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Physico-chemical parameters of plastic bag water sold at Man (Côte d'Ivoire)

Kossonou Yao Kamelé*[1], Koffi Yao Mesmin[2], Koffi Affoué Carole[1], Adingra Kouassi Martial-Didier[3], Mea Mea Wilfried[1], Tano Kablan[3]

[1]*Department of Agronomic Forest and Environmental Engineering, Man University, Man, Côte d'Ivoire*

[2]*Department of Sciences of Nature, Nangui Abrogoua University, Abidjan, Côte d'Ivoire*

[3]*Department of Food Science and Technology, Nangui Abrogoua University, Abidjan, Côte d'Ivoire*

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Abstract

The aim of this study is to assess the physico-chemical quality of water packaged in semi-industrial bags and those packaged in an artisanal way in the town of Man (Côte d'Ivoire). Thus, three brands of semi-industrial water (Casa Plus, Bonheur and Félicité) and three neighborhoods (Domoraud, Camp Plus and Thérèse) where women produce water in bag in an artisanal way were targeted. Parameters such as pH, conductivity, temperature, turbidity and minerals were determined according to ISO and Hach methods. It appears that the samples of water in artisanal and semi-industrial bags sold in Man comply with the rules of sanitary quality of drinking water for all the parameters tested except the turbidity. As the most important effect linked to turbidity is its ability to protect microorganisms against disinfection, it would be important to assess the bacteriological quality of these bags water sold in the municipality of Man.

* **Corresponding Author:** Kossonou Yao Kamelé ✉ kossonou.recherche@gmail.com

Introduction

Water is an essential element for life of humans, animals and plants (Kahoul & Touhami, 2014). It therefore deserves special attention as it can be the object of serious threat due to human activities. According to Zmirou *et al.* (2003), all human activities calling on the mobilization of natural resources lead to the production of waste (solid and liquid) and gaseous effluents capable of causing a transfer of pollutants. Water could be a source of disease due to its contamination by household, industrial, agricultural and organic wastes. It is for this reason that the quality of drinking water appears to be a worrying issue all over the world (Blé & Mahaman, 2009). The risks of the spread of hydric diseases such as cholera, hepatitis, dysentery are becoming greater (Brangeon, 2015).

The WHO guidelines (2017) indicate that water safety and quality are fundamental for human development and well-being. However, drinking water is water intended for human consumption and which is not likely to endanger health in its current use.

In the world, especially in Africa, the most recorded health risk is linked to consumption of contaminated water. This fact constitutes a real problem in terms of public health (Santsa *et al.*, 2018). Given the daily water requirements for dehydration, the marketing of water has increased to the point of selling drinking water in bag. In Côte d'Ivoire, the marketing of plastic bag water is available in two semi-industrial and artisanal forms. The sale of these bags waters offers several significant socioeconomic opportunities to the populations (Blé *et al.*, 2015). Thus, because of their affordable cost, their refreshing nature and their accessibility, often ice-cold water packaged in bags are offered to consumers at various points in the municipalities of Côte d'Ivoire, particularly in Man, in often precarious conditions. These waters are often preferred to tap water despite the questionable quality and the lack of hygiene observed around the sale of these waters. According to WHO-UNICEF (2017), 2.1 billion people do not have access to safe drinking water in their homes and more than double do not have safe sanitation services. In addition, nearly 3.1% of deaths in the world are explained by poor quality of water, sanitation and hygiene. Hydric diseases that can be contracted during the consumption of this water are diseases linked to biological agents or diseases linked to physico-chemical parameters (Diop, 2006; Frantzy, 2017).

For the acceptance of water for drinking, it must me*et al*l quality guidelines set by WHO. It exceeds a certain range of physico-chemical parameter and promotes a complete absence of faecal germs indicative of contamination. Sanitation and access to drinking water are therefore essential elements for improving living conditions and human health (Wari, 2012). It is therefore necessary to monitor the physico-chemical quality of the semi-industrial and artisanal type water in bags consumed at Man (Côte d'Ivoire). The general objective of this work is to assess the health risk linked to the physico-chemical quality indicators of the bags water sold at Man. This specifically involves measuring the pH, electrical conductivity, turbidity and determining the mineral profile of these bags water consumed in Man (Côte d'Ivoire).

Material and methods

Material studied

The bags water sold in the streets of Man (Côte d'Ivoire) was used for the various physico-chemical analyzes. These are "Casa Plus", "Bonheur" and "Félicité" waters selected for the water packaged in semi-industrial bags and the water in artisanal bags taken from the "Thérèse", "Domoraud" and "Camp Plus" districts.

Methods

Sampling

In the municipality of Man, there are mainly three brands of semi-industrial bagged water. These are the "Casa Plus", "Bonheur" and "Félicité" brands. Thus, 18 plastics bags water of each brand were purchased from 18 different vendors on the same day. A total 54 semi-industrial water bags were needed for the physico-chemical analyzes. Similarly, 81 handcrafted bag water were purchased from 27 different vendors with three bags per vendor in three districts of the city of Man. These different bags water were sent to the laboratory of the Training and

Research Unit for Agronomic Forest and Environmental Engineering in a cooler for the various analyses.

Preparation of sample

Once in the laboratory, the various bags water was rinsed under a jet of water to rid them of any impurities. Then they were air dried with blotting paper. After drying, it was a matter of taking the bags water for the assays. This sample consisted of taking 03 samples from each brand of water (with 03 repetitions) which gave us 54 samples (9x6) for all samples.

Before use, the samples of the same brand were vigorously shaken to homogenize the contents well, then the bags water were opened using a platinum loop heated with a bunsen burner. After opening the bags, aliquots were made under a laminar flow hood from the same bag of water for subsequent analyzes.

pH

The pH was measured with a digital pH meter (Mettler Toledo, China) according to the method described by ISO 10523. A quantity of 50mL was collected in a jar. Then the pH was read on a digital screen by immersing the pH meter electrode directly into the solution after having calibrated the pH meter using standards.

Electrical conductivity

Largely a function of temperature, its measurement makes it possible to assess the level of mineralization of water (Rodier *et al.*, 2009). The WHO sets 400 µS/cm as the reference limit for electrical conductivity measured at 25 ^{0}C for drinking water.

The method described by ISO 7888 was used for determination of conductivity. It was performed using a conductivity meter (WTW 315i, Germany) and is expressed in micro siemens per centimeter (µS/cm). This device also gave the temperature of each sample.

Turbidity

Turbidity refers to the content of a fluid in matters which disturb it. In waterways it is usually caused by suspended matter and colloidal particles which absorb, scatter and/or reflect light. Turbidity was determined according to nephelometric method described by ISO 7027. It is expressed in Nephelometric Turbidity Unit (NTU). Turbidity was mea-sured using a turbidimeter (Hach 2100 QIS, China).

Minerals

The minerals present in the plastic bag water were determined according to the standards mentioned in Table 1. Thus, the trace elements, heavy metals and other minerals were measured by spectrophotometry using a spectrophotometer (ICP Avio 200, USA).

This method consisted of measuring the optical density of chemicals as a function of their ab-sorption wavelength. It is a simple, precise and fast method which makes it possible to reduce the errors which could be due to the manipulations (Rodier *et al.*, 2009).

Table 1. References of standards for determination of water minerals.

Minerals	Standards references
Iron, Manganese, Zinc, Arsenic, Copper, Cadmium, Lead, Chromium, Calcium, Magnesium, Potassium, Sodium, Aluminum	ISO 11885
Ammonia	Hach 8038
Free chlorine	ISO 7393-2
Chloride	Hach 8113
Fluorides	Hach 8029
Nitrates	Hach 8039
Nitrites	Hach 8507
Sulphide	Hach 8131
Sulfate	Hach 8551

Source: WHO (2017)

Statistical Analysis

The processing of data was carried out with Excel 2019 spreadsheet. These results of physico-chemical analyze were compared with WHO guidelines values for quality of water intended for human consumption. They were subjected to a one-way of variance analysis (ANOVA) followed by the Tukey test using XLSTAT software version 2021. The statistical significance of the difference between water samples in semi-industrial and artisanal bags was determined at 5% threshold.

Results

Determining the physico-chemical parameters in water intended for human consumption is an important step in assessing its quality. It remains one of the means of identifying possible cases of contamination by chemical substances.

Table 2 presents the values of pH, electrical conductivity, temperature and turbidity of water in plastic bags consumed at Man. Handcrafted and semi-industrial bagged water samples have pH and electrical conductivity values that meet required standards for pH (6.5-8.5) and electrical conductivity (≤ 400 µS/cm) in drinking water. Statistical analysis revealed that there is a significant difference between pH values of artisanal-type bag water produced at "Domoraud" district and those of the other two districts, "Camp Plus" and "Thérèse". Then, it showed a difference between pH values of water in semi-industrial bags of "Bonheur" brand and the two other semi-industrial types (Casa Plus and Félicité). Statistical analysis also showed that pH values of "Domoraud", "Casa Plus" and "Félicité" samples did not show any significant difference between them. As well as the "Camp Plus" and "Thérèse" samples. The analyzes showed that there was no significant difference between the electrical conductivity values for all samples tested.

Table 2. Physical characteristics of the plastic bag water sold at Man.

Water samples		Parameters			
		pH	Conductivity (µS/cm)	Temperature (°C)	Turbidity (NTU)
Artisanal type	Domoraud	6.9 ± 0.14^{ab}	99.27 ± 1.16^{a}	24.83 ± 0.31^{ab}	0.008 ± 0.0^{ab}
	Camp Plus	7.05 ± 0.29^{a}	150.6 ± 55.95^{a}	24.6 ± 0.35^{ab}	0.004 ± 0.0^{abc}
	Thérèse	7.06 ± 0.19^{a}	145.1 ± 40.82^{a}	24.5 ± 0.1^{b}	0.008 ± 0.0^{a}
Semi-industrial type	Casa Plus	6.7 ± 0.13^{ab}	92.4 ± 3.32^{a}	24.9 ± 0.26^{ab}	1.44 ± 0.42^{a}
	Bonheur	6.53 ± 0.2^{b}	78.62 ± 0.2^{a}	25.17 ± 0.06^{a}	0.93 ± 0.1^{a}
	Félicité	6.7 ± 0.06^{ab}	98.93 ± 1.27^{a}	24.93 ± 0.15^{ab}	2.53 ± 1.94^{a}
Standards (WHO, 2017)		6.5-8.5	≤ 400	NGV	RGV (≤ 0.2)

The means followed by different letters in the same column are statistically different at the 5% level.

NGV : No Guide Value, RGV : Recommended Guide Value

As for the temperature of plastic bag water in the laboratory room, it was between 24.5 ± 0.1 and 25.17 ± 0.06 °C. Statistical analysis has shown that there is no significant difference between temperature values except for water produced in an artisanal way in "Thérèse" district and water produced in semi-industrial way "Bonheur" brand.

The turbidity values of water in artisanal and semi-industrial bags are higher than the standard prescribed (≤ 0.2 NTU) by WHO (2017). Statistical analysis showed no significant difference between the turbidity values of the bagged water sold at Man.

Table 3 shows the concentrations of trace elements present in plastic bag water sold at Man. These results show that iron and zinc concentrations are almost zero except for the zinc content of water semi-industrial bags. Manganese values meet the WHO standard for all bagged water samples. Statistical analysis revealed no significant difference between iron values for all plastic bag water sold at Man except those of artisanal type bag water from "Camp Plus" district and semi-industrial type "Bonheur" brand. The analysis also showed a significant difference between zinc values of artisanal-type waters of the "Domoraud" and "Camp Plus" districts.

The data also showed the presence of heavy metals in the samples tested (Table 4). These are mainly arsenic, copper, cadmium, lead and chromium. The arsenic and lead concentrations are all less than 0.005mg/L, those of copper are between 0.004 to 0.006mg/L. Cadmium concentrations range from 0.001 to 0.002mg/L and chromium concentrations are all less than 0.002. These measured parameters all comply with the WHO standards for which the guide values are specified or recommended.

Table 3. Trace elements present in plastic bag water sold at Man.

Water samples		Parameters		
		Fe (mg/L)	Mn (mg/L)	Zn (mg/L)
Artisanal type	Domoraud	0.03± 0.0[a]	0.002 ± 0.0[bc]	0.008 ± 0.0[ab]
	Camp Plus	0.01 ± 0.0[b]	0.003 ± 0.0[b]	0.004 ± 0.0[abc]
	Thérèse	0.03 ± 0.0[a]	0.002 ± 0.0[bc]	0.008 ± 0.0[a]
Semi-industrial type	Casa Plus	0.03 ± 0.0[a]	0.005 ± 0.0[a]	1.44 ± 0.0[a]
	Bonheur	0.01 ± 0.0[b]	0.001± 0.0[c]	0.93 ± 0.0[a]
	Félicité	0.003 ± 0.0[ab]	0.004 ± 0.0[a]	2.53 ± 0.0[a]
Standards (WHO, 2017)		NGV	≤ 0.4	NGV

The means followed by different letters in the same column are statistically different at the 5% level.

NGV : No Guide Value

Table 4. Heavy metals present in plastic bag water sold at Man.

Water samples		Parameters				
		As (mg/L)	Cu (mg/L)	Cd	Pb (mg/L)	Cr (mg/L)
Artisanal type	Domoraud	<0.005± 0.0[a]	0.005 ± 0.0[ab]	0.001 ± 0.0[b]	<0.005± 0.0[a]	<0.002 ± 0.0[ab]
	Camp Plus	<0.005± 0.0[b]	0.006 ± 0.0[b]	0.002 ± 0.0[ab]	<0.005± 0.0[b]	<0.002± 0.0[a]
	Thérèse	<0.005± 0.0[a]	0.005 ± 0.0[ab]	0.002 ± 0.0[a]	<0.005± 0.0[a]	<0.002 ± 0.0[a]
Semi-industrial type	Casa Plus	<0.005± 0.0[a]	0.006 ± 0.0[a]	0.002 ± 0.0[ab]	<0.005± 0.0[a]	<0.002 ± 0.0[ab]
	Bonheur	<0.005± 0.0[b]	0.004± 0.0[b]	0.001± 0.0[b]	<0.005± 0.0[b]	<0.002± 0.0[a]
	Félicité	<0.005± 0.0[a]	0.005 ± 0.0[ab]	0.001 ± 0.0[b]	<0.005± 0.0[a]	<0.002 ± 0.0[a]
Standards WHO (2017)		≤ 0.01	≤ 2	≤ 0.003	RGV (≤ 0.01)	RGV (≤ 0.05)

The means followed by different letters in the same column are statistically different at the 5% level. RGV : Recommended Guide Value

Table 5. Macro-elements Present in Plastic Bag Water Sold at Man.

Parameters (mg/L)	Artisanal water samples			Semi-industrial water samples			Standards (WHO, 2017)
	Domoraud	Camp Plus	Thérèse	Casa Plus	Bonheur	Félicité	
Ammonia	0.64± 0.46[a]	1.50 ± 0.66[a]	1.08± 0.48[a]	0.82 ± 0.48[a]	0.9 ± 0.05[a]	0.87 ± 0.33[a]	NGV
Calcium	8.4 ± 0.08[ab]	7.67 ± 0.6[bc]	7.66 ± 1.11[bc]	7.75 ± 0.13[abc]	6.4± 0.04[c]	9.12 ± 0.05[a]	NGV
Free chlorine	< 0.02 ± 0.0[b]	0.08 ± 0.01[a]	< 0.02 ± 0.0[b]	0.07 ± 0.02[a]	0.06± 0.01[ab]	0.08 ± 0.03[a]	0.2-5
Chloride	7.3 ± 4.98[a]	7.87 ± 5.39[a]	9.47 ± 0.91[a]	6.5 ± 2.56[a]	5.0 ± 0.26[a]	5.93 ± 1.36[a]	NGV
Fluorides	< 0.02± 0.0[c]	0.13 ± 0.07[bc]	0.34 ± 0.01[ab]	0.13 ± 0.08[bc]	0.44 ± 0.0[a]	0.14± 0.16[bc]	≤ 1.5
Magnesium	2.07 ± 0.75[a]	2.25 ± 0.22[a]	2.52 ± 0.01[a]	2.31 ± 0.02[a]	1.94 ± 0.01[a]	2.47 ± 0.01[a]	NGV
Nitrates	6.07± 0.85[abc]	6.63± 0.46[ab]	4.27± 1.6[cd]	4.5± 0.53[bcd]	3.023 ± 0.31[d]	7.37± 0.49[a]	≤ 50
Nitrites	0.05± 0.01[a]	0.14± 0.07[a]	0.11± 0.07[a]	0.05± 0.01[a]	0.08 ± 0.0[a]	0.07± 0.0[a]	≤ 3
Potassium	4.05 ± 0.03[ab]	3.8 ± 0.32[b]	4.19 ± 0.01[a]	3.97 ± 0.04[ab]	3.24± 0.06[c]	3.18 ± 0.02[c]	NGV
Sulfide (µg/L)	< 5.0 ± 0.0[b]	< 5.0 ± 0.0[b]	13.0± 4.58[a]	< 5.0 ± 0.0[b]	16.33± 1.53[a]	< 5.0± 0.0[b]	NGV
Sodium	5.27± 0.26[ab]	4.83± 0.37[b]	5.59± 0.06[a]	5.23 ± 0.03[ab]	4.24 ± 0.09[c]	5.16± 0.09[ab]	NGV
Aluminum	0.13 ± 0.0[ab]	0.08± 0.04[bc]	0.13 ± 0.01[a]	0.10 ± 0.01[abc]	0.08 ± 0.0[bc]	0.06 ± 0.0[c]	RGV (≤0.2)
Sulfate	19.0 ± 3.0[ab]	19.0± 3.60[ab]	19.0 ± 1.73[ab]	20.33 ± 3.51[ab]	15.0± 0.0[b]	23.33 ± 2.08[a]	NGV

The means followed by the different letters in the same row are statistically different at the 5% level.

NGV : No Guide Value, RGV : Recommended Guide Value

Table 5 shows the other minerals present in plastic bag waters sold at Man. The results showed that minerals measured all comply with the WHO standard (2017) for which the guide values are specified or recommended. The bags water have low sulphide concentrations (<5.0µg/L) except water of "Thérèse" district (13.0µg/L) and "Bonheur" brand (16.33µg/L). Likewise, the plastic bag water sold at Man have very low concentrations of free chlorine, fluorides, nitrates and nitrites compared to the guide values. Statistical analysis showed no significant difference between the concentrations of ammonia, chloride, magnesium and nitrites in the water in bag sold in Man. Also, the sulphate concentrations of water in artisanal bags showed no significant difference at the 5% level. It is the same for the semi-industrial bags of the "Casa Plus" brand.

Discussion

Water is an essential element for the life of man and that of other living beings; its presence in quantity and quality contributes to maintaining health (WHO, 2017). Drinking water packaged in bags is therefore the most widely consumed food, especially in cities and sub-Saharan markets where it is frequently used for quenching thirst during periods of extreme heat. The study of physico-chemical characteristics of drinking water packaged in bags according to different brands sold in the markets.

Handcrafted and semi-industrial bagged water samples have pH values that meet the required standard for pH (6.5-8.5). Although pH has no direct impact on the health of the consumer, it is one of the important operational parameters of drinking water quality WHO (2017). As low or high pH can promote the growth of certain microorganisms or limit the action of chlorine in water. The results obtained in this work are similar to those obtained by Nomoa (2017) on borehole water in Ouagadougou (Burkina Faso). This author obtained pH values between 6.2 and 7.2. Manizan *et al.* (2011) and Kouadio *et al.* (2013) obtained pH values between 6.5 and 8.5 for the water in semi-industrial and artisanal bags sold at Abidjan. As for Kouadio *et al*. (2020), they obtained pH values between 5.8 and 6.8 for the bags water sold in seven towns of Côte d'Ivoire.

Regarding the electrical conductivity measured at 25 °C, it made it possible to assess the mineralization of water. Analysis of the conductivity data indicated that the results of all samples are satisfactory with values ranging from 78.62 µS/cm to 150.6µS/cm against a standard ≤400 µS/cm for drinking water. These values show that bags water sold in the municipality of Man has a low mineralization. This result is different from those found by Nomoa (2017) for water from semi-industrial boreholes which displayed values greater than 1000 µS/cm. This difference in results could be explained by the fact that water from these borehole samples has a large amount of dissolved minerals in ionized form. Referring to cloudiness of water, turbidity is one of the important parameters in drinking water. The turbidity values of water in artisanal and semi-industrial bags are higher than standard prescribed (≤ 0.2 NTU) by WHO (2017). This situation would be due to the absence or malfunction of filtration device before bagging. There is also a suspicion of dust gushing due to the lack of sanitation of frame in storage container during indirect bagging (N'diaye, 2008). Also, visible turbidity reduces the acceptability of drinking water. Indeed, many consumers associate turbidity with food safety and consider cloudy water to be unsuitable for drinking (HCSP, 2015). The work carried out by Kouadio *et al.* (2020), also showed that the turbidity of plastic bag water sold in the towns of Korhogo, Bouaké, Daloa, Man, Abengourou, San-Pedro and Abidjan was not compliant with WHO standard. Regarding trace elements, plastic bag water has very low iron and zinc contents except for the zinc content of water in semi-industrial bag. This difference in result could be related to water source used to fill water bags. Zinc levels in surface water and groundwater usually do not exceed 0.01 and 0.05mg/L, respectively, concentrations in tap water can be much higher following dissolution of zinc from the pipes (WHO, 2017). This would mean that semi-industrial bagged water is made from tap water. As for iron and manganese, their contents are almost zero in all the samples tested. The plastic bag water sold at Man is not colored like the water rich in iron. At these low concentrations, iron and manganese are not of concern to the health of bag water user.

The data also showed that heavy metals such as arsenic, copper, cadmium, lead and chromium present in bagged waters meet the standard prescribed by WHO for each of the listed parameters. The metals contents observed in waters of area are low. According to Mohod & Dhote (2013), toxic metals are generally present in industrial, municipal and urban effluents. This low concentration measured for these heavy metals could be linked to the complete absence of industrial activities and municipal effluents in the production area of these bags water.

In the mountainous west of Côte d'Ivoire, Ahoussi *et al.* (2013) also showed that very low concentrations of arsenic (<0.002mg/L), cadmium (<0.002mg/L), lead (0.01) and chromium (≤0.03) were obtained in the waters of springs exploited by the population of the village Mangouin-Yrongouin (Biankouman).

Recent work by Ahoussi *et al.* (2018) on drinking water in this same region precisely in the village of Kpangouin (Man) also showed that this water was poor in arsenic (<0.001mg/L) and cadmium (<0.001mg/L). It seems that in the absence of industrial activities, the concentration of these metals in natural waters hardly poses a problem of compliance with standards. Thus, the low concentrations of these metals in the plastic bag water sold at Man proves that these metals are not of concern for the health of the consumer of bag water artisanal and semi-industrial type.

Regarding ammonia in water, it is an indicator of possible bacterial contamination or pollution from sewage or animal waste. The levels observed in plastic bag water are much lower than those likely to cause toxic effects. Toxicological effects are observed only for exposures at doses greater than about 200mg/kg body weight. In addition, natural levels in groundwater and surface water are usually less than 0.2mg/L. Ammonia contamination can originate from the interior lining of cement mortar pipes. The ammonia present in the drinking water does not have a direct impact on the health plan, which is why no guideline value is proposed.

The concentrations of free chlorine in all the bags water sold at Man are very low, which could be explained by the reactivity of this molecule (Caurant & Ghestem, 2014, Vargas *et al.*, 2021). Indeed, free chlorine can combine with organic substances to form halogenated forms (chloroform, etc.).

Like free chlorine, the concentration of hydrogen sulfide is almost zero. In fact, sulphides are rapidly oxidized in well-aerated water, which reflects this low concentration in plastic bag water. The level of hydrogen sulfide observed in drinking water is usually low, but it is likely to affect the acceptability of the water because this gas has a penetrating "rotten egg" odor (WHO, 2017). The concentrations of fluorides, nitrates, nitrites and aluminum in water in artisanal and semi-industrial bags sold at Man are not of concern for health of populations. Indeed, these concentrations are below the guide values or recommended by WHO. The plastic bag water also contains calcium (6.4-9.12mg/L), chloride (5.0-9.47mg/L), magnesium (1.94-2.52mg/L), potassium (3.18-4.19mg/L), sodium (4.24-5.59mg/L) and sulfate (15.0-23.33mg/L). These different elements are essential for the maintenance of the body. During this work on spring waters from the mountainous west: case of the village of Mangouin-Yrongouin (Biankouman), Ahoussi *et al.* (2013) found mean concentrations of calcium (89.87mg/L), chloride (234.0mg/L), magnesium (18.33mg/L), potassium (35.33mg/L), sodium (32.63mg/L) and sulfate (35.07mg/L) higher than those in this study. Determining the physico-chemical parameters in water intended for human consumption is an important step in assessing its quality. It remains one of the means of identifying possible cases of contamination by chemical substances.

Conclusion

At the end of this work, it emerges that the samples of water in bags of artisanal and semi-artisanal type sold at Man comply with the rules of sanitary quality of drinking water for all parameters tested except the turbidity of these bag water. In addition, the concentrations of macro-elements are low in all the plastic bags water tested. As the most important effect linked to turbidity is probably its ability to protect microorganisms against disinfection, it would be important to assess the bacteriological quality of these plastic bags water sold at municipality of Man.

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