

# Biological and Chemical Quality of Sachet-Packaged Water in Togo: Public Health Risk Analysis in the Urban and Peri-urban Areas of Atakpamé, Togo

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**Abstract** Water is vital for human health, yet many regions struggle to provide safe drinking water that meets WHO drinking water quality (GDWQ). Since the 2000s, there has been a proliferation of sachet-packaged water in Togo, commonly called "Pure Water". It is perceived as a safer alternative to tap water and is highly appreciated by the local population due to its affordability and availability. Therefore, this study aims to assess the health risks associated with water consumption in Atakpame by analyzing microbiological and physico-chemical parameters. A mixed-method approach was employed, combining field surveys and laboratory analyses to evaluate compliance with standards. The survey revealed that over 70% of factories have an unhealthy environment, with inadequate employee hygiene practices, highlighting severe public health concerns. The physicochemical assessment highlighted issues of over-demineralization, with significant cations such as calcium ( $\leq 17$  mg/L) and magnesium ( $\leq 7.8$  mg/L) nearly absent. This raises concerns about the nutritional quality of the water but also suggests that current purification methods may excessively strip beneficial minerals for human health. A comparative study of samples at T0 and T30 showed germ growth during storage. Awareness-raising among the population, improved production practices, and employee training can mitigate the various health risks. Addressing these challenges is essential for protecting public health in Atakpame and ensuring that sachet-packaged water remains a safe and reliable source of hydration for communities across Togo.

**Keywords:** Health Risks, Sachet-Packaged Water, Production Plant, WHO Drinking Water Quality

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## 1. Introduction

Drinking water is critical in preventing water-related diseases and must be given special attention. Water is an essential resource for human life for socioeconomic and industrial needs [1]. However, safe drinking water access remains a significant challenge across the world. Drinking water is crucial for preventing waterborne diseases. Thus, water intended for drinking must first and foremost meet physicochemical quality criteria, including the absence of undesirable or toxic chemical elements, a balanced natural mineral content, and is free from pathogens, especially in developing countries [2] with limited health care. In urban and semi-urban areas of Togo, boreholes and wells are often the primary sources of drinking water [3,4], where there is a discontinued supply from the water supply network. However, because of the uncertain quality of this

water, sachet-packed water, perceived as a safer and more accessible alternative, has become inescapable. Sachet-packaged water is one of the fastest-growing beverages in the world, particularly in developing countries [5]. Since the 2000s, the production and marketing of "pure water" has been developed under various labels. The sale of water in sachets is an activity that offers significant socio-economic opportunities for the population and production unit owners. Nevertheless, water-packaged quality raises questions about production practices and the water treatment technologies used before packaging.

Some studies have shown that some packaged waters' microbiological and chemical quality does not always comply with expected health standards, exposing consumers to health risks [6,7,8,9,10]. The presence of enteropathogenic bacteria such as *Escherichia coli*, *Salmonella*, and *Klebsiella*, often identified in these waters, is associated with severe diseases such as cholera, typhoid, and dysentery [11,12]. In Togo, 'Pure Water' has

become ubiquitous since the 2000s, particularly in large towns and semi-urban areas [6,13,14]. Although it offers socio-economic opportunities, there are growing concerns about the quality of this water, particularly about production conditions and treatment practices [7,8,11,15] [16,17,18,19]. Several studies have highlighted these waters' bacterial and chemical contamination, calling into question their safety for consumption [6,20]. In this context, the present study aims to assess the health risks associated with consuming sachet-packed water. A mixed methodological approach was adopted to carry out this study, combining field surveys and laboratory analyses of sachet-packed water sampled in the Atakpamé conurbation and its semi-urban areas.

Stratified random sampling was used to select a representative number of water labels available on the marketplace. These waters' microbiological and physicochemical quality was assessed, and the extent to which they comply with WHO guidelines for drinking water (GDWQ) was determined.

## 2. Material and Methods

### 2.1. Study Area

Atakpamé, the fifth most peopled city in Togo, is the capital of the Plateaux region (Figure 1).

Located 161 kilometers north of Lomé, it covers an area of approximately 88 km<sup>2</sup>. The population of Atakpamé increased from 69,221 inhabitants in 2010 to 98,193 in 2022, with an estimated annual population growth rate of 2.94% (INSEED, 2023). Climatological data related to temperature and precipitation was sourced from the

Meteorological Centers of Atakpamé database (figure 2). The average annual temperature varies little, moving around 26°C, with February (28.5°C) being the hottest month and August being the coldest (24°C). The city enjoys a tropical climate with one major dry and rainy season and shorter dry and rainy seasons, similar to the Togolese capital, Lomé. The two rainy seasons occur from April to July, followed by a short rainy season from September to November (Figure 2). Monthly rainfall over 30 years ranges from 3 mm (December) to 257 mm (July), making July the wettest month and December the driest. This rainfall supports agricultural activities and makes the area an essential agrarian trade center. Additionally, the city of Atakpamé, crossed by the international road connecting the North to the South, serves as a stop for many commercial and personal vehicles. This tropical climate and the population's commercial, artisanal, and agricultural activities contribute to a continuous need for hydration through packaged water, which is presumed to be potable.

### 2.2. Survey and Assessment of Pure Water Production Sites

First of all, technicians involved in the water service of the Division of Sanitary Control and Inspection (DCIS), a service of the Direction of Hygiene and Basic Sanitation (DHAB) representing Water Sanitation and Hygiene (WASH) direction, were interviewed. Afterward, store and production site visits and staff interviews were conducted to get valuable information on facilities used for water production, storage practices, and hygiene of premises and employees. Only those who have freely accepted to be parties of the study were involved.

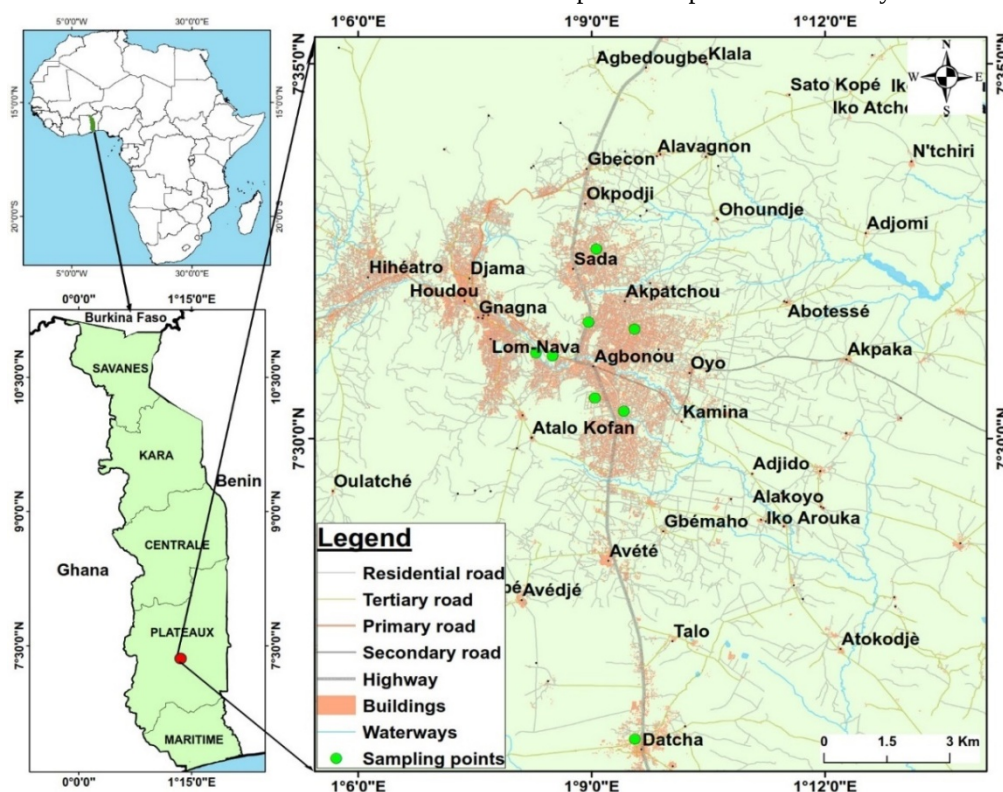


Figure 1. Map showing the location and distribution of sampling points

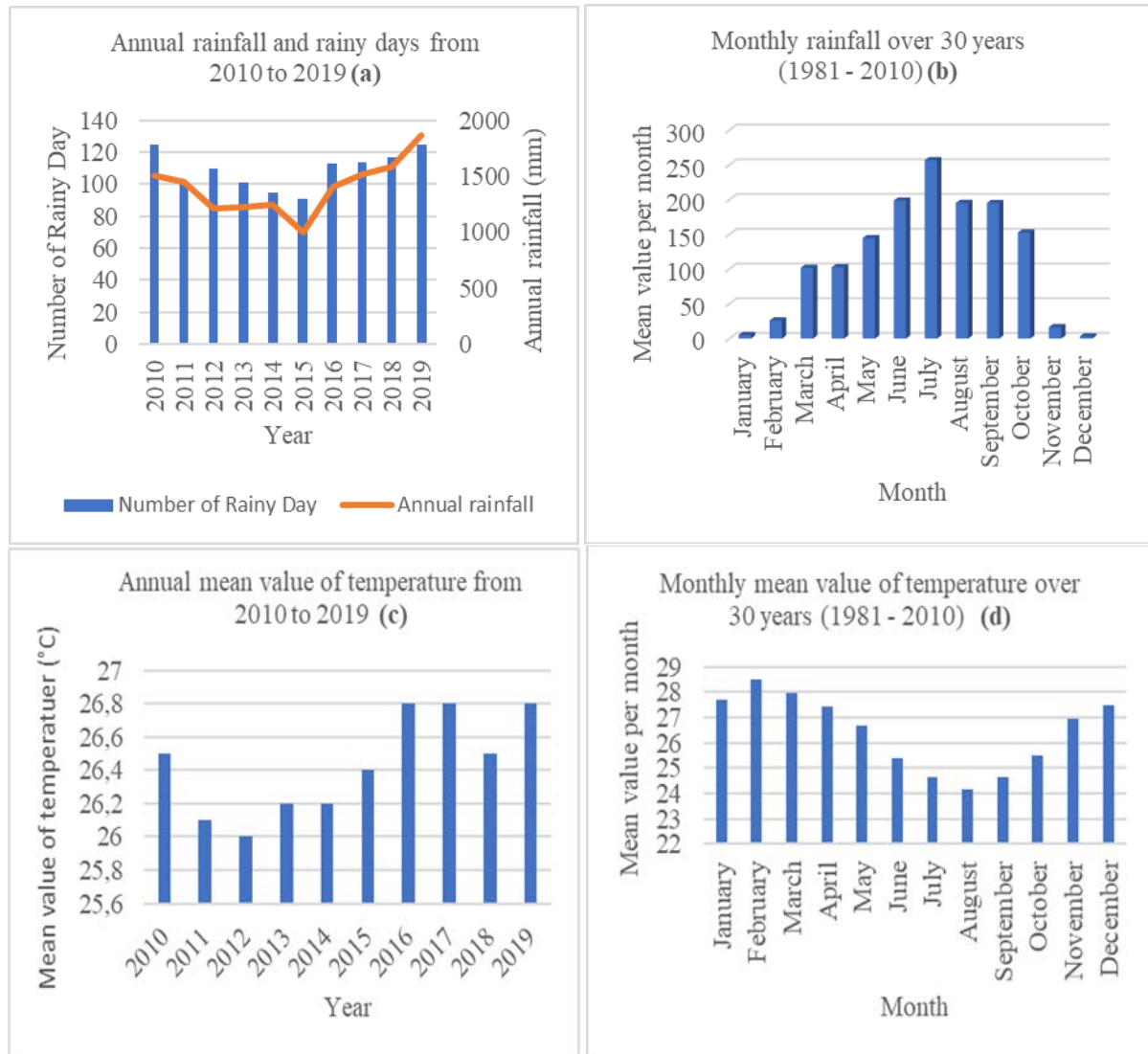


Figure 2. Climatological data (rainfall values: a and b; temperature: c and d)

### 2.3. Sampling and Parameters Analysis

The sampling of pure water was carried out in two phases. The first phase involved applying sterile sampling to analyze microbiological and physicochemical parameters immediately after production. The second phase consisted of collecting samples on the thirtieth day to evaluate the evolution of the exact parameters of the same water brand. Three samples for each brand of sachet-packaged water were collected at each level at the shop store to ensure representativeness. The eight (08) brands of water were selected at 08 different stores (B1-B8) (Table 1) for sampling at  $t=30$  after a previous identification à T0. The samples were transported under sterile conditions and stored in a cool box before analysis to prevent further germ growth. The germ types, culture media, criteria, and incubation conditions are outlined in Table 2. The physicochemical parameters were measured using standardized methods, and appropriate instruments were employed to ensure result accuracy using AFNOR

standardized methods. The samples were collected with sterile tools to avoid contamination and stored at 04°C during the transport, and the accepted concentration standards for each parameter are listed in Table 3. The study was conducted from June 30 to October 30, 2022. Both microbiological and physicochemical analyses were carried out in official labs dedicated to water controls.

Table 1. Anonymous sample distribution in the selected location

| Location  | Number of samples | Water brand | Code Stores |
|-----------|-------------------|-------------|-------------|
| Campement | 3                 | E1          | B1          |
| Sahélien  | 3                 | E2          | B2          |
| Kpota 1   | 3                 | E3          | B3          |
| Kpota2    | 3                 | E4          | B4          |
| Sada      | 3                 | E5          | B5          |
| Keta      | 3                 | E6          | B6          |
| Lyata     | 3                 | E7          | B7          |
| Datcha    | 3                 | E8          | B8          |

**Table 2. Germs, culture media, criteria, and incubation conditions**

| Germs                             | Reference of the standard used | Growing environment | Criteria | Temperature and incubation time |
|-----------------------------------|--------------------------------|---------------------|----------|---------------------------------|
| Aerobic mesophilic germs UFC/mL   | NF EN ISO 4833-1               | PCA                 | ≤100     | 72h ± 3h at 30 °C               |
| Total coliforms UFC/mL            | NF EN ISO 4832                 | VRBL                | 0        | 30 °C 24h ± 2h                  |
| Thermo-tolerant coliforms UFC/mL  | NF V08-060                     | VRBL                | 0        | 44 °C ± 1 °C 24h ± 2h           |
| Sulfite-reducing anaerobes UFC/mL | NF T90-415                     | TS                  | 0        | 44 °C ± 1 °C 24-48h             |
| Fecal streptococci UFC/ mL        | NF EN ISO 15213                | VRBG                | 0        | 37 °C 24h ± 2h                  |

VRBL: Violet to Red Neutral to Bile and Lactose.

VRBG: Violet to Red Bile and Glucose Neutral

PCA: Plate Count Agar

TS: Tetrathionate Sulfite agar

**Table 3. Physico-chemical parameters and methods used**

| Parameters          | Unit                  | Method            | WHO standard (*) - EU |
|---------------------|-----------------------|-------------------|-----------------------|
| Color               | mg Pt-Co/L            | Platinum/Cobalt   | 20(*) 20              |
| Turbidity           | NTU                   | Nephelometry      | 5(*)                  |
| Odour               |                       | Qualitative       | Subjective limit      |
| Taste               |                       | Qualitative       | Subjective limit      |
| Temperature         | °C                    | Thermometer       | -                     |
| pH                  | -                     | Electrometry      | 6.50 - 8.50           |
| EC                  | µS/cm                 | Conductimetry     | 400 (guide number)    |
| TDS                 | mg/L                  | Conductimetry     | 1000(*) 1500          |
| Carbonate           |                       | Acidimetry        | -                     |
| Bicarbonate         |                       | Acidimetry        | > 30 (guide number)   |
| Calcium             |                       | Complexometry     | 100 (guide number)    |
| Magnesium           |                       | Complexometry     | 50                    |
| Potassium           |                       | Spectrophotometry | 12                    |
| Sodium              |                       | Spectrophotometry | 150                   |
| Ammonium            |                       | Spectrophotometry | 1.5 (*) 0.5           |
| Total iron          |                       | Spectrophotometry | 0.3 (*) 0.2           |
| Manganese           |                       | Spectrophotometry | 0.4 (*) 0.05          |
| Nitrates            |                       | Spectrophotometry | 50 (*) 50             |
| Nitrite             |                       | Spectrophotometry | 3.0(*) 0.1            |
| Chloride            |                       | Argentimetry      | 250 (*) 250           |
| Sulphate            |                       | Nephelometry      | 400 (*) 250           |
| Orthophosphates     |                       | Spectrophotometry | -                     |
| Fluorides           |                       | Spectrophotometry | 1.5(*)                |
| Oxidizability KMnO4 | (mgO <sub>2</sub> /L) | Basic/Hot         | (guide number)        |

## 2.4. Data Analysis

The microbiological and physicochemical analysis of sachet-packaged water in Atakpame employed descriptive statistics and deductive methods to assess water quality and safety. Descriptive statistics were used to determine central tendencies and variability for each parameter. Additionally, the data were compared to

WHO guidelines for drinking water (GDWQ) to evaluate compliance with recommended limits and identify potential health risks. A heat map of parameters and samples was used to present a synthetic view and rapidly identify problematic samples or parameters. These tools are also essential for formulating recommendations for improving bagged water quality.

## 3. Results and Discussion

### 3.1. Survey Results

#### 3.1.1. Socio-demographic Data

The survey reveals that in the study area, approximately 25% of employees in the sachet water production units have only primary or secondary education levels, while 5% have university degrees. Additionally, 75% of the employees work part-time. These factors create challenges in adopting and mastering good hygiene practices (GHP), as lower education levels and part-time work can hinder the effective implementation of proper hygiene protocols. The lack of consistent training and the transient nature of part-time employment increase the risks of maintaining optimal hygiene standards in the production units. The workforce is predominantly male, with 62.86% of men and 37.14% of women. This distribution can be explained by the nature of the activities within the production units, mainly due to a fixed income that is less attractive than other economic opportunities.

Atakpame, for instance, is a hub of economic activity around bus stops, where price fluctuations and the availability of agricultural and fish products empower young women to set their prices, often depending on the buyer. These results contrast those from a study by [13] in the Togolese capital, Lomé, where 65% of the employees were female. The socio-economic conditions of the study area may, therefore, affect the gender distribution of employees.

#### 3.1.2. Overview of Production Companies

Surveys were conducted from June to September 2022 during the coldest period at Atakpame (figure 3). Based on information gathered from the Direction of Hygiene and Basic Sanitation (DHAB), we identified 12 packaged-water production companies (WPC) representing 42,86% of WPC in the Plateaux region. There are currently around 234 (WPC) selling across Togo, 72% located in the administrative area of the capital, Lomé. In 2022, only eight (8) production companies have approval from the Interministerial Committee for the Control of Packaged Water (CICEC), and seven (7) of these companies hold a hygiene certificate issued by the Division of Health Control and Inspection (DCIS).

Facility design is outlined by the National Institute of Hygiene (INH), but few WPC comply with it. More than 75% of the production units have residential spaces integrated within their premises, with inadequate room dimensions to ensure indoor ventilation. These findings are consistent with previous studies at other Togolese cities [6,13] reporting that more than 60% of production sites are surrounded by stagnant wastewater and illegal

dumps, and WPC did not adhere to INH hygiene standards. Similar observations were made in the study by [20], which noted that production sites often consist of a single room that serves as a production area and storage space for sachet water. The sanitary evaluation of production companies generally focuses on the production facilities, their environment, the production system, good hygiene practices (GHP), and the management of waste (plastic sachets) generated from production. These shortcomings have led to the closure of several production sites in previous years. However, this does not prevent the establishment of new companies, with few currently holding contracts for physicochemical and microbiological analysis of their production.

### 3.1.3. Storage Conditions for Finished Product and Inputs

The storage conditions for raw materials and finished products in WPC are concerning, with 50% of companies placing materials directly on the floor, exposing them to dust and insects (Figure 4 and Figure 5). Only 33% of WPC use pallets, but 75% are made of wood, which can harbor contaminants [6]. Best practices suggest using plastic or metal pallets, but this is rare. Extended storage, especially during low sales seasons, exacerbates the risks of microbiological contamination. While sachet water is generally stored for no more than three days during high sales periods, it can be stored for weeks during off-seasons, and storage time can extend beyond a week or even a month, increasing contamination risks [21,22]. Sachets often lack production and expiration date labels, and using unprotected transportation methods like tricycles, less expensive transportation, and sunlight exposure further degrades water quality. To avoid contamination, raw materials and finished products must have no contact with the ground, whatever the nature of the soil, and must be stored on suitable, clean pallets [8,23]. However, the opposite is true, as illustrated in Figure 4. Additionally, untreated water is often stored in exposed plastic tanks, compromising its safety. Improved storage and transportation practices are urgently needed to ensure water quality.



a



b



c

**Figure 3.** External (a b) and internal (c) aspects of two different production companies



a



b



C

**Figure 4.** Some storage conditions of sachet-packaged water in production companies (a b c)



**Figure 5.** Unsanitary packaging room

## 3.2. Sample Analysis Results

### 3.2.1. Descriptive Statistics of the Physicochemical Analysis

The descriptive statistics (Table 4) of the sachet-water samples treated by reverse osmosis reveal several key water quality parameters. The average temperature was 27.5°C (SD = 1.4), favorable to microbial growth. Turbidity was low, averaging 0.15 - 0.71 NTU below WHO standards. Only one sample had a pH value outside the recommended range of 6.5 to 8.5 at T0. Electrical conductivity (EC) varies from 18.21 to 480 µS/cm (SD = 147.67), with an average at 117.15 µS/cm at T0 against lower values at T30, indicating variability in ion concentrations and likely adsorption of minerals on sachets. TDS confirmed a similar tendency. Other

parameters except iron were abnormal compared to WHO guidelines. These findings suggest that reverse osmosis, while effective in reducing turbidity, may excessively remove beneficial minerals, raising concerns about the nutritional quality of the water [24,25]. Balancing purification with mineral retention is essential to ensure that sachet water remains safe.

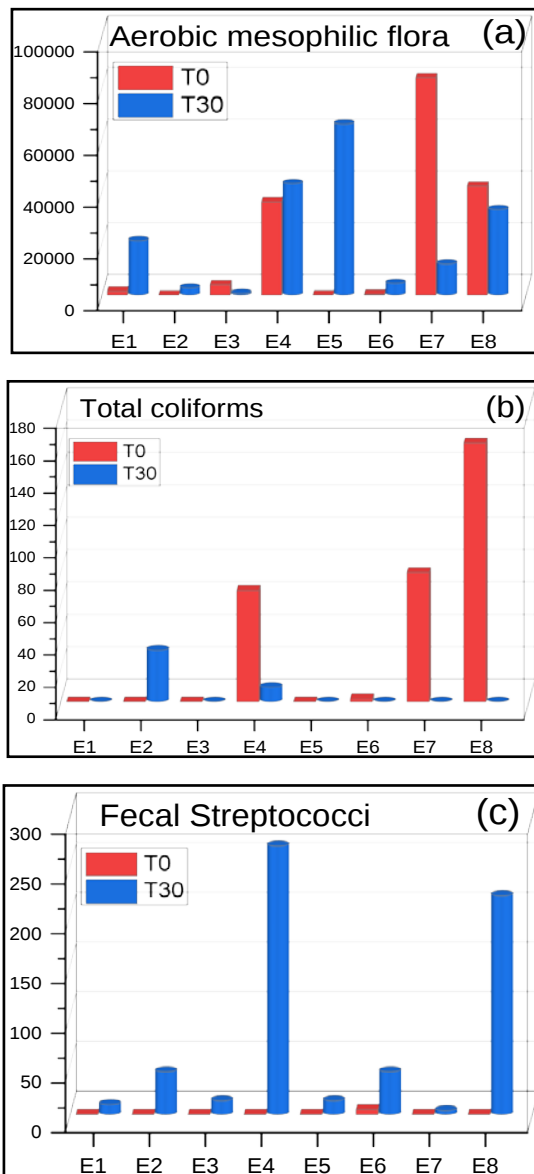
### 3.2.2. Microbiological Analysis of Water Samples

Aerobic mesophilic bacteria (Figure 6a) contamination increased substantially in most samples after 30 days. For instance, sample E1 rose from 1500 to 21000 CFU/mL, and E5 from 53 to 66000 CFU/mL. At T30, total coliforms (Figure 6b) were detected, especially in E4 (69 CFU/mL) and E2 (32 CFU/mL), indicating potential fecal contamination. Additionally, fecal streptococci (Figure 5c) were present in E2 (43 CFU/mL) and E4 (270 CFU/mL) after 30 days [5,7]. These results suggest that prolonged storage and improper hygiene during production contribute to the degradation of microbial water quality, making it inappropriate for human consumption [14,21,22]. The microbiological analysis of sachet-water samples revealed significant contamination over time. The levels of aerobic mesophilic bacteria (Figure 5a) increased substantially in most samples after 30 days. For instance, in sample E1, counts rose from 1500 to 21000 CFU/mL, while in E5, they surged from 53 to 66,000 CFU/mL. Total coliforms (Figure 6b) were detected in samples, particularly in E4 (69 CFU/mL) and E2 (32 CFU/mL) at T30, indicating fluctuation in potential fecal contamination. Additionally, fecal streptococci (Figure 6c) were found in E2 (43 CFU/mL) and E4 (270 CFU/mL) after 30 days. No thermotolerant coliforms and sulfite-reducing anaerobes were detected in samples, suggesting a moderate risk of waterborne diseases typically associated with anaerobic environments. Like coliform bacteria, fecal streptococci are recommended as a group of fecal indicator organisms for evaluating the microbiological quality of groundwater [1,26]. They are found in the intestinal tracts of humans and various animals and have some advantages over the coliform group in assessing the microbiological safety of water. Notably, these include that fecal streptococci are more resistant to treatment processes and environmental stresses and tend to persist in the environment longer than coliform bacteria. Thus, microbial contamination by these indicators displays a non-neglective risk for waterborne disease. These results suggest that prolonged storage, coupled with employees' inadequate hygiene along packaging and no remanent feature of UV-based disinfection of water after reverse osmosis of raw water, are essential factors in the microbial water quality of sachet-packaged water [14,21,22].

**Table 4.** Descriptive statistics of the physicochemical analysis

| Parameters       | (T0)  |        |        |        |        | (T30) |      |       |       |       |
|------------------|-------|--------|--------|--------|--------|-------|------|-------|-------|-------|
|                  | Min   | Max    | Mean   | StD    | CV     | Min   | Max  | Mean  | StD   | CV    |
| T°C              | 28.7  | 29.3   | 28.89  | 0.21   | 0.73   | 25.9  | 26.3 | 26.11 | 0.14  | 0.52  |
| Turbidity        | 0.12  | 1.6    | 0.71   | 0.54   | 76.51  | 0.01  | 0.34 | 0.15  | 0.13  | 85    |
| pH               | 5.74  | 7.54   | 6.61   | 0.63   | 9.48   | 6.45  | 7.96 | 7.43  | 0.47  | 6.31  |
| TDS              | 30.39 | 369.12 | 92.46  | 112.28 | 121.43 | 23.6  | 82.2 | 62.81 | 21.62 | 34.41 |
| c25°C            | 32.1  | 480    | 117.15 | 147.67 | 126.06 | 32.2  | 86.8 | 70.65 | 18.21 | 25.77 |
| Ca <sup>2+</sup> | 1.4   | 17     | 3.55   | 5.44   | 153.19 | 0.6   | 2.4  | 1.58  | 0.57  | 36.2  |

|             | (T0) |       |      |        |        | (T30) |      |       |       |        |
|-------------|------|-------|------|--------|--------|-------|------|-------|-------|--------|
| $Mg^{2+}$   | 0.8  | 7.8   | 2.5  | 2.33   | 93.2   | 1     | 2    | 1.4   | 0.39  | 27.53  |
| $Mg^{2+}$   | 2.9  | 11.4  | 6.43 | 3.31   | 51.49  | 2.5   | 5    | 4.09  | 0.84  | 20.45  |
| $K^{+}$     | 1.1  | 8.2   | 2.86 | 2.53   | 88.44  | 1     | 1.8  | 1.38  | 0.29  | 20.84  |
| $HCO_3^{-}$ | 36.6 | 329.4 | 79.3 | 101.24 | 127.66 | 24.4  | 61   | 40.41 | 11.73 | 29.02  |
| $Cl^{-}$    | 2    | 4     | 3    | 1.07   | 35.63  | 1     | 7    | 3.88  | 2.42  | 62.36  |
| $SO_4^{2-}$ | 0.01 | 10.39 | 3.28 | 4.36   | 132.91 | 0.01  | 5    | 1.77  | 2.43  | 137.66 |
| $NO_3^{-}$  | 0.18 | 3.94  | 1.07 | 1.19   | 111.29 | 0.33  | 5.52 | 1.88  | 1.77  | 93.86  |
| $NO_2^{-}$  | 0    | 0.06  | 0.01 | 0.02   | 212.38 | 0     | 0.12 | 0.02  | 0.04  | 282.84 |
| $NH_4^{+}$  | 0    | 0     | 0    | 0      | NA     | 0     | 0.48 | 0.07  | 0.17  | 234.11 |
| $CO_3^{2-}$ | 0    | 0     | 0    | 0      | NA     | 0     | 0    | 0     | 0     | NA     |
| $Fe_T$      | 0    | 1.03  | 0.43 | 0.35   | 81.24  | 0     | 0.16 | 0.03  | 0.06  | 191.63 |
| $KMnO_4$    | 0    | 1.3   | 0.58 | 0.53   | 92.38  | 0     | 1.6  | 0.71  | 0.56  | 78.84  |
| $PO_4^{3-}$ | 0    | 0.04  | 0.01 | 0.01   | 181.14 | 0     | 0.58 | 0.07  | 0.21  | 282.84 |



**Figure 6.** Comparative evolution of Aerobic Mesophilic Flora (a), Total Coliforms (b) and Faecal Streptococci (c)

### 3.3. Health Implications of the Microbiological and Physicochemical Results

A heat map based on shading matrices of results is represented to have a global view of sachet-packaged water's microbiological and physicochemical quality for highlighting significant public health concerns. Heat Map analysis helps to target the highest values parameters according to sachet-packaged water brand. Red values to green values indicate higher data values than lower ones.

Figure 7 shows the substantial increase in aerobic mesophilic bacteria (AMF) count after 30 days of storage, suggesting a risk of microbial proliferation over time (Ngumbu et al., 2017; Adesakin et al., 2022). Hence, assessing the spatial and temporal variations of aerobic mesophilic bacteria (AMF) can provide valuable insights into the microbiological stability of the sachet-package water and facilitate routine drinking water analyses. AMF should be integrated within a multi-parameter approach for analyzing microbial growth in drinking water [27] because of its limitations as a water quality indicator. Thus, AMF count is not a straightforward way to know microbiological-specific risks. Hence, the use of total coliforms as an indicator for assessing the microbiological safety of water has significantly contributed to the reduction of waterborne disease outbreaks in countries that have adopted this practice [26], and its determination will give more information about water contamination.

Between T0 and T30, fecal streptococci (FS) counts in E4 and E8 are fewer than in E6, indicating an increase. At the same time, E6 reflects a decrease compared to E4 and E8 in fecal contamination by this germ, even showing an increase corresponding to a less intense color on the heat map at T30. This reflects that at T30, FS in E4 and E8 are more contaminated than E6. This helps to have a mind map about contamination evolution and matter for health risk communication and management. E8 has the highest value for T0 for eleven (11) parameters among 21. The highest concentration of AMF, and,  $NO_3^{-}$ ,  $SO_4^{2-}$ , FS and

$\text{NO}_2^-$ , and TC were identified in E7, E1, E2, E6 and E8, respectively. Contrary to that, FS, AMF,  $\text{K}^+$ ,  $\text{NO}_3^-$  and  $\text{NO}_2^-$ ,  $\text{SO}_4^{2-}$  and, TC concentrations were the highest at T30 in E4, E5, E4, E1, E3 and E2 respectively. The overall microbial profile points out inadequate handling and storage practices. Prolonged storage and improper packaging environment during production create a conducive environment for bacterial growth, emphasizing the need for improved water treatment, packaging, storage, and handling practices to ensure the safety of sachet water for consumers. However, the occurrence of waterborne disease outbreaks in countries without coliform and fecal streptococci highlights the need for improved methods to assess the microbiological quality of water [26].

The physicochemical analysis of sachet water samples highlights several health concerns. The water temperature promotes bacteria growth, responsible for numerous diseases, including cholera, typhoid, and dysentery, which have led to significant epidemics [26]. The pH values, ranging from 5.74 to 7.96, with an E1 value below the WHO's recommended range of 6.5 to 8.5, could affect mineral solubility and microbial activity. The variability in total dissolved solids (TDS) and electrical conductivity (EC) indicates over-demineralization from reverse osmosis, leading to low values of essential minerals like calcium and magnesium with an average rate of removal up to 97% [25]. Demineralized water consumption can lead to mineral absorption from the body and eliminate the same through urine. Then, consuming low-mineral water with excreted minerals can cause adverse health effects such as fragility of bones and teeth, increasing the risk of

osteoporosis and dental caries. Furthermore, the absence of carbonate ions and low concentrations reduce the water's buffering capacity, which can impact taste and acidosis disease.  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{NH}_4^+$ ,  $\text{NO}_3^-$ ,  $\text{NO}_2^-$ , all are below the recommended concentration of drinking water [1]. While these findings suggest minimal chemical pollution, the lack of essential minerals may compromise the nutritional quality of the water, requiring improvements in treatment practices [25]. Remineralization of water by adding calcium carbonate ( $\text{CaCO}_3$ ), magnesium sulfate ( $\text{MgSO}_4$ ), and magnesium carbonate ( $\text{MgCO}_3$ ) salts in a well-determined proportion will result in slightly alkaline water. Drinking alkaline water may help further prevent osteoporosis and safeguard pancreatic beta cells due to its antioxidant properties [28]. The physicochemical and microbiological quality of packaging can lead to contamination during the bagging of water. Our field surveys have shown that some producers expose the sachets to UV radiation for 24 hours before use. However, this practice may cause material degradation, potentially resulting in significant microplastics and plasticizers in the sachet-packaged water [29]. Research on the cancer risk associated with bottled water consumption has revealed alarming results, with 37% (n=30) of samples showing a high cancer risk, which could contribute to an increased likelihood of cancer [30]. The findings underscore the critical need for improved environmental management practices at production sites, including better site selection away from pollution sources, enhanced hygiene protocols, and rigorous quality control measures to ensure the safety and reliability of sachet-packaged water.

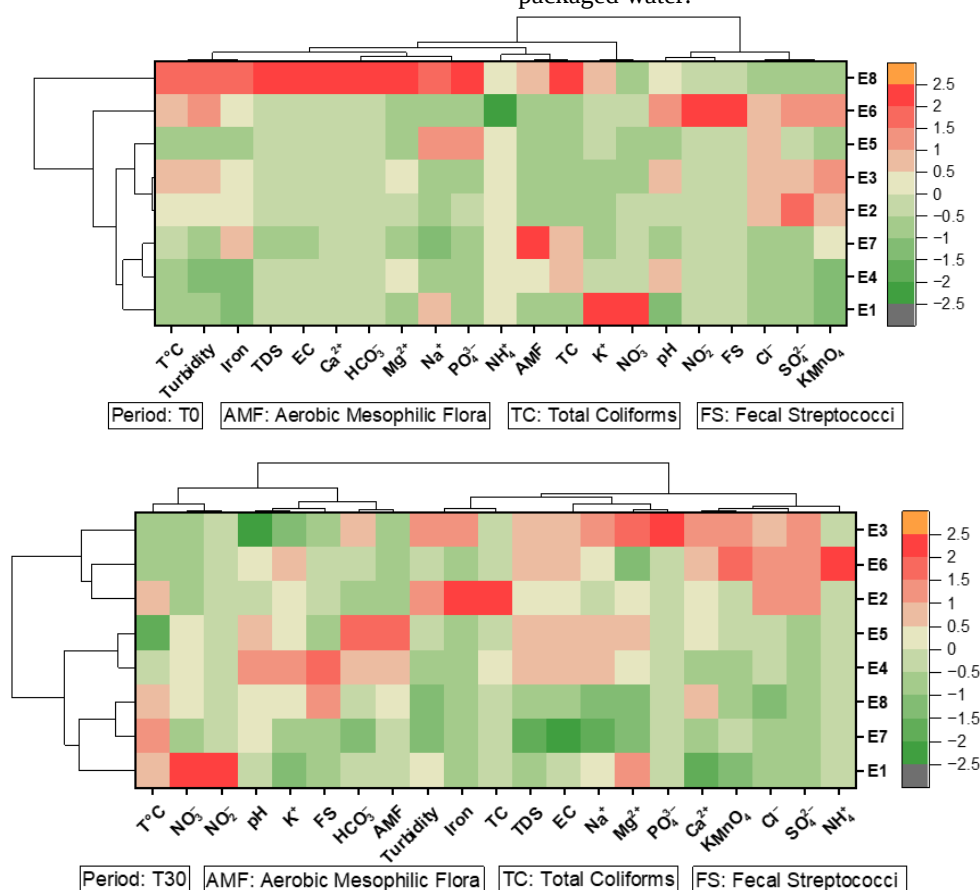


Figure 7. Heat map of sachet-packaged water à t=0 (above) and t=30 (below)

## 4. Conclusion

Investigating sachet-packaged water's biological and chemical quality in Atakpamé, Togo, highlights significant public health risks associated with its consumption. Despite the widespread belief that sachet water is a safer alternative to tap water, the findings reveal alarming deficiencies in production practices and environmental conditions. Approximately 75% of production sites are in polluted environments, which could directly contribute to microbiological contamination. In several samples, mesophilic aerobic bacteria, total coliforms, and fecal streptococci indicate a severe risk of waterborne diseases, including diarrhea and typhoid fever. Moreover, the physicochemical analysis demonstrates trends, such as excessive demineralization of calcium and magnesium, which can compromise the nutritional value of water. This imbalance raises critical questions about the long-term health implications for consumers who rely on sachet water as their primary source of hydration at the workplace and household level. Health authorities and water producers must implement comprehensive quality control measures to mitigate these risks. This includes enhancing water treatment protocols, improving storage conditions, and ensuring that production facilities are located away from potential sources of contamination. Additionally, raising public awareness about the importance of safe drinking water and related health risks can empower consumers to make informed choices between drinking water from a drinking water supply network and sachet-packaged water for drinking purposes. Addressing the identified shortcomings in producing and distributing sachet-packaged water is crucial to safeguarding public health in Atakpame and similar regions. Collaborative efforts among stakeholders will be essential to ensure that sachet-packaged water remains a safe and reliable source of drinking water for all.

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