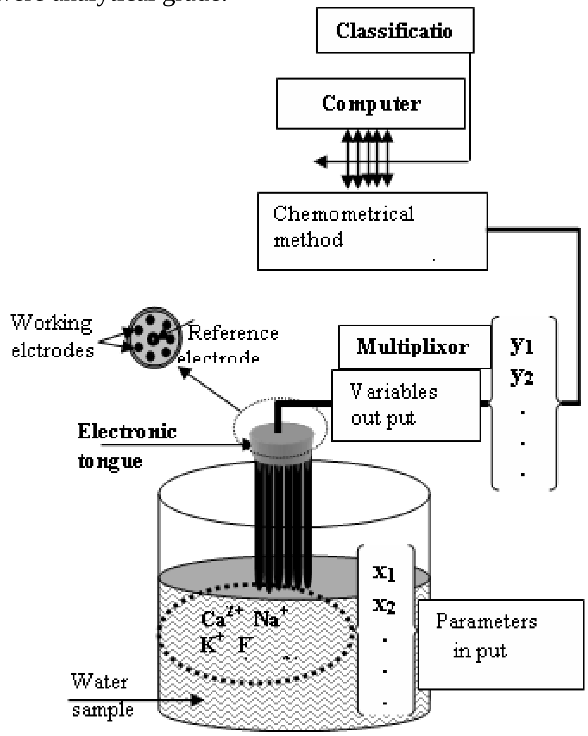

Fig. 2 The set-up of a potentiometric electronic tongue.

1. 3. The dataset and statistical procedures

In this multivariate analysis study, principal component analysis was employed to investigate the factors which caused variations in the observed quality data at the aquaculture water quality monitoring. Statistical analysis was conducted using the statistical software package SPSS 11.0, and significance was determined at the 95% confidence level.

2. RESULTS AND DISCUSSION

2.1 Principal component analysis for water samples classification

Principal component analysis (PCA) linked with sensor arrays has shown to be very powerful and represents a good statistical method among many familiar successful multivariate analysis applied for resolving a variety of problems. As known PCA is a mathematical transform which is used to explain variance in experimental data [4]. In addition, this chemometric method has been often used for the classification and comparison of different water samples such as mineral [5], ground [6], river [7], waste and polluted water [8]. The classification of different aquaculture waters in the factorial plane PC_2 versus PC_1 is given by fig. 3.

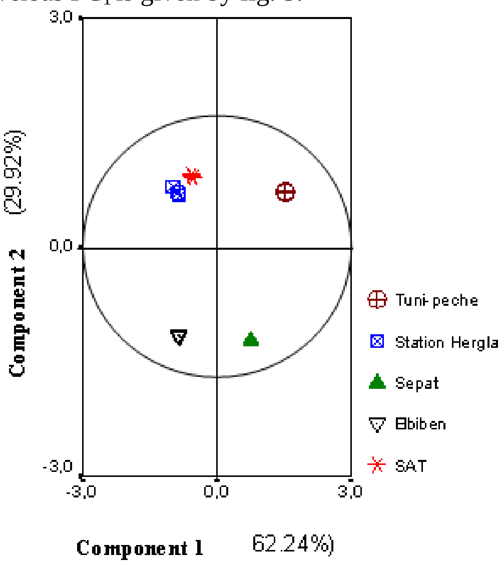

Fig. 3: Projection of the different aquaculture water samples in the 1st factorial plane.

The interpretation of the first two principal component axes enables the classification of the aquaculture waters with high separated imprints. A high correlation is noted between samples of water obtained from Hergla and SAT aquaculture farms.

2.2 Discrimination of the water quality in the aquaculture of Hergla farm

Aquaculture water quality can be influenced by the fish metabolism and the rest of nutrient. For this reason it is very necessary to control and maintain the optimal conditions for the surviving and good growing of the organisms to be closest to a natural ecosystem [9]. In this purpose we are interested to a continuous control of aquaculture water quality of Hergla farm. First, we have characterized water samples taken from three different zones such as: at the entry, at the medium and at the exit of the aquaculture basin. By analysing the projections of the variables on the 1st factorial plane by plotting PC1 against PC2 (Fig.4), it is concluded that the first axis (PC_1) explains almost 61.55 % of the total variance, which is a typical mineralization axis with NO_3^-, NH_4^+ ,Ca^{2+} parameters occurring in its positive side and the pH, Na^+, F^- parameters in its negative side. Furthermore, such assembly parameters with the highest or the lowest loadings localised on the first contributes significantly for its interpretation.

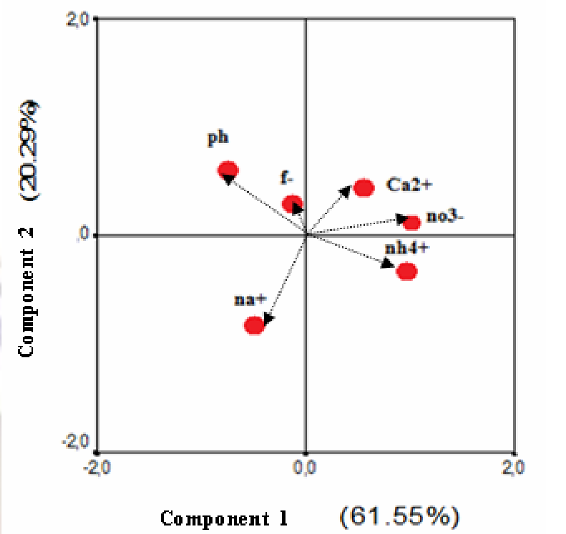

Fig. 4: Projection of the physiochemical parameters (pH, F^-,Ca^{2+}, Na^+, NH_4^+ and NO_3^- in the 1st factorial plane.

The second axis (PC_2), that explains about 20.29 of the total variance, discriminates F^- and pH type waters with higher PC loadings from another type composed by lower PC loadings given by the Na^+ ions. The lost information was closed to 18 %. Fig. 5 shows the classification and the good separation of the different tested water samples. This result indicates the gradual change of the basin water quality from one site to the other. The projection of the factorial plane of the different water samples on the variables factorial space demonstrates that the water at the entry of the basin is characterized by a high level of sodium (sea water). At the middle of the basin the water is charged by nitrate due to the fish metabolism and at the exit of the basin water is relatively charged by ammonium due to the nitrogen and phosphorus fish excretion.

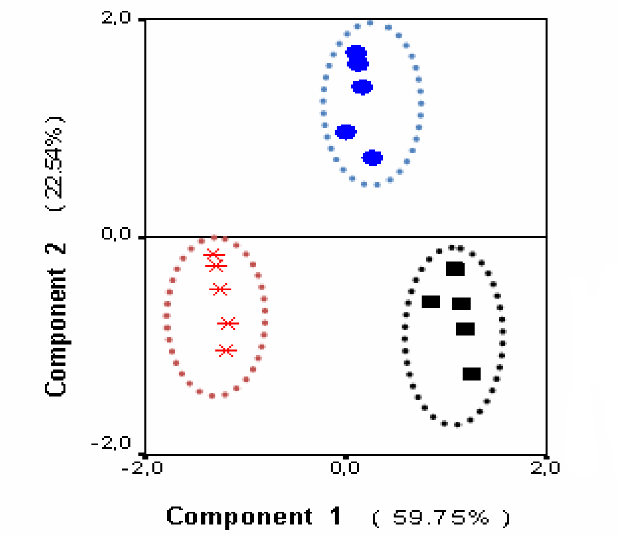

Fig. 5: Projection of the aquaculture water samples taken from different points of the lack in the 1st factorial plane. Lack entry (□), Lack center (,), Lack exit (!).

3.3 Efficiency of the Hergla lagoon system in the aquaculture wastewater treatment

The impact of the aquaculture on the environment is more and more increasing. Also, it is necessary to control the wastewater quality and to reduce its negative effect for the ecosystem conservation. In the picicole Hergla farm, the treatment of the wastewater is performed by a lagoon system. Furthermore to characterize the effluent water samples and to evaluate the water quality, seven points or stations were chosen (four points in the lagoon and three points from the exit to the shore where the final waste is spoiled).

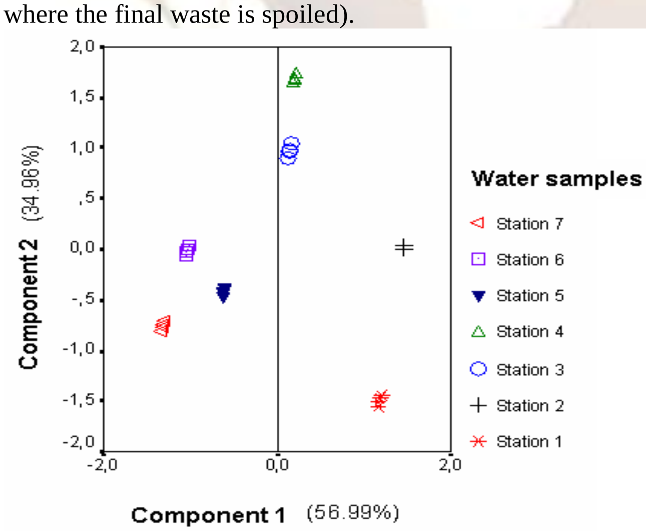

Fig. 6: Projection of the aquaculture water samples taken from different points of the Hergla lagoon in the 1st factorial plane.

Fig. 6 shows the comparison and the classification of the aquaculture wastewater samples taken from significant zone of the lagoon. A good differentiation between the water samples was observed to be classified in two classes. We note a first class containing the water samples taken from the points 1,2,3 and 4 charged by a low amount of ammonium and a high amount of nitrate. The second class contains the water samples taken from the points 5, 6 and 7 characterized by a high amount of nitrate and low amount of ammonium. To densify the hierarchic representation Fig.7 represents the variation of the concentration of ammonium and nitrate in function with the taking away points of the lagoon. The gradual change of the nitrate amount -observed from the first point to the final point- explains the ability of the lagoon system in the aquaculture wastewater treatment. In addition, the lagoon represents an entire ecosystem in witch bacteria and marine flora (micro-algues) act with cooperation in the treatment process. Moreover, aquatic plants play an important role in aquaculture wastewater treatment by removing ammonium, nitrate, phosphorus, inorganic nutrients and other toxic compounds [10-12].

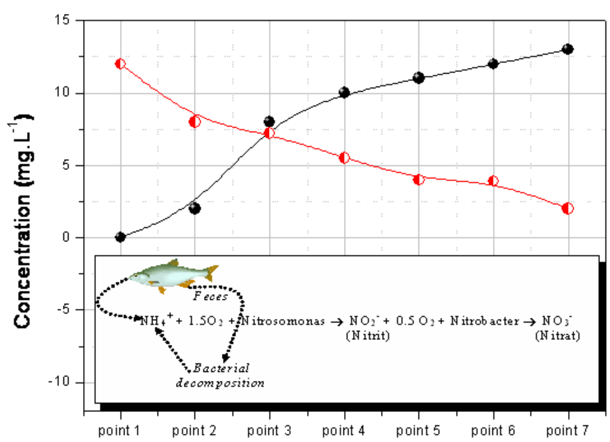

Fig. 7: Profiles of concentrations of NH_4^+ and NO_3^- in aquaculture water samples taken from different points of the Hergla lagoon. (6)NH_4^+ and (,) NO_3^-.

This result explain that the repartition of total nitrogen in the lagoon is characterized by a remarkable special variability. Consequently, we observe that aquaculture water in the lagoon is charged with ammonium and nitrate with antagonist average concentration from the entry to the exit. This behaviour can be explained as follows:

- In fish, ammonia is the major nitrogenous waste product of protein catabolism, and it is excreted primarily in un-ionized form (NH_3) through the gills [13,14]. Ammonium is also produced through the microbial decomposition of fish feces and uneaten food in a process called ammonification.

- Nitrate accumulates in aquaculture systems as a result of nitrification [15, 16].

As known accumulation of ammonia in water is one of the major causes of functional and structural disorders in aquatic organisms [17, 18]. The lagoon described here as treatment system participates in the ammonium and nitrate concentration regulation. It represents a good treatment system if the wastewater at the shore presents an acceptable quality more or less to the allowed typical standard norm. Fig.8. shows the differentiation and the comparison of the different wastewater samples collected from varied position of the lagoon with the standard norm. It was shown that spoiled water at the shore presents a physiochemical composition similar to the water sea considered as the Tunisian norm.

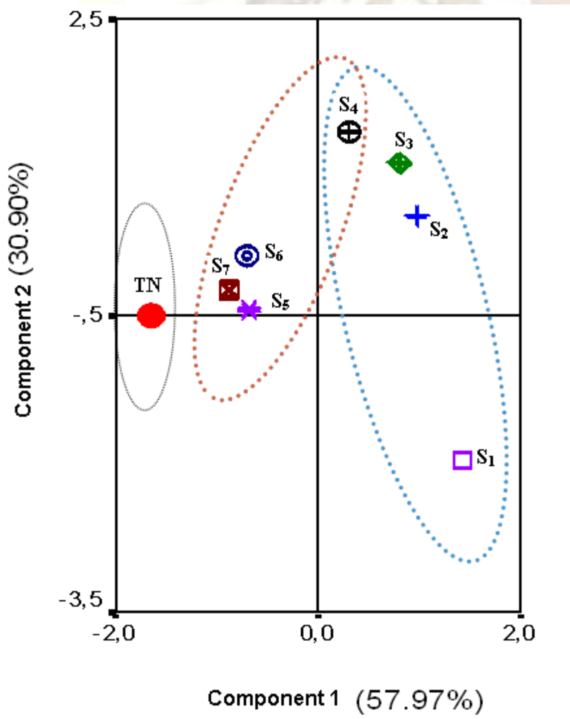

Fig.8: Classification of aquaculture water quality samples taken from different point (S_1 to S_8) of the lagoon in comparison with the Tunisian norm (TN).

In previous work it was shown that aquaculture can cause risk of pollution when the farm is placed near water resources useful for human drinking or for agriculture watering [19]. In addition, when the farm is placed directly near the sea without purification system the risk of pollution becomes more and more intense. In this work, the aquaculture wastewater of Hergla farm was compared to other wastewater obtained from other sources such as Industrial and ONAS (the National Sanitation Utility) wastewaters. As shown in fig. 9 the factorial plane is characterized by a good repartition of different wastewater in comparison with the Tunisian standard norm with 97 % of information. In fact we observe a noticeable correlation between the aquaculture wastewater and the Tunisian norm in comparison with the other wastewaters.

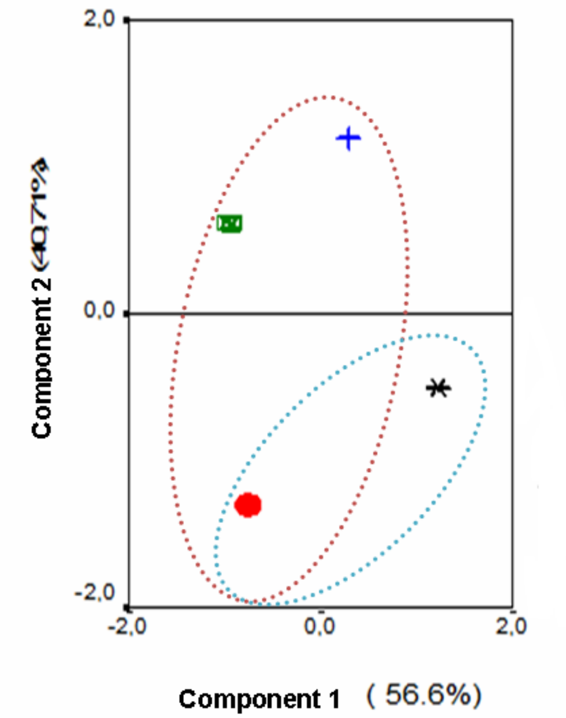

Fig.9: Comparison of the aquaculture wastewater to other resources wastewater. (□) Aquacol reject water, (□) ONAS reject water, (%) Industrial reject water (,) Tunisian norm.

CONCLUSION

In this report a chemometric method based on the principal component analysis was applied for aquaculture water quality control. It was demonstrated that it is possible to classify aquaculture water samples obtained from different fish farms. This new strategy applied to the Hergla farm allows the precise prediction of the aquaculture water change in function with the fish metabolism/excursion and the remaining nutrient composition. For good and favourable aquaculture medium a continuous assessment of many physiochemical parameters is recommended for early sufficient detection of the environment problems. The acceptable aquaculture wastewater quality in comparison with the Tunisian standard norm explains the resistant effect of the lagoon against the pollution. This result is the consequence of an important exchange with the sea. By the way a rapid combined chemometric-electrochemical method was developed for water pollution control in order to investigate the impact of the aquaculture wastewater activity on the environment.

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