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Study Of The Bacteriological Quality Of Tap Water From The Boma Center To Kongo Central/Dr Congo

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Abstract – This study, which focuses on the bacteriological quality of distribution water from the center of Boma to Kongo Central in the Democratic Republic of Congo, was carried out in the port and historic city of Boma in twelve sampling stations during the rainy season. The city of Boma where insalubrity remains a real public health problem, bacteriological analyzes consisted of the search for Escherichia coli, fecal coliforms, total coliforms and faecal streptococci; analyses of the physical and chemical quality of the water in the network mainly concerned pH, residual free chlorine and turbidity according to the WHO requirement. pH showed a seasonal average of 83.3% of the sample compliance rate with the 2011 WHO recommendations, residual free chlorine presented 58.3% and 75% for turbidity.

From a bacteriological point of view: 42 samples (58.3%) out of a total of 72 complied with WHO (2011) recommendations for Escherichia coli, 24 samples (33.3%) complied for faecal coliforms and 24 samples (33.3%) were compliant for total coliforms. Concerning faecal streptococci, 60 samples, or 83.3% compliance rate with the said recommendations with the highest pollution rate at the E.R.KIK station and a low rate observed at the E.R.KIS station.

Overall, the estimated non-compliance rate of 47.9% of samples with WHO recommendations in this distribution system sufficiently demonstrates the lack of effective treatment of the water distributed or the lack of ongoing maintenance in the system. This lack of treatment and maintenance can be the cause of some waterborne epidemics that regularly threaten the population of the city of Boma. All in all, the results obtained during the study period prove that this distribution system provided water that contained some faecal pollution indicator bacteria.

Keywords – Microbiology quality, Distribution network, water, Boma

I. Introduction

The biological role of water in living beings in general and in humans in particular remains essentially vital, the qualitative and quantitative deficiencies of drinking water are at the root of serious consequences in terms of health (Bontoux, 1983).

International data show that 2.1 billion people (30 per cent of the world's population) do not have access to domestic drinking water services. Of the world's population without access to safely managed water, 844 million people do not even benefit from a basic drinking water service. And of these, 263 million live more than 30 minutes from an improved water source and 159 million continue to drink untreated surface water drawn from streams or lakes (Geldreich, 1998).

Five (4.5) billion people, or 60% of the world's population, do not have safely managed sanitation services. 2.3 billion still lack basic sanitation facilities. Of these, 600 million people share toilets or latrines with other households, and 892 million defecate in the open, a practice that is increasing in sub-Saharan Africa and Oceania due to population growth (Davis and Hirji, 2003).

Sustainable Development Goal (SDG) 6.3 adopted in 2015 by the United Nations General Assembly is precisely entitled as follows: "By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing emissions of chemicals and hazardous materials, halving the proportion of untreated wastewater and significantly increasing water recycling and safe reuse globally," it is far from being reached in the DRC (Génevaux, 2017).

In addition, the DRC faces both financial and logistical difficulties in serving its population with drinking water. To date, many territories and cities are facing a shortage of drinking water although it has significant water potential that can supply all of Africa because, the DRC, formerly Belgian Congo then Zaire, is a Central African country, located in the heart of the African continent, the country is endowed with important natural resources that can be an undeniable asset for its development. The country is drained by the Congo River which originates in the plateaus of southern Katanga in the village Musofi, near the Zambian border, at an altitude of 1400 meters and flows into the Atlantic Ocean after making an arc over the Equator. The river provides the country with a river network that covers the entire territory (Wamuini, 2010).

With an average flow of 45,000m3 per second, the Congo River is the second largest in the world after the Amazon River. Its basin covers 3,730,474 km^2 and it is crossed by countless rivers (Nikiana, 2004).

The distribution network in the centre of the city of Boma, which uses only six tanks as a whole, shows a certain defect observed by water leaks on some avenues (245 leaks / month on average). This defect is aggravated by erosions and anarchic constructions that characterize certain neighborhoods and municipalities of Boma (MinE DR Congo, 2019).

To date, the DRC in general and the city of Boma in particular are faced with this difficulty of qualitative and quantitative insufficiency in drinking water. The Boma water distribution network distributes only 20,000 m^3 of water per day for an estimated population of 371,398 inhabitants (Boma City Hall, Democratic Republic of Congo, Annual Report 2018).

This study reveals the bacteriological profile of faecal pollution indicator germs in the network and alerts the public authorities to be able to take the necessary measures to guarantee the health of the population. It is an assessment of the water quality of the Boma Centre distribution network in Kongo Central/DRC. The present research aims to evaluate the bacteriological, physical and chemical quality of water in the distribution system; isolate faecal water pollution indicator bacteria from this network; determine whether or not the water in this network complies with WHO standards (WHO, 2011).

II. STUDY ENVIRONMENT

The water analyzed was taken from the water distribution network of the port and historic city of Boma, a city crossed by DR Congo's No. 1 national road. It is located 125 km from the port city of Matadi, 114 km from the city of Muanda, 140 km from Tshela and 470 km from the city province of Kinshasa. This city is located at 05° 50′ 55" South and 13° 03′ 22" East and covers an area of 4,332 km2.

It is bounded: to the north, by the Angolan province of Cabinda and the territory of Lukula; in the South, by the Republic of Angola; to the east, by the territory of Seke-Banza and to the west, by the Atlantic Ocean. The city of Boma is full of steep torrents in its western part which, during the rainy seasons, supply the Kalamu River with water considerably and thus make it very aggressive for the floods that the city fears. According to the annual report of the Boma City Hall (Boma City Hall, Democratic Republic of Congo, Annual Report 2018), this city of Boma has an estimated population of 371,398 inhabitants.

The coordinates of the water sampling stations in Boma's distribution network in Kongo Central are given in Table I.

Table 1. Geographic coordinates of water sampling stations

Stations	Localization	Longitude	Latitude	Altitude
E. BRA	Bralima water station	E 13° 04' 49.4''	S 05° 51' 32.4''	42 m
E. KM8	Water station of kilometer 8	E 13° 02' 35.4''	S 05° 47' 56.3''	24 m
E. MBA	Mbangu Water Station	E 13° 03'	S 05° 48' 55.0''	28 m

		30.5’’		
E. RAU	Water station of the reservoir of the old factory	E 13° 03’ 29.2’’	S 05° 50’ 56.5’’	61 m
E. RDP	Rond-Point water station	E 13° 03’ 26.3’’	S 05° 49’ 40.3’’	34 m
E. RKIK	Kikiaka Reservoir Water Station	E 13° 02’ 55.4’’	S 05° 49’ 44.0’’	146 m
E. RKIS	Kisantu Reservoir Water Station	E 13° 03’ 14.6’’	S 05° 50’ 06.9’’	96 m
E. SKA	Water station in the Seka-Mbote district	E 13° 02’ 50.1’’	S 05° 51’ 10.6’’	28 m
E. VBA	Lower town water station	E 13° 03’ 41.0’’	S 05° 51’ 11.6’’	19 m
E.TRF	Discharged treated water station and flare-up	E 13° 03’ 40.6’’	S 05° 51’ 33.5’’	18 m
E.TRSF	Discharged treated water station without flare-up	E 13° 03’ 40.6’’	S 05° 51’ 33.5’’	18 m
E.TST	Treated and stored water station	E 13° 03’ 41.1’’	S 05° 51’ 34.3’’	17

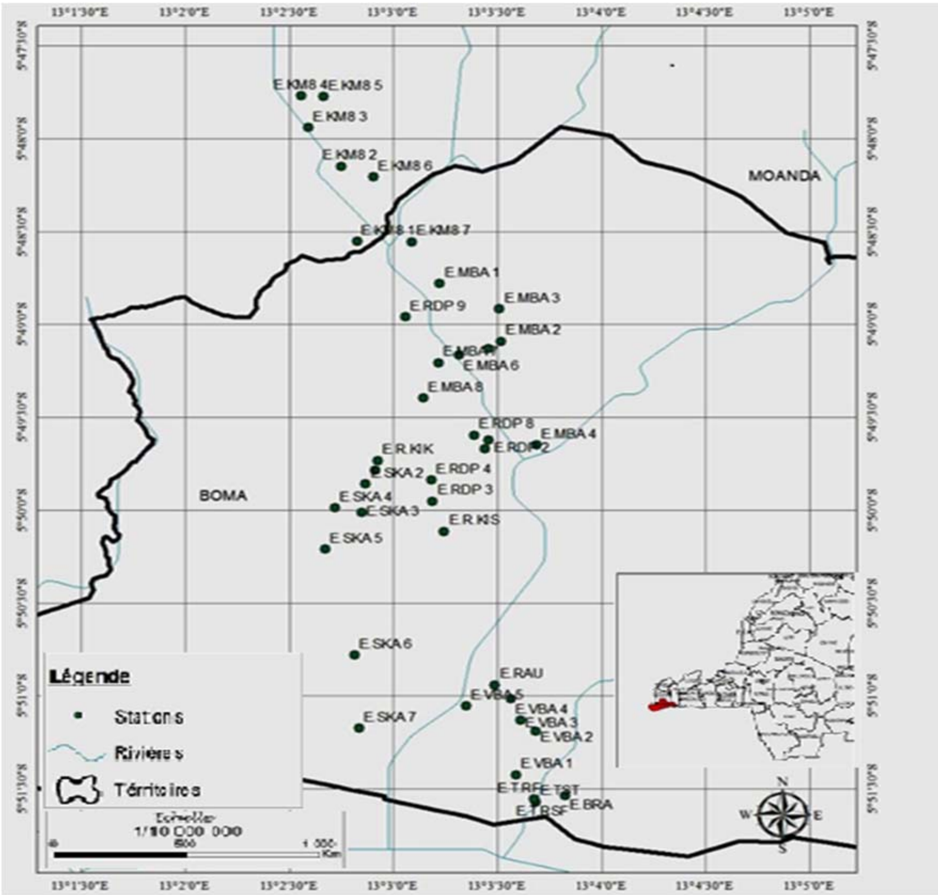

Figure 1: Geospatial map of the water distribution network in central Boma

III. Methods

3.1. Water sampling

Each month constitutes a sampling campaign; Twelve samples are collected at the rate of one sample per station during six months of the rainy season. All parameters were analysed in each sample. Water samples were taken according to the usual precautions: flame the tap for one minute using a 75% ethyl alcohol burner; withdraw water from emery-capping borosilicate glass vials (500 mL) and seal tightly; label the vials containing the samples with the location, date, time and temperature of the water to be analysed; wrap in aluminum foil, place in a cooler at 4°C, and send to the lab (Rodier *et al.,* 1984).

3.2. Analysis of physical and chemical parameters of water

Analyses of these parameters included pH, temperature (°C), turbidity (UNT), conductivity (µs/cm), dissolved oxygen (mg/L), permanganate oxidability (mg/L), residual free chlorine (mg/L), biological oxygen demand (mg/L).

Permanganate oxidability measurement was performed at the Boma Centre Water Distribution Network Laboratory using the LOVIBOND spectrophotometer and SD 320 conductivity meter. PH, temperature, turbidity, conductivity and dissolved oxygen were measured in situ using a multi-parameter probe model OAKTON PCD650.

3.3. Bacteriological analysis of water

Bacteriological analyses focused on the detection of faecal pollution bacteria in particular, Escherichia coli, faecal coliforms, total coliforms and faecal streptococci in the distribution waters, in accordance with the rules laid down (Rodier, 1994).

For the isolation of these bacteria, some culture media were used: Mac Conkey (MCc) for coliform analysis; Brillant Green Bile Broth 2% (BGBB) for confirmation of coliforms; 2% Nutrient Agar or Agar Nutrient AT 2% for total germ analysis; Simmons citrate agar used for the confirmation of Escherichia coli.

For the determination of different so-called faecal germs present in the water samples, seeding in petri dishes was used in accordance with the rules given by (Rodier, 1994) : the equipment used such as: petri dishes, pyrex test tubes, graduated pipette, beaker were sterilized beforehand in the oven (170 ° C) brand KOTTERMANN / PH4 MKI for 60 minutes; the Petri dishes previously numbered according to the different types of water samples to be analyzed were arranged on the table with flame; the culture media prepared and sterilized in the MOCHIM-LABO brand autoclave for 15 minutes at 121 ° C were poured into the different petri dishes and 1 ml of each sample was distributed in each petri dish; after waiting five minutes to allow the culture medium to solidify, these boxes were placed in the IB-9052A brand incubator in the upturned position to avoid wetting the medium; the results were read 24 hours later at 37°C for coliforms and 48 hours later at 44°C for faecal streptococci.

As for colony identification, Eschericia coli was in the form of red colonies with metallic reflection or pink colonies on MacConkey medium, red colonies for fecal coliforms, white colonies for total coliforms and small red colonies arranged in chains represented faecal streptococci.

3.4. Statistical analysis

The data obtained were analysed using Student's test (t-test), Principal Component Analysis (PCA) and Hierarchical Ascending Classification (CAH).

The t-test was used to compare the averages of different bacteriological, physical and chemical parameters during the 2018 rainy season.

The CPA analyzed and visualized a dataset containing individuals described by several quantitative variables. This statistical method was used differently to explore the data of individuals with multiple variables as parameters. CAH is a classification method designed to produce groupings described by a number of variables or characters (Lebart et al., 1995). In automatic classification, there are no a priori groups. The method looks in the point cloud for dense areas that will form groups that will remain to be interpreted later.

IV. Results

4.1. Physical parameters of tap water

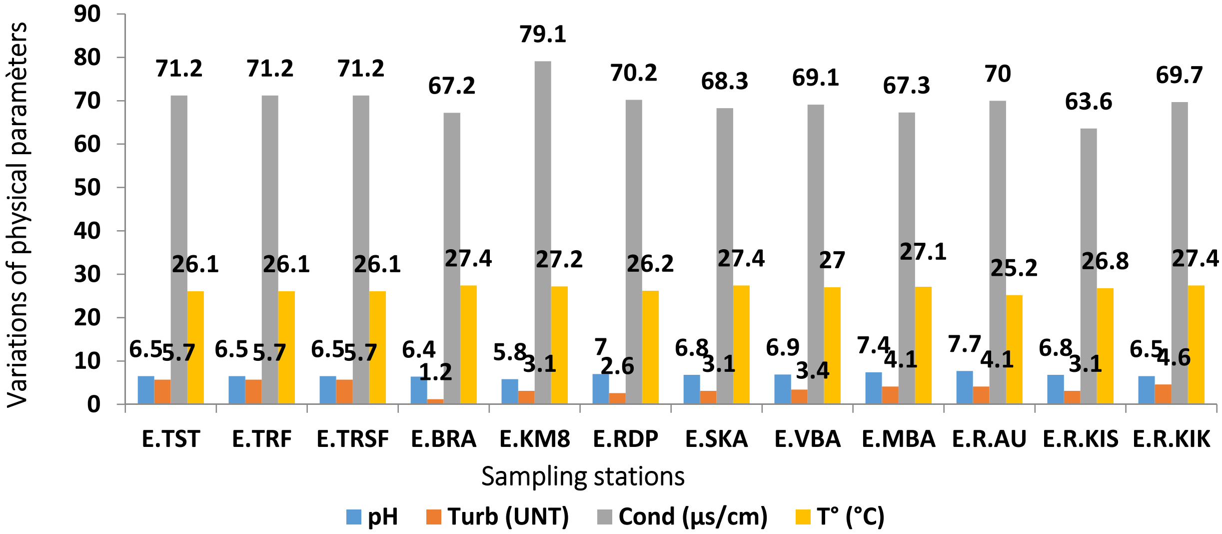

Figure 2. Variations in the average values of the physical parameters of the tap water analyzed in the rainy season 2018.

The highest mean pH value (7.7) was recorded at station E.RAU and the low value (5.8) at station E.KM8.

The highest mean turbidity value (5.7UNT) was observed at stations E.TST, E.TRF and E.TRSF and lowest (1.2 UNT) was observed at station E.BRA. The conductivity had the highest mean value (71.2 µS/cm) at the E.TST, E.TRF and E.TRSF stations and the lowest value (63.6 µS/cm) at the E.RKIS station.

The average temperature values taken during the year 2018 vary between 26.1 and 27.4°C and therefore do not comply with the interval set by the European Union Directive of 1998 (15-25°C).

4.2. Chemical parameters of the tap water of the city of Boma

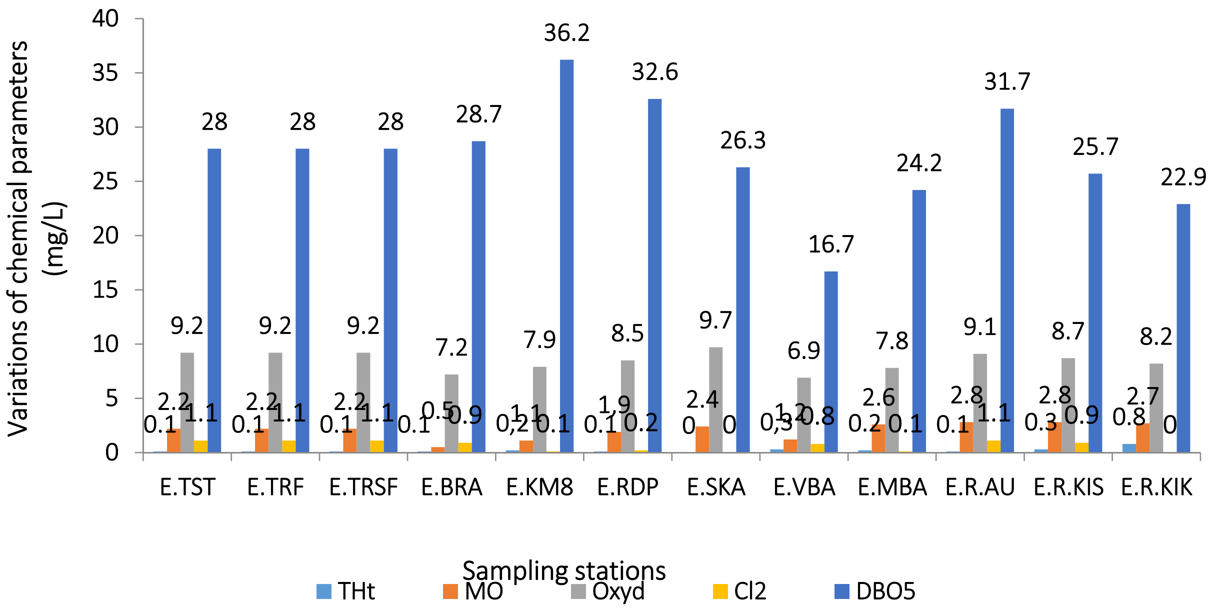

Figure 3. Variations in the average values of the chemical parameters of the tap water analyzed in the rainy season 2018.

The highest mean oxidability value to permanganate (or oxidizable materials) (2.8 mg/L) was observed at stations E.R.AU and E.R.KIS; however, the lowest value (0.5 mg/L) analyzed at E.BRA stations (Fig.3).

The low mean dissolved oxygen value is observed at E.VBA station (6.9mg/L) and the highest value (9.7mgl) was calculated at E.SKA station.

Free chlorine residual has the lowest mean value (0.1 mg/L) recorded at stations E.km8 and E.MBA and the highest mean (1.1 mg/L) at stations E.TST, E.TRF, E.TRSF and E.RAU.

The highest mean biological oxygen demand (36.2 mg/L) is at station E.KM8 and the lowest (16.7 mg/L) at station E.VBA.

4.3. Bacteriological parameters of the tap water of the city of Boma

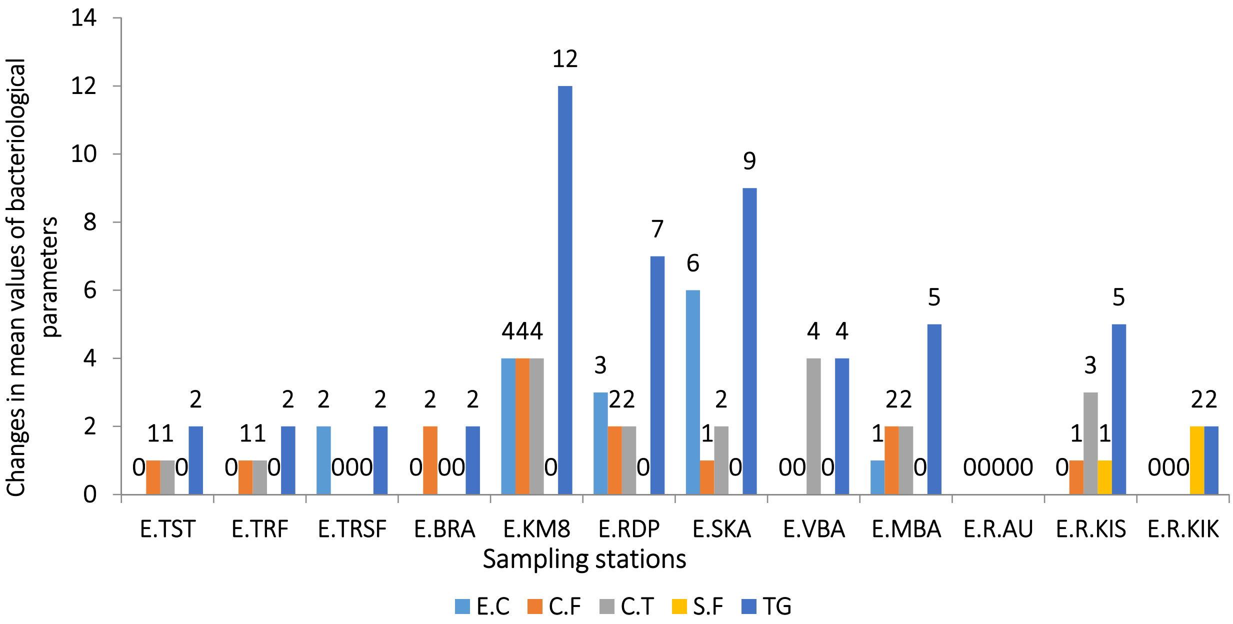

Figure 4. Variations in the average values of bacteriological parameters of tap water analyzed in the rainy season 2018.

Out of 72 samples analysed: 42 samples (58.3%) comply with the 2011 WHO recommendations and another 30 samples (41.7%) are non-compliant with high Escherichia coli pollution levels at station E.SKA, followed by stations E.KM8, E.RDP, E.TRSF and E.MBA (fig.4).

For faecal coliforms, 24 out of 72 samples (33.3%) meet WHO 2011 recommendations and another 48 (66.7%) do not meet these recommendations. The highest level of faecal coliform pollution was observed at station E.km8 and the lowest rate at stations E.TST, E.TRF, E.SKA and E.R.KIS.

For total coliforms, 24 samples (33.3%) meet the same recommendations (WHO, 2011) and another 48 (66.7%) are non-compliant. The highest pollution rate was observed at stations E.km8 and E.VBA, and the lowest rate was recorded at stations E.TST and E.TRF.

For faecal streptococci, 60 samples (83.3%) comply with these WHO recommendations and 12 samples (16.7%) do not comply with these recommendations. The highest pollution rate was observed at the KIKIAKA reservoir station and the low rate at the E.R.KIS station.

4.4. Statistical analysis

4.4.1. Correlation between bacteriological, physical and chemical parameters of tap water in the city of Boma

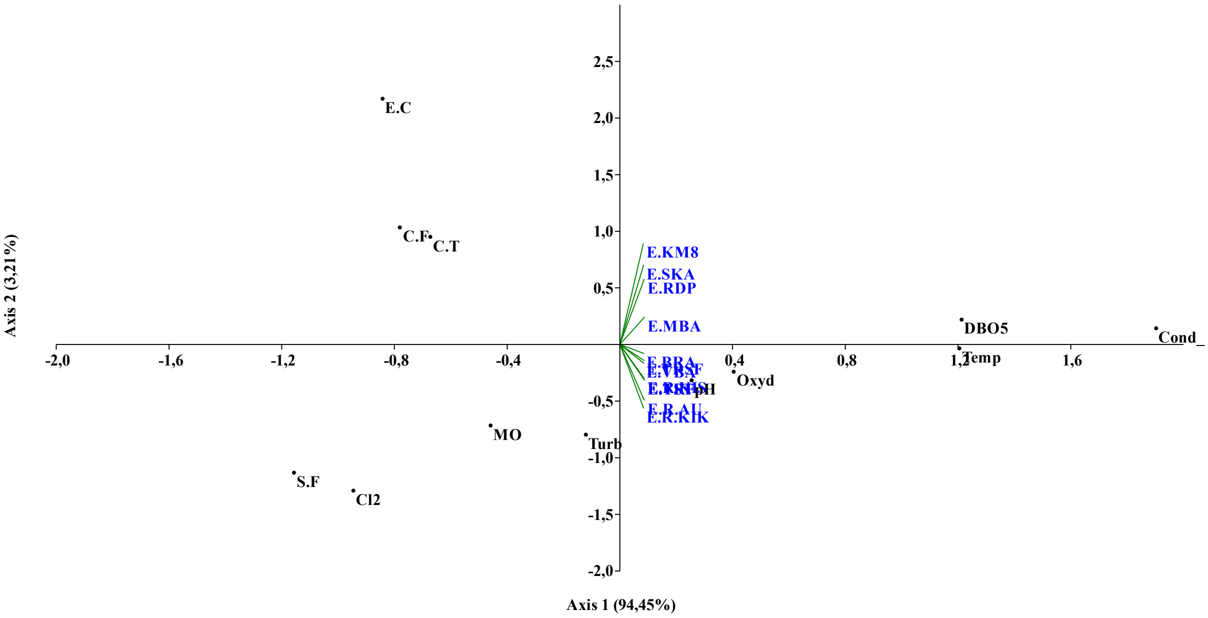

Figure 5: Correlations between bacterial presence and physico-chemical parameters in the Boma water distribution network in the rainy season in 2018

Two main axes (axis 1 and axis 2) were chosen because they explain 97.7% of the dispersion of variables; Axis 1 (94.45%) better explains the correlation *between bacteria and physico-chemical parameters and axis 2 is residual and presented 3.21%.*

With regard to correlations between axis 1 and isolated bacteria, faecal coliforms and total coliforms correlate positively with axis 1.

Axis 1 positively correlated with the following physical and chemical parameters: BOD5, pH, conductivity, temperature and dissolved oxygen.

The following microorganisms: Escherichia coli, fecal coliforms, total coliforms and faecal streptococci correlated positively with physico-chemical parameters: Chlorine, Permanganate oxidability (M.O) and turbidity.

4.4.2. Hierarchical Ascending Classification (HAC)

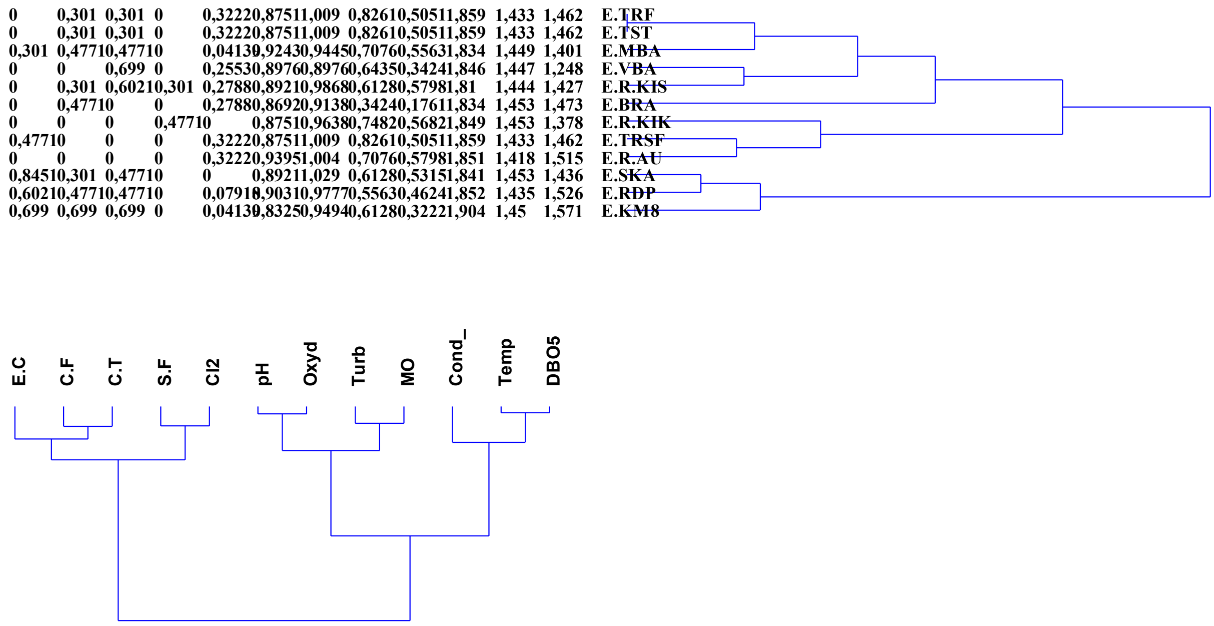

Figure 6. Dendrogram of reconciliation of stations and physical, chemical and bacteriological parameters of the water distribution of the city of Boma in 2018.

Two groups of physical, chemical and bacteriological parameters were distinguished (Fig.6), pH, dissolved oxygen, turbidity, permanganate *oxidability (M.O), conductivity, temperature and BOD5 were close.* The second group is residual free chlorine, faecal streptococci, Escherichia coli, faecal coliforms and total coliforms that have come closer together (fig.6B). Therefore, the residual free chlorine content determines the population of bacteria (fig.6A).

Levels of reconciliations were also observed between two groups of stations. The E.SKA, E.RDP and E.KM8 stations are very close and distant from the mains water parameters at the E.TRF, E. TST, E.MBA, E.VBA, E.R.KIS, E.BRA, E.R.KIK, E.TRSF and E.R.AU stations.

V. Discussion

The average pH values presented during the rainy season are slightly acidic (6.73±0.47) with a compliance rate of 83.3% of samples with the 2011 WHO recommendations. These results are close to those presented by (Lebart *et al.*, 1995) in Chad (pH 6.848±0.82), for treated water from the network. The results obtained showed highly significant differences for pH.

The residual free chlorine in the Boma water distribution network has averages (0.617±0.47) with a sample compliance rate of 58.3% in the rainy season. These system averages (0.1 to 1.1 mg/L) appear to be the same as those found by (Mahamat *et al.*, 2015 ; Durand, 2016) in Montreal (0.1 to 1 mg/L); These seasonal mean values show no significant difference for residual free chlorine (0.8376).

The mean turbidity values (3.9±1.3) presented during this season ranged from 1.2 to 5.7 NTU and the rate of compliance with the 2011 WHO recommendations reached 75%. The results obtained in this study differ from those found by (Mahamat *et al.*, 2015) (turbidity 0.116±0.08).

The turbidity values recorded were slightly above the limit (5 NTU) prescribed by WHO with a considerable increase at the factory exit (5.7NTU) in the three TST-TRFS-TRSF stations (Figure 2). This low turbidity could be due to the presence of finely divided suspended solids such as clays and silts (WHO, 2011). It should be noted that high turbidity can promote the proliferation of microorganisms that can bind to suspended particles having a protective effect of these microorganisms against disinfection (Gnazou *et al.*, 2015). Thus, these waters were all cloudy and their bacteriological quality was therefore suspect at the E.TST, E.TRF and TRSF stations.

The average temperatures observed (27±0.7) in all samples of the rainy season in 2018 are not in line with the interval set by the European Union in 1998 (15 and 25°C) as the WHO has not set guidelines for the temperature of treated water in the distribution system. The low mean (25.2°C) was recorded at the reservoir station of the former plant and the high mean value (27.4°C) was observed at the E.BRA, E.SKA and E.R.KIK stations. The rise in average temperatures observed during the season may be due to the location of this network in the tropical zone where the temperature of the environment can have a direct influence on that of the water, especially when the pipes are exposed under the ground.

The results obtained in this study showed that the average values of bacteriological parameters recorded throughout the 2018 rainy season show differences in the levels of compliance rates (in %) of samples with the recommendations of [10]: Escherichia coli (58.3%); Faecal coliforms (33.3%); Total coliforms (33.3%) and faecal streptococci (83.3%). These higher average values differ from those found by (Diop, 2006) in Dakar and (Mavema, 2010) in Mbanza-Ngungu.

Out of a total of 72 samples analysed: Escherichia coli, 30 samples (41.7%) do not comply with the 2011 WHO recommendations with high pollution levels at E.SKA station and lowest levels at E.MBA station; faecal coliforms, 48 samples (66.7%) do not comply with these recommendations..

The highest pollution rate was recorded at station E.km8 and the low rate at stations E.TST, E.TRF, E.SKA and E.R.KIS. Total coliforms, 48 samples (66.7%) did not meet these recommendations. The highest pollution rate is at stations E.KM8 and E.VBA; the lowest was observed at E.TST, E.TRF and E.KIS stations.

Regarding faecal streptococci, 12 samples (16.7%) do not comply with WHO recommendations (2011), which is sufficient proof that the Boma water distribution network is poorly polluted by faecal streptococci with an 83.3% compliance rate with reference recommendations. The highest pollution rate was reported at the E.R.KIK station and the low rate at the E.R.KIS station.

The poor quality of the water in the network under study could be due to the unsanitary conditions that are emerging throughout the city, by the intermittent distribution of water, but also by the infiltration of microorganisms from water leaks observed in the network. The existence of positive correlations between Escherichia coli, faecal coliforms and total coliforms (Figure 5) indicates the common originality of these microbes.

VI. Conclusion

Following the physical, chemical and bacteriological analyses carried out on the water of the distribution network of the city of Boma, it should be noted that the results obtained throughout the rainy season of 2018 sufficiently prove that some water samples taken from this network are not within the limits as set by the WHO (2011).

Regarding the three main physical and chemical parameters recommended by the World Health Organization for treated water in the network: pH has 83.3% sample compliance rate with the 2011 WHO guidelines, residual free chlorine has 58.3% compliance rate and turbidity has a compliance rate of 75%.

From a bacteriological point of view, the non-compliance rate of 47.9% of samples with WHO recommendations in this distribution network demonstrates the lack of effective treatment of the water distributed or the lack of permanent maintenance in the network. This insufficiency both in treatment and maintenance can be the cause of some waterborne pathologies that regularly threaten the population of the city of Boma, partially confirming the hypotheses of this research.

All in all, on the basis of the results obtained, measures should be considered with a view to warning the population of the health risks incurred by the consumption of water from this network. It is therefore recommended that the company producing drinking water in Boma renew and bury the dilapidated distribution network, map the water distribution network in Boma, dedicate well-defined sites for the dumping of polluting waste that must be far from water sources, regularly initiate government control at the level of resource areas etc.

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