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SURVEY OF THE QUALITY PHYSICAL, CHEMICAL AND BACTERIOLOGICAL OF THE UNDERGROUND WATERS OF THE CONTINENTAL TERMINAL OF THE TOWNSHIP OF ABOMEY-CALAVI (BENIN)

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ABSTRACT: *Campaigns of withdrawal of the underground waters have been done during the year 2013 to the level of the boring situated in the township of Abomey-Calavi, to control their quality. These withdrawals were the object of analysis according to the techniques of assessment of water quality described by Rodier (1978) and to the recommendations of the world organization of health (WHO). The physical and chemical analysis showed that 98.7% of the studied boring present some concentrations superior to the norms recommended by the WHO (1994) and by Benin (2011). The studied boring present without exception a bacteriological pollution. The very elevated microbial germ presence in water could constitute a sanitary risk importing for the inhabitants who consume the water of these boring.*

KEYWORDS: Underground Water, Quality, Boring, Physical, Chemical, Bacteriological.

INTRODUCTION

Water is an indispensable element for life and for the real and lasting socio-economic development of a country, it is therefore necessary to have a better knowledge on resources in water exist the information concerning especially:

The vulnerability of resources to a possible factor,

The necessary measures to develop, to manage and to protect resources.

In Benin the underground waters constitute a part important of the hydraulic heritage of the country, because of its relatively easy exploitation. The underground waters are traditionally resources in water privileged for the drinking water, because more safe from the pollutants that the waters of surface (Guergazi and al, 2005). In the targeted region, the underground waters were always a source important of provision in drinking water for the local populations and, for the watering of the animals and for the irrigation. The boring are the sources of most drinkable waters in farming environment of the township. The National Society of the Waters of Benin (SONEB) to achieved in the precinct of Godomey of the township of Abomey-Calavi; of the boring to leave of which it exploits intensively the underground waters of the continental terminal that it treats to nourish in drinking waters the urban populations of the township of Abomey-Calavi; the whole population of Cotonou, biggest city of the country and to nourish in drinking waters the population of the city of Sèmè. However the food quality of water represents a growing preoccupation. The challenge to which copes all regions of Benin and particularly the farming zones are the protection of the quality of resources in underground water. Indeed, the underground water pollution represents one of the most troubling aspects and the use of these waters at food ends represents a danger for health (Laferriere and al, 1996). The present work is interested in the survey of the physical, chemical and bacteriological quality of the

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underground waters of the watertable of the continental terminal in the Township of Abomey-Calavi.

MATERIAL AND METHOD

Sampling

Every drill existing in the township of Abomey-Calavi before the launching of this survey in January 2013 have been sampled to have a general picture of table water of the continental terminal. We did to the total seventy seven withdrawals to the level of seventy seven boring for the physico-chemical analysis. For the bacteriological analyses we have ourselves sampled nine boring at the rate of a boring by precinct of the township.

Region of Survey

The township of Abomey-Calavi counts seventy (70) villages and districts of cities distributed on nine (09) precincts that are: Calavi-Centre, Godomey, Akassato, Zinvié, Ouèdo, Togba, Hêvié, Kpanroun and Golo-Djigbé. The township of Abomey-Calavi, situated in the South part of Republic of Benin and the Department of the Atlantic, is limited at the North by the township of Zè, to the South by the Atlantic Ocean, to the East by the townships of Sô-Ava and Cotonou and to the west by the townships of Tori-Bossito and Ouidah. It is the vast township of the department of the Atlantic of which it occupies more than 20% of the surface. It spreads on a surface of 536km² representative 0.48% of the national surface of Benin. The township of Abomey-Calavi is very close to the biggest plan of water Beninese lagoon: The Nokoué lake. Indeed, Long of 20km (East-west) and large of 11km (North - South), the Nokoué lake has a surface of low water of about 160km^2 and represent the largest plan of water Beninese and most important lagoon of the point of view of its planning because of its proximity with the city of Cotonou. The Nokoué lake influences the underground water pollution considerably close to him (HOUNSINOU, 2012).

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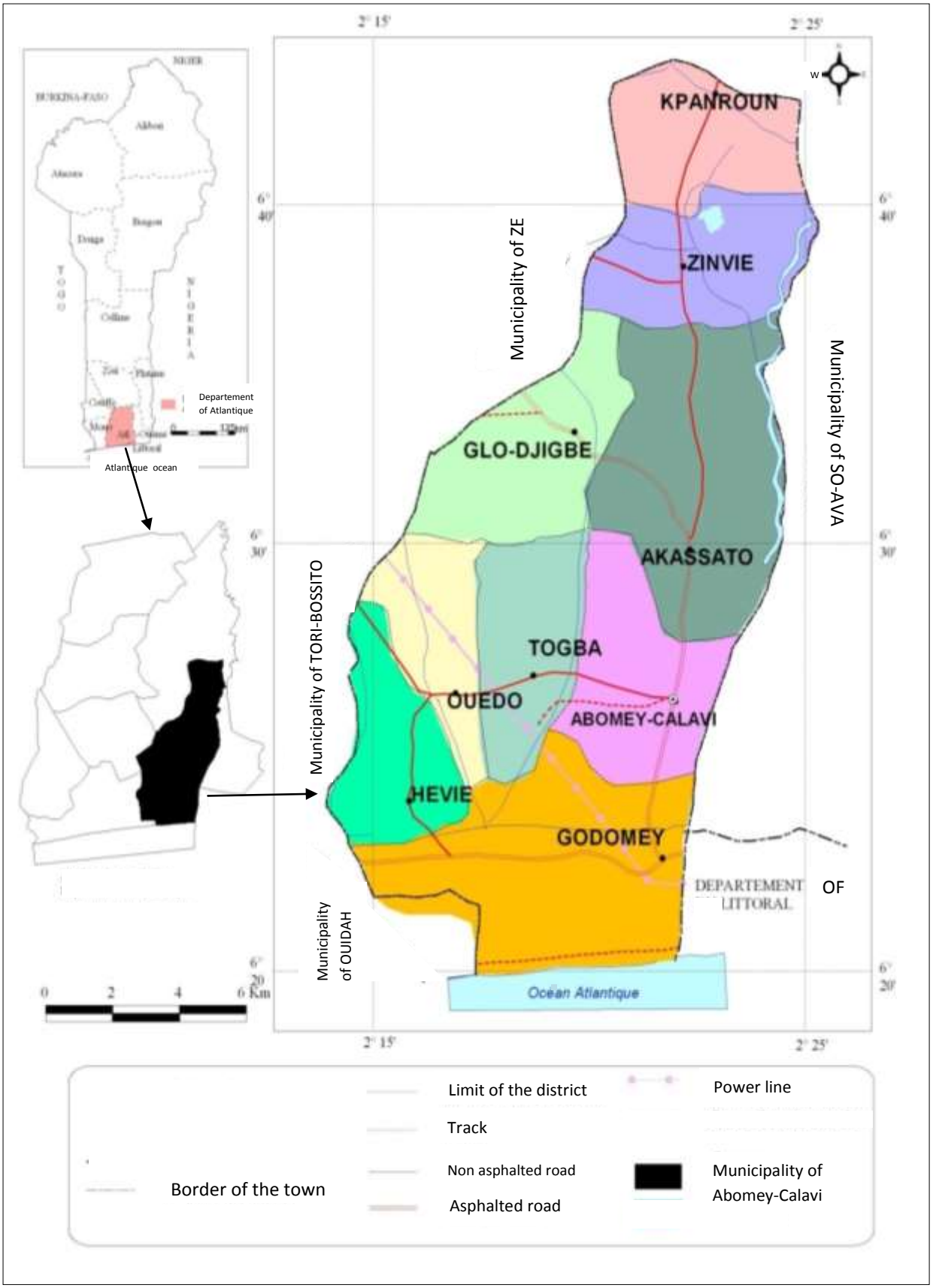

Pic 1: Location of the municipality of Abomey-Calavi

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Physical and Chemical Parameters Analyzed

The survey has been led on seventy seven samples of water coming from the seventy seven boring in the township of Abomey-Calavi. The withdrawals of the samples for the physical and chemical analysis have been put in small bottles in plastic then routed to the laboratory for the analysis. The physical and chemical analyses concerned the parameters following: TDS, color, toughness, pH, electric Conductivity, temperature, alkalinity, calcium, magnesium, total iron, ammonium, carbonate, chloride, sulphate, nitrate, nitrite, phosphate, turbidity, fluoride, iodide…

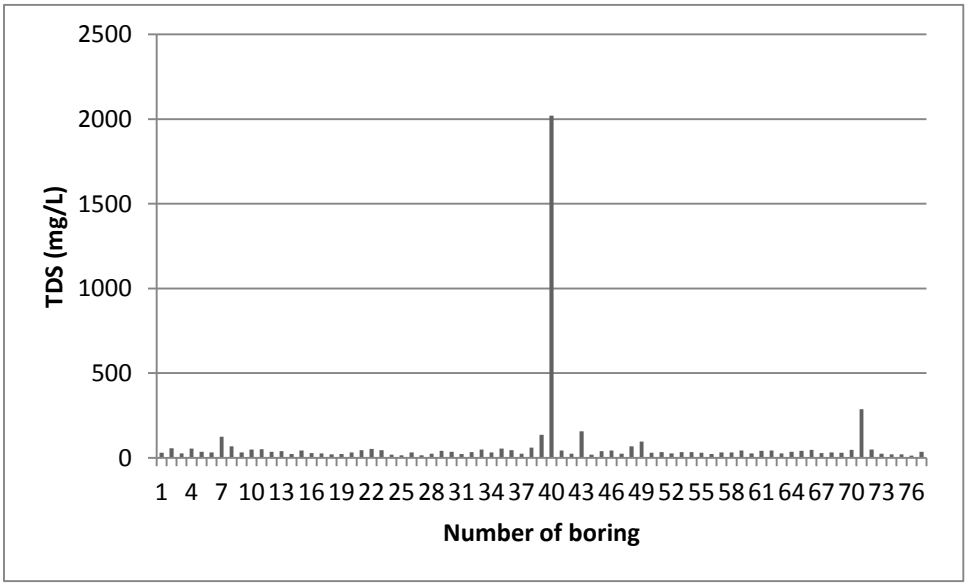
Microbiological Analyses

We did during our work searches for it of the indicatory germs of pollution next one: The total coliforms; the coliforms thermotolerants and the intestinal enterococci.

RESULTS AND DISCUSSION

Physical and Chemical Quality of Water

TDS: It is essentially about the strong minerals in water: calcium, magnesium, sodium, bicarbonates, chlorides and sulphates; they confer to water its taste (DEGBEY, 2002). The TDS informs on the mineralization of a water. The saltiness of waters can also be represented by the TDS that corresponds to the sum of the concentrations of the major chemical elements (Ca, Na, Mg, K, Cl, SO_4, NO_3, and HCO3) (GOMEZ, 2009). In the case of the survey region, the TDS of the waters of the tablecloth of the continental terminal varies a 13 mg/L, in the boring F_{76}; to 2,020 mg/L, in the boring F_{40} (picture2). It is to note that the value of the TDS of the waters of F_{40} boring is extensively superior to those of the other boring waters.



Picture2: Variation spatial of the values of the TDS.

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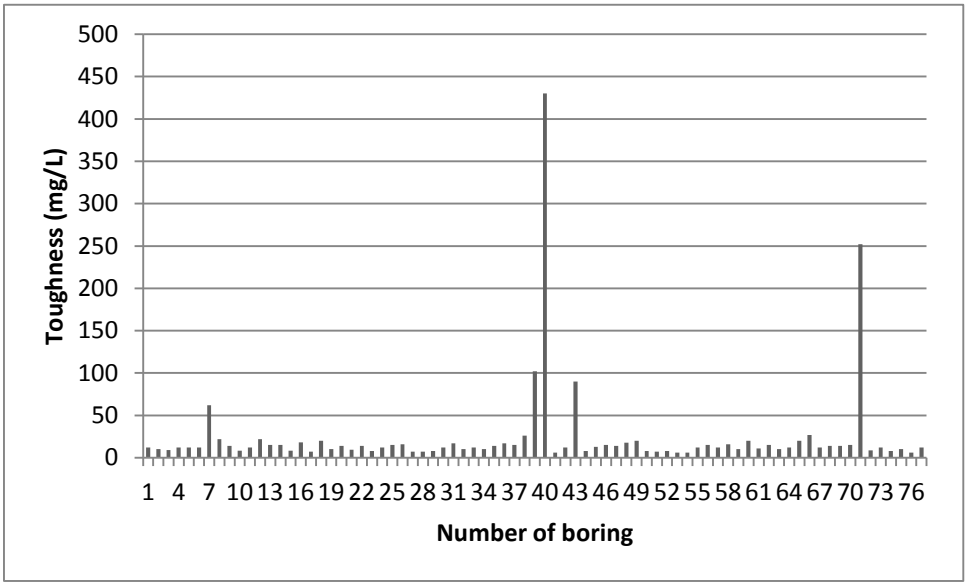
The Toughness

The total toughness of a water is produced by the salts of calcium and magnesium that it contains. One distinguishes: a toughness carbonated that corresponds to the content in carbonates and bicarbonates of that and Mg and a toughness non-carbonated produced by the other salts. The toughness is measured by the title hardness expressed in °F (French degree); 1°F correspond to 10 mg of Calcium carbonate in 1 liter of water. It results mainly from the contact of the underground waters with the rocky formations: The calcium drifts of the attack of the CO_2 dissolves by the chalky rocks (dolomites) or of the dissolution under shape of sulphate in gypsum. The toughness of a natural water depends on the geological structure of soils crossed. In the analyzed samples (picture 3), this parameter presents a big variation of a boring to the one that would be bound of the geological formation of the watertable and in particular to his composition in magnesium and in calcium (BELGHITI and al, 2013). The toughness of the survey zone varies 6mg/L, in the boring F_{41}, F_{53} and F_{76} to 430mg/L, in the boring F_{40}. According to the Beninese legislation, the toughness of a water destined to the consumption must pass 200mg/L (decree n° 2001-094 of February 20th, 2011). The toughness of all waters sampled is compliant to the norms of Benin accept the boring F_{40} and the boring F_{71}.



Picture3: Spatial variation of the values of the total toughness.

PH: This parameter measures the acidity or the alkalinity of a water. It translates the balance thus between acid and basis on a scale of 0 to 14, 7 being the pH of neutrality to 25°C. This parameter characterizes a big physical and chemical balance number and depends on multiple factors, of which the origin of water. The natural water pH is bound to the nature of rocks crossings. In most natural waters, of the pH is consisted usually between 6 and 8.5 whereas in the tepid waters, this one is understood between 5 and 9 (HCEFLCD, 2007). The values of pH admitted for a drinking water by the WHO are consisted between 6.5 and 8.5. In the case of the survey region, the values of the pH of the waters of the tablecloth of the continental terminal show sensitive variations, with a minimum of 4.12 to the boring F_{51} and a maximum of 7.67 in the boring F_{40} (picture 4). 92.20% of the pH measured are lower to the lower value admitted by the WHO for a drinking water. This acidity of the waters of the tablecloth is probably owed to soil.

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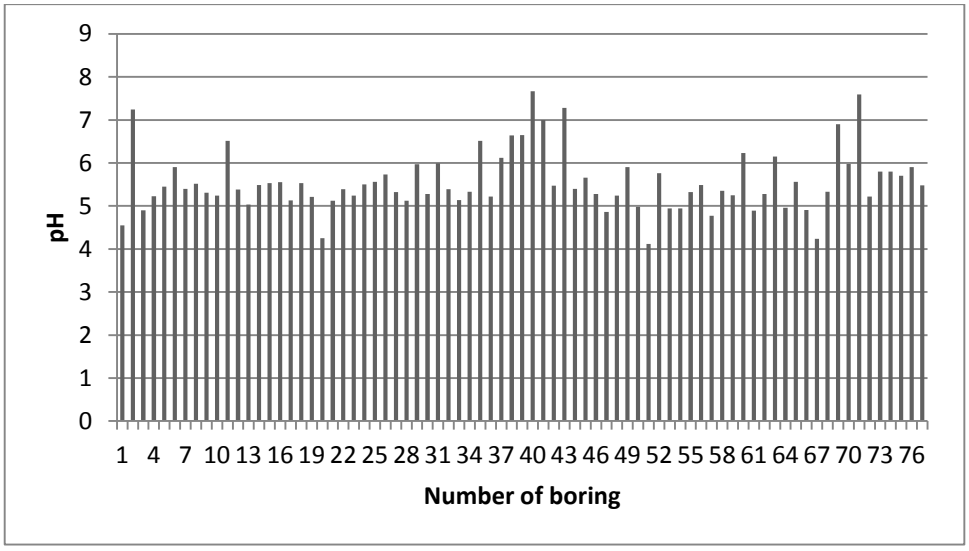
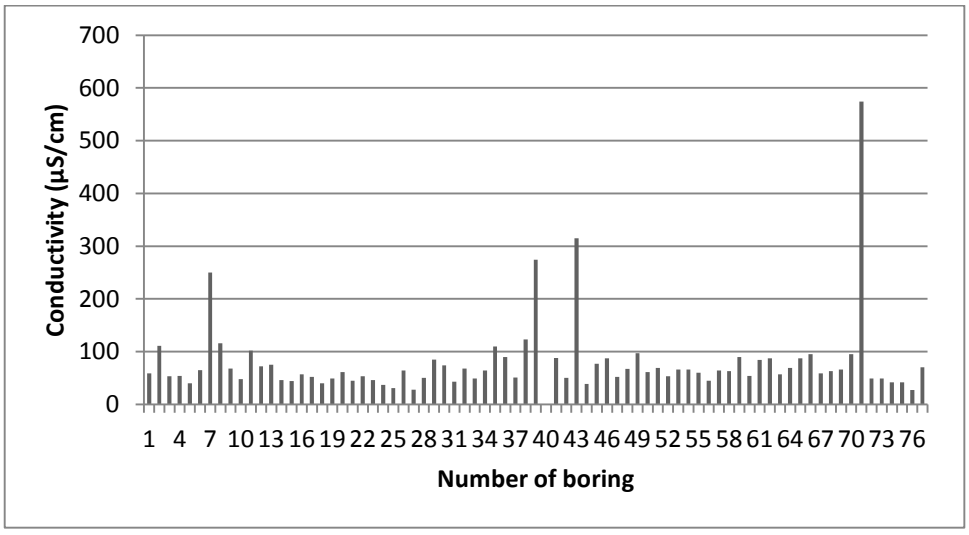


Picture4: Spatial variation of the pH values.

Conductivity

Conductivity measures the capacity of water to drive the current between two electrodes. Most matters dissolved in water are under shape of ions. The measure of the conductivity permits to appreciate the quantity of salt dissolved therefore. The electric conductivity depends on loads of endogenous and exogenous organic matter, generating of salts after decomposition and mineralization and also with the phenomenon of evaporation that concentrates these salts in water, it varies as according to the crossed geological substratum. In the case of the survey region, the values of the electric conductivity of the waters of the tablecloth of the continental terminal show sensitive variations, with a minimum of 27µS/cm to the boring F_{76} and a maximum of 574µS/cm in the boring F_{71} (picture5). The values of the conductivity of the waters of the tablecloth of the continental terminal of the township of Abomey-Calavi are compliant to the norms of the WHO and Benin according to which the admissible maximal value of the conductivity of the drinking water is of 2,000 µS/cms.



Picture5: Spatial variation of the values of the electric conductivity.

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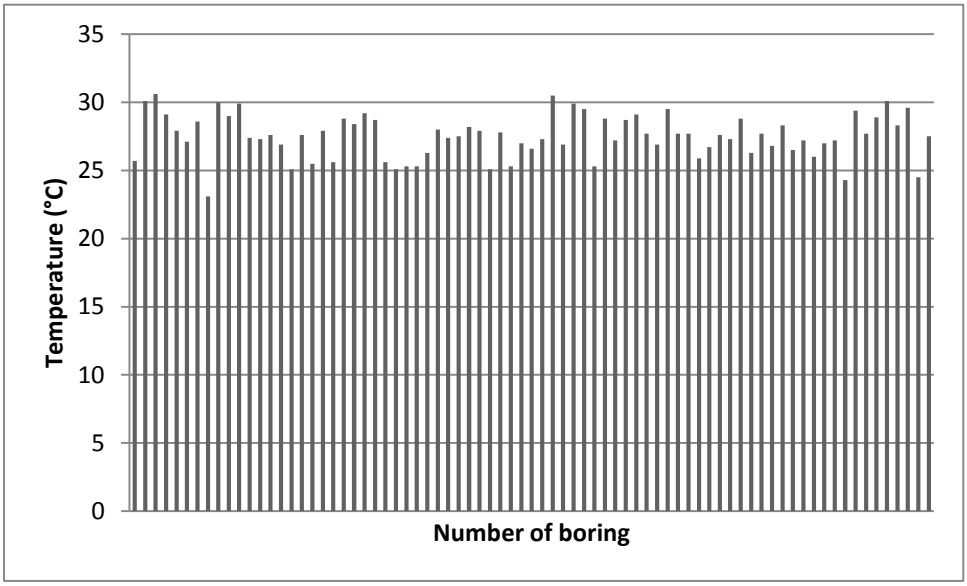
Temperature

The temperature plays a role in the solubility of salts and especially of gases, in the dissociation of salts dissolved therefore on the electric conductivity, in the determination of the pH, for the knowledge of the origin of water and eventual miscellanies. The temperature of waters is influenced strongly by the environmental conditions bound to the geographical position of the locality, to the geology of the lands crossed, to the hydrology and especially to the climate (Fall, 2007). The temperature of water is an important factor in the biologic production. It comes because it affects the physical and chemical properties of this one; in particular its density, its viscosity, the solubility of its gases (notably the one of the oxygen) and the chemical and biochemical reaction speed (HCEFLCD, 2006). In the region of survey, the gotten results show that the temperature doesn't present big variations of a boring to the other (picture6), with a minimum of 23.1°C (boring F_8) and a maximum of 30.6°C (boring F_3).



Picture6: Spatial variation of the values of the temperature.

Turbidity

The turbidity translates the presence of particles in abeyance in water (organic remnant, clays, microscopic organisms…). A strong turbidity can allow microorganisms to set on particles in abeyance. When the turbidity is lower in 5 FNU, water is lucid. When it is understood between 5 and 30 FNU, water is slightly troubled and when the turbidity is superior to 50 FNU, water is troubled (GOMEZ, 2009). When the turbidity is raised, water is colored. According to the norms of Benin of February 20th, 2011, the turbidity of a water destined to the consumption must be lower or equal in 5 FNU. In the region of survey, the gotten results show that the present turbidity of big variations of a boring to the other (picture 7), with a minimum of 0 FNU (boring F_4, F_{10}, F_{14}, F_{22}, F_{23}, F_{25}, F_{28}, F_{29}, F_{37}, F_{52}, F_{68} and F_{69}) and a maximum of 64 FNU (boring F_{38}). 50.64% of waters analyzed have a turbidity compliant to the norms of Benin.

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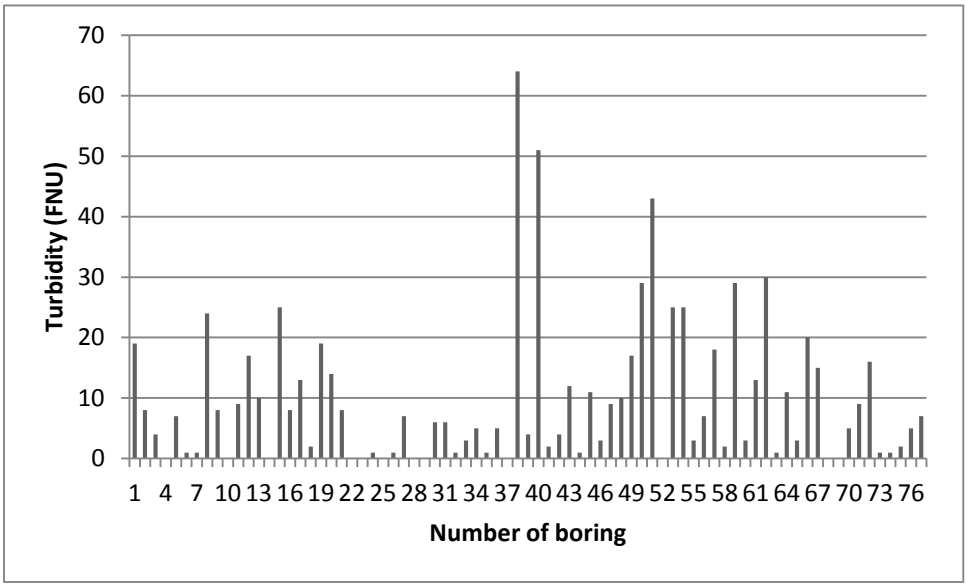
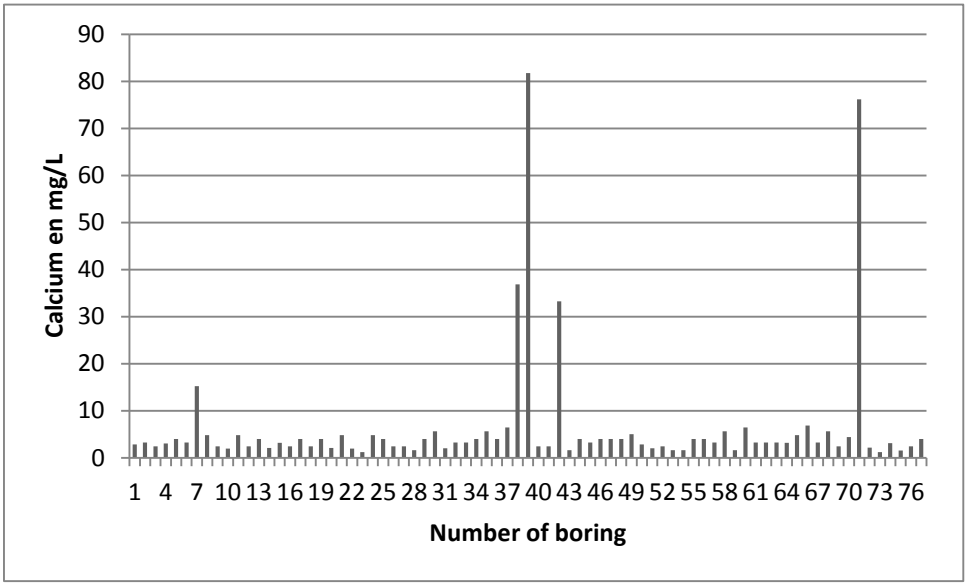


Picture8: Spatial variation of the values of the turbidity

Calcium

It is a major component of the water toughness. The calcium is generally the dominant element of the drinking waters (Fall, 2007). The maximal value of the calcium in a drinking water according to the WHO is of 400mg/L. In the region of survey, the gotten results show that the concentration in calcium presents big variations of a boring to the other (picture 9), with a minimum of 1.2mg/L (boring F8) and a maximum of 81.76 mg/L (boring F_3).



Picture9: Spatial variation of the concentration in calcium

Magnesium: (Mg2+)

Magnesium constitutes a major element in the toughness of water and its content depends on the sedimentary rock composition (Fall, 2007). The maximal value of magnesium in a drinking water according to the WHO is of 50mg/L. In the region of survey, the gotten results show that

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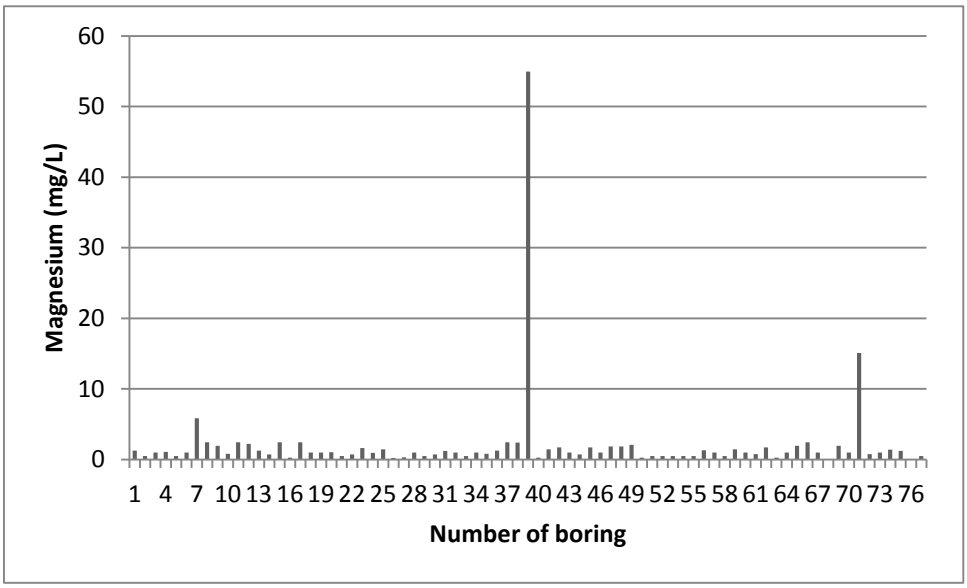
the concentration in magnesium varies from a boring to the other (picture10), with a minimum of 0mg/L (boring F_{68} and F_{76}) and a maximum of 54.96 (boring F_{39}). Only the water of the F_{39} boring has a concentration in magnesium superior to the admissible maximal value of the WHO for a drinking water.



Picture10: Spatial variation of the concentration in magnesium

Iron: ($Fe^{2+/3+}$)

The presence of iron in the underground waters has multiple origins: Iron, under shape of pyrites (FeS_2), is associated fluently to the rock sedimentary put down in reducing environment (marls, clays) and to the metamorphic rocks. It often meets to strong concentrations in the waters of the breastplates of pedestal change. Present, under reduced shape (Fe^{2+}), iron is oxidized by the oxygen of air and hurl down under ferric shape when water is pumped. Iron is soluble to the state of Fe^{2+} ion (ferrous ion) but insoluble in the Fe^{3+} state (ferric ion). The value of the potential of oxidation-reduction of the middle conditions its solubility and the content of water made of iron therefore. The captive tablecloths isolated of the exchanges with the surface are in reducing conditions: their water is ferruginous. This dissolved iron hurls down in middle oxidizing, in particular to the level of the sources and to the exit of the conducts. The presence of iron in water can encourage the proliferation of some stumps of bacteria that hurl down the iron where corrodes the pipelines. The maximal value of total iron in a drinking water according to the WHO is of 0.2mg/L. The contents made of total iron in the region of survey vary 0mg/l (boring F_{16}, F_{24}, F_{29}, F_{34}, F_{58}, F_{68} and F_{69}) to 2.45 mg/l (boring F_{49}) (picture 11). 79.22% of the studied boring waters have a concentration made of total iron compliant to the norms of the WHO for a drinking water.

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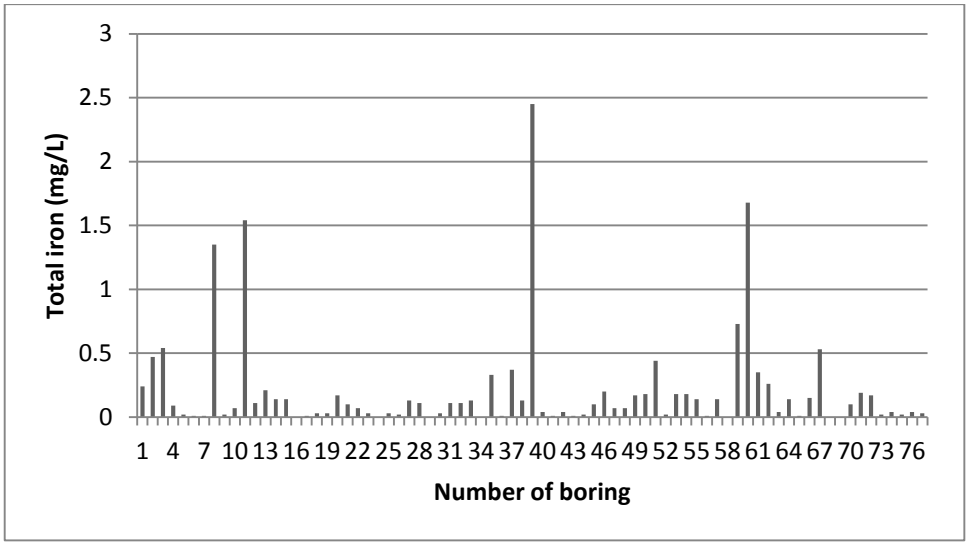
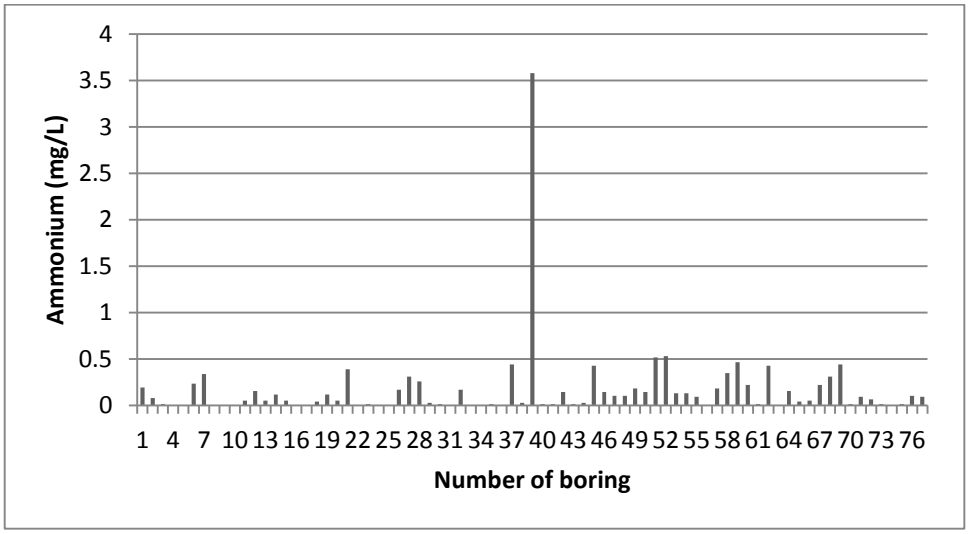


Picture11: Spatial variation of the concentrations in ions ammonium.

Ions Ammonium: (NH_4^+)

Ions ammonium constitutes the first element in the mineralization of the organic matter in nitrates. The maximal value of ammonium in a drinking water according to the WHO is of 0.5mg/L. In the region of survey, the gotten results show that the concentration in ammonium varies appreciably from a boring to the other (picture 12), with a minimum of 0mg/L (boring F_4, F_5, F_8, F_9, F_{10}, F_{16}, F_{17}, F_{22}, F_{24}, F_{25}, F_{31}, F_{33}, F_{34}, F_{36}, F_{56}, F_{63} and F_{74}) and a maximum of 3.5798mg/L (F_{39} boring). 98.7% of the studied boring waters have a concentration in ammonium compliant to the norms of the WHO for a drinking water.



Picture12: Spatial variation of the ions ammonium values

Bicarbonate: ($HCO3^-$)

This element, for which no value of reference is defined, is present in all waters to considerable contents. Their meaningful presence in the wells and relatively important in the boring is a characteristic of the underground waters of the regions of the pedestal of Africa (Collective, 1984; CEFIGRE, 1985; OGA, 2009). In the region of survey, the gotten results

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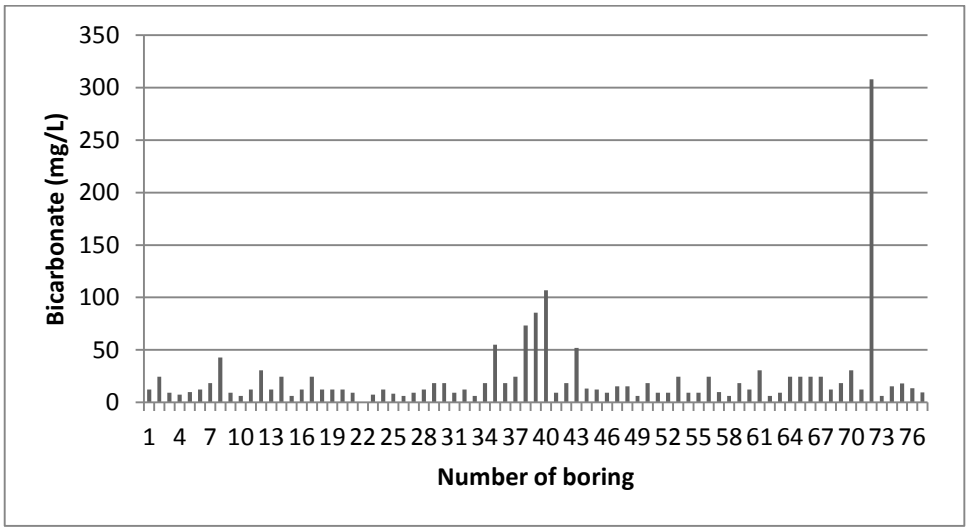
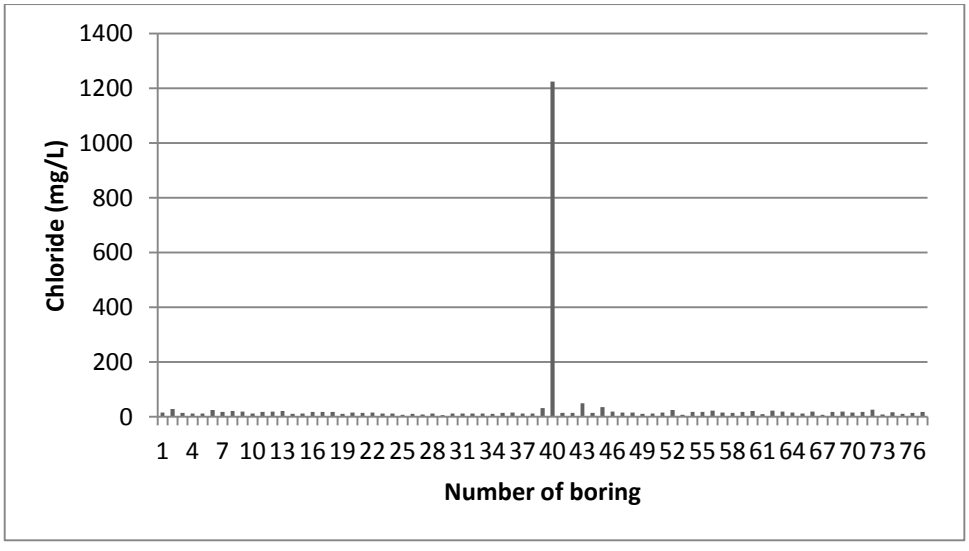
show sensitive variations of a boring to the other (picture 13), with a minimum of 0.1 mg/L (boring F_{22}) and a maximum of 308.05mg/L (boring F_{72}).



Picture13: Spatial variation of the values of carbonates.

Chloride: (Cl^-)

The origin of the ions chlorides in the underground waters can be bound to the geological formations. They can be also of organic origin. The nitrogenous pollution of organic origin is often accompanied by a pollution by the ions chlorides. The abundance of the ions chlorides in waters can be due to the activity natural of the plant table setting (YAO, 2009). The maximal value of the ions chlorides in a drinking water according to the WHO is of 250mg/L. In the region of survey, the gotten results show that the contents of waters analyzed vary slightly for 76 boring (picture 14), with a minimum of 6.65mg/L (boring F_{29}) and a maximum of 35,5mg/L (boring F_{45}). The content in chloride of the waters of the boring F_{40} (1,224.8mg/L) is extensively superior to the one of the other boring. The waters of the boring F_{40} are the only boring of the survey zone of which the concentration in ions chloride is not compliant to the norms of the WHO for a drinking water.



Picture14: Spatial variation of the values of the chlorides.

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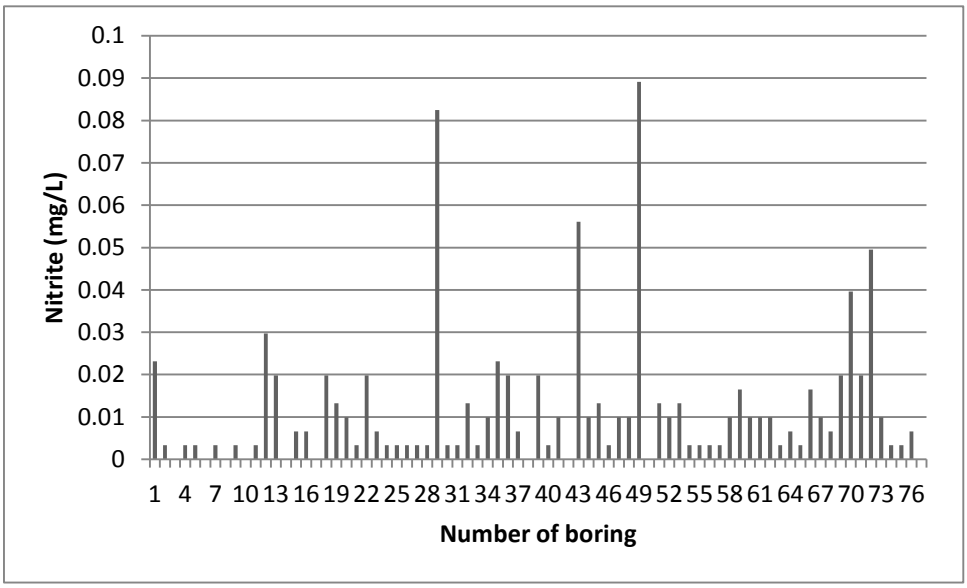
Nitrite: ($NO2^-$)

The nitrites form themselves from a reduction of the nitrates or from an incomplete oxidization of ammonium (SIAEPF, 2010). The underground water contamination by the nitrates can be caused by the spreaing of manure, of chemical manures, or the domestic strong garbage or by the septic facilities. These products free the nitrates that infiltrate in this one with reactions of decomposition in nitrites to the contact of soil. These nitrites, evolve to reach the tablecloths of underground water (KAKPO, 2008). The strong contents correspond to the reduction of the nitrates in nitrites by the anaerobic sulfito-reducing. They can also be bound to the bacterial oxidization of ammonia (Bengoumi and al., 2004). The maximal value of nitrite in a drinking water according to the WHO is of 0.1mg/L. In the region of survey, the gotten results show that the concentration in nitrite varies appreciably from a boring to the other (picture15), with a minimum of 0mg/L (boring F_3, F_6, F_8, F_{10}, F_{14}, F_{17}, F_{38}, F_{42}, F_{50}, and F_{77}) and a maximum of 0.0891mg/L (boring F_{49}). All studied boring waters have a concentration in ammonium compliant to the norms of the WHO for a drinking water.



Picture15: Spatial variation of the values of the nitrites.

Phosphate

The maximal value of phosphate in a drinking water according to the WHO is of 5mg/L. In the region of survey, the gotten results show that the concentration in phosphate varies appreciably from a boring to the other (picture 16), with a minimum of 0.01mg/L (boring F_{53}) and a maximum of 3mg/L (boring F_{30}). All studied boring waters have a concentration in phosphate compliant to the norms of the WHO for a drinking water.

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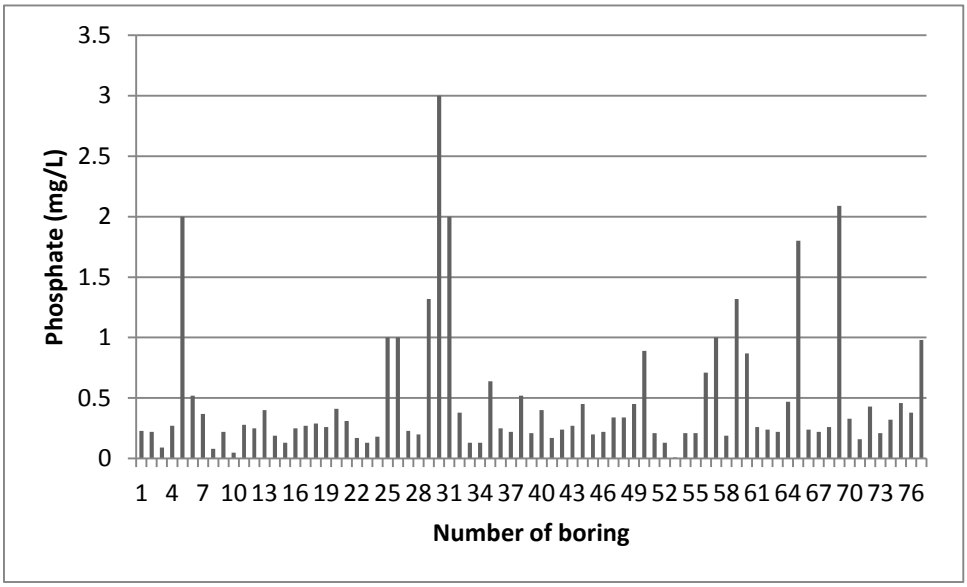

Picture16: Spatial variation of the values of the phosphates.

Ions Fluorides: (F^-)

The main sources of fluorine in the underground waters are the sedimentary rocks but also the rocks magmatic and some veins. The zones of water cures are also concerned. Fluorine in moderate concentration can have beneficial effects for health in terms of prevention of the tooth decay. When the distributed waters in contain less 0,5mg/L, the use of salt fluorinated is recommended. A defaulting or an excess in fluorine provoke some inconveniences whereas some moderate doses are beneficial for health. Fluorides ingested with water are nearly absorbed in totality and distribute themselves quickly in the organism (essentially the skeleton and the teeth).

The margins between useful and poisonous doses sum up as follows:

- Less 0.5mg/L: Deficiency in fluorine to warn the tooth decays,
- Enters 0.5 and 1.5mg/L: Optimal dose to warn the carries,
- Enters 1.5 and 4mg/L: Risk of bony fluorosis (bony and articular pains accompanied by distortions).

Of made it of the fixing of the ion calcium by ion fluorine, this last driven a hypocalcaemia. To very strong dose (a few hundreds of mg), ion fluoride can provoke the pathological states, as gastroenteritis hemorrhagic, nephrite sharp and various illnesses of the liver and the muscle cardiac .Des vomits, abdominal pains, nauseas, diarrheas or even convulsions are the first symptoms of the poisoning (http://île - de - France .santé. gouv. Fr /satanenv/eau/param / fluor. htm). The maximal value of ions fluorides in a drinking water according to the Beninese legislation is of 1,5mg/L. In the region of survey, the gotten results show that the concentration in ions fluoride varies appreciably from a boring to the other (picture 19), with a minimum of 0mg/L (F_5 boring, F_{10}, F_{12}, F_{13}, F_{14}, F_{19}, F_{20}, F_{22}, F_{23}, F_{28}, F_{29}, F_{32}, F_{34}, F_{37}, F_{38}, F_{45}, F_{47}, F_{50}, F_{52}, F_{59}, F_{60}, F_{61}, F_{64}, F_{68}, F_{69} and F_{74}) and a maximum of 0,74mg/L (F_{16} boring). All studied boring waters have a concentration in fluoride compliant to the norms of Benin for a drinking water.

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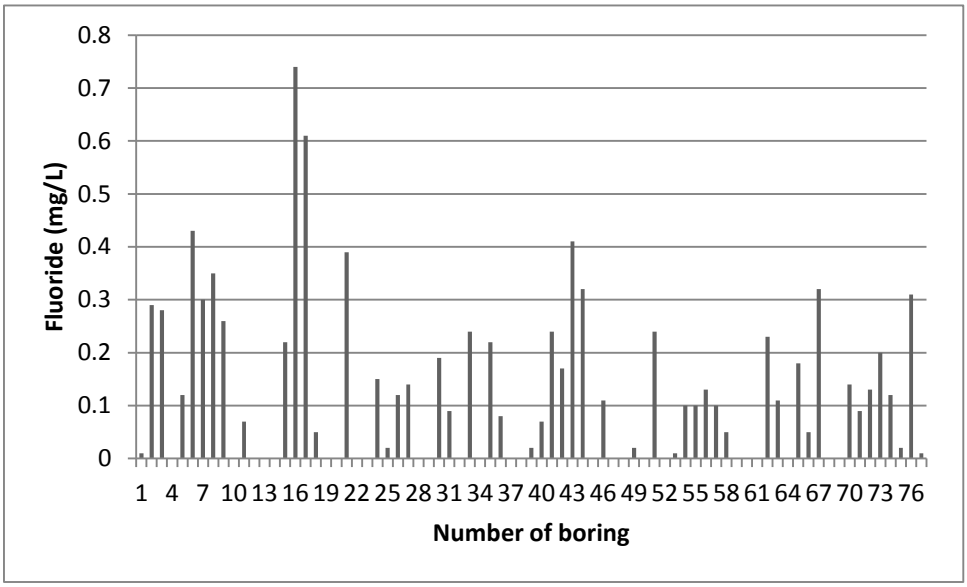

Picture17: Spatial variation of the values of fluorides.

All the samples have values of conductivity and contents in calcium, in sulphate, in nitrite and in phosphate conform to the norms of the WHO. The values of the turbidity and the toughness and the content in fluoride are respectively compliant to the norms of Benin in 50.64%; 97.40% and 100% of the samples analyzed. The values of the pH, of magnesium, of iron, the chlorides, the nitrates and ammonium are respectively compliant to the norms of the WHO in 7.2%; 98.7%; 79.22%; 98.70%; 98.70% and 97.4% of the samples.

BACTERIOLOGICAL QUALITY OF WATER

We appreciated the bacteriological quality of the tablecloth of the continental terminal of the township of Abomey-Calavi through the measure of three parameters: total coliforms, coliforms thermotolerants and the intestinal enterococci. The picture returns the middle concentrations of these microbial germs below for every precinct of the township of Abomey-Calavi.

The groups of coliforms understands the bacteria belonging to the family of the Enterobacteriaceaces and makes to two entities appear: one is mainl the one of the coliforms of fecal origin or coliforms thermotolerants hosts of the digestive tube of the man and of the animals warm-blooded; the other of non-fecal origin, is part of the aquatic bacterial communities (comes of the infiltration waters) or telluric (comes of the earth).

A gram of excreted includes a million to one billion of coliforms thermotolerants. The species the more frequently associated to this bacterial group is the *Escherichia coli* and in a least measure, some species of the Citrobacter kind, Enterrobacters and Klebsiellas (Santé Canada, 1991; Edbery and al, 2000; GOMEZ, 2009). The bacterium *Escherichia coli* represents all time 80 to 90% of the coliforms thermotolerants detected (Edberg and al, 2000). The interest of the detection of the coliforms thermotolerants, as indicatory organisms of fecal pollution, resides in the fact that their survival in the environment is generally equivalent to the one of the pathogenic bacteria and that their density is generally proportional to the degree of pollution produced by the fecal matters (CEAEQ, 2000).

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A gram of excreted includes hundred one thousand to 100 million intestinal enterococci. These are bacteria of rounded shape and of which the individuals, regroup in chain. They are of fecal origin or no (plants, bugs, soils). They can be a pathogenic bacterium indicator (because of their inability to increase in the aquatic environment) and of virus because of their strong resistance (surviving longer in aquatic environment that the coliforms thermotolerants) (HOUNSINOU, 2012).

Table 1: the middle microbial germ concentration by precinct to the level of the boring.

	Averages of the concentrations to the level of the boring		
	total Coliforms (/100mL)	Coliforms thermotolerants (/100mL)	intestinal enterrococcis (/100mL)
Abomey-Calavi	9	3	2
Akassato	8	2	1
Glo-Djigbé	7	1	1
Godomey	25	9	7
Hevié	21	7	5
Kpanroun	8	2	1
Ouedo	12	5	3
Togba	6	1	1
Zinvié	15	6	4

With regard to the total coliforms, the middle concentration is the order of 12.33/100ml. The maximal middle concentration is recorded in the precinct of Godomey (25/100ml). The research of the coliforms thermotolerants by precinct shows that the waters of boring to the level of the survey region contain a middle concentration of the order 4/100 ml. The maximal average in coliforms thermotolerants is recorded in the precinct of Godomey (9/100ml). As for the intestinal enterococci, we noted that the middle concentration of the boring waters in the region of survey is the order of 2.77/100ml, with a maximal middle value recorded in the precinct of Godomey (7/100ml). The watertable of the continental terminal shelters strong densities of total coliforms, coliforms thermotolerants and intestinal enterococci. These results are similar to those found to the level of the watertable of the plio-quaternary in the region of Meknès to Morocco (Belghiti and al, 2013).

CONCLUSION AND RECOMMENDATIONS

The results of the physical and chemical analysis of the water of the continental terminal of the township of Abomey-Calavi are not compliant to the norms of the WHO and Benin in 98.7% of the studied boring. Some very elevated concentrations present bacteriological view point, the studied boring, in germs of fecal contamination in all boring without exception, what probably constitutes a threat for the farming zone inhabitants who consume the water of these boring that they consider like drinkable.

To avoid the possibility of all sanitary risk us recommend:

- Treatment of water on a domestic scale by the use of the swath water with the help of an account drops,

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- Extension of the network of the drinking water of the National Society of the waters of Benin (SONEB) in farming environment,
- Conception of the purification network for the worn-out water evacuation,
- Pickup of garbage,
- Protection of the catchments.

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