**Physicochemical and microbiological characteristics of surface and groundwater frequently used by households in some districts of Daloa, Côte d'Ivoire**

**Abstract**

**Background:** Water is an essential resource for life and health. Its sanitary quality is an ongoing public health issue. Indeed, water-borne diseases are constantly evolving. In underdeveloped countries, access to drinking water remains a major concern for populations. Due to water supply shortages in Daloa, residents are turning to different sources, such as surface water and groundwater, for their needs. However, the quality of these waters is not monitored, posing serious health risks. This study aims to assess the physicochemical and microbiological characteristics of the various water sources used in the city.

**Place and Duration of Study:** The research was conducted at the Laboratoire of Agrovalorisation, Department of Biochemistry-Microbiology, Jean Lorougnon Guédé University of Daloa, from March 2024 to April 2024.

**Methodology:** We analyzed groundwater from 2 boreholes and 2 wells, and surface water from 2 lakes. A total of 60 samples were taken, 10 for each site. Physicochemical analyses included pH, temperature and the detection of certain heavy metals (Fe, As, Cd, Hg, Pb). Microbiological analysis was based on faecal and total coliforms, faecal streptococci and fungal flora (yeasts and moulds). Following identification of certain strains, an antibiogram was performed.

**Results:** Surface waters (lakes) are highly polluted. Microbial loads are as follows: GAM (405.105-659.105 CFU/mL), fecal coliforms (685.103-766.103 CFU/mL), fecal streptococci (39.102-45.102 CFU/mL) and fungal flora (659.103-685.103 CFU/mL). These values are well above WHO standards. The identification of microbial strains revealed the presence of *Listeria sp*, *E. coli* and *Pseudomonas* *sp*, which are pathogenic microorganisms. The antibiogram revealed multidrug-resistant strains

**Conclusion :** The use of this water would constitute a risk for the health of the consumer.

**Keywords:** Water, pathogen, heavy metals, multidrug resistant, sanitary quality, Daloa

**Introduction**

Waterborne diseases have increased worldwide, particularly in developing countries (Ako et al., 2009; Jadhav, 2011; Nyamai et al., 2021). These diseases primarily affect children, the elderly, and immunocompromised individuals (Freeman et al., 2012). The World Health Organization reports that approximately 600,000 children die from diarrheal diseases caused by a lack of clean water, sanitation, and hygiene. Contaminated water can lead to bacterial infections, epidemics (Breitenmoser et al., 2011), severe health issues, and significant social and economic losses (Emmanuel et al., 2009). Diarrhea is the most prevalent illness associated with consuming water contaminated by pathogens through the fecal-oral route.

One of the Millennium Development Goals' primary objectives was to reduce the population without access to clean water to 50% by 2015 (Rubino et al., 2019). Unfortunately, this target has not been met, and to date, over 30% of the world's population still lacks access to domestic drinking water services. The challenging access to water is particularly acute in developing countries, where the quantity and quality of water resources are at risk (Ahoussi et al., 2013). Access to clean water is crucial for improving living conditions, as the lack of water encourages water consumption from various sources, posing health risks (Kouadio et al., 2020).

In sub-Saharan Africa, poor water quality leads to over half a million deaths from diarrheal diseases annually. Bacteria associated with poor water quality include *Enterobacteriaceae*, *Entamoeba histolytica*, and *Aeromonas* sp (Maran et al., 2016; Nyamai et al., 2021). In Côte d'Ivoire, access to water remains a major concern for the population (Yapo et al., 2016; Kanohin et al., 2017; Ahoussi et al., 2013). Despite various projects to provide water to all localities, challenges persist, and drinking water is still inaccessible (Mangoua et al., 2010). Many towns have inadequate drinking water coverage, compounded by urbanization, deterioration of water supply infrastructures, and insufficient financial resources for rehabilitation and expansion of facilities (N'Guessan, 2009). This results in poor water quality in some areas, including Daloa in south-west Côte d'Ivoire.

In Daloa, only 4.3% of households in vulnerable neighborhoods are connected to the water management and distribution company, while 95.7% are not (Awomon et al., 2019). Consequently, residents resort to alternative water sources such as natural springs, borehole water, traditional wells, and bagged water, which are not without health risks and may lead to waterborne diseases due to bacteria and heavy metals such as Arsenic (As), Cadmium (Cd), and Mercury (Hg) (Charlet and He, 2013; Affum et al., 2015). Indeed, the regular consumption of this type of water is the main cause of the increase in water-borne diseases such as typhoid fever in certain localities of the Ivory Coast (Kouadio et al., 2017; Awomon et al., 2019). In order to draw the attention of the authorities to the problem of access to drinking water for the population of the town of Daloa, and to raise awareness of the risks involved in using non-potable water, we have undertaken this study.

This study aims to assess the physicochemical and microbiological quality of certain surface and ground waters used domestically in Daloa, which may pose health concerns due to their extensive use. Specifically, we are investigating the presence of heavy metals such as Arsenic (As), Cadmium (Cd), Mercury (Hg), and Lead (Pb), as well as certain microorganisms, including Mesophilic Aerobic Germs (MAG), *Escherichia coli*, fecal and total coliforms, fecal streptococci, and fungal flora, while also determining their antibiotic resistance profile.

**Materials and methods**

**Description of the study area**

This study occurred in Daloa, a town in the western part of Cote d'Ivoire. Daloa's GPS coordinates are longitudes 6°24' to 6°29' West and latitudes 6°50' to 6°55' North. Daloa is also known as the capital of the Haut Sassandra region. It is 141 km from Yamoussoukro, the political capital, and 383 km from Abidjan, the economic capital of Cote d'Ivoire. The town covers an area of 17,761 km2 and has an estimated population of 705,378 (RGPH, 2022).



Department of Daloa

Legend

. District

 Collection site

**.Olivier**

Figure 1: Map of the city of Daloa and its districts (Kouassi, 2021)

**Sample**

The water sources used in this study are from 5 districts of Daloa: Lobia, Tazibouo, Olivier, Gbokora, and Commerce (Figure 1). Water samples were collected between March 2024 and April 2024. Groundwater samples were taken from wells and boreholes. For surface water, samples were taken from lakes. For well water, samples were taken in the Tazibouo and Oliviers districts. And for borehole water, samples were taken in the Tazibouo district, precisely at the Centre d'Accueil Diocèses (CAD) and Lobia château. As for surface water, samples were taken from lakes in the Commerce and Gbokora districts. Sampling was carried out according to Bancessi et al (2020), with a slight modification.

Water samples were taken twice a day (in the morning between 7am and 12pm and in the afternoon between 4pm and 6pm) at each sampling point, once a week. The various water samples were collected in 500 mL sterile glass bottles. The water bottles are coded. The samples are then taken to the laboratory in 3 different coolers (one for each type of water: well, spring and lake) containing carboglasses. They are analyzed as soon as they arrive. A total of 60 samples were taken, 10 for each site

**Physicochemical Analyses**

**Temperature and pH**

The temperature of water samples is measured on-site at each water sampling location. We used an FY-10 Thermometer from China with an electronic display, which was turned on a few minutes before taking any measurements. For spring and well water samples, the thermometer probe is placed in the water collected in a 50 mL Falcon tube. When sampling lake water, the probe is placed directly in several points of the lake, and the recorded value is the average of the readings from these points.

The pH of the different water samples is measured in the laboratory using a pH meter from Hanna, Romania. The pH meter probe is placed directly into 50 mL of water in a 100 mL beaker.

**Metallic trace elements**

Traces of heavy metals (Fe, As, Cd, Hg, Pb) in the samples were determined by inductively coupled plasma optical emission spectroscopy (ICP/OES) according to the protocol of Bozorgzadeh et al.(2021).

**Microbiological Analyses**

The samples were subjected to microbiological analysis using a series of dilutions. Mother suspensions and decimal dilutions were prepared following the NF EN ISO 6887-1 recommendations. The microbial analysis was conducted following the standards outlined in Table 1.

**Table 1: Water quality assessment criteria**

|  |  |  |
| --- | --- | --- |
| **Researched germs** | **Criteria** | **References** |
| **Fungal flora** | 105 UFC/100 mL | 76/160/EEC of 8 December 1975 Decree 91-980 of 20 September 1991 |
| ***E. coli*** | Absence/100 mL |
| **Fecal coliform** | 10 UFC /100 mL |
| **Fecal Streptococci** | Absence/100 mL |
| **Coliform totals** | 10 UFC /100 mL |
| **Enterobacteria** | 10UFC/100 mL |
| **Mesophilic Aerobic Germs** | 105 UFC/100 mL |

**Research for Mesophilic Aerobic Germs (MAG) (Standard NF/ISO 4833:2003)**

We used Plate Count Agar (PCA) to enumerate the GAM according to the standard procedure. We took 1 mL of each dilution using a sterile pipette and placed it in a Petri dish. Then, we poured approximately 20 mL of the PCA medium, previously prepared and kept cool, into the Petri dish. The contents were homogenized manually using light circular movements for 1 minute. After solidification, we placed the dishes in an incubator at 30°C for 48 to 72 hours, and only plates with colonies between 30 and 300 were used for counting.

**Total coliform and fecal coliform tests (Standard** **ISO 4832: 2006 and ISO 21528-2: 2004)**

VRBL culture medium (Biokar, France), previously prepared and maintained in supercooling at 45°C, is inoculated with 1 mL of each dilution. The plates are then placed in an oven at 44°C for fecal coliforms and 37°C for total coliforms. After 24 h incubation, the characteristic colonies are purplish, 0.5 mm or more in diameter, sometimes surrounded by a reddish zone.

**Fecal streptococci search (Standard ISO7899-2:2000)**

The search for fecal streptococci was carried out on BEA agar (Biokar, France), previously prepared and poured into Petri dishes (to a quantity of 20 mL). They were inoculated at the surface with 0.1 mL of the chosen dilution. The culture was incubated at 37°C for 24 h. Colonies present on the different black plates are counted.

**Fungal flora search (Standard NF/ISO 16212: 2011**

To test for fungal diversity in samples of different types of water, Sabouraud chloramphenicol agar (Alpha Biosciences, USA), previously prepared and maintained in supercooling, was inoculated with 1 ml of each dilution prepared. Incubation took place at 30°C for 3 to 7 days. Mold colonies are pigmented, velvety, cottony, and more or less swollen, while yeast colonies resemble those of bacteria. They may have regular or irregular edges, convex or flat shapes, and are often opaque.

Conventionally, the identification of fungal genera is based on morphological criteria: on the one hand, macroscopic observation of the mycelium, and on the other, microscopic observation of reproductive structures.

Macroscopic observation: observation with the naked eye to determine morphological and cultural characteristics (growth rate, appearance of mycelium, color of mold colonies after inoculation of pure strains on specific culture media). Microscopic observation: observation of hyphal compartmentalization, presence of chlamydospores, shape, and size of conidia, phialides, etc.) from a sampled mycelium fragment (Domsch et al., 1980).

**Biochemical tests to identify bacterial strains**

Characteristic colonies from specific media are re-isolated on PCA media. After Gram staining, two to three colonies are transferred to Leminor's reduced staining media.

**Antibiogram test of identified isolates**

Pure cultures of the species obtained were used to prepare the inocula. To this end, a suspension was prepared in a hemolysis tube by bubbling pure 24 to 48 h colonies obtained on nutrient agar into 2 ml of sterile physiological water. Once thoroughly homogenized, the suspension is read on the Densimat and adjusted to 0.5 McFarland opacity. The final inoculum of the species is obtained by adding 100 µl of this suspension to 10 mL of sterile physiological water in a screw-top test tube. This final suspension, containing around 108 CFU/mL, is the inoculum used for the antibiogram.

Mueller Hinton agar (BioRad, France) was used for antibiotic susceptibility testing. It was prepared according to the manufacturer's recommendations. The prepared medium was poured into Petri dishes at a rate of 20 mL per Petri dish. 3 mL of pre-prepared inoculum is poured onto the surface of Mueller Hinton agar. After a contact time of 5 minutes, the excess inoculum is removed with a pipette. Using a sterile swab, excess inoculum is removed by pressing on the edges of the plate at a 60° angle. The dish is dried at 37°C for 3 min. Antibiotic discs (BioMérieux, France) were aseptically applied to the agar surface using forceps.

The antimicrobials tested were Kanamycin (KAN), Aztreonam (AZT), Imipenem (IPM), Piperacillin (PIP); Cefuroxin (CXM); Cefepim (CEF), amikacin (AMK); ampicillin (AMP); Ceftazidime (CAZ); Ciprofloxacin (CIP), colistin (CL); gentamicin (GM). Depending on the inhibition diameter, the strain is classified as sensitive (S), intermediate (I), or resistant (R) to the antibiotic, group, or families of antibiotics according to the manufacturer's prescriptions (CA-SFM, 2020). According to Maran et al. (2016), Bacteria resistant to two or more antimicrobials were classified as multidrug-resistant.

**Statistical analysis of data**

All tests were carried out in triplicate, and the numerical values obtained were expressed as the arithmetic mean plus the corresponding standard deviation. STATISTICA 7.1 software was used for these analyses. Kruskal-Wallis analysis of variance was used to compare microbiological germ loads and physico-chemical parameters between the water types studied.

**Results and Discussion**

**Results**

**Temperatures and pH Values of the various water sources**

The table below shows the temperature and pH values of the various water sources studied. Lake water is very high, at 31°C, compared with an average of 24°C for borehole and well water. Lake water is also highly acidic, with pH values (4.10-4.30) below those recommended by the WHO (6.5-8.5).

**Table 2: Temperature and pH of the various water sources**

|  |  |  |
| --- | --- | --- |
| Types of water | Means temperatures  | Means pH |
| Drilled wells water  | **from lobia** | 24.10 ±0.78a | 6.30 ±0.56a |
| **from CAD** | 23.90 ±1.02a | 6.27 ±0.42a |
|  |  |  |  |
| Well water | **from Tazibouo** | 24.3 ±0.75a | 6.91 ±0.52a |
| **from Olivier** | 25.1 ±0.45a | 6.83 ±0.74a |
|  |  |  |  |
| Lake water | **from commerce** | 31.12 ±0.36b | 4.10±0.68b |
|  | **from Gbokora** | 31.59 ±0.25b | 4.30±0.41b |
|  |  |  |  |
| Normes OMS 2017 | **\*24.2°C** | **6.5–8.5** |

Values bearing the same letter in the same column, are not significantly different (p = 0.05)

**Heavy metals in the various water sources**

Research into heavy metals in the different types of water shows a variation from one kind of water to another. Levels remain below WHO standards for mercury, Arsenic, and Cadmium. On the other hand, iron levels in lake water remain very high, ranging from 2023 µg/L to 3031 µg/L for Commerce and Gbokora lakes, respectively. Lead levels in groundwater remained below the norm, reaching 8.31 and 7.91 µg/L for spring water and 6.99 and 7.59 µg/L for healthy water.

**Table 3: Heavy metal content in different types of water**

|  |  |
| --- | --- |
|  Types of water | Heavy metals (µg/L) |
| **Mercury (Hg)** | **Arsenic (As)** | **Cadmiun (Cd)** | **Plomb (Pb)** | **Fer (Fe)** |
|  Drilled wells water | **from Lobia** | 0 | 1.03±0.78a | 0.01±0.01a | 8.31±0.728a | 998.65±78a |
| **from CAD** | 0 | 1.20±0.89a | 0 | 7.98±0.528a | 1032±0.104a |
|  |  |  |  |  |  |  |
| Well water | **from Tazibouo** | 0 | 1.8±0.378a | 00 | 7.59±0.75a | 765±0.823a |
| **from Olivier** | 0 | 1.6±0.558a | 00 | 6.99±0.132a | 743±57,8a |
|  |  |  |  |  |  |  |
| lake water | **from Commerce** | 0.41±0.76b | 2.02±0.78d | 0.3±0.78a | 13.14±0.78c | 2023±25.78a |
|  | **from Gbokora** | 0.96±0.01b | 2.7±0.78d | 0.6±0.78a | 17.36±0.78a | 3031±56.89a |
|  |  |  |  |  |  |  |
| Standard of OMS 2017 | **5** | **10** | **3** | **10** | **300** |

Values bearing the same letter in the same column, are not significantly different (p = 0.05)

**Microbiological quality of studied waters**

Microbiological analysis assessed the microbial quality of the various water sources studied. The following germs were tested: MAG, fungal flora (yeasts and molds), fecal streptococci, fecal coliforms, and E. coli. The various results obtained are presented in Table 4. The MAG load is lower in borehole water, between 145 and 201 CFU/100 mL. These values are below the WHO recommended standard of 105 CFU/100 mL. There was an absence of fecal coliforms in these waters.

**Table 4: Microbial load of the different types of water under investigation**

|  |  |
| --- | --- |
| Type of water | Microbial loads (UFC/100mL) |
|  | **MAG** | **F F** | **FC** | **FS** |
| Drilled wells water | **from Lobia** | 145 ± 98a | 30±10 a | 00±00 a | 3±30 a |
| **from CAD** | 201 ±31 b | 10±03 a | 00±00 a | 7±10 a |
|  |  |  |  |  |  |
| Wells water | **from Tazibouo** | 129.103 ±208 a | 1575± 83a | 52.102± 484,29b | 63±12c |
| **from Olivier** | 127.103 ±324ab | 1231± 47b | 48.102± 388,90 | 52 ±23c |
|  |  |  |  |  |  |
| Lake water | **From Commerce** | 405.105 ±1010c | 685.103±502a | 371.104 ±2041c | 39.102± 749d |
|  | **from Gbokora** | 659.106 ±1322 d | 766.103±203b | 432.104 ± 1606c | 45.102± 147a |
|  |  |  |  |  |  |
|  OMS Standard 2017 | **105 ufc/100mL** | **105 ufc/100mL** | **Abs/100mL** | **10 ufc/100mL** |

MAG: Mesophilic Aerobic Germs; FF: Fungal Flora; FS: Fecal Streptococci; FC: Fecal Coliforms (and *E. coli*); Values bearing the same letter, in the same column, are not significantly different (p = 0.05)

**Microbial diversity of the water analyzed**

**Bacterial species**

Table 5 lists the different bacterial species found in the waters analyzed. Lake water showed the greatest bacterial diversity: *Listeria sp* (01), *Citrobacter diversus* (01), *E. coli* (02), *Enterobacter aerogenes* (03), *Pseudomonas sp* (04), *Klebsiella oxytoca* (01)), followed by well water (*Enterobacter aerogenes,* *Klebsiella oxytoca*) and drilled well water (none).

**Table 5: Distribution of bacterial species in different types of water**

|  |  |
| --- | --- |
| **Types of water** | **Bacterial species found** |
| Lake water | *Citrobacter diversus* (1)*, E. coli sp*, *Enterobacter aerogenes sp* (3), *Pseudomonas sp* (4), *Listeria sp* (1) |
| Well water | *Enterobacter aerogenes sp*  (1), *Klebsiella oxytoca sp* (1) |
| Drilled well water | None |

**Distribution of fungal species in different types of water sources**

Table 6 lists the fungal species found in the waters analyzed. Fungal diversity varies from one type of water to another. Common contaminant species are the genera *Aspergillus sp* and *Trichoderma sp*.

**Table 6: Distribution of fungal species in different types of waters**

|  |  |
| --- | --- |
| **Types of water** | **Fungal species found** |
| Lakes water | - *Aspergillus nidulans (01) ; Trichoderma sp. (02) ; Trichoderma harzianum (01) ; Beauveria sp. (01) ; Scopulariopsis brevicaulis(01) ; Onychochola sp. (03); Aspergillus fumigatus (02) ; Aspergillus niger (02) ;Aspergillus versicolor (01).*  |
| Wells water |  *Trichoderma sp. (02) ; Trichoderma harzianum (01) ; Beauveria sp. (01) ; Scopulariopsis brevicaulis(01) ; Onychochola sp. (03); Aspergillus fumigatus (02) ; Aspergillus niger (02) ;Aspergillus versicolor (01).*  |
| Drilled wells water | *Trichoderma, Fusarium, Penicillium et Cladosporium* |

**Antibiotic resistance of bacterial strains**

Antibiotic susceptibility testing was conducted on the strains to determine their resistance to the various antibiotics tested. The results are shown in Table 7 below. Most strains were resistant to at least 2 antibiotics. *Citrobacter diversus* strain resists more than half the antibiotics tested (7/12). All strains are sensitive to colistin.

**Table 7: Antibiotic resistance of isolated strains**

|  |  |
| --- | --- |
| Strains | Antibiotics tested |
|  | **KAN** | **AZT** | **IPM** | **PIP** | **CXM** | **CEF** | **AMK** | **AMP** | **CAZ** | **CIP** | **CL** | **GM** |
| *Pseudomonas* | R | R | S | R | S | S | S | R | S | S | S | S |
| *Enterobacter aerogenes* | R | R | S | S | R | R | S | R | S | S | S | S |
| *klebsiella oxytoca* | R | R | R | R | R | R | S | I | S | S | S | S |
| *citrobacter diversus* | R | R | R | R | R | R | S | R | S | S | S | S |
| *E. coli* | S | R | S | R | R | R | R | S | S | S | S | S |

**Kanamycin (KAN), Aztreonam (AZT), Imipenem (IPM), Piperacillin (PIP), Cefuroxin (CXM), Cefepim (CEF), amikacin (AMK), ampicillin (AMP); Ceftazidime (CAZ); Ciprofloxacin (CIP), colistin (CL); gentamicin (GM).**

**Discussion**

Accessing drinking water is difficult in various regions of Côte d'Ivoire, especially in Daloa, forcing people to use available groundwater and surface water (Awomon et al., 2019). Our study examined the physical, chemical, and microbiological quality of water sources in the Commerce, Tazibouo, Gbokora, and Oliviers districts. The sources of supply include wells, natural lakes, and drilled well water.

Lake water has an acidic pH (4.10 and 4.30) and high temperatures above 30°C, likely due to daily exposure to solar radiation. The average annual temperature in Daloa is around 30°C (Yao et al., 2015). The low pH is below WHO standards, attributed to human activities such as domestic wastewater and household waste discharges into the lakes. Furthermore, these activities produce CO2 from the decomposition of organic compounds, leading to the acidity of the water (Ahoussi et al., 2013). Well and drilled well water mostly meets WHO standards (24.2°C and pH 6.5-8.5) due to less exposure to sunlight and environmental pollution. The observed low pH in these samples may result from the acidic Latossol soil of these regions (Maran et al., 2016).

Iron levels in different water types exceed the WHO standard (≤ 300 µg/L), with spring water having iron levels of 998.65 and 1032 µg/L at the Lobia and CAD sites, respectively. Surface waters have even higher levels, around 10 times the recommended standard. This is particularly evident in Gbokora Lake, with an iron content of 3,000 µg/L. These findings are likely due to the region's geology, mainly comprised of ferromagnesian rocks, which can lead to the accumulation of iron in soils and subsequent leaching into groundwater (Naho, 1988; Djadé et al., 2020).

Regarding microbiological analysis, groundwater is less contaminated than surface water in our study. Spring water has the slightest contamination, with no fecal coliforms present. This disparity may be due to groundwater being protected from airborne pollution, unlike surface water. However, some wells are regularly treated with chlorine, which inhibits pathogenic microorganisms' proliferation (Belghiti et al., 2013). Bacterial strains, mainly from the *Enterobacteriaceae* family, are more prevalent in surface waters, likely originating from run-off water. Groundwater showed an absence of *E. coli*. Similarly, fungal flora, including *Aspergillus* sp and *Trichoderma* sp, is present in different types of water in the study, with surface waters being the most contaminated. Their presence in groundwater is attributed to their ability to form biofilms due to humidity (Maran et al., 2016). They generally produce substances that modify the organoleptic characteristics of the water (bitter taste and unpleasant odors). The antibiograms conducted on the different identified strains show a resistance profile to more than two antibiotics, indicating that they are multidrug-resistant bacteria (Maran et al., 2016). Previous research studies in the Daloa region, including those by Kouassi et al. 2020 and Zébré et al. (2022), have also observed multidrug resistance in environmental strains. The Citrobacter strain exhibits the highest multi-resistance, with 58% resistance. Citrobacter species are gram-negative bacilli that have been noted to cause infections in immune compromised patients. He is best known as the cause of sepsis and meningitis leading to central nervous system (CNS) abscesses ( Oyeka and Suresh, 2017)

This finding suggests that resistant bacteria in water indicate the presence of pathogenic organisms that can spread infection among groundwater consumers (Mukhopadhyay et al., 2012). On the other hand, all the strains are sensitive to colistin, one of the last-resort antibiotics (Lim et al., 2010). The emergence of resistance mechanisms in certain bacteria to this last-resort antibiotic remains a public health problem, as it is generally used for patients with complex infections (Falagas et Kasiakou, 2005; Dortet et al., 2016).

Upon analyzing these multi-resistant strains, most were found in surface waters, particularly lakes. These waters are often affected by human activities. Human activity can spread resistant micro-organisms, potentially resulting in the dissemination of multidrug-resistant agents in hospitals, communities, and the environment, posing a public health problem (Wellington et al., 2013; Larsson et Flach, 2022).

**Conclusion**

The study provided important information on the quality of surface water and groundwater widely used in the districts of Lobia, Tazibouo, Olivier, Commerce and Gbokora in Daloa. The results showed that the borehole water meets the standards recommended by the WHO. Surface water is the most contaminated, with various types of microbiological contamination, including bacteria and fungi. The bacteria present in surface water are multi-resistant. This represents a public health problem and a risk of illness in the population. Although well and borehole water complies with the standards recommended by the WHO, it nevertheless requires regular monitoring and control to avoid any risk of water-borne diseases among the population. Finally, to prevent the health risks identified in surface water, local authorities are recommended to raise awareness among the population of the need not to use this water for domestic purposes, and to prohibit rubbish dumps and the discharge of domestic and industrial wastewater into surface water.

**Disclaimer (Artificial intelligence)**

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

**References**

Abai A. E., Ombolo A., Ngassoum M. B., Mbawala A. 2014. Suivi de la qualité physico-chimique et bactériologique des eaux des cours d’eau de Ngaoundéré, au Cameroun. *Afrique science* 10(4):135 - 145

Affum A. O., Osae S. D., Nyarko B. J. B., Afful S., Fianko J. R., Akiti T. T., Adomako D., & Acquaah S. O., Dorleku M., Antoh E., Barnes F., Affum E., A. 2015. Total coliforms, arsenic and cadmium exposure through drinking water in the Western Region of Ghana: application of multivariate statistical technique to groundwater quality. *Environ Monit Assess*, 187 (1): 2-23

Ahoussi K. E., Koffi Y. B., Kouassi A. M., Soro G. Biemi J. 2013. Étude hydrochimique et microbiologique des eaux de source de l’ouest montagneux de la Côte d’Ivoire : Cas du village de Mangouin-Yrongouin (sous-préfecture de Biankouman), *Journal of Applied Biosciences*, 63 (1) : 4703- 4719

Ako A. A., Nkeng E. G., Takem E. E. G.2009. Water quality and occurrence of water-borne diseases in the Douala 4th District, Cameroon. *Water Science & Technology,* 52(12):2321-2329

Attien P., Toe E., Kouassi K. A., Zébré A. C., Gomé M. N., Sina H, Nanouman Marina Christelle Assohoun-Djeni N. M. C., Konan A., Coulibaly I., Baba-Moussa L., Dadie A. 2022. Evaluation of Health Risks Related to the Consumption of Fish from the Guéssabo River. Food and Nutrition Sciences, 13: 55-64

Awomon D. F., Coulibaly M., Niamké G. M., Santos D. S. 2019. La problématique de l’approvisionnement en eau potable et le développement des maladies à transmission hydrique dans les quartiers d’extension Orly de la ville de Daloa (Côte d’Ivoire), *Revue Espace Territoires Sociétés et Santé*, 1 (2) : 91-108.

Bancessi A., Catarino L., Silva M. J., Ferreira A., Duarte E., Nazareth T. 2020. Quality Assessment of Three Types of Drinking Water Sources in Guinea-Bissau. *Int. J. Environ. Res. Public Health,* 17 (19): 1-15

Belghiti M. L., Chahlaoui A., Bengoumi D., EL Moustaine R. (2013). Etude de la qualité physico-chimique et bactériologique des eaux souterraines de la nappe plio-quaternaire dans la région de Meknès (Maroc*), Larhyss Journal*, 14 : 21-36

Bozorgzadeh, E., Pasdaran, A. and Ebrahimi-Najafabadi, H. (2021) Determination of Toxic Heavy Metals in Fish Samples Using Dispersive Micro Solid Phase Extraction Combined with Inductively Coupled Plasma Optical Emission Spectroscopy. *Food Chemistry*, 346

Breitenmoser A., Fretz, R., Schmid J., Besl, A., Etter R. 2011. Outbreak of acute gastroenteritis due to a washwater-contaminated water supply, Switzerland, 2008. *J. Water Health,* 9 (3): 569–576.

Charlet L., He J. 2013. A review of arsenic presence in China drinking water. *Journal of Hydrology*, 492: 79–88

Djadé P. J. O., Traore A., Koffi J.T., Keumean K. N., Soro G., Soro N. 2020. Evaluation du niveau de contamination des eaux souterraines par les éléments traces métalliques dans le département de Zouan-Hounien (Ouest de la Côte d’Ivoire). *Journal of Applied Biosciences* 150: 15457 - 15468

Domsch K. H., Gams W., Traute-Heidi A. 1980. Compendium of soil fungi.Academic Press, London, 859 p

Dortet L., Bonnin R., Jousset A., Gauthier L., Naas T. 2016.Émergence de la résistance à la colistine chez les entérobactéries : une brèche dans le dernier rempart contre la pan-résistance !. [*Journal des Anti-infectieux*](https://www.sciencedirect.com/journal/journal-des-anti-infectieux)*,* 18(4) : *139-159*

Emmanuel E., Pierre M. G, Perrodin Y. 2009. Groundwater contamination by microbiological and chemical substances released from hospital wastewater: Health risk assessment for drinking water consumers. *Environment International,* 35 (2009) 718–726

[Falagas](https://pubmed.ncbi.nlm.nih.gov/?term=Falagas+ME&cauthor_id=15825037) M. E., [Kasiakou](https://pubmed.ncbi.nlm.nih.gov/?term=Kasiakou+SK&cauthor_id=15825037) S. K.2005. Colistin: the revival of polymyxins for the management of multidrug-resistant gram-negative bacterial infections. *Clin Infect* Dis, 40(9):1333-41

Freeman M.C., Trinies V., Boisson S., Mak G., Clasen T. 2012. Promoting household water treatment through women’s self help groups in rural India: Assessing impact on drinking water quality and equity. *PLoS ONE*, 7 (9) :1-9

Jadhav J.2011.Bacteriological quality of water and water borne diseases in Bangalore: a longitudinal study. *East Afr J Public Health,* 8(1):42-4.

Howard, G., Pedley, S., Barrett, M., Nalubega, M., & Johal, K. (2003). Risk factors contributing to microbiological contamination of shallow groundwater in Kampala, Uganda. *Water Research*, 37(14), 3421–3429.

Kanohin F. O., Yapo O. B., Dibi B., Bonny A. C. 2017. Caractérisation physico chimique et bactériologique des eaux souterraines de Bingerville. Int. J. Chem. Sci 11 (5): 2495-2509

Kaynar1 P. M., Demli F., Orhan G, İlter H. 2022. Chemical and microbiological assessment of drinking water quality. *Afri Health Sci* 22(4). 648-652

Kouadio A. N. B., Yeo K. M, Aboua K. N., Gone D. L. 2017. Demande en chlore et paramètres déterminant la consommation du chlore des eaux de puits traditionnels d’Agboville (Côte d’Ivoire). *Environmental and Water Sciences Public Health and Territorial Intelligence,* 1 (4): 23-33.

Kouadio E. F., Yoboué B. A., Akmel D. C., Assidjo N.E. 2020. Quantitative assessment of the risk related to the ingestion of metals due to the consumption of well water (in Côte d'ivoire). *Int. J. Adv. Res*. 8(11): 964-971

Kouassi K. A., Koffi A. C., Kouassi K. C., Dadie A., Dje K. M. 2020. Evaluation of the microbiological quality and antibiotyping of strains of Escherichia coli strains isolated from street foods made from beef sold in Daloa (Côte d'Ivoire). *Int. J. Appl. Microbiol. Biotechnol. Res*, 8:10-17

Kouassi, K. C.2021. Caractérisation nutritive des plantes aromatiques du Département de Daloa (Région du Haut Sassandra, Côte d’Ivoire) Mémoire de Master de Biotechnologie et Biosécurité Alimentaire (Option Biotechnologie Agroalimentaire). UFR Agroforesterie, Université Jean Lorougnon Guédé, Daloa, Côte d’Ivoire, 82 p.

Larsson D. G. J., Flach C.2022. Antibiotic resistance in the environment. *Nature Reviews | Microbiology*, 20: 257–269

Lim L.M., Ly N., Anderson D., Yang J.C., Macander L., Jarkowski A., Forrest A., Bulitta J B., Tsuji B.T. Resurgence of colistin: a  review of resistance, toxicity, pharmacodynamics, and dosing. *Pharmacotherapy*, 30(12):1279–1291

Mangoua M. J., Touré S., Goula B. T. A., Yao K. B. 2010. Évaluation des caractéristiques des aquifères fissurés du bassin versant de la Baya. (Est de la Côte d’Ivoire). *Revue Ivoire Science* *Technologie*, 16 : 243-259.

Maran N. H, Crispim B, Iahnn S. R, Pires de Araújo R, Grisolia B. A, Pires de Oliveira K. M. 2016. Depth and Well Type Related to Groundwater Microbiological Contamination. *Int. J. Environ. Res. Public Health,* 13 (1036): 2-9

Mukhopadhyay C., Vishwanath S., Eshwara V.K., Shankaranarayana S.A., Sagir A. 2012. Microbial quality of well water from rural and urban households in Karnataka, India: A cross-sectional study. *J. Infect. Public Health*, 5: 257–262

Murray A., Lantagne D. (2015). Accuracy, precision, usability and cost of free chlorine residual testing methods, *Journal of Water and Health*, 1 (13): 79- 90.

Naho J.1988. Cycle supergène de l’or en milieu ferralitique. Exemple du gisement d’Ity en Côte d’Ivoire. Thèse de Doctorat ès Géosciences et Matière Première, INPL, Nancy, 132p

N’Guessan S.R. 2009*.* Approvisionnement en eau potable des villages d’Assouba Ayebo et Adaou. Mémoire de Master, UFR Génie Sanitaire et Environnement (GSE), Institut International d’Ingénierie de l’Eau et de l’Environnement (Burkina Faso), 94 p.

Nyamai M., Wright A. J., Mutembei H., Muema J., Mair L. H.T., Mutunga M., Thumbi S. M. 2021. The nexus between improved water supply and water-borne diseases in urban areas in Africa: a scoping review. *AAS Open Res,* 4 (27): 1-22

Ohou-Yao M. J. A., Séka A. M., Mambo V., Yapo O. B., Konan K. F., Houénou P. V. 2014. Contamination des eaux de puits traditionnels par les nitrates sur le bassin versant de la Lobo (Buyo, sud-ouest de la Côte d’Ivoire). *J. Appl. Biosci*. 78:6654-6665

[Oyeka](https://pubmed.ncbi.nlm.nih.gov/?term=Oyeka+M&cauthor_id=27658860) M.,Suresh A.2017.Citrobacter braakii Bacteremia: Case Report and Review of the Literature. *Infect Disord Drug Targets*, 17(1):59-63

RGPH.2022. Résultats définitifs du recensement générale de la population et de l’habitat 2021.Ministère du Développement et du Plan de la République de Côte d’Ivoire. 1p

Rubino F., Yahaira C., Pérez J. G. J, Smith C.2019. Bacterial Contamination of Drinking Water in Guadalajara, Mexico. Int. J. Environ. *Res. Public Health*, 16 (67): 2-11

Yao A.B. 2015. Evaluation des potentialités en eau du bassin versant de la Lobo en vue d’une gestion rationnelle (Centre-ouest de la Côte d’Ivoire). Thèse de Doctorat, UFR des Sciences et Gestion de l’Environnement, Université Nangui Abrogoua (Abidjan, Côte d’Ivoire), 192 p.

Yapo R. I., Mambo V., Aldera C. Ohou-Yao M. I., Ligban R., Dao D., Stamm C., Bbonfoh B. (2016). Caractérisation saisonnière des eaux de puits à usage maraîchère et domestique de Korhogo (Côte d’Ivoire). *International Journal of Biological and Chemical Science,* 10 (3): 1433-1449.

[Wellington](https://pubmed.ncbi.nlm.nih.gov/?term=Wellington+EM&cauthor_id=23347633)E. M. H., [Boxall](https://pubmed.ncbi.nlm.nih.gov/?term=Boxall+AB&cauthor_id=23347633) B. A., [Cross](https://pubmed.ncbi.nlm.nih.gov/?term=Cross+P&cauthor_id=23347633) P., [Feil](https://pubmed.ncbi.nlm.nih.gov/?term=Feil+EJ&cauthor_id=23347633) E. J., [Gaze](https://pubmed.ncbi.nlm.nih.gov/?term=Gaze+WH&cauthor_id=23347633) W. H., [Hawkey](https://pubmed.ncbi.nlm.nih.gov/?term=Hawkey+PM&cauthor_id=23347633) M. P., [Johnson-Rollings](https://pubmed.ncbi.nlm.nih.gov/?term=Johnson-Rollings+AS&cauthor_id=23347633) A. S.,[Jones](https://pubmed.ncbi.nlm.nih.gov/?term=Jones+DL&cauthor_id=23347633) D. L, [Lee](https://pubmed.ncbi.nlm.nih.gov/?term=Lee+NM&cauthor_id=23347633) M. N., [Otten](https://pubmed.ncbi.nlm.nih.gov/?term=Otten+W&cauthor_id=23347633) W., [Thomas](https://pubmed.ncbi.nlm.nih.gov/?term=Thomas+CM&cauthor_id=23347633) C. M,  [Williams](https://pubmed.ncbi.nlm.nih.gov/?term=Williams+AP&cauthor_id=23347633) A. P. 2013. The role of the natural environment in the emergence of antibiotic resistance in gram-negative bacteria. *Lancet Infect Dis*, 13(2):155-65.

Zébré C. A., Attien Y. P., Sina H., Gome M., Konate I., Baba-Moussa L. 2022. Sanitary Investigation on Microbial and Heavy Metals of Grilled Fish Sold in the Night Street Market of Daloa (Ivory Coast). *Journal of Advances in Microbiology*, 22(12) : 1-9