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Full Length Research Paper

Physico-chemical and bacteriological characterization of sachet water sold in Yaounde City, Cameroon

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The objective of this study is to take an inventory of all the sachet water brands sold in Yaounde and to assess their sanitary quality. This study was carried out on 100 samples, representing 20 sachet water brands sold in the urban city of Yaounde, Cameroon. Selected physico-chemical and bacteriological analyses of the sachet water were done. The results showed that their pH values and nitrate level were in line with the WHO guideline values. The chloride ion contents were significantly lower than the limit values for drinking water, *Escherichia coli* was absent in all brands and 75% of the samples contained intestinal *enterococci*. Sachet water brands can be grouped into 3 homogeneous classes based on *streptococcal* contamination, chloride and nitrate content, and the level of pH. Packaging material and storage conditions (exposure to sun) can aggravate this contamination. Sachet water can be contaminated and become undrinkable.

Key words: Sachet water quality, potability, Yaounde, Cameroon, physico-chemical parameters, bacteriological analyses.

INTRODUCTION

Water is a source of life due to its indispensable characteristics and the place it occupies in our daily life. Accessibility and availability of fresh clean water is a key to sustainable development and an essential element for health, food production and poverty reduction (Adetunde and Glover 2010). Water is a widely consumed commodity, hence it is necessary to study its potability. Because of its affordable price (5 and 10 CFAF in Ivory Coast and 50 CFAF in Cameroon), its availability and accessibility, water packaged in sachets is highly consumed. Several brands from drinking water production companies (legal or illegal) have thus emerged in several big cities in Africa. But this abundance is not without problems, particularly in terms of quality of products. Lack of

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hygiene and the questionable quality of these waters mean that the risk of water-borne infections is serious and frequent. The consumption of soiled water most often begins gastroenteritis or even dysentery, typhoid fever and cholera (Mossel et al., 1993; WHO, 1994). According to WHO (1994) and PNUD (1990), 80% of diseases in the world are waterborne, and drinking water is very often responsible for this. In developing countries, more than 25 million people die every year due to consumption of contaminated water (GRET, 1994).

With this situation, some studies have been conducted to assess the health risk, quality and potability of these waters distributed in some African big cities (Akely, 1994; Samake, 2002). In four municipalities of Abidjan, N'diaye (2008) and Aboli et al. (2007) conducted a bacteriological study of drinking water sold in sachets. These studies highlighted the existence of some pathogenic and non-pathogenic germs (*Enterococcus faecalis*, *Escherichia coli*, *Pseumonas* sp., *Staphylococcus* sp. and *Salmonella enterica serovar typhimurium)*, indicators of faecal and environmental contamination of sachets water. The analyses also revealed that sachet water offered to consumers is of low quality. In a similar study, Kouadio et al. (1998) studied the potability of drinking sachet water sold around the public primary schools of Abidjan and they observed that all the samples collected had poor microbiological and chemical quality. Rutz (1996) reported that sachet water vending machine may not be free of microorganisms, because a bacterium, *Streptococcus faecalis* was isolated from sachet water producing machines. Obiri-Danso et al. (2003), who examined the microbiological quality of sachet drinking water and bottled water sold in the streets of Kumasi, Ghana, concluded that bottled water sold in the Ghanaian market is of good microbiological quality. Hoteyi et al. (2014) analyzed the risks of consuming sachet water in the city of Porto-Novo in South Benin. This study showed that sachet water produced from borehole and traditional wells contained 95% pathogens while that from tap had 5% pathogens. The borehole and traditional wells tested samples had high contents of nitrates ranging from 75 to 97 mg/l concentrations.

Looking at the recurrence of the diarrheal diseases and serious health risks due to the consumption of sachet water, an inventory of all the water sachet brands sold in the city of Yaounde, Cameroon was taken and their sanitary quality was assessed. More specifically, a survey of water sachet sellers or producers, collection of various sachets water brands sold in the markets of Yaounde, as well as the study of the potability of the collected samples was done.

MATERIALS AND METHODS

Collection of samples

Different sachet water brands available in the main markets of the city of Yaoundé were collected from the vendors. In the main markets of the 7 subdivisions of Yaoundé (Etoudi, Mokolo, Mvog-Mbi, Mvog-Ada, Essos, Acacia and Nkolbisson), all sachet water brands available were sampled. The analyses covered 100 water samples corresponding to 20 sachet water brands (5 samples per brand). The vendors were also interviewed on their sources of supply and the storage conditions of the sachet water.

Physicochemical analysis

Some physic-chemical parameters of the sachet water were analyzed at the soil Laboratory of the Institute of Agricultural Research for Development (IRAD), which is certified ISO 12025. The pH was determined using the potentiometric method. The quantities of nitrates (NO^{-}_{3}) were determined by the automated colorimetric method (ISO 7890-3 December, 1998). Chloride was measured by titration with silver nitrate according to AFNOR NF ISO 9297.

Microbiological analysis

Two types of microbiological analysis were carried out at the 'Centre Pasteur Laboratory' of Yaounde, Cameroon which is also certified ISO 12025. They are:

1. The coliform bacteria analysis: Enumeration of *Escherichia coli* through membrane filtration method according to NF ISO 9308-1 norm.
2. The Intestinal Enterococci analysis: The membrane filtration method according to NF ISO 7899-2 norm was used for the enumeration of the faecal coliforms.

Statistical analysis

The statistical analysis was done using three soft wares: 1. EXCEL 2010: Descriptive statistic;
2. Graphpad Prism 5.0: Variance analysis (ANOVA); and 3. XL STAT 2015 for Hierarchical Ascending Classification (HAC) and Principal Components Analysis (PCA). Descriptive statistics helped to graphically illustrate changes in physico-chemical parameters for the different brands surveyed. Analysis of variance (ANOVA) was used to assess the significance of changes in the physico-chemical parameters for the different brands studied. Factorial analysis of the different sachet water brands and their physico-chemical parameters allowed the grouping of the water brands into homogeneous classes. The groupings, according to the degree of similarity (Pearson correlation coefficient), were performed using a hierarchical clustering (Dendrogram). The representation of sachet water brand and physico-chemical parameters on a multi --factorial design was carried out by a principal component analysis (PCA). PCA was performed according to average values of the physico-chemical parameters measured for each of the brands. The proximity between the different brands was shown.

RESULTS

Inventory of the different brands of sachet water sold in the markets of Yaoundé

In Yaoundé City, a total of 20 brands of sachet water were recorded: Crys Water, Alpha, Omega, Aquarrel, Faro Nostra, Max water, Roi, Kanadienne, Charone, Eau de montagne, Golden, Equina, Bonatura Water, Pomi

Water, Bonheur, Natural, Ilma, Boni Water, Prince and Lerex Water. The large number of sachet water brands shows that markets are areas of great affluence where there are several economic activities and where the need to drink is needed. Sachet water sellers are unaware of the chain of production, their role being limited only to sales. For further work, and for confidentiality reasons, the various water sachet brands were coded.

Physical description of sachet water brands

The physical examination of the sachet water allowed us to notice the absence of some conventional information which must appear on food package, namely the manufacturing date and the serial number which did not appear in any brand of the sachet water. The absence of the serial number on the sachet water made it difficult to respect the FIFO (First In, First Out) principle which is essential in the food industries. Ten brands out of 20 had an expiration date, and only 6 brands out of 20 had an operating license. Some bits of information concerning the volume and physico-chemical parameters were wrong.

The physical characterization of the sachet water, like the absence or presence of an operating license made us to group the water into semi-industrial and artisanal types. Out of the 20 brands collected, 6 were of a semi-industrial operation (SW-18, SW-13, SW-12, SW-7, SW-4 and SW-3), and 14 of an artisanal type (SW-1, SW-2, SW-5, SW-6, SW-8, SW-9, SW-10, SW-11, SW-14, SW-15, SW-16, SW-17, SW-19 and SW-20).

The absence, insufficiency, or the wrong character of the information contained in certain sachet water collected may reflect a fraudulent activity that takes place without any regulatory compliance.

Conservation of sachets water during marketing

In general, the average duration of evacuation of 100 sachets water varied from 1 to 2 days depending on whether it is raining or dry season. According to the actors, types of conservation varied. The itinerant vendors kept them essentially in buckets and coolers (60%) while vendors who had shops kept them in refrigerators (40%).

These pre-sale conservation conditions, which in most cases were unsuitable (exposed in buckets or coolers), were likely to favour certain biological reactions (microbial proliferation and container-contents migration) which may reduce the sanitary quality of sachet water.

Physico-chemical and bacteriological characterization of sachet water

Some physico-chemical parameters of pollution were analysed, namely pH, contents of chlorides and nitrates ions (Table 1). The pH of the different water sachets varied between 6.5 and 8.5. Their chloride contents were between not detectable and 3.2 mg/l. There was no significant difference between the semi-industrial and artisanal type. Fifty percent of the water brands were not detectable for chloride ions.

The sachet water nitrates levels were between not detectable and 18 mg/l. Seventy percent of the water brands had also zero nitrates content, against 40% of brands which had positive values but remained largely lower than 50 mg/L.

The bacteriological analysis of the sachet water showed high faecal Enterococci contamination levels. In fact, 14 out of 20 brands were contaminated with levels varying between 2 and 56 CFU/100 ml.

The distribution of the sachet water contamination by faecal Enterococci varied according to the type, be it semi-industrial or artisanal (Table 2): Sixty-seven percent contamination was from the semi-industrial type against 71.5% contamination from the artisanal type.

Statistic interpretation of results

Analysis of variance of factors

The analysis of variance of two factors revealed highly significant p values (<0.05), indicating a significant variation in the physico-chemical and bacteriological parameters for the different sachet water brands. Variation in the parameters themselves for the different brands was also observed and 99% chance of the identified sachet water brands was very different.

Classification of different sachet water brands

Hierarchical ascendant classification

The dendrogram in Figure 1 illustrates the hierarchical ascending classification of different sachet water brands according to the evaluated physicochemical and micro-biological parameters. The dendrogram was created on the basis of similarities between these quality parameters according to Pearson correlation coefficient.

The discriminant analysis of the dendrogram revealed that the different identified brands can be grouped into 3 homogeneous classes. The first class comprised 9 brands: WS-1, WS-8, WS-3, WS-19, WS-16, WS-6, WS-12, WS-4 and WS-7; the second class included 4 brands: WS-17, WS-2, WS-13 and WS-15 and finally, the third class included 7 brands: WS-11, WS-14, WS-20, WS-5, WS-18, WS-9 and WS-10. These classes comprised brands with close or similar physico-chemical and microbiological parameters.

Principal component analysis

Figure 2 illustrates the principal component analysis of

Table 1. Summary sheet of physicochemical and bacteriological analysis results of sachets water.

S/N	Water brands	Faecal coliforms (*E. coli*) (VG = 0/100 ml)	Feacal streptococci (Enterococci) (GV = 0/100 ml)	pH (6.5<GV< 8.5)	Nitrate (GV = 50 mg/l)	Chloride (GV = 250 mg/l)
1	SW- 1	nd	02±00	7.5±0.12	nd	2.12±0.04
2	SW-2	nd	02±00	7.5±0.04	18±1.1	nd
3	SW-3	nd	nd	7.7±0.10	nd	0.71±0.22
4	SW-4	nd	02±00	7.5±0.02	nd	0.71±0.01
5	SW-5	nd	52±02	7.24±0.03	nd	3.19±0.05
6	SW- 6	nd	nd	7.47±0.01	nd	Nd
7	SW-7	nd	02±00	7.81±0.05	nd	nd
8	SW-8	nd	01±00	7.43±0.02	nd	2.13±0.02
9	SW-9	nd	24±01	7.29±0.07	nd	nd
10	SW-10	nd	20±02	8.23±0.06	nd	nd
11	SW- 11	nd	11±01	7.87±0.90	nd	nd
12	SW-12	nd	nd	7.62±0.40	nd	nd
13	SW-13	nd	03±00	7.58±0.20	12±0.7	2.13±0.08
14	SW-14	nd	06±01	7.06±0.06	nd	2.29±0.07
15	SW-15	nd	2±00	6.73±0.07	10±	nd
16	SW- 16	nd	nd	7.5±0.04	nd	nd
17	SW-17	nd	nd	7.02±0.05	8±0.9	2.29±0.10
18	SW-18	nd	56±02	8.3±0.06	4±0.6	nd
19	SW-19	nd	nd	7.5±0.19	nd	nd
20	SW-20	nd	17±01	7.58±0.07	9±0.8	2.49±0.09

GV, Guide value; nd, not detectable.

Table 2. Distribution of the contamination of sachets water by faecal Enterococci.

Type of manufacturing	Contamination	Number	Percentage
Semi-industrial (N=06)	Positive	4	67.0
	Negative	2	33.0
Artisanal (N=14)	Positive	10	71.5
	Negative	4	28.5

sachet water brands based on the physicochemical and microbiological parameters measured. It is the representation of the water brands as well as the quality parameters evaluated in a multi-factorial plan. The graph thus revealed that some brands were characterized by a high content of streptococci (WS-11, WS-14, WS-20, WS-5, WS-18, WS-9 and WS-10) and showed that all these brands were those of class 3 in the dendrogram. A second group of brands was characterized by similar contents of chlorides and nitrates (WS-17, WS-2, WS-13 and WS-15); all these brands belong to class 2 in the dendrogram. Finally, one last group of brands was characterized by close levels of pH (WS-1, WS-8, WS-3, WS-19, WS-16, WS-6, WS-12, WS-4 and WS-7). These brands were those of class 1 in the dendrogram.

However, the classification of water according to their quality parameters (physicochemical and bacteriological characteristic) made us to notice that waters of class 3 were the most unfit for consumption.

DISCUSSION

Water is the basic daily beverage of human beings. The human body needs daily and generous amount of water to function properly and avoid dehydration. Unfortunately, this water so important to life is not always safe for consumption. When it is of poor quality, it can affect our health and eventually the human life (Livre bleu de Belgaqua, 1998). The concentration of certain physico-

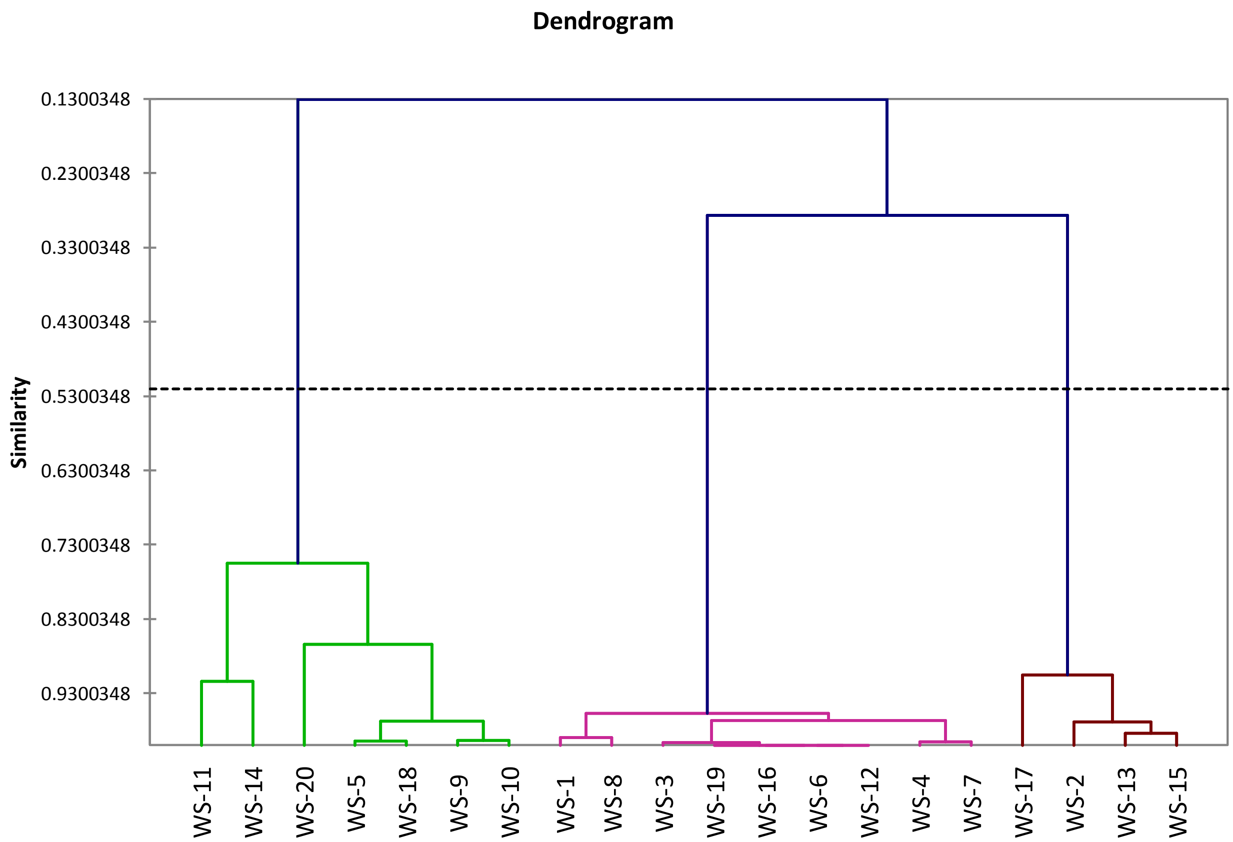

Figure 1. Hierarchical ascending classification (HAC) of water brands based on physicochemical and microbiological parameters measured.

chemical parameters or the presence of certain germs in water can serve as factors of pollution.

pH is one of the most operational water quality parameters, thus it needs to be controlled in all stages of water treatment to ensure water clarification and disinfection. According to WHO (1994), pH values for drinking water should range between 6.5 and 9.5. This range is in conformity with the study results (7.02 - 8.3) as it fell within the WHO drinking water-guideline. In addition, these sachet water brands are unlikely to cause health problems such as acidosis (Asamoah and Amorin, 2011).

Chlorides are important inorganic anions contained in variable concentrations in natural water usually in the form of salts of sodium (NaCl) and potassium (KCl); an excess amount of which, if taken over a period of time, can constitute a health hazard (Oyelude and Ahankorah, 2012). Chlorides are often used as pollution index in surface and ground waters (WHO, 2000) and high concentrations may result in taste problems (APHA, 1998). WHO (1986) recommended 250 mg/l as the maximum chloride ion level allowable in drinking water. This guide value helps to conserve the water aseptic. The chloride content found in the sachet water was lower (between 0 and 3.19 mg/l) than that of the WHO guideline. This is as a result of the sachet water being exposed to sunlight during sales. Solar radiations promote the conversion of chlorine into inactive chloride ions. Moreover, solar heat, by raising the temperature of the sachets favours microbial growth (Kouadio et al., 1998).

At elevated concentrations, nitrate ion is known to result in cyanosis in infants. Nitrates constitute the final stage of the oxidation of nitrogen and represent the form of nitrogen in the highest degree of oxidation in water. Nitrates can be at the origin of the formation of nitrites and nitrosamines, responsible for two potentially pathological phenomena: The methemoglobinemia and the risk of cancer disease (WHO, 2000). Except for 6 sachet water brands (WS-2, WS-13, WS-15, WS-17, WS-14 and WS-20), there was no nitrates in the other sachet water brands analysed (14 brands). The measured contents remained well below the threshold for drinking water according to WHO standards (50 mg/L). This indicated that the water studied was not subjected to nitrate pollution.

Faecal coliforms, such as *Escherichia coli*, are indicative of faecal contamination in drinking water (Bourgeois et al., 1990; WHO, 2000; N'diaye, 2008). The presence of *E. coli* in drinking water reflects in most cases the

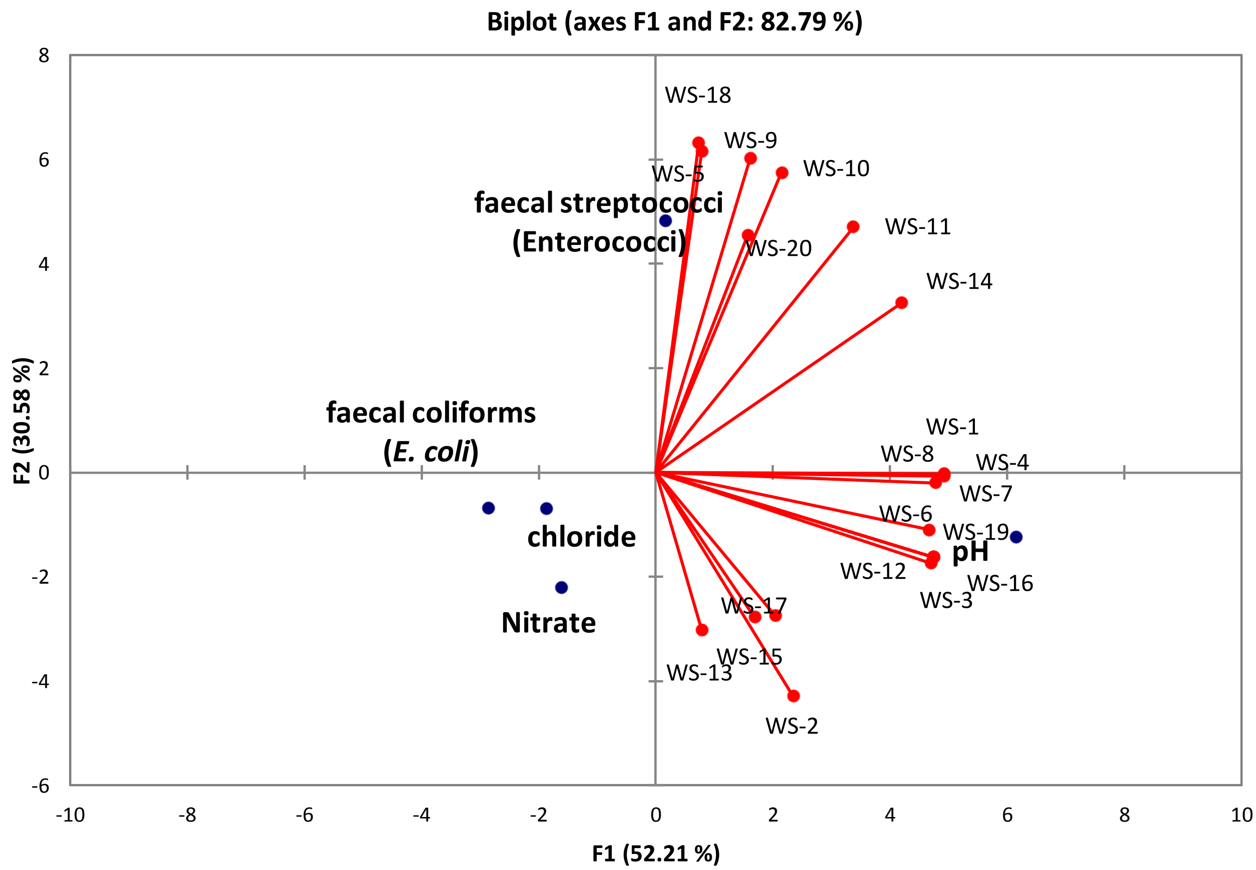

Figure 2. Principal component analysis of water brands according to the physicochemical and bacteriological parameters.

existence of risk of the presence of enteric pathogenic micro-organisms (Quebec, 2004). WHO (2000) Standard recommends 0 CFU/mL of faecal coliforms in drinking water. However, the bacteriological analysis of sachet water showed a strong contamination by the faecal coliforms (70%) and a complete absence of contamination of sachet water by *E. coli*. The presence of these coliforms in the water revealed either an ineffective treatment or a contamination after treatment due to lack of hygienic care. Similar results were obtained by Navou (2000), Diop (1995), and Degbey (2009) when studying the quality of drinkable water in Bobo-Dioulasso City (Burkina Fasso), Khombole City (Senegal), and Godomey City (Benin) respectively. According to Obiri-Danso et al. (2003), the standard of hygiene in the various stages in the production of the factory plastic-bagged sachet water is similar to that of bottled water. It was difficult to independently verify this claim with regard to the factory-filled sachet water brands. But these results did not allow us to thoroughly confirm the complete absence of contamination of sachet water by *E. coli*. According to Vaurette and Le Duc (2014), the lifespan of *E. coli* in natural waters and sediments can vary from few hours to several days, depending on environmental conditions. However, given the fact that the manufacturing date of this sachet water was not known, it became difficult to estimate the duration of storage.

Depending on the types of process, the industrial-type sachets as well as the artisanal ones were unfit for consumption because of the presence of germs which showed faecal contamination that resulted in poor bacteriological quality.

During sales, sachet water brands are kept in buckets and coolers and exposed to temperature and sunlight. Storage conditions and the environment are also important factors of contamination. Several authors have demonstrated that temperature and x-rays can promote the migration of plastic elements to food, and also promote microbial growth in food (Limm and Hollifield, 1996; Etienne and David, 2002; Tehrany and Desobry, 2004). Residual odours of storage place and the trace element of outer wall of sachet (plastic) can also pass through the container and deteriorate the food, both organoleptically and toxicologically (Cristina, 2011).

Conclusion

This study aimed to take an inventory of all the water sachet brands sold in Yaounde City and to assess their potability. The results obtained highlighted that contaminations were essentially of faecal origins: 75% of the samples contained intestinal *enterococci*. Majority of them were not fit for human consumption. However, further work is needed to complete the microbial and physic-chemical contaminations. These sachet water brands do not only meet a vital need, but are a source of income for vendors. Their ban without adequate replacement measures is not feasible. To protect consumers' health by reducing health risks, a number of recommendations can be made: The sensitization of consumers about the health risks they incur, the education of sellers and the monitoring of their activity by the municipal hygiene services.

CONFLICT OF INTERESTS

All authors declare that there are no conflicts of interest.

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