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PHYSICO-CHEMICAL AND BACTERIOLOGICAL QUALITY OF THE MEKHADA MARSH WATERS IN NORTH-EAST OF ALGERIA

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Abstract

Water is an essential part of biological life. Maintaining its quality is a major concern for a society that needs to meet ever-increasing water needs. Algeria, which has a strategic position and counts no less than 254 wetlands, 42 of which are classified internationally for their importance and the role they play; These wetlands are threatened by the combined action of adverse factors related to changes in land cover and economic development projects that affect the ecological character of these sites. The chemical composition of a water plays an important role in determining its quality, thus the possibility of its use for drinking water supply or other uses (irrigation, industry, etc.). The marshes of the Mekhada constitute a special environment, where the winter a lake settles down, and during the summer pastures. This area is the convergence of the Bou Namoussa and El Kebir wadis. It is limited to the north by dunes and to the south by sandstone massifs. This marsh is a very important site for welcoming overwintering and also summer water birds. The aim of this work is to monitor the variations in the physico-chemical and microbiological parameters of the waters of the Mekhada marsh, at the level of this fishing zone. Analysis of water physico-chemical parameters showed that some parameters do not meet international standards, notably nitrites; nitrates; phosphates; ammonium. In addition, microbiological analysis showed the presence of significant fecal contamination by total coliforms, thermotolerant coliforms and faecal streptococci.

Key Words: *Mekhada, Physico-chemical parameters, Microbiological quality*

Introduction

Wetlands and their ecosystem functions are extremely valuable to the world's population (De Groot *et al*., 2007). However, because of widespread and increasing anthropization, these habitats have declined sharply over the past several decades on a global scale (Green *et al*., 2002). At Mediterranean basin level, this decline is likely to be further amplified by climate change, which could lead to the disappearance of 85% of Mediterranean wetlands in the medium term, threatening exceptional habitats (Amezaga *et al.,* 2002; Gam, 2008).

Mediterranean wetlands have a very dynamic nature. They can be flooded, either intermittently or only for part of the year (Caessteker, 2007). Typical wetland landscapes in this region include deltas, coastal lagoons and marshes, lakes and salt flats, etc. (Pearce and Crivelli, 1994).

At present, wetlands are threatened by a complex combination of adverse factors related to changes in land use and economic development projects that affect the ecological character of these sites. According to the Ministry of Sustainable Development, Environment and Parks (MDDEFP) report in 2013, the use of fertilizers and pesticides, the development of livestock farming and the discharge of wastewater without prior treatment generate an alteration in water quality, and make its use unsuitable for the desired uses (Necib *et al.,* 2013) and disturb the balance of the aquatic ecosystem. Nevertheless, Hébert and Légaré (2000) reported that surface waters naturally contain a wide variety of microorganisms, some of which can promote the decomposition of organic matter and the recycling of nutrients. However, other microorganisms from animal and human excreta can represent a real health risk (Chaker and Slimani, 2014).

The Mekhada marsh is a unique environment, where a lake is formed in winter, and while in summer, it becomes a pasture area. The variation of the natural environment is governed by the confluence of the Bounamoussa and El Kebir-Est wadis, and is delimited in the north by dunes and in the south by sandstone massifs (Djidel, 2004). This marsh is a very important site for wintering and summering waterbirds (Boumezbeur, 1993) in addition to the remarkable flora and fauna for which it provides habitat. However, the water quality of this marsh is subject to various sources of pollution generated by the accelerated development of economic activities, including agriculture and industry (Harrat and Achour, 2010). In addition to these sources of pollution, there is significant fishing activity for eels and various fish in the estuary and mouth of the Mafragh wadi (Boumezbeur, 1993). Due to the difficulty of access to this site, only a few researchers have really focused on assessing the degradation of this ecosystem. The aim of this study is to monitor variations in the physico-chemical and microbiological parameters of the waters in the fishing area of the Mekhada marsh.

Materials and Methods

Study Area

The Mekhada Marsh is a wetland area (36° 48' N, 8°00' E) located in the lower parts of the alluvial and columnar filling basin of the Mafragh plain. It covers an area of 8,900 hectares. It is the confluence of the El-Kebir Est wadi and Bou Namoussa wadi, and is separated from the sea by a dune barrier. The main source of the outflow is the Mafragh wadi, which crosses this dune barrier. It is a marsh with fresh water, except for its downstream part, which is brackish due to contact with the Mediterranean Sea at the mouth. It is a huge swampy area with a depth of 0.5 to 1 meter.

The permanent water of this marsh, estimated at 1,000 mm per year (W.M.O. 2016), is justified by the importance of the blade of water by the wadis that feed the marsh. All this water comes from the natural barrier formed by drained the Cheffia and Bouabed mountains in the south. In summer, the marsh is also supplied with fresh water from an important natural reservoir, the dune area.

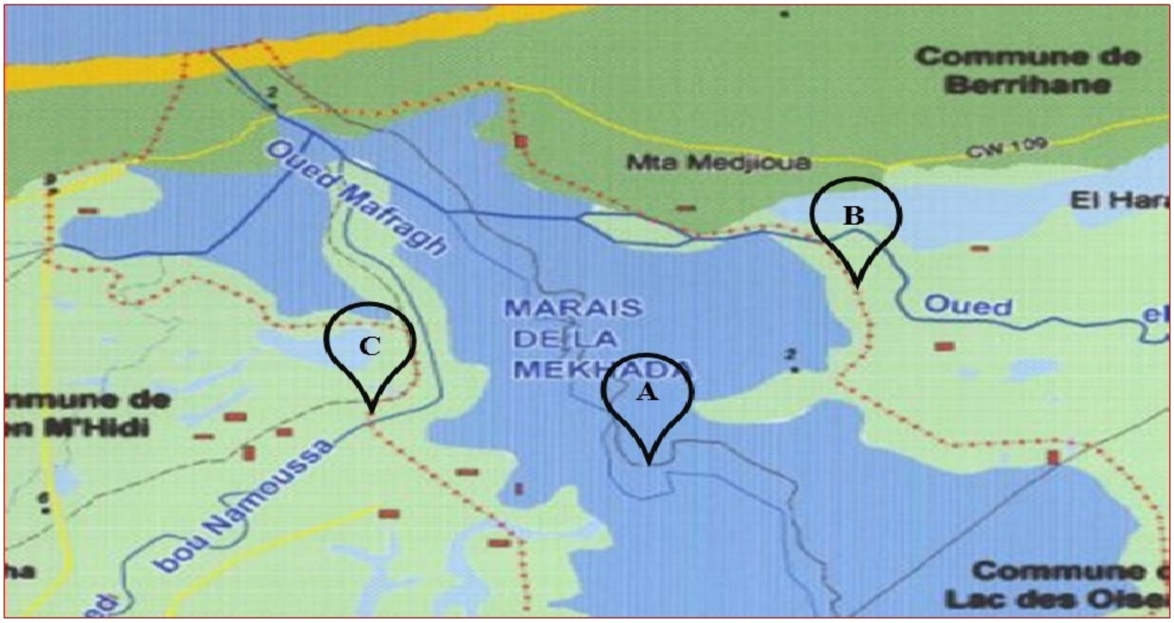

Fig. 1: Location map of the Mekhada marsh study area (northeastern Algeria) and A.B.C sampling stations (Anonymous, 2013)

Sampling and Methods of Analysis

The sampling was carried out in the marsh's downstream zone, an area that is flooded all year round, which results in an artisanal fishing activity carried out by the surrounding rural populations. However, in order to have a good coverage of this immense space and to ensure that our sampling is representative, this downstream part is divided into three stations. The first (station A) covers the central part, the junction zone of the two wadis that feed the marsh, the second station (station B) covers the western part and the third station (station C) is located in the eastern part of the marsh. Nevertheless, at each of these stations, three randomly selected sampling points were sampled during both the wet and dry periods of 2015.

Water samples are collected using a plastic bucket attached to a rope long enough to reach the water body in the marsh. The water taken from the surface water slice of about 50 cm thick is transferred to PVC bottles. At each sampling, the temperature, pH, electrical conductivity and dissolved oxygen were measured in situ immediately after the sample was taken using a Multi340i (WTW) brand multi-parameter field case. Once on-site analyses are completed, samples are transported from the sampling point to the laboratory in a cooler at 4°C. The assays are carried out within 4 hours for bacteriological parameters and within 24 hours for physico-chemical parameters.

For the parameters analyzed off-site, in particular the nitrogen cycle, including nitrates, nitrites, ammonium, phosphate, COD and BOD_5, they were determined according to the standard procedures recommended by AFNOR (1997) and Rodier *et al.* (2009). Generally, the enumeration and detection of faecal bacteria and pathogenic bacteria are the main focus of bacteriological analyses of surface and groundwater (Guiraud, 1998). As a result, total coliforms, thermo-tolerant coliforms and fecal streptococci are then analyzed according to the analytical protocols established by (Rodier *et al.,* 2009).

A bacteriological contamination index was also calculated from the enumeration of different germs associated with organic pollution according to (Leclercq, 2001). In order to determine the spatial and temporal typology of the expression of pollution, we used two multidimensional methods. Firstly, an analysis of the main components carried out on the raw matrix of physicochemical and bacteriological variables, the result of which summarizes the effect of the initial variables and gives a preliminary idea of the elements and pollution sites (Pagès, 2008). Secondly, a hierarchical classification based on the Ward criterion, using the Euclidean distance, the latter is performed on new individual coordinates at the PCA level. This practice ensures a better interpretation of the individual PCA plans that define the required typology (Escoffier and Pagès, 2008).

Results and Discussion

During the dry season, the pH varies between 7.51 ± 0.45 and 7.9 ± 0.46. Nevertheless, during the wet season the pH values are between 6.82 ± 0.73 and 7.23 ± 0.65. The analysis of variance shows that the differences in pH are highly significant ($p=0.001$) between the two seasons. Gouaidia, (2008) attests that this parameter depends on the geological nature of the field. However, the pH values observed in this study are weak acidic to neutral and within normal limits. In addition, water contact with ambient air can influence this factor by increasing its value (Bengoumi *et al.,* 2004), which partly explains the relatively high pH values recorded during the summer probably due to the reduction in water volume following intense evaporation during that season. According to Neal *et al.* (2000), pH can have adverse effects on aquatic life by blocking self-purification processes if it is outside the biological range generally between 6.5 and 8.5; for example, a decrease in pH can increase the toxicity of certain molecules (such as organic substances, heavy metals, etc.) (Rodier, 1996). Nevertheless, our results are consistent with those reported by Bouchleghem *et al.,* (2014) and Labar *et al.* (2014) during research on the waters of the Bounamoussa and El Kebir wadis.

A high salinity value means a large amount of ions in solution. Electrical conductivity also depends on charges of endogenous and exogenous organic matter, which generates salts after decomposition and mineralization and also with the evaporation phenomenon that concentrates these salts in water, it also varies according to the geological substrate crossed (Belghiti *et al.,* 2013) the measured values fluctuate between 707.49-± 374.65 µS/cm and 732.49-± 319.52 µS/cm during the low water period. This indicates a highly mineralized brackish or even saline water during this summer period. However, a highly significant decrease ($p=0.000$) in the values of this parameter is observed during the wet period. Moreover, El Morhit *et al.* (2008) attest that conductivity is also a function of water temperature, it is more important when the temperature increases, in addition to a dilution of water by rainwater input (Makhouhk *et al.,* 2011) which explains the difference between the dry and wet period reported in this study. The high electrical conductivity value of the water at this site is due to the high concentrations of dissolved salts (Sahraoui, 2014). Due to its proximity to the marine environment, the Mekhada marsh contains a salt wedge that penetrates up to 13 km upstream of the mouth of the Mafragh wadi. The value of this parameter also depends on the evaporation of water that concentrates salts in the marsh, (El Morhit *et al.,* 2008).

During the dry season, dissolved oxygen values range from 3.26 ± 0.14 to 3.79 ± 0.15 Nevertheless; during the wet season, dissolved oxygen values range from 3.18 ± 0.05 to 3.54 ±0.08. These low dissolved oxygen values favor the development of pathogens (Rodier, 1996) that consume oxygen for the oxidation of organic matter. During the dry season, the COD (Chemical Oxygen Demand) values oscillate between 62.33 ± 24.50 and 88.49 ± 30.63 Nevertheless; during the wet season the COD values are between 26.8± 7.10 and 30.5 ± 7.58. These values can be explained by the high suspended matter content due to the presence of a polluting tomato canning plant on Bou Namoussa wadi (Bouchelaghem *et al.,* 2014).

Evaluation of the Organic Pollution Index (OPI) on the research site

The Mekhada's organic water pollution index, as shown in Table 2, provides the degree of pollution that has been estimated according to Leclercq and Maquet (1987). Its principle is to divide the values of the pollutants into 5 classes and to determine from its own measurements the class number corresponding to each parameter to make it the average (Bahroun *et al.,* 2011).it reveals high levels of organic pollution. The significant alteration in the quality of the marsh water is perceived during both sampling periods. The presence of a wild landfill near the marsh and raw wastewater from neighboring towns could be at the origin of this pollution. Indeed, these wastewater are characterized by a high suspended matter content that promotes rapid and continuous growth of algae and aquatic plants in the wadis of Bou Namoussa (Zaoui, 2016) and El-Kebir (Bahroun *et al.,* 2011) that transport them to the marsh. In addition, the high BOD5 values, reflecting high concentrations of organic matter, and can also indicate possible deficiencies in dissolved oxygen in the marsh waters, inducing weak ammonification and oxidation reactions of ammonium ions giving high concentrations of nitrite ions. Anaerobic processes, such as the reduction of nitrate ions to nitrite ions and nitrogen (N_2) can occur under these environmental conditions (Rodier, 1996). These processes can then explain the high nitrite concentrations observed, particularly during the dry period when intense speculative agricultural activities on the Mafragh plains can lead to large quantities of nitrate ions in the marsh waters (ONID, 2013).

Furthermore, the presence of nitrite ions in significant quantities makes water suspicious because the presence of these ions is often associated with deterioration in microbiological quality (Rodier *et al.,* 2009). High ammonium concentrations (0.77mg/l) indicate faecal contamination of human or animal origin or pollution of industrial origin. These high summer ammonia concentrations may also be related to very high bacterial activity (Rodier *et al.,* 2009).

Phosphorus is a biogenic element essential for algae growth. High levels (≥.2mg/l) of this element in surface waters can lead to eutrophication (Du Chaufour, 1997) characterized by excessive development of aquatic vegetation. When these plants complete their cycles and eventually die, their phosphorus is gradually released into the water body where it will then be diluted during the wet season (Leclercq, 2001).

The Index of Microbiological Water Quality Evaluation of the Research Site

The results of the microbiological quality index, as shown in Table 3, indicate a high degree of contamination for both sampling periods. This contamination probably comes from wastewater, which contains a few hundred thousand organisms per 100ml (USEPA, 1983). Storm sewers, which carry runoff from streets, process water from certain industries, such as food and paper factories, can be a significant source of bacteriological contamination with concentrations of up to a few tens of thousands of fecal coliforms per 100 ml (MDDEP, 2011).

The main source of bacteriological contamination of the waters of this marsh is the excrements of farmed and wild animals, mainly birds. Moreover, the concentration of fecal coliforms is proportional to animal abundance (Patoine, 2011).

Typology of the Spatio-temporal Expression of Pollution

The dual analysis (ACP and Classification Ward) reveals the spatiotemporal typology of pollution according to the gradients defined in the ACP pattern (Dim1xDim2). We have selected the Dim1xDim2 pattern (knowing that the two factorial axes of the two-dimensional pattern have zero correlation) of the PCA which accounts for 50.5% of the total variability. The first component with an inertia (variability) of 4.8 explains 32%, while the second component explains a variability of 18.5% (2.76), as noted in Figure 2. However, a greater or lesser proximity between two variable points indicates a greater or lesser correlation between these variables. Furthermore, the further away the variables are from the origin and close to a factorial axis, the stronger their correlation with this axis is (Bouzillé, 2007).

The Dim1xDim2 pattern of the variable PCA (correlation circle) has a size effect that reflects an increase in the phenomenon studied and its persistence. The correlation values between the initial variables and the scores of the selected components, as given in Table 5, highlight the expression of the gradients. The component (Dim1) is a linear combination of the variables (TTC, BOD_5, COD, T, NH_4^+, pH, EC and DO). The component (Dim2) opposes two groups of variables. The first group gathers the variables (NO_3^-, NO_2^-, and FS) and the second group gathers the variables (PO_4^{-3}, DO, pH, T).

The variables of the first gradient of the first component summarize an intense biological activity and microbiological contamination accelerated by the high suspended matter content due to the presence of a polluting tomato canning plant on Bounamoussa and El Kebir wadis (Bouchelaghem *et al.,* 2014). The variables of the second gradient contrast a nitrogenous eutrophication effect with a phosphate eutrophication effect; most of the organic phosphorus comes from waste from protein metabolism and its elimination in the form of phosphates from human urine (Du Chaufour, 1997); as well as the mineralization of organic matter from untreated waste water. Nevertheless, experiments with artificial pollution have shown that nitrates alone do not lead to a significant increase in crop production, while a low phosphate supply is sufficient to trigger plant proliferation. It is therefore well known that phosphorus is the limiting element (Leclercq, 2001).

Figure 5, shows the group typology that defines the spatio-temporal aspect resulting from individualized PCR, as mentioned in Figure 3 (combination: Month-station) and the Ward grouping applied to individuals' scores, observed in Figure 4. The results reveal three distinct groups describing a seasonal aspect. The first component opposes surveys that define the summer season to surveys that define the winter, fall and spring seasons. The second contrasts the fall season with the winter and spring seasons.

Conclusion

Based on the results obtained during the two monitoring periods, the observations concerning water quality in the Mekhada marsh are of extreme concern. Moreover, the organic pollution index indicates a significant alteration and this for the two periods considered, this alteration can be of natural origin or exogenous origin (urban discharges and agricultural practices). From a bacteriological point of view, the studied sites have very high concentrations of contamination germs from the discharge of untreated wastewater, which are characterized by a high content of suspended matter and nutrients (nitrites; nitrates, phosphates). The main component analysis makes it possible to select a plan that includes two axes, expressing 50.5% of the total variance. Axis 1, which expresses 32%, forms a group by the variables (TTC, BOD_5, COD, T, NH_4^+, pH, EC and DO) representing intense biological activity, axis 2 expresses 18.5% of the total variance, opposes a nitrogen eutrophication effect and a phosphate eutrophication. However, it is important to note that bacteriological and physico-chemical results, although essential, represent only punctual data, which means that they characterize a specific period of time and a specific location. Therefore, we believe that periodic researches on water quality in and around the Mekhada marsh area are necessary to improve our knowledge of physico-chemical and bacteriological data and to prevent possible diseases.

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Table 1: Descriptive statistics for water chemistry

	Zone	Variables								
		pH	DO Mg/l	EC meq/µs	BOD mg/l	COD mg/l	NH_4^+ mg/l	PO_4^{-3} mg/l	NO_3^- mg/l	NO_2^- mg/l
Dry season	A	7.88±0.45	3,79±0.15	731,66±143.77	2,81±1.34	62,33±24.50	0,47±0.01	6,39±1.36	26,63±1.41	0,2±0.007
	B	7.9±0.46	3,5±0.26	732,49±319.52	2,81±2.70	65,49±72.59	0,48±0.02	8,11±0.21	30,05±1.65	0,2±0.04
	C	7.51±0.26	3,26±0.14	707,49±347.65	3,51±0.35	88,49±30.63	1,08±0.77	5,86±0.42	30,85±2.58	0,17±0.04
Wet season	A	7.23±9.18	3,54±0.08	626,2±240.03	1,29±1.09	23,6±2.22	0,15±0.07	4,5±3.84	32,49±9.09	0,19±0.12
	B	6.9±0.65	3,33±15	561,7±4195.19	1,06±0.45	30,5±7.58	0,14±0.08	5,9±5.30	32, 8±13.03	0,18±0.09
	C	6.82±0.73	3,18±0.05	555,6±239.66	0,91±0.41	26,8±7.10	0,16±0.10	3,72±2.86	33,83±14.97	0,19±0.11
P		0.001***	0.46 ns	0.000***	0.01**	0.000***	0.027*	0.000***	0.000***	0.000***

*ns: not significant *significant (P<0,05) **very significant (P<0,01) ***highly significant (P<0,001)*

Table 2: Organic pollution index (OPI) for both water level periods

Sampling points	Wet period	Dry period
A	2.75	2.5
B	2.75	2.5
C	2.75	2.5

Table 3: Average values of TC, TTC and FS at the three stations during the two periods

	Wet period			Dry period		
	A	B	C	A	B	C
TC	10766.66	10766.66	11516.66	14000	14000	13500
TTC	44249.99	42160.66	44999.99	28216.66	25866.66	48666.66
FS	1099.99	974.99	116.66	1066.66	1033.33	1183.33

TC : total coliforms . TTC : thermo-tolérants coliforms, FS : fecal streptococci

Table 4*:* Microbiological Quality Index (MQI) for both water level period

Sampling points	Wet period	Dry period
A	1.66	1.66
B	1.66	1.66
C	1.66	1.66

Table 5: correlation between variables and axes

	T	pH	EC	DO	NH_4^+	NO_2^-	NO_3^-	PO_4^{-3}	BOD_5	COD	Zn	Cu	TC	TTC	FS
F1	0.67	0.63	0.55	0.49	0.67	0.22	0.43	0.3	0.85	0.8	0.27	0.19	0.33	0.89	0.27
F2	-0.3	-0.69	0.3	-0.59	0.25	0.69	0.73	-0.5	-0.1	-0.2	0.2	0.1	0.22	-0.89	0.43

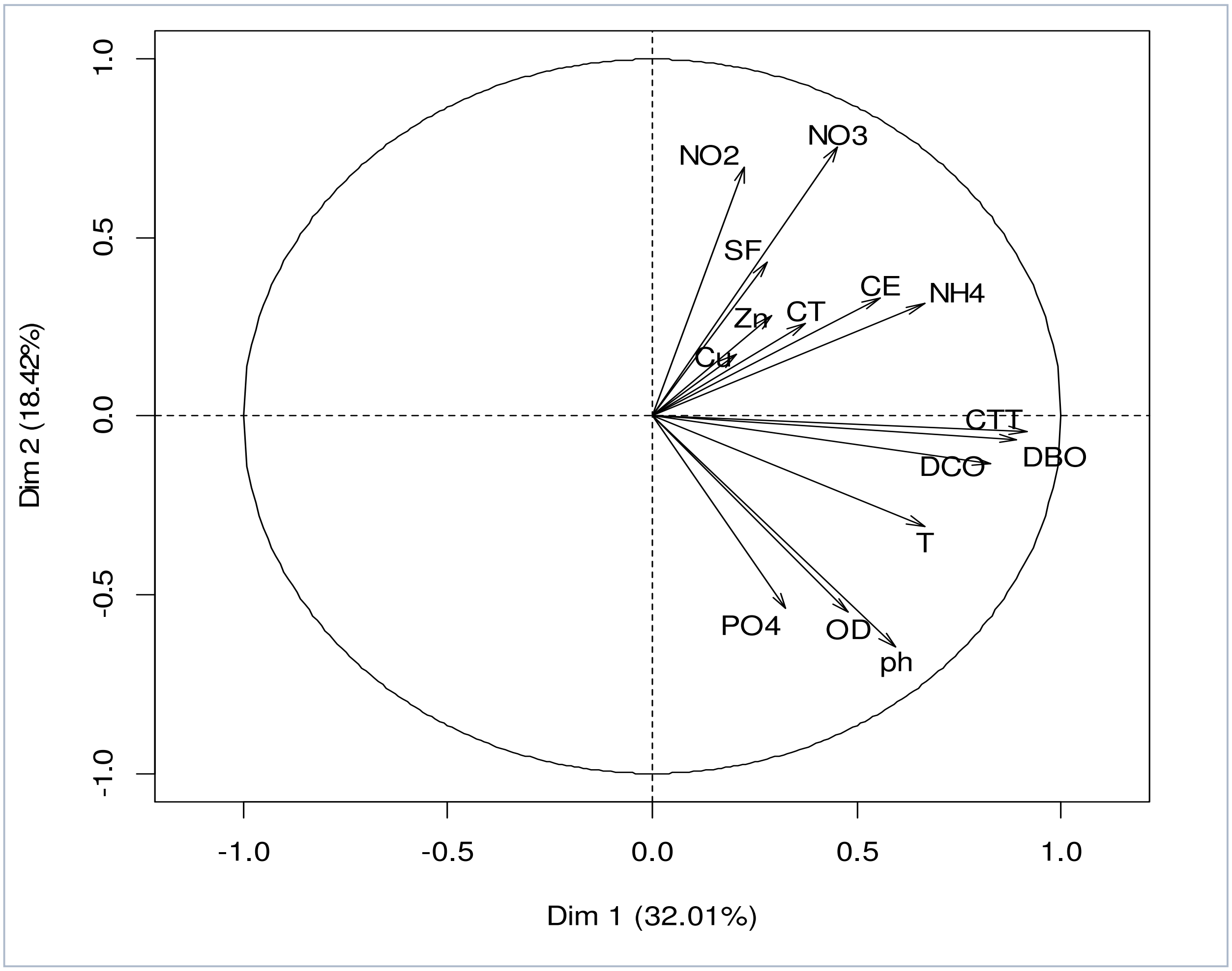

Fig. 2: Plan Dim1xDim2 of the ACP variables representing the correlation circle and the histogram of the inertia rates

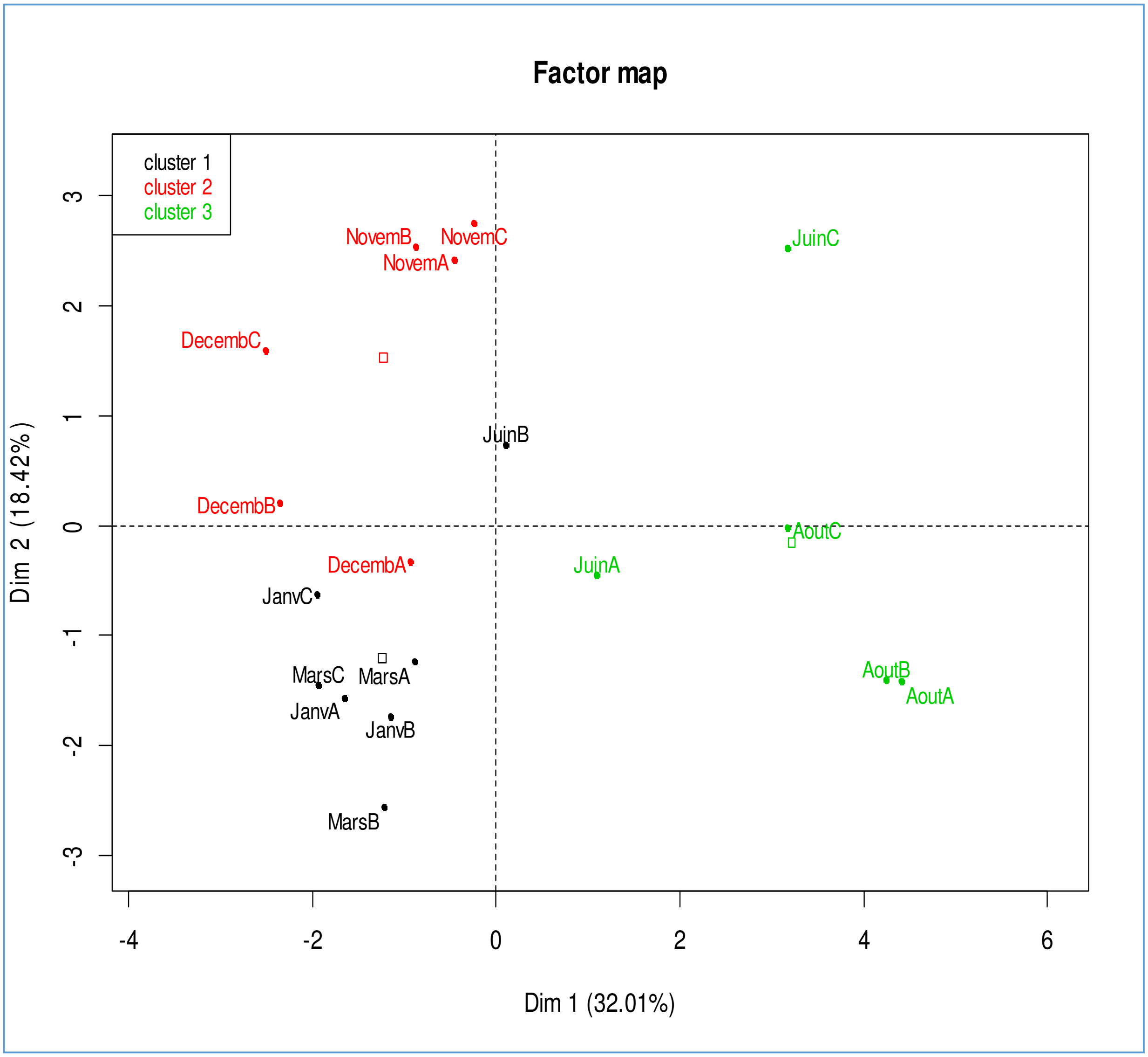

Fig. 3: Plan DIM1xDim2 of ACP individuals (combination station -season)

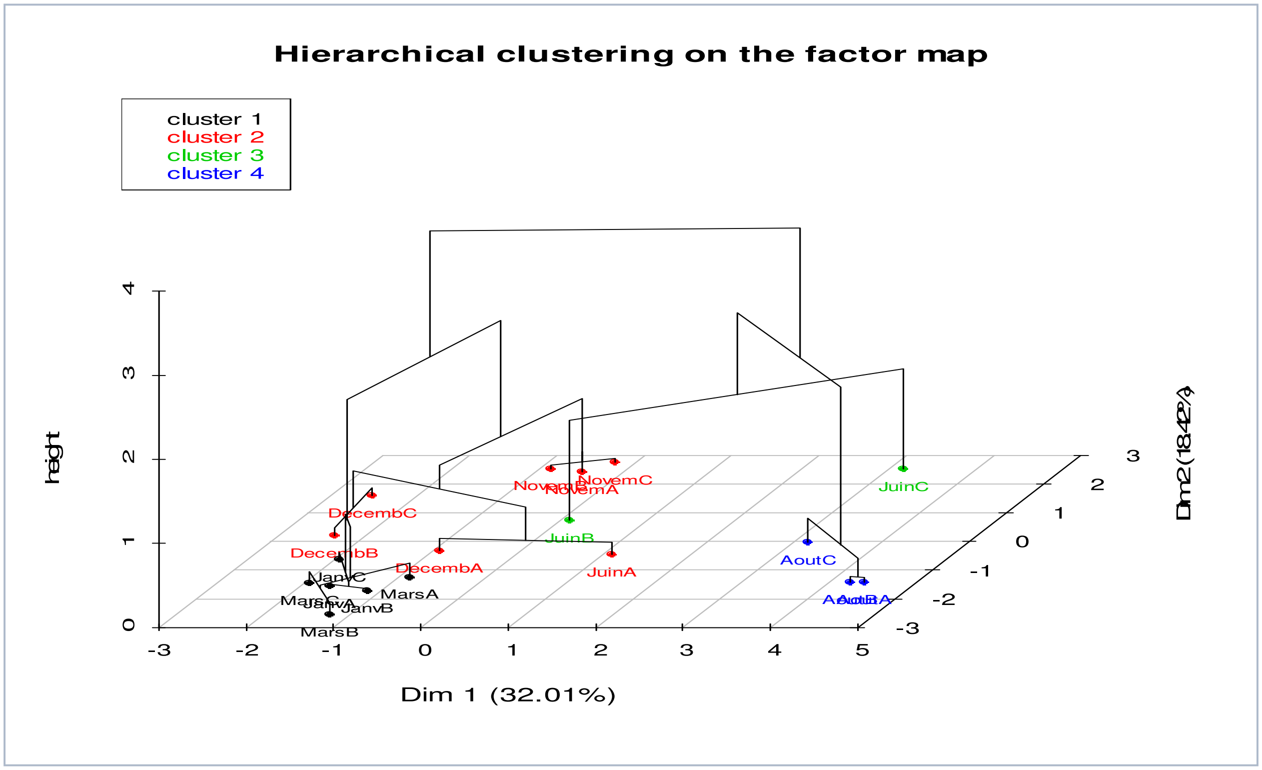

Fig. 4: Correlation dendrogram according to the Ward criterion between the objects (combination: station -season) and the histogram of the inertia gains

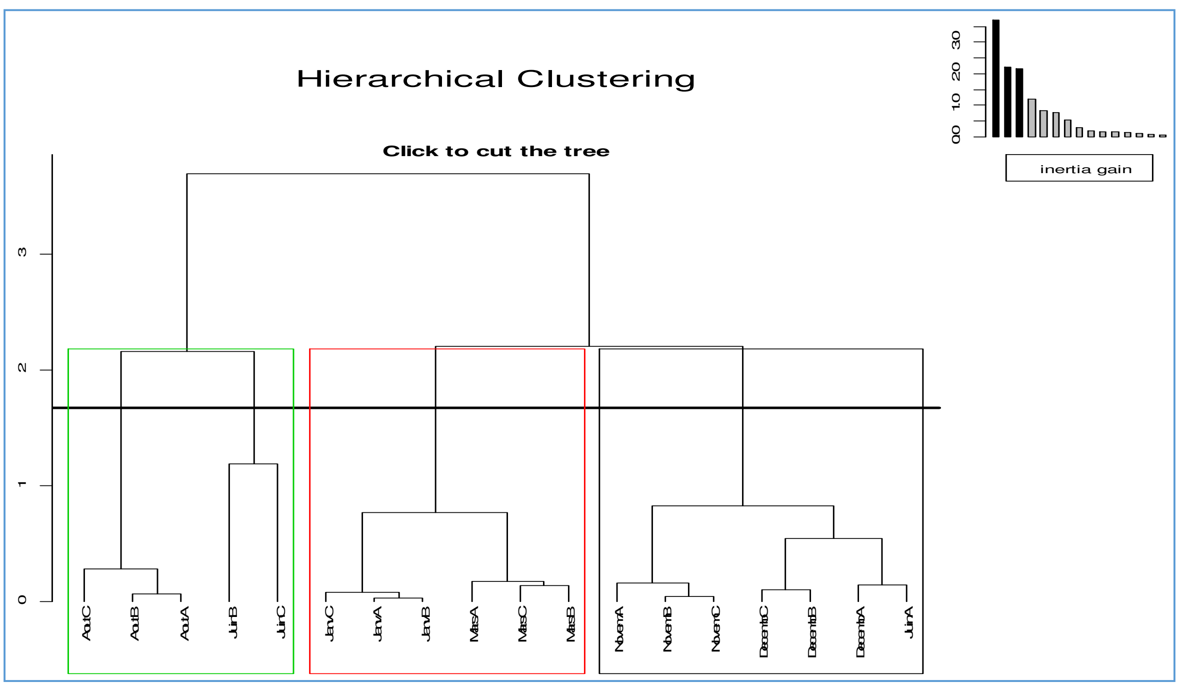

Fig. 5: double representation of the ACP plan and the hierarchical tree