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Monitoring and Physico-Chemical Analysis of Water in a Provincial Hospital Center in Morocco

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Abstract

In hospitals, water plays a very important role. Its use varies from one service to another, while its contamination can reduce its quality and can occur at any time between the source and the points of use at the unit care level. The health risks linked to water use in hospitals are chemical and microbiological, in particular for users and health professionals. For this reason, our work aims to assess the physico-chemical quality of water in the provincial hospital center IBN BAJA, TAZA in Morocco. The analyses were carried out on 72 samples during one year in six specialized surgical care units, at a rate of six samples per month per care unit. The following physico-chemical parameters: temperature, pH, turbidity, conductivity(EC), dissolved oxygen, nitrite (NO_2^-), nitrate (NO_3^-), Complete Alkalimetric Titration (T.A.C.), iron (Fe^{2+}), aluminium (Al), Oxidability to potassium permanganate (Oxy to $KMnO_4$), magnesium (Mg^{2+}), ammonium (NH_4^+), manganese (Mn^{2+}), chlorides (Cl^-) and Calcium (Ca^{2+}); were measured.

The results were processed and statistically analysed by Principal Component Analysis, which showed that the studied waters are conform to drinking water standards from a physico-chemical point of view. They do not present any risk to consumers, especially to immune-compromised patients and health professionals.

Key words: hospital, water, physico-chemical, surgery, PCA

INTRODUCTION

Water is an essential element for human life and is important for the satisfaction of population needs, whether it is used for consumption, cleanliness, food hygiene and care. Hospitals are among the public institutions that consume very large amounts of water, averaging 750 litres per day per bed depending on the hospital size [1]. Water quality monitoring is necessary in hospitals to prevent microbiological or chemical contaminations. In hospitals, the inadequacy between water quality and its use exposes both patient and institution to major risks of nosocomial infections of water origin and this contamination can occur through the digestive or respiratory tracts, through cutaneous and mucous membrane contact or through parenteral path [2]. It is estimated that 4% of deaths worldwide and 5.7% of disease burden is related to water's sanitation and hygiene [3].

The contamination level varies qualitatively and quantitatively over time and according to the departments and hospitalized patients. Contamination also depends on humidity and temperature conditions. Water-related infectious diseases are a major problem and are the main cause of population morbidity and mortality [4].

Water consumption may present a short-term microbiological risk, but the medium- and long-term risks are associated with continued consumption of chemically contaminated water [5]. Indeed, some bacteria can remain in water and adapt to all physicochemical environmental conditions before any contamination [6]. Moreover, it has been shown that some chemical contaminants have adverse effects on human health as a result of exposure to water, especially drinking water [7].

Therefore, there is a need to identify and assess the main health risks associated with water use in health care facilities, in order to determine how to address and how to control these risks.

For this purpose, the present study concerns the assessment of physico-chemical quality of water network in a provincial hospital center of IBN BAJA TAZA in Morocco.

MATERIALS AND METHODS

A prospective study was carried out over a period of 12 months, from October 2018 to September 2019, in a provincial hospital center: IBN BAJA Taza in Morocco having a capacity of 317 beds and composed of two buildings linked by a footbridge. The old building created in 1956 contains the pediatrics, child surgery and gynecology-obstetrics surgery departments, while the new building created in 1994, houses the medical department; men and women surgery, emergency resuscitation, medico-technical departments and administration.

The samples were taken in six hospital departments specialized in surgery: men's surgery, women's surgery, central operating room, sterilization, gynecology and infant surgery. The sampling frequency adopted during the study period (October 2018-September 2019) was one sample per month for each unit. Sixteen parameters were measured, including eight on site[8]: temperature, conductivity, pH using a multi-parameter analyzer Type CONSORT - Model C535, turbidity using a turbidimeter Type HACH-Model 2100P and dissolved oxygen both by the Oximeter and by the Winkler titration method [9] and volume for bicarbonates, calcium and magnesium (table 1).

Collection, transport and storage of water samples refer to protocols and procedures defined by the National office of drinking water (ONEP) [9, 10]. The methods used at the Laboratory are: volumetric for chlorides and oxidability; and based on molecular absorption spectrophotometry for sulphate, nitrate, nitrite and ammonium ions [10, 11].

RESULTS AND DISCUSSION

Monitoring and physico-chemical evaluation of hospital water plays a very important role in determining the quality of water used in different units. To meet this objective, we have analyzed the different physico-chemical parameters of water from specialized surgery departments in a provincial hospital center of Taza (Morocco) during a period of 12 months.

In this hospital centre, minimal temperature was recorded in February with an average of 15.73 °C, while the upper average temperature was recorded in October with 24.51 °C (Fig. 1). This shows that water temperature varies from one month to another which may be due to the influence of ecological factors [12]. In fact the variation in water temperature depends on the atmospheric variation of during seasons [13]. In relation to services, the minimum average was observed in the women's surgery department with a value of 18.45°C and the maximum average in the children's surgery department with a value of 18.74°C (table 1).

With respect to hydrogen potential (pH), characterized by ions concentration in water [14], maximum value (7.69) and minimum one (7.14) were respectively observed in March and April (fig2). Moreover, mean value was observed in women's surgery ward and the maximum value was recorded in the children's surgery unit (table 2). Hence, the values found in this study respect both Moroccan drinking water standards "NM 03.7.001" [15] and WHO ones [16].

Turbidity is an optical characteristic of water which is essential to determine its quality [17]; and is due to the existence of clay, silt and fine particles of organic and inorganic substances [18]. Results obtained by the turbidimeter in this study recorded an average value of 0.66 NTU in October, as well as variations between months in an interval of 0.42 NTU and 0.52 NTU. These values are consistent with Moroccan standards which require that the median turbidity must be ≤ 1 NTU and the sample one must be ≤ 5NTU (fig3).

Conductivity constitutes a good marker of water origin, degree, by appreciating the quality of ions, their concentration and their mobility in an electric field, [19]. The measurements carried out gave results between 691.33 µs/cm in October and 1235 µs/cm in March, May and July (fig4). This showed that electrical conductivity variation remained in line with Moroccan water drinking standards [15].

Whereas dissolved oxygen, is a key indicator of water pollution which plays an important role in stimulating corrosion of metal pipes [20]. In this study, the average dissolved oxygen values are between 7.13 for March, April, May, July, August, September, October; and 7.35 mg/L for the other months (January, February, November and December).

Furthermore, average calcium (Ca^{2+}) concentrations varied between 41.06 mg/L in April and 110mg/L in January & February, with a maximum value recorded in November (154 mg/L). Generally in comparison with the defined standards according to Rodier (2009) and the Moroccan standards [15] which stipulate that a value > 200 mg Ca^{2+}/L in a water represent a risk for its users, these values are close to normal (fig6).

Similarly, the average values recorded for magnesium (Mg^{2+}) are 1.10 mg/L in February and October, 52.04 mg/L in September and July, and 58.96mg/L in April (fig7). It's important to note that decrease in Mg^{2+} concentrations increases the risk of certain cardiac and metabolic diseases in humans [21,22].

As regard for chloride (Cl^-), the highest value was observed in March with an average of 332.51mg/L, while the lowest value was recorded in May with an average of 93.18mg/L (fig8). This ion remains among the most important inorganic anions in water due to its high solubility [21].

Regarding Nitrite (NO_2^-), the mean value recorded was 0.0004mg/L, for all months, except for April when 0.0042 mg/L was recorded. Maximal value was observed in pediatric surgery 0.025mg/L and can be explained by some problems in the pediatric surgery service channels on one hand and in old buildings on the other hand.

Nitrate (NO_3^-), on the other hand, comes from the decomposition of proteins from animals and plants organic matter, during the nitrification phenomenon realized by nitrifying bacteria. In this hospital, the average nitrate value recorded was 10.57 mg/L in November, and it reached 18.37 mg/L in July (fig9). A maximum value was recorded at the child surgery department level (table2).

Oxidability by potassium permanganate allows to estimate total organic pollution of water and to appreciate effectiveness of oxidation treatments. The average values recorded during this study were 0.84 mg/L in October and 1.01 mg/L in July. Whereas for the various hospital departments, the maximum value recorded was 1.06 mg/L in the children's surgery unit.

Regarding the Complete Alkalimetric Titration (CAT), which represents the concentration of carbonate ions, bicarbonates, hydroxides, phosphates and salts of humic and fulvic acids present in water [23], the maximum value was obtained in November (5.51), while the minimum value (3.55mg/L) was recorded in August (fig10). As for the different departments, it is still the child surgery department which registered the maximal value (4.58mg/L).

Table 1: The physico-chemical components analysis methods

Parameter	Analysis method	Unit
Conductivity	Conductivity meter Type CONSORT - Model C535	µs / cm
Turbidity	Turbidimeter Type HACH-Model 2100P	NTU
Ph	pH Meter CONSORT Type - Model C535 1 - 4 Temperature Mercury thermometer / multi-parameter analyser CONSORT Type - Model C535	1-14
Dissolved oxygen	Winkler titration method	. mg O2 /L
Title Alkaline	Titrimetry with 0.1N hydrochloric acid with phenophthalein	meq /L
Title Full Alkaline	Titrimetry with 0.1N hydrochloric acid with methyl orange	mg / L
Calcium	Hardness Titration complexometry with EDTA 0.02M with HSN	mg /L
Magnesium	Deducted by difference between total hardness and calcium	mg /L
Oxidability	Potassium permanganate in acidic medium and boiling for 13 min	mg O2 /L
Nitrates	Sodium salicylate	mg /L
Nitrites	Zamballi reagent method	mg /L
Ammoniums	Sodium phenol nitroprusside and chlorine solution	mg /L
Chlorides	Determination by mercuric nitrate in the presence of an indicator: diphenylcarbazone	mg /L
aluminium	flame atomic absorption spectrometry	mg/L
iron	molecular absorption spectrometry	mg/L
Temperature	Mercury thermometer / multi-parameter analyser CONSORT Type - Model C535	° C

As for ammonium, representing the most toxic form of nitrogen, the maximum value was detected in October (0.01mg/L) and the maximum average was also recorded in the children's surgey ward.

Regarding iron which presence modifies water’s taste and colour and also stimulates the "iron bacteria" growth, the maximum average value recorded during the whole year was < 0.0007mg/L in March while the maximum value recorded in departments was observed in the sterilization unit (0.001mg/L).

Manganese and aluminium were not detected in this hospital samples, even though manganese is mainly used in iron and steel alloys productions or as an oxidant for cleaning, bleaching and disinfecting; and aluminium is the most abundant metallic element, making up about 8% of the earth's crust. Aluminium salts are widely used as coagulants in water treatment to reduce organic matter content, colouration, turbidity and microbial load.

Correlation study and Principal Component Analysis:

The obtained results demonstrate that majority of the water physico-chemical quality variables at IBN BAJA hospital center meet national and international standards. Moreover, there is no significant correlation between the studied parameters, according to the study of correlation and agreement between the following 14 variables: temperature, pH, turbidity, conductivity (EC), dissolved oxygen, nitrite (NO_2^-), nitrate (NO_3^-), full alkalimetric titration (CAT), iron (Fe^{2+}), aluminum (Al), oxidizability by potassium permanganate (Oxy in KMnO4), magnesium (Mg^{2+}), ammonium (NH_4 +), manganese (Mn^{2+}), chlorides (Cl-) and calcium (Ca^{2+}).

With regard to the following chemical elements: Ca^{2+}, NH_4^+ and Iron in water there was no significant correlation with the other variables. While a positive but non-expressive correlation was revealed between $KMnO_4$, Oxidability and Cl^- with the other parameters. In turn, water temperature inferred positive but non-significant correlations just with pH (R = 0.105), turbidity (R = 0.276) and NH_4^+ (R = 0.294).

For water pH, an unquestionable correlation was recorded with Turbidity, Dissolved Oxygen, TAC, Ca^{2+} and NH_4^+, and negative correlations were observed with conductivity (R = -0.322), Mg^{2+} (R = -0.532), $KMnO_4$ oxidation (R = -0.65), NO_2^- (R = -0.030), NO_3^- (R = -0.448), Cl^- (R = -0.542), Fe^{2+} (R= -0.205).With respect to conductivity, positive was proved only with TAC (R= 0.346), Ca^{2+} (R= 0.100), Mg^{2+} (R= 0.402), $KMNO_2$ (R= 0.396), NO3-(R= 0.691), Cl^- (R= 0.314) and Fe^{3+}(R= 0.339). Similarly, a positive correlation was found between turbidity and the following parameters: TAC, Ca^{2+}, $KMnO_2^-$, NO_2^-, NH_4^+ oxidation (table 3).

Concerning the dissolved oxygen study, positive agreement was found between TAC (R=0.287) and Ca^{2+} (R=0.416).

Furthermore, TAC showed a significant positive agreement with Ca^{2+} (R=0.640) and non-significant agreements with Cl^- (R=0.234) and Iron (R=0.105).

Negative correlations have been observed between "Mg^{2+} and NH_4^+" on the one hand, and between "NO_2^- with Cl^- and NH_4^+" on the other hand. Other significant positive correlations were found between "Mg_2^+ and NO_3^-" (R=0.766) as well as between NO_3^- and each of Cl^- (R= 0.518) and Iron (R=0.419).

Table 2: the mean values of water physico-chemical parameters in hospital care units

	P1	P2	P3	P4	P5	P6	WHO.STA	MOR. STA
Tenperature °C								
Mean	18.45	18.56	18.47	18.70	18.68	18.74	-	-
SD	2.42	2.52	2.63	2.65	2.41	2.39		
MIN	15.40	16.00	15.00	15.50	16.00	16.40		
MAX	24.40	24.50	24.60	24.60	24.50	24.50		
pH								
Mean	7.33	7.33	7.34	7.34	7.34	7.35	6.5- 9.5	6.5- 8.5
SD	0.17	0.16	0.16	0.15	0.13	0.15		
MIN	7.18	7.11	7.11	7.11	7.13	7.10		
MAX	7.78	7.74	7.72	7.68	7.63	7.64		
Cond µS/cm								
Mean	981.00	976.75	988.25	984.91	986.33	998.50	2000	2700
SD	214.18	210.22	190.85	193.33	198.24	187.67		
MIN	672	682	690	675	677	652		
MAX	1270	1260	1244	1270	1240	1255		
Turbidity (NUT)								
Mean	0.49	0.47	0.51	0.44	0.46	0.54	< 5	≤ 5
SD	0.08	0.08	0.09	0.09	0.08	0.29		
MIN	0.34	0.36	0.32	0.31	0.33	0.28		
MAX	0.62	0.59	0.63	0.61	0.62	1.40		
O2 Dissolved mg/L)								
Mean	7.25	7.33	7.30	7.15	7.13	7.08	≥ 5	5 ≤ O2 ≤ 8
SD	0.12	0.09	0.05	0.16	0.16	0.21		
MIN	7.12	7.16	7.24	6.96	6.92	6.68		
MAX	7.52	7.44	7.40	7.48	7.36	7.52		
CAT (méq/L)								
Mean	4.46	4.45	4.50	4.46	4.50	4.58	< 15	-
SD	0.71	0.66	0.73	0.68	0.76	0.64		
MIN	3.50	3.60	3.60	3.50	3.50	3.60		
MAX	5.60	5.50	5.60	5.50	5.60	5.50		
Ca++ (mg/L)								
Mean	86.11	86.52	85.95	85.29	87.43	89.53	100	-
SD	28.85	29.50	29.01	29.07	27.54	27.29		
MIN	41.60	40.80	41.60	40.00	40.80	41.60		
MAX	160.00	158.40	155.20	151.20	147.20	152.00		
Mg++ (mg/L)								
Mean	27.90	28.28	27.84	28.45	27.56	28.17	50	-
SD	20.33	20.37	19.98	20.47	19.46	20.01		
MIN	0.64	0.52	0.64	0.84	0.68	0.72		
MAX	60.48	59.04	57.60	60.48	57.12	59.04		
Oxy au KMnO4 (mg/L)								
Mean	0.87	0.88	0.84	0.95	0.95	1.06	< 5	5
SD	0.18	0.11	0.10	0.14	0.09	0.14		
MIN	0.56	0.72	0.64	0.80	0.88	0.88		
MAX	1.12	1.00	1.00	1.12	1.12	1.44		
NO2- (mg/L)								
Mean	0.0000	0.0001	0.0000	0.0003	0.0003	0.0038	< 0.1	0.5
SD	0.0000	0.0003	0.0000	0.0005	0.0005	0.0073		
MIN	0.0000	0.000	0.000	0.000	0.000	0.000		
MAX	0.0000	0.001	0.000	0.001	0.001	0.025		
NO3- (mg/L)								
Mean	13.73	14.27	14.21	14.31	14.42	15.55	50	50
SD	2.31	2.96	2.42	2.84	3.13	4.05		
MIN	10.40	10.20	11.04	10.32	10.18	10.04		
MAX	17.25	18.14	17.83	18.09	18.43	21.45		
NH4+(mg/L)								
Mean	0.0002	0.0000	0.0010	0.0011	0.0014	0.0084	0.5	0.5
SD	0.0004	0.0004	0.0018	0.0018	0.0020	0.0227		
MIN	0.0000	0.0000	0,00000	0,00000	0,00000	0,00000		
MAX	0.0001	0.0000	0,00407	0,00407	0,00407	0,08000		
Cl- (mg/L)								
Mean	184.44	182.66	181.18	177.24	184.24	190.25	< 250	750
SD	61.58	65.04	64.18	60.98	63.49	63.84		
MIN	95,85	92,30	90,53	92,30	88,75	99,40		
MAX	330,15	337,25	333,70	323,05	330,15	340,80		
Fe (mg/L)								
Mean	0.0003	0.0003	0.0011	0.0000	0.0000	0.0008	<0.3	0.3
SD	0.0009	0.0009	0.0012	0.0009	0.0009	0.0011		
MIN	0,000	0,000	0,000	0,000	0,000	0,000		
MAX	0,003	0,003	0,003	0,000	0,000	0,003		

P1 : Woman surgery
P2 : Men surgery
P3 : Sterilization

P4 :Central operating theater
P5 : Gynecology
P6 : Infant surgery

SD : Standard deviation
WHO.STA : World Health Organisations standards
MOR .STA : Moroccan standards

Table 3 : Correlation matrix

		T°	pH	Condu	Turb	O2diss	TAC	Calcium	Mg2+	KmnO	NO2-	NO3-	NH4	CL-	Fe2+
Corrélation	T°	1,000													
	pH	,105	1,000												
	Condu	-,344	-,322	1,000											
	Turb	,276	,382	-,128	1,000										
	O2diss	-,287	,219	-,170	-,190	1,000									
	TAC	-,429	,097	,346	,014	,287	1,000								
	Calcium	-,219	,306	,100	,125	,416	,640	1,000							
	Mg	-,074	-,532	,402	-,244	-,386	-,407	-,769	1,000						
	KmnO	-,065	-,091	,396	,092	-,575	-,021	-,112	,295	1,000					
	NO2-	,056	-,030	-,049	,210	-,300	-,040	-,166	,134	,253	1,000				
	NO3-	-,085	-,448	,691	-,126	-,489	-,200	-,477	,766	,490	,071	1,000			
	NH4+	,294	,134	-,109	,710	-,457	,026	,018	-,103	,222	,343	-,042	1,000		
	Cl	-,013	-,542	,418	-,272	-,189	,239	-,256	,499	,170	-,029	,518	-,056	1,000	
	Fe2+	-,205	-,381	,339	-,089	-,049	,109	-,235	,303	,178	,161	,419	-,028	,446	1,000

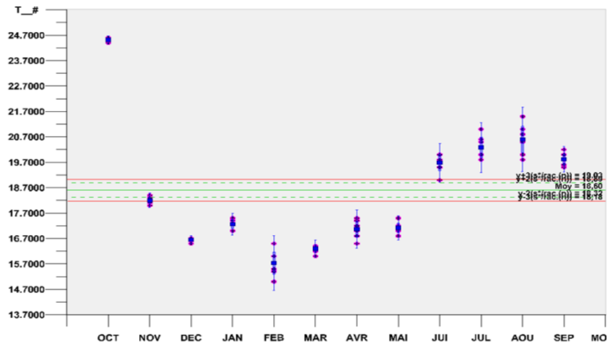

Figure1: Monthly temperature variation in Taza hospital center

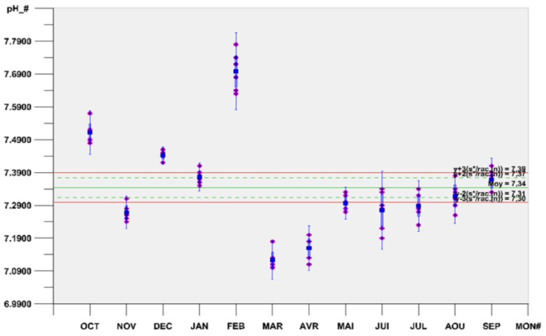

Figure 2: Monthly PH variation in Taza hospital center

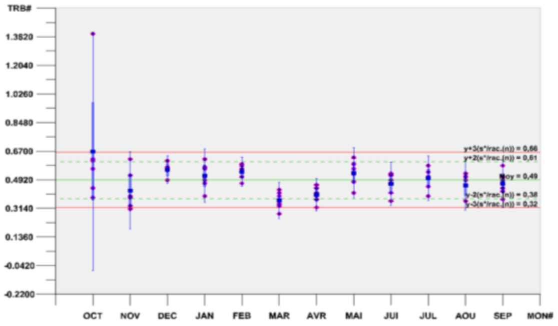

Figure 3: Monthly turbidity variation in Taza hospital center

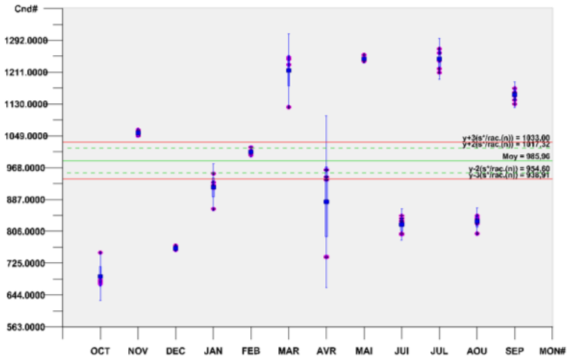

Figure 4: Monthly conductivity variation in Taza hospital center

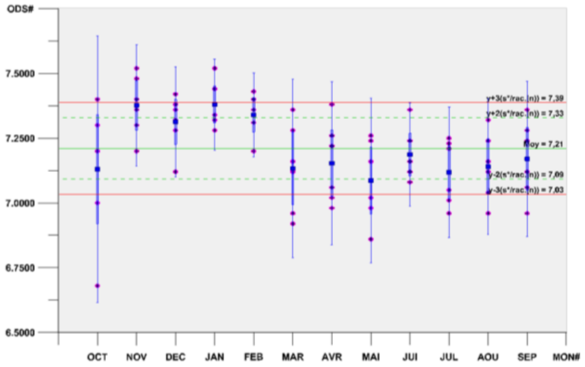

Figure 5: Monthly dissolved oxygen variation in Taza hospital center

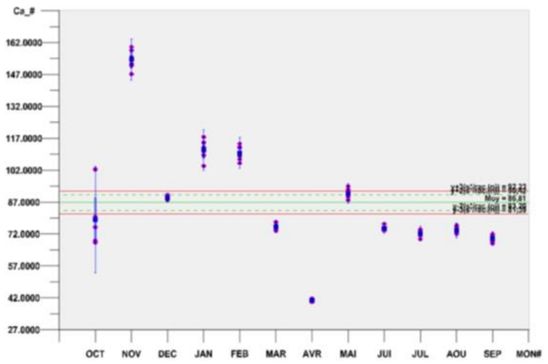

Figure 6: Monthly calcium variation in Taza hospital center

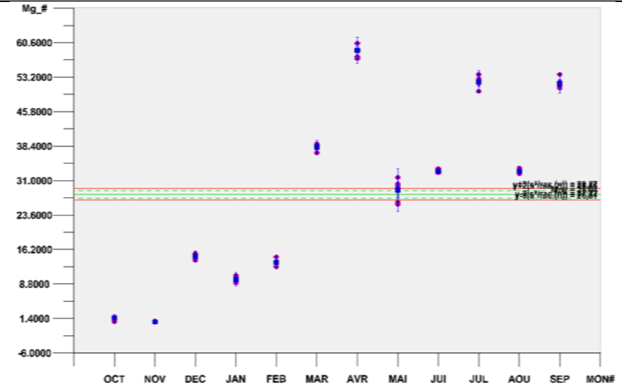

Figure 7: Monthly Magnesium variation in Taza hospital center

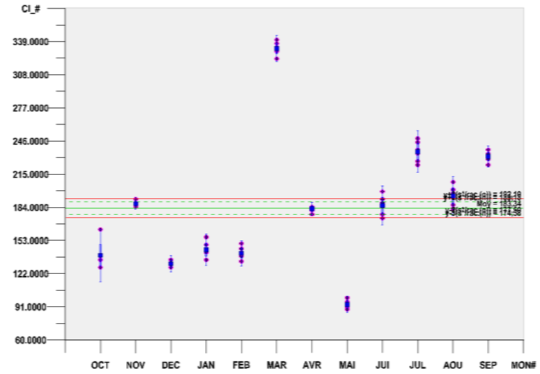

Figure 8 : Monthly Chloride variation in Taza hospital center

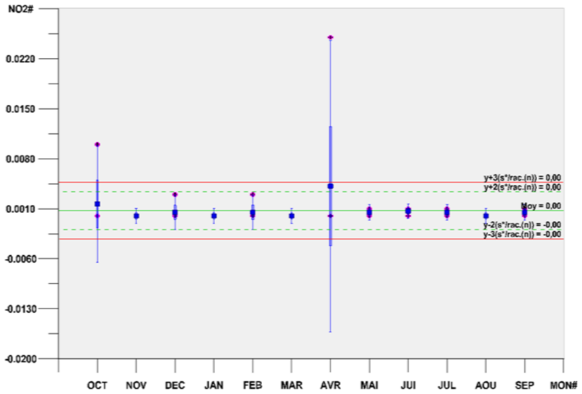

Figure 9 : Monthly nitrite (NO2-) variation in Taza hospital center

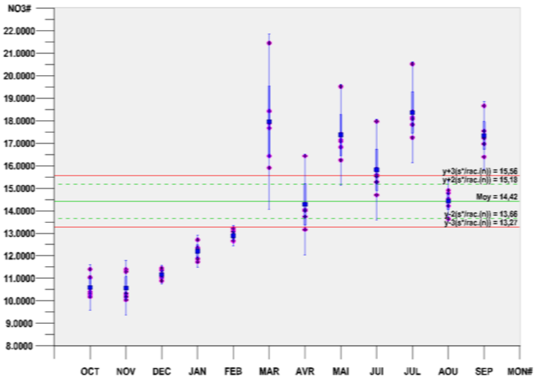

Figure 10 : Monthly nitrate (NO3-) variation in Taza hospital center

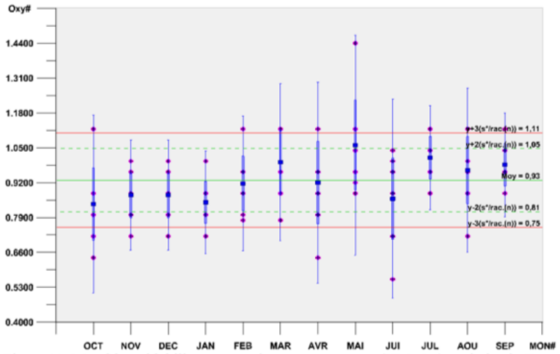

Figure 11: Monthly oxidability to potassium permanganate ($KMnO_4$) variation in Taza hospital center

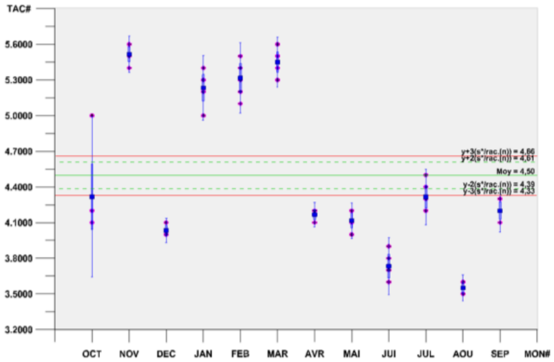

Figure 12: Monthly alkalimetric variation in Taza hospital center

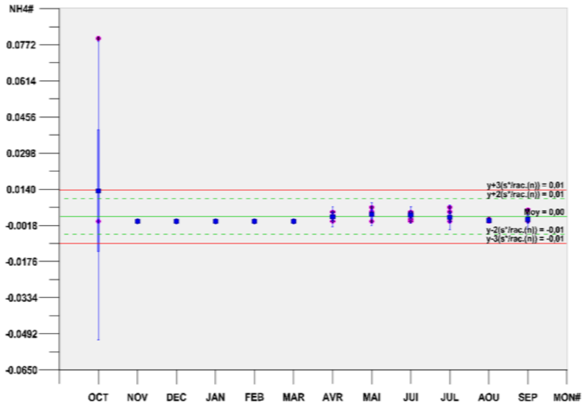

Figure 13 : Monthly ammonium NH4+ variation in Taza hospital center

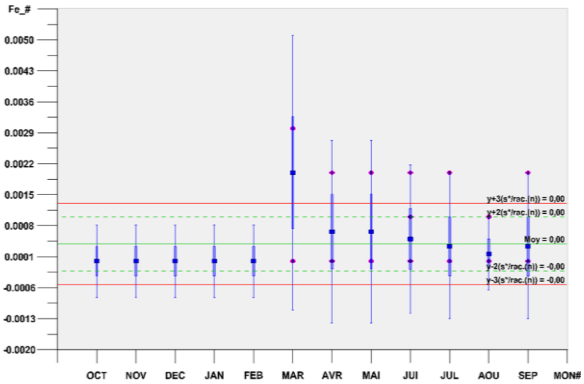

Figure 14 : Monthly Iron variation in Taza hospital center

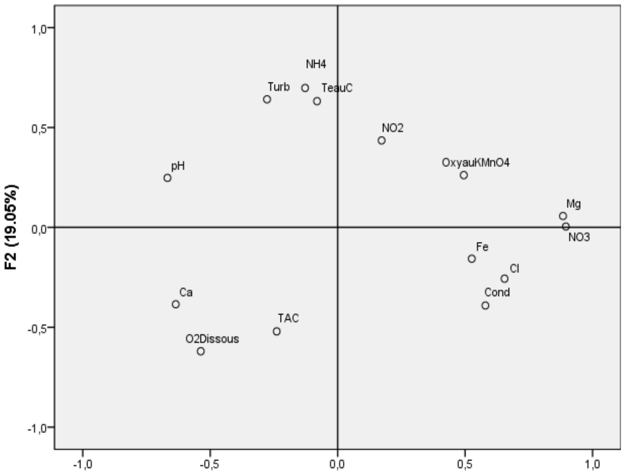

Fig 15 : Variables projection on the first factorial plane*

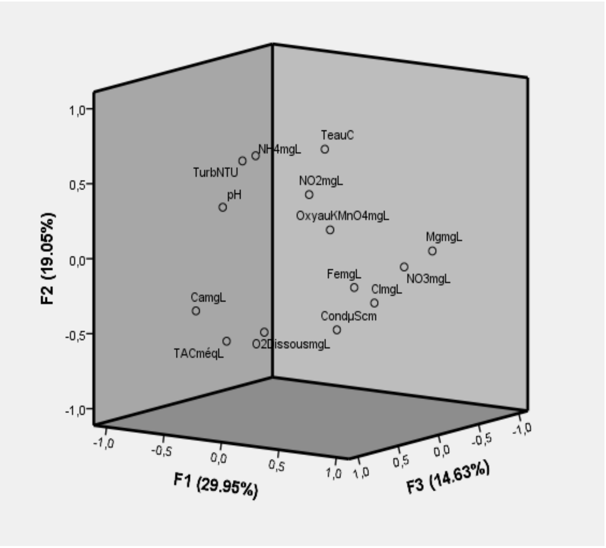

Fig 16 : Variables projection on the second factorial plane

- **The principal component analysis :**

The principal component analysis of our results reveals that the majority of data can be explained by three factorial plans, which account for 63.64% of the total data with 29.95% for the F_1 axis, 19.05% for the F_2 axis and just 14.63% for the F_3 axis.

With regard to the "F1-F2" plan study (fig 15) , its positive part is constituted by : NO_3^-, Mg^{2+} / Cl^-, Conductivity, Fe^{2+}, $OxyKMnO_4$ and NO_2^-, while its negative part is composed of: pH, Ca^{2+}, NH_4^+, TAC, Temperature, dissolved O2 and Turbidity. With respect to the study of the positive part of the F2 factor, it is established by NO_3^-, Mg^{2+}, pH, NO_2^-, NH_4^+, Turbidity, Temperature, and Oxy au $KMnO_4$. Comparing this with the factorial design "F1-F3", it is found that its positive part is represented by NO_3^- , pH, TAC, Ca^{2+}, Conductivity, Fe^{2+}, Oxidability $KMnO_4$, NH_4^+, Turbidity, NO_2^-, Cl, while the negative part is formed by : Dissolved O_2, Temperature and Mg^{2+} (fig16).

CONCLUSION

This study was carried out for the first time at the provincial hospital center of Taza and the results obtained show that the spatio-temporal variation of the physico-chemical quality in the water points studied meets national and international standards despite some increases and decreases in certain parameters during the year in the different services studied. Moreover, neither Mn nor Al was detected in the analyzed water samples. Furthermore, no significant correlation was found between the studied parameters, according to correlation and agreement study between the 14 variables tested. Hence, analysed waters have physico-chemical properties that make them recommended both for human consumption and for use in different care types.

Conflict of Interest

Authors declare No Conflict of Interest.

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