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Sanitary Status and Bio-monitoring of Surface Water Quality in the City of Maroua (Far North, Cameroon)

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Abstract: A study to assess the physico-chemical and microbiological quality of surface water was conducted from September 2019 to September 2020 in the town of Maroua. With the objective of evaluating the physico-chemical and microbiological quality of the surface water of this town. The sampling stations were chosen on 3 main watercourses in each district of the town. Sampling was done on a fortnightly basis for one year. The results were grouped by seasons. The physico-chemical analyzes consisted of measuring the following parameters: temperature, pH, electrical conductivity, turbidity, chloride, sodium and sulphate content. The biological analyzes of the water focused on the search for bacteria, yeasts and microscopic fungi. The spatiotemporal variations of the physico-chemical parameters revealed water with relatively high temperatures during the two seasons. Suspended solids are generally higher in water during the rainy season (45, 227, 321 and 427 mg/l respectively at M4, M1, M5 and M3) reflecting on high turbidity over 2800 NTU during both seasons at M2 station in Kaliao mayo. The microbiology of water has shown three groups of microorganisms like bacteria, yeasts and fungi. From the microorganisms isolated, the majority were bacteria 84%, yeasts 8% and fungi 8%. The most represented germs in surface water's samples in Maroua are by medical interest importance: *Salmonella* spp., *Vibrio* spp., *Legionella* spp., then *Campylobacter* spp. and *Aeromonas* spp.. Alongside, *Mycobacterium* species, *Candida* spp., *Cryptococcus* spp. and *Trichophyton* spp. were scarce. These results testify to the occurrence of pathogenic germs in surface water in the city of Maroua. Hence the resurgence of epidemic diseases such as Cholera.

Keywords: Bio-monitoring, Physico-Chemistry, Microbiological Quality, Surface Water, Maroua

1. Introduction

Water intended for human use must meet a number of physico-chemical and microbiological criteria, as it constitutes an important reservoir for the survival and dissemination of microorganisms (bacteria, viruses, protozoa and parasites); which makes it unfit for human consumption. Some microorganisms carried by water are pathogenic for humans and are the cause of many diseases known as waterborne diseases [1]. Water, which is a rare commodity in the northern part of the country, specifically in the Far North Region [2]; Epidemic outbreaks periodically occur in the Sahelian areas [3]. Knowledge of the factors influencing the pathogenic germs isolated in the surface water that the population uses is important, but the health status and the bio-monitoring at close frequencies of the quality of the water could make it possible to predict the emergence or the re-emergence of an epidemic. The factors identified could contribute to the implementation of concrete disease surveillance and prevention measures. In terms of health, the problems of access and sanitation to water could have a contribution to the measures to be taken to reduce the risks of exposure to waterborne diseases. It is within this framework that a study focused on the factors influencing the pathogenic germs isolated from surface water in Maroua, was initiated with the main objective of evaluating the physico-chemical and microbiological quality of the surface water in this town. More precisely, to measure the physico-chemical parameters of these water, to count the germs known as water quality indicators and the interactions with some pathogenic germs responsible for health problems in this part of the territory.

2. Materials and Methods

2.1. Presentation of the Study Area

The city of Maroua, capital of the Far North region of Cameroon is located in a plain and consists of a hydrographic network with temporary wet season flow consisting of mayos which descend from the Mandara mountains and head towards the northern plain and in the East of the Region; where they disappear into the great Yaeré which they flow during the rainy season [4]. The Sudano-Sahelian climate [5], is characterized by a long dry season which lasts seven months on average, from November to May and a short rainy season from June to October. The average annual precipitation is 833.32 mm of water per year with more than 57% per year of rain concentrated in the months of July and August. Average temperatures vary between 20°C and 36°C during the rainy season and between 42°C and 48°C during the dry season [2]. The vegetation in the Diamaré plain is quite sparse, it is the domain of shrubby and grassy savannah [6]. Economic activities in the city of Maroua, as in the region, are essentially the practice of animal husbandry, subsistence farming, crafts including pottery and iron work. Despite all these economic advantages, the poverty rate in the region is estimated at 65.9%.

2.2. Method

The study took place in two phases: a first phase devoted to the prospecting and choice of stations in the 3 Borough municipalities that make up the city. 3 watercourses were favoured for the collection of samples respectively in each district. These are the Tsanaga, Kaliao and Lougueyo rivers. On each watercourse (mayo), 2 sampling stations were selected for this study, coded M1 to M6 (Mayo 1 to 6). The second phase consisted of the actual sampling and the samples were taken bimonthly during the two seasons over one year, from September 2019 to September 2020. Some physico-chemical and microbiological parameters were measured both on the field and laboratory [7, 8]. During the dry season, the rivers are completely dried up, the samples were taken in holes 50 centimeters to 6 meters deep dug by the populations for their water supply and the watering of the cattle (figure 1).

Figure 1. *Partial view of the sampling stations in the town of Maroua.*

The physico-chemical parameters measured as well as the apparatus used are summarized in Table 1 below.

Table 1. *Physicochemical parameters measured and devices used [8].*

Variables measured on the water	Measuring devices and methods	Units
Temperature	Alcohol thermometer (immersed 2/3 in water for 3 minutes)	°C
TDS	HANNA model HI 9829 portable multimeter equipped with an electrode probe (immersed in water at 1/3 for 5 minutes)	mg/L
Electrical conductivity		µs/cm
pH		CPU
Alkalinity	Volumetry (assay using H_2SO_4 N/50 in the presence of methyl Bromocresol green red	mg/L
Chloride		mg/L
Sulphates		mg/L
Nitrites		mg/L
Turbidity	HANNA spectrophotometer model Iris 918 (colorimetry)	FTU
Color		Pt-Co
MY		mg/L
Sodium		mg/L

As regards the measurement of biological variables, the aim here was to search for bacterial germs, yeasts and microscopic fungi. Isolation was carried out by two methods: the direct method and plating using the classic Most Probable Number (MPN) method according to ISO 9308-3, which specifies the miniaturized method for the detection and enumeration of *Escherichia coli (E. coli)* in surface water by liquid plating [9]. In addition, the Most Probable Number (MPN) indicates the density of bacteria most likely present in the water sample. It is a statistical analysis method based on the number of positive tubes in a water sample. After the counts, the cultures of the observed colonies were continued until the microorganisms were identified. The Petri dishes were incubated at the desired temperature and for a specific period of time (24 h to 48 h) which could vary depending on the type of microbial indicator and the culture medium. Then the colonies observed were taken for inoculum which was used for Gram control, subculture on selective media depending on the Gram result.

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The data collected was grouped and processed using Microsoft Office 2013's EXCEL program. The actual statistical analyzes began with the Kolmogorov and Sminorv normality test, to check whether the data was evenly distributed around the mean. The non-parametric Kruskal-Wallis test (H test) was used to verify the spatial and temporal significance of the differences (or similarities) in the variances of the abiotic parameters and the densities of the biological variables, relating to the distribution of organisms. harvested. In this work, the hierarchical classification analysis (ACH) was used to group the stations on the one hand, of their abiotic similarities, and on the other hand, of the similarity of the isolated germs on the basis of the average densities [10]. The Canonical Correspondence Analysis (CCA) made it possible to relate the matrix of variables measured overall and during the seasons [11]. These analyzes were performed using the PAST program "PAlaeontological STatistics" and SPSS 25.0 software [12, 13].

3. Results and Discussion

3.1. Results

3.1.1. Physico-Chemical Characteristics of Water from Mayo to Maroua

The water temperature ranged from 31.5°C at M1 during the rainy season to 37.1°C (M4) during the dry season (Figure 2 (A)). Overall, high temperature values are recorded during the very accentuated dry season in this region. However, there is no significant difference between the seasons, nor from one station to another ($p > 0.05$). The turbidity was very high at the M2 station (significant $p = 0.00024$) in the Kalios mayo, above 2800 NTU during the two seasons. It is spatially decreasing from Maroua I (M1) to Maroua III (Figure 2 (B)) and generally higher during the dry season.

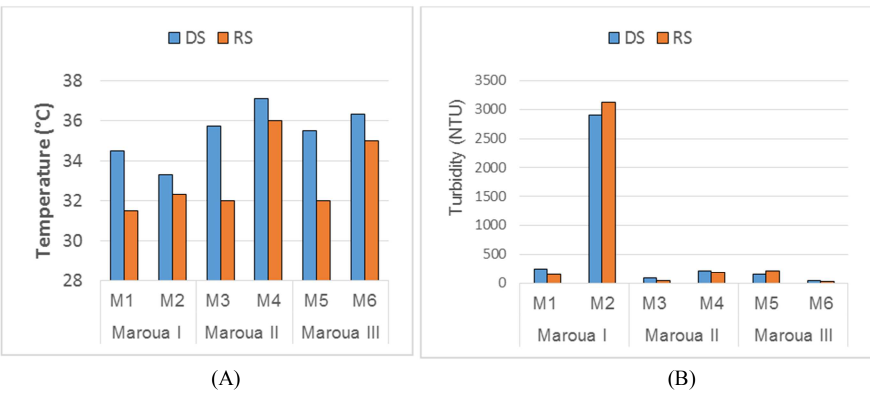


Figure 2. *Variations in temperature (A) and turbidity (B) of the water during the study.*

The color of the water varied from 258 Pt-Co (M3, M6) to 9627 Pt-Co (M2) with an average of 4942.5 ±1709.12. The M2 station being very characteristic of the variation obtained (Figure 3). Suspended solids are on the whole higher in the water during the rainy season (45, 227, 321 and 427 mg/l respectively at M4, M1, M5 and M3) except at M2 and M6 where they were higher abundant during the dry season.

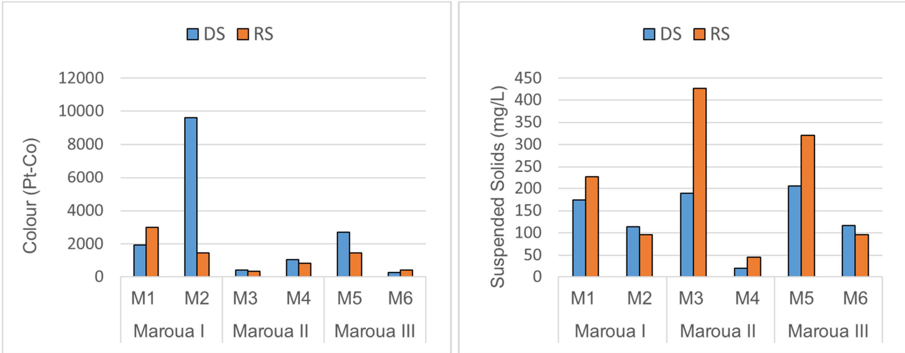


Figure 3. *Variations in water color and suspended solids during the study.*

The variations in electrical conductivity and TDS follow the same spatio-temporal pattern during the study. Indeed, for these two parameters, the highest values (362 mg/l and 770 µS/cm) are obtained at M6 at Maroua III (Figure 4). However, the difference in variation is not significant for these 2 variables.

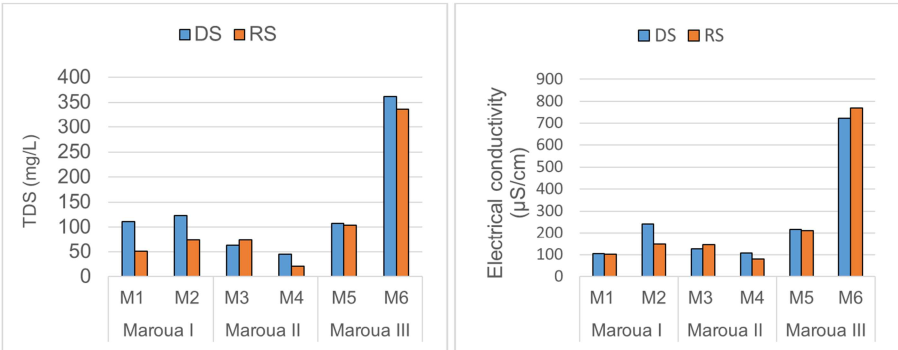


Figure 4. *Variations in dissolved solids and electrical conductivity of water in the rivers studied.*

The pH profile is spatially increasing from Maroua I to Maroua III. The pH values obtained in the mayo waters gave a minimum of 7 (M1) and a maximum of 10.4 (M6). This profile follows that of the variation in alkalinity in this same region during the study. Indeed, the alkalinity varied from 12 mg/l at M1 during the dry season to 134 mg/L at M5 during the rainy season. The waters are at basic pH and alkaline during the rainy season (Figure 5).

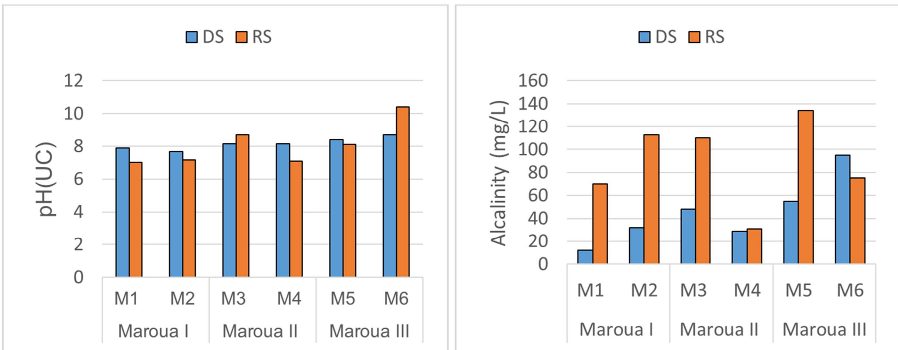


Figure 5. *Variations in the pH and alkalinity of the water in the rivers studied.*

The chloride content in the mayo waters varied around an average of 4.1 ± 6.2 with a minimum of 0 mg/L (M1, M4) and a maximum of 11.2 mg/L (M2).

Sodium ion content varies greatly in Mayo waters, from 0.04 mg/L (M1 and M5) in different seasons to 16 and then 17.4 mg/L (M4, M2) during the rainy season. We note that the sodium ion contents varies significantly from upstream to downstream in the different districts ($p = 0.00011$).

The nitrite concentrations in the mayo waters recorded showed a slight variation which oscillated between 0 mg/L (M3, M 6) and 2.1 mg/L (M1).

As for the sulfate ion content, it fluctuated between 0.7 mg/L (M1 to 4.77 mg/L during the dry season. High sulfate values are recorded during the dry season.

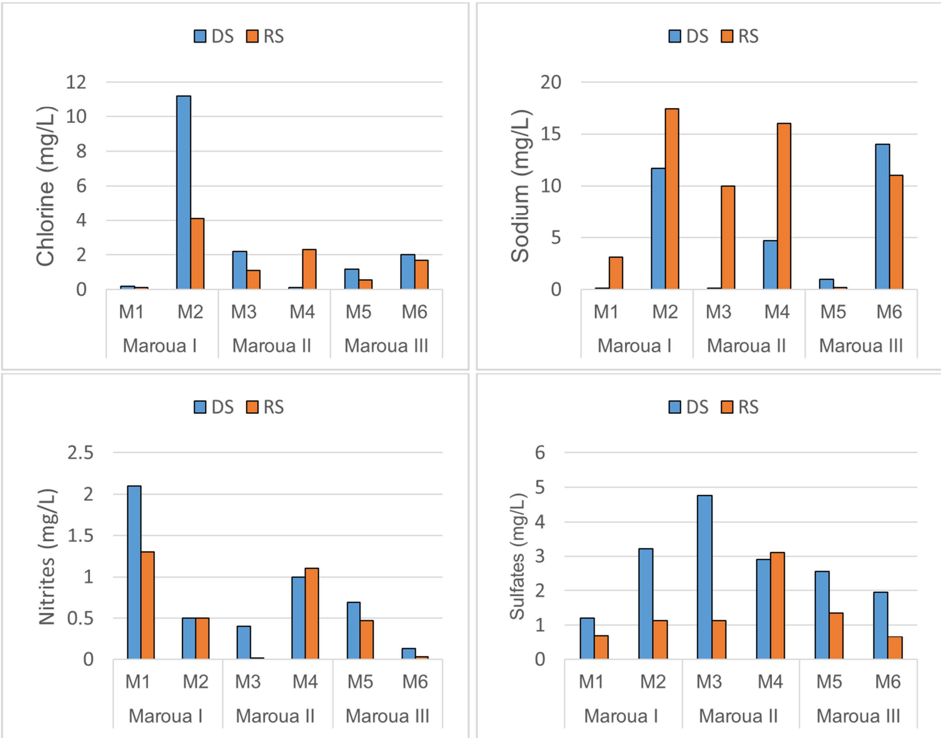


Figure 6. *Variations in the chloride (A), sodium (B), nitrite (C) and sulphate (D) ion content of the water in the rivers studied.*

3.1.2. Microbiological Characteristics of Water from Mayo to Maroua

(i). Pollution Indicator Bacteria in Surface Waters in Maroua

Figure 7 provides information on the type of pollution, its origin and its evolution in space and time (seasons).

Figure 7 shows that the total flora is more spatially diverse during the rainy season. Indeed, except at M1 where the variation is not perceptible from one season to another, the density of BHAMs in stations M2, M3 and M4 is 200 times higher during the rainy season (significant difference between the seasons p=0.00003). Stations M5 and M6 recorded the fewest germs of the BHAM group (less than 350 CFU/ml) during the study.

Faecal coliforms are the most abundant with an average density of 14100±11230 CFU/ml. The M2 station is significantly different, having the highest load 33000 and 42100 CFU/ml respectively during the dry season and the rainy season.

On the contrary, the E. coli species is more represented during the dry season at all stations and on average 100 times higher during this season at Maroua I, II, III and IV.

As for the Faecal Streptococci group, they are also more abundant during the dry season with a peak at M2 whatever the season, except in M6, where they are abundant during the rainy season.

(ii). Gastrointestinal Pathogens Bacteria in Surface Water in Maroua

The second group of isolated bacteria is that of pathogenic bacteria present in surface waters in Maroua (Figure 8). The genus Camppylobacter, whose density varies between 13 (M4) and 329 CFU/ml (M2) during the dry season. The Salmonella genu varies between 23 (M4) and 456 CFU/ml (M1) during the rainy season. The profile is slightly uniform during the 2 seasons for this group of bacteria in the water studied. The variation profile of *Vibrio* spp. in the water studied is particularly characteristic: the highest densities are recorded during the dry season (except at M6), this density ranges from 17 (M3) to 236 CFU/ml (M2).

(iii). Pathogens Emerging Bacteria in Surface Water in Maroua

Another group of so called emerging pathogenic bacteria, because of the difficulties in eliminating them from water and their involvement in the persistence of other germs in water, includes here the bacteria of the genera Mycobacterium, Aeromonas and Legionella presented in Figure 9. Figure 9 shows a decreasing density variation of the genus Legionella in surface waters in Maroua. It varies from 8 CFU/ml (at M6 during the dry season) to 290 CFU/ml at M1 during the dry season. The genus Mycobacterium spp. is present in surface water at Maroua III (M5 and M6). However, its density profile is low, with a maximum of 55 CFU/ml at M5 during the dry season, followed by 50 CFU/ml at M6 during the rainy season. The density profile of the genus Aeromonas spp. is concave, with a minimum of 20 CFU/ml (at M4 during the rainy season) and a maximum density of 199 CFU/ml (at M3 during the dry season).

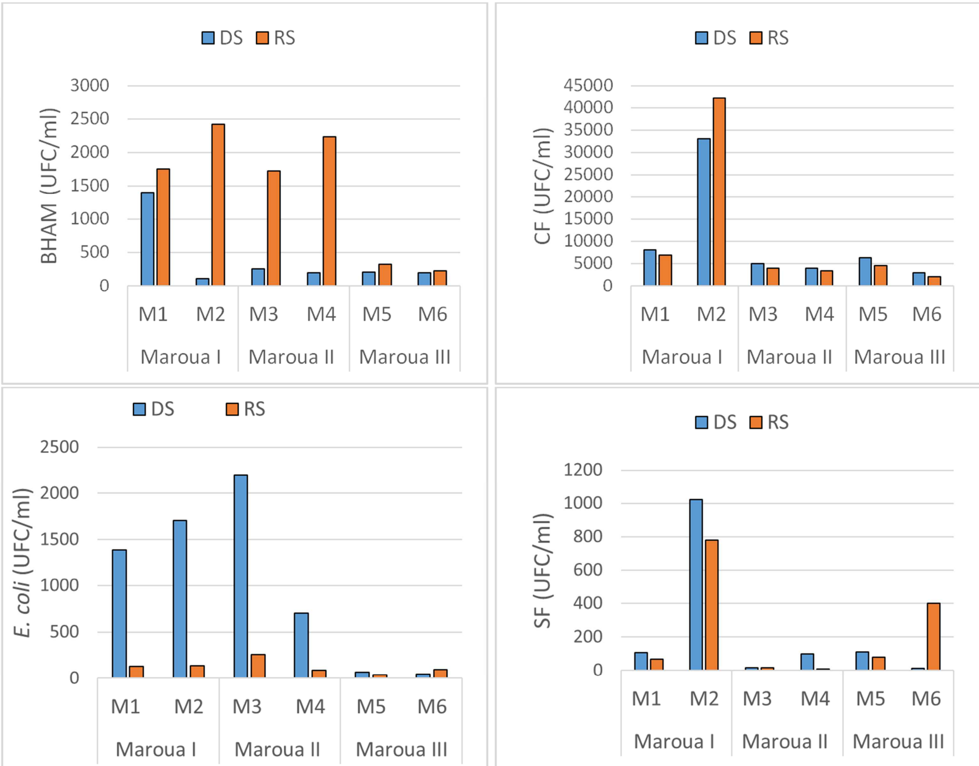


Figure 7. *Spatiotemporal variations of bacteria indicating water pollution.*

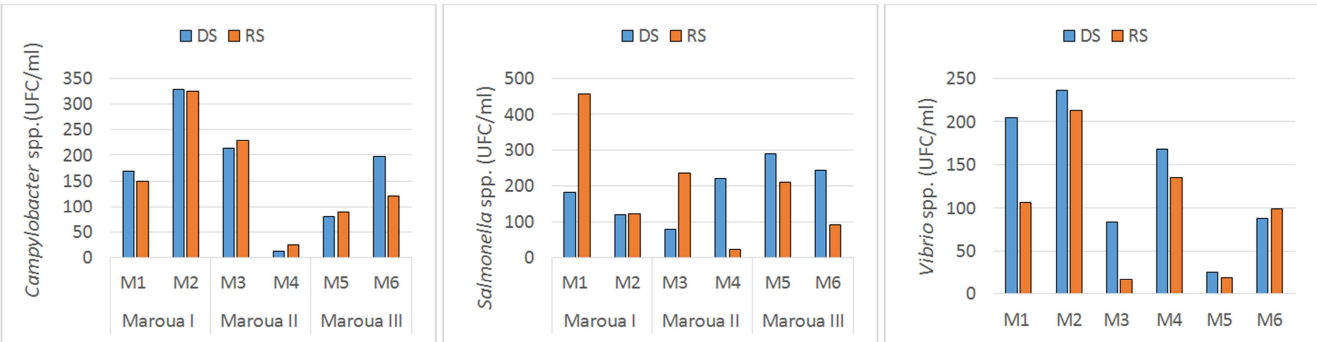


Figure 8. *Spatiotemporal variations of gastrointestinal bacteria in surface waters in Maroua.*

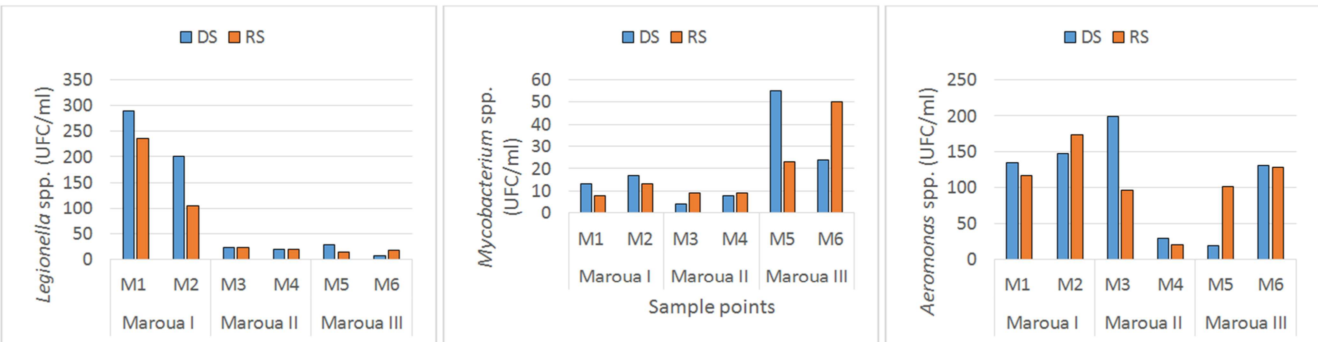


Figure 9. *Spatiotemporal variations of pathogenic emerging bacteria from surface water in Maroua.*

(iv). Yeasts and Microscopic Fungi in Surface Water in Maroua

In Figure 10, the isolated species are microscopic fungi present in aquatic environments, some are pathogenic for humans and livestock. The genus Aspergillus was isolated in all the samples and the density varied between 10 (M3 during the rainy season) and 173 CFU/ml (M5 during the dry season) respectively at Maroua II and Maroua III where the greatest densities were raised. The average density of

Candida spp. remained around 17.5 ± 3.2 CFU/ml during the study, except at station M2 marked by a peak of 72 CFU/ml during the dry season.

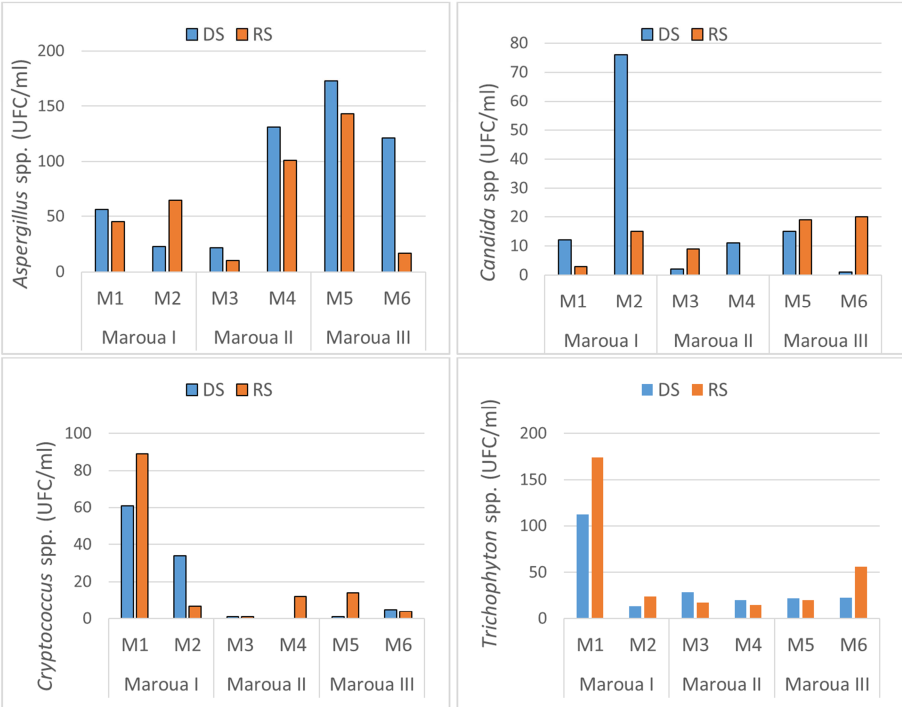


Figure 10. *Spatiotemporal variations of pathogenic microscopic fungi in surface water in Maroua.*

As for the genus *Cryptoccocus* sp., Maroua I is the most contaminated site. The density variation profile is spatially decreasing (from Maroua I to Maroua III). Overall, densities are higher during the rainy season except at M2 where the dry season dominates with a density of 34 CFU/ml. This profile follows that of the genus *Trichophyton* sp where the highest values (112 CFU/ml during the dry season and 174 CFU/ml during the rainy season) are presented at M1 (Figure 10).

3.1.3. Average Abundances of Isolated Germs and Characteristics of Study Stations

Figure 11 shows the average compared abundances of the germs isolated during the study. It appears that the most represented germs in surface water in Maroua are, in descending order, *Salmonella* spp., *Vibrio* spp., *Legionella* spp., then *Campylobacter* spp. and *Aeromonas* spp.. Alongside, *Mycobacterium* species, *Candida* spp., *Cryptococcus* spp. and *Trichophyton* spp. are scarce on the whole with atypical values both in space and in time.

The dendrogram in Figure 12(A) shows that the stations are grouped 2 by 2; M3 and M4 are related at 82% similarity. M1 and M5, from 2 different sites are 74% linked during the dry season for all the variables studied. M2 moves away from the previous pairs of stations with 26% similarity. In Figure 12(B), the profile of the similarities between the stations is almost consistent with their geolocation of the sampling points in the city of Maroua. Indeed, the closest pairs of stations are M3 and M4 linked at 84% (are on the Kaliao watercourse in the district of Maroua II. Then, M5 and M6 linked at 74% are the points on the course of water Lougeyo at Maroua III. The point M2 remains atypical for all the parameters measured during the 2 seasons. These similarities are transposed in space according to the canonical analysis of the correspondences which gives the provisions of Figure 12.

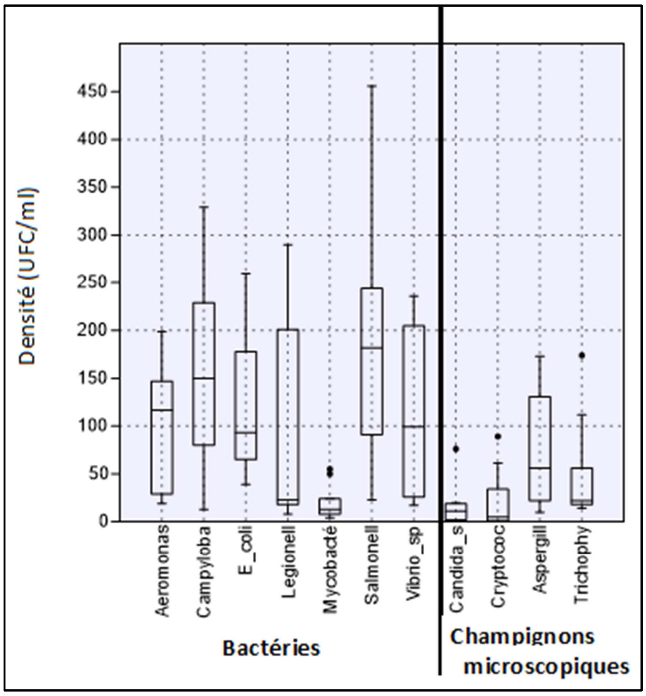


Figure 11. *Comparative densities of germs isolated from surface waters in Maroua.*

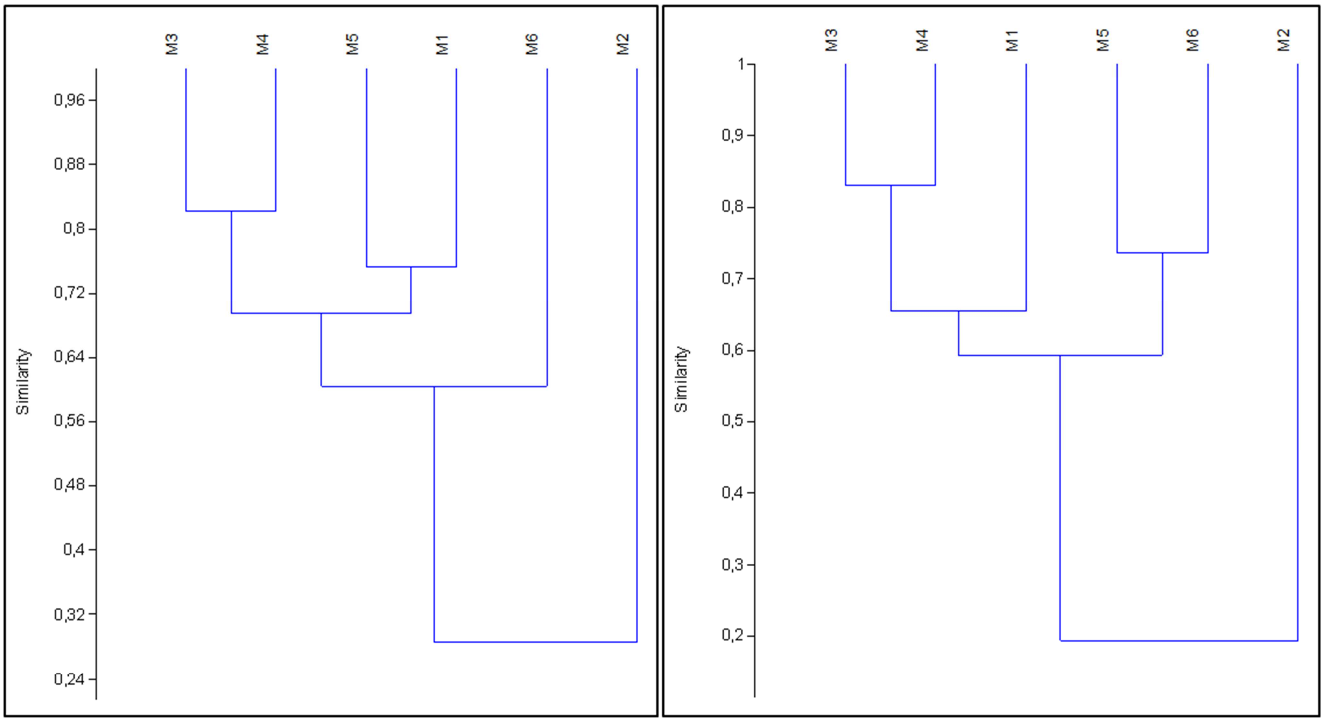


Figure 12. *Dendrograms of similarities between the study stations during the dry season (A) and the rainy season (B) of surface water in Maroua.*

During the dry season (Figure 13), the CCA shows a 3-group clustering of the stations: (M6-M5), M2 and (M1, M3 and M4). Axis 1 represents 99.19% of the total variance and component 2 0.79%. This discrimination of the stations into 3 kernels is superimposable on Figure 13, the kernels are tighter, which corroborates the degrees of similarity expressed in figure 13 on the dendrograms.

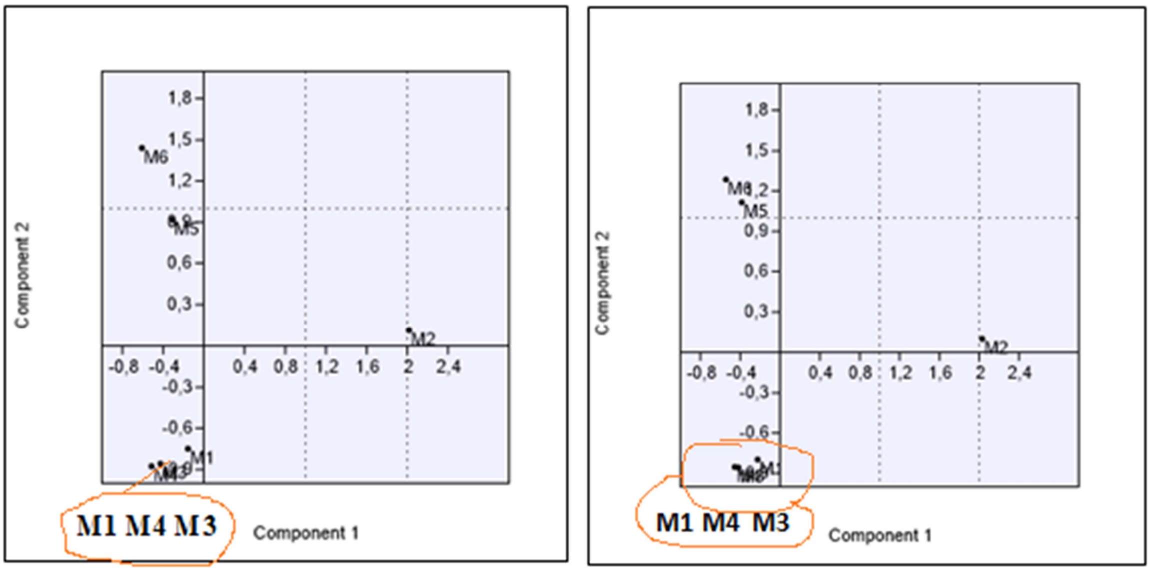
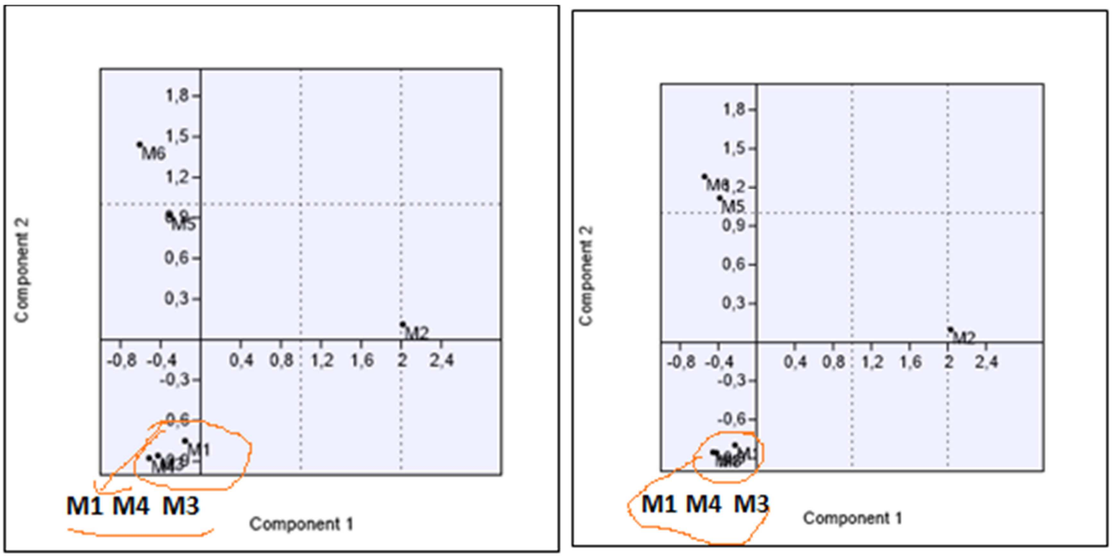


Figure 13. *Dendrograms of the similarities between the study stations during the dry season (A) and the rainy season (B) of surface waters in Maroua.*

During the dry season (Figure 14), the ACC shows a gathering of 3 groups of stations: (M6-M5), M2 and (M1, M3 and M4). Axis 1 represents 99.19% of the total variance and component 2, 0.79%. This discrimination of the stations in 3 nuclei can be superimposed on Figure 14, the nuclei are closer together, which corroborates the degrees of similarity expressed in Figure 14 on the dendrograms.



(A) (B)

Figure 14. *Canonical analysis of the correspondences of the variables studied during the dry season (A) and the rainy season (B) of surface waters in Maroua.*

3.2. Discussion

To understand better the influence of environmental factors on the pathogenic germs present in surface water in Maroua, the critical synthesis of the results obtained after microbiological and physico-chemical analyzes of surface water was made according to the specific objectives. A comparative study of the physico-chemical quality according to the isolated germs made it possible to see some relations between the qualitative aspect of the germs, their abundances and the physicochemical variables which regulate the values.

3.2.1. Variations in Physico-chemical Parameters

The results of temperatures obtained agree with those in the plain of Kar-Hay in the far north, on the wells of obtained an average temperature of 29.1°C. These high temperature values recorded in the districts of Maroua 1, 2 and 3 may be due to the influence of the climate on the water withdrawn. This agrees with the ideas of Tillement who says that the variation of the water temperature is linked to that of the seasonal atmospheric temperature. High water temperature stimulates the growth of microorganisms and can increase problems related to taste, odor, staining and corrosion [16]. This also accompanies the thinking of Rodier et al. where water temperature governs almost all physical, chemical and biological reactions. In addition, this high temperature in urban areas could be explained by deforestation, favoring greater exposure of water to incident solar rays [17]. The TDS values in these water are generally high and would be due to the presence and mineralization of ions (calcium, magnesium.) contained in these water.

Turbidity values in these water were high in mayo water and visible turbidity reduces the acceptability of drinking water. Although most of the particles that contribute to turbidity do not have a health impact (although they can be indicators of the presence of dangerous chemical and microbial contaminants), turbidity to health safet considers that cloudy water is unsafe to drink [14].

The pH of the water sampled as a whole is generally that recommended by the WHO. These mostly alkaline pH values are favorable for sprout growth, as the majority of species have their growth optimum around neutral pH. The environment of water points is also favorable to the alkalinity of these water, referring to the WHO [15] which says that extreme pH values can be due to accidental spills, treatment failures and cement mortar pipe coatings that are insufficiently cured or applied when the water alkalinity is low.

3.2.2. Qualitative and Quantitative Variations of Isolated Germs

The bacteriological analysis results of the water samples from the Maroua 1, 2 and 3 municipalities taken show that the number of faecal coliforms (3474.88 CFU/100 ml ± 8760.53) and vibrio (53. 75 CFU/100 ml ± 67.62) recorded in these water could be linked to environmental activities around water points. In addition, spatially, the commune of Maroua I has the highest bacterial loads, this would be linked to the population density which is higher compared to the other two communes (Maroua 2, Maroua 3). The commune of Maroua 1 being densely populated, human activities are accentuated there and the sanitation system is deplorable. The channels are loaded with waste because of the relatively flat relief, the circulation of water is difficult. Likewise, the systematic search for all germs is very expensive, so it is recommended to search for pathogenic germs, of health importance, or emerging in relation to the health problems recorded in the region. The characterization of mayo water in the three municipalities of the town of Maroua during the two seasons revealed that they contain many bacteria of faecal origin. These results are similar to those of Moussa in 2018 [3, 17]. in his study of wells in the town of Garoua. The density of BHAMs in stations M2, M3 and M4 being 200 times higher during the rainy season (significant difference between the seasons p=0.00003) could be explained by the factor linked to environmental sanitation and behavior of the community: laundry [3, 14]. These are genera and species of bacteria whose presence in water does not in itself constitute a risk to the health of populations, but indicates the importance of biological pollution of water [14].

The presence of Salmonella, Campylobacter and Vibrio reflects contamination by ingestion of water or food soiled by human faeces [18]. Their reservoir being strictly human, they are either sick or asymptomatic chronic carriers (excretion of enterobacteriaceae for over a year in the stool) [19, 20]. *Campylobacter* are spiral bacteria from the digestive tract of animals, occasionally transmitted to humans. Alongside the germs mentioned above, there is another group of so called emerging pathogenic bacteria because of the difficulties in eliminating them from the water and their involvement in the persistence of other germs in the water. In this group are classified *Legionella*, the genus *Mycobacterium* and the genus *Aeromonas*. *Legionella* species are naturally present in aquatic environments, including surface water [21]. One of the particularities of this family of bacteria is that it is detectable in water of very variable temperature. The other major particularity of this thermophilic bacterium is its mode of survival based on the natural parasitism of various protozoa of the aquatic microflora (ciliates and free amoebae of the Naegleria, Acanthamoeba type) [22, 23]. Bacteria of the Mycobacteriaceae family are intracellular and can survive for one year in cattle faeces and on soil. These bacteria are found in nature where they live as saprophytes, but also in other organisms as parasite.

The yeasts isolated in the water during this study in the different stations show that the water is loaded with this microbial group, although the percentage is 2% with an average of 9.25 (± 13.92). Hence, the importance of looking for yeasts in drinking water. The fungi found in water show that the search for fungi in drinking water is important given its effects on human health. It is therefore necessary to include in the microbiological analyzes the search for fungi in drinking water. These results are similar to those of Hageskal in 2007 which had isolated molds in 42.3% of groundwater samples and in 69.7% of surface water samples [24]. Several works have reported the presence of filamentous fungi in drinking water around the world, although the frequencies of mold recovery are variable [25].

4. Conclusion

The aim of the study was to assess the physic-chemical and microbiological quality of surface water. It was carried out from September 2019 to September 2020 in the town of Maroua in the municipalities of Maroua 1, Maroua 2, Maroua 3. It was focused on the analysis of surface water of three Mayo-type seasonal rivers: Palar, Kalio and Lougeyo. From the physico-chemical analyses, it appears that the surface water is characterized by high temperatures, moderately mineralized, rich in dissolved particles and organic matter, prone to contamination by organic waste. The microbiological analyzes made it possible to highlight the bacteria indicating pollution, among other things faecal coliforms, faecal streptococci and BHAM which are more abundant, 200 times higher during the rainy season (p=0.00003). The group of so called emerging pathogenic bacteria comprising bacteria of the genera Mycobacterium, Aeromonas and Legionella. The group of gastrointestinal pathogens bacteria represented by species *Camppylobacter*, *Salmonella* and the genus *Vibrio* responsible for frequent outbreaks in this region. In addition to bacterial germs, some pathogenic yeasts and microscopic fungi have been isolated from these water, in particular *Aspergillus* spp., *Candida* spp., *Cryptoccocus* sp. and *Trichophyton* sp. These results sufficiently show the occurrence of pathogenic germs in surface water in the town of Maroua, the need to regularly monitor these water points prized by the population for their health interest. The presence of these germs would be favored by the alkaline pH, the temperature and the unsanitary activities around the water points.

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