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Abundance of the bacteria *Listeria* during the great rainy and dry seasons in some wells and lake waters in an urbanized equatorial zone of Cameroon (Central Africa)

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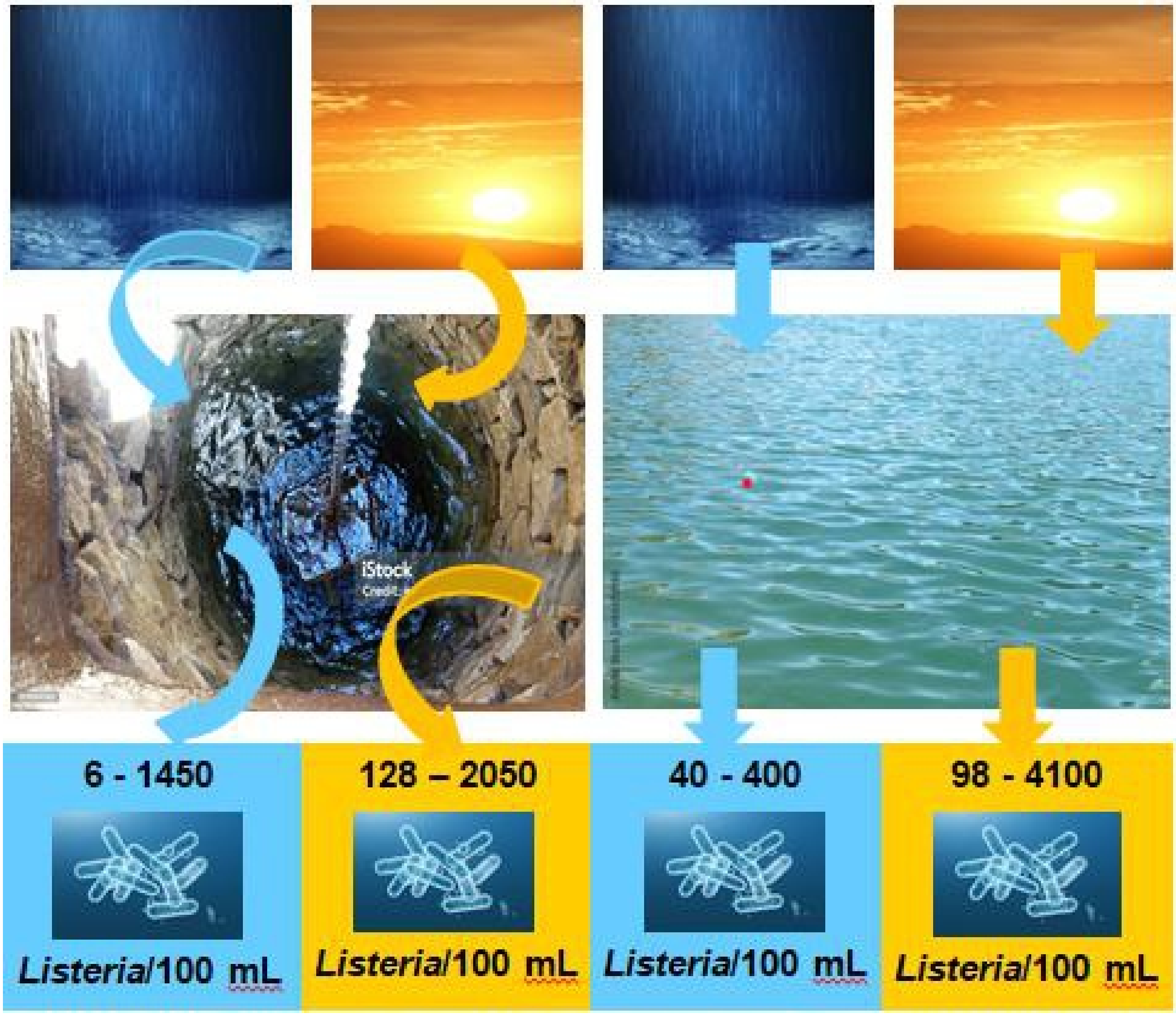
Graphical Abstract

Abundance of the bacteria Listeria during the great rainy and dry seasons in some wells and lake waters in an urbanized equatorial zone of Cameroon (Central Africa)



ABSTRACT

Bacteria of the Listeria genus are zoonotic pathogens responsible for listeriosis. This study aimed to investigate the abundance of Listeria in wells and lakes waters during the major rainy and dry seasons and assess the health risks faced by users. Samplings were carried out monthly on 4 wells and 4 lake water stations. Bacterial abundance was assessed using selective agar culture media. Physicochemical analyses indicated that wells are slightly acidic, contain lower dissolved dioxygen concentrations and higher content in dissolved CO_2 levels than lake water, which was predominantly alkaline. In wells, abundance of Heterotrophic aerobic mesophilic bacteria (HAMB) varied from $2x10^4$ to $89x10^5$ CFU/100 mL during the rainy season, and from $4x10^4$ to $8x10^5$ CFU/100 mL during the dry season. That of Listeria varied from 6 to $14.5x10^2$ CFU/100 mL during the rainy season, and from $1.28x10^2$ to $20.5x10^2$ CFU/100 mL during the dry season. In lakes, abundance of HAMB varied from $24x10^3$ to $36x10^5$ CFU/100 mL during the rainy season, and from $26x10^3$ to $16x10^5$ CFU/100 mL during the dry season. That of Listeria ranged from 40 to $4x10^2$ CFU/100 mL during the rainy season, and from 98 to $41x10^2$ CFU/100 mL during the dry season. Abundance of Listeria was negatively correlated with the water pH in wells during the rainy season, whereas with dissolved oxygen in lake during the dry season ($P \leq 0.05$). Dissolved CO_2 seemed to favor Listeria abundance in lake during the dry season ($P \leq 0.05$). No significant difference in Listeria abundance was found between the rainy and dry season ($P>0.05$). The survival of Listeria in aquatic environment would greatly depend on factors other than those considered in this study. Despite the relative temporal variations in the abundance of the bacterial contaminant, the risk of listeriosis associated with the analyzed water appears unchanged with the season change.

Keywords: *Listeria abundance, wells and lake water, dry season, rainy season, ecological factors*

1. INTRODUCTION

Aquatic bacteria play a crucial role in human health, contributing to the decomposition of organic matter, nutrient cycling, and water purification, but they can also be pathogenic and cause infections [1]. Listeriosis is a zoonotic, waterborne infectious disease of human origin, primarily caused by a bacterium of the genus *Listeria monocytogenes*, a species pathogenic to humans and animals, and widespread in nature [2]. It is transmitted by ingestion of contaminated water and mainly affects people with weakened immune systems [3]. These bacteria, once they colonize the intestines of their hosts, are released into the bloodstream by monocytes and multiply in target organs, namely the liver and spleen [4].

Bacteria of the genus *Listeria* are of particular properties. They are Gram-positive bacilli, that can live alone, in chains, or in pairs in a V shape. They are often mobile due to the peritrichous cilia when grown between 20 and 25°C, and immobile at 37°C. They are neither spore-forming nor encapsulated and are capable of growing under aerobic or anaerobic conditions [5,6,7]. Biochemically, *Listeria* strains are catalase-positive, oxidase-negative, and hydrolyze esculin without producing gas. They ferment many carbohydrates such as glucose, fructose, mannose, salicin, cellobiose, maltose, trehalose, and D-arabitol in 24 hours. The genus *Listeria* comprises 17 species, among which six species are more frequent: *Listeria monocytogenes, L. ivanovii, L. seeligeri, L. innocua, L. welshimeri* and *L. grayi* [5,6,7]. Their biotopes include soil, natural and urban environment, plats, surface and ground water [8]. According to other authors, the contamination of surface and ground water may mostly originate from contaminated sewage or wastewater [9,10].

Water is one of the essential nutrients for every human being [7]. Water commonly used by humans can be groundwater or surface water. Groundwater is often accessed through wells and boreholes. Surface water includes rivers and lakes. These three types of aquatic systems (well water, rivers, and lakes) function differently due to differences in flow velocities, chemical properties, and interactions with environmental factors. Furthermore, it is often said that the seasons, which are often determined by meteorological factors, impact the microbiological functioning of aquatic ecosystems.

Many studies have already been conducted on various aquatic biotopes in Yaoundé, Cameroon. These studies have revealed that these waters harbor a diverse bacterial microflora composed of, among others, Pseudomonadaceae, Aeromonadaceae, Vibrionaceae, and Enterobacteriaceae [11,12], Their abundance dynamics are influenced by meteorological factors as well as factors related to bacterial species [13,14], Their transfer from the soil surface to the water table is influenced by various elements, some of which are related to the bacteria themselves, including the shape of the bacterial cell wall, the physiological state of the bacteria, and the presence or absence of surface appendages [15]. Other factors are related to the physicochemical and hydrological properties of the infiltrating waters [16].

However, few studies have been conducted on bacteria belonging to the genus *Listeria*. Very little is known about the impact of seasonal variation on *Listeria* abundance dynamics, as well as the influence of ecological factors on *Listeria* distribution in the city of Yaoundé (Cameroon).

In the equatorial zone of Cameroon, the climate comprises four distinct seasons: a short rainy season from mid-March to mid-June, a short dry season from mid-June to mid-August, a long rainy season from mid-August to mid-November, and a long dry season from mid-November to mid-March of the following year. During the long rainy season, runoff can carry numerous pollutants into both surface and underground aquatic ecosystems, potentially impacting their microbial quality. It is often stated that seasonal variation is one of the factors influencing the microbiological functioning of aquatic ecosystems [17,18,19]. Meteorological factors determine the distribution of the seasons which in turn influence the infiltration of runoff into the soil. This process can transport a significant number of substances into aquatic ecosystems, both groundwater and surface water, that may impact the microbiological quality of the biotope [20,21].

Little is known about the differences or similarities that may exist in the abundance of *a* given bacterium in different water systems within the same geographic area during the same season or from one given season to another. This study aimed at assessing the abundance of *Listeria* in wells and lake water during the main rainy season and the main dry season in Yaoundé (Cameroon, Central Africa), and the potential impact of some abiotic factors.

2. MATERIALS AND METHODS

2.1. Description of the water sampling sites

The city of Yaoundé is located on the western edge of the South Cameroon Plateau, between 3°90' North latitude and 11°50' East longitude, specifically 300 km from the Atlantic coast, and covers an area of 304 km^2 [22]. Yaoundé's hydrographic network is very diverse, consisting of streams, rivers, lakes, and ponds [23]. This explains the variety of water sources available to the population. Temperatures range from 18°C to 28°C during the wet season and from 16°C to 31°C during the dry season, with an estimated annual average of 23.5°C and an annual temperature range of 2.4°C. Average rainfall is 1564.7 mm per year, or an average of 153 days per year. Frequent winds are humid and blow from the Southwest [24].

The study included four groundwater points and four water stations on two lakes. The groundwater points were coded Wells-1, Wells-2, Wells-3, and Wells-4. The stations on each lake were coded Lake1-Upst, Lake1-Down, Lake2-Upst, and Lake2-Down. The location of all these water points is shown in Figure 1. Similarly, the geographic coordinates for each point are recorded in Table 1.

Meteorological data for the sampling period were downloaded from the NASA website (https://power.larc.nasa.gov/data.access.viewer/). During this study, precipitation ranged from 0.01 to 7.34 mm/day. Air temperature ranged from 22.93 to 27.67°C. Relative humidity ranged from 60.53 to 88.27%, and solar irradiance from 3.15 to 4.96 kWh/m^2/day. The temporal variations of these data are shown in Figure 2.

2.2. Sampling

This study was carried out from September 2025 to February 2026, a period including the long rainy season and the long dry season. It consisted of taking and analyzing water samples on a monthly basis. The water samples were collected in 250 mL and 1000 mL double-capped polyethylene bottles for physicochemical analyses, and in sterile 500 mL glass bottles for bacteriological analyses.

2.3. Physicochemical analyses

The physicochemical parameters considered were pH, electrical conductivity, carbon dioxide, dissolved oxygen, nitrogen ammonia, nitrate and nitrite ions, and calcium and magnesium hardness. These analyses were performed according to the standard techniques [25]. Some parameters were measured and/or fixed in the field. Subsequently, the samples were transported to the laboratory in a temperature-controlled cooler [26].

2.4. Bacteriological analyses

Bacteriological analyses consisted of isolating and enumerating heterotrophic aerobic mesophilic bacteria (HAMB) and bacteria belonging to the genus *Listeria*. For the enumeration of HAMB in lakes, 1mL of sample was diluted 1:100, and then 100µL of water sample (lakes and wells) was inoculated using the surface-spreading technique on ordinary agar. The Petri dishes were then incubated at 24 ± 2°C for 5 days [27]. Each analysis was performed in triplicate.

Listeria bacteria were detected and isolated on *Listeria* Oxford Agar Base supplemented with antibiotics (cyclohexymide, colistin sulfate, acriflavin, cefotetan, and phosphomycin sodium salt) [28].

Lake water samples were analyzed by surface spreading on the agar, while groundwater samples were analyzed by membrane filtration using a cellulose acetate membrane with a pore size of 0.45 µm. Analyses were performed in triplicate. Petri dishes were then incubated at 37°C ± 1°C for 24 to 48h ± 2h. The isolated colonies were counted using the direct colony count method. Mean bacterial abundances were calculated and expressed as Colony Forming Units (CFU)/100 mL of analyzed water.

2.5. Data analysis

The mean values of abundances of the isolated bacteria were expressed in CFU/100 mL of water sample. The relationships between the considered parameters were assessed using Spearman's correlation test. A comparison of cell abundances between different stations was made using the Mann-Whitney U test.

3. RESULTS

3.1. Physicochemical characteristics of waters samples

The values of the abiotic parameters are presented in **Figure 3** and **Figure 4**. This shows a spatio-temporal fluctuation of the values of each parameter, whether in lakes or in wells respectively.

3.1.1. Physicochemical parameters in Lakes

The pH ranged from 7.3 to 10.76 U.C. (Figure 3). Dissolved CO_2 levels fluctuated from 0.17 to 80.96 mg/L. The lowest value was recorded in Lake L2-Upst in December, while the highest was observed in Lake L1-Upst in November. Dissolved oxygen levels ranged from 0.27 to 7.99 mg/L. The highest value was recorded in Lake L1-Down in February, while the lowest was observed in Lake L1-Upst in January (Figure 3).

Electrical conductivity ranged from 212 to 474 µS/cm, with the lowest value recorded in Lake L2-Down in October and the highest in Lake L1-Upst in September. Calcium hardness fluctuated from 0.01 to 3.97 mg/L of $CaCO_3$ with the highest value noted in Lake L1-Upst in November and the lowest value recorded in lake L2-Upst in February (Figure 3). Magnesium hardness ranged from 0.05 to 6.32 mg/L $CaCO_3$, nitrite ion levels from 0.01 to 1.6 mg/L, nitrate ion levels from 0.06 to 8.2 mg/L, and ammonia nitrogen levels from 0.19 to 2.58 mg/L (Figure 3).

Mean values for abiotic parameters were calculated for all lakes. They were 8.23±0.83 U.C for pH, 23.84±19.52 mg/L for CO_2, 3.74±2.29 mg/L for dissolved oxygen, 305.79±82.38 µS/cm for electrical conductivity, 1.48±1.08 mg/L of $CaCO_3$ for calcium hardness, 2.04±1.38 mg/L of $CaCO_3$ for magnesium hardness, 0.17±0.42 mg/L for nitrite, 1.39±1.64 mg/L for nitrate and 1.16 ± 0.61 mg/L for nitrogen ammonia.

3.1.2. Physicochemical parameters in wells

The pH ranged from 5.5 to 7.83 U.C. (Figure 4). The electrical conductivity ranged from 311 to 776 µS/cm. The concentrations of dissolved CO_2, dissolved oxygen, calcium hardness, and magnesium hardness ranged from 14.08 to 117.92 mg/L, 3.06 to 5.62 mg/L, 0.01 to 4.88 mg/L, and 0.01 to 2.53 mg/L of $CaCO_3$, respectively (Figure 4). Regarding nitrogen compounds, the concentrations ranged from 0.01 to 0.26 mg/L for nitrite, from 0.03 to 7.6 mg/L for nitrate, and from 0 to 4.32 mg/L for ammonia nitrogen (Figure 4).

The average values of the abiotic parameters were calculated for all analyzed well water points.

They were 6.51±0.62 U.C. for pH, 64.36±27.51 mg/L for dissolved CO_2, 4.33±0.73 mg/L for subsurface oxygen, 438.21±169.11 µS/cm for electrical conductivity, 1.73±1.52 mg/L of $CaCO_3$ for calcium hardness, 1.01±0.73 mg/L of $CaCO_3$ for magnesium hardness, 0.032±0.053 mg/L for nitrite, 1.86±0.083 mg/L for nitrate, and 1.83±2.08 mg/L for ammonia nitrogen.

3.2. Bacterial abundance in water samples

The variation in the abundance of heterotrophic aerobic mesophilic bacteria (HAMB) and *Listeria* recorded in wells and lakes is shown in Figure 5. In wells, HAMB abundances ranged from $2x10^4$ to $89x10^5$ CFU/100 mL. The lowest value was observed in well-3 in November, while the highest was obtained in well-4 in October (Figure 5). *Listeria* bacteria abundances fluctuated from $0.06x10^2$ to $22.8x10^2$ CFU/100 mL. The lowest value was obtained in well-3 in October, while the highest abundance was obtained in well-4 in December (Figure 5). Overall, it can be noted that abundance of *Listeria* in wells varied from 6 to $14.5x10^2$ during the rainy season, and from $1.28x10^2$ to $20.5x10^2$ CFU/100 mL during the dry season. The abundance of Heterotrophic aerobic mesophilic bacteria (HAMB) varied from $2x10^4$ to $89x10^5$ CFU/100 mL during the rainy season, and from $4x10^4$ to $8x10^5$ CFU/100 mL during the dry season.

In lake waters, HAMB abundances ranged from $2.4x10^4$ to $333x10^4$ CFU/100 mL. *Listeria* abundances fluctuated from 38 to $41x10^2$ CFU/100 mL (**Figure 5**). The lowest value was recorded in Lake L1-Down in October, while the highest abundance was recorded in Lake L1-Upst in January (**Fig. 5**). Overall, in can be noted that abundance of *Listeria* varied from 40 to $4x10^2$ during the rainy season, and from 98 to $41x10^2$ CFU/100 mL during the dry season. The abundance of HAMB varied from $24x10^3$ to $36x10^5$ CFU/100 mL during the rainy season, and from $26x10^3$ to $16x10^5$ CFU/100 mL during the dry season.

3.3. Correlations amongst the considered parameters

The Spearman correlation coefficients have been calculated between the bacterial abundances and the abiotic parameters considered. This has been done between the collected data.

3.3.1. Correlations between physicochemical parameters and bacterial abundances

During the rainy season, a significant negative correlation ($P \leq 0.01$) was observed between *Listeria* densities and water pH (Table 2). Significant negative correlations were also observed between HAMB abundances and dissolved O_2 ($P \leq 0.01$) and nitrite ($P \leq 0.01$). However, a significant positive correlation ($P \leq 0.05$) was observed between HAMB and ammonia nitrogen (Table 2). During the dry season, significant negative correlations ($P \leq 0.05$) were observed between HAMB abundance, dissolved O_2, ammonia nitrogen, and calcium (Table 2). However, no significant correlation was observed between *Listeria* densities and the abiotic factors considered.

3.3.2. Correlations between meteorological parameters and bacterial abundances of *Listeria* and HAMB

Correlation coefficients were calculated between meteorological factors and bacterial abundances (Table 3). In groundwater, during the rainy season, HAMB abundance are negatively correlated with temperature and insolation ($P \leq 0.01$) and positively correlated with rainfall and humidity ($P \leq 0.01$) in wells.

In this biotope, *Listeria* densities are negatively correlated with rainfall and humidity ($P \leq 0.05$). In lakes waters, *Listeria* and HAMB are sometimes negatively or positively correlated with the considered meteorological factors (Table 3). The variability in correlation between meteorological factors and *Listeria* and HAMB, is also observed during the dry season whether considering wells or lake water (Table 3).

3.4. Comparison among the considered factors

Bacterial abundances and physicochemical parameters across all wells and lake sampling stations were compared using the Mann-Whitney U test. The results show that, in both the rainy and dry seasons, and in both lakes and wells, electrical conductivity and nitrogen ammonia varied significantly between sampling sites ($P \leq 0.05$) (Table 4). Bacterial abundances do not vary significantly between sites during either the rainy or the dry season ($P > 0.05$) (Table 4).

Using the Mann-Whitney U test, bacterial abundances and physicochemical parameters in each type of biotope were compared between the dry and rainy seasons. It revealed that electrical conductivity, nitrogen ammonia, and magnesium concentrations vary significantly from one season to another in lakes and wells ($P \leq 0.05$) (Table 5). Carbon dioxide varies significantly in the lakes from the dry to the rainy season ($P \leq 0.05$). Bacterial abundances do not vary significantly between the rainy and the dry season ($P > 0.05$) (Table 5).

4. DISCUSSION

The pH values of analyzed water samples ranged from 6 to 8 in most cases. This slight alkalinity in lakes could be due to the combined action of carbonate precipitation and photosynthesis through the consumption of carbon dioxide [29], while their values in groundwater could be linked to the soil mineralogy [30]. In Yaounde town, the bedrock is rich in minerals such as magnesium, potassium, and calcium, whose weathering can influence groundwater pH. It has also been established that the acidity of groundwater in urban areas could result from organic pollution [31]. More recent investigations in Cameroon corroborate this anthropogenic control. Using a multi-tracer approach on hard-rock aquifers, some authors showed that processes govern water quality in lateritic hillside areas, whereas anthropogenic inputs, mainly nitrate accumulation linked to human activity, predominate in valleys and on slopes [32]. These values correspond to the tolerance range of the majority of aquatic living organisms [33].

The electrical conductivity in lake water and groundwater indicated moderate mineralization. It is indicated that the mineralization of groundwater is primarily due to vertical movements that bring up mineralized fluxes from deeper layers [34]. This could also be due to human activity, and the said activity is influenced by the biodegradable organic matter which therefore reflects the level of pollution [35].

Bacteriological analysis of well and lake water samples revealed that these waters harbor a diverse bacterial community. The HAMB bacteria were present in all sampling points during the study period. The average bacterial abundance of HAMB in groundwater was higher than in lake water. This could be due to the fact that the environment surrounding the sampling points is conducive to their development, particularly due to an abundant source of mixed pollution, contaminated runoff, and infiltration. It has been indicated that surface and groundwater contamination depends on the pollutant load and the permeability of the overlying soil [20].

In this study, ammonia nitrogen appears to promote the emergence of total microflora in the studied sites.

The abundance of HAMB was relatively higher than that of *Listeria*. *Listeria* strains abundance in wells were relatively greater than lake water samples. This predominance could be explained by their ubiquitous nature and their ability to survive in harsh conditions. *Listeria* bacteria are widespread in nature; only their abundance varies from one environment to another [4]. The low abundances observed in lakes would indicate very low levels of biological and organic pollution, while the highest concentrations obtained could be linked to point sources of pollution identified near the sampling sites, to multiple inputs from runoff and infiltration, or to the resuspension of these bacteria by rain [36]. This point-source pattern mirrors more recent surveys of environmental waters. Multidrug-resistant and biofilm-forming *Listeria* cells have been reported across rivers, wastewater, and irrigation water in comparable proportions [37].

The spread of *Listeria* in nature is exacerbated by certain ecological factors. In this study, factors such as temperature and insolation positively influenced the population of *Listeria*, while water pH and relative humidity negatively impacted bacterial density. It is indicated that *Listeria* bacteria have the ability to resist or thrive in saline and acidic environments [36]. This ubiquity allows them to develop numerous adaptation mechanisms to the unfavorable conditions present in the ecological hosting niches. Physiological works have clarified the molecular basis of this acid resilience, describing an acid tolerance response, together with glutamate decarboxylase, arginine de-aminase, and F1F0-ATPase systems that buffer the bacterium's internal pH and allow cross-protection against related stresses such as bile salts and osmotic pressure [38]. This reinforces the hypothesis that the water pH recorded could act as a limiting factor rather than an eliminating factor for the pathogen [39].

Regarding the impact of seasonal factors on the HAMB abundance, the distribution of these germs during the study period did not take into account seasonal variation or ecosystem type ; they grow everywhere in search of vital resources. In the aquatic environment in general, multiple microorganisms coexist as communities competing for resources [20]. Similarly, *Listeria* bacteria, described as ubiquitous, do not take into account seasonal factors or biotope type. This is due to the ability of this pathogen to survive and grow in dry, cold, and high-salt environments. The bacterium can easily grow in different food matrices kept in the refrigerator. *Listeria* can adapt to the conditions of the gastrointestinal tract by overcoming unsuitable conditions of this microenvironment, including acidity, osmolality, low oxygen, and the antimicrobial effect of bile salts and peptides [7]. This capacity to withstand acid, cold, and osmotic stress simultaneously is now considered a hallmark of the species environmental persistence and a key factor in its recurrent detection in food-linked and aquatic environments alike [40].

A comparison between the dry and rainy seasons reveals that electrical conductivity and nitrogen ammonia vary significantly in both wells and lakes. This marked seasonal dynamic regarding mineralization and nitrogenous compounds aligns with the findings of some authors who linked such fluctuations in African surface waters to variations in runoff and soil leaching between dry and wet periods [37].

Conversely, bacterial abundances, both of HAMB and *Listeria*, do not differ significantly between the two seasons; this is consistent with observations during other studies, where the presence of *Listeria* in surface waters remained constant regardless of seasonal rainfall cycles [8]. This bacterial stability in the face of highly fluctuating water chemistry confirms that the environmental survival of *Listeria* depends more on the availability of organic matter and the protection afforded by biofilms than on the seasonal physicochemical parameters themselves.

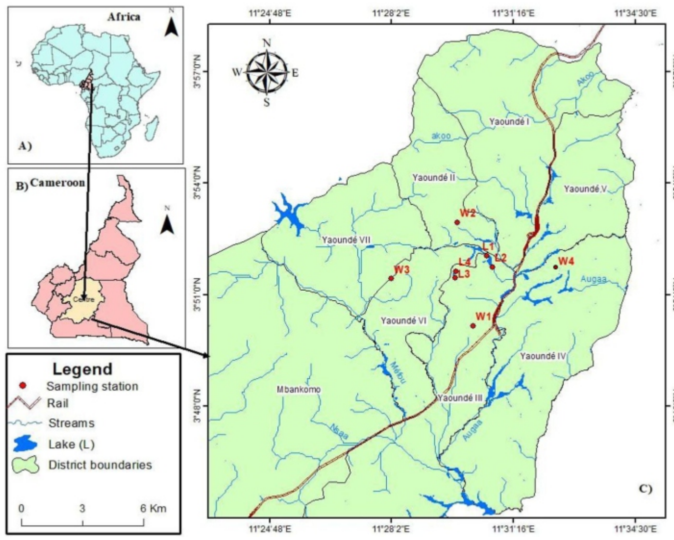


Figure 1: Sampling wells and sampling lake station (National Institute of Cartography, Cameroon).

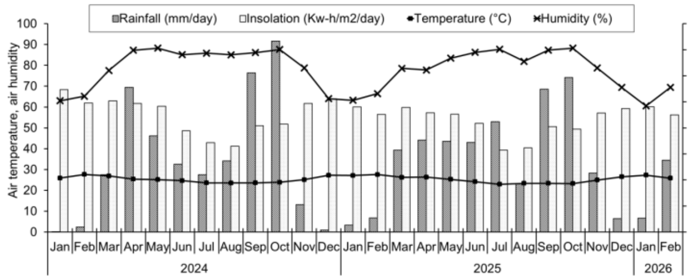


Figure 2: Temporal variations of rainfall, insolation, air relative humidity and air temperature at Yaounde, before and during the sampling period

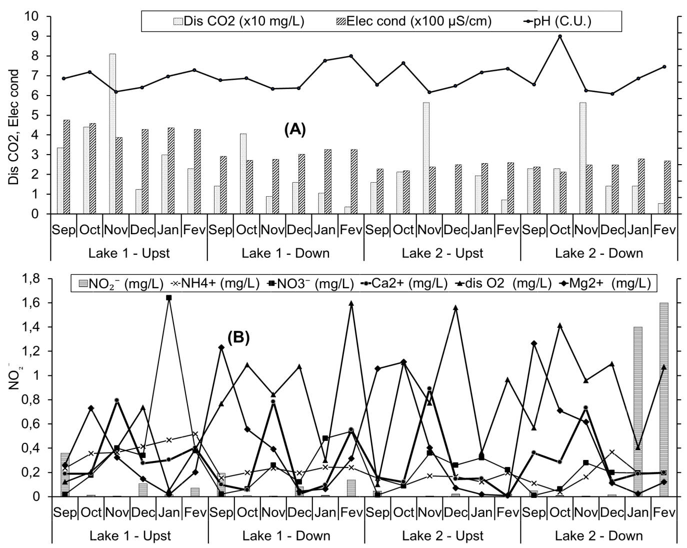


Figure 3: Temporal variation of pH, electrical conductivity and concentration of dissolved CO2 (A), and concentrations of calcium, magnesium, nitrite, nitrate, nitrogen ammonia and dissolved oxygen (B), in each sampling lake station

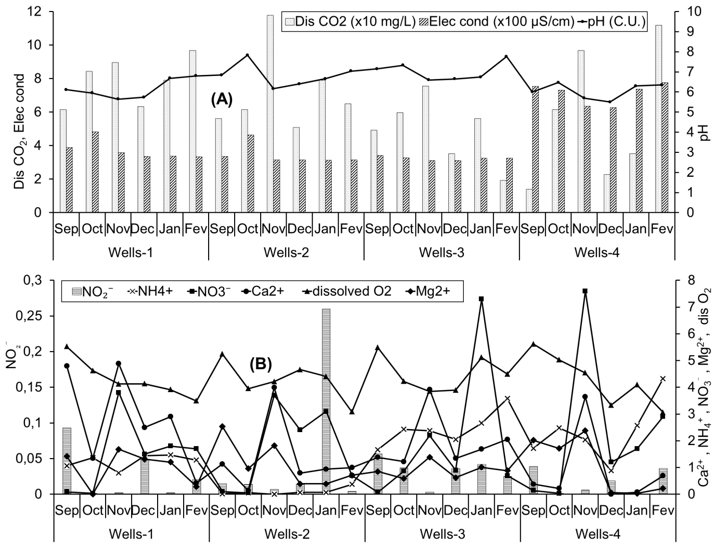


Figure 4: Temporal variation of pH, electrical conductivity and concentration of dissolved CO2 (A), and concentrations of calcium, magnesium, nitrite, nitrate, nitrogen ammonia and dissolved oxygen (B), in each sampling wells

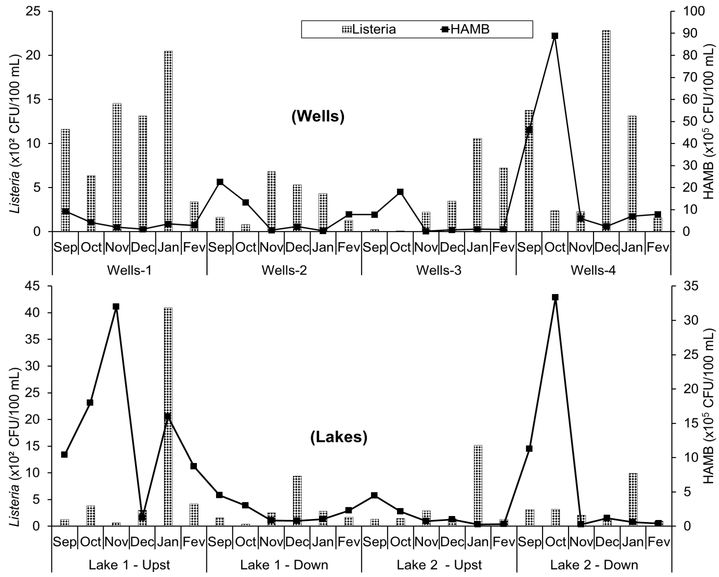


Figure 5: Temporal variation of the Listeria and HAMB abundances in each sampling wells and each sampling lakes stations

Table 1: Geographic coordinates of sampling points.

Sampling site and type of water	Geographic coordinates of the sampling site and total depth of well			
	Latitude	Longitude	Altitude (m)	Total well depth (m)
Lake 1- Upst (L1)	03°52'05.6''N	011°30'31.8''E	722	
Lake 1- Down (L2)	03°51'44.6''N	011°30'42.3''E	715	
Lake 2- Upst (L3)	03°51'27.9''N	011°29'43.4''E	720	/
Lake 2- Down (L4)	03°51'22.7''N	011°29'44.4''E	721	
Wells- 1 (W1)	03°49'58.7''N	011°30'17.8''E	715	12
Wells- 2 (W2)	03°50'16.5''N	011°29'43.9''E	696	0,5
Wells- 3 (W3)	03°52'18.2''N	011°27'50.3''E	717	17
Wells- 4 (W4)	03°50'57.9''N	011°31'06.4''E	736	25

Table 2: Correlation coefficients between physicochemical parameters and bacterial abundances

Water abiotic parameter	Rainy season				Dry season			
	Wells		Lake water		Wells		Lake water	
	Listeria	HAMB	*Listeria*	HAMB	*Listeria*	HAMB	*Listeria*	HAMB
pH	**-0.832****	0.322	0.147	0.434	-0.459	-0.102	-0.245	-0.042
Dis. O₂	0.189	**0.594***	0.140	-0.273	0.354	**-0.637***	**-0.629***	-0.077
Dis. CO₂	0.352	**-0.725****	-0.074	0.063	-0.473	0.390	**0.820****	0.245
E. cond.	0.364	0.531	-0.238	0.147	0.393	**0.682***	0.473	**0.683***
NO_2^-	-0.214	0.308	0.007	0.507	-0.182	**-0.649***	-0.291	-0.014
NO_3^-	0.214	-0.483	0.007	-0.315	0.047	-0.011	0.263	**0.669***
NH_4^+	-0.238	0.266	-0.273	0.056	0.056	0.158	0.185	**0.861****
Calcium	0.441	**-0.762****	0.378	-0.084	0.130	-0.357	0.259	**0.615***
Magnesium	0.357	0.224	0.364	0.098	0.133	-0.347	-0.326	0.522

*ddl=11; **: P≤0.01; *: P≤0.05; E. cond.: electrical conductivity; Dis.: dissolved*

Table 3: Correlation coefficients between meteorological parameters and bacterial abundances

Meteorological parameter	Rainy season				Dry season			
	Wells		Lake water		Wells		Lake water	
	Listeria	HAMB	*Listeria*	HAMB	*Listeria*	HAMB	*Listeria*	HAMB
Temp.	0.500*	-1.000**	-0.500*	-0.500*	1.000**	-0.500*	1.000**	0.500*
Rainfall	-0.500*	1.000**	0.500*	0.500*	-0.500*	1.000**	-0.500*	0.500*
Humidity	-0.500*	1.000**	0.500*	0.500*	-1.000**	0.500*	-1.000**	-0.500*
Insolation	0.500*	-1.000**	-0.500*	-0.500*	1.000**	-0.500*	1.000**	0.500*

*ddl=11; **: P≤0.01; *: P≤0.05; Temp.: air temperature*

Table 4: P-values from the comparison of bacterial abundances and physicochemical parameters across all wells and lake stations, during the dry season and the rainy season

Water parameter	Rainy season		Dry season	
	Wells	Lake water	Wells	Lake water
Listeria	0.07028	0.4593	0.5169	0.516
HAMB	0.3996	0.2181	0.1677	0.05723
pH	0.05343	0.9725	0.153	0.7395
Dis. O₂	0.5777	0.2181	0.3191	0.4684
Dis. CO₂	0.6391	0.2683	0.253	0.3595
E. cond.	**0.03781***	**0.02488***	**0.02339***	**0.02393***
NO_2^-	0.7911	0.5506	0.6634	0.4061
NO_3^-	0.9787	0.887	0.9481	0.1461
NH_4^+	**0.02488***	**0.04148***	**0.04926***	**0.03313***
Calcium	0.2642	0.6217	0.08619	0.6625
Magnesium	0.1032	0.3996	0.06491	0.4123

*ddl=11 ; **: P≤0.01 ; *: P≤0.05 ; E. cond. : electrical conductivity; Dis.: dissolved*

Table 5: P-values for the comparison between the dry and rainy seasons regarding bacterial abundances and physicochemical parameters in well and lake waters samples.

Analyzed parameters	Wells	Lakes
Listeria	0.1323	0.4023
HAMB	0.2858	0.08932
pH	0.06439	0.94
Diss O₂	0.1878	0.3233
Diss CO₂	0.4126	**0.04981***
E. cond.	**0.008861****	**0.003037****
NO_2^-	0.8539	0.3778
NO_3^-	0.9079	0.2163
NH_4^+	**0.00881****	**0.009282****
Calcium	0.1268	0.4303
Magnesium	**0.03948***	**0.009939****

*N= 12 observations ; ddl=11 ; **: P≤0.01 ; *: P≤0.05 ; E. cond. : electrical conductivity*

5. CONCLUSION

Bacteriological analysis revealed widespread contamination of sampling sites by HAMB bacteria and *Listeria*, with higher abundance in wells than in lake water, reflecting the impact of infiltration and contaminated runoff. The ubiquitous nature of *Listeria* and its remarkable ability to adapt to environmental stressors could explain its persistence and the observed seasonal variations. These results confirm that the survival and proliferation of this pathogen depend more on the availability of favourable environmental conditions. The physicochemical parameters analyzed, specifically pH and electrical conductivity, revealed potability standards and requirements for aquatic life, although they reflected the combined influence of natural and anthropogenic processes. Given these findings, regular water quality monitoring and measures to manage pollution sources are essential to limit health risks associated with *Listeria* exposure in drinking and environmental waters in Yaounde (Cameroon).

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Informed consent statement

No informed consent was required to conduct the study.

Ethical approval

No ethical approval was required to conduct this study

Declaration of interests

The authors declare no conflict of interest.

Authors' contribution

Conceptualization: Geneviève Bricheux, Télesphore Sime-Ngando, Moïse Nola; **Data collection**: Paule J. Atou'ou; Pélagie Ladibé, Yves Poutoum Yogne; **Data analysis**: Paule J. Atou'ou, Yves Poutoum Yogne, Moïse Nola; **Investigation:** Télesphore Sime-Ngando, Moïse Nola, Philippe Bouchard; **Methodology:** Paule J. Atou'ou, Yves Poutoum Yogne, Florence Donnadieu-Bernard; **General supervision**: Moïse Nola, Télesphore Sime-Ngando and Moïse Nola; **Writing original draft**: Paule J. Atou'ou, Moïse Nola and Philippe Bouchard; **Writing-review editing:** Geneviève Bricheux, Moïse Nola and Télesphore Sime-Ngando. All authors agreed to submit final version of the manuscript.

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COVER LETTER

Date: 11 August 2026

Dear Editor-in-Chief of *Environmental Reports*,

Here is our manuscript we are submitting to your journal as **Research Article**.

It is entitled: **Abundance of the bacteria *Listeria* during the great rainy and dry seasons in some wells and lake waters in an urbanized equatorial zone of Cameroon (Central Africa)**

No part of this manuscript has not been previously published by any of the authors and is not under consideration for publication in another journal at the time of submission.

Summary

Listeriosis is a zoonotic, waterborne infectious disease of human origin, primarily caused by a bacterium of the genus *Listeria monocytogenes*. Few studies have been conducted on bacteria belonging to the genus *Listeria*. Little is known about the differences or similarities that may exist in the abundance of a given bacteria in different water systems within the same geographic area during the same season or from one given season to another. This study aims to assess the abundance of *Listeria* in wells and lake water during the main rainy season and the main dry season in Yaounde (Cameroon, Central Africa). Samplings were carried out monthly on 4 wells and 4 lakes water stations. Bacterial abundance was assessed using selective agar culture media. Physicochemical analyses indicated that wells are slightly acidic, contained lower dissolved dioxygen concentrations and higher content in dissolved CO_2 levels than lake water, which was predominantly alkaline. Abundance of *Listeria* in wells varied from 6 to 14.5×10^2 during the rainy season, and from 1.28×10^2 to 20.5×10^2 CFU/100 mL during the dry season. In lakes, it ranged from 40 to 4×10^2 during the rainy season, and from 98 to 41×10^2 CFU/100 mL during the dry season. The *Listeria* abundance was negatively correlated with the water pH in wells during the rainy season, whereas with dissolved oxygen in lake during the dry season ($P \leq 0.05$). Dissolved CO_2 seems favors *Listeria* abundance in lake during the dry season ($P \leq 0.05$). No significant difference in *Listeria* abundance has been found between the rainy and dry season ($P > 0.05$). The survival of *Listeria* in aquatic environmental would depend on factors other than those considered in this study. Despite the relative temporal variations in the abundance of the bacterial contaminant, the risk of listeriosis associated with the analyzed water appears unchanged with the season change.

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