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Hydrochemical evaluation of drinking water in the distribution network of Brazzaville, Congo

Bernard NDOKI[1]*, Laurent MATINI[2], Joseph Marie MOUTOU[3]

[1]*Laboratoire de Génie des Procédés Industriels (GPI), ENSP, UMNG, B.P: 69, Brazzaville, Congo
[2]Laboratoire de Chimie, ENS, UMNG, B.P: 69, Brazzaville, Congo
[3]Laboratoire de Chimie Minérale Appliquée (LCMA), ENS, UNMG, B.P: 69, Brazzaville, Congo
*Corresponding author: barnerdoki@gmail.com, Tél. (00242) 06.911.81.85

Abstract The physicochemical composition of water in the distribution network in Brazzaville was evaluated. The water supply network, by nature very extensive, is exposed to several factors such as the technical status and the age of the network, which can probably modify the physicochemical quality of the water intended for the population. Data was collected during two sampling campaigns, September 2016 (dry season) and March 2017 (rainy season). Ten sampling points were selected. The analysed parameters are: turbidity (Turb), pH, TOC, UV Abs, residual chlorine (Cl_{2res})., Br^-, NH_4^+, total trihalomethanes (THMT), Cd, Pb, Fe, Zn, As and Cu, which have been compared with WHO standards for drinking water. A multivariate statistical analysis was used to determine the parameters that control the water quality of the distribution network. Factor analysis using the principal component extraction method identified four factors accounting for 83.47 % of the total variance. The highest proportion was attributed to factor 1 (36.67 %) following by factor 2 (17.16 %). These two factors account for more than half of the data variability. The hierarchical ascending classification revealed three groups of sampling points discriminated by the same parameters highlighted by the factor analysis.

Keywords water distribution network, trihalomethanes, multivariate statistical analysis

1. Introduction

The physicochemical quality of water in drinking water supply systems is essential for public health [1]. The distribution network, which by its nature is very extensive, has many potential entry points: fire hydrants, accessories, connections, which have a considerable impact on the chemical composition of the water [2]. This composition also depends on the structure of the distribution network and the reactive substances that the water could have encountered during the flow [3]. The type and intensity of processes occurring in water supply systems determines the form of contamination (suspension, colloidal or dissolved) [4-5]. Therefore, the main problem of all drinking water supply systems is the loss of water stability during transmission from the water treatment plant to consumers [6]. Thus, the chemical composition of the water of the distribution network in dissolved materials, of mineral or organic nature, determines its quality [7]. However, this quality may be impaired during its transmission in the factory network to consumers [8]. Continuous hydrochemical evaluation of the network's water composition makes it possible to quickly detect abnormal situations, especially with respect to the usual quality parameters that are good indicators of contamination (chlorine, turbidity, TOC, THMT, for example) [9]. In order to better understand the hydrochemical composition of the water of the

Société Nationale de Distribution d'Eau (SNDE), two sampling campaigns were carried out, one in the dry season (September 2016) and another in the rainy season (March 2017). This network is fed by surface water taken from two rivers, Djiri and Djoué. Surface waters are treated at the Djiri plant and the Djoué plant, respectively. These surface waters undergo conventional treatment (coagulation-flocculation, decantation, filtration and chlorine disinfection) before being returned to the distribution network. The present study was conducted to characterize the hydrochemical properties of the water network and to determine the levels of pollutants (THMT and metals) present in the water. Multivariate statistical analysis (Ascending Hierarchical Classification and Factor Analysis) were carried out in order to highlight the parameters that control the water quality of the network.

2. Materials and Methods

2.1. Location of the Study Area

Located on the right bank of the Congo River, Brazzaville is the capital of Congo. It has nine districts and its geographical position is 4°16'04" South Latitude and 15°16'31" East Longitude. In this city are located two water treatment plants, the Djoué plant in south of the city located in the district 1 Makélékélé (Figure 1) and the Djiri plant in north of the city located in the district 9 Djiri (Figure 2). Each of the two plants processes 122,400 m^3/day and 163,200 m^3/day, respectively.

Figure 1: Geography and sampling points in the southern zone of Brazzaville

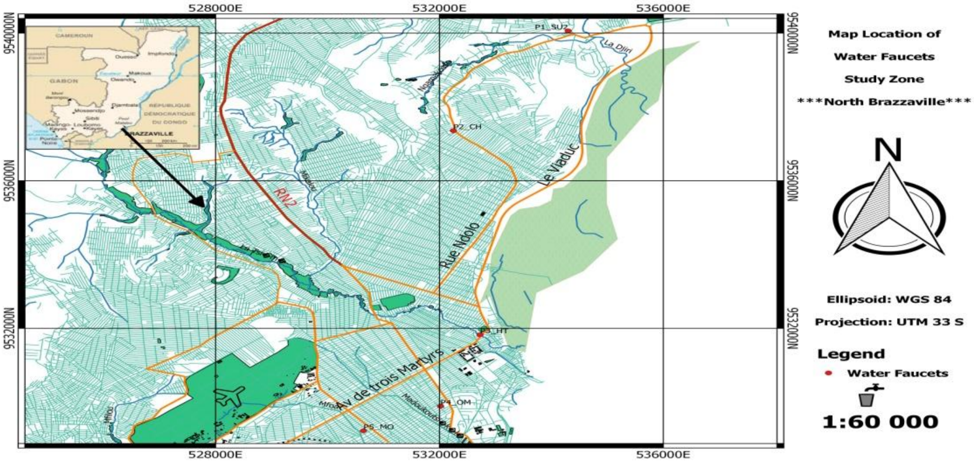

Figure 2: Geography and sampling points in the northern zone of Brazzaville

Each sampling point is characterized by geographic coordinates using a Garmin E-Trex GPS (Table 1, Table 2). The sampling covered two seasons: dry season (2016, September) and rainy season (2017, March). The samples were taken at ten points of the network and each point was located at distant 1.5 km from the other (Figure 1, Figure 2). Bottles of 1000 ml glasses were used. Before use, these vials were thoroughly washed and rinsed. They were then dried and then wrapped in aluminum foil and sterilized by autoclaving (125 °C) for 15 minutes.

Table 1: Geographical coordinates of tap water samples (South Area)

Sampling point	X	Y
P1_SU1 (Plant outlet Djoué)	523614.67	9526208
P2_TR (Terinkyo)	526898.38	9525910.6
P3_PD (Djoué bridge)	525736.96	9523654.9
P4_PK (PK Station)	524918	9528327.3
P5_DI (District Diata)	527081.33	9528292

X: Latitude, Y: Longitude

Table 2: Geographic coordinates of tap water samples (North Area)

Sampling point	X	Y
P1_SU2 (Plant outlet Djiri)	534298.94	9540060.5
P2_CH (Ngamakosso water tower)	532246.46	9537357.6
P3_HT (Talangai hôpital)	532724.44	9531825.2
P4_OM (District Ouenze mazanza)	532019	9529891.3
P5_MO (District Moungali)	530641.33	9529226.7

2.2. Experimental Procedure

The following parameters were determined in the water samples taken from the Brazzaville water distribution network: temperature (T), pH, turbidity (Turb), Residual chlorine ($Cl_{2res.}$), total organic carbon (TOC), ammonium ion (NH_4^+), bromide ion (Br^-), absorbance 254 nm (UV Abs.) and THMT. The temperature was measured using a WTW brand thermometer. The pH was measured using a pH-meter type AR25, Fischer scientific. Turbidity was measured using a HACH Lange nephelometric infrared turbidimeter (Model 2100P IS). The parameters T, pH and Turb were determined in-situ. Residual chlorine was determined using the DPD method (diethyl-p-phenyldiamine) using a Test Pak apparatus (Comparator 2000+ Lovibond, Tintometer-Group, France). The bromide ion was determined using SpectroDirect / PC spectro II-3 O4 using the tablet method (DPD n° 1). Ammonium (NH_4^+), TOC concentrations and UV absorbance were determined by the 2-3 indophenol method, the persulfate method and at 254 nm, respectively, using SpectroDirect / PC spectro II-3 O4. The concentration of the lead (Pb), copper (Cu), iron (Fe), cadmium (Cd), zinc (Zn) and arsenic (As) metals was determined using the ICP-OES method at the laboratory of the General Surveillance Society (SGS) in Pointe-Noire (Congo). The THMT analyzes were carried out by the Laboratory "Environmental Laboratory Services" of the « Société Générale de Surveillance» (SGS France) via SGS CONGO. This laboratory has Cofrac accreditation (French Accreditation Committee). Sample collection for THMT analyzes is done using 40mL glass vials for auto-sampler. The elimination of residual free chlorine is done by adding 4 mg of sodium thiosulfate per vial of 40mL. The method used refers to DIN EN ISO 10301. The analysis technique includes a concentration phase of THMT by dynamic headspace (Purge and Trap), coupled with an Agilent brand gas chromatograph (model 6890N, Santa Clara, CA, USA), equipped with an Agilent mass spectrometry detector (model 5973, Santa Clara, CA, USA). The limit of detection was 0.1 µg/L for most of the compounds measured.

2.3. Statistical Treatment of Data

The basic statistical criteria, that is to say, minimum and maximum values, standard deviation, coefficient of variation and correlation matrix were calculated for all parameters analyzed from the tap water samples. Statistical analyses of the data were performed with STATISTICA 7.1 software.

3. Results and Discussion

3.1. Assessment of the Potability of Waters

The analytical parameters were compared with WHO standards for drinking water [10]. These values are given in Table 3.

Table 3: Guidance Values for Drinking Water Quality (WHO)

Parameters	Turb.	pH	Cl_2.rés	NH_4^+	Br^-	COT	THMT
Guidance values OMS (2011)	2	6.5– 8.5	0.2	0.5	-	2	100

Parameters	Pb	Cu	Zn	Cd	Fe	As
Guidance values OMS (2011)	0.01	2	3	0.003	0.2	0.01

Except pH, Turb. (NTU), THMT (µg/L), all other units are expressed in mg/L.

The average values of all the parameters during the two seasons are given in Tables 4 and 5.

Table 4: Average values of physicochemical parameters (dry season and rainy season)

Sample code	T	Turb.	pH	COT	Abs. UV	$Cl_{2\ res}$.	Br^-	NH_4^+	THMT
P1_SU1	23.6	6.65	6.65	12.55	0.141	0.85	0.0165	0.05	11.45
P2_TR	24.1	6.475	6.98	11	0.132	0.15	0.025	0.04	13.85
P3_PD	23.25	3.34	7.3	7.95	0.07	0.075	0.016	0.425	9.65
P4_PK	23.9	2.56	7.1	5.75	0.054	0.15	0.0275	0.045	19.05
P5_DI	24.3	4.63	7.38	6.05	0.055	0.15	0.0365	0.005	30.5
P1_SU2	23.85	2	7.05	11.45	0.09	0.8	0.046	0.18	18.05
P2_CH	23.7	2.35	6.72	7.8	0.071	0.4	0.0315	0.143	23.9
P3_HT	24.2	1.3	7.16	7.25	0.07	0.25	0.041	0.125	29.6
P4_OM	23.85	1.245	7.23	4.7	0.0355	0.05	0.027	0.131	25.3
P5_MO	23.95	1.905	7.51	3.3	0.0185	0.2	0.037	0.161	30.75
Minimum	23.250	1.245	6.650	3.300	0.019	0.050	0.0160	0.005	9.650
Maximum	24.300	6.650	7.510	12.550	0.141	0.850	0.0460	0.425	30.750
Mean	23.870	3.246	7.108	7.780	0.074	0.308	0.0304	0.131	21.210
Variance	0.093	4.039	0.074	9.286	0.001	0.084	0.0010	0.014	63.265
SD	0.306	2.010	0.273	3.047	0.039	0.290	0.0099	0.119	7.954

Table 5: Average concentration of metals (mg/L), dry season and rainy season

Sample Code	Pb	Cu	Zn	Cd	Fe	As
P1_SU1	0.003	0.0158	0.0435	0.001	0.0675	0.003
P2_TR	0.010	0.0165	0.03	0.005	0.13	0.0045
P3_PD	0.010	0.0172	0.009	0.004	0.0675	0.004
P4_PK	0.004	0.0111	0.065	0.002	0.21	0.005
P5_DI	0.009	0.005	0.03	0.001	0.087	0.004
P1_SU2	0.004	0.010	0.049	0.002	0.057	0.002
P2_CH	0.005	0.017	0.03	0.001	0.115	0.003
P3_HT	0.01	0.015	0.018	0.002	0.315	0.003
P4_OM	0.003	0.017	0.03	0.002	0.13	0.0028
P5_MO	0.011	0.0097	0.08	0.003	0.21	0.0025
Minimum	0.003	0.005	0.009	0.001	0.058	0.002
Maximum	0.010	0.018	0.080	0.005	0.315	0.005
Mean	0.007	0.014	0.039	0.002	0.139	0.004
Variance	0.000	0.000	0.000	0.000	0.007	0.000
S D	0.004	0.004	0.021	0.001	0.083	0.001

The water temperature varies between 23.6 and 24.3 °C with an average of 23.87 ± 0.30 °C in the distribution network. The turbidity varies between 1.24 and 6.65 NTU with an average of 3.24 ± 2.01 NTU. All recorded values do not comply with WHO regulations for drinking water. This reflects pollution by organic or mineral matter [11]. The pH of the water in the network varies between 6.65 and 7.51 with an average of 7.10 ± 0.27. These pH values are within the range of WHO limit values for drinking water. Total organic carbon (TOC) ranges from 3.3 to 12.55 mg/L with an average of 7.78 ± 3.04 mg/L. In all samples, the TOC concentration is above the WHO standard of 2 mg/L. The UV absorbance varies from 0.019 to 0.141 cm^{-1}. The composition of organic matter is a key factor in THMT production. Thus, the formation of THMT is all the more important as organic matter, rich in aromatic nuclei, reacts with chlorine. This THMT formation is accompanied by a decrease in the UV absorbance of the water in the distribution network [12, 13]. Residual chlorine in the water samples varies between 0.05 and 0.85 mg/L with an average of 0.3 ± 0.29 mg/L. Half of the water samples have chlorine residual below the guideline value of 0.2 mg/L, which can induce microbial reviviscence and increase the vulnerability of water [14]. Bromide and ammonium concentrations ranged from 0.16 to 0.46 mg/L (average of 0.30 ± 0.1mg/L) and from 0.005 to 0.425 mg/L (average of 0.131±0.119 mg/L), respectively. THMT result from the combination of several parameters and are considered as a measure of organic pollution and an indicator of water quality. THMT concentrations ranged from 9.05 to 30.75 µg/L, with an average value of 21.21 ± 7.94 µg/L. These values are all within the limit set by WHO [15]. On the other hand, some samples taken during the dry season showed values higher than 40 µg/L. These are P4_OM and P5_MO samples whose concentration in THMT exceeds the USEPA standard stage 2. Other samples have THMT average values around 30 µg/L, such as P5_DI, P3_HT and P5_MO (Table IV). The water temperature in these samples is quite high, 24.3, 24.2 and 23.95 °C, respectively.

The concentrations of metals such as Cu, Zn, Fe and As are within the limits authorized by the WHO for drinking water. However, those of lead and cadmium exceed the respective limit value for drinking water. These high concentrations of Pb and Cd could be attributed to disordered discharges of used materials in the environment, obsolete network that leads to infiltration of wastewater into the network.

3.2. Correlation between the parameters

These relationships are given by the correlation matrix as shown in Table VI. A strong association was observed between the parameters TOC and Abs. UV, $Cl_{2\ res.}$ such as: TOC – Abs. UV (r = 0.95) and TOC – $Cl_{2\ res.}$ (r = 0.72). TOC and Abs. UV are characteristic indicators of organic matter. The association between TOC and $Cl_{2\ res.}$ shows the reactivity of chlorine with organic matter. A strong correlation was observed between turbidity and Abs. UV (r = 0.78). The high values of turbidity observed in the water samples could be attributed to the presence of organic matter. The trihalomethanes content found in the water samples were significantly correlated with the following parameters: T (r = 0.69). The temperature significantly influences the formation of chlorination by-products, while bromide is one of the precursors of chlorination by-products [15]. We also note that these two parameters (T and Br^-) have a positive correlation (r = 0.64), which highlights their contribution in the formation of chlorination by-products.

An average correlation is observed between the metals Cd and Pb (r = 0.50), Zn and Cu (r = 0.53). This shows that metals (Cd, Pb) and (Zn, Cu) could have the same origin in water. On the other hand, the correlations between the metals and the pH are either insignificant or negative and the average pH of the water in the network is close to neutrality (pH = 7.10 ± 0.27). This could mean that the presence of metals such as Cu, Pb, Zn and Cd is not related to the pH of the water. Their origin could be related to the state of the network and its immediate environment [9, 13]. The value of pH is an important factor in the solubility of metals. In acidic medium, the metals are easily solubilised and are in the form of ions. This can lead to a health risk for the consumer.

Table 6: Correlation matrix of the different physicochemical parameters

	T	**Turb.**	**pH**	**COT**	**Abs. UV**	**Cl_2 res.**	**Br-**	**NH_4^+**	**THMT**	**Pb**	**Cu**	**Zn**	**Cd**	**Fe**	**As**
T	1.00														
Turb.	-0.03	1.00													
pH	0.27	-0.41	1.00												
COT	-0.24	**0.62**	**-0.73**	1.00											

Abs. UV	-0.15	**0.78**	**-0.75**	**0.95**	1.00										
Cl_2 res.	-0.20	0.24	**-0.64**	**0.72**	**0.58**	1.00									
Br-	**0.64**	-0.55	0.30	-0.21	-0.37	0.14	1.00								
NH_4^+	**-0.73**	-0.35	0.26	-0.06	-0.21	-0.14	-0.21	1.00							
THMT	**0.69**	-0.55	0.49	**-0.71**	**-0.70**	-0.31	0.28	-0.33	1.00						
Pb	0.03	-0.47	-0.31	-0.19	-0.19	-0.04	0.24	0.06	0.40	1.00					
Cu	0.28	-0.10	**0.64**	-0.59	-0.54	-0.24	0.27	-0.06	0.58	-0.12	1.00				
Zn	0.17	-0.12	0.15	-0.27	-0.28	0.20	0.27	-0.34	0.23	-0.24	0.53	.1.00			
Cd	-0.11	-0.14	-0.51	0.29	0.25	0.16	-0.09	0.02	-0.08	0.50	**-0.74**	**-0.70**	1.00		
Fe	0.49	-0.47	0.28	-0.49	-0.38	-0.38	0.36	-0.19	0.55	0.42	0.19	0.19	-0.04	1.00	
As	0.16	0.31	-0.01	-0.06	0.13	-0.54	-0.36	-0.20	-0.20	-0.07	-0.29	-0.26	-0.01	0.25	1.00

Significant correlation in bold, at $p < 0.05$ (two tailed)

3.3. Multivariate statistical analysis

Multivariate exploratory analyzes were implemented to facilitate the interpretation of the results. The two techniques were used such as hierarchical ascending classification (HAC) and factor analysis (FA). Both types of statistical analysis are widely used to characterize the hydrochemistry of water. The hierarchical ascending classification is a method that allows a reduction of data by grouping them into classes whose entities have similar properties [16-18]. Factor analysis provides an understanding of the correlation structure of water quality parameters and identifies the most important factors that contribute to this structure [19, 20].

3.3.1. Hierarchical ascending classification (HAC)

The result of this classification is given in the form of a dendrogram (Figure 3) to distribute the sampling points of the water in homogeneous groups. This classification makes it possible to reduce the number of sampling sites in the case of a temporal monitoring program. Figure 3 presents the results of the classification of the sampling points in homogeneous groups. Three groups stand out in this classification: Group 1 (n=3), Group 2 (n=4) and Group 3 (n=3). In these groups, the associations between water samples are obvious. In group 1, the samples P3_HT and P5_DI have similar characteristics. It is the same for P4_OM and P2_CH (Group 2), P2_TR and P1_SU1 (Group 3). The parameters that discriminate these three groups of water samples were obtained by comparing their median values (Figures 4a-d).

- Group 1: it groups water samples P5_MO, P3_HT and P5_DI. This group is distinguished from the other two groups by a highest median value of THMT concentration (30.28 µg/L) and an average temperature of 24.15 °C. Group 1 sampling points should be monitored continuously in THMT formation.

- Group 2: it joins the points P4_OM and P2_CH, P1_SU2 and P4_PK and has two subgroups: the subgroup 2-1 consisting of the points P4_OM and P2_CH and the subgroup 2-2 consisting of the pointsP1_SU2 and P4_PK. Group 2 is characterized by THMT median value of 21.57 µg/L;

- Group 3: it essentially consists of points P3_PD, P2_TR and P1_SU1. It has two subgroups namely, subgroup 3-1 with a single point, P3_PD and subgroup 3-2 consisting of points P2_TR and P1_SU1. Group 3 is characterized by a low median value of THMT content (11.65 µg/L).

It is important to note that arsenic (As) concentrations are relatively close from one group to another, such as 0.0034, 0.003 and 0.0036 mg/L, respectively. For lead, the average content is relatively similar between the two first groups, 0.007 mg/L and 0.006 mg/L, respectively. On the other hand, group 3 presents a median value of 0.004 mg/L. For cadmium, the average content is relatively similar between groups 1 and 3, 0.0021 mg/L and 0.0023 mg/L, respectively. On the other hand, group 2 presents a median value of 0.003 mg/L. Cadmium is known as a toxic metal. The concentration of lead in tap water exceeds the allowed value for drinking water at certain sampling points; these values are detrimental to health. It is points P3_TR, P3_PD and P5_MO, respectively. A continuous control of the concentration of lead, a toxic metal, is therefore necessary [21].

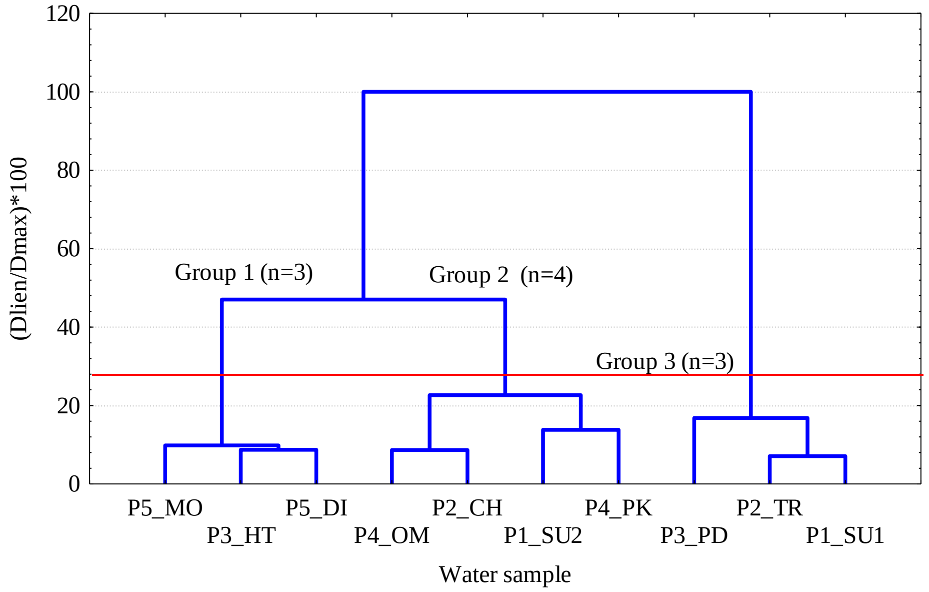

Figure 3: Dendrogram of water samples

The parameters that discriminate these three groups are: THMT, COT, Br^-, $Cl_{2\ res.}$, Fe, NH_4^+, Abs. UV and to a lesser extent turbidity and metals As, Cd, Cu and Pb (Figures 4a-d).

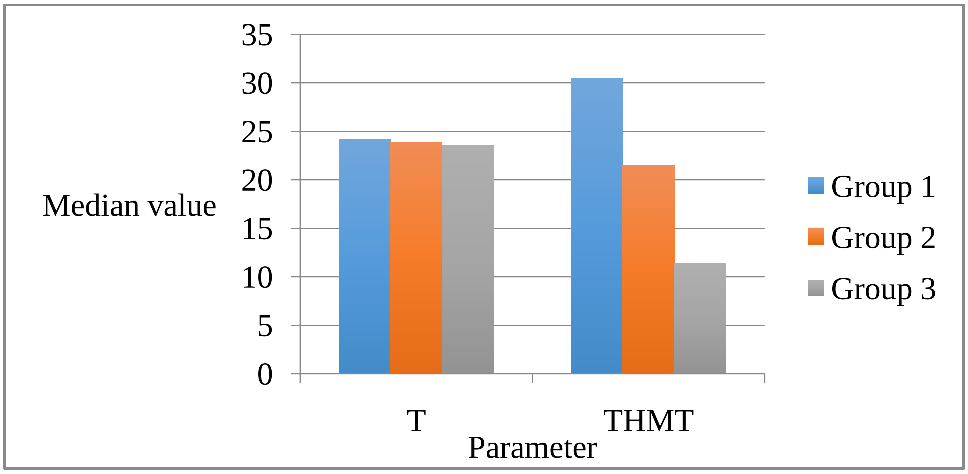

Figure 4a: Discriminant parameters (T and THMT)

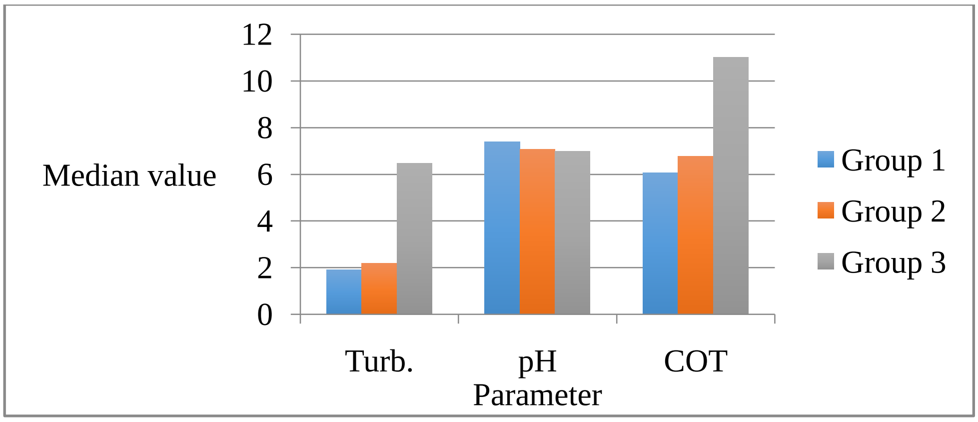

Figure 4b: Discriminant parameters (Turb., pH and TOC)

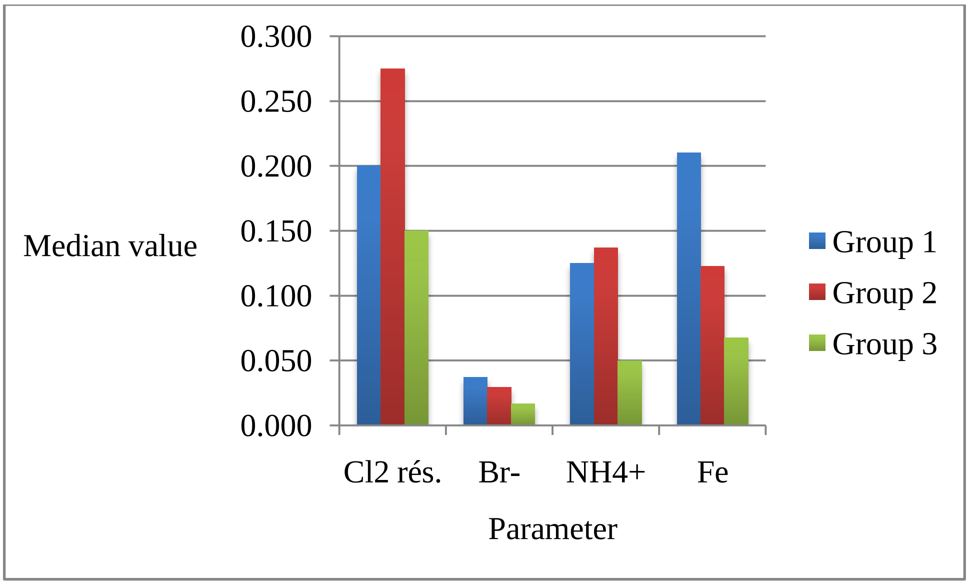

Figure 4c: Discriminant parameters ($Cl_{2.\ res}$, Br^-, NH_4^+ and Fe)

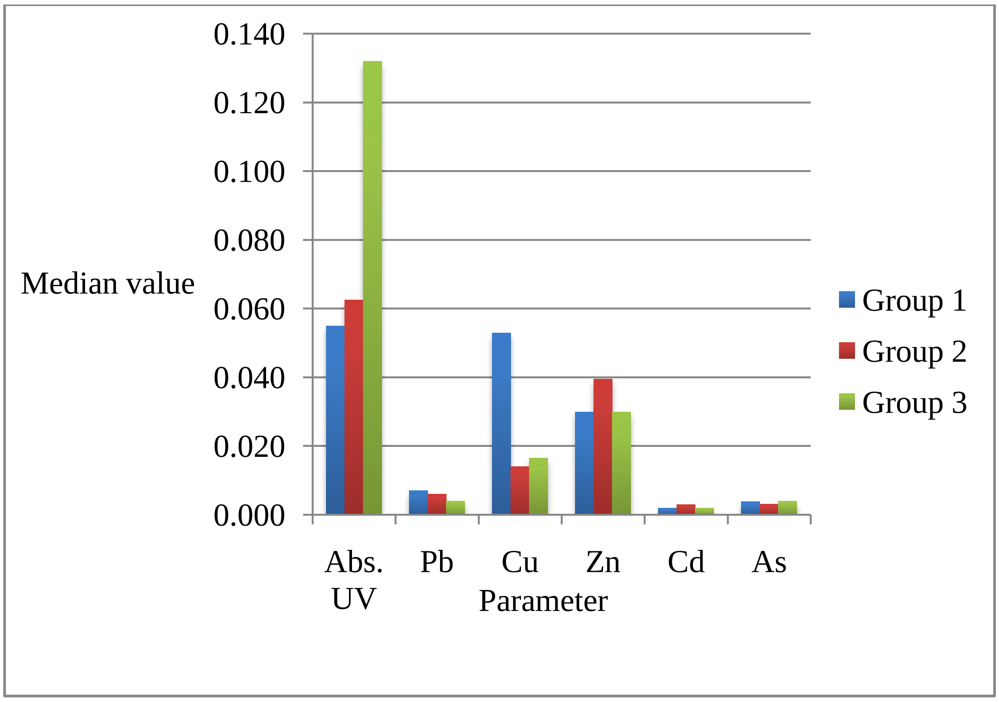

Figure 4d: Discriminant parameters (Abs., Pb, Cu, Zn, Cd and As)

3.3.2. Factor Analysis (FA)

Factor analysis was performed using the hydrochemical data obtained. Four factors of eigenvalues greater than 1 were extracted according to the Kaiser criterion, after standardization by a varimax rotation, which facilitates their interpretation [22]. These factors correspond to 83.47 % of the total variance. Variables that have the highest coefficients in absolute values contribute most to the definition of the factor. The information given by the other factors decreases with respect to the first factor. The eigenvalues and variances explained are presented in Table 7.

Table 7: Eigenvalues and variance of factors

Factor	Eigenvalue		% total variance	
	individual	cumulative	individual	cumulative
1	5.50	5.50	36.67	36.67
2	2.57	8.07	17.16	53.83
3	2.41	10.48	16.05	69.87
4	2.04	12.52	13.59	83.47

Factor 1: explains 36.67 % of the total variance. It is positively correlated with pH and THMT and reflects the acceptable nature of drinking water by its pH and is the presence of chlorination by-products THMTs. The factor 1 is therefore the axis of the reservoir because it explains 36.67 % of the total variance. Factor 1 is also associated with the presence of organic matter including TOC and Abs. UV (two characteristic quantities of the natural organic matter and precursor of SPC), turbidity (Turb.) and residual chlorine ($Cl_{2\ res.}$) in the distribution network.

Factor 2: it explains the largest percentage of the residual variance (17.16 %). It is the anthropic axis. It is positively correlated with lead and cadmium. These metals in the form of ions can have the same origin (accumulation sediment in pipes, incrustation in pipelines [23]. Factor 2 indicates water pollution by metals.

Factor 3: it explains 16.05 % of the total variance and is characterized by a strong positive correlation with the water temperature and negatively correlated with NH_4^+ (ammonium ions) which reflect the presence of organic matter. Ammonium ion is an important parameter to monitor because it forms chloramines in reaction with chlorine [24]. They are generally concentrated in biomass. Their source is mainly anthropogenic are introduced into the system either by leaching fertilizer applied, either by the discharge of wastewater. In the case of this study, ammonium ions are mainly attributed to the degradation of organic matter which is responsible for organic pollution [25].

Factor 4: it explains 13.59 % of the total variance, characterized by a positive correlation with residual chlorine ($Cl_{2\ res.}$) and a negative correlation with arsenic (As). Arsenic is dissolved in the geological structure that contains Na, K and Cl [26]. Arsenic is not associated with chlorine; this suggests different origins. The geological origin assumes that arsenic and chlorine would have a similar evolution, that is, these two compounds should evolve together. Therefore, an increase in chlorine is accompanied by an increase in arsenic. In our case, the majority of samples do not exhibit this relationship. Therefore, arsenic could come from the infiltration of runoff into the network, while chlorine is the effect of industrial activity during the process of chlorination of water [27].

Table 8: Factor loadings of the variables

Parameter	Factor 1	Factor 2	Factor 3	Factor 4
T	0.15	-0.10	**0.93**	-0.07
Turb.	**-0.78**	-0.32	0.01	-0.42
pH	**0.78**	-0.46	-0.02	-0.11
COT	**-0.93**	0.16	-0.14	0.09
Abs. UV	**-0.95**	0.13	-0.03	-0.14
$Cl_{2\ res.}$	**-0.71**	0.03	-0.01	0.66
Br-	0.33	0.03	0.57	0.57
NH_4^+	0.33	0.14	**-0.86**	0.1
THMT	0.67	0.01	0.63	0.27
Pb	0.29	**0.74**	0.19	0.23
Cu	0.49	-0.69	0.18	0.21
Zn	0.08	-0.67	0.29	0.39
Cd	-0.19	**0.91**	-0.03	0.01
Fe	0.52	0.19	0.55	-0.12
As	-0.02	0.10	0.17	**-0.90**

In bold, marked loadings > 0.65

4. Conclusion

The two field campaigns conducted during dry (September 2016) and rainy (March 2017) seasons have allowed to characterize the hydrochemical properties of the water in the network, and to determine the levels of pollutants present in the water. Factorial analysis using the principal component method has identified the existence of four factors that alone account for 83.47 % of the total water variance. The highest proportion was attributed to factor 1 which accounted for 36.67 % of the chemical composition of the water. In two seasons, the concentration of trihalomethanes in the distribution system water increases as distance from the treatment plant is increased. This increase is associated with a decrease in TOC and residual chlorine. The analysis shows that the water disinfection by-products (THMT) did not exceed the allowable limits. The study has shown that these waters are characterized by the significant presence of organic matter (TOC) greater than 2 mg/L, significant turbidity greater than 2 NTU. Metals such as lead and cadmium have higher values than those authorized by WHO. We can say that the drinking water supply system of Brazzaville is characterized by poor quality, it requires a thorough treatment and a regular control before it is distributed.

References

[1]. Bakhache B, Nikiforov I. Reliable detection of faults in measurement systems. International Journal of Adaptive Control and Signal Processing. (2000) 14(7), 683–700.

[2]. Lai T L. Information bounds and quick detection of parameter changes in stochastic systems. IEEE Transactions on information Theory. (1998) 44(7), 2917–2929.

[3]. Matini L, Moutou J M, Kongo-Mantono M S. Evaluation hydro-chimique des eaux souterraines en milieu urbain au Sud-Ouest de Brazzaville, Congo. Afrique Science. (2009) 05(1), 82–98.

[4]. Jachimowski A. Factors affecting water quality before treatment. Ecological Engineering. (2016) 18(1), 118-125.

[5]. Fahiminia M, Mosaferi M, Taadi R A, Pourakbar M. Evaluation of point-of-use drinking water treatment systems' performance and problems. Desalin Water Treat. (2014) 52(10-12), 1855.

[6]. Świderska-Bróż M, Wolska M. Influence of hydraulic parameters on water pollution system. Environment Protection Engineering. (2007) 33(4), 5-16.

[7]. Jain P, Sharma J D, Sohu D, Sharma P. Chemical analysis of drinking water of villages of Sanganer Tehsil, Jaipur District. Int. J. Environ. Sci. Tech. (2005) 2(4), 373-379.

[8]. Bergel T, Pawełek J, Rułka Z. Turbidity of water provided by the water supply systems in the Malopolskie Voivodeship. Environmental Pollution Control. (2009) 31(4), 61-64.

[9]. Jachimowski A. Factors affecting water quality in a water supply network. Journal of Ecological Engineering. (2017) 18(4), 110-117.

[10]. World Health Organization (WHO). Guidelines for drinking-water quality. Geneva, Switzerland. (2011)

[11]. Mishra B K, Priya T, Gupta S K, Sinha A. Modeling and characterization of natural organic matter and its relationship with the THMs formation. Global NEST Journal. (2016) 18(4), 803-816.

[12]. Di Cristo C, Esposito G and Leopardi A. Modelling trihalomethanes formation in water supply systems. Environmental technology. (2013) 34(1), 61-70.

[13]. Świderska-Bróż M, Wolska M. The principal parameters of water quality deterioration in distribution system. Engineering and Protection of Environment. (2005) 8(2), 159-169.

[14]. Adekunle A, Awokola O, Oluwasanya G, Laniyan A. Hydro-chemical studies for pollution assessment: A case study. Leonardo Journal of Sciences (2016) 29, 87-98 ISSN 1583-0233.

[15]. Nikolaou A, Lekkas T. The role of natural organic materials during formation of chlorination by-products. Acta Hydrochimica – Hydrobiologica. (2001) 29, 63-77.

[16]. Zeng X, Rasmussen T C. Multivariate statistical characterization of water quality in lake Lanier, Georgia, USA. J. Environ. Qual. (2005) 34, 1980-1991.

[17]. Sabri N A, Abdullah M P, Mat S, Elfithri R, Khalik W M. Evaluation of Hydrochemistry Variation in Water Quality of Cempaka Lake, Malaysia using Multivariate Statistical Analysis. J. Mater. Environ. Sci. (2016) 7(12), 4403-4410.

[18]. Lu. K L, Liu C W, Jang C S. Using multivariate statistical methods to assess the groundwater quality in an arsenic- contaminated area of Southwestern Taiwan, Environmental Monitoring and Assessment. (2012) 184(10), 6071-6085.

[19]. Memet V, Gökot B, Bekleyen A, Sen B. Geochemistry of the Tigris River basin, Turkey: Spatial and seasonal variations of major ion compositions and their controlling factors. Quaternary International. (2013) 304, 22-32.

[20]. Nepolian M, Chidambaram S, Thivya C, Paramaguru P, Pradeep K, Banaja P R. Assessment of Hydrogeochemical and Quality studies in groundwater of Villupuram District, Tamilnadu, India. Int. Res. J. Earth Sci. (2016) 4(3), 1-10.

[21]. Banerjee S, Chattopadhyaya M C. Adsorption characteristics for the removal of a toxic dye, tartrazine from aqueous solutions by a low cost agricultural by-product. Arabian Journal of Chemistry. (2017) 10(2), 1629-1638.

[22]. Kaiser H F. The varimax criterion for analytic rotation in factor analysis. Pyrometrical. 23, (1958) 23, 187-200.

[23]. Kwietniewski M, Kowalska B, Wąsowski J, Chudzicki J, Kowalski D, Miszta-Kruk K. Problems of water quality management in distribution systems. Water and Sanitary Engineering. (2012) 3, 117-121.

[24]. Regan J M, Gregory W, Noguera D R. Ammonia- and Nitrite-Oxidizing Bacterial Communities in a Pilot-Scale Chloraminated Drinking Water Distribution System. Applied and environmental microbiology. (2002) 68(1), 73-81.

[25]. Gieseke A, Purkhold U, Wagner M, Amann R, Schramm A. Community structure and activity dynamics of nitrifying bacteria in a phosphate-removing biofilm. Appl. Environ. Microbiol. (2001) 67, 1351-1362.

[26]. Mosaferi M, Shakerkhatibi M, Dastgiri S, Asghari M, Khataee A, Sheykholeslami S. Natural Arsenic Pollution and Hydrochemistry of Drinking Water of an Urban Part of Iran. Avicenna J Environ Health Eng. (2014) 1(1), 7-16.

[27]. Bakalowicz M. Géochimie des eaux karstiques. Une méthode d'étude de l'organisation des écoulements souterrains. Sci., univ. Besançon, Géologie. (1976) 25(3), 49-58.