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Hygiene practices and indicators of faecal pollution of groundwater supplying populations living around Lake Toho in South-West Benin

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Abstract

The objective of this work is to examine the microbiological quality of groundwater intended for consumption around Lake Toho while identifying the risks of contamination associated with it. To do this, nineteen (19) water samples, i.e. five wells and fourteen boreholes, were analyzed by the seeding method. Also, we carried out a field survey which focused on nine villages in the three districts (Houin, Zoungbonou and Lokossa) located near the lake. The villages are chosen taking into account the degree of vulnerability of the populations, according to human activities (agriculture, market gardening and fishing) and proximity to the watercourse. The results obtained showed that all the waters analyzed were contaminated by common germs. 37% of the water revealed contamination with E. coli, 26% with shigella. These results show recent faecal contamination of water. Similarly, more than half of the water, or 53%, showed non-compliance with respect to total coliforms, which would indicate old faecal contamination. The germs present in the waters degrade the quality of the water and thus expose the population that consumes it to several waterborne diseases. Drinking water must be free of any presence of these germs in general according to the recommendations of the WHO and the standard of drinking water in Benin, the water analyzed would all be unfit for human consumption. Adequate treatment and regular monitoring must be applied to guarantee the good health of the populations.

Keywords: Groundwater, microbiological, contamination, compliance.

Introduction

Water is an essential resource, indispensable in the life not only of humans, but also of animals and plants[1,2]. It can also become a source of disease through its pollution by industrial waste, wastewater discharges, agricultural or household waste, excreta and various organic waste[3-5]. The quality of water thus has the power to maintain or deteriorate the state of health in both humans and animals[6]. Groundwater, which represents approximately 97% of total liquid continental freshwater[7], is best exploited for the supply of drinking water (AEP). In Benin, they are taken either directly from a personal well, or from a borehole at home, or by the boreholes of SONEB (National Water Company of Benin).

As in some regions, population growth has allowed the occupation of sites lacking sanitation, hygiene and especially health and social infrastructure as well as a drinking water supply network[8].

The populations living around Lake Toho in Benin have large-diameter wells, boreholes and numerous water supply networks, but no sanitation infrastructure (wastewater disposal structures) or system of waste collection and management. Although the DWS structures provide the advantage of solving the problem of water availability, that of better quality is called into question.

Several studies have been conducted on the water quality of Lake Toho, specifying its different physico-chemical states. Thus[9] in 2018, after his work on the inventory of water resources management of Lake Toho in Athiémé in 2018, showed that Lake Toho is polluted by nitrogen compounds ($N\text{-}NO_3^-$, $N\text{-}NH_3$), phosphorus and organic matter. Pollution is accentuated by animal waste and human defecation. A contamination of these waters was revealed in 2021 by lead and cadmium[10]. However, none of his work studied the quality of groundwater serving as the basis for all the activities carried out and the uses of water.

In Benin, there are pollution problems related to poor management practices of water bodies in general and lakes in the southwestern part in particular, especially Lake Toho. Indeed, because of its proximity to the populations, Lake Toho receives almost all the waste resulting from domestic and agricultural anthropogenic activities. This state of affairs contributes to enriching the aquatic environment with pollutants potentially dangerous to public health[11]. The massive fish kills in May 2018 and August 2021 are an illustration of the degradation of the waters of Lake Toho. Thus, we carried out a field survey which focused on nine villages in three districts (Houin, Zoungbonou and Lokossa) located near the lake.

The objective of this study was to assess the bacterial contamination of water from wells and boreholes supplying the populations living around Lake Toho in the South-West of Benin in order to identify the origins and the health risks to which they are exposed.

Materials and methods

Study site: Lake Toho is a lake in southwestern Benin, located near the localities of Houin, Kpinnou and Zoungbonou. It has the shape of a crescent oriented south-north. It extends over 9.6 km^2 at low water and $15km^2$ during flood periods with an average depth of 2.1m [12]. It is surrounded by three different districts of three different communes, namely: Kpinnou in the commune of Athiémé, Zoungbonou in the commune of Houéyogbé and Houin in the commune of Lokossa (Figure-1).

Sampling: Investigation: A field survey was carried out on nine villages in the three districts (Houin, Zoungbonou and Lokossa) located near the lake and the counting was done with the SPHINX software. The villages are chosen taking into account the degree of vulnerability of the populations, according to human activities (agriculture, market gardening and fishing) and proximity to the watercourse. The sample size was determined following the method of Schwartz. It was calculated with a degree of confidence of 95% and a margin of error of plus or minus 5%. A sampling rate of 30% was applied to the result to determine the exact number of households to interview per village.

Sample collection: The present work having for mission to evaluate the bacteriological quality of groundwater around the lake, the samples were taken at the level of the AEP works of the three districts. The sampling was carried out in February 2022 and took into account nineteen (19) DWS works, i.e. five (05) wells and fourteen (14) boreholes; which are grouped in Table-1. A map showing the water points withdrawn is presented in Figure-2.

The sampling and transport equipment consists of sterile 500 mL bottles to contain each sample, a cooler equipped with cooling elements and a burner to sterilize the taps before sampling. The bucket at each well is used for sampling. The samples were kept at a temperature of 4°C until the laboratory where analyzes were immediately carried out.

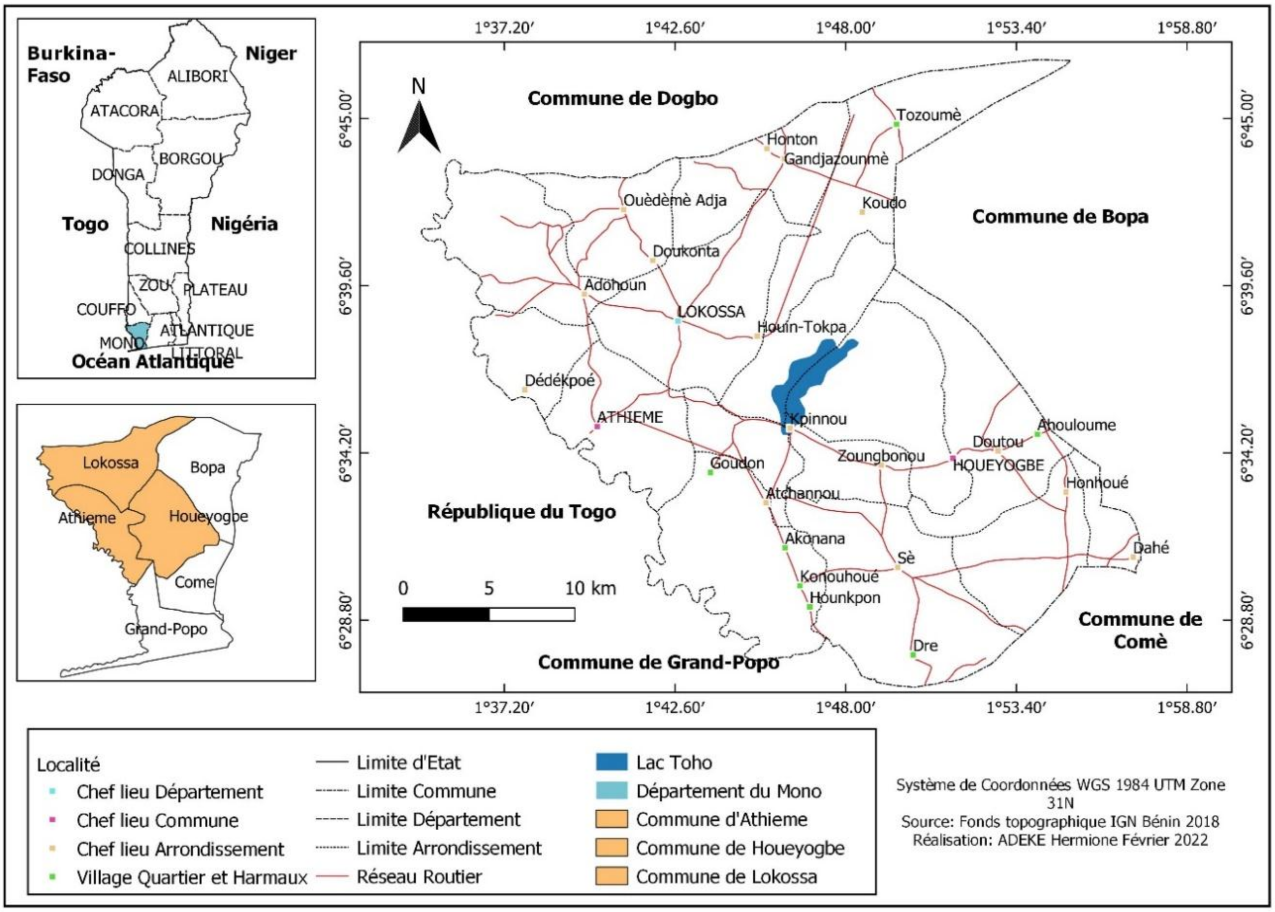

Figure-1: Lake Toho location map.

Table-1: Water sampling sites in municipalities.

Site Num	Borough	Location	Type of work	Geographical coordinates	
				Latitude	Longitude
1	Kpinnou	Kpocondji Yosso	Forage	06°35'10,453"	1°46'70,101"
2		Hahame	Well	06°35'26,405"	1°45'26,842"
3		Itehoue	Forage	06°35'26,405"	1°45'26,842"
4		Kponou Douvo	Forage	06°36'36,676"	1°45'16,836"
5	Houin	Wankanmin	Forage	06°37'57,350"	1°45'13,153"
6		Veha	Forage	06°39'50,196"	1°46'58,743"
7		Logbo	Forage	06°37'70,654"	1°45'55,464"

8	Kpinnou	Itehoue	Well	06°35'36,987"	1°45'31,084"
9		Condji Agname	Well	06°35'20,797"	1°44'36,109"
10		Condji Agname	Well	06°35'30,462"	1°44'31,258"
11		Goudon	Forage	06°33'49,584"	1°43'50,806"
12		Bota	Forage	06°34'25,016"	1°45'12,381"
13		Agbodougbe	Forage	06°3Z4'11,629"	1°46'30,098"
14		Don-Kondji	Forage	06°34'30,153"	1°45'42,014"
15		Azonlihoue	Well	06°35'11,569"	1°45'26,060"
16	Zoungbo-Nou	Hounkpotannou	Forage	06°35'54,146"	1°47'10,874"
17		Dadahoue	Forage	06°36'23,501"	1°47'44,105"
18		Tohonou	Forage	06°37'11,802"	1°47'26,332"
19		Goudohoue	Forage	06°36'52,677"	1°47'21,705"

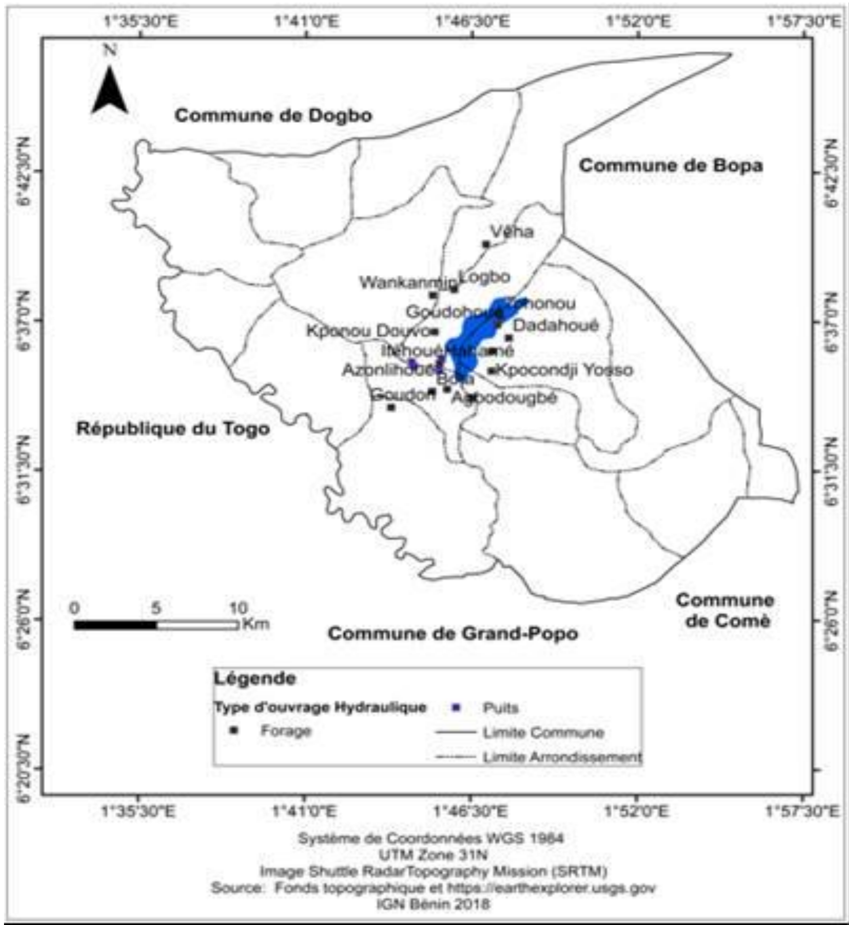

Figure-2: Distribution map of AEP points.

Analysis and processing of samples: In the laboratory, different germs were searched for in these waters from different culture media, which are listed in Table-2.

Table-2: Parameters sought and microbiological analysis methods.

Parameters	Standards	Reagents	Incubation temperature	Colony color
Total Coliforms	Inoculation	Chromogenic Coliform Agar	37	White
Escherichia Coli		Vbrg	37	Red Agar
Enterococcus faecalis		Slanetz and Bartley	44	Beige agar
Total Mesophilic Flora		Plate Count Agar	37	White
Shigella		Hectoen	44	Purple

Total coliforms: include various species of bacteria such as Citrobacter, Enterobacter, Klebsiella, Serratia and Escherichia[13], most of which pose no health risks. They are used as an indicator of water quality degradation due to the distribution system (biofilm formation, soil infiltration, surface water inflows)[14]. They indicate a lack of treatment efficacy, vulnerability to contamination or bacterial recolonization of the network. It is not necessarily linked to faecal contamination.

E. coli: they are genera of bacteria constituting total coliforms. They are of human and animal origin and indicate the potential presence of human enteric viruses[15,16]. They are not all offensive. The E. coli identified following bacteriological analyzes are mostly harmless strains. However, their presence in the waters indicates recent faecal contamination.

Mesophilic flora: technological indicator and provides no indication of the possible presence of pathogenic germs[17].

Shigella: these are very virulent enterobacteriaceae which cause an infection of the digestive tract with a few dozen germs. They mainly affect children aged 6 months to 5 years, caregivers, the elderly, pregnant women and immunocompromised subjects. This germ is encountered in regions of overcrowding, poor sanitation, lack of hygiene and unsanitary water[18].

Faecal enterococci: found most often in humans[19]. They are ubiquitous lactic acid bacteria frequently found in the microbial flora of the gastrointestinal tract of warm-blooded animals, as well as in a variety of food products. They are used either as antimicrobial agents or for the organoleptic properties of foods, and sometimes as probiotics. Their presence in the water testifies to contamination of faecal origin and the presence of enteropathogenic microorganisms. It is associated with the presence of E. coli in pipes[20]. Drinking water containing enterococci presents a risk of developing gastroenteritis and various nosocomial infections[21,22].

The culture medium dishes were incubated at the respective temperatures indicated in the table above. Shigella were searched for by introducing 1ml of the inoculum into 19ml of Hectoen prepared in test tubes. Incubation is done at 44°C for 24 or even 48 hours. The results were assessed against Beninese standards for water intended for human consumption and WHO guidelines. During sampling, the environment of the structures was assessed.

Results and discussion

Results of the surveys carried out: A total of 330 residents were questioned during this survey work, i.e. 282 men and 48 women. The files were analyzed and the results obtained are illustrated by the graphs.

Activities around the lake: 98.2% of respondents say that the main activity around Lake Toho is agriculture. In the dry season, the population says that they only use lake water but that in the rainy season, they use other sources such as created backwaters, wells and streams.

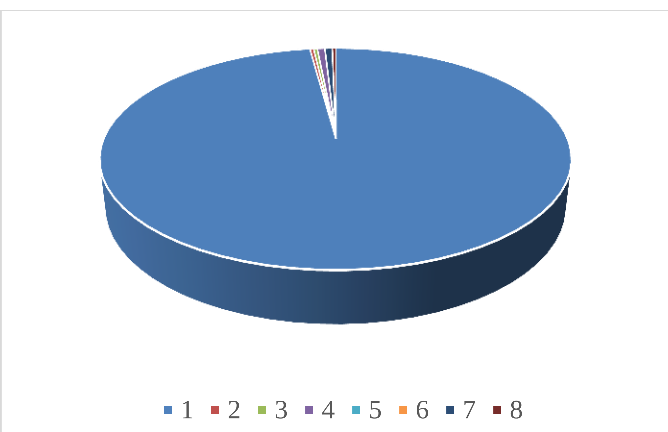

Figure-3: Different activities carried out by the local population.

Waste management around the lake: More than half of the population (89.1%) does not have bins for the management of household waste. Some dump them directly on the ground on wild dumps or shallows and others in the yard during the rain which evacuate them towards the lake. Only 5.2% say they have trash cans in their homes.

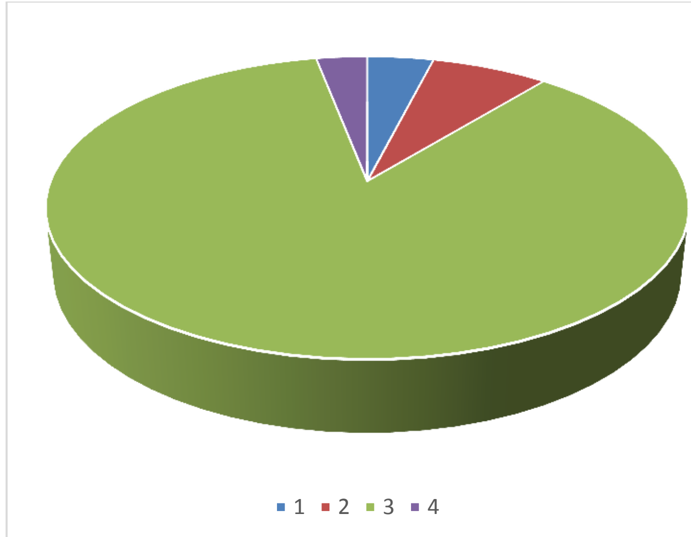

Figure-4: Methods of household waste disposal.

Origin of pollution according to local residents: People surveyed recognize that the origin of pollution is linked to the proximity of households to the lake (84.7%) and also linked to the products used to amend the soil (11.1%). Most also recognize that the waste goes directly to the lake. They all testify to a change due to the pollution of the lake and also to the pollution of the soil due to the burial of solid waste that does not reach the lake.

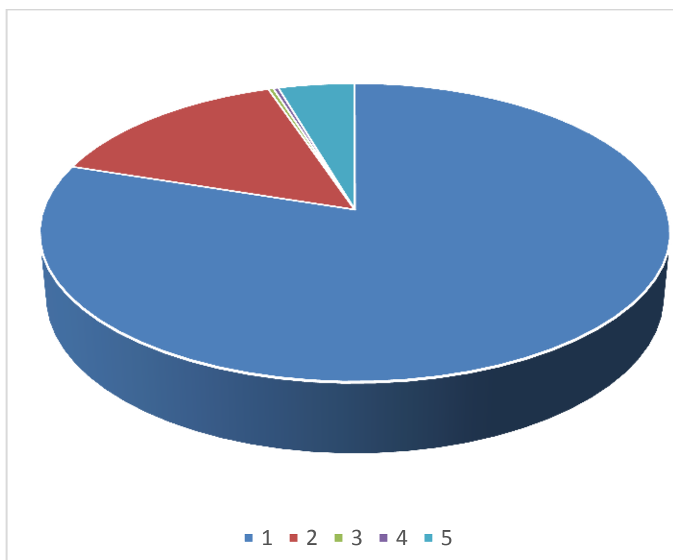

Figure-5: Origin of pollution according to local residents.

Insecticides and pesticides used by farmers: Several insecticides and herbicides are used for this activity and, depending on the time of year. They are represented by the figures Local residents recognize that their practices contaminate plants and soil.

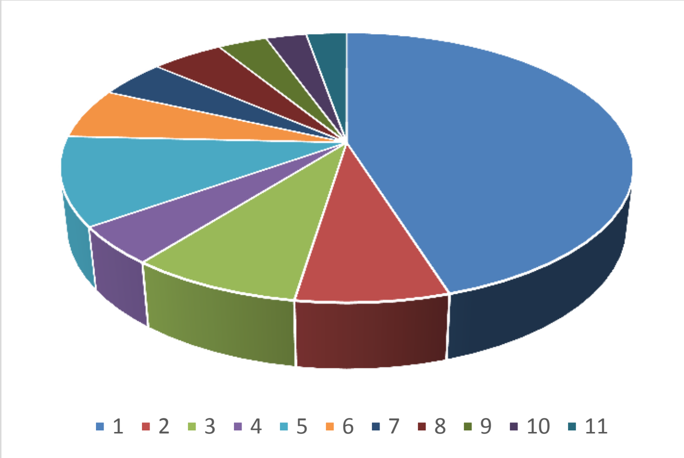

Figure-6: Different insecticides used by farmers.

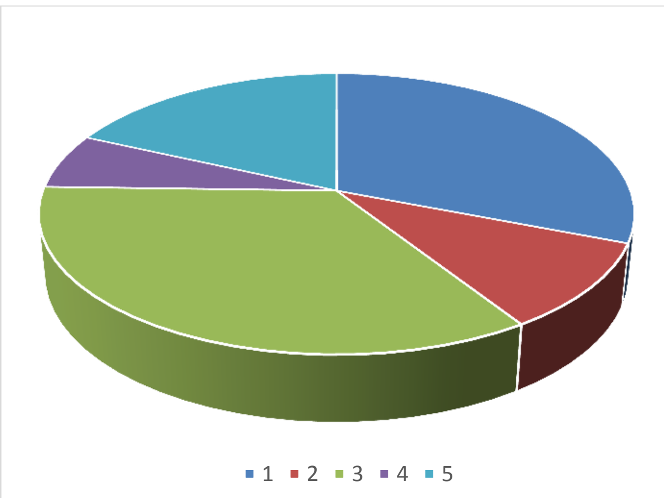

Figure-7: Different pesticides used by farmers

Direct field observations: The surroundings of the water supply structures (boreholes and wells) studied are poorly maintained. All wells are open pits. The microbes brought by the wind and the rain therefore have direct access to it. Some wells are surrounded by dumps. In contact with water, some waste could come into contact with the water table by infiltration or runoff towards another point where the water table is flusher. Water buckets are sometimes placed directly on the ground. A new use is synonymous with pollution, the introduction of microbes into these waters, which will only multiply.

In Dadahoué, the borehole used by the population is unfinished. It is an artesian, of average flow channeled by a PVC pipe with an uncontrolled flow, thus creating a flood all around. To take a sample, it is necessary to enter the water created, therefore, several germs will be transmitted there. The permanent presence of water could promote the migration of germs. Weeds grow around this point.

In Doncondji, the borehole serving the population is defective. The head of the borehole was removed and fittings were inserted into it. The water is sucked up by the sampler itself using a connection. This promotes the sharing of microbes orally (everyone sucks). In the absence of a sampler, the connector heads are placed in basins whose microbiological cleanliness is visibly mediocre because of its red internal color instead of its appearance. In the rainy season, this borehole overflows, the sample is taken with a bowl from each household with its germs. This testifies to a rapid recharge of the water table and therefore an inadequate filtration of microorganisms and also testifies to the shallow depth of the structure. Mouth aspiration and surface sampling are modes of water contamination: the sampler's hands and mouth contain microbes whose sources are unknown. The perimeter of the structure is a pool of water with greenish deposits that may constitute a source of microbes, surely in contact with the aquifer through potential infiltration.

In Agbodougbé, the drilling is defective and the supply is made through a pipe and a connection from which water flows at all times. It is surrounded not only by water but also by weeds, serving at times as dumps.
The rest of the boreholes are closed and converted into standpipes. No activity is carried out within a radius of 5 m.

Microbiological parameters: The samples taken were subjected to microbiological analyses.

Total coliforms, E. coli, mesophilic flora, shigella and faecal enterococci were detected in all samples.

The microbial loads recorded at the different sampling sites are presented in Table-3.

Table-4 groups the drinking water quality standards, the extreme values of the various bacteriological parameters accepted by Benin.

All the waters analyzed are contaminated by at least one germ of the germs sought.

Faecal enterococci are the only pathogens absent from groundwater around Lake Toho. It can be seen from this table that regardless of the type of microorganism involved, the levels of contamination in the groundwater samples around Lake Toho are high. The values of all these parameters are higher than the standard values for the quality of water intended for consumption in the Republic of Benin. i. The bacterial load of total coliforms varies from 0 at the Kponou Douvo, Condji Agnamé, Bota, Doncondji, Logbo and Tohonou sites to 30,000 at a well in Itéhoué for 100mL of sample. ii. The strains of E. Coli are absent at the Kpocondji Yosso, Kponou Douvo, Condji Agnamé, Goudon, Agbodougbé, Azonlihoué, Wankanmin, Vêha, Hounkpotannou, Dadahoué and Tohonou structures but vary from 0 to 500 per 100mL on the two (02) Hahamé wells and from Itéhoué, Bota, Don – Condji, Logbo and Goudohoué.

Table-3: Average bacterial loads in groundwater around Lake Toho.

Parameters	Total coliforms (/mL)	E. coli (/mL)	Total mesophilic flora (ordinary germs) (/mL)	Schigellae (/mL)	Faecal enterococci (/mL)
Kpocondji Yosso	100	0	30000	Presence	-
Hahamé	1300	200	30000		-
Itéhoué	30000	100	2000		-
Itéhoué	7700	500	15200		-
Kponou Douvo	0	0	1100	Presence	-
Condji Agnamé	0	0	200		-
Condji Agnamé	0	0	200		-
Goudon	0	0	30000		-
Bota	500	100	30000		-
Don-Kondji	0	200	19200		-
Agbodougbé	0	0	30000		-
Azonlihoué	500	0	30000	Presence	-
Wankanmin	200	0	30000		-
Vêha	0	0	30000		-
Logbo	0	400	13700	Presence	-
Hounkpotannou	700	0	300		-
Dadahoué	18500	0	100	Presence	-
Tohonou	0	0	100		-
Goudohoué	100	Presence	500		-

Table-4: Drinking water quality standard in Benin.

Parameters	Values	Units
Total coliforms	00	Number / 100 mL
Escherichia Coli		
Shigella		
Enterococcus faecalis		
Total mesophilic flora	50	Number / mL

Contrary to enterococci, all the waters analyzed were highly contaminated by the total mesophilic flora (TMF). The contamination of well water by FMT led to a total non-compliance.

Shigella colonies were observed in stocked environments containing water from the Kpocondji Yosso, Kponou Douvo, Azonlihoué, Logbo and Dadahoué sites.

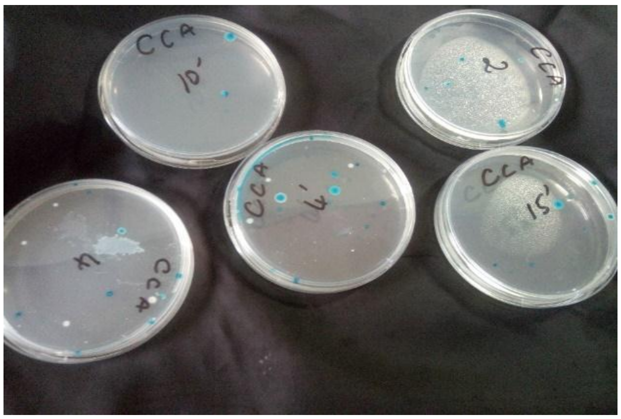

Figure-8: E. coli in green on CCA.

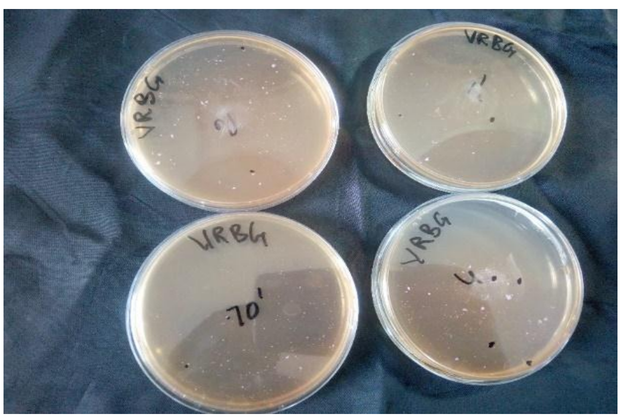

Figure-9: *E. coli* on VRBG.

Figure-10: Total Aerobic Mesophilic Flora (FMAT) in PCA medium.

Discussion: Our study focused on the bacteriological parameters of the 19 samples taken. These are contamination indicator germs such as total coliforms, E. coli, common germs, shigella and enterococci. The bacteriological parameters show a significant load of total coliforms in the waters. The loads obtained vary from 100 to 30,000 CFU/100mL instead of 0 CFU/100mL recommended by the WHO. High concentrations of total coliforms in groundwater have also been found in Meknes in Morocco[23].

The presence of Escherichia coli strains in the collected water samples indicates faecal contamination and the potential presence of ecologically similar pathogens. These strains were also observed in the groundwater studied in Abengourou in Côte d'Ivoire[24]. E. coli is a very abundant germ in the human and animal intestinal flora, the only one strictly of faecal[25]. It does not exist in the natural environment but can survive for a few months in water, soil or on plants, although it rarely multiplies in these environments[13,26] at unless high temperature conditions and the presence of nutrients allow[27].

The contamination of a water table is favored by its depth, the type of solid waste management, and the permeability or not of the soil and the method of drawing[25,28,29]. However, there are several main sources of groundwater contamination including septic tanks, wastewater discharges from factories and sewer systems[30]. Infants, young children and people with weak immune systems consuming these waters containing microorganisms are exposed to diseases such as diarrhea, nausea, cramps, headaches and many others[31]. The detection of these microbes in water should therefore be considered as reflecting the possible presence of pathogenic microorganisms of faecal or enteric origin[13].

The total mesophilic aerobic flora is significantly present in the samples in all the waters analyzed and varies from 100 to 30000 CFU/100mL. The WHO recommendation and Benin standard are 50 CFU/100mL. This value indicates a fairly high level of contamination. This may be due to water seepage from Lake Toho. Lakes are special ecosystems, very often very rich in living organisms. The development of these bacteria can create serious problems in distribution networks such as corrosion, chlorine consumption and the appearance of bad taste.

It is noted the presence of shigella in the waters of the sites of Kpocondji Yosso, Kponou Douvo, Azonlihoué, Logbo and Dadahoué; making the water unfit for human consumption. These are bacteria of human origin, very virulent, causing an infection of the digestive tract[18].

The analysis of the bacteriological results of the waters shows that most of the waters are contaminated and of anthropogenic origins (human and animal presence). All the other sites, i.e. 68% of the water analyzed, showed the presence of either total coliforms, Escherichia coli or even Shigella; all these bacteria testifying to the existence of faecal contamination. Their presence in the water confirms microbiological pollution, which is justified by the proximity of the populations of the lake, the poor management of waste, the infiltration of agricultural waste water into the groundwater, the existence of non-watertight latrines near the works of water supply, poor protection of catchment structures (open wells, poorly constructed boreholes, etc.)[32-35].

Conclusion

The evaluation of the bacteriological quality of groundwater captured and served by the DWS works (wells and boreholes) in the districts surrounding Lake Toho in the municipalities of Zoungbonou, Athiémé and Lokossa was the objective of this work. A total of nineteen (19) samples were collected and analyzed. High contamination by various bacteria (total coliforms, E. coli, shigella, and total mesophilic flora) have been identified in the waters. Except for the works of Condji Agnamé and that of Tohonou, which only shows a given quantity of mesophilic flora, all the other waters are excessively charged either in e. coli, either total coliforms or shigella. Some boreholes like that of Hahamé show contamination of three different parameters at the same time. These results reflect the poor quality of drinking water in the area due to the activities carried out in the area in general, the lack of sanitation in the region, poor hygiene practices in homes, among many others.

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