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*Full Length Research Paper*

# Comparative evaluation of lead, cadmium, nitrates, total iron and their derivatives, in drinking water in the lacustrine township of Sô-Ava between 2009 and 2012

**Kinsiclounon Gilles E[1,3,4], Edorh Patrick A[2,3], Guedenon Patient[3*], Senou Masimin[4], Deguenon Yvette[3], Akpovi Casimir[4], Kaki Christophe[5] Loko Frederic[4], Boko Michel[3], Gbeassor Messanvi[6], Creppy Edmond E.[7]**

[1]Health and Medical Research Institute, P. O. Box: 974, Abomey-Calavi
[2]Biochemistry and Cellular Biology, University of Abomey-Calavi (UAC), 01BP 526,
[3]Interfaculty Centre of Training and Research in Environment for Sustainable Development (CIFRED), University of Abomey-Calavi (UAC), 03 BP 1463, Jéricho,
[4]Laboratory of Applied Research in Biology (LARBA), Genie Environment Department of Polytechnic, University (EPAC), University of Abomey-Calavi (UAC) 01BP 526 Cotonou, Benin Republic
[5]Sciences of Earth Department, Faculty of Sciences and Techniques, University of Abomey-Calavi (UAC), 01BP 526 Cotonou, Benin.
6Department of Physiology and Pharmacology, Faculty of Sciences, University of Lomé (UL), Togo P. O. Box: 1515 Lomé, Togo
[7]Laboratory of Toxicology and Applied Hygiene/UFR of Pharmaceutical Sciences, 146, Road LeoSaignat, 33076 Bordeaux Cedex, France
*Corresponding author`s email: kinsgil69@yahoo.fr

**Abstract**

**Water is source of life. It becomes source of death when it contains substances which are poisonous to the organism. It is in this setting that in 2009 some studies had been conducted at Sô-Ava in Benin, in order to evaluate the level of contamination of the drinking water. These studies had shown that water is contaminated by organic matters, by chemical matters and by poisonous metals such as the nitrites and their derivatives, the total iron, the lead and the cadmium. The current study has the objective of examining the sense of the evolution of these parameters over a period of 4 years. The thirty (30) samples of water analysed in 2009 have been taken all over again in 2012, as well during the season of rains as during the dry season. They have been submitted to the different analyses in laboratory as they were in 2009. The results clearly show that the concentrations of these substances in the drinking water are not bettered as such. Over the two periods, the concentration in the nitrates increased, but this increase is not significant enough (F=1.18 p=0.2876). The concentration in nitrites knew a globally significant increase between those two periods (F =7.58 p=0.0108). As for the total iron, the concentration didn't vary globally from one period to the other (F=0.21 p=0.6517) but it stayed superior to the norm of the WHO. The average concentration in ammonium increased appreciably from one period to the other (F = 9, 41 p=0, 0051). Concerning the lead, its concentration stayed constant throughout the time (F=0.85 p=0.3662) but it remained superior to the norm. The average concentration in cadmium knew a significant growth throughout the time reaching up to threshold of 10% (F=3.79 p = 0.0630). It comes out of these studies that, in the township of Sô-Ava, the populations are exposed to the xenobiotics; which situation would surely have some impact on the health of the populations. With such a reality, it is important that new policies of purification of the environment should be clearly defined by the authorities at all level with effective involvement of the populations themselves in order to evaluate the impacts of those substances on people's organism.**

**Keywords:** Sô-Ava, drinking water, nitrates and derivative, lead, cadmium.

## INTRODUCTION

Water is a strategic resource. It is the fundamental element necessary for an economic, industrial and social development. It must then be not only available in sufficient quantity, but also and especially in good quality (Edorh, 2007).

In the past few years, water became all over the world a rare commodity, especially because of the climatic changes (Load and al, 2008). The shortage of water noted today is aggravated by the bad conditions of hygiene and sanitation of the environment which endangers the quality of the available water (Clégbaza, 2000). In the developing countries, the illnesses transmitted by water constitute the first reason of morbidity and mortality within the most resource-less populations (World Water Council, 2005).

In Benin, in order to improve the state of health of the populations and to increase productivity and make the infectious and parasitic illnesses transported by water to regress, several programs have been put in place by the International Decade of Water and Sanitation (IDWS). The objective of these programs is to encourage for the whole population good access to the drinking water (OMS/UNICEF, 2000). This strategy entailed important changes and permitted to improve significantly the situation of provision in drinking water. In spite of all these efforts, the hydric illnesses didn't regress actually according to the available sanitary statistic data. These illnesses are and remain the main causes of morbidity and mortality especially causes of infantile mortality in the farming zones (MEHU/GTZ, 1997). This situation is very critical in the lacustrine township of Sô-Ava according to the available statistic data and which reveal that 75% of the infantile deaths are caused by the illnesses related to water (town administration, 2006).

To verify this hypothesis, we had conducted several studies in 2009, notably the assessment of the level of contamination of the drinking water in Sô-Ava. The results confirmed that the drinking water is contaminated by chemical matters, by organic matters and by poisonous metals. The concentrations in nitrates and their derivatives, in total iron, in lead and in cadmium are troubling and that raise a real public health problem. A close follow-up of these parameters throughout the time now turns out to be necessary. That is why the current work intends to achieve a comparative study of the concentrations of these poisonous substances over a period of four (4) years running from 2009 to 2012, in order to determine the sense of the evolution of these concentrations. This survey required the use of materials and methods.

## MATERIALS AND METHOD

The map below shows the geographical situation of the place of the study and the geographical distribution of the studied points of water.

Distinct samples of waters were taken in 2009 and in 2012, during the season of rains and during the dry season, in all the seven districts which compose the township of Sô-Ava (Figure 1).

The samples of waters are taken by means of sterile small plastic bottles. The technique used to take the samples of the underground water is the technique of Di Benedetto and al. (1997). It consists (1) in letting the water flow for 10 minutes of running before taking the sample (2) in going on taking the sample of water (after having rinsed the bottle 3 times with the water to be sampled) until the volume of the bottle is filled.

For the case of the surface waters, the samples were taken in a representative way according to the technique of Di Benedetto and al. (1997). This technique permits to appropriate the samples of water the nearest possible to the sources of pollution: on the surface, in the middle place and in the depths of the marshes of the Nokoué Lake, the Sô river.

Besides, it is necessary to underline that the different samples of water were taken after having determined the geographical coordinates of the various zones of the study place. In the township of Sô-Ava, the samples of water were taken in several places in order to discern the phenomenon of contamination correctly.

In total, 30 samples of water have been analysed: 10 from the National Water Supply (SONEB), 10 from the private digging wells, 5 from the sinking wells of the National Direction of Water Supply (DGH) and 5 from the surface waters (Figure1).

The small bottles when they are filled up are cleaned and enveloped in the aluminium paper to avoid the penetration of light which could modify some physical and chemical parameters of water such as the ammonium and the nitrites. After that, they are labelled and are kept cold at 4°C in a cool icebox containing some ice blocks before being routed on to the laboratory.

The nitrates (NO3) have been measured out by absorption at 400 nm in the DRA2000 spectrophotometer of which the range of measurement varies between 0 and 4.5 mg/L.

As for the nitrites (NO), they have been measured out by absorption at 507 nm in the spectrophotometer DR\2000 HACH of which the range of measurement varies from 0 to 0.3 mg/L.

The ammonium (NH4) and the total iron could be measured out by absorption at 425 nm in the spectrophotometer DR\2000 HACH of which the range of measurement varies from 0 to 2.5 mg/L. Some dilutions at 1/10 and 1/20 have also been done on the too much concentrated samples. Those different analyses have been done in the laboratory of the National Direction of Water of Benin Ministry of Mines and Energy.

The total concentrations in lead and cadmium of the

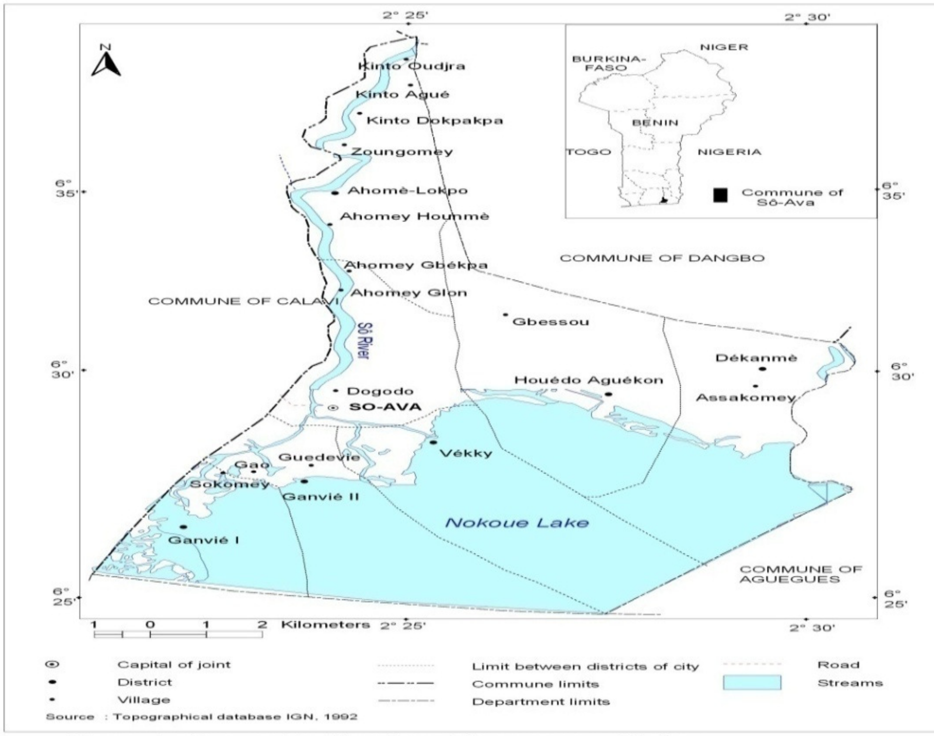


**Figure 1.** Geographical location of the commune So-Ava

drinking water have been measured out by the Spectrophotometry od Atomic absorption (SAA) by the blowing of flame, ICP-AES by ICP-MS (Inductively Coupled Plasma - Mass Spectrometry) that presents the advantage of a multi-elements analysis (Devez, 2004). Those poisonous metals have been analysed in the laboratory of Benin National Institute of Research in Agriculture (INRAB) by the spectrophotometer of atomic absorption with flame, according to the protocols of Anane and al. (1995) and of Vaidya and Rantala (1996).

The statistical treatments of the data were about an analysis of variance with a factor of classification with measurements repeated throughout the period of time (2009 and 2012). The used data beforehand underwent a logarithmic transformation. This test is followed by Scheffe's test of multiple comparisons to compare the different points of waters. In order to compare the data throughout the time the method of contrast has been used.

With regard to the norm, a t test with one sample has been used when the data follow a normal distribution, but in the contrary, the test of Wilcoxon with one sample has been used. Between the two periods, the aim was to verify if some improvements have been observed or not regarding the norm.

## RESULTS

The results are presented by types of metal including nitrates, nitrites, ammonium, total iron, lead and cadmium.

### Nitrates

Figure 2 presents the evolution of the concentration of nitrates during the time period. The concentration of nitrates varies from a water point to another during each period and throughout the time.

Indeed, in 2009, the average concentration of nitrates was 10.60 mg/L and varied significantly from a water point to the other. In 2012, this concentration increased and reached 12.55±S 9.84 mg/L. However, this increase is not significant enough ($F=1.18$ $p=0.2876$) and no actual difference is noticed between the water points during the year. The concentrations of nitrates in the private boring waters stay the weakest during the period of study and are slightly rising. In the same, except for the water of the General Direction of the hydraulics (DGH), the average concentrations of the other water points increased slightly.

No improvement is observed with regard to the

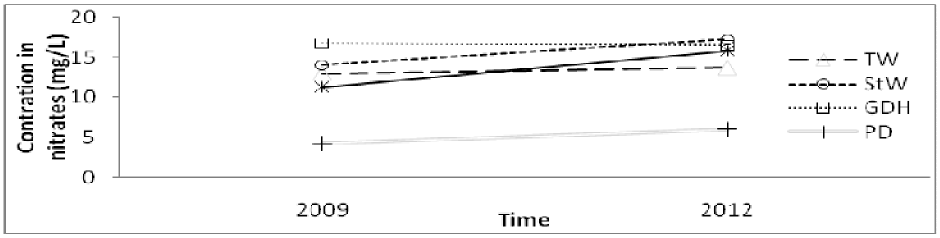


**Figure 2.** Evolution of the concentration of nitrates between 2009 and 2012, and between different water points. TW = tap water, StW = Stored water, GDH = General Direction Hydraulics of, PD = Private drilling, SW = Surface water.

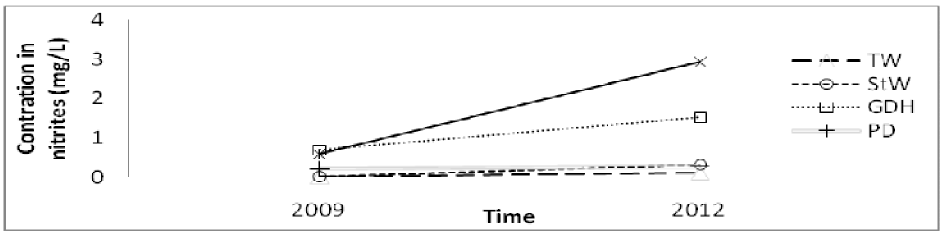


**Figure 3.** Evolution of the concentration of nitrites between 2009 and 2012 and between different water points. TW = tap water, StW = Stored water, GDH = General Direction Hydraulics of, PD = Private drilling, SW = Surface water.

norm. Indeed, the concentration remained below the norm at any water point as was the case in 2009.

## Nitrites

Figure 3 presents the evolution of the concentration of nitrites between 2009 and 2012. In 2009, the averageconcentration varies significantly from a water point to another. It is the average of 0.29 mg/l and varies from 0.017 mg/l (tap water) to 0.69 mg/l (surface water). In 2012, this concentration is 0.91 mg/L and varies from 0.119 mg/L (tap water) to 2.93 mg/L (surface water). The global increase between these two periods is significant enough (F =7.58 p=0.0108). Apart from the concentration with the surface water that is noticeably different from the one with tap water, the stocked water, and the private boring water, the other water points are two by two identical. In the same way, between the two periods, the concentrations at each water point are respectively identical (F de Lamda de Wilks =1.44 p = 0.2493).

In 2009, the concentration of nitrites largely overpasses the norm with the water of the DGH, the stretches of water and the private boring water. It is below the norm with the tap water and the stocked water. But, in 2012, the concentration of nitrites respects the norm as well with the tap water and the stored water as with the private boring water.

## Total Iron

Figure 4 present the concentration of total iron didn't vary globally from one period to the other (F=0.21 p=0.6517). In 2009, the overall average concentration is 1.69 mg/l. The lowest average concentration is 0.48 (DGH) and the highest concentration is 7.44 mg/l (stretches of water). In 2012, it is on the average of 1.56 mg/L and varies from 0.54 mg/L (tap water) to 5.65 mg/L (surface water). Between 2009 and 2012, the concentrations of total iron of the DGH water, the water of the private boring, the tap water and stocked water are noticeably identical. These concentrations are roughly lower than the ones recorded at the stretches of water. The concentrations at the water points recorded separately remained identical throughout the time (F de Lamda de Wilks=1.53 p = 0.2239).

With regard to the norm, the concentration of total iron at each water point is largely beyond the requirements of the WHO no matter the period.

## Ammonium

Figure 5 presents the evolution of the concentration of ammonium between 2009 and 2012. The analysis reveals that the average concentration of ammonium increased appreciably from one period to the other (F = 9.41 p=0.0051). In 2009, the average concentration was of 0.21 mg/L and varied significantly from a water point to another. The average concentrations vary from 0.21 mg/L (DGH water) to 0.857 mg/L (surface waters).

In 2012, the average concentration of ammonium is 4.21 mg/L. The lowest concentration is recorded with the tap water (0.25 mg/L) and the highest is recorded with the surface waters (21.97 mg/L). The concentration of ammonium of the surface waters differs significantly

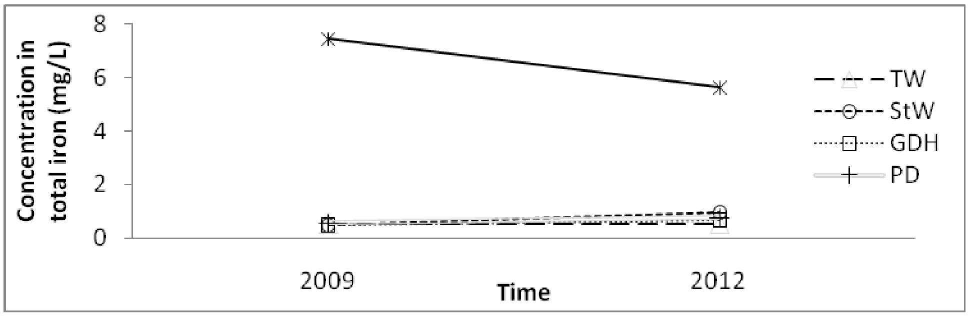


**Figure 4.** Evolution of the concentration of total iron between 2009 and 2012 and between the different water points. TW = tap water, StW = Stored water, GDH = General Direction Hydraulics of, PD = Private drilling, SW = Surface water.

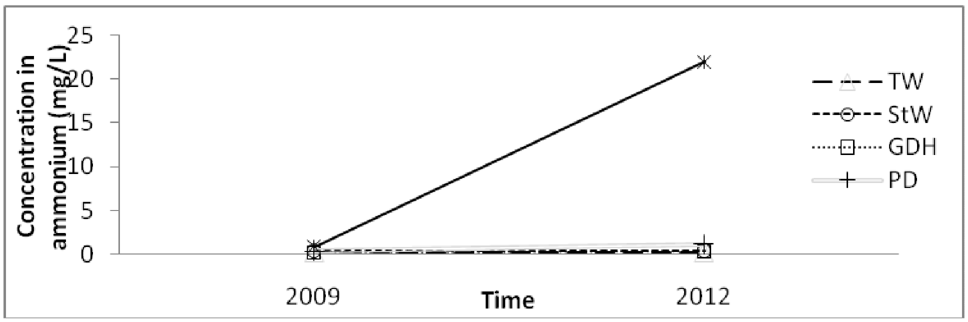


**Figure 5.** Evolution of the concentration of ammonium between 2009 and 2012 and between the different water points. TW = tap water, StW = Stored water, GDH = General Direction Hydraulics of, PD = Private drilling, SW = Surface water.

from the one recorded at the other water points which have statistically identical concentrations.

With regard to the norm, in 2009 as well as in 2012, the concentrations of ammonium of the water of the private boring and the stretches of water statistically overpass the value fixed by the WHO. However, the concentrations of all the water points and those of the tap water, the stocked water and the water of the DGH respect the norm.

## Lead

Figure 6 presents the evolution of the concentration of lead between 2009 and 2012. The concentration of lead stayed constant throughout the time (F=0.85 p=0.3662). In 2009, this concentration is the average of 0.05 mg/L and varies significantly from a water point to another. The lowest concentration is recorded with the tap water (35 mg/L) and the highest with the surface waters (0.62 mg/L). In 2012, the concentration of lead also varies from a water point to another. It is the average of 0.04 mg/L. Apart from the tap water and the surface waters that have different concentrations; all the other water points have identical concentrations.

In 2009 as well as in 2012, the norm is respected with the tap water, the stocked water, and the private boring water. The norm is not respected with the surface waters and with the water of the General Direction of the hydraulics.

## Cadmium

Figure 7 presents the evolution of the concentration of cadmium between 2009 and 2012. From the analysis of this figure, it comes out that the average concentration of cadmium grows significantly (threshold of 10%) throughout the time (F=3.79 p = 0.0630). In 2009, the concentration of cadmium is the average of 0.012 ±S 0.001 mg/L of water. This concentration doesn't vary significantly from a water point to another. The lowest value is recorded with the tap water (0.0076 mg/L) and the highest (0.014 mg/L) is recorded with the surface waters. Apart from the surface waters which lowered throughout the time, the concentrations of the other water points increased slightly. The average concentration in 2012 is 0.123 mg/L. The lowest value is recorded with the tap water and the highest is recorded with the boring waters.

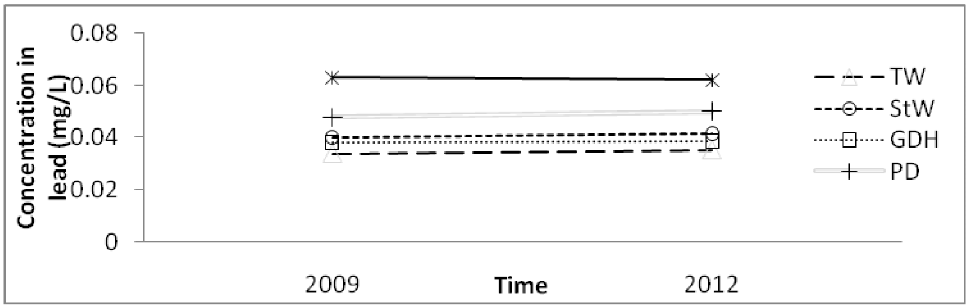


**Figure 6**. Evolution of the concentration of lead between 2009 and 2012 and between the different water points. TW = tap water, StW = Stored water, GDH = General Direction Hydraulics of, PD = Private drilling, SW = Surface water.

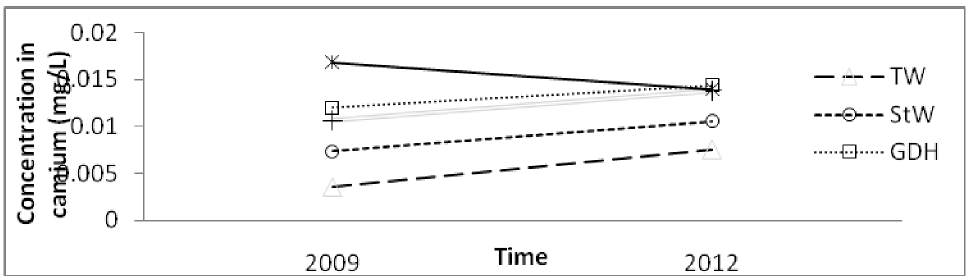


**Figure 7.** Evolution of the concentration of cadmium between 2009 and 2012 and between the different water points. TW = tap water, StW = Stored water, GDH = General Direction Hydraulics of, PD = Private drilling, SW = Surface water.

Between 2009 and 2012, the norm is respected with the tap water and with the surface waters. But, it is not respected for all the water points, the stocked water, the water of the General Direction of the hydraulics and the private boring water as well.

## DISCUSSION

The drinking water should not contain more than 0.3 mg/L of total Iron, according to the WHO. All the samples of water from Sô-Ava that we analysed in 2009 contained the total Iron the concentration of which extensively goes beyond the norm (Kinsiclounon, 2009). In 2012, the concentration of total Iron didn't vary globally from one period to the other (F=0.21 p=0.6517) and stayed superior to the value of reference. Indeed, the Nokoué lake and the Sô river are receptacles for the plateau of the neighbouring townships the soils of which are red laterite soils formed on the " Continental Terminal ", and for the agricultural regions of the north with their tropical ferruginous soils more or less sandy, the largest in Benin covering over 60 to 70% of the total area of the country (Azontondé, 1991). By leaching, heavy metals like Iron are poured into the Nokoué Lake and accumulate in the sediments of the rivers (Khaki and al., 2011) to contaminate the groundwater (Anane and al, 1995). That would justify the identical tendencies of the results in 2009 and 2012.

The concentrations in nitrites and in ammonium that we got in 2012 were extensively superior to the values of reference (MPH - Decree, 2001). These results are similar to those of 2009. But, the average concentration in ammonium increased appreciably from one period to the other (F = 9.41 p=0.0051); and that could mean that the drinking water is under perpetual contamination by chemical and organic substances. The geographical situation of the township of Sô-Ava, the nature of the soil, the bad domestic garbage management, the bad management of worn-out waters and faeces, the cyclic phenomenon of flooding, the obstruction of the lake by the hyacinths of water and the raving of the animals are as many factors that could justify the permanent pollution of the drinking water in the lacustrine city of Sô-Ava. According to Clédjo and Boko (1999), the chemical pollution of the lacustrine environment is provoked on the one hand by the runoff (the Sô and the Ouémé rivers' sub-affluent) that sweeps the whole pouring basins which are soiled by the fertilizers and pesticides formerly used for the cultivation of cotton, on the other hand, by the various salts cumulated up at the subsidence and carried along during the high waters, and especially by the industrial or artisanal garbage of Cotonou and neighbouring cities and villages. In addition to these elements, the lake is overloaded by organic matters with the excessive implantation of the akadja parks made of branches that decompose easily in the water (palm-tree leaves). Adding to these elements, there are the rapid accumulation of the domestic garbage of the lacustrine villages and the hyacinths during the subsidence, marked by a very high rate of the saltiness of the lake. These facts could also justify the results of the analyses done after the recursive death of the fishes of the Nokoué Lake in May 1998. It comes out then that the measurements of the water quality done in about ten stations indicate some extremely weak rates of oxygen. That indicates that in this precise period of the year, the Nokoué Lake presents all conditions of a bad quality of oxygen for fishes. The lethal effect of the low content of oxygen in the water seems to be catalysed by the presence of extremely dangerous poisonous substances for fishes, like ammonia (Lalèyè, 1998). The most current pollution is biologic; it is caused by infectious agents like men (the fact that the residents defecate directly in the waters of the lake and the Sô river), by the animals and the vectors of illnesses like the bugs.

The raising of the small livestock (nick and goats) and poultry is still very extensively practiced in the lacustrine villages. These animals are scavengers; they circulate freely at low water, and pigs usually look for their food in the immersed manures immersed at 50 cm under water. At the time of the rises in the water level (the high waters), the small livestock lives together with the men in the kitchen or on the platform made for that circumstance. This life style has some influence on the quality of the drinking water and on the health of the lacustrine populations as well. The results of our studies would justify the upsurge of some diseases in lacustrine environments according to the hydrologic rhythm. The main diseases are the following: malaria, bilharziasis, cholera etc. The low waters coincide with the upsurge of hyper-endemic malaria and the bilharziasis (Clédjo and Boko, 1993); the period of rise in the water level is marked by the syndrome of the gastoenteritises (Cholera, Salmonellosis, Shigellosis, the amoebiasis, and the intestinal nematodes), and the illnesses of the respiratory track (cough, cold and the tuberculosis) evolving according to air dryness (Clédjo, 1993, Akyo, 2007, Kinsiclounon, 2009).

The same observations are made at Godomey-Togoudo, a city situated on the west of our study place, where the groundwater is polluted bacteriologically, because of high population growth on the one hand, and because of their bad behaviours concerning management of domestic garbage and worn-out waters (Hazoumè, 2003).

In the same way, in Cotonou, city situated on the South of our study place, the groundwater captured by the wells, is in perpetual contamination because of the populations' behaviours. Most latrines and septic tanks are not watertight. In addition, about 83% of the households living in the poor districts answer the calls of nature into the open environment. The faecal pollution of water in Cotonou is moreover aggravated by the nature of soil and by the bad quality of the draining works (Ahoussinou, 2003).

It is also the case in Port-Novo, a city situated on the East of the township of Sô-Ava, where the wells are badly maintained and water coming from these wells is of bad quality (Agodou and Orou-Goura, 1979).

The concentration in lead stayed constant during the period ($F=0.85$ $p=0.3662$), whereas the average concentration in cadmium grows meaningfully (to thresholds of 10%, $F=3.79$ $p = 0.0630$).

Lead is the most important of the heavy metals, since it is at the same time poisonous and very widespread (Boutron and Patterson, 1983). It enters into water the most often through domestic garbage and during the corrosion of the plumbing materials used for the realization of the boring and the water pipes (Feuillade and al., 2001). These data are to be taken very seriously especially concerning children's health; with them, even at small doses poisoning can occur (Peden and al., 2009). We can notice with the intoxicated children a modification of the maturation of the nervous system with a delay of the motor development (Galaf and Ghannam, 2003) and an alteration of the memory together with audition problems (François - Henri and al, 2004). Lead can cause haematological, gastro-intestinal, reproductive, immunological and apoptotic disorders (Xu and al., 2008).

Cadmium, contrarily to lead, adsorbs only feebly with soil particles (Camobreco and al., 1996); and that explains the fact that its quantities in water are relatively weak but in progression. It can be dragged down the depths to contaminate the groundwater (Richard and al., 1998). Nevertheless, an excessive exposition to cadmium could cause death (Othumpangat and al., 2005). It enters into the cells and accumulates in strong concentration in the cytoplasmic and nuclear area (Beyersmann and al., 1997), and has a strong affinity for the liver and the kidneys (Cai and al., 2001).

The constancy of lead concentrations in the drinking water could be due to the infiltration of metal previously accumulated in the sediments of the Nokoué Lake. Indeed, the poisonous metals contained in the running waters from the agricultural regions of northern Benin, flow into the lakes and accumulate in the sediments (Khaki, 2011). Added to all these factors of water pollution (Kinsiclounon, 2013), there are the wild garbage dumps installed on the bank of the Nokoué lake (Dovonou, 2008).

These accumulations depend on the nature of the sediment (Khaki, 2011) because copper, zinc, nickel, cadmium and lead each accumulates differently in the sediments of the lake (Pazou and Boko, 2006). That could justify the growth of the concentrations of cadmium between 2009 and 2012. The water points of

Ganvié and Houédo-Gbadji, areas highly polluted by human and animal activities (Kinsiclounon, 2009), would be the most concerned.

## CONCLUSION

The concentration in nitrate varies from a water point to another during each period and throughout the time. No improvement has been observed though this concentration only stayed below the norm at all the water points in 2009 as well as in 2012.

The concentration in nitrite, knew a significant overall increase between the two periods. As for total Iron, its concentration didn't vary globally over the period; but it remained beyond the norms required by the WHO.

The average concentration in ammonium increased appreciably from one period to the other. But in 2009 and 2012, the concentrations in ammonium of the private sinking and the stretches of water go beyond the norm fixed by the WHO statistically. However, it is important to note that the concentrations of all the water points and those of tap waters, those of stocked waters and those of the General Direction of Water Supply respect the norms.

The concentration in lead remained constant throughout the time. The norm is not respected concerning surface waters and the waters of the General Direction of Water Supply and Hydraulics.

The average concentration in cadmium grows significantly throughout the time. Between 2009 and 2012, the norm is respected with tap water and surface waters. But, it is not respected with stocked waters, with the waters of the General Direction of Water Supply and Hydraulics, and with private sinking waters.

It is evident from this study that the concentration of these poisonous substances did improve during the period of the study. The water from the sinking undergoes a very high level deterioration. The populations were exposed to enormous risks of contamination during at least four years. This poses a real public health problem. A rigorous follow-up every year turns out therefore to be necessary.

Facing such a reality, it is important to evaluate the poisonous effects of these substances on health and to define new policies of purification of the environment with the involvement of the populations themselves.

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