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Research Article

Environmental Risk Factors and Bacteriological Aspect of Drinking Water in Lake-Side Town of Sô-Ava in Benin

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Abstract: This study was made to comprehend the effects of human behaviour on bacteriological quality of drinking water consumed by the population of Sô-Ava and to identify the possible environment factors that deteriorate the quality of water. Thirty samples of water were collected in different ways, during rainy season and dry season for bacteriological examination. To identify the environmental factors, 165 couples were questioned. The results recorded showed that during dry season the amounts of germs were within WHO safety limits for each and every sampling station while during rainy season the results highly exceeded the safety limits. The isolation of germs like total coliforms, faecal coliforms, *Escherichia coli* and *Clostridium perfringens* revealed a faecal pollution. The presence of pathogens like *Staphylococcus*, *Salmonella* and *Shigella* in surface water constituted a threat for the groundwater. The factors responsible for these contaminations were many and were mainly related to hygienic condition and sanitation according to the opinion poll. The improvement of health for the population of So-Ava implies-in addition to improving the quality of water, hygiene and sanitation and appropriate environment management of the town.

Keywords: Environmental factors, germs, town of Sô-Ava, water

INTRODUCTION

The importance of water can never be overemphasized because it contributes to the good functioning and the balance of human physiology. However, the increase of its consumption is related to the growth of the world population (Odoulami, 2009). The availability of potable water is affected by lack of hygiene and sanitation of the environment (Clégbaza, 1999).

In Benin, till the 20th century, safe drinking water remains inaccessible for a large part of the population and exposes them to a lot of diseases (Akodogbo, 2004). The city of Sô-Ava is one of the cities in Benin where there is high birth rate (INSAE-RGPH 3, 2002). There are only water sources in good condition (Kinsiclounon, 2009) for a population of about 90,000 inhabitants (INSAE-RGPH 3, 2002). Therefore, there is only one tap for 7,500 people. And this causes a great human concentration around the tap with the risk of contamination (Akyo, 2005). The residents are therefore exposed to different sorts ofwater-borne diseases. In fact, in the towns of Sô-Ava, infectious and parasitic diseases continue to creep up according to health statistics. These diseases are the main causes for morbidity and mortality especially for infant mortality (INSAE-RGPH 3, 2002). The main factors are mainly lack of hygiene and cleanliness of the environment (Vilagnes, 2000; Kinsiclounon, 2009).

The main problem of drinking water at Sô-Ava is related to the environment. The geographical location of the area (Fig. 1), the way of life of its inhabitants (Fig. 2) and the periodic invading of water hyacinth (Fig. 3) cause a major problem of hygiene and sanitation for the population (Akyo, 2006). In addition, this is worsened by periodic flooding of the area and runoff water full of agricultural waste from the northern part of the country (Kaki, 2011). These are factors

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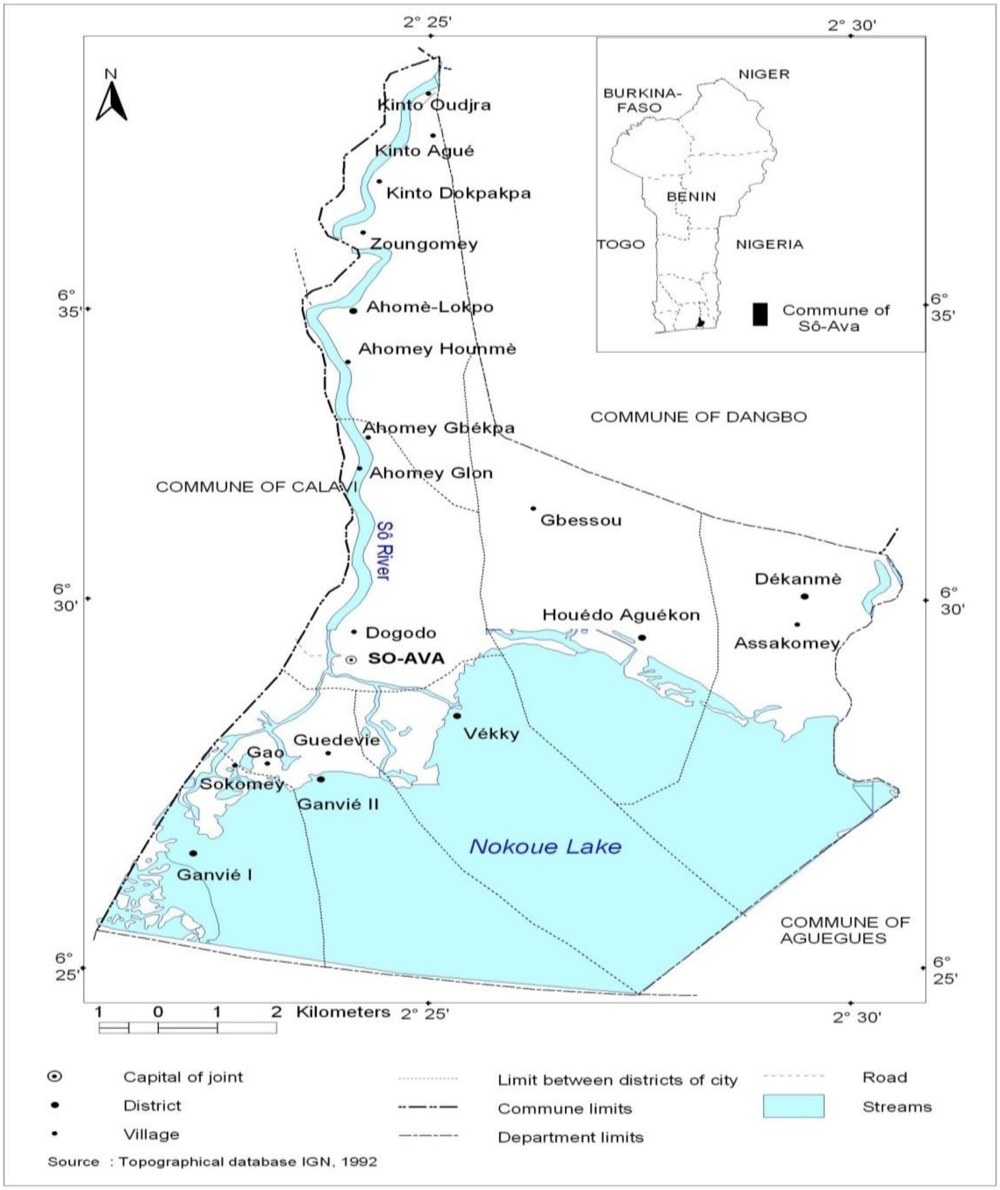


Fig. 1: Geographical location of the commune Sô-Ava

Fig. 2: One of the villages of Sô-Ava on water (INSAE-RGPH 3, 2002)

Fig. 3: Water hyacinths clogging the lake during wet period (Kinsiclounon, 2009)

among many that deteriorate the quality of drinking water (Edorh *et al*., 2007).

Lack of hygiene around the tap and wrong management of waste are the main sources of contamination, added to bacterial pollution of drinking water (Hazoumè, 2003). Degbey (2003) has shown that drinking water in the town of Abomey-Calavi situated in the west of Sô-Ava is contaminated by coliforms, Escherichia coli, faecal *Streptococcus*, *Salmonella* and *Shigella*, *Clostridium* and *Staphylococcus*. Dovonou (2008) has equally proven that water from well situated in the coast of Cotonou, a city in the south of Sô-Ava is contaminated by coliforms and faecal *streptococcus*. According to this author, factors that cause this pollution are of different origins.

N'Fally (1997) has shown that lack of water in the area of Sô-ava makes the inhabitants drink water of bad quality which is the source of different kinds of diseases like diarrhoea, cholera, typhoid fever, guinea worm, schistosomiasis etc.

Regarding this situation, it is important to know the level of bacterial contamination of drinking water consumed by the inhabitants of Sô-Ava and to identify the factors that contribute to this contamination.

MATERIALS AND METHODS

Materials used for study: The town of Sô-Ava is located in the south-east of Benin in west Africa. It occupies a part of the valley of Oueme river, Nokoue lake and Sô river from where the name is derived (Fig. 1). The morphological map of the town of Sô-Ava shows many parts-namely alluvial plain, shallow, terraces, surface water and depressions. These inhabitants came to refuge in the middle of the lake since 17^{th} century because of tribal war. They made their houses on piles for the sake of security (Fig. 2). They then became fishermen (INSAE-RGPH 3, 2002). When there are floods, the lake is covered by water hyacinths (Fig. 3).

Methods:

Water sampling: The sampling was carried out in July-August and in November-December 2009, months which are rainy and dry season, respectively. Water was collected with small bottles of 250 mL. These bottles have stoppers made of polystyrene to which a thread is attached to be able to remove the stopper (a knot is made to make at each meter to assess the depth of immersion) especially in the case of boreholes where this operation is very hard. The bottle is removed when it is full. Moreover, the technique of sampling water from boreholes was used by Di Benedetto *et al*. (1997). It consists:

- leaving the water to run for 10 min before sampling
- Continuing the sampling of water (rinsing the bottle three times using the water to be sampled) until the bottle is full

For the surface water, the sampling was carried out in a representative way according to the technique of Di Benedetto *et al*. (1997). The technique enables one to collect water samples very close to sources of pollution: on the surface, in the middle and in-depth of Nokoue Lake, of the river and of marshes.

However, it is important to stress that the different water samples were collected alongside with the geographical coordinates of the sampling stations of the study area.

In total, 30 samples of water were analyzed: 10 from tap, 10 from boreholes, 5 from boreholes of DGH and 5 of surface water (Fig. 1). This sampling was carried out during rainy and dry season. Once the bottles were full, they were cleaned and wrapped with aluminium paper to avoid the penetration of light which can cause alteration in some physical and chemical parameters of water such ammonium and nitrates. They were labelled and kept in a cool place at 4°C in a cooler containing some ice for laboratory analysis.

Laboratory analysis: The operation was done by filtering 10 to 100 mL of water samples that was already diluted using cellulosic membrane. All the bacteria in the sample were retained on the surface of the membrane; they were then put to culture using agar-agar as nutrient. The identification of the bacteria was carried out after 48 h of incubation at 37°C (Dovonou, 2008). The solid media used for culture were:

- Methylene blue eosin for determination of *Escherichia coli*
- Trypcase-Sulfit-Neomycin for *Clostridium perfringens*
- Slanetz agar-agar to isolate *streptococcus*

The enumeration of micro-organisms was carried out by counting the colonies.

To appreciate the origin of this bacteriological pollution of the samples, the enumeration of:

- Total coliforms
- faecal coliform
- *Escherichia coli* that indicates recent faecal pollution
- *Clostridium perfringens*, an indicator of old faecal pollution
- Faecal *streptococcus* was carried out in water samples

Besides, the ratio between Escherichia coli/faecal *streptococcus* was calculated.

If the ratio is more than 4, the faecal contamination comes from human waste. If it is less than 1, the contamination comes from animal waste (Baba-Moussa, 1994). Some pathogenic germs like *Staphylococcus*, *Salmonella* and *Shigella* were searched for in this water.

Survey method for identification of polluting factors: The survey was also carried out in July-August and November-December 2008 months which correspond to the rainy season and dry season respectively throughout commune and allowed us to do

Table 1: Environmental factors

Factors	Description
Factor 1	Disposal of domestic wastes, effluents and excretas in Nokoué lake, Sô river and swamps
Factor 2	Burial of human bodies in floodable and superficial graves
Factor 3	Disposal of animal dead bodies n Nokoué lake, Sô river and swamps
Factor 4	Disposal of ashes resulting from of wastes burning n Nokoué lake, Sô river and swamps
Factor 5	Disposal of effluents in Nokoué lake, Sô river and swamps
Factor 6	Organic pollution due to the invasion of vegetable debris from traditional method known as Acadjas
Factor 7	Pollution caused by water hyacinths clogging
Factor 8	Pollution caused by the runoff of fertilizers and pesticides from the north to the south during wet season

analytical study on different exogenous factors that contribute to the contamination of drinking water. The data collection, survey of the land, unrestricted observation and laboratory analysis allowed us to evaluate the bacteriological pollution of well water and boreholes of the commune and to identify the possible risk related to its consumption. One hundred and sixty five households over 14594 of the commune (INSAE-RGPH3, 2002), i.e., 1.13% of households were questioned. The questionnaire was related to water supply, the drainage of waste water, faecal and domestic waste, method of burying human dead bodies, evacuation of dead animals, environmental management after fire setting, release of untreated effluents into Sô river, the saturation of Nokoué lake with fish pond, invasion of the lake by water hyacinthss and transportation of agricultural input by leaching from north of the country during flood (increase of the water level in the lake.

Bacteriological analysis data: The comparison of the bacteriological data was carried out considering of the two periods separately. The average amounts of bacteria of different sampling stations were compared among them by Kruskal Wallis test followed by Turkey-Kramer multiple comparison test modified by Dunnett (1980). The average amount of bacteria was compared regarding the safety limits (MSP, 2001) for all the sampling stations and each water source by student test if the data followed a normal distribution and by the test of Wilcoxom test on the contrary. The comparison of the amount of bacteria during the two periods was done for the whole of the sampling stations and also for each and every sampling station individually. The test t was used for grouped test data if the terms of normality were not respected. In the opposite, it is the alternative of Mann-Whitney test that was used

Analysis of environmental data: In order to analyze the environmental data, eight factors were considered (Table 1). The perception of the possible polluting causes/factors of the lake in the study area was gathered from 165 questioned households. For each factor, they can answer with “Yes” or “No” according to what they think whether the factors contribute or not to environmental pollution and therefore to the contamination of drinking water.

Table 2: Degree of agreement and value of kappa proposed by Landis and Koch (1997)

Accord	Kappa
Excellent	0.81
Good	0.80-0.61
Moderate	0.60-0.21
Bad	0.20-0.00
Very bad	<0.00

The classification of the different factors was done according to the answers recorded during opinion poll. The Kappa de Fleiss test of Similarity allowed us to appreciate the degree of similarity between the results recorded from the survey. Normally, we included the calculation of Kappa K coefficient with its p degree of significance in order to interpret the result with certainty. In order to test the null hypothesis HO “independent of opinion” (whereas K = O) versus the alternative hypothesis H1 (K>O). Actually, the K coefficient is a real number, without dimension, ranging between -1 and +1. The agreement will be higher than the value of K, that is close to +1 and the maximum agreement is reached if K = 1 (Table 2). When there is independent of opinion, the K coefficient is zero and in case of total disagreement among opinion, the K coefficient is -1. The IRR package of R software (http: //www. r. project. org) was used to get the Kappa de Fleiss test of similarity.

RESULTS

Results of bacteriological analysis of water:

Total coliforms: The average amount of germs varies significantly from one sampling station to another and from one period to another (Fig. 4).

During the rainy season (July), the average amounts of total germs varied significantly from one water source to another. The same tendency was observed during dry season (December). During these two seasons, a significant increase of total amount of germs was noticed with all the sampling stations (W = 599.05 p = 0.0000) (Fig. 4c)

Concerning the safety values (Table 3), during the period of water receding, only the water from SONEB tap (running water) showed an amount of germs lower than the safety values.

***Escherichia coli*:** The average amount of *Escherichia coli* varied according to water sources and periods to another (Fig. 5). According to statistical tests, the

Table 3: Comparison of the amount of germs in water with the permissive limits (yes = below the permissive limits and no = above the permissive limit)

		Sampling stations					
Isolated germs	Season	Tap water	Stored water	D G H	Private drillings	Surface water	All sampling stations
Total germs	Wet season	Yes	Yes	Yes	Yes	No	Yes
	Dry season	Yes	No	No	No	No	No
Escherichia coli	Wet season	Yes	Yes	Yes	Yes	No	Yes
	Dry season	Yes	No	No	No	No	No
Faecal *streptococcus*	Wet season	Yes	No	Yes	Yes	No	Yes
	Dry season	Yes	No	No	No	No	No
Clostridium perfringens	Wet season	Yes	Yes	Yes	Yes	No	Yes
	Dry season	Yes	Yes	No	Yes	No	No
Staphylococcus	Wet season	Yes	Yes	Yes	Yes	No	Yes
	Dry season	Yes	Yes	No	Yes	No	Yes
Salmonella and *Shigella*	Wet season	Yes	Yes	Yes	Yes	No	Yes
	Dry season	Yes	Yes	Yes	Yes	No	Yes

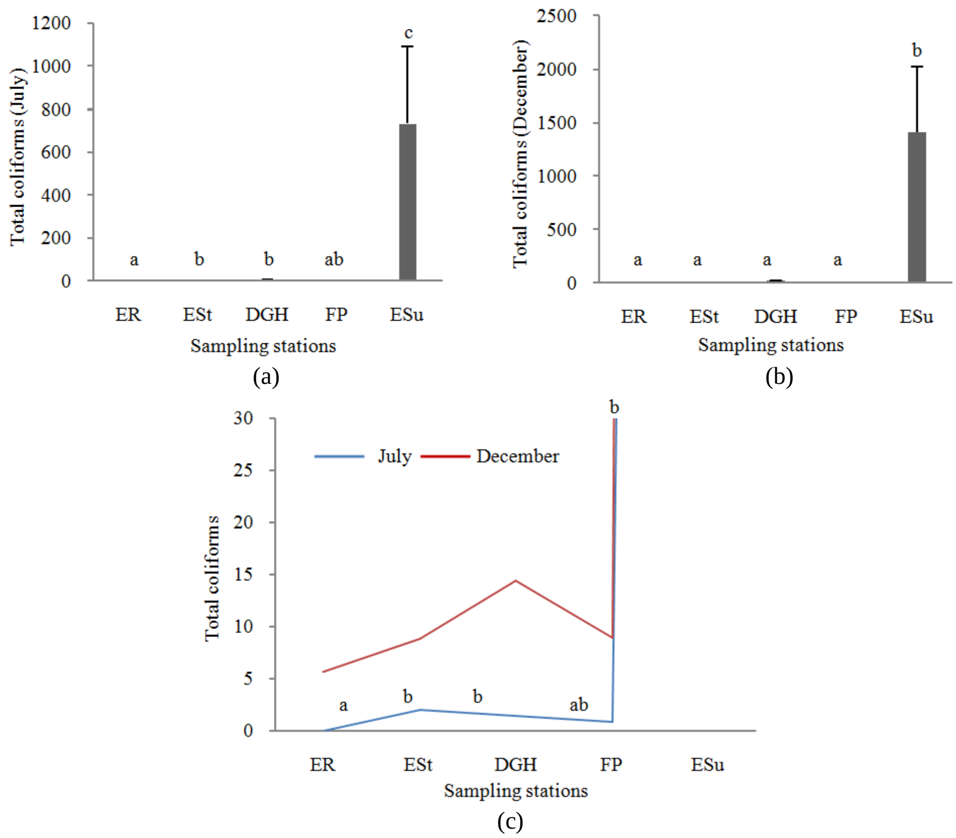
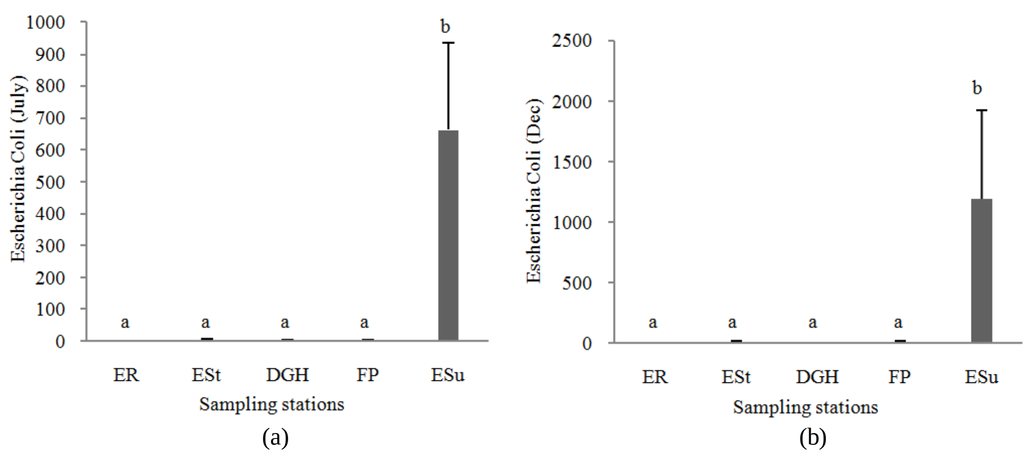
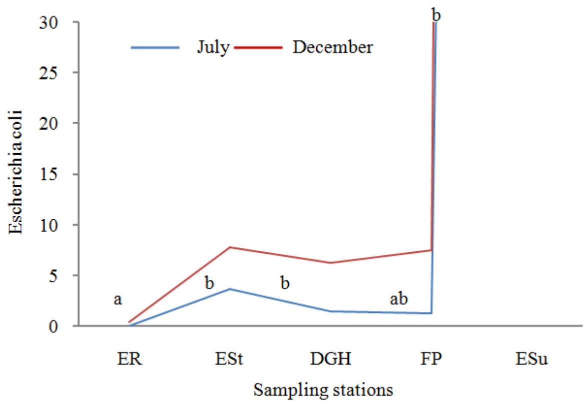


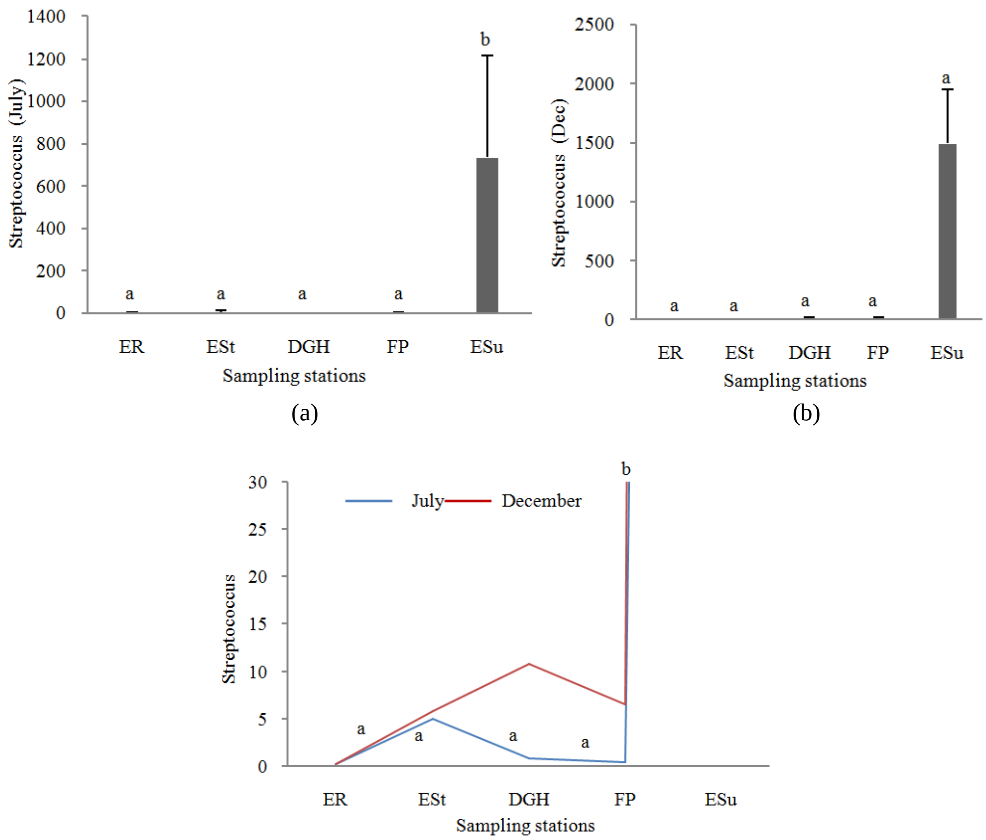
Fig. 4: Amount of total germs (in 100 mL) of water according to periods and sampling stations





(c)

Fig. 5: Amount of *Escherichia coli* (in 100 mL) in water according to periods and sampling stations



(c)

Fig. 6: Amount of faecal *Streptococcus* (in 100 mL) of water by periods and sampling stations

variations were significant from one sampling station to another (Krus kal-Wallis Chi-square = 18.34; p-value = 0.0010)

During the flood in November, the same variation of the amount of *Escherichia coli* was noticed between sampling stations (Krus Kal-Wallis Chi-square = 17.9; p-value = 0.0012).

Between these two periods, a significant difference is observed regarding all the sampling stations (W = 770.5; p = 0.0333).

The comparison of the amount of *E. coli* and the permissive values revealed the same trend as in the case of total coliforms. However, during dry season, only tap water exhibited content in *E. coli* below the safety value (Table 3).

Faecal *streptococcus*: The content in faecal *streptococcus* varied according to sampling stations and seasons (Fig. 6). During both receding and flood

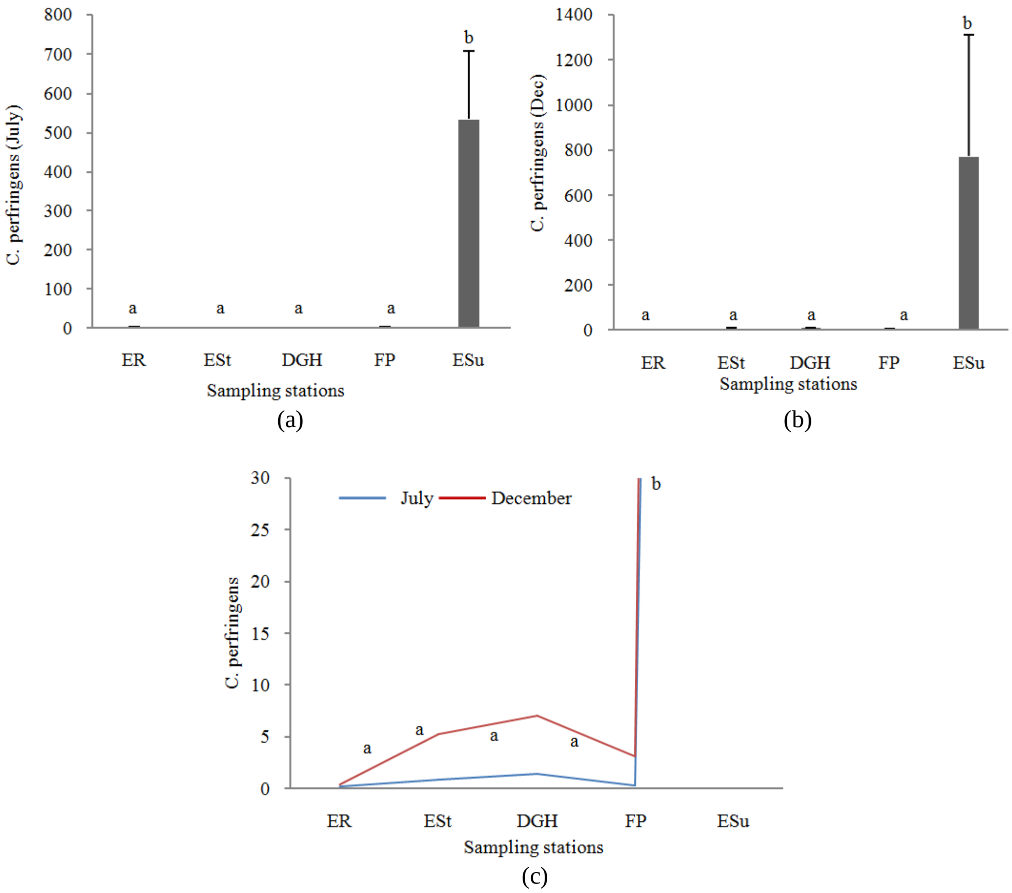


Fig. 7: Amount of *Clostridium perfringens* (in 100 mL) of water according to periods and sampling stations

periods, this variation was significant among the sampling stations (Krus Kal-Wallis Chi-squared = 20.1, p-value = 0.00046 for receding period and Chi-square = 19.3, p-value = 0.0006 for wet period). Moreover, a significant difference is observed between these two periods for all the sampling stations (N = 762.0; p = 0.0242) and private boreholes in terms of content in *E. coli*.

Considering the permissive values, for the dry season, the content in *E. coli* exceeded the safety value for stored and surface waters. But in wet season, only tap water exhibited *E. coli* amount lower than the permissive value.

***Clostridium perfringens*:** In respect of *C. perfringens*, the overall mean values recorded were of 89.4 during dry season and 131.4 during flooded period and varied significantly from one sampling station to another (Chi-carre de Kruskal-Wallis = 19.87, p-value = 0.00053 for dry season and Chi-carre de Kruskal-Wallis = 19.82, df = 4, p-value = 0.00054 for wet season). Also, a significant increase of the amount of *C. perfringes* (W = 736.5; Prob = 0.0085) was reported for all sampling stations and private boreholes. During flooded period, the amounts of *C. perfringens* were above the permissive limits for all the sampling stations (Fig. 7).

***Staphylococcus*:** The amount of *Staphylococcus* varied according to sampling stations (Chi-carre de Kruskal-Wallis = 21.190, Prob = 0.00029). It also varied according to sampling stations during receding period of water (Chi-carre de Kruskal-Wallis = 20.8902, Prob = 0.00033). But during rainy season, the difference was not significant for tap and surface waters. The comparison of the amount of *Staphylococcus* between the two periods showed significant differences for all the sampling stations (Fig. 8).

***Salmonella* and *shigella*:** During wet period, the overall mean amounts of *Salmonella* and *Shigella* were of 24.6 and varied from one water sampling station to another (p-value = 0.00000). There was no *Salmonella* and *Shigella* in tap water, stored water, at the management body and private boreholes (Fig. 9). Only surface water showed high amounts of *Salmonella* and *Shigella* with a mean value of 147.4. However, during flood, the amounts of *Salmonella* and *Shigella* varied

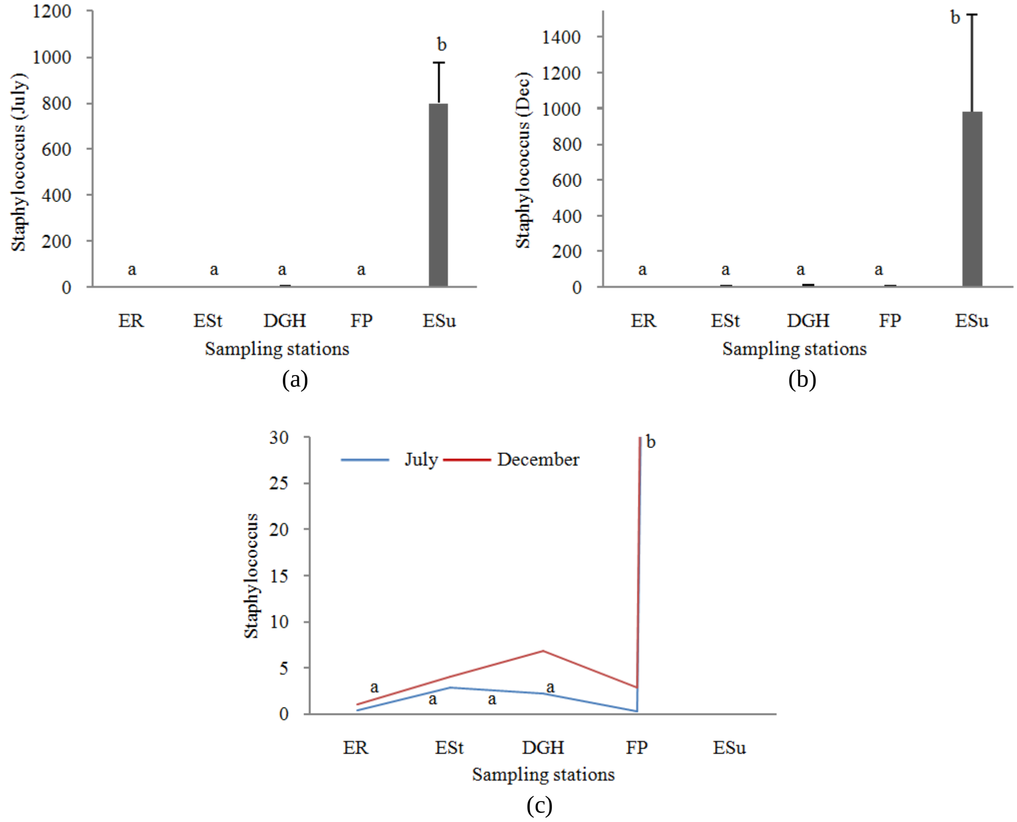


Fig. 8: Amount of *Staphylococcus* (in 100 mL) of water according to periods and sampling stations

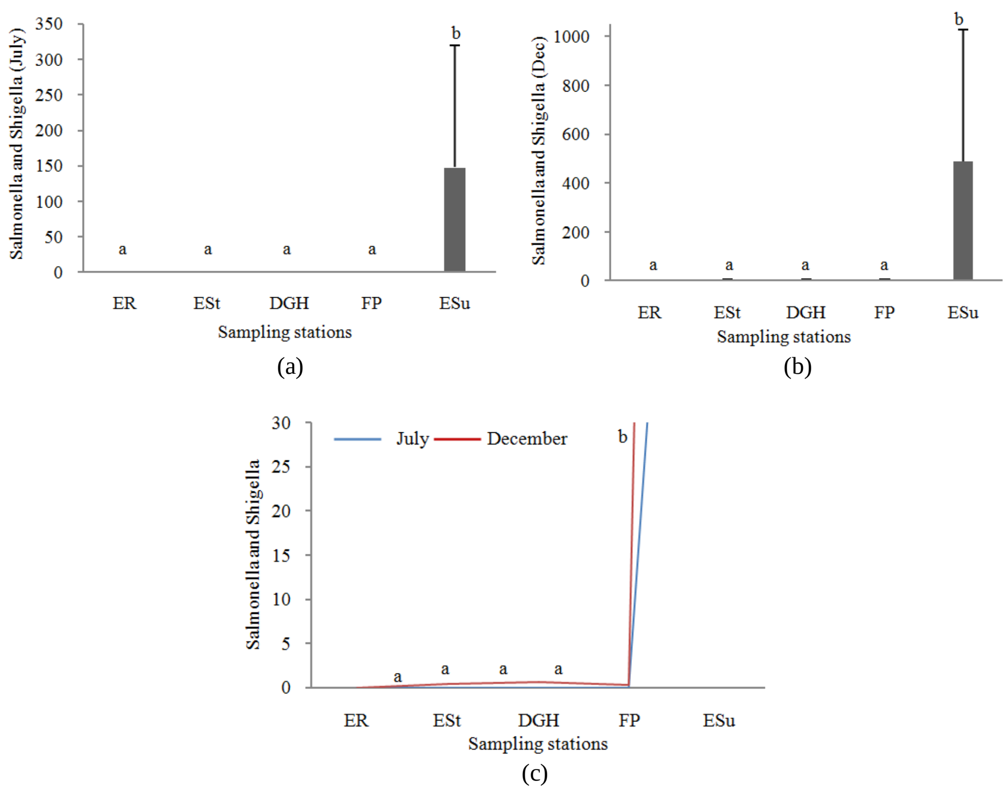


Fig. 9: Amount of *Salmonella* and *Shigella* (in 100 mL) of water according to periods and sampling stations

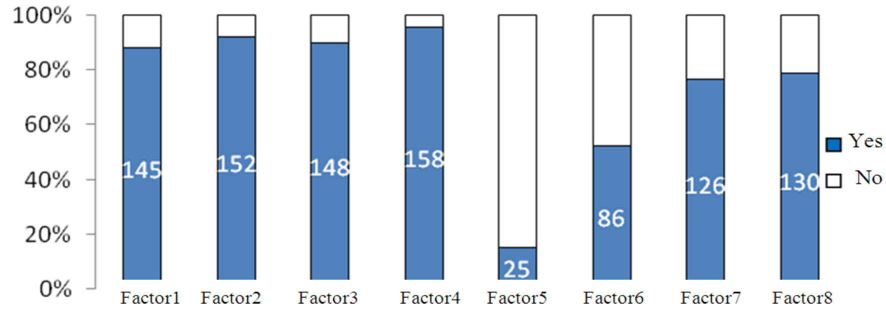


Fig. 10: Environmental factors

according to sampling stations (Chi-carre de Kruskal-Wallis = 17.07, Prob = 0.0018). In the tap water, stored water, management body and private boreholes, the amount of *Salmonella* and *Shigella* rarely exceeded permissive levels. But with surface water, the content in *Salmonella* and *Shigella* largely exceeded the permissive values with a mean value of 490.

No significant difference was observed among sampling stations in terms of comparison of *Salmonella* and *Shigella* contents according to periods (W = 822.0 Prob = 0.1715).

Result of the survey: Figure 10 shows the importance of factors likely to be the cause of environmental pollution in study zone:

Factor 1: Disposal of domestic wastes, effluents and excretas in Nokoué lake, Sô river and swamps

Factor 2: Burial of human bodies in floodable and superficial graves

Factor 3: Disposal of animal dead bodies n Nokoué lake, Sô river and swamps

Factor 4: Disposal of ashes resulting from of wastes burning n Nokoué lake, Sô river and swamps

Factor 5: Disposal of effluents in Nokoué lake, Sô river and swamps

Factor 6: Organic pollution due to the invasion of vegetable debris from traditional method known as Acadjas

Factor 7: Pollution caused by Water hyacinths clogging

Factor 8: Pollution caused by the runoff of fertilizers and pesticides from the north to the south during wet season.

The analysis of Fig. 10 revealed that the top factor seen by the local population as the cause of environmental pollution was factor 4 that is “Disposal of ashes resulting from of wastes burning n Nokoué lake, Sô river and swamps”. It was followed by factor $N^0$2, then factor 3 and 1. The factor seen by the local population to have little effect on environmental pollution was factor 5 that represents << the release of effluents into Sô-River>>. The K Kappa de Fleiss coefficient ranged from -0.049 to 0.0007 at 5%. There was a concordance among the opinion poll carriers concerning the choice of factors.

However, the degree of similarity in the perception was very weak since was K>0.

DISCUSSION

Discussion relating to bacteriological results: Between these two periods, it was observed that there was significant increase of germs. During dry period, the amounts of microorganisms were within the permissive limits for all sampling stations except surface water that displayed higher amounts of microorganisms. During rainy season, apart from tap water whose content in microorganisms was below safety values, all the other sampling stations recorded mean values of germs exceeding safety values. This could be due to the fact that during rainy season, there is a release of bacteria into Nokoué Lake. Actually, the runoff waters from the North of Benin are full of germs and are drained into Sô River and Nokoué Lake. The cyclic phenomenon of rise in water level causes flooding of houses, massive death of animals, defecation into water, proliferation of insects and invasion of water hyacinth etc. All these interconnected events could explain the increase in the amount of germs in all the sampling stations recorded in this study during rainy season. Our results are similar to those of Dovonou (2008). According to that author, most of the sewage activities from the city of Cotonou is found on the bank of Nokoué lake. And during the rainy season, the dump is carried by runoff water and a large amount of the waste is channelled towards the lake. Our observations are in concordance with that of Akiyo (2005) at Sô-Ava. This latter reveals that 90% of housekeepers throw their domestic wastes into the nature in the central department of this town. This suggests that the population that consumes the water is exposed to the risk of water-born diseases (*Salmonella* disease, *shigella* disease, cholera etc.). These observations reported by Guedenon (2009) supports our results. According to him, the demographic increase and industrial development in cities like Cotonou are the principal causes of chemical, organic and toxicological pollution of Nokoué Lake in Benin. According to Djafarou (2004), the groundwater is exempt from pathogenic germs, but that the lack of hygiene around the sampling stations and the mismanagement of wastes could lead to a possible bacteriological contamination of water that the population unfortunately consumes. Degbey (2003) remarked that all the wells of Abomey-Calavi (town situated at the west of Sô-Ava) are bacteriologically contaminated with coliforms, *Escherichia coli*, *Streptococcus faecal*, *Salmonelles*, *shigelles*, *Clostridium* and *Staphylococcus*.

Discussion relating to polluting factors: The polluting factors perceived by the population of Sô-Ava as contributing to the deterioration of the physico-chemical and bacteriological quality of drinking water concord with the results of Kinsilounon (2009) and Akyo (2006) who reported that the geographical location of Sô-Ava (Fig. 1, 2 and 3) and the nature of the soil (Azontondé, 1991) makes the population evacuate the domestic wastes, sewage dead animals and excreta in open air. This adds to the problems of hygiene and cleanliness around the sampling stations. This investigated perception of the population confirms the results of N'Fally (1997). According to the latter, many substances contribute to the pollution of Sô River and Nokoué lake such as faecal matters, domestic wastes, sewage, pesticides and heavy metals (Dovonou, 2008). Actually, rainy water through runoff and infiltration could trigger the migration and the dispersion of pathogenic germs as well as chemical and organic substances and therefore, cause the contamination of groundwater especially when the soil as the case of the present study area is characterized by a strong permeability due to its sandy nature (Kinsiclounon, 2009; Akyo, 2006).

These different wastes deposited into Sô River and Nokoué lake directly by people and indirectly through the runoff containing chemical pollution and pathogenic germs could cause serious contamination groundwater by a system of leaching and infiltration (Kaki *et al*., 2011). Our results are similar to those of Guedenon (2009) and Dovonou (2008). According to these authors, demographic increase and the development of cities like Cotonou are the main causes for bacteriological, chemical, organic and toxicological pollution of lakes in Benin. Also, Kaki *et al*. (2011) explained that during high tide period, agricultural inputs are transported from farms in the north to the south through runoff into the lakes of Benin. As a result, there is alteration of aquatic ecosystems (Devez, 2004; Mendil and Uluözlü, 2007) and a slowdown of organic matters degradation (Edorh *et al*., 2007) contributing to the accumulation of heavy metals in the sediments of these lakes (Guedenon *et al*., 2012; Zerbe *et al*., 1998) and to the contamination by heavy metals of groundwater and fishes of the lake (Bodansky and Latner, 1987).

CONCLUSION

The present study allowed us to assess the bacteriological characteristics of various water sampling stations. All the water samples except those of tap water are strongly contaminated with faecal *Coliformes bacteria*, *Escherichia coli*, *Clostridium perfringen*, *Staphylococcus aureus*, *Salmonella* and *Shigella*.

The levels of these microorganisms are higher during flooded period than in dry season.

The different results pose public health problem through water-borne diseases outbreaks.

To mitigate the situation, all the authorities should facilitate the accessibility of the local population to clean and safe drinking water which is the birthright of all citizens. Besides, the local population should be educated to cleanliness, sanitation and a better environment management.

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