



**SPATIAL VARIABILITY OF THE BACTERIOLOGICAL QUALITY OF GUIDER
AND FIGUIL REGIONS (NORTHERN CAMEROON) GROUNDWATER**

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ABSTRACT

Wells waters are regularly used by the poor populations of Guider and Figuil (Cameroon) regions, for household usages and as drinking water sources. This study aimed to assess the bacteriological and physico-chemical qualities of wells water in these areas. Ten wells were chosen for this purpose based on their spatial distribution, their importance for the population, their distance to the latrines pits, their level of development, their accessibility, their perennity and the consent of the owner. The analysis of physico-chemical parameters was performed using an Exteck EC 500 Trademark portable appliance, for pH, electrical conductivity, total dissolved solids, salinity, and an Exteck RE 300 Trademark portable redoxmetre, for the redox potential. The membrane filtration and platage techniques have isolated several groups of bacteria, such as heterotrophic aerobic mesophilic bacteria (2300 ± 820 to 67917 ± 13507 CFU/mL), faecal coliforms (123 ± 28 to 3236 ± 1017 CFU/100 mL), *Escherichia coli* (197 ± 103 to 1474 ± 110 CFU/100 mL) and faecal streptococci (78 ± 18 to 984 ± 101 CFU/100 mL), from the wells water samples. The results show that the wells waters of Guider and Figuil have slightly alkaline pH values and high values of electrical conductivity, total dissolved solids and salinity. The Guider and Figuil regions wells water are heavily contaminated with bacteria and this faecal contamination has animal, human, or mixed origin, according to the wells. The abundances of bacteria and physico-chemical parameters values of the water vary from one well to another ($p < 0.05$). Wells should be built away from the houses and treating their water, before use, is necessary in these areas.

Keywords: Bacteria, Well water, Spatial variation, Water quality, Pollution.

INTRODUCTION

Drinking water is essential to human life. Its availability, in quality and sufficient quantity in nature, helps maintain the health of the user population [1]. The poor water quality is, on the other hand, the source of many diseases.

According to [2], 80% of diseases and over one third of deaths, in developing countries, are caused by the consumption of contaminated water. Indeed, the low capacity of drinking water distribution by the structures in charge, leads people to use natural waters, regardless of their bacteriological and physico-chemical properties.

Population growth, accelerated and uncontrolled cities development, the intensification of industrial and agricultural activities are environmental factors that are likely to produce huge amounts of pollutants. These, directly discharged into nature without any prior treatment, degrade the physico-chemical quality of surface and ground water [3, 4]. They promote the development of pathogens responsible of many waterborne diseases such as cholera, typhoid, amoebiasis, diarrhoea [5-7, 4, 8-10] and food poisoning.

In the Northern Cameroon, diarrhoeic diseases, almost endemic, are mainly caused by *Escherichia coli*, *Salmonella* and *Shigella*. In 2011, 23152 cases of cholera,

including 843 deaths, have been reported essentially in seven of the ten regions of the country, with 4752 cases and 267 deaths in the North [11].

Many studies have highlighted bad bacteriological and physico-chemical qualities of groundwater and streams water in some cities of sub-Saharan Africa [12-18]. Pollution of these waters proceeds from waste discharged into the environment by human activities. Moreover, studies conducted in some cities of Cameroon as Garoua [19], Douala [20, 21] and Yaoundé and its surroundings [22-24] showed faecal pollution of surface and ground water.

In Guider and Figuil areas, the “Camerounaise des Eaux”, for the most affluent population, distributes water intended for human consumption. The poor population, the majority, makes use of well water for domestic purposes. These wells are mostly located near rivers, household deposits, industrial effluents, in populated areas and, sometimes, near septic tanks. The quality of these waters is evaluated by simple organoleptic criteria (colour, taste and smell) by this population. All these factors predispose to the alteration of the physico-chemical and bacteriological qualities of well water in these regions, due to close hydrological interdependence between surface and ground water [4]. Very

few studies have been conducted on the bacteriological and physico-chemical qualities and sources of contamination of groundwater in Northern Cameroon region, in general, and in Guider and Figuil areas, in particular.

The main purpose of this work is to evaluate the bacteriological and physico-chemical qualities of wells water intended for human consumption, in the Guider and Figuil regions, in Northern Cameroon.

MATERIALS AND METHODS

Presentation of study regions

Guider (9°56'03" N and 13°56'55"E) and Figuil (9°45'31"N and 13°57'46"E) regions are located in the Department of Mayo-Louti (**Figure 1**), respectively, at 100 and 94 km from the town of Garoua, capital of the Northern Region of Cameroon.

A relief of corrugated plain characterizes these areas, with an altitude ranging between 300 and 400 m [25]. The climate is a classic Sudanese type, characterized by high thermal amplitude (26°C) and two seasons: a dry season, from November to April and a rainy season, from May to October. The average rainfall is 900 mm with an irregular distribution.

The hydrography of these regions is, for the most part, dependent on the Mayo-Louti and some other rivers. All the rivers of these regions are characterized by temporary

flows of wet seasons, hence the name of Mayo [25].

The vegetation is made of sparse and bushy savannah, characterized by shrubs including many thorny. During the rainy season, there is formed a green carpet, where shrubs are scattered to the grassy areas. By the contrary, when the dry season lengthens, grasses become scarce, leaving bare soils.

Description of sampling sites

For the study, 10 wells were chosen, of which 4 in Guider centre, 2 in Gatouguel-Guider and 4 in Figuil. A GPS receiver (Garmina trademark) has been used for location of study sites and determination of their altitude, graduated rope to measure the depth of the wells. The distances from the wells points to the potential sources of contamination were measured, using a decametre. Data on wells development were noted and questions were asked to users on their wells water practices (**Annex 1**).

Sampling and analysis techniques

Sampling

The samples were taken, from May to August 2013. The wells were selected based on their spatial distribution, their importance for the population, their distance from the latrines pit, their level of development, their topographic position, their accessibility, their owner consent and the sustainability of the project.

Water samples for physico-chemical analysis were collected in polyethylene bottles of 250 mL. Those for bacteriological analyzes were collected in sterile glass bottles (Pyrex) of 500 mL. These vials were labelled and transported to the laboratory of the Pasteur Centre, Garoua Annex, in refrigerated coolers for immediate analysis.

Physico-Chemical Analysis

The physico-chemical analyzes were made on a few parameters that characterize water: pH, electrical conductivity (EC), total dissolved solids (TDS), salinity (Sal) and redox potential (rH). pH, EC, TDS and Sal were measured, *in situ*, using an Exteck EC 500 brand portable multifunction tester and values are expressed in CU, $\mu\text{S}/\text{cm}$, mg/L and ppm, respectively. The measurement of the redox potential, also, was made, *in situ*, using an Exteck RE 300 brand portable redoxmetre and the values are expressed in mV.

Bacteriological Analysis

The study focused on bacteriological parameters quantifying faecal bacteria: faecal coliforms (FC), faecal streptococci (FS), *Escherichia coli* and heterotrophic aerobic mesophilic bacteria (MAHB). The MAHB were isolated by the platage technique [26]. Other bioindicators of faecal contamination were isolated by membrane filtration method [27]. Counting isolated germs was performed on Petri dishes, using

a Jouan CC 120 brand colonies counter and bacterial abundances were expressed as CFU/100mL of water. The culture media used and incubation conditions of the isolated germs are shown in **annex 2**.

Determination of the Origin of Faecal Wells Contamination

The origin of faecal contamination of the wells was determined from the ratio of faecal coliforms/faecal streptococci [28, 29]. A ratio greater than 4 indicates an anthropogenic contamination. A quotient between 2 and 4 indicates a contamination of both human and animal origin, with a human predominance. A report between 1 and 2 indicates an uncertain contamination origin. A quotient between 0.7 and 1 indicates a contamination of both human and animal origin, with an animal predominance. A quotient less than 0.7 indicates an animal contamination.

Data Analysis

Data on the environmental determinants were recorded and analyzed, using SPSS 19.0 software. Spatial variations in the values of the analyzed bacterial parameters were illustrated by histograms. Comparison between means was made by Least Significant Difference-LSD procedure, at the 95.0% confidence level, and Duncan test, at the 0.05 level, was used to distinguish homogeneous groups. The ratios faecal coliforms/faecal streptococci were

calculated for each well and allowed to deduce the origin of faecal contamination of the wells.

RESULTS AND DISCUSSION

Results

Spatial variation of physico-chemical parameters

As shown by one-way ANOVA analysis, the values of the physico-chemical parameters of the studied wells vary strongly ($p < 0.001$) from one well to another (**Table 1**).

For all the examined wells, the average values of pH vary from 7.35 ± 0.20 (W7 well in Figuil) to 7.85 ± 0.06 (W1 well in Guider).

EC average values of the wells water fluctuate between 339.25 ± 49.58 (W5 well in Guider) and 1940.17 ± 61.48 $\mu\text{S}/\text{cm}$ (W7 well in Figuil).

The mean levels of TDS vary from 301.67 ± 30.71 to 1356.08 ± 38.96 mg/L, respectively, in W4 (Bébééré III-Guider) and W7 (Lamordé-Figuil) wells.

The average amounts of salinity in the different sampling points vary from 285.00 ± 9.40 to 965.08 ± 29.38 ppm. These values are, respectively, stored in the W6 (Gatouguel II-Guider) and W7 (Lamordé-Figuil) wells.

The mean values of the rH, in the analyzed wells water, vary from 128.50 ± 13.28 to 143.50 ± 9.99 mV. The lowest value is

found in the W1 (Sanguéré-Guider) well and the highest one in W7 (Lamordé-Figuil) well.

It must be noted that most of the highest values of the tested physico-chemical parameters are found in W7 Lamordé-Figuil well.

Spatial Variation of Bacteriological Parameters

The obtained values of the bacteriological parameters vary from one well to another (**Figures 2 and 3**) and analysis of variance shows a significant difference between the wells parameters values ($p < 0.05$).

The BHAM are present in high concentrations in all sampled wells. W9 (Factory Chaux-Roca-Figuil) well is the one which has registered the highest MAHB average abundance value (67917 ± 13507 CFU/mL) and the lowest average abundance value (2300 ± 820 CFU/mL) is obtained from the W1 (Sanguéré-Guider) well. There is a significant mean difference, at the 0.05 level, between W1 well and the others and the same trend is observed with W9 and W10 wells.

The FS are present in all the wells. Their average abundances vary from 78 ± 18 CFU/100 mL, recorded in W2 (Soukatak-Guider) well to 984 ± 101 CFU/100 mL, in the W9 (Factory Chaux-Roca-Figuil) well. There is a significant mean difference, at the 0.05 level, between W9 well and the others.

The FC lowest average abundance value (123 ± 28 CFU/100 mL) is recorded at W2 (Soukkata-Guider) well and that of *E. coli* (197 ± 103 CFU/100mL), at the W7 (Lamordé-Figuil) well. The highest values is found at the W9 (Factory Chaux-Roca-Figuil) well and at the W6 (Gatouguel II-Guider) well, respectively, for FC (3236 ± 1017 CFU/100 mL) and *E. Coli* (1474 ± 110 CFU/100 mL). Concerning the FC loads,

there is a significant mean difference, at the 0.05 level, between W9 well and the others, while, regarding *E. coli*, this difference is between W6 and W9 wells and all the others.

Origin of Wells Faecal Contamination

To determine the pollution origin of the wells waters, FC/FS ratios were calculated, according to the [28] method (Table 2). The obtained values vary from 0.88 to 6.82.

Table 1: Physico-Chemicals Values of the Studied Wells Water

Well	pH (UC)	EC (μ S/cm)	TDS (mg/L)	Sal (ppm)	rH (mV)
W1	7.85 \pm 0.06 ^a	861.33 \pm 55.97 ^a	603.92 \pm 37.96 ^a	426.67 \pm 26.11 ^a	128.50 \pm 13.28 ^a
W2	7.79 \pm 0.15 ^{ab}	1208.67 \pm 11.80 ^b	844.08 \pm 8.86 ^b	598.67 \pm 9.25 ^b	130.25 \pm 13.71 ^a
W3	7.85 \pm 0.09 ^a	1613.17 \pm 34.27 ^c	1131.17 \pm 26.48 ^c	789.75 \pm 40.96 ^c	130.92 \pm 14.19 ^a
W4	7.54 \pm 0.19 ^{cd}	430.08 \pm 42.04 ^d	301.67 \pm 30.71 ^d	213.83 \pm 20.67 ^d	132.42 \pm 15.87 ^{ab}
W5	7.55 \pm 0.11 ^{cd}	339.25 \pm 49.58 ^e	236.08 \pm 35.71 ^e	169.08 \pm 24.01 ^e	132.17 \pm 11.94 ^a
W6	7.50 \pm 0.58 ^{cd}	569.75 \pm 23.34 ^f	398.17 \pm 14.37 ^f	285.00 \pm 9.40 ^f	135.75 \pm 10.76 ^{ab}
W7	7.36 \pm 0.20 ^c	1940.17 \pm 61.48 ^g	1356.08 \pm 38.96 ^g	965.08 \pm 29.38 ^g	143.50 \pm 9.99 ^b
W8	7.66 \pm 0.10 ^{abd}	1744.75 \pm 54.69 ^h	1224.92 \pm 45.73 ^h	868.17 \pm 32.79 ^h	137.67 \pm 9.09 ^{ab}
W9	7.61 \pm 0.13 ^{bd}	1160.75 \pm 159.75 ^b	810.67 \pm 111.37 ^b	579.17 \pm 79.47 ^b	132.92 \pm 10.14 ^{ab}
W10	7.83 \pm 0.10 ^a	890.58 \pm 13.48 ^a	630.17 \pm 13.86 ^a	449.42 \pm 7.30 ^a	134.25 \pm 10.92 ^{ab}

W1: Sanguéré-Guider well, W2: Soukkata-Guider well, W3: Bébéré II-Guider well, W4: Bébéré III-Guider well W5: Gatouguel I-Guider well, W6: Gatouguel II-Guider well, W7: Lamordé-Figuil well, W8: Kolléré-Figuil, W9: factory Chaux-ROCA-Figuil well, W10: Karéwa-Figuil well. EC: Electrical Conductivity, TDS: Total Dissolved Solids, Sal: Salinity and rH: redox Potential. Within each column, the numbers with the same letter belong to the same group of means within which there are no statistically significant differences (Duncan test), at the 0.05 level

Table 2: Pollution Sources of the Studied Wells, According to [28] Method

Wells	FC/FS ratio	Contamination origin
W1	1,14	Uncertain
W2	1,59	Uncertain
W3	0,88	Mixed, animal predominance
W4	6,82	Human
W5	3,73	Mixed, human predominance
W6	2,25	Mixed, human predominance
W7	4,72	Human
W8	2,56	Mixed, human predominance
W9	3,29	Mixed, human predominance
W10	1,72	Uncertain

FC: faecal coliforms, FS: faecal streptococci

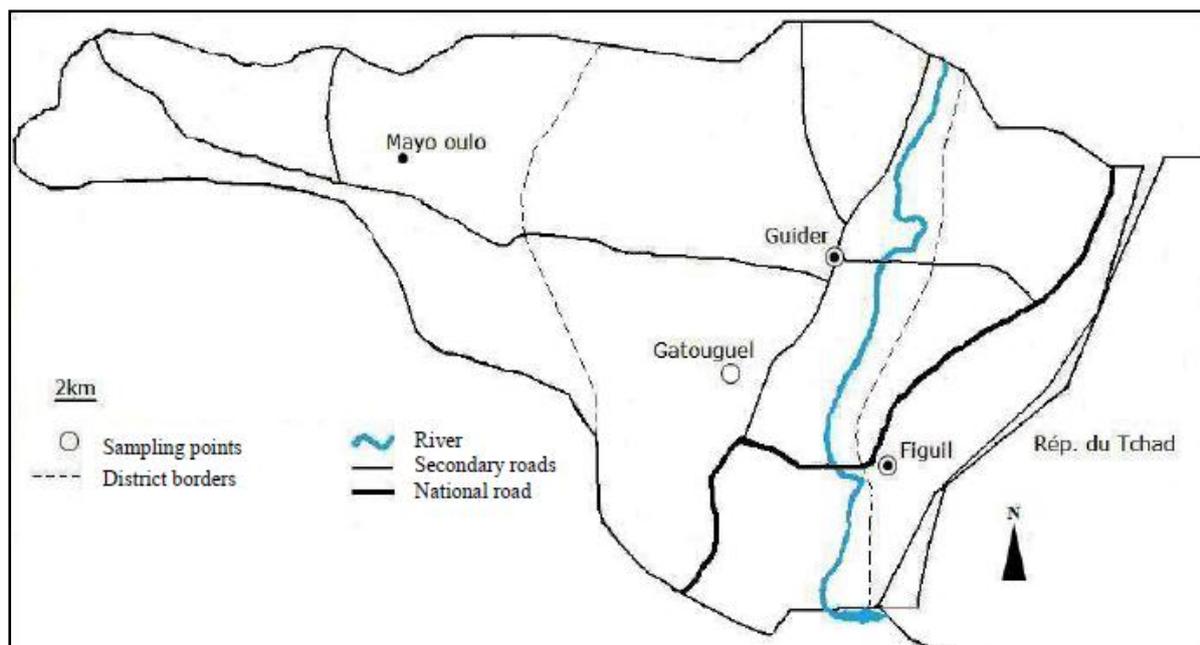


Figure 1: Studied Area Map, Showing the Sampled Cities

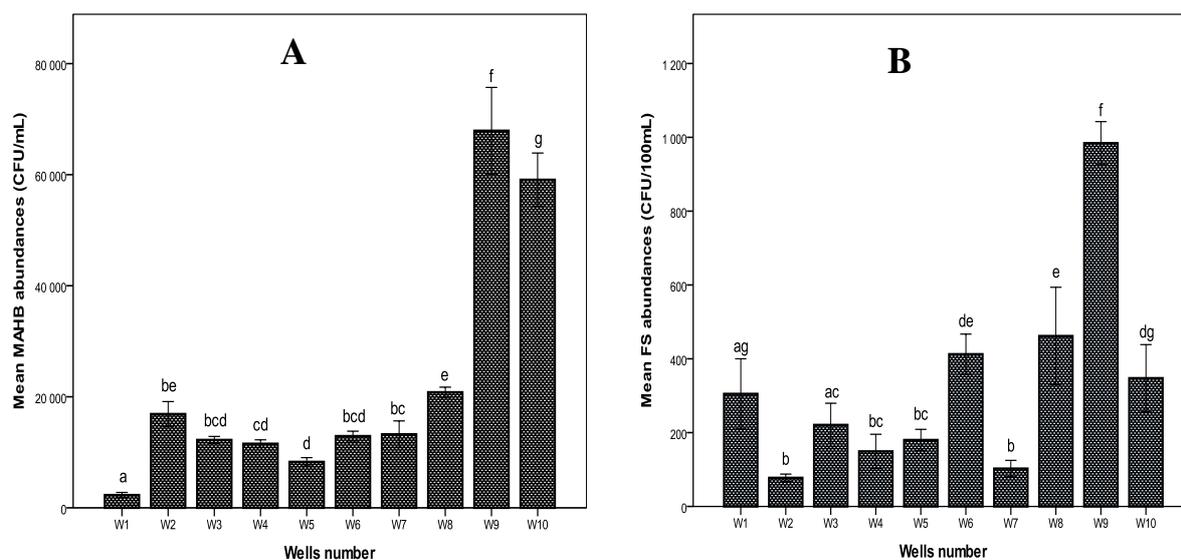


Figure 2: Spatial distribution of MAHB (A) and of FS (B) in the studied wells water. MAHB: Mesophilic Aerobic Heterotrophic Bacteria, FS: Faecal Streptococci, W1: Sanguéré-Guider well, W2: Soulkata-Guider well, W3: Bébéré II-Guider well, W4: Bébéré III-Guider well W5: Gatouguel I-Guider well, W6: Gatouguel II-Guider well W7: Lamordé-Figuil well, W8: Kolléré-Figuil, W9: factory Chaux-ROCA-Figuil well, W10: Karéwa-Figuil well. In each histogram, rectangles with the same letter belong to the same group of means within which there are no statistically significant differences (Duncan test), at the 0.05 level.

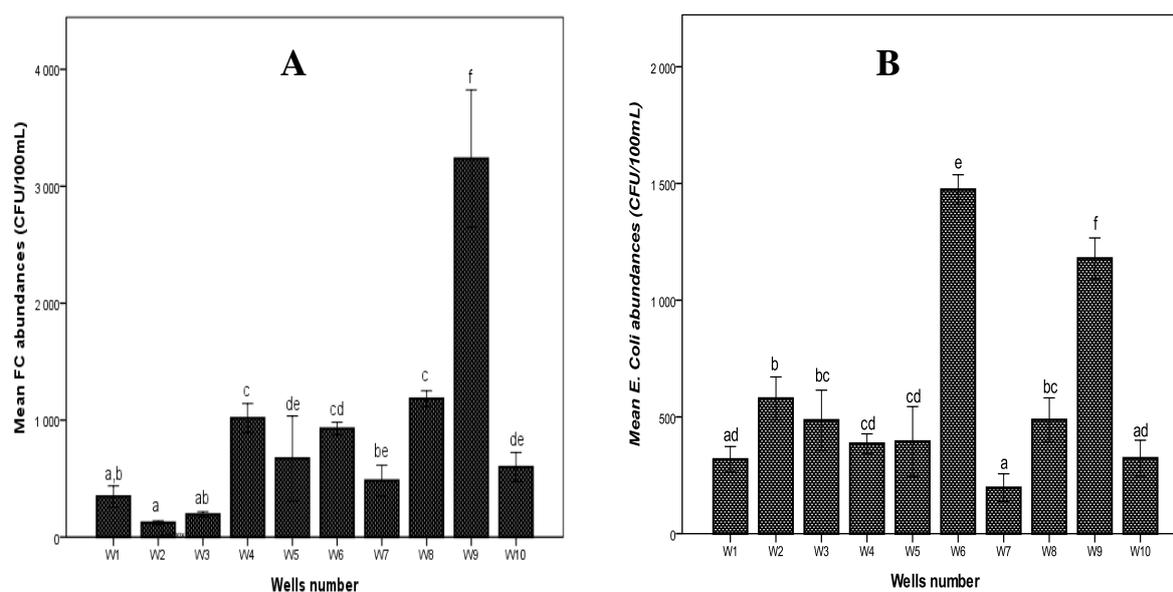


Figure 3: Spatial distribution of FC (A) and of *E. coli* (B) in the studied wells water. FC: Faecal Coliforms, W1: Sanguéré-Guider well, W2: Soulkata-Guider well, W3: Bébéré II-Guider well, W4: Bébéré III-Guider well W5: Gatouguel I-Guider well, W6: Gatouguel II-Guider well W7: Lamordé-Figuil well, W8: Kolléré-Figuil, W9: factory Chaux-ROCA-Figuil well, W10: Karéwa-Figuil well. In each histogram, rectangles with the same letter belong to the same group of means within which there are no statistically significant differences (Duncan test), at the 0.05 level.

DISCUSSION

Spatial Variation of Physico-Chemical Parameters

The pH of water represents its acidity or alkalinity [30]. The mean values of pH and rH of Guider and Figuil regions wells water range, respectively, from 7.35 ± 0.20 to 7.85 ± 0.06 (W7 well in Figuil) and from 128.50 ± 13.28 to 143.50 ± 9.99 mV. According to [31], the pH of a drinking water should be between 6.5 and 8.5. The wells water in these regions, therefore, has a pH close to neutrality and up to WHO standard. Similar results were obtained by [1], for drinking water, in Bamako (Mali) and [32] in certain areas of the city of Fez, in Morocco wells water. This trend of pH may be due, on one hand, to the nature of the soil, since the pH of groundwater, although vulnerable to

fluctuations, is not very different from the casking ground [33], and on the other hand, to the action of microorganisms present in these waters and the closeness of the wells to latrines.

The waters of the W1 and W3 wells, in Guider and W10, in Figuil have a higher pH than that of the other wells ($p < 0.05$). This can be explained, in one hand, by the presence of manure and fertilizers, as they stand in cultivation areas and, in the other hand, by the proximity of domestic wastewater and runoff around. These pollutants may contain basic compounds which increase the pH of the water. These same reasons and, especially the presence of nutrients, would also cause the recorded very high values of rH.

The EC is a good indicator of the degree of mineralization of water. According to [34], the recorded values, for this parameter, can be used to classify the sampled wells into 3 groups. The first group includes the wells water with accented mineralization (conductivity between 333 and 666 $\mu\text{S}/\text{cm}$); there are W4, W5 and W6 wells. Water points constituting the second group are those with important mineralization (conductivity between 666 and 1000 $\mu\text{S}/\text{cm}$), W1 and W10 wells belong to this group. The wells forming the third group have a high mineralization (conductivity above 1000 $\mu\text{S}/\text{cm}$); there are W2, W3, W7, W8 and W9 wells.

The EC and salinity are closely related parameters. Measuring the first parameter allows to assess quickly, but very roughly, the overall mineralization of water and the monitoring of its progress [30].

Spatial variations of the EC and, hence, the degree of mineralization of the analyzed wells water may be related to that of the nature and the concentration of dissolved salts, according to water points [35]. These spatial fluctuations of the values, also, are related to spatial variations in the solubility of soil minerals and the importance of contributions from surface minerals, resulting from human activities [35]. Moreover, the EC depends on the loads of endogenous and exogenous organic

materials. These charges generate salts, after decomposition and mineralization, and with the evaporation phenomenon, they concentrate the salts in water. It, also, varies depending on the crossed geological substrate [36]. Any ground water contains various salts in solution that derived from the location and movement of water in the past [37]. Differences in conductivity are the result of soil leaching and remobilization of accumulated sediments which are done at different degrees, according to the slope of the site, in one hand, and the result of a defective cleaning up, in the other hand [3]. The high values of electrical conductivity and salinity obtained in Guider and Figuil wells water corroborate those obtained by [19] with some Garoua (Cameroon) wells water.

The TDS are, in general, salts of inorganic compounds and some organic materials. The measurement of the content of STD represents the total concentration of substances dissolved in water. Applying the [30] classification on the TDS contents in studied wells water, we note that these waters have a high concentration of TDS, with the exception of W5 well (236.08 ± 35.71 mg/L). The high levels of TDS in these waters may be natural (biological activity of aquatic environments: decomposition of plants or microorganisms, etc.) or be related to domestic pollution

[36]. These high levels were also recorded by [19], in the wells of Garoua (Cameroon) and [35], in the wells of Douala and Yaoundé (Cameroon), where the analyzed wells are located near rivers and in populated zones.

Spatial Variation of Bacterial Abundances

Bacteriological analysis revealed the presence of indicators of faecal contamination bacteria. These bacteria belong to the group of MAHB, FC, *E. coli* and FS, with fluctuating high abundances. Similar abundances were obtained by [19] in the waters of wells in the town of Garoua. The abundance of faecal bacteria in the water can be owed to their proximity to latrines, rivers and garbage deposits [38]. These bacterial abundances can also come from the abundance of nutrients in these waters. The environmental conditions are valid for the growth of all faecal bacteria with, of course, variability, depending on the bacterial species [39]. The multiple comparison with Duncan test at the 0.05 level, let us to classify the studied wells in homogeneous groups, according to each bacteria pool abundances. Therefore, according to MAHB, CF, *E. coli* and FS abundances, we have, respectively, 7, 6, 7 and 7 groups of wells, showing that the bacteriological quality of water varies from one well to another. This spatial variation in

abundance of bacteria in these waters probably reflects differences in population density [19], spatial fluctuations of soil physical properties of these regions and the variability of these soils microorganisms potential retention [4]. The slightly alkaline pH also promotes the proliferation of bacteria, since most of them are growing in neutral or slightly alkaline pH medium [35].

Origin of Wells Faecal Pollution

The W1, W2 and W10 wells ratios are between 1 and 2, indicating, thus, an uncertain origin of faecal contamination of these wells, as they are, either roadside (W1 and W10) or in the owner habitat (W2), and all near latrines. The quotient of W5, W6, W8 and W9 are between 2 and 4, showing a mixed origin, with a human predominance, resulting from the watercourses proximity and anthropogenic activities. The W4 and W7 ratios are more than 4, reflecting a human pollution, due to their location in the owners habitats, where there are many activities and latrines. The W3 proportion is between 0.7 and 1, translating, so, a mixed origin, with an animal predominance, which can be related to the roadside position of the well, allowing animals to invade the well perimeter. Many other authors have used the FC/FS ratio and have found that it is a good indicator of water pollution origin [40, 41].

CONCLUSION

Guider and Figuil regions wells water host

high densities of various groups of bacteria, indicating faecal contamination. This study revealed the presence of MAHB, faecal coliforms, *E. coli* and faecal streptococci, in relatively, high numbers. The densities of these different groups of bacteria vary, according to the wells. The presence of faecal streptococci and faecal coliforms translate a faecal pollution that can be related to the proximity of these wells with latrines, pen farms and waterways.

Abundances of different groups of bacteria and the amounts of some of the studied physico-chemical parameters, in these waters, exceed WHO recommended standards, for drinking water. Therefore, the water quality of the wells of Figuil and Guider regions is very bad, for human consumption. Their use should be preceded by an adequate treatment.

To prevent the population of the Guider and Figuil regions of waterborne diseases, improving and monitoring the quality of wells water are needed. Therefore, to protect and make them safe, the following actions are required: digging of wells away of septic tanks; protection of the wells by cover slabs and construction of a platform.

Further studies should take into account other physico-chemical parameters of the water and the identification of the most common pathogenic bacterial species. In addition, they should be extended

throughout the Division and account for both spatial and temporal variations.

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Annex 1: Description, Location and Development of the Studied Wells

Wells	Depth (m)	Potential pollution sources localization	Development	Water uses
W1	5	11 m from latrines, 6 m from a stream	Coverless, roadside, a rim of 0.3 m	All domestic works, with monthly bleach treatment
W2	9	12 m from latrines,	Coverless, a rim of 0.5 m	All domestic works, without treatment
W3	8	10 m from latrines	Coverless, a 0.5 m curb	All domestic works, without treatment
W4	9	9 m from pen cattle and latrines	Coverless, under a mango tree, an edge of 0.5 m	All domestic works, without treatment
W5	8	6 m from a water course	Roadside, coverless, concrete curb of 0.3 m, a casing	All domestic works, without treatment
W6	5	6 m from a water course	Roadside, coverless, two Caterpillar wheels rim	All domestic works, without treatment
W7	9	11 m from several latrines	Covered, two Caterpillar wheels rim	All domestic works
W8	6	13 m from latrines	Coverless, car tire curb stone	All domestic works, without treatment
W9	14	10 m from cement factory, near garbage	An edge of 0.6 m, a casing, coverless	Domestic purposes, except drinking
W10	10	15 m from many latrines	An edge of 0.3 m, covered, roadside	All domestic purposes

Annex 2: Culture Media Used, Incubation Conditions and Characteristics of Isolated Microorganisms

Isolated germs	Culture medium	Incubation conditions (temperature, time)	Colonies characteristics
<i>E. coli</i>	Hektoen	44°C, 48h	Flat yellow, with a centre point
MAHB	Ordinary agar (PCA)	37°C, 48h	varied
FC	Hektoen	44°C, 48h	Yellow
FS	AEB	44°C, 48h	Punctiform black, with halo

MAHB: Mesophilic Aerobic Heterotrophic Bacteria, CF: Faecal Coliforms, SF: Faecal Streptococci, AEB: Azid Esculin Bile