MERIT RESEARCH JOURNALS
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Merit Research Journal of Environmental Science and Toxicology Vol. 1(4) pp. 091-098, June, 2013
Available online http://www.meritresearchjournals.org/est/index.htm

Full Length Research Paper

Risks of contamination of drillings water with toxic metals accumulated in sediments of Nokoué Lake in Benin

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Accepted June 06, 2013

The present study aimed at understanding the connection between surface water, groundwater and heavy metal contamination. To achieve our goal, thirty samples of water collected from different water stations were analyzed for heavy metals at the toxicological laboratory of the national agricultural institute of Benin (INRAB). The results revealed a contamination of water samples with copper, zinc and nickel with concentrations lower than the safety limits by WHO which are respectively 3 mg/L, 5 mg/L and 0.05 mg/L. However, lead mean concentrations in stored and drilling water were above permissive value (0.04). In respect of cadmium, higher values were recorded in some drillings and surface waters. This may be due to the infiltration of heavy metals usually concentrated largely in sediments into drilling and groundwater. To face the challenge of public health problem posed by the contamination with heavy metals, it is important to implement new agricultural and sanitation policies

Keywords: Nokoué Lake, heavy metals, water, contamination

INTRODUCTION

All forms of life upon the earth depend upon water for their mere existence. Life and water may be aptly said to be two faces of the same coin. (Vyas *et al.,* 2007).

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Lakes and lagoons of African cities have been in last decades, exposed to serious pollution risks due to the growing number of inhabitants and to the intensification of industrial and art activities (Bawa et al., 2007). Heavy metals contamination in river is one of the major quality issues in many fast growing cities, because mainten-ance of water quality and sanitation infrastructure did not increased along with population and urbanization growth especially for the developing countries (Akoto *et al.,* 2008; Ahmad *et al.,* 2010). Trace metals enter in river from variety of sources; it be can be either natural or anthropogenic (Akoto *et al*., 2008). Main anthropogenic sources of heavy metal contamination are mining, disposal of untreated and partially treated effluents contain toxic metals, as well as metal chelates from different industries and indiscriminate use of heavy metal-containing fertilizer and pesticides in agricultural fields (Nouri *et al.,* 2008). Rivers in urban areas have also been associated with water quality problems because of the practice of discharging of untreated domestic and small scale industries into the water bodies which leads to the increase in the level of metals concentration in river water (Khadse *et al.,* 2008; Juang *et al.,* 2009; Sekabira *et al.,* 2010). Trace metal contaminations are important due to their potential toxicity for the environment and human beings (Gueu *et al.,* 2007; Lee *et al.,* 2007; Adams *et al.,* 2008; Vinodhini and Narayanan, 2008; Guedenon et al., 2011 and Guedenon et al., 2012). Although some of the metals like Cu, Fe, Ni and Zn are essential as micronutrients for the life processes in animals and plants, many other metals such as Cd and Pb have no known physiological activities (Kar *et al*., 2008; Suthar and Singh, 2008; Aktar *et al.,* 2010). Metals are non-degradable and can accumulate in the human body system, causing damage to nervous system and internal organs (Lee *et al.,* 2007; Lohani *et al.,* 2008). However, the rivers play a major role in assimilation or transporting municipal and industrial wastewater and runoff from agricultural and mining land (Singh *et al.,* 2004).

In Benin, Nokoué Lake is an important source of drinking water for a large population. Several varieties of effluents resulting from agricultural fields (Kaki et al, 2011) and from domestic and industrial activities of waterside cities, especially the city of Cotonou pour in Nokoué lake through runoff water (Kinsiclounon, 2008; Guedenon, 2011; Kaki et al., 2011). Nokoué Lake is also subjected to a hydrological dynamics characterized by contributions in salty water of the Atlantic Ocean and by contributions in fresh water of Ouémé River and Sô River (Boko, 2006). The present study aims at assessing the vulnerability of drilling waters to heavy metals pollution.

MATERIALS AND METHODS

Description of study area

Situated between 6°24 ' and 6°38 ' north latitude and 2°27 ' and 2°30 ' east longitude, the lake Nokoué is situated in the southeast of Benin in western Africa. It lies on a surface of 160 km2 (Figure 1). This surface can be even doubled or tripled during the rainy season (city hall of Sô-Ava, 2005). Figure 1 depicts the study area.

Method of sampling waters

Having identified the water sources (figure 1), the samplings of waters were done in July-August and November-December, 2008 which correspond respectively to the rainy season and to the dry season. It all included two series of different samplings.

Waters were sampled by means of sterile flasks in 2 litre plastic. Besides, the technique of sampling drillings water is the one used by Di Benedetto *et al.,* (1997).

It consists in allowing the water to flow for 10 minutes before sampling then continuing taking samples of the water (after having rinsed the bottle using the water to be sampled for 3 times) until the volume of the bottle was filled.

For surface waters, the samplings were made in a representative manner according to the technique of Di Benedetto et al., (1997). To identify the possible sources of pollution, the sampling was carried out at different levels: in the swamps, on the surface, in the middle and in depth of Nokoué lake and Sô river. 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 (Figure 1). Once the flasks 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. They were labelled and kept in a cool place at 4°C in a cooler containing some ice for laboratory analysis.

Heavy metals analysis

Heavy metals analysis was carried out with the help of Atomic absorption spectrophotometer by flame emission, ICP-AES by ICP-MS (Inductively Coupled Plasma - Mass Spectrometry) that has the advantage of a multi-elements analysis (Devez 2004). Water samplings were analyzed for lead, cadmium, zinc and iron at the laboratory of NRAB according to according to the guidelines of Anane et al. (1995) and Vaidya and Rantala (1996)

Statistical analysis

The statistical analysis of the data was carried out in two phases in order to compare the concentrations for various heavy metals regarding water sources, and to compare each of these concentrations with the safety values. To be able compare the various concentrations, we did the variance analysis test with a classification factor followed by the SCHÉFFÉ test of multiple-comparison in case when the conditions of normality and equality of the variance were respected. The non

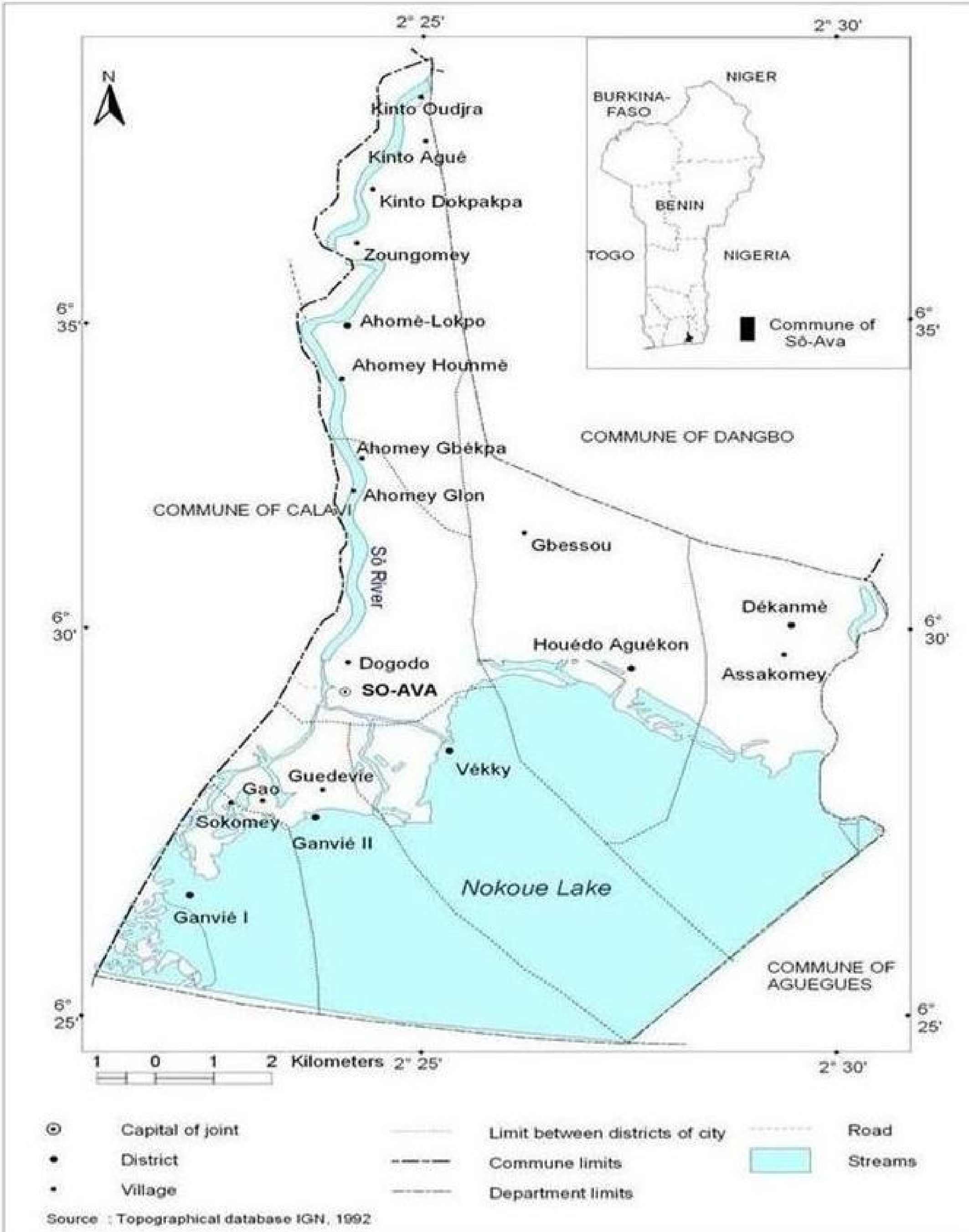

Figure 1. Geographical location of the commune Sô-Ava

parametric KRUSKAL WALLIS test was used in case the conditions were not respected even after the processing of variables.

As regards the standard values, the comparisons were done by the t student test in a sample if the normality condition was respected and by the WILCONSON test in a sample if the normality was not respected after processing of variables.

RESULTS

The results are presented by heavy metal.

Copper

The copper concentration varied from 0.002 to 5.987 mg/L

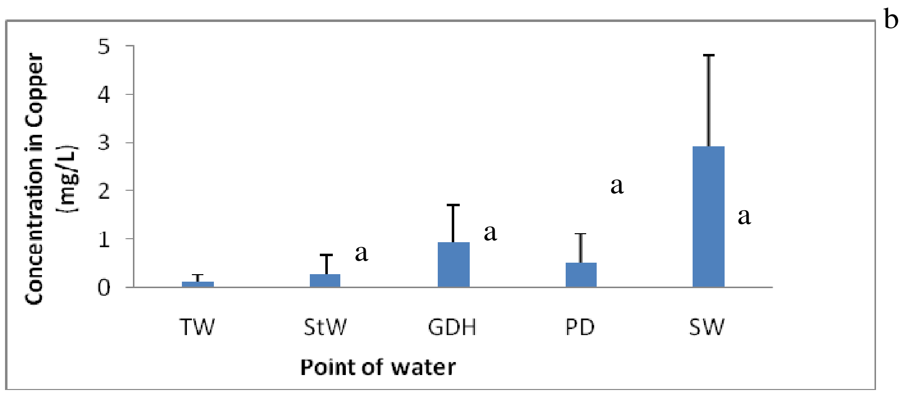

Figure 2. Copper concentrations according to water sources

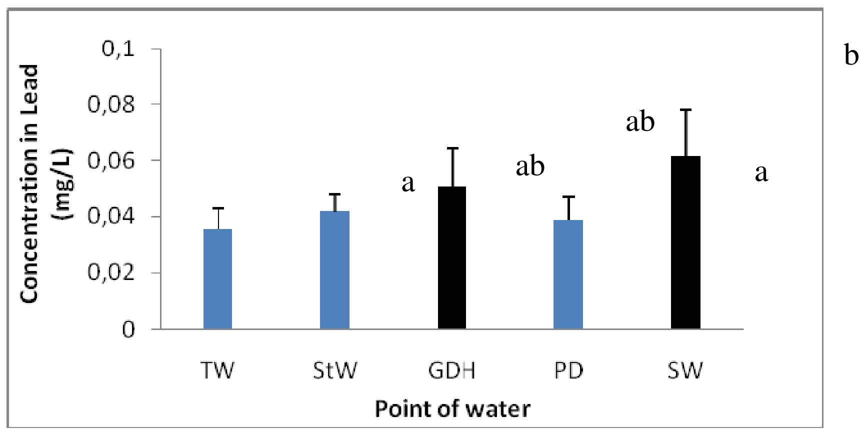

Figure 3. Lead concentrations according to water sources

with an average of 0.960 ± 1.282 mg / L. This concentration varied significantly from a water source to another (chi-squared by KRUSKAL-WALLIS = 17.83; p - value = 0.0013). the copper mean content was lower on average 0.12 ± 0.15 mg / L at the level of faucet and relatively high (2.94 ± 1.67 mg / L) at the level of the surface water. Except for surface waters which have rather high concentrations in copper, the other water sources had concentrations in copper which displayed no significant difference (Figure 2). The comparison of the different mean concentrations with the safety values showed that all the different concentrations were within permissive limits.

TW = taps water, StW = Stored water, GDH = General Direction of Hydraulic, PD = Private drilling, SW = Surface water.

Water sources having the same symbols a or b have no significant difference values. The bars coloured in black corresponds to the water sources which is significantly different from the permissive value.

Lead concentration varied from 0.03 to 0.08 mg/L with an average of 0.05 mg / L. It varied significantly from one water source to another (chi-squared by KRUSKAL-WALLIS = 12.48, p - value = 0.0140). The lowest value was recorded with tap waters (0.035 mg / L) while the highest value was recorded with surface waters (0.62 mg/L)

Except for surface waters which have a concentration significantly higher than lead concentrations in tap waters and some surface waters, all the concentrations are equal two-two (Figure 3).

Also it was observed that tap waters, storage, and private drilling had their concentrations in lead within the permissive limits. However, with regard to surface waters surface and water from general management, the recorded concentrations in lead were significantly higher than the permissive value

TW = taps water, StW = Stored water, GDH = General Direction of Hydraulic, PD = Private drilling, SW = Surface water.

Cadmium

The mean concentration in cadmium was of 0.012 ± 0,001 mg/L. The minimal concentration of cadmium

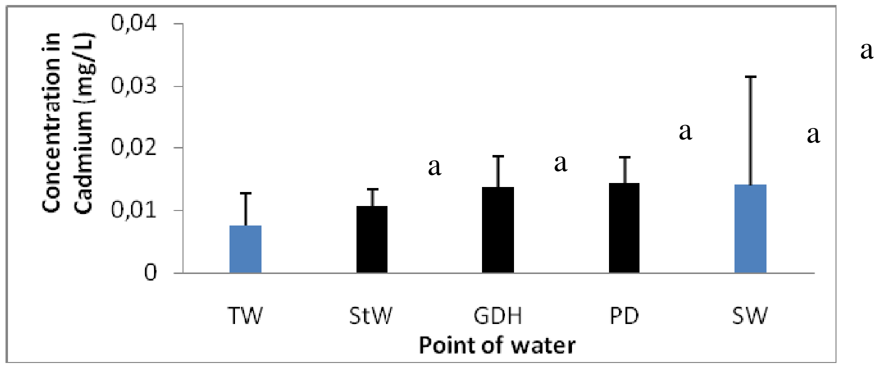

Figure 4. Cadmium concentrations according to water sources

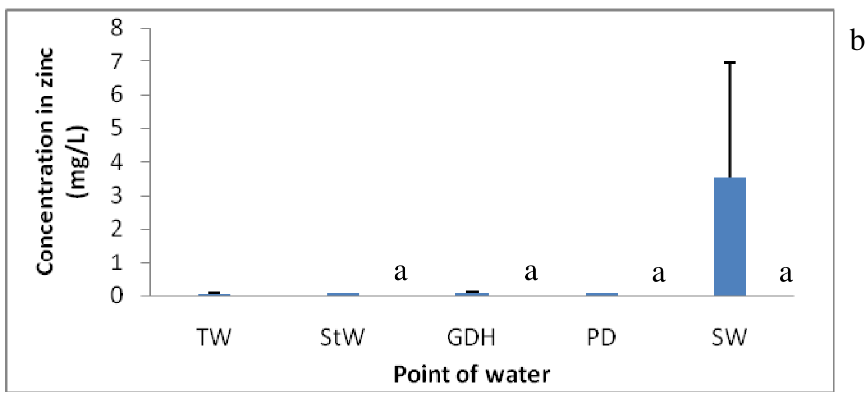

Figure 5. Zinc concentrations according to water sources

recorded was 0.001 mg/L and the maximal concentration was 0.045 mg / L. There is no significant difference among the difference sources of water (chi-squared by KRUSKAL-WALLIS = 7.36; p - value = 0.1181).

However, the lowest concentration in cadmium was registered with tap water (0.0076 mg / L) and the highest of 0.014 mg/L with surface and drillings waters (Figure 4). Besides, it was observed that apart from tap and surface waters whose values were within the permissive limits, all the other sources had concentrations in cadmium above the permissive limits.

TW = taps water, StW = Stored water, GDH = General Direction of Hydraulic, PD = Private drilling, SW = Surface water.

Water sources with the same symbols (a, b, etc.) have values statistically identical for the considered parameter. Black bars correspond to water sources which showed significant differences with the safety value.

The mean concentration of zinc was of 0.643±1.822 mg / L and varied from 0.024 mg / L to 8.134 mg / L. It varied significantly from one water source to another (chi-squared by KRUSKAL-WALLIS = 16.47; p - value = 0.0024). Concentration in zinc was high with surface waters when compared with the other water so-urces which had zinc concentrations statistically identical.

TW = taps water, StW = Stored water, GDH = General Direction of Hydraulic, PD = Private drilling, SW = Surfaces water.

Water sources with the same symbols (a, b, etc.) have average values statistically identical for the considered parameter. Black bars correspond to the water sources which have values significantly different from safety value.

Nickel

The mean concentration in nickel was of 0.031 ± 0,014 mg / L with a minimum of 0.009 mg / L and a maximum of 0.070 mg / L.

It was observed that the concentrations in nickel varied significantly from one water source to another (F = 6.53; p - value = 0.0010). The lowest nickel concentration was recorded with stored waters and the highest concentration was recorded with surface waters. Nickel mean concentration of surface waters was significantly different from those of tap and stored waters. There was no significant difference with the other sources of water in terms of nickel (Figure 5). However, the comparison of the mean concentrations of the different sources of water

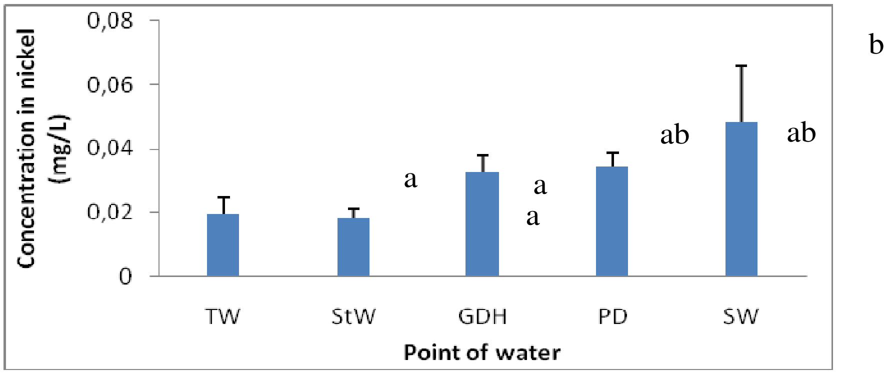

Figure 6. Nickel concentrations according to water sources

with the permissive value for nickel showed no significant difference.

Nickel

TW = taps water, StW = Stored water, GDH = General Direction of Hydraulic, PD = Private drilling, SW = Surfaces water.

Water sources with the same symbols (a, b, etc.) have average values statistically identical for the considered parameter. Black bars correspond to the water sources which have values significantly different from safety value.

RESULTS AND DISCUSSION

In the lakeside municipality of Sô-Ava, the drinking water is contaminated by heavy metals. It varies significantly from one metal to another and from one water source to another one. The levels of contamination complied with the standard of WHO in terms of copper, zinc and nickel, which were respectively 3 mg/L, 5 mg/L and 0.05 mg/L, whereas the content in lead at the level of the stored water, of the water of the Hydraulics main office and the surface water exceeded largely the safety limit by WHO (0.04 mg / L). With respect to cadmium, the recorded concentrations at the different sources were lower than WHO's safety value that is 0.005 mg/L. This contamination of water observed in the present study could be due to the infiltration of metals accumulated in sediments of Nokoué Lake.

Kaki *et al.,* (2011) and Guedenon *et al.,* (2012) proved that toxic metals contained in run off water coming from the agricultural regions in the North of Benin were accumulated in the sediments of lakes and rivers in Benin. According to those authors, the accumulated heavy metals in sediments could be released in waters when the physicochemical parameters change. Besides, Guedenon *et al*., (2011) and Aissi et al.(2012) reported the different factors at the origin of water contamination including: fraudulent traffic of petroleum products, daily dumping of acadja boughs, domestic and biomedical garbage dumps in border of the stretch of water, discharges of waste waters and effluents from the city of Cotonou without any preliminary processing, infiltration of Ouémé river charged with residues of pesticides, discharges of feces and droppings and the discharges of household waste by the lakeside populations.

Results from our previous works were similar to those reported in the present study. Actually Kinsiclounon (2009) showed that at Sô-Ava, run off water transports the agricultural residues from north to south of Benin to contaminate the lake Nokoué. And by infiltration the drinking water is contaminated by organic and chemical matters (Kinsiclounon, 2011) by total Coliformes, feces Coliformes of Escherichia coli, Clostridium perfringens and by pathogenic germs as Staphylococci, Salmonellas and Shigella. According to the latter, factors favoring this contamination were many and were especially connected to the conditions of hygiene and of purification of the environment (Kinsiclounon, 2012).

Results of the study by N' Fally (1997) could explain the present phenomena in our study. According to him, several substances contribute to the pollution of Sô river and of Nokoué lake and therefore drinking water including feces, household waste, waste water, pesticides and heavy metals playing an essential role in the construction of drillings or contained in waste stemming from fires (Dovonon, 2008).

The mudding and the filling of Nokoué lake had been demonstrated by Agassounon (1998) and Guillard (1906). According to Agassounon, these phenomena were due to the modification of the vegetation in the lakeside cities from 5900 to 5500 years BP, which passed from a forest surface to a prairie plant cover. Guillard specified that the depth of Nokoué lake did not exceed 1,70 m, and nevertheless a few years ago this lake was accessible to ships of open sea by 1810 (Chantard, 1890).

The alluvial deposits, particularly those of Sô river, of Ouémé River and the runoff water would explain this decrease of depth of the lake. Except for these elements, the lake was overloaded by organic matters with the excessive presence akadja parks made by boughs which decompose easily (palm tree leaves). The accelerated accumulation of household waste of the lakeside villages and water hyacinth during the ebb, marked by a very high rate of salinity of the lake was added to these elements. The hyacinths of water accumulated organic matters and toxic metals (Boko, 2006). The periodic intervention of the salt water destroyed these vegetables which thus contribute to the auto-filling and to the auto-pollution.

The filling of the lake was also accelerated by the erosion of the empty plateau by the taking flavours adapted to akadja such as *Dialium guineensis, Blighia sapida, leucaniodiscus cupanoides and Rauvolfia vonitaria* (Clédjo and Boko, 1999). Our observations justify themselves well because the general report of the orientation plan between 1998-2002 realized by the Beninese Ministry of the Economic Restructuring and the Employment Promotion Plan (BMEREP, 1999), had shown that the surface of the lake would have changed from 160 km^2 to 138 km^2, thus a decrease of 22 km^2.

Our results were identical to those of Boko (2006) and those of Guedenon (2011). According to these authors, the demographic growth and the industrial development of cities as Cotonou were the main causes of chemical, organic and toxicological pollution of the lakes in Benin. The pollution of the lake was caused on one hand by runoff water Sô river and Ouémé river (sub-tributaries) which sweep all the pouring ponds and which were soiled by fertilizers and pesticides used for the cotton culture upstream, by different salts deposited during diminution and transported during high tides and especially by the industrial or traditional production discharges of Cotonou on one hand and cities and peripheral villages on the other hand.

Our results were close to results of analyses registered after the mass death of fishes such as Tilapias, Chrysichthys, Mules, Elops, Ethmaloses etc. of the Nokoué lake in May, 1998. It emerged that the measures of the quality of the water made in about ten stations indicated extremely low rates of oxygen. This suggested that in this precise period of the year, Nokoué lake accumulates all the conditions of a low quality of oxygen for fishes (Lalèyè, 1998). The lethal effect of the low contents in dissolved oxygen seems catalyzed by the presence of extremely dangerous toxic matter for fishes such as ammonia and toxic metals (Arrignon, 1976).

Also, Forstner and Wittmann (1979) had already demonstrated that the presence of heavy metals in the environment is due to the anthropological and natural activities. The same observation was done by Nriagu (1989), Veena et al (1997), Sokolowska (1996) and Zerbe et al. (1998) who reported that run off waters charged with metals are rejected in streams to accumulate in sediments. The accumulation of toxic metals in certain species of fishes of lakes (Guedenon, 2012) confirms our results. This accumulation depends on the nature of the sediment (Kaki, 2011): copper, zinc, nickel, cadmium and lead accumulate differently in sediments of the lake (Pazou and Boko, 2006).

This could justify the variation of contamination registered from one metal to another and from one water source to another. Our results were similar to those obtained by Ellégbédé (2011) at Kérou. According to the latter, most of the drillings situated in cotton fields are strongly anthropologic, contaminated by copper, lead, cadmium, zinc, nickel and iron. This contamination is caused either by fertilizers used in cotton fields or by infiltration of human and animal organic matters. Copper, zinc and nickel concentrations reported by Ellégbédé are similar to our values and to those of Galdes and Valloe (1983) in respect of zinc. As for lead and for cadmium, they are found, the same as in Sô-Ava, in most of the drillings situated in cotton fields in Kerou. Our results confirm the researches of Feuillade et al who indicate that these discharges release the leachates rich in lead and in cadmium. Although the water of the drillings which was analyzed at Sô-Ava was far from cotton fields contrary to the works of Ellégbédé, our observations are similar. This highlighted the relation between the surface water and the groundwater then the relation between the source and the site of pollution.

CONCLUSION

In the lakeside municipality of Sô-Ava, the drinking water is contaminated by heavy metals. This contamination varies from one water source to another and depends on some metal. The levels of certain metals comply with the standard of WHO while the rate of the lead and that of the cadmium exceed the accepted standard. This contamination would be due to the infiltration of toxic metals accumulated in sediments of Nokoué Lake

This situation which joins well within the framework of the public health is very disturbing with regard to sanitary disorders which these metals could cause to humanity. The pollution of surface water by heavy metals due to the anthropological activities contaminates the groundwater with risks of lethal pathologies for human beings who are themselves origin of this pollution.

This study showed that the drillings, can be contaminated by toxic metals even situated far from the agricultural fields or wild garbage dumps. This highlights the relation between the surface water and the groundwater.

This research allows us to ring the alarm bell about the risk of poisoning with lead and the spherical renal diseases which press on the population in this study area. It also allows the authorities in charge with agriculture and the purification to take into account the phenomenon of pollutions of lakes by toxic metals for the manufacturing or the import of the agricultural inputs. The ideal scenario would be to take into account the content of these substances in the manufacturing or the choice of fertilizers and some pesticides used in cotton fields in Benin in order to decrease the contamination of subterranean waters.

It is also important for these authorities to seek revision of their policy of hygiene and purification adapted to the geographical situation of the environment at different levels, with the cooperation of the population.

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