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Risks of Drinking Water Contamination by Chemical and Organic Substances in the Lakeside City of So-Ava in Benin Republic

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Abstract

Water is the source of life. It is also the cause of death when it is contaminated by chemical and organic substances. It is in this perspective that the present study was realized in the lakeside municipality of Sô-Ava in order to comprehend the impact anthropogenic behaviour on the physico-chemical quality of drinking water. Thirty (30) samples of water were collected and subjected to various laboratory analyses. The results showed that all the analyzed samples of water contain total Iron, nitrites, nitrates and ammonium which widely exceed the standards fixed by WHO which are respectively 0.3 mg / L, 0.5 mg / L, 0.2 mg / L and 0.5 mg / L. Therefore, there is contamination of the water of the study areas with organic and chemical matters. Considering the alarming values of recorded in the present study, it is important that new policies for drinking water supply and purification start being implemented by the authorities at various levels with the cooperation of the population.

Keywords: Municipality of Sô-Ava, pollution, water, organic, chemical.

Introduction

The survival of human being requires healthy and sufficient water because water contributes to the smooth running and to the balance of human physiology. Thus, in order to be safely drinkable, water has to be exempt from toxic substances and from excessive quantities of mineral or organic materials[1]. However, more than thirteen million persons die every year of waterborne diseases[2]. Safe drinking water remains, at the end of XXth century, an inaccessible facility for a big part of the world population, which explains the numerous diseases[3].

To mitigate this insufficiency of safe drinking water, the Beninese government improved the accessibility to safe drinking water by investing into the construction of new hydraulic infrastructures with the help of International Decade of Water and Purification[4,5]. In spite of these efforts, water-borne diseases did not know a significant regression according to sanitary statistics. These diseases remain the main causes of morbidity and mortality in rural areas[6].

The lakeside city of Sô-Ava, one of the most populated municipalities of Benin, is not spared in spite of the numerous means invested by the various governments during these last few years. Actually, the geographical environment situation (figure 2), the nature of its soil and the increase in population pose here real problems of hygiene and purification. This is aggravated by the fraudulent traffic of aromatic polycyclic hydrocarbons which prove to be a potential source for chemical pollution of the lake. This exposes the population to permanent insanitation[7]. This insanitation is worsened during wet season when a big part of the municipality area is immersed by the overflowing of lakeside waters[8]. Since a few years ago, the lake has been invaded by water hyacinth (figure 3). This clogging of the lake disrupts the lakeside transport and slows down the degradation of organic matters thus modifying the aquatic ecosystem[9]. Yet the lake water can infiltrate to supply the groundwater with water and therefore wells and drillings[10].

Recent studies showed that in Benin the sources of drinking water are contaminated. In the municipality of Kérou situated in the North of Benin, groundwater was contaminated either by fertilizers used in cotton fields or by infiltration of human and animal organic matters[11]. Also, in the municipality of Abomey-Calavi, bordering municipality of our study area, it was proved that all the wells studied presented a high level of chemical and bacteriological pollution[12].

No study was carried out in the lakeside area to assess the contamination of water used by the population. Thus the present investigation is carried out to assess the level of chemical and organic contamination of water used by the population for drinking and domestic use.

Material and Methods

Study materials: The municipality of Sô-Ava, the present study area, is situated in the south-east of Benin in western Africa. It occupies part of the low valley of Ouémé river, of Nokoué lake and of Sô river whence its name Sô-Ava figure-1. The morphological map of the municipality of Sô-Ava shows several units. It particularly consists in alluvial plains, slums, terraces, ponds and depressions. The population of this city has moved to the middle of the lake since the XVII th century because of tribal wars. Thus its inhabitants create houses on piles background which guarantees them real security (figure 2) and have become exclusively fishermen[13].

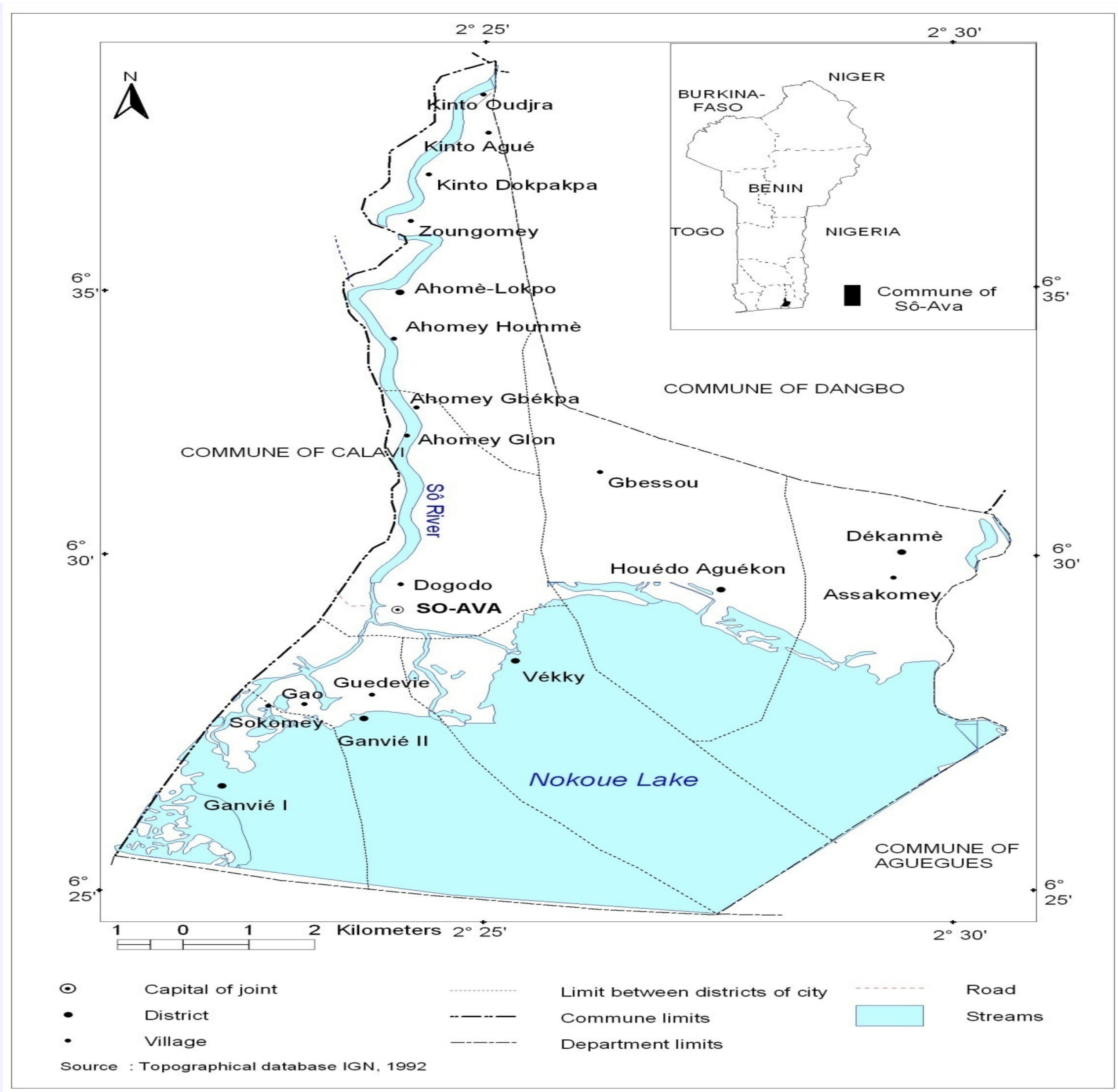


Figure-1
Geographical location of the commune Sô-Ava

Figure-2
One of the villages of Sô-Ava on water
(Source, INSAE-RGPH 3, 2002)

Figure-3
Water hyacinths clogging the lake during wet period

Research Methodology

Sampling of Water: The various samplings of water were made at different sites of our study area and their Geographic coordinates were recorded. In the municipality of Sô-Ava, water samples were collected in several locations in order to unravel the contamination phenomenon. The samplings were done during July-August and November-December 2009, periods which correspond respectively to the rainy season and to the dry season.

All in all, 30 samples of water were analyzed: 10 of the National Company of Water supply of Benin (SONEB), 10 of private drillings, 5 of drillings of the General Management of Hydraulics (DGH) and 5 of the surface water Figure- 1**.**Water samples were collected with 2 litre plastic sterile flasks according to the technique used by Di Benedetto et al. (1997). It consists in i) letting the water flow for 10 minutes before sampling ii) having rinsed the bottle 3 times with the water to be sampled iii) collecting the water until the bottle is filled. For surface waters, samples were collected in a representative way according to the technique of [14].

Once filled, the flasks were cleaned, wrapped in aluminium foil to avoid light contact which could modify some physical-chemical characteristics of the water such as ammonium and nitrites. They were then labelled and placed at 4°C for laboratory analyses.

Laboratory analyses: Physical parameters: Physical parameters comprise pH, conductivity and temperature. The measurement of these physical parameters was carried out by means of a multi-parameter of HANNA COMBO brand.

Chemical parameters: Chemical parameters comprise nitrates, nitrites, Ammonium, phosphate, carbonate, sulphate, calcium, magnesium, total iron, chlorides, fluorides and iodides.

Nitrates (NO3) were measured by absorption at 400 nm in the range 0 - 4.5 mg / L using DR/2000 spectrometer. Nitrites (NO.) were measured by absorption at 507 nm in the ranges between 0 and 0.3 mg / L using the DR\2000 HACH spectrometer. The content in ammonium (NH4) was measured absorption at 425 nm in ranges from 0 to 2.5 mg / L using DR\2000 HACH spectrometer. The phosphate (PO42-) and the carbonate were measured by absorption at 890 nm in the ranges 0 - 2.5 mg / L using DR / 2000 HACH spectrometer .concentrated samples. The analysis of sulphate (SO42-) was carried by absorption at 450 nm in the ranges 0 - 70mg / L using the DR / 2000 HACH spectrometer. Calcium and magnesium were measured at 505 nm using the DR / 2000 HACH spectrometer in 505 nm. With regard to total iron, chlorides, fluorides and iodides, they were analyzed by means of flame atomic absorption spectrometer.

In order to make an accurate reading, dilutions in 1/10 and in 1/5 were made on the concentrated samples.

Statistical analysis of the data: The statistical analysis of the data was carried out following three essential points: a descriptive analysis of the data and one way ANOVA in order to compare the physical-chemical parameters of the different categories of water samples and a comparison of the mean values recorded with the standard safety limits.
Besides, the analysis of the variance is followed by a multiple comparison test of the means.

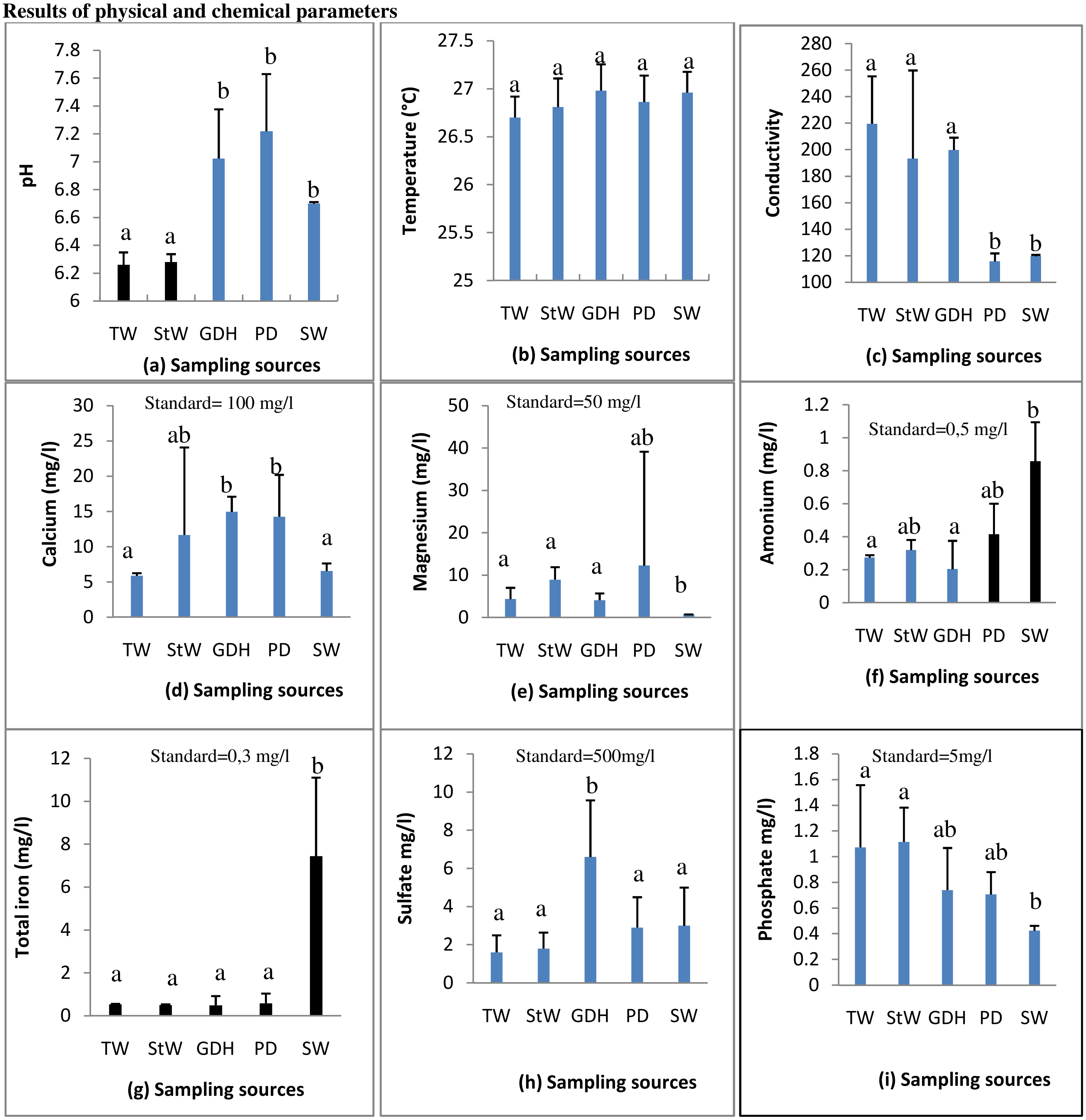
The descriptive study essentially deals with calculating the means and their standard deviations

As regards to the analysis of the variance, the first applied tests were concerned with checking the conditions of application. It deals with normality and equality of the variance. The test of Ryan Joiner was used to check the normality. The test of Bartlett was used to check the equality of the variances. The multiple comparison test of Sheffé was also used. In the case of non compliance with the conditions of application regarding the variance analysis (even after processing of variables), it is the non-parametric test of Kruskal Wallis which was used.

As regards to the comparisons with standard values, if the data follow a normal distribution, one way t test for each a sample was done. Should the opposite occur, it is the non - parametric test of Wilcoxon for each sample which was done. The Minitab software was used to carry out these tests.

Results and Discussion

Results of physical and chemical parameters



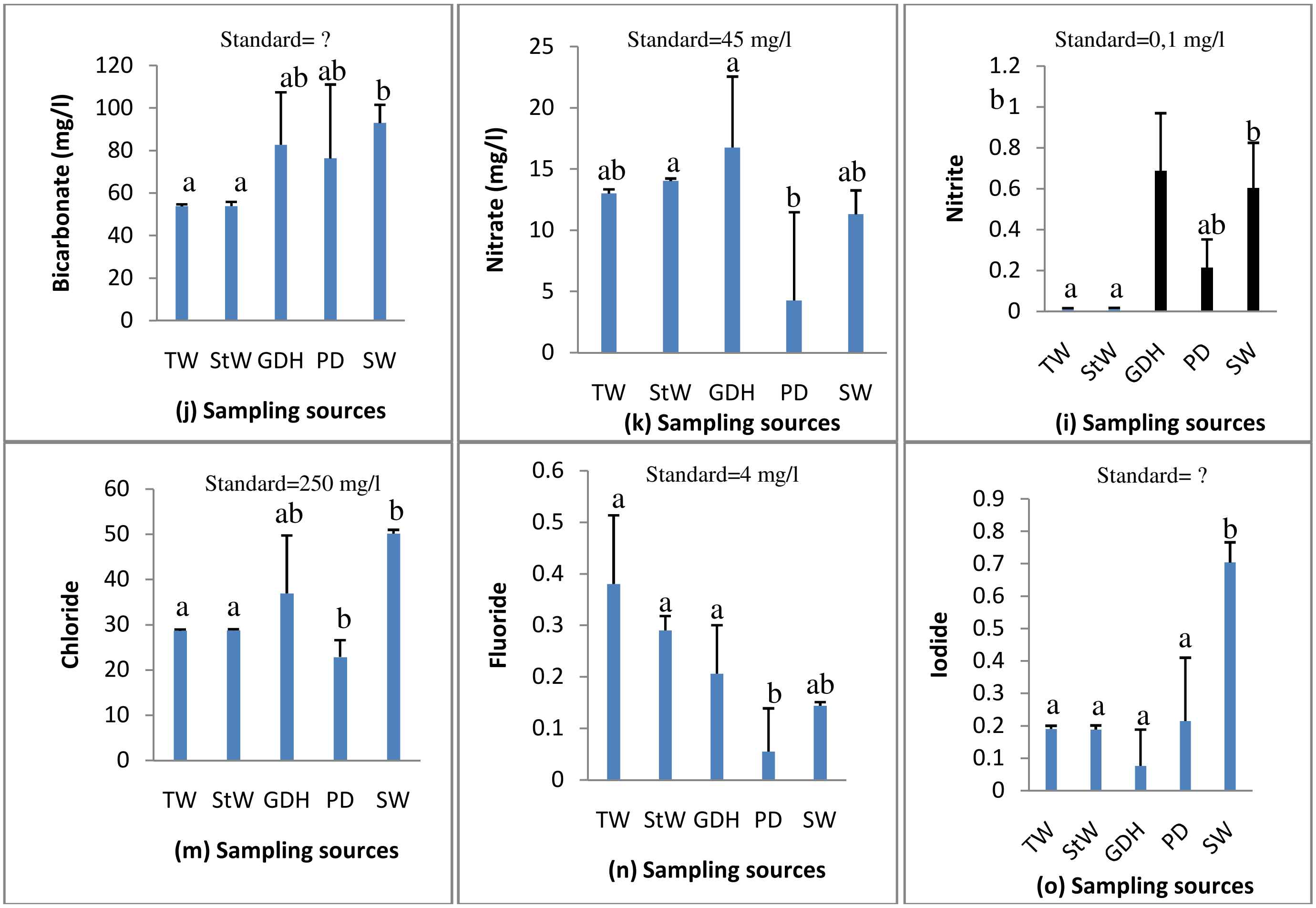


Figure-4
Presents the results of the physical and chemical parameters for drinking water

Figure-4: Physical-chemical parameters of water samples according to various water sources. TW= taps water, StW= Stored water, GDH= General Direction of Hydraulic, PD= Private drilling, SW= Surface water.

Water sources having the same symbols (a, b, etc.) have statistically identical mean values for the considered parameter. Bar charts in black correspond to the water sources that are statistically different from safety values.

Table-1
Comparison between pH and standards

sources	Safety limits: 6.5-8.5	Observation
Tap	No	Lower than 6.5
Storage	No	Lower than 6.5
Private drilling	Yes	-
General management	Yes	-
Lake/pond	Yes	-
The whole	Yes	-

Analysis of results: Analysis of results connected to physical parameters:
Figure-4a presents the various values of pH according to water sources. The average pHs varied from a water source to another. There was a highly significant difference at 95 % (Chi-Square = 22.90; Prob = 0.0001) between water sources. Only the water from SONEB differed significantly from WHO safety limits.

Figure – 4b presents the various temperatures according to the various water sources. The average temperature varies from 26.7 to 27.0 °C with a global average of 26.85°C. There is no significant difference at 95 % between the temperatures of various water sources. Also, all the values of temperatures of all water sources were within the safety values (25-28°C).

With respect to the conductivity of waters figure – 4c, it ranged from 115.8 µ / cm (tap) to 219.6 µ / cm (General management) with a global mean value of 173.6 µ / cm. A significant difference was observed between various water source (Chi-Square=14.1656 Pr > Chi-Square=0.0068). For all the different samples, the values of conductivity fell within the safety values.

Analysis of results connected to chemical parameters: Figure – 4d **s**how**s** the mean concentrations in calcium according to various water sources. It is observed that the mean concentrations in calcium ranged from 5.9 mg / l (tap) to 15.0 mg / l (General management) with a global average value of 11.27 mg / l. A significant difference at 95 % is observed between the mean concentrations of various water sources (Chi-Square = 17.94; Pr > Chi-Square = 0.0013). All the mean contents of calcium were below safety limits.

In respect of magnesium, its mean concentrations varied significantly between water sources (Chi-Square = 16.56; Pr > Chi-Square = 0.0024). They ranged between 0.74 mg / l (pond) to 12.26 mg / l (private drilling) with a global average value of 7.10 mg / l Figure – 4e. Compared with the standard, all concentrations of various water samples from water sources were significantly lower than the safety value.

Figure–4f presents the mean concentrations in ammonium according to water sources. The analysis of this figure proves that the concentrations in ammonium varied significantly from one water source to another (Chi-Square=15.23 Pr > Chi-Square = 0.0042). Considering the safety value, ammonium mean concentrations of private drillings and surface water statistically exceeded the standard values. However, there was no significant difference between the safety value and the mean concentrations of tap waters, stored water and general management water.

Figure–4g shows the various values of total iron according to water sources. It is observed that the mean concentrations of total iron varied significantly from one water source to another (Chi-Square=12.66 Pr 0.0130). All the mean concentrations of total iron recorded in the present study were above the permissive limit fixed by WHO.

The concentrations in sulphate are shown on Figure – 4h. The analysis of this figure revealed that the mean concentrations of sulphate varied from one water source to another (F value = 3.5 Pr > F = 0.0212). Besides, all the mean concentrations in sulphate registered were highly lower than the permissive limit by WHO.

Figure–4i presents the concentration in phosphate according to various water sources. The analysis of this figure proves that the concentrations in phosphate varied significantly from one water source to another (Chi-Square 14.22 Pr > Chi-Square= 0.0066). As regards to the standard values, they were respected for the different studied water sources.

Figure–4j presents the results of the concentrations in bicarbonate from the five water sources. The analysis of this figure reveals that the average concentration in bicarbonate was 72.65 mg / l and it varied from one water source to another (Chi-Square=18.5644 Pr > Chi-Square=0.0010). It was of 73 mg / l at the level of taps and storages and of 93 mg / l at the level of ponds.

The mean concentrations in nitrate by water source are presented on Figure – 4k. These mean concentrations varied significantly from one water source to another (Chi-Square = 15.4421 Pr > Chi-Square=0.0039). All the mean contents in nitrate were statistically lower than the standard values of WHO.

Figure-4l shows the mean concentrations in nitrite according to various water sources. These concentrations ranged from 0.017 mg / l (private drilling) to 0.69mg / l (general management) varied significantly from one water source to another (Chi-Square = 15.6070 Pr > Chi-Square=0.0036).

The mean concentrations in nitrites significantly exceeded the permissive limits for waters from the general management, the ponds and the private drillings. But with respect to the tap and storage waters, their mean contents in Nitrites were lower than the permissive values.

Figure–4m presents the mean concentrations in chlorides according to the various water sources. These concentrations varied significantly from one water source to another (Chi Square =19.5264 Pr > Chi- 0.0006). For all the sources, the mean concentrations in chlorides were lower than the standard value by WHO.

The mean concentrations in fluoride Figure – 4n varied significantly from one water source to another (Chi-Square 19.95 Pr > Chi square -= 0.0005). Besides, all the mean concentrations recorded in this study were lower than the safety value by WHO.

The mean concentrations in iodide according to various water sources were shown on Figure – 4o. These mean concentrations varied significantly for each water source (Chi-Square = 14.4687 Pr > Chi-Square = 0.0059) and were in the range of 0.08 mg / l (general management) to 0.7 mg / l (ponds). It can be noticed that the mean content in iodide of ponds was higher than those of the other water sources.

Water from SONEB and surface water were slightly more acidic than those from drillings which were more or less neutral. The stored water, whatever its origin did not comply with WHO standards. The acidity of drinking water could be connected either to the nature of the Sô-Ava soil or to the dilapidation of SONEB infrastructures in the municipality. Actually, over time the salinity of Nokoué lake water could rust the water pipeline and therefore pollute the water [9]. Besides, the stored water could be also contaminated during the manipulation. Our results differed from those of others respectively at Grand - popo and at Abomey-Calavi who found a pH close to neutrality[15, 9].

However, the recorded neutral pH of drilling water was similar to the results of others in the municipality of Kérou[11]. The variation of pH could mean that waters didn't come from the same docks or that one is more contaminated than the other one with chemical or organic materials. In the municipality of Allada, Boukari reported that the pH of underground waters was low between the range 4 – 6 16. This acidic characteristic can be justified either by the presence of CO2 or by the absence of strong base (CO32-).It could also be due to the presence of humic acid from the decomposition of vegetable matter[17].

Temperature plays an important role in the dissociation of salts, in the increase of chemical activity and the determination of electric conductivity[17, 16].

In the case of Sô-Ava, the values of temperature of all water samples lay within the safety limits by WHO (25-28°C). These results were similar to those of others in Cotonou which are in the range of 25 - 30°C[18, 19]. The high values of temperatures recorded by these authors could be due to the influence of the outside temperature on the waters sampled, groundwater being at a low depth for some wells and average for others. The results in Brazzaville are higher (28 to 30°C) than the values in the present study[20].

According to some, the rise of water temperature in tropical climate could be good conditions to enhance the efficiency of water disinfection with chlorine for the bactericidal [21]. Efficiency of chlorine is 5 times higher between 25 and 28°C. These temperatures represent a good environment for microorganisms' culture. It means that in tropical environment, the rise of water temperature creates good conditions for its pollution. Also, it is reported that the rise of temperature or acidity of the water increases the accumulation of heavy metals in the sediments of Nokoué lake [10]. The electric conductivity is connected to the presence of ionic species in solution [17, 16]. Whatever the water source might be the conductivity values were within permissive values. The results recorded at Sô-Ava were in accordance to those of others respectively in the municipalities of Kérou and Allada [16,11]. The former remarked that the plain of Allada in Benin is characterized by a very low mineralization (IT < 100µS / cm) and (100 µS / cm < IT < 200 µS / cm). He also showed that the seaside plain is characterized by an average to important mineralization (200µS / cm < IT < 600 µS / cm) with some relatively high mineralization sites (IT > 600µS / cm) nearby the ocean [16]. The strong values of conductivities in the littoral plain could be connected to a previous dissolution of chlorides and sulphates originating from sub-littoral deposits containing carbonates, phosphates and sulphates or presence of nitrates from surface waters [17]. The values of electric conductivity recorded at Sô-Ava were within WHO safety limits and were close to the spatial distribution of mineralization on the plain of Allada which shows that waters are weakly mineralized and this may be connected to the nature of the soil. However, the high values of conductivity recorded in the littoral plain show that these waters present an important mineralization which would probably be due to the infiltration of brackish waters in the lagoon complex, upon the nearness of the sea and the dissolution of minerals [16].

The significant difference in conductivity observed between the various water sources could be due to the variation of the ionic species in solution. That could mean that some waters are differently contaminated by chemical or organic materials.

The concentrations in calcium and in bicarbonate were also within permissive limits whatever water source was considered.

In respect of magnesium, sulphate, chlorides, fluorides and iodides, their mean concentrations in all the water samples were significantly lower than the safety values. These results are similar to others who attribute the level of the aforementioned minerals to the nature of the soil of Sô-Ava [9, 22].

According to WHO, drinking water should contain no more than 0.3 mg / L of total Iron. All the analyzed water samples exhibited total Iron concentrations largely above the safety values. Nokoué lake and Sô river are receptacles for the nearby plain municipalities whose soil is iron-red formed on "Continental Terminal» and the agricultural regions of the North having more or less sandy tropical ferruginous soil, best represented in Benin where they cover 60 to 70 % of the total surface of the country[23]. So, by the wear away process, heavy metals and in this case, iron can accumulate in sediments of water streams to contaminate the groundwater [11, 24].

The accumulation of heavy metals varies according to the nature of the sediment[11]. That could justify the difference in the total iron recorded from one water source to another.

According to WHO recommendations, water intended for consumption should not contain more than 0.5 mg / L of ammonium and 0.2 mg / L of nitrites. The results recorded in the municipality of Sô-Ava were largely higher to the permissive values (MSP-guidelines, 2001). Thus, the drinking water is contaminated by organic and mineral substances. Our report is similar to another one done in Sô-Ava[8]. He revealed that in the central district of this municipality, 90 % of the households deposit household waste outside.

Other results in the municipality of Kandi and the city of Cotonou confirm our findings when they reveal that the quasi-totality of well waters is polluted by chemical and organic materials [25,27,28,29]. The same remark about the quality and management of drinking water in the sub-prefecture of Grand-Popo was done by another researcher[15]. She came to the conclusion that water samples from all wells were chemically and bacteriologically contaminated. Other studies on the impact of household waste on the quality of the groundwater in Cotonou revealed that well waters were contaminated because of the mismanagement of solid and liquid waste resulting from human activities[18, 30, 31].
These results also confirm inquiries led in the outskirts region[26].

He showed that in the city of Niamey (Niger), the superficial tablecloth accessible through wells presents a strong nitrogenous pollution attributed to various causes: the defect of purification and collection of household waste, the transfer of pollutants to the superficial layer, the conditions of wells and the structure of installations.

The differences observed in the mean concentrations in ammonium and in nitrites from one water source to another indicate that certain waters are more contaminated than others. The most polluted sources could be referred to water sources situated in locations that are highly polluted by human and animal activities as Ganvié and Houédo Gbadji.

Conclusion

In the lakeside municipality of Sô-Ava, the pH, the temperature and the conductivity, the concentrations in calcium and in bicarbonate were within the permissive limits by WHO.

In respect of magnesium, sulphate, chlorides, fluorides and iodides, their concentrations were significantly lower than safety values.

However, all the analyzed samples of water contain some amount of total Iron that largely exceeded safety values. Also the results of nitrites and ammonium recorded from the majority of waters were widely higher than the reference values. These waters are thus contaminated by organic and chemical substances and their contamination is connected to the geographical situation of the municipality and the nature of its soil which make hygiene and purification of the environment difficult to deal with. The situation is worsened by the increase in population.

Thus the duty to protect the health of human beings by making regular controls of the quality of drinking water and by building purification infrastructures is left to those in charge of our societies.

The improvement of the health of population in the municipality of Sô-Ava implies, the hygiene and the purification of the environment adapted to the geographical situation of this city, along with the improvement of the quality regarding water of domestic use.

A big decentralization and empowerment of the local actors is not meant to deprive the State of its general responsibility, particularly its mission, to ensure to all, the right to safe drinking water.

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