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# Assessment Of Microbiological Risks Associated With Well And Spring Water Consumed In Daloa (Côte D'ivoire)

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***Abstract:***
***Background****: Access to safe drinking water remains a formidable challenge in developing countries, marked by pronounced socioeconomic inequalities, especially in underprivileged urban areas. In Daloa (Côte d'Ivoire), a segment of the population resorts to unconventional water sources owing to the poor quality of the municipal supply, thereby exposing users to microbiological hazards. This study set out to assess the risk of microbial contamination in well and spring water consumed by the inhabitants of Daloa.*
***Materials and Methods****: A socio-demographic survey was conducted in six neighbourhoods of the city, involving 207 residents, to inventory their water sources and perceptions of water quality. Subsequently, water samples were collected from two types of points (wells and natural springs) and analysed in accordance with ISO standards for aerobic mesophilic flora, total coliforms, Escherichia coli and intestinal enterococci.*
***Results****: The results revealed that the great majority of respondents believed their various water supplies to be of good quality because of their clarity. However, microbiological assays demonstrated the systematic presence of indicator organisms above the limits recommended by the World Health Organization, particularly in wells. These contaminations are attributable to the unsanitary surroundings of the spring points and the absence of proper curbstones or covers on the wells.*
***Conclusion:*** *It is essential to acknowledge that alternative water supply sources are by no means devoid of risk for the population. It would therefore be advisable to enhance the protection of water catchment points, to undertake regular analyses, and to employ simple treatment methods (chlorination, boiling) prior to consumption.*
***Key Word****: Water microbiology, Fecal contamination, Daloa, Total coliforms, Escherichia coli, Intestinal enterococci*

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## I. Introduction

Water, as the source of life, constitutes a cornerstone of sustainable socioeconomic development. Ensuring its availability for all uses has become a paramount global challenge, both for public health and for the resilience of communities and economies[1]. In 2022, 73 % of the world's population (approximately six billion people) accessed drinking-water services classified as "safely managed," meaning they were supplied from improved sources, located on premises, available at all times, and free from contamination[2]. The remaining 27 % (2.2 billion people) relied on basic or unimproved services, such as untreated surface water drawn from lakes, rivers, or rudimentary wells[2]. In urban areas, profound inequalities persist: low-income inhabitants or those residing in informal or unauthorized settlements have limited access to improved water infrastructure[3]**.** To overcome these difficulties, many communities resort to precarious and unconventional means well water, spring water, public fountains, or purchases from local sellers. These practices involve collection, transportation, and storage steps that can compromise the microbiological quality of the water and pose health risks[4,5,6]. In Côte d'Ivoire, 65 % of the urban population is served by the Société de Distribution d'Eau de Côte d'Ivoire (SODECI)[7]. In Daloa, the regional capital of Haut-Sassandra, public distribution is sometimes deemed inadequate: altered taste or suspicious coloration prompts some households to turn to wells, boreholes, or springs.
Accordingly, the overarching objective of this study is to assess the microbiological risks associated with the various water sources consumed in Daloa. Specifically, it aims to identify the water sources most frequently used by the city's inhabitants and to evaluate their microbiological quality based on the following indicators: aerobic mesophilic flora, total coliforms, *Escherichia coli*, and intestinal enterococci.

## II. Material And Methods

**Study area**

The city of Daloa, covering 5 305 km² with a population of 245 360, is situated 383 km northwest of Abidjan (06°30′–08°00′ N, 05°00′–08°00′ W). Six neighbourhoods were selected, encompassing both residential districts (Oliviers, Tazibouo, Gbokora) and working-class quarters (Abattoir, Marais, Texas). A structured questionnaire was administered to record socio-demographic profiles, water sources employed, perceptions of water quality, and hygienic conditions around collection points. In October 2024, two hundred and seven individuals participated in the survey.

**Socio-demographic survey of primary water supply sources**

Utilizing the bespoke survey instrument, an inquiry into the water supply sources employed by the local populace was undertaken. The investigation was conducted in six neighbourhoods of the city of Daloa during October 2024. These comprised three residential quarters, Oliviers, Tazibouo, and Gbokora, and three working-class districts, Abattoir, Marais, and Texas. Data collection initially focused on socio-demographic characteristics, namely sex, age cohort, and educational attainment. Subsequently, respondents were asked to enumerate all water supply sources they used, to identify their preferred source, and to appraise the hygienic quality of the water they consumed. Direct field observations were also performed to assess the sanitary conditions surrounding each water point and to document community behaviour during water collection. In total, 207 individuals were surveyed at the various water points.

**Water Sampling for Microbiological Testing**

To perform the microbiological assays, samples were taken from those water points exhibiting the most degraded hygienic conditions. During the survey, three samples were collected at each water point. Each sample was labelled according to its district of origin and the specific water supply source. Sampling was carried out in August, September, and October, with one collection per month, in strict accordance with the requirements of[8,9]. The time elapsed between sample collection and receipt at the laboratory transported in a refrigerated cooler did not exceed seven hours.

**Microbiological Tests**

**Enumeration of Total Microbial Flora[10]**

The principle of total germ enumeration entails inoculating a suitable culture medium (Mueller-Hinton agar) with the concentrated water sample, then incubating the Petri dishes at 36 °C for 44 hours. During this period, all viable microorganisms present in the sample will grow, forming discrete colonies. To proceed, sterile pipette tips were affixed to a micropipette calibrated at 100 µL. The flask containing the water was vigorously shaken to ensure homogeneity, and 100 µL of the sample was withdrawn and deposited onto a section of the Petri dish. Using a Pasteur pipette, the inoculum was then gently spread across the entire agar surface. Colony counts were conducted after 44–48 hours of incubation. The total number of colonies on the agar was recorded, multiplied by a factor of ten, and reported as colony-forming units per millilitre (CFU/mL).

**Detection and Enumeration of Total Coliforms and *Escherichia coli***

The detection and enumeration of E. coli and total coliforms were performed in accordance with[11]. Following membrane filtration, each filter was gently placed onto Chromogenic Coliform Agar (CCA), taking care to avoid entrapped air beneath the membrane. The Petri dishes were inverted and incubated at (36 ± 2) °C for (21 ± 3) hours. After incubation, the membranes were examined and colonies were differentiated as follows:
- Colonies exhibiting a positive β-D-galactosidase reaction (pink to red) were recorded as presumptive coliforms other than *E. coli.*
- Colonies displaying both a positive β-D-galactosidase reaction and a positive β-D-glucuronidase reaction (dark blue to violet) were recorded as *E. coli.*

Presumptive coliform colonies not identified as *E. coli* were subsequently confirmed by an oxidase test.

**Detection and Enumeration of Intestinal Enterococci**

This section of[12] specifies a method for the detection and enumeration of intestinal enterococci based on the filtration of a defined volume of water sample through a membrane filter with a pore size of 0.45 µm, sufficient to retain the bacteria. The filter is then placed on a selective solid medium containing sodium azide, to inhibit the growth of Gram-negative bacteria, and 2,3,5-triphenyltetrazolium chloride, a colorless dye that is reduced by intestinal enterococci to red formazan. Typical colonies are convex, exhibiting red, brown, or pink coloration either centrally or across the entire colony.

**Microbiological Indicators of Drinking Water**

Numerous pathogenic microorganisms such as viruses, bacteria, and protozoa may be present in water. Among bacterial indicators, total coliforms and intestinal enterococci are employed to assess the microbiological quality of drinking water. The World Health Organization dictates that water is deemed potable when a 100 mL sample contains no colonies of these organisms[13]. For total aerobic mesophilic flora, the specification limit for water to be considered fit for consumption is a maximum of 300 colonies of this organism per millilitre of sample (Table 1).

**Table 1:** Microbiological indicators for drinking water

| Microorganisms of interest | Limit of acceptable colony |
|---|---|
| Total flora | ≤300/mL |
| Total coliforms | 0/100 mL |
| *Escherichia coli* | 0/100 mL |
| Intestinal enterococci | 0/100 mL |

**Data Processing**

The analyses of data obtained from the population survey on water supply sources, together with the microbiological examinations conducted on the water samples, are presented in a series of tables and graphical formats (histograms and pie charts). For the microbiological analyses, the mean colony counts from the three samplings were calculated using Excel 2024, which was also employed to generate the various tables and charts.

## III. Result

**Socio-Demographic Survey and Water Usage**

**Socio-Demographic Profile of Respondents**

The analysis of the collected survey data reveals the gender distribution of individuals who frequent water points to procure water for their households. According to the findings, 67.63% of these individuals were man, compared to only 32.37% woman respondents (**Figure 1**). Furthermore, just over half of the respondents approximately 51.69% were aged between 31 and 40 years. A further 24.64% were aged between 41 and 50 years, while about 19.32% fell within the 18 to 30-year age bracket. Only 2.90% and 1.45% were respectively in the age ranges of 51 to 60 years and over 60 years. These figures clearly indicate that the vast majority of the population visiting water points is relatively young.

Regarding the level of education of the respondents, the results are shown in **Figure 2**. According to this figure, 19.42% of the respondents reached primary level, 40.29% secondary level and 29.61% were or are university students. It is also noted that 6.31% of the respondents had no educational level and that 4.37% had only benefited from a Koranic education system.

**Water Sources Consumed and Population Opinions Regarding Their Hygienic Quality**

**Water Supply Sources of Respondents**

Analysis of data on water sources consumed by the populations of the various surveyed neighborhoods shows that the main water supply sources are wells, boreholes, spring water, and public water distribution (SODECI). Indeed, 45.41% of respondents reported using spring water as their source of supply, 37.68% used boreholes, 10.63% used wells, and only 6.28% reported using the public water distribution company (SODECI) as their source of water supply (**Figure 3**). Among these populations, some use only one source for their water supply; they represent approximately 88.89% of respondents. The rest, however, may use two or three sources for their water supply (**Figure 4**).

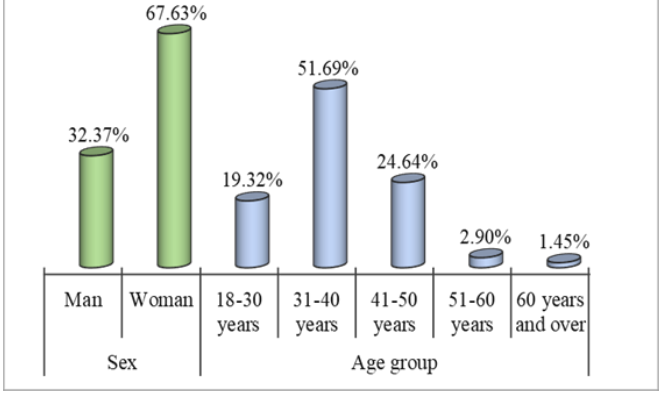


**Figure 1**: Distribution of respondents by sex and age range

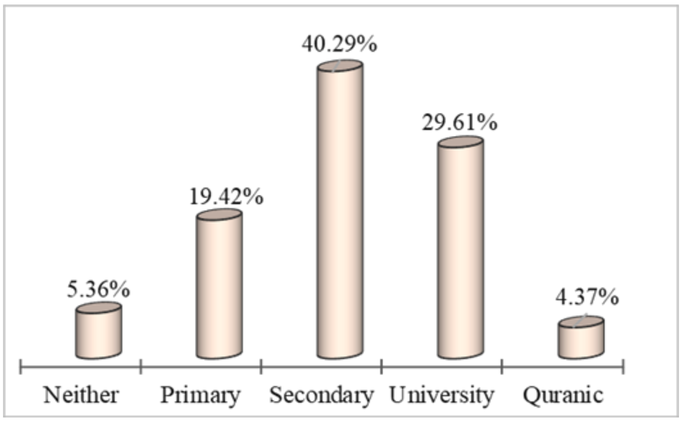


**Figure 2**: Respondents' educational attainment

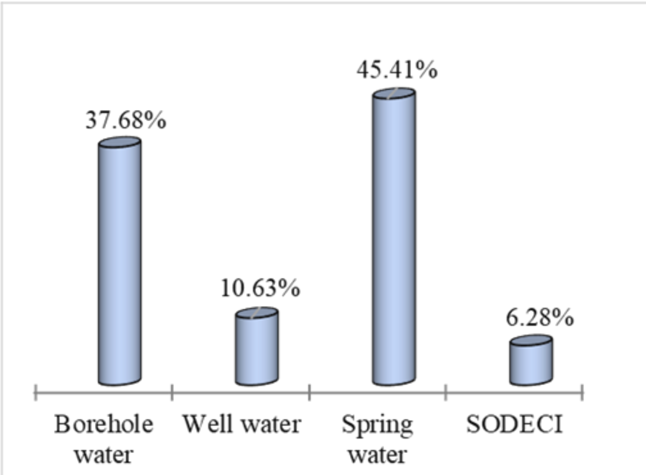


**Figure 3:** Primary sources of water supply across the surveyed neighborhoods

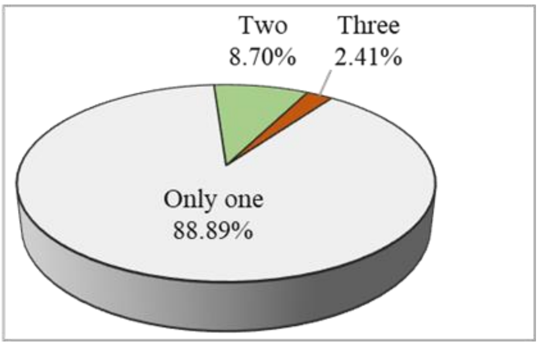


**Figure 4**: Count of water sources used to meet household needs

**Figure 5** shows the population's preference for water sources used by education level. According to this figure, education level has no influence on the preference for a source. Among these sources of supply, spring water (45% of respondents) and boreholes (37.68%) are the most used. Public distribution water (SODECI), in this survey, is the least used source of supply, approximately (6.28% of respondents).

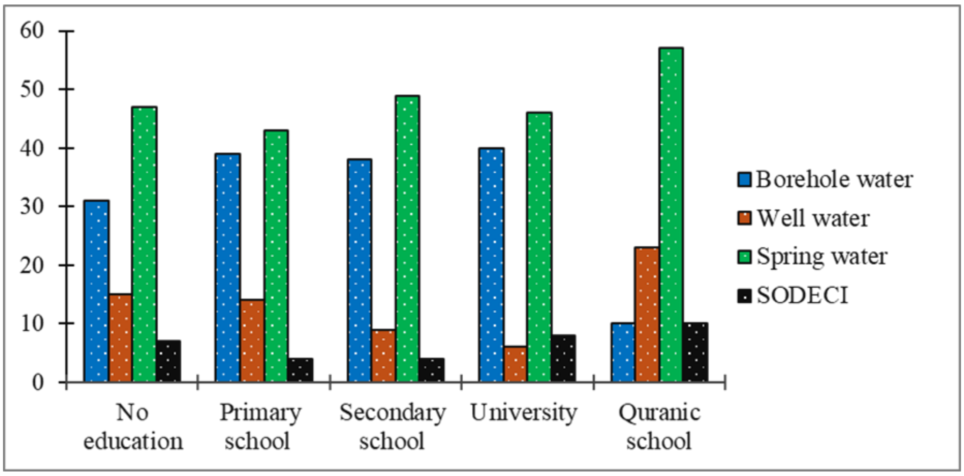


**Figure 5**: Water source preferences based on educational attainment

**Hygienic Conditions of Water Points and Respondents' Perceptions of Water Quality**
**Direct Observations Conducted in the Field**

During the survey, direct field observations were carried out around several water points. As depicted in the following figures, two spring water sources were documented. At the first site (Figure 6a), the surrounding environment was found to be severely unhygienic. The area appeared neglected, with a stagnant pool of water contaminated by human activity in proximity to the source.

At the second site (Figure 6b), also a spring water point, a terrace had been installed around the source. However, the piping laid to facilitate water access rested directly on the ground, thereby increasing the risk of contamination by surrounding.


**Figure 6**: Hygienic conditions around spring water sources

As for wells and boreholes, these water points seem to be better maintained than spring water points. However, at the well level, a good number have fairly rudimentary covers as in Figure 7a. The well in Figure 7b is better covered than the previous one, but at the water collection point, the water escaping from the scoop can easily return to the well with dirt carried by the palms of the feet or the bottom of the shoes due to the continuity between the opening of the well and the surface where the foot is placed. Regarding boreholes, the hygienic conditions around the points are acceptable and the water access pipes are a bit like those of the public water distribution company (Figure 8a and 8b).


**Figure 7**: Hygienic conditions around the wells


**Figure 8**: Hygienic conditions around the boreholes

**Respondents' Opinions on the Hygienic Quality of the Water They Consume**

The results of respondents' opinions on the hygienic quality of the water they consume are presented in Figures 9 and 10. According to **Figure 9**, various reasons lead the populations of the surveyed neighborhoods to prefer a particular water source. For many, the water used is "good" and "clean," while for others, it is easily available (3.92% of cases), or close to home (8.33% of respondents), or because it is the only source available in the neighborhood (2.45% of respondents). Approximately 85% of respondents believe that the water source used is of good hygienic quality.

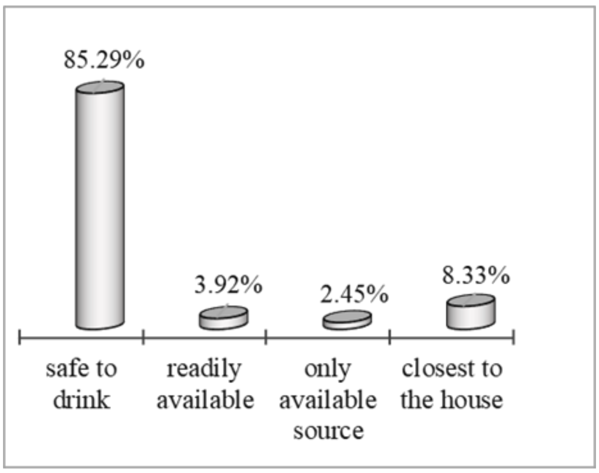


**Figure 9**: Criteria guiding water source choices among study participants

Apart from stating that the water consumed is good or clean, for these populations, there is no need to worry and that the water consumed is completely safe (approximately 92% of those surveyed). Similarly, for the vast majority (approximately 94%), they have never shown signs of gastrointestinal disorders such as diarrhea since the first moments of consumption of the water they use. Furthermore, almost all of the respondents (approximately 98%) considered that the hygienic conditions around the various water points (spring water, boreholes and wells) did not represent any danger for them. Thus, for all the respondents it was therefore not necessary for them to treat the water before any consumption (**Figure 10**).

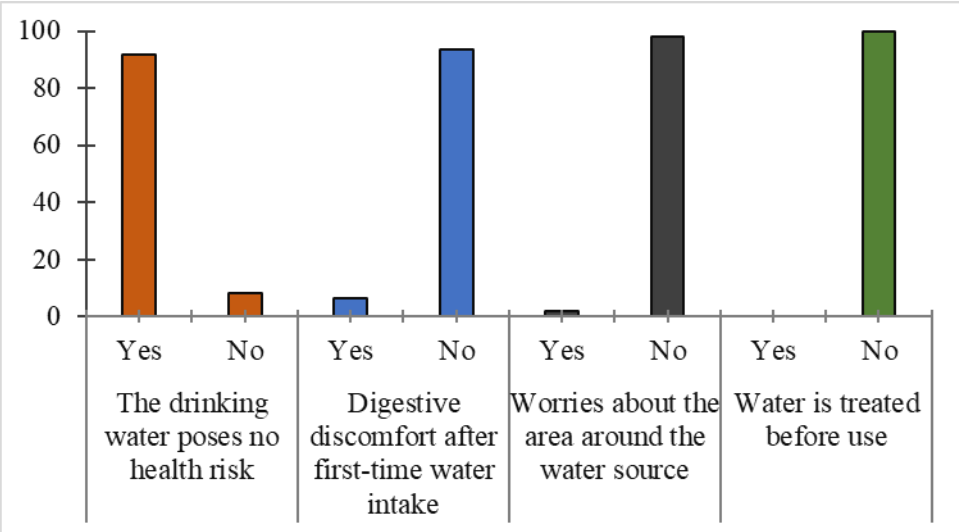


**Figure 10**: Population's assessment of the quality of the water it consumes and of the environment around the water point

**Microbiological Quality**

The spring and well water samples collected in the six (06) districts where the surveys were conducted were all clear. The search and enumeration of germs in these water samples showed that all samples had a germ count above the specification limit. When considering the total mesophilic aerobic flora, the specification limit for water of the best microbiological quality should be less than or equal to 300 germs/mL of water (Table 2). However, the data in the table show that all well water samples, regardless of the neighborhood, had a total flora concentration above the specification limit. The same is true for the spring water samples from the six neighborhoods surveyed, with the exception of the water samples from the Gbokora, Tazibouo, and Les Oliviers neighborhoods, which had total flora concentrations less than or equal to 300 germs/mL, as recommended. For three other remaining germs, namely total coliforms and intestinal enterococci, all water samples analyzed from both wells and springs contained them. However, for these germs, for better microbiological water quality, the standard is to not count any germs per 100 mL of sampled water. These three germs had higher concentrations in well water samples than in spring water samples (Table 2). In summary, microbiological analyses carried out on well and spring water samples showed that these water sources are subject to microbial contamination.

**Table 2**: Germs enumerated in water samples collected from wells and spring sources in the surveyed neighborhoods

| Water sources | Analyzed water samples | Sample description | Germs enumerated at 36 °C in CFU | | | |
|---|---|---|---|---|---|---|
| | | | Total flora | Total coliforms | *Escherichia coli* | Intestinal enterococci |
| Spring water | ABATTOIR | Transparent water | >300 | 86 ± 16.37 | <1 | 11 ± 3.44 |
| | GBOKORA | Transparent water | 256 ± 36 | 58 ± 11.13 | 4 ± 2.11 | 10 ± 5.66 |
| | MARAIS | Transparent water | >300 | 98 ± 14.18 | 43 ± 10.76 | <1 |
| | OLIVIERS | Transparent water | 192 ± 42 | 68 ± 11.53 | 17 ± 0.74 | <1 |
| | TAZIBOUO | Transparent water | 40 ± 5.56 | <1 | <1 | <1 |
| | TEXAS | Transparent water | >300 | 96 ± 8.54 | 88 ± 9.79 | 26 ± 7.39 |
| Well | ABATTOIR | Transparent water | >300 | 96 ± 21.52 | 84 ± 30.03 | 61 ± 17.21 |
| | GBOKORA | Transparent water | >300 | 87 ± 14.42 | 61 ± 23.12 | 43 ± 6.55 |
| | MARAIS | Transparent water | >300 | 78 ± 16.88 | 30 ± 8.54 | <1 |
| | OLIVIERS | Transparent water | >300 | 36 ± 2.58 | 5 ± 1.87 | 21 ± 5.65 |
| | TAZIBOUO | Transparent water | >300 | 16 ± 4.15 | 6 ± 3.45 | 9 ± 5.13 |
| | TEXAS | Transparent water | >300 | 88 ± 24.02 | <1 | 75 ± 27.41 |
| Limit of acceptable colony (d) | | | ≤300/mL | 0/100 mL | 0/100 mL | 0/100 mL |

CFU: Colony-Forming Units

## IV. Discussion

The analysis of socio-demographic data reveals that respondents in Daloa were predominantly young men. This overrepresentation is likely due to the timing of the survey and the more visible participation of men in public water collection. However, this trend contrasts with traditional domestic practices in West Africa, where women are typically responsible for household water supply. Preferences expressed for spring water, followed by boreholes and wells, align with the observations reported by[6]. Limited reliance on water distributed by SODECI stems primarily from a lack of network access in several neighborhoods of Daloa, while the use of wells often reflects the only available supply point near respondents' homes. Field hygiene assessments indicated better protection measures at boreholes compared to wells and natural springs. These findings guided the sampling strategy for microbiological analysis, aimed at assessing more precisely the impact of environmental conditions on water quality. Despite over 90% of respondents reporting a sense of safety, microbiological results painted a starkly different picture. All samples from wells and springs exceeded the World Health Organization (WHO) thresholds for mesophilic aerobic flora, total coliforms, *Escherichia coli*, and intestinal enterococci. These contamination levels are consistent with findings by[14,15], who reported fecal pollution levels above 83% in urban African wells. The presence of fecal indicator bacteria is likely attributable to several factors: lack of protective curbs and sealed covers, resuspension of sediments and waste during water collection, and direct contamination from runoff and domestic refuse[16,17]. For spring water, unsanitary surroundings stagnant puddles, organic debris, and unprotected access further increase the risk of surface infiltration and contamination[16].

From a health standpoint, the detection of *Escherichia coli* and intestinal enterococci in drinking water signals exposure to enteric pathogens potentially responsible for diarrhea, typhoid fever, and other severe infections. Moreover, the presence of enterococci underscores their role in nosocomial infections, highlighting the need for rigorous and continuous monitoring[16,18]. Despite the samples' clarity, poor microbiological quality necessitates domestic treatment before consumption boiling, chlorination, or appropriate filtration. These simple and accessible methods can significantly reduce risks associated with contaminated water.

This study, conducted during the rainy season and early dry season, does not allow for assessment of seasonal variability in microbiological quality. Further investigations, particularly during extended dry periods, are needed to understand fluctuations and adjust preventive measures accordingly. In light of these results, it is vital to strengthen the physical protection of water collection points (curbs, covers, drainage), establish a regular microbiological monitoring program, and raise public awareness about safe water hygiene practices. These combined actions will help reduce waterborne diseases and improve public health outcomes in Daloa.

## V. Conclusion

Access to safe drinking water remains a major challenge in the neighborhoods of Daloa. In the absence of full connection to the SODECI distribution network, residents increasingly rely on boreholes, natural springs, and wells as alternative sources of water. The present study aimed to assess the microbiological risks associated with these modes of supply. While the survey revealed a strong preference for and perceived safety of spring water and borehole water, microbiological analyses contradicted these perceptions. All samples collected from these sources showed clear indicators of fecal contamination: total flora, total coliforms, *Escherichia coli*, and intestinal enterococci consistently exceeded WHO-recommended thresholds. Although the presence of such microorganisms does not invariably lead to illness, their elevated concentrations necessitate the implementation of domestic treatment methods including chlorination and boiling as well as physical protection of collection points through curbs, sealed covers, and proper drainage. Moreover, establishing regular microbiological monitoring and conducting awareness campaigns on safe water practices are essential for improving water quality and safeguarding public health in Daloa.

To effectively preserve public health, urgent measures must be taken to reinforce the physical protection of water collection points (curbs, covers, drainage), implement an annual program of microbiological surveillance, raise awareness about simple household water treatments (boiling, chlorination), and promote the extension of the SODECI network into underserved neighborhoods.

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