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Pollution of Well Water of Some Areas of the Municipality of Abomey-Calavi, Benin

Sagnon Parfait Hounsinou[1*], Daouda Mama[1], Abdoukarim Alassane[1], Nicaise Yalo[1], Etienne Sagbo[2], Moussa Boukari[1] and Dominique Sohounhloue[3]
[1]Laboratoire d'Hydrologie Appliquée, Faculté des Sciences et Techniques (FAST), Université d'Abomey – Calavi, 01 BP: 526 Cotonou, Benin
[2]Laboratoire de Chimie Inorganique et de l'Environnement (LACIE), Faculté des sciences et techniques (FAST), Université d'Abomey – Calavi, 01 BP : 526 Cotonou, Benin
[3]Laboratoire d'Etude et de Recherche en Chimie Appliquée (LERCA), Ecole Polytechnique d'Abomey – Calavi (EPAC), Université d'Abomey-Calavi, Benin
doctorantparfait@yahoo.fr

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Abstract

For the monitoring and control of waterborne diseases, a five-month-prospective-study run from January to March 2012 and from January to February 2013 which objective is the preliminary assessment of the hygienic quality of well water used for drinking and also for domestic activities by residents of some areas of Abomey-Calavi was conducted. A total of 20 water samples collected at 20 wells suspected to be a risk to the health of their users. Bacteriological lab tests reveeled a pollution of all the water wells due to bacteria such as thermotolerant coliforms, intestinal enterococci and total coliforms. This shows that these waters may be responsible for the spread of waterborne diseases. 60% of these waters are polluted by Escherichia coli. The relationship between thermotolerant coliforms and intestinal enterococci showed that the origin of fecal contamination is human-like in 50% of wells, animal type in 5% of the wells and mixed (human and animal) in 5% of the wells studied. Physico-chemically, 50% of water wells tested have a pH lower than normal, all well water analyzed have a redox potential higher than normal and concentrations of lead and zinc in accordance with WHO standards.

Keywords: Well water, Pollution, Risk, Health, Abomey-Calavi, Benin.

Introduction

Water is essential to all plant, animal life and in particular to the life of human beings. The human body consists essentially of water. In vital organisms, water plays the role of supporting exchanges without which there is no life[1-2]. Freshwater resource is groundwater, surface water and rainwater. These water reserves are renewable but several studies worldwide have shown that these waters are more or less polluted and source of many diseases such as cholera, typhoid fever, polio, infectious hepatitis.

In developing countries, very few people have access to drinking water. In Benin, due to insufficient financial means, an overwhelming majority of the population (about 65%) have not subscribed to the National Water Company of Benin (SONEB). This population consumes natural waters without pre-treatment and is exposed to many diseases[3].

In the departments of Atlantique and Littoral (southern Benin), during rainy season, many people suffer from waterborne diseases including cholera causing death. The Ayélawadjè health center (Cotonou), referral hospital in the treatment of cholera has received in recent years cholera patients residing in Cotonou and Abomey-Calavi. In 2005, this health center recorded 344 cases of cholera within 20 weeks of epidemic; in 2008, 506 cases were recorded in 14 weeks and an outbreak in 2010, until 6th December, 667 cases were recorded. The epidemic worsens over time. This is probably why several evaluation studies of pollution of wells have been done in the municipalities of Abomey-Calavi and Cotonou. These studies were conducted by Bossou in 2002; Degbey in 2004[2-4]. But none of these studies has diagnosed the source of fecal contamination (human or animal) of water from these wells. Particularly, in Abomey-Calavi, a city with exploding population, an increasing majority of the population consumes well water. Physico-chemically, previous studies of Abomey-Calavi often do not take the pollution of groundwater by heavy metals into account.

This study aims at diagnosing the exact cause of bacterial contamination of well water to do preventive recommendations to address intermittent epidemics of cholera in Abomey-Calavi.

Materials and Methods

Study area: The Republic of Benin has 12 departments (geographic regions), each department has several towns and each town has several districts or suburbs. The town of Abomey-Calavi, located in the southern part of Benin and the

Department of the Atlantic is limited on the north by the municipality of Zè, south by the Atlantic Ocean, on the east by the municipalities of So- Ava and Cotonou and on the west by the municipalities of Tori-Bossito and Ouidah. It is the largest town of the department of the Atlantic which occupies more than 20% of the area. It covers an area of 536 km^2 representing 0.48% of the national area of Benin. The general census of the population in 2002 reports for Abomey-Calavi 307,745 people that is 21% of the population of the departments of Atlantique and Littoral. 74.12% of the population lives in urban areas and 25.88% in rural areas. The town of Abomey-Calavi today suffers the influence of nearby Cotonou, the economic capital of the country. Indeed, the narrowness of Cotonou and its large population leads to an extension to Abomey-Calavi. In the town of Abomey-Calavi, population growth is 5.84% in urban areas and 2.89% in rural areas. Central Calavi (Figure-1) is one of the districts of Abomey-Calavi. In this district the population is dense.

The town of Abomey-Calavi is a mountainous relief. The main features are: a band with sandy spits of land and eta barprettylowporosityanddepression. The coastal plain of low altitude (0-5m) is separated by the Djonou lagoon. It is entirely sandy or swampy places.

The town of Abomey-Calavi is located in an intertropical are a inthetropics. In this area, the climate is sub-equatorial and characterized by two rainy seasons (September to November and March to July) and two dry seasons (November to March and July to September).

The study covers two main types of geological formations[2]: The Quaternary formations that are sandy deposits of the barrierbeach, lagoon deposits of clay and sand and alluvial deposits consist of sand and clay. Coarse sand on the coastal façade have a thickness of about 6m with a porosity exceeding 40%. Up the coast, the fine, grayish marine silty sands, have a thickness of 15m and a porosity of around 35%. Finally follow the clay gravelly sand from alluvions whose characteristics are fairly similar to ordinary sands of the coastal façade.

The tertiary formations consist mainly of clay and sand of terminal continental. Two large units can be distinguished in this group: The first consists of sandy clay deposit changed to bar sand dating from the Upper Miocene. In this unit and a little deeper, we note the presence of an alternation of clay and quartz sand and lower gravel with a particle size that is increasing or decreasing upwards. The second is made of rounded and angular gravel deposit bathed in sandy-clayey matrix generally brick red and altered facies barsand.

There are three aquifers on the plateau: the terminal continental aquifer is shallow (120m), the Paleocene aquifer at a depth of 320m, the Maastricht an aquifer at 1500m depth[2].

Drinking water is primarily drawn from the aquifer of the Continental Terminal[5]. We have a rich aquifer, but unfortunately subject to substantial pollution of surface water, septic tanks, lack of hygiene.

Sampling sites: Central-Calavi (Figure-1) is one of the districts of the town of Abomey-Calavi. In this district, the population is dense. Generally, in each house, there is a traditional well. Our study focused on traditional wells of some areas of the district of Calavi-center. We selected two groups of wells.

The first group of wells is located on the banks of Lake Nokoué. We suspect that the water from these wells is contaminated by water from the lake because of the proximity of the latter. The water of these wells is also suspected of being contaminated by septic tanks (human pollution) due to the shallowness of these wells. These wells are less vulnerable to pollution by seepage due to the large slope that quickly drains runoff water into the lake after each rain.

The second group is wells is far from lake Nokoué. These wells are less vulnerable to pollution by septic tanks but more vulnerable to pollution by water seepage (bacterial pollution of animal type). In fact, during the rainy season, runoff water stagnate on roads and in homes for days or weeks.

Depending on the location of these water points and sources of pollution, we selected a representative number of points for which water samples were collected. These wells were identified by their geographical coordinates using GPS. These coordinates are then projected onto the base map of the district of Calavi (Figure-2).

Sampling conditions: Water samples for physical and chemical analysis were collected in clean plastic bottles previously labeled and placed in a cooler.

Water samples for microbiological analysis were collected according to the WHO standards at approximately 50 cm from the free surface of the water in previously labeled sterilized bottles. These bottles of water are placed in a cooler with pieces of ice.

Analyzes performed on the sampling sites and in laboratories: According to the AFNOR standards, temperature, pH, dissolved oxygen, oxygen saturation rate, redox potential were measured by pH/ oximeter with a probe WTW340i, salinity, conductivity and TDS were measured by a conductivity meter with a WTW 340i probe and turbidity was measured using a colorimeter HACH DR 890.

Zinc and lead contents of samples were measured according to the AFNOR standards by NOVA 60 spectrophotometer and after properly using the necessary reagents.

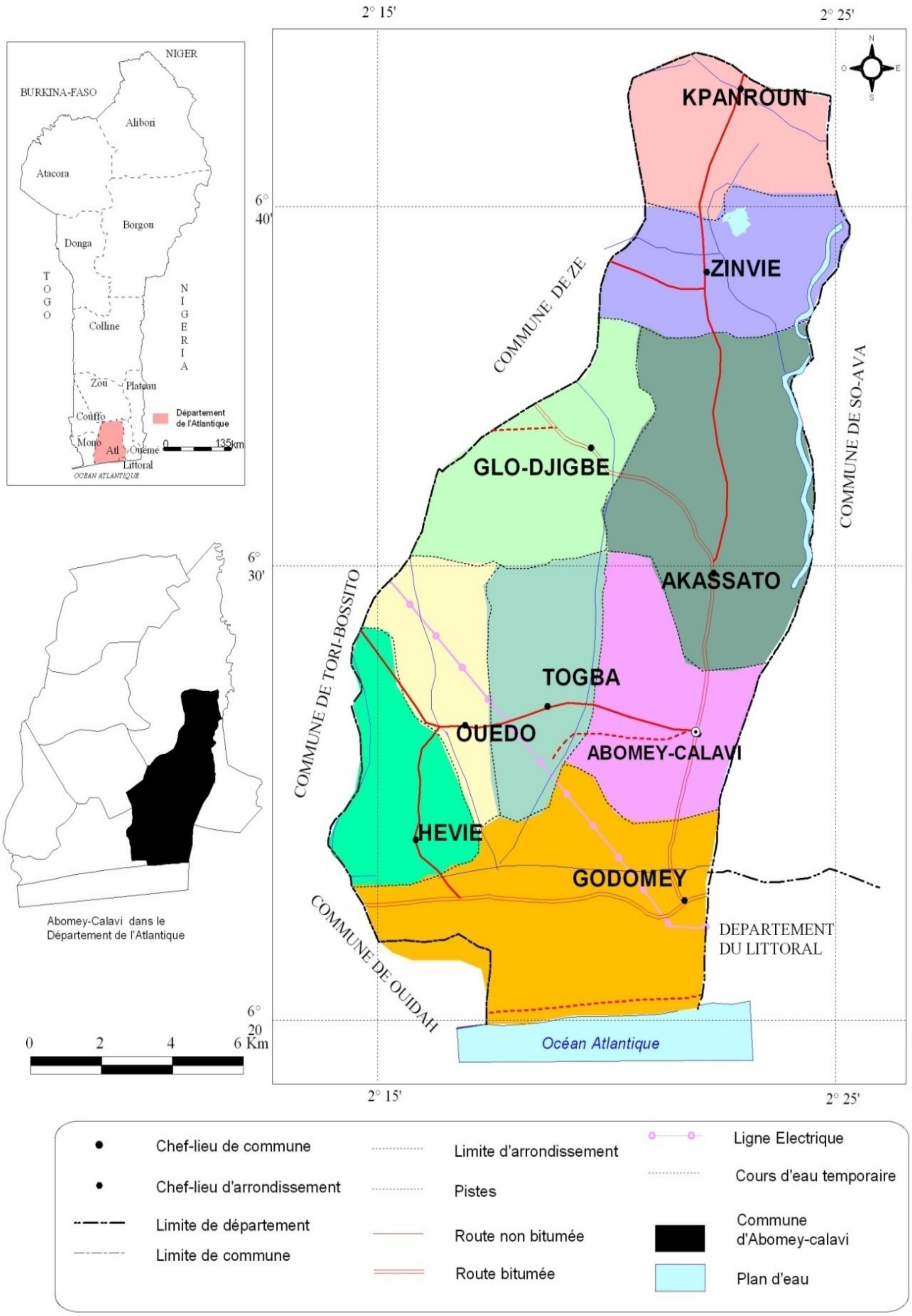

Figure-1
Location of the municipality of Abomey-Calavi

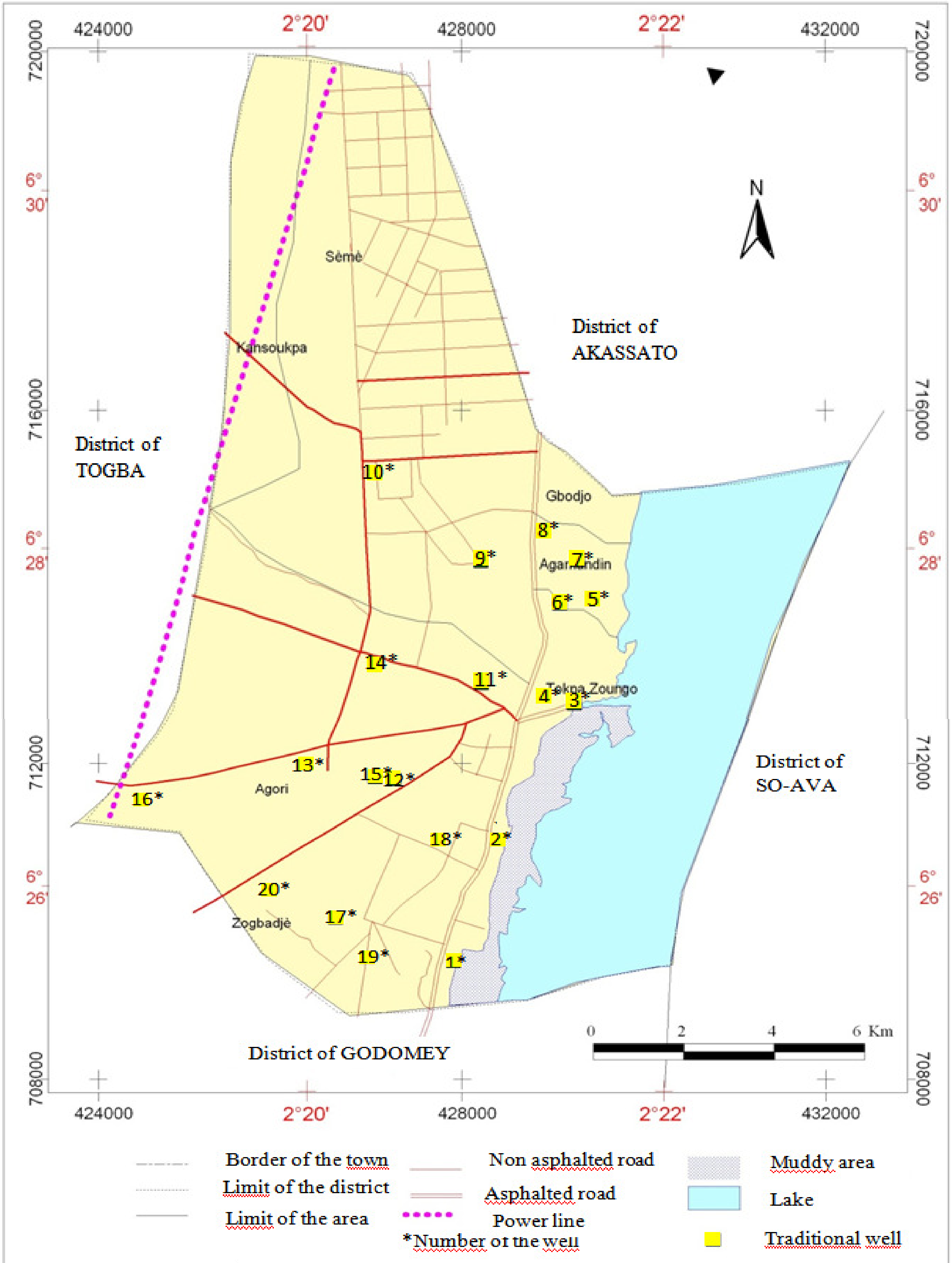

Figure-2
Well water sampling sites

Microbiological parameters were measured according to the agar incorporation method described in the book 'Le Rodier'[6]. Microbiological parameters measured were: common germs, thermotolerants coliforms, *Escherichiacoli*, total coliforms and intestinal enterococci.

Results and Discussion

We present here the results as graphs in which the green horizontal lines represent maximum allowable standards and red horizontal lines represent the minimum allowed standards for each parameter. We performed analyzes for 20 wells and we averaged the results found.

Results and Interpretation of Physical and Chemical Parameters

pH: This parameter measures the acidity or alkalinity of water. The pH value is the result of a complex relationship with several other parameters (carbonic acid, total hardness/hydrotimetric title (TH), Complete alkalimétric title (TAC) and temperature). It also depends on chlorophyll assimilation, breathing of organisms and the lower metabolism of bacteria and fungi[7-8].

The low values of pH enable adsorption and the high pH values result in the desorption of the germs in the soil. Bacteria live shorter in acidic soils (pH between 3 and 5) than in alkaline soils[4-10].

Well water studied have a pH ranging from 4.36 to 7.2. 50% of these waters have a pH that does not meet WHO standards. This acidity confirms the results obtained in 2004 by Degbey in Abomey-Calavi and is due to the geological nature of the soil.

Electrical conductivity: This parameter enables to approximate the overall mineral water.

Conductivity of well water analyzed varies from 66.8 to 1128 µS / cm. 40% of these well water samples have a conductivity higher than WHO standards. 15% have a high mineralization, 5% have a very high mineralization and 5% an excessive mineralization. The more mineralized well waters are located near the lake. The lake is therefore the source of this pollution.

Total dissolved solid (TDS): This parameter measures the refraction of water. To switch from electrical conductivity of a water sample expressed in µs / cm to TDS mg / L, it should be multiplied by a conversion factor that depends on the chemical composition of the dissolved solids and can vary between 0.54 to 0.96. 0.67 is a number generally used as a proxy if the exact conversion factor is not known. The conversion factor is 0.5 by default[11]. It corresponds to a solution of $CaCO_3$ (1µS/cm = 0.5 mg / L). The conversion factor is 0.56 for the well water we analyzed. For the well water we studied, the conductivity standard is met when the TDS is less than 140mg / L.

Dissolved oxygen: The presence of dissolved oxygen is essential for the maintenance of aquatic life[8]. Most bacteria present in feces are facultative anaerobic, so that the dissolved oxygen generally in low concentration in groundwater (2 to 8 mg / L), influence little their survival in the soil[4,9,12]. Standards for dissolved oxygen not being mentioned in the WHO standards, we used the Moroccan standard NM 03.7.001.

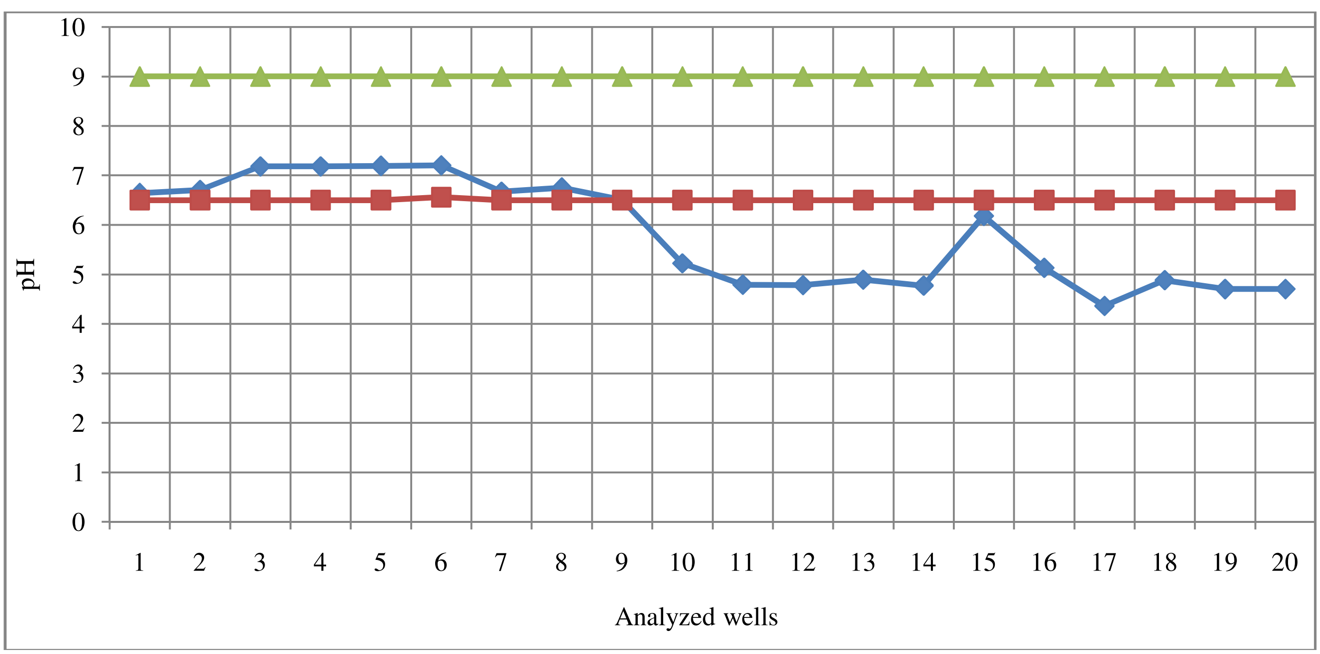

Figure-3
pH of well water analyzed

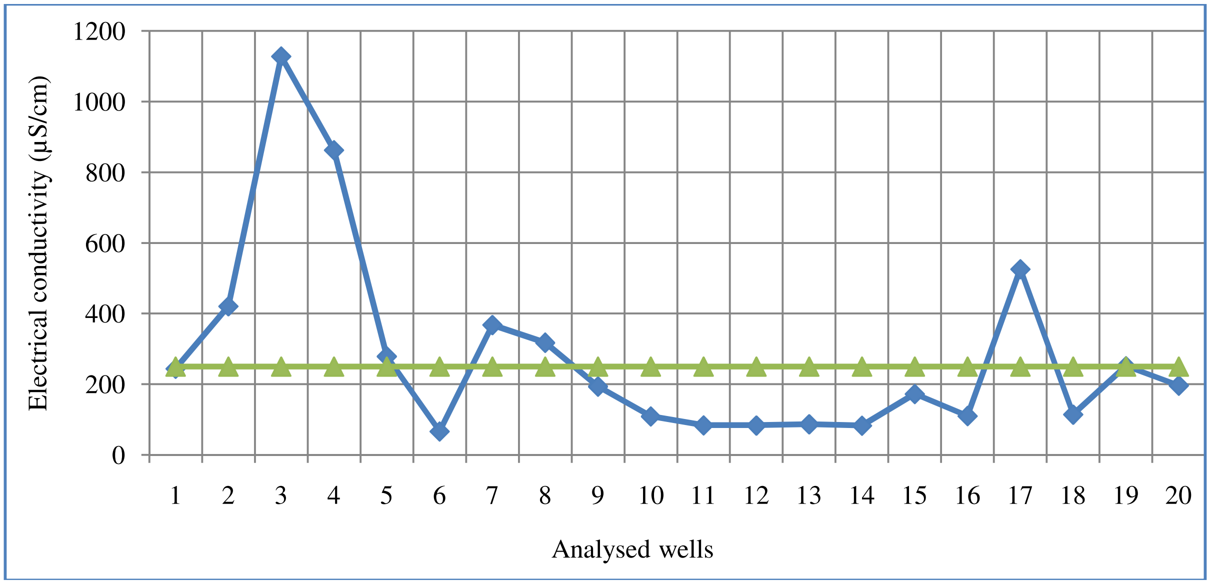

Figure-4
Electrical conductivity of well water analyzed

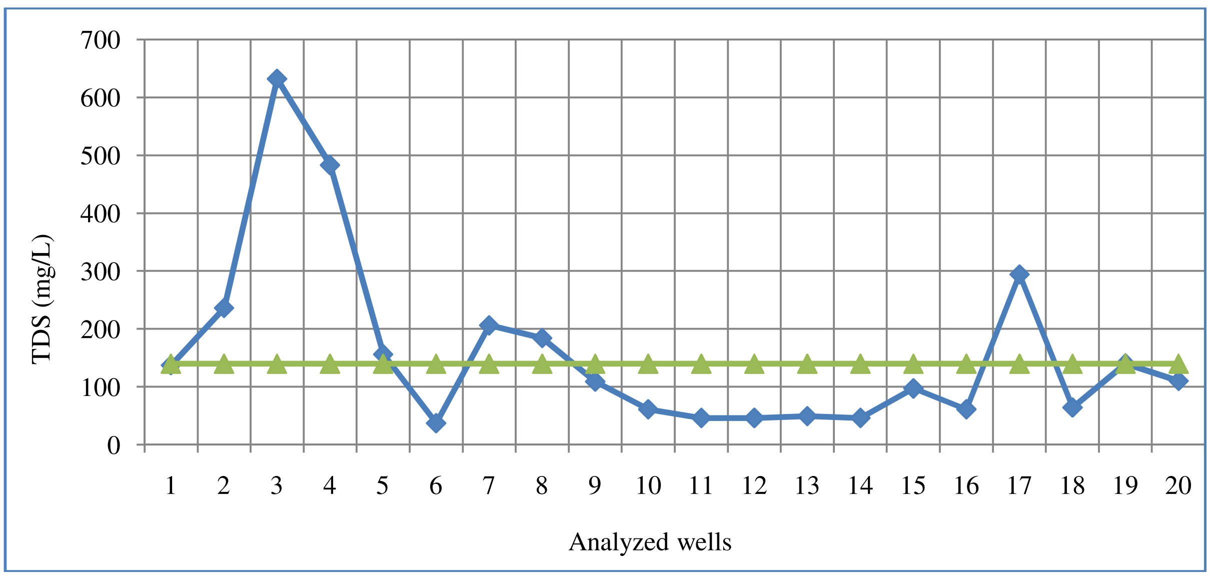

Figure-5
TDS of well water analyzed

None of the studied wells meets this standard and they have concentrations ranging from 1.83 mg / L to 2.87 mg / L.

Percentage of oxygen saturation: The standard of percentage of oxygen saturation is not mentioned in the WHO standards for drinking water. It is considered that the percentage of oxygen saturation is less than or equal to 75.

All analyzed well water samples have a percentage of oxygen saturation below 75%. The percentage of oxygen saturation of these waters varies from 22.3% to 35.1%.

Turbidity: This parameter reflects the unclear state of water or not. When turbidity is high, water is colored[13-14].

Turbidity of well water analyzed varies from 1 FNU to 18 FNU. 35% of water analyzed has turbidities that were not in accordance with Beninese standards. These wells are located around the lake. It is a pollution by the lake.

Redox potential: The potential of well water analyzed varies from 183 mV to 326mV. All these waters have a redox potential higher than WHO standards.

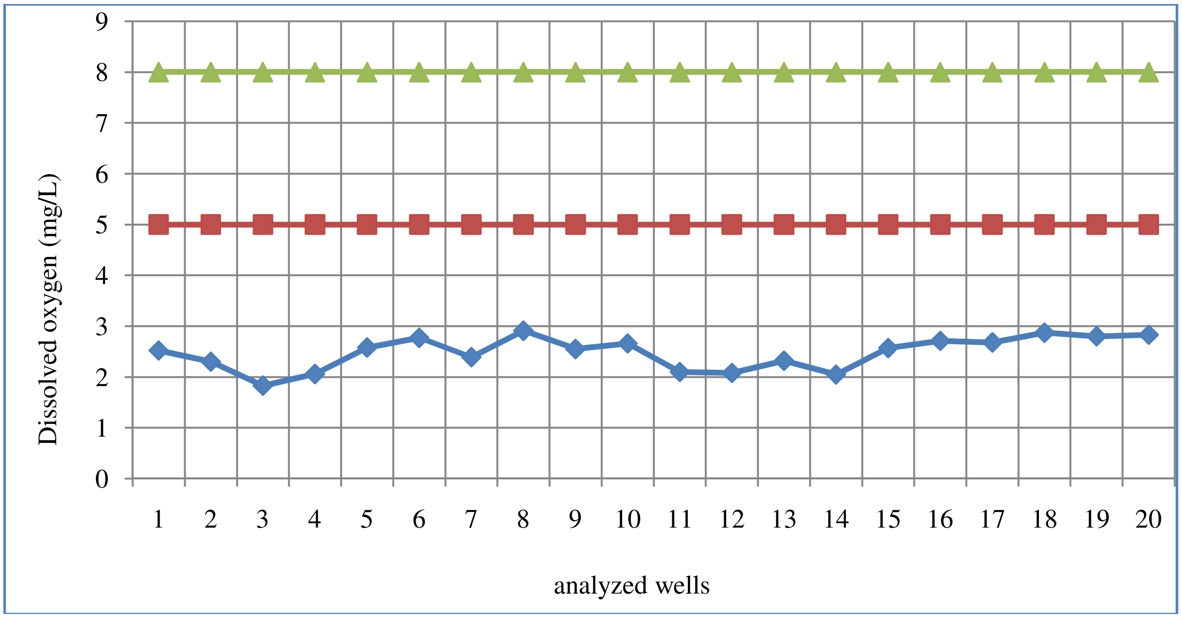

Figure-6
Dissolved oxygen of well water analyzed

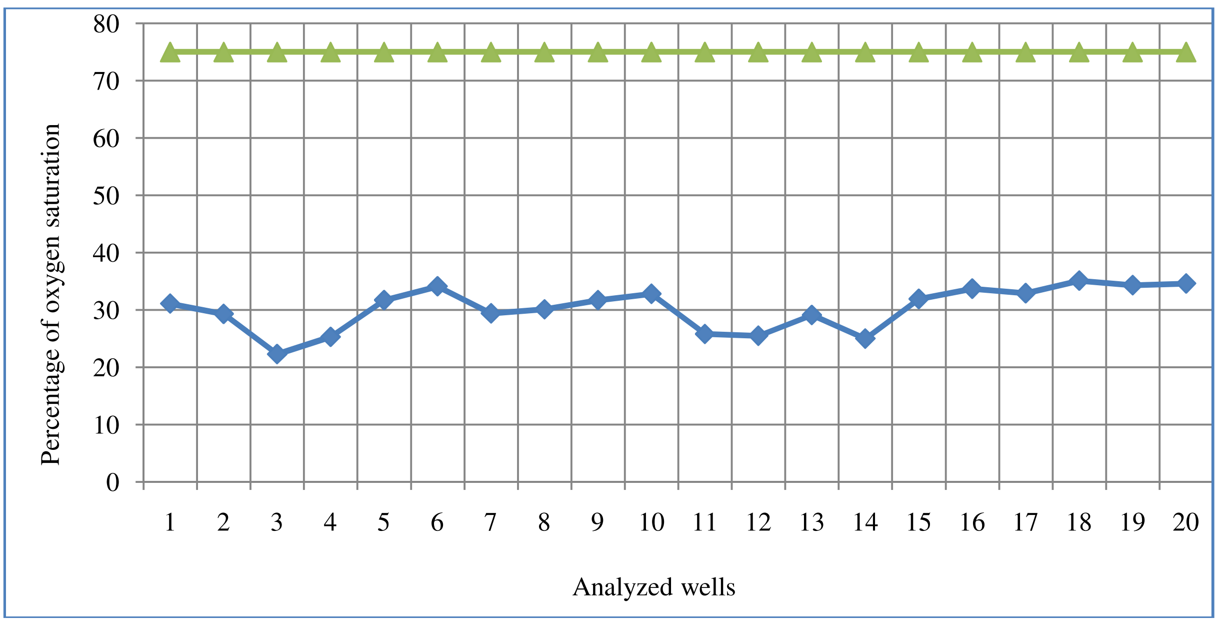

Figure-7
Percentage of oxygen saturation of well water analyzed

Lead: Lead is a toxic substance[15]. Presence of lead in groundwater may result from contamination by surface water or from the ground. Lead is naturally present in the soil up to a few dozens of mg / kg of soil[4-16].

Lead concentration of all analyzed water meets WHO standards.

Zinc: Zinc is an undesirable substance. The presence of zinc in groundwater may come from contamination by surface water or from the soil[16]. Zinc is naturally present in the soil. It is more abundant than lead in the earth's crust.

The zinc content of all analyzed water meets WHO standards.

Results and Interpretation of Microbiological Parameters: The majority of micro-organisms (viruses, bacteria or protozoa) that can cause diseases are likely to be found in water and are from humans or animals feces. A human being excretes about 13 million *E. coli* per gram of stool and a patient may excrete up to 100 billion rotavirus per gram of stool[17].

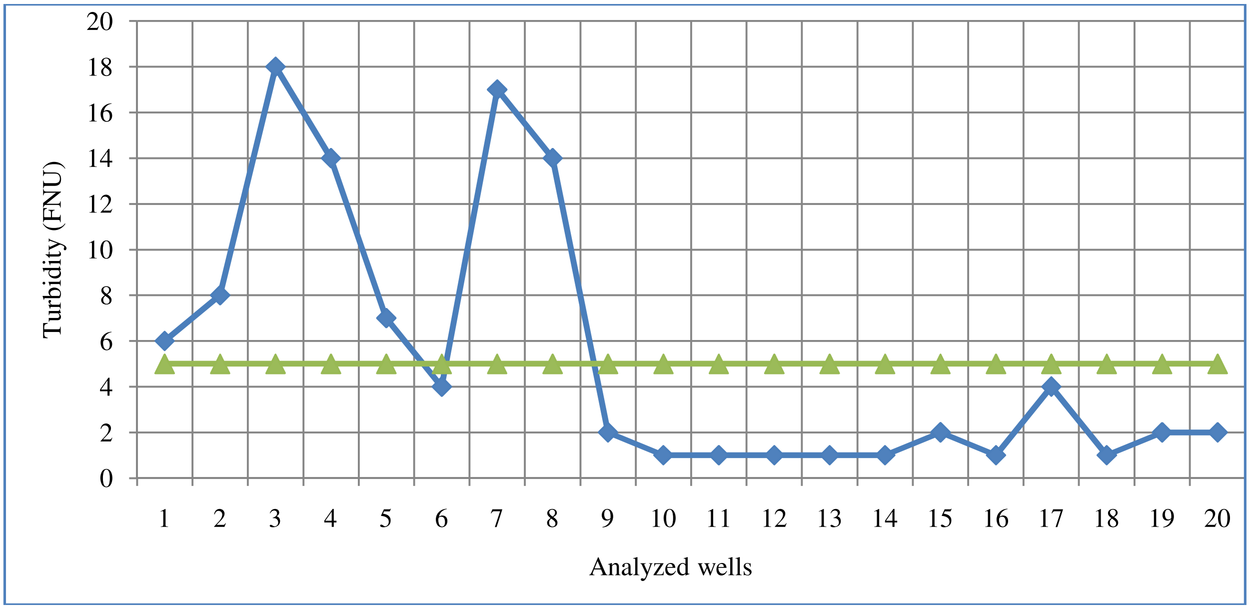

Figure-8
Turbidity of well water analyzed

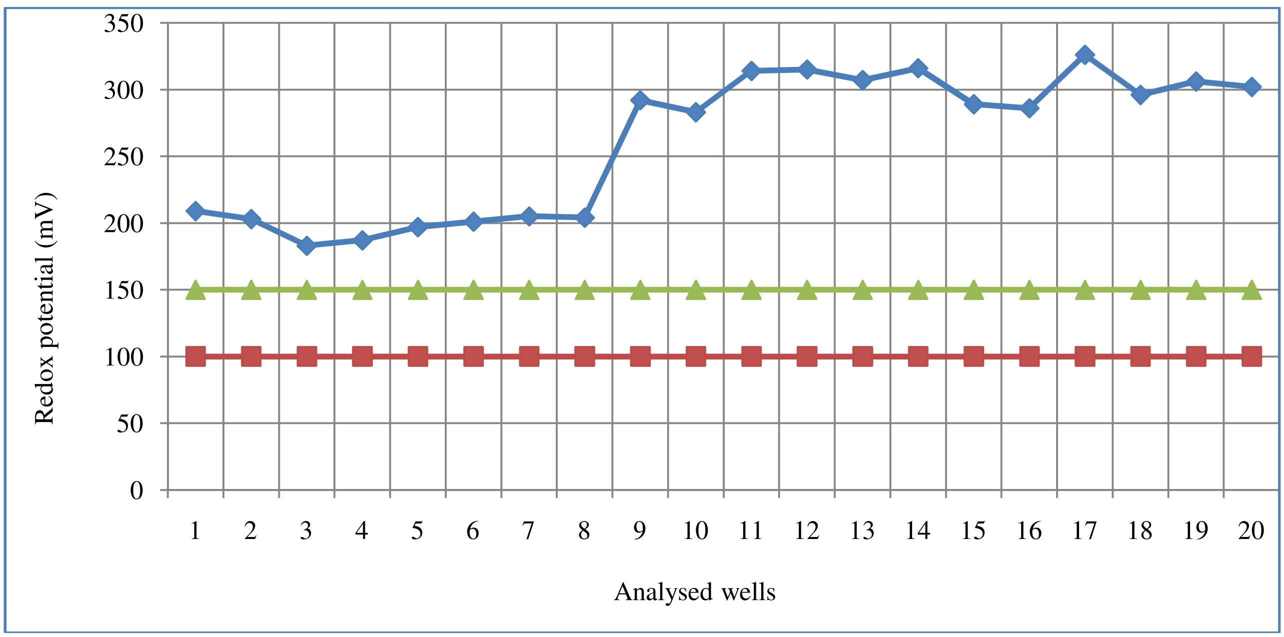

Figure-9
Redox potential of well water analyzed

Bacteria are prokaryotic microorganisms belonging to the group of Protista. Reproduction is done by fission. Their size varies from 1 to 10 µm[5].

Some bacteria by their omnipresence in human feces are often used as indicators of faecal pollution. These bacteria are normally present in the intestine of a healthy human being. Bacteria commonly used as indicators of faecal pollution are: thermotolerant coliforms, faecal streptococci Enumeration of common germs.

All well water analyzed is contaminated by common germs with concentrations exceeding WHO standards. Concentrations of these germs vary from 75/mL water to 3.9 10^3/ mL of water.

Enumeration of total coliforms: This is a heterogeneous group of bacteria of fecal and environmental origin. Most of these species can naturally be found in soil and vegetation. Their presence in water does not indicate fecal contamination nor a health risk, but a degradation of the bacterial quality of water. This degradation can be attributed, among other things, to an infiltration of surface water into the well, or the gradual development of a layer of bacteria on the well called "biofilm". The presence of total coliform bacteria indicates a potential vulnerability of a well pollution of surface waters[17].

All well water samples analyzed were contaminated by total coliforms. The concentration of total coliforms in analyzed well water varies from 400/100mL to 336 10^3/100mL.

Enumeration of Thermotolerant coliforms: One gram of excreta has one million to one billion (1000000-1000000000) thermotolerant coliforms. They multiply very quickly at 44 ° C and are unable to grow at low temperature (4 to 10°C). They are mainly represented by *E. coli*

All well water samples analyzed were contaminated with thermotolerant coliforms. Concentrations of thermotolerant coliforms vary from 20/100mL to 90 10^3/100mL.

Enumeration of *Escherichiacoli* (*E. coli*): They are very abundant in the human and animal intestinal flora, and it is also the only species that is strictly of faecal origin. Their presence in water indicates that it is contaminated through fecal pollution and can therefore contain pathogenic microorganisms[18].

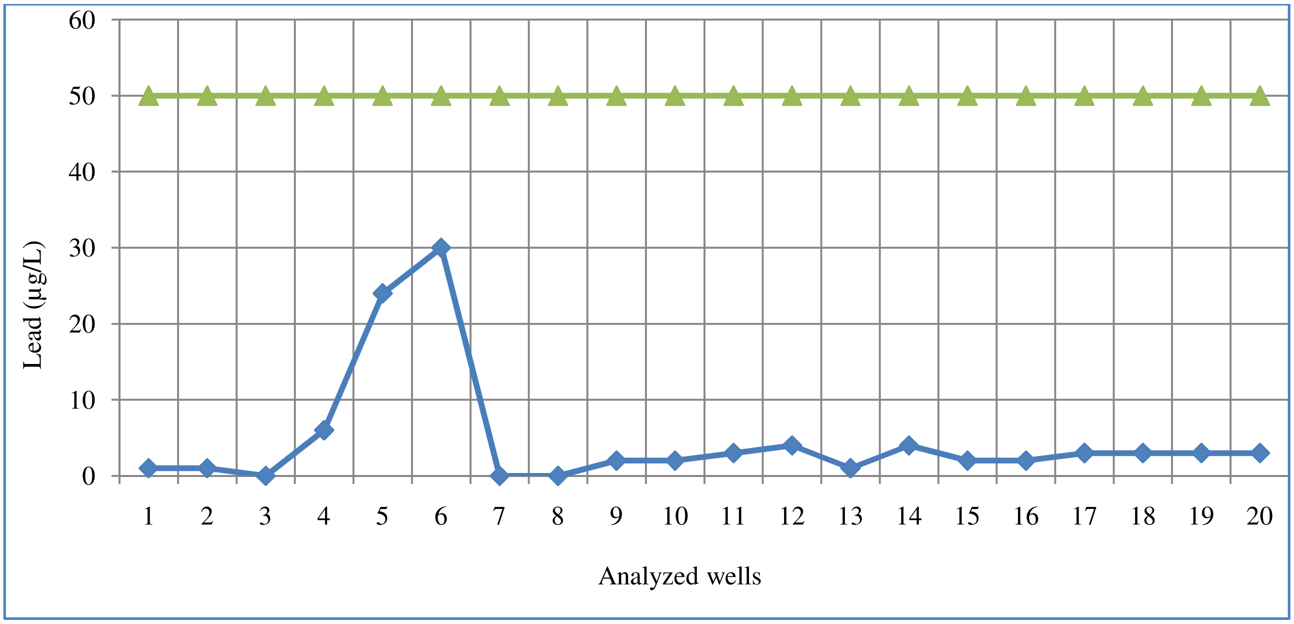

Figure-10
Concentration in lead of well water analyzed

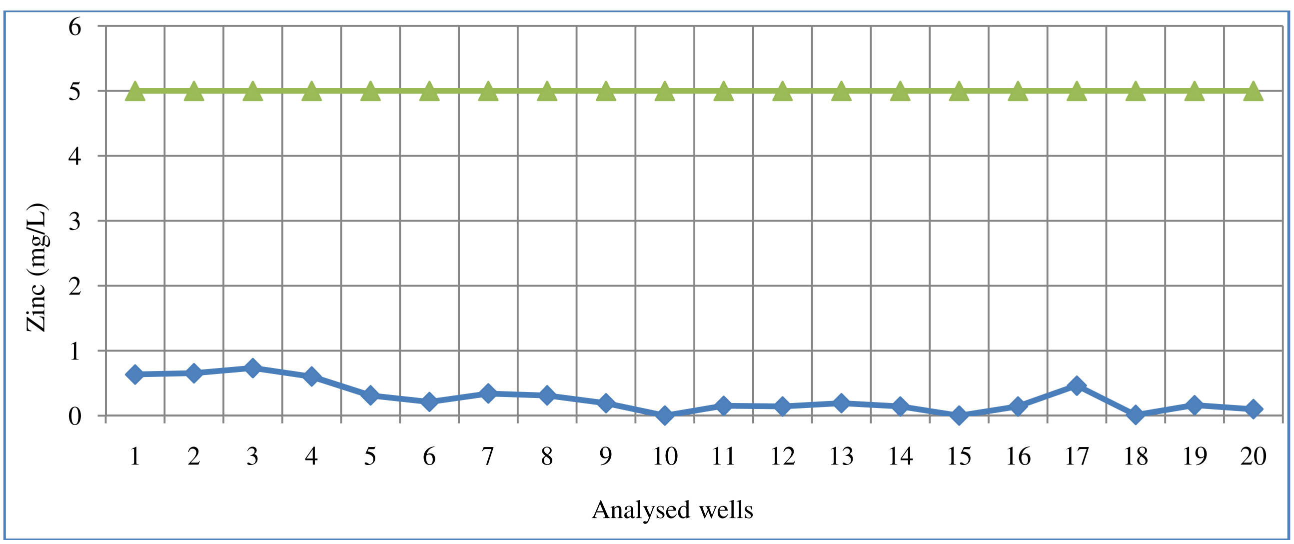

Figure-11
Concentration in zinc of well water analyzed

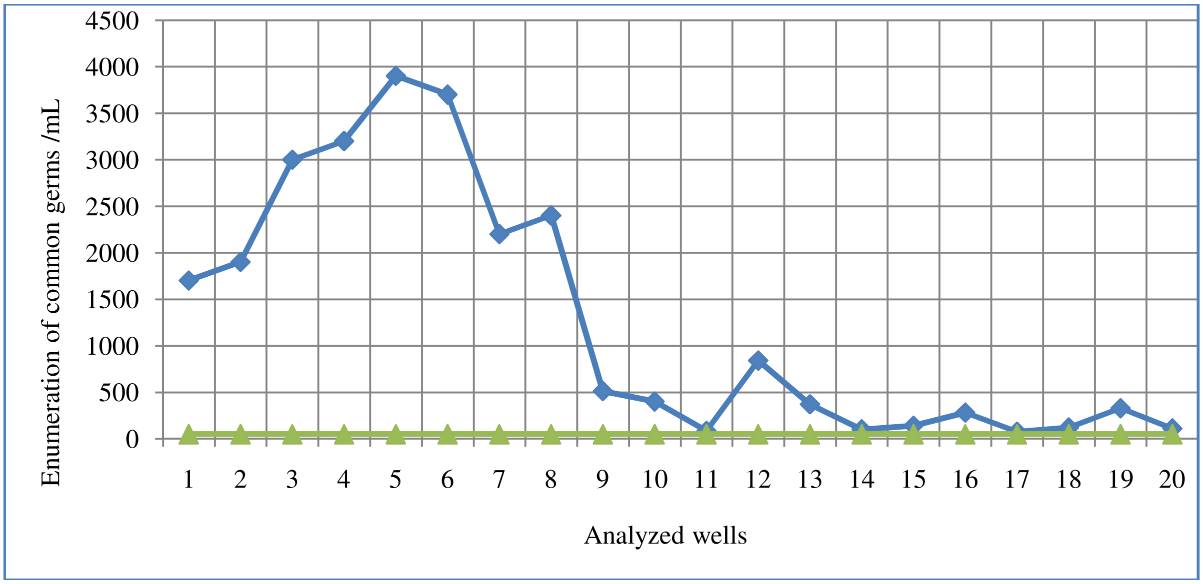

Figure-12
Number of common germs in well water analyzed

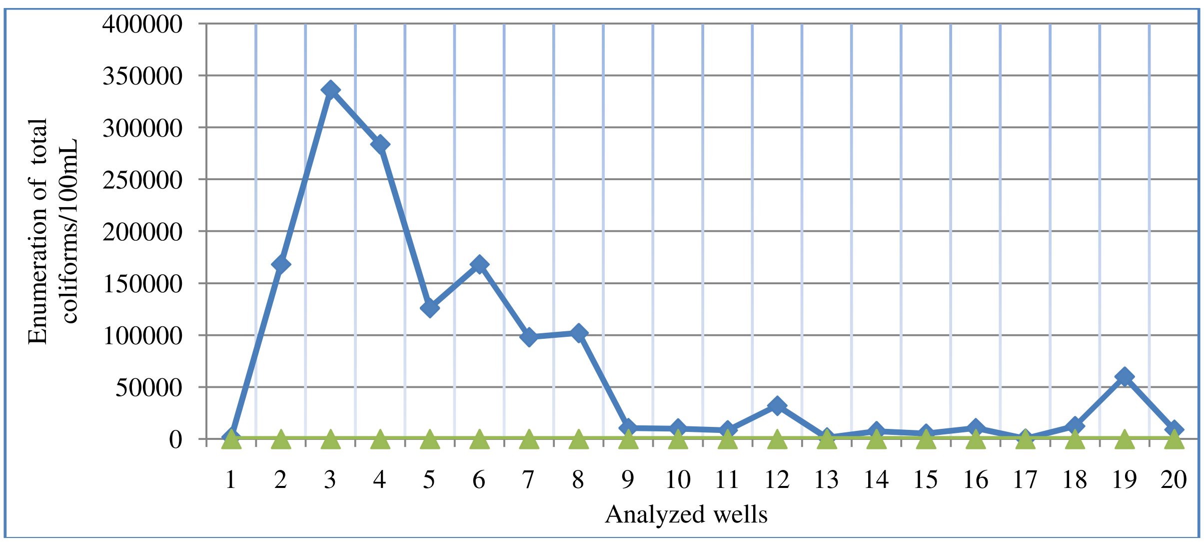

Figure-13
Number of total coliforms in well water analysed

40% of well water samples analyzed show no contamination by *E. coli* while the density of E. coli in the remaining wells varies from 20/ 100mL to 64 10^3/ 100 mL. The presence of *E. coli* in water indicates fecal contamination but does not identify the origin of animal or human fecal matter.

Enumeration of intestinal enterococci (IE): They are less abundant in the intestinal flora of humans and animals than *E. coli* and some species of this group are not of faecal origin. Detection of enterococci bacteria in well water may indicate faecal contamination or infiltration of surface water[17].

One gram of excreta has one hundred thousand IE. These are round bacteria whose individuals gather into chain. They are of fecal origin or not (plants, insects, soil). They can be an indicator of pathogenic bacteria (due to their inability to multiply in the aquatic environment) and viruses because of their high resistence (surviving longer than aquatic thermotolerant coliforms)[4].

A number of bacterial species normally absent from the intestine of a healthy person can be secreted intermittently and in varying amounts depending on location and health status of the population

All well water samples analyzed were contaminated with IE. Concentrations of thermotolerant coliforms vary from 40/100mL to 10 10^3/100mL.

The relationship thermotolerant coliforms / IE is generally higher than 4 in human feces and less than 1 in animal feces. This property is used in the search for IE to determine if pollution is of human or animal origin[4-9].

The following table shows the origin of fecal contamination in well water analyzed.

50% of well water studied are contaminated by fecal matter of human origin, 5% of the water is contaminated with animal fecal matter and 5% by fecal matter of both origins (animal and human).

All the wells analyzed are polluted: Physically and chemically, all the well waters studied are polluted. Redox potential and dissolved oxygen in these waters do not meet the recommended standards. 50% of well water analyzed has a pH too acidic and not in accordance with WHO standards. To remedy this, the inner walls of the wells must be covered with concrete. Cement contains bases such as calcium hydroxide $Ca(OH)_2$. The action of these bases on these waters will make their pH normal.

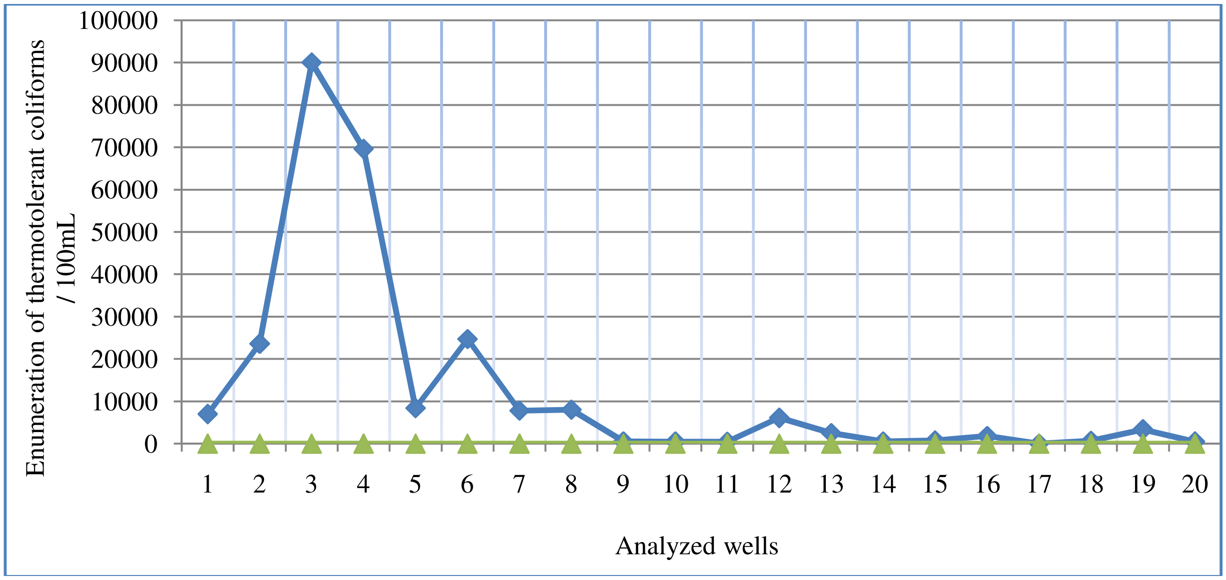

Figure-14
Number of thermotolerant coliforms in well water analyzed

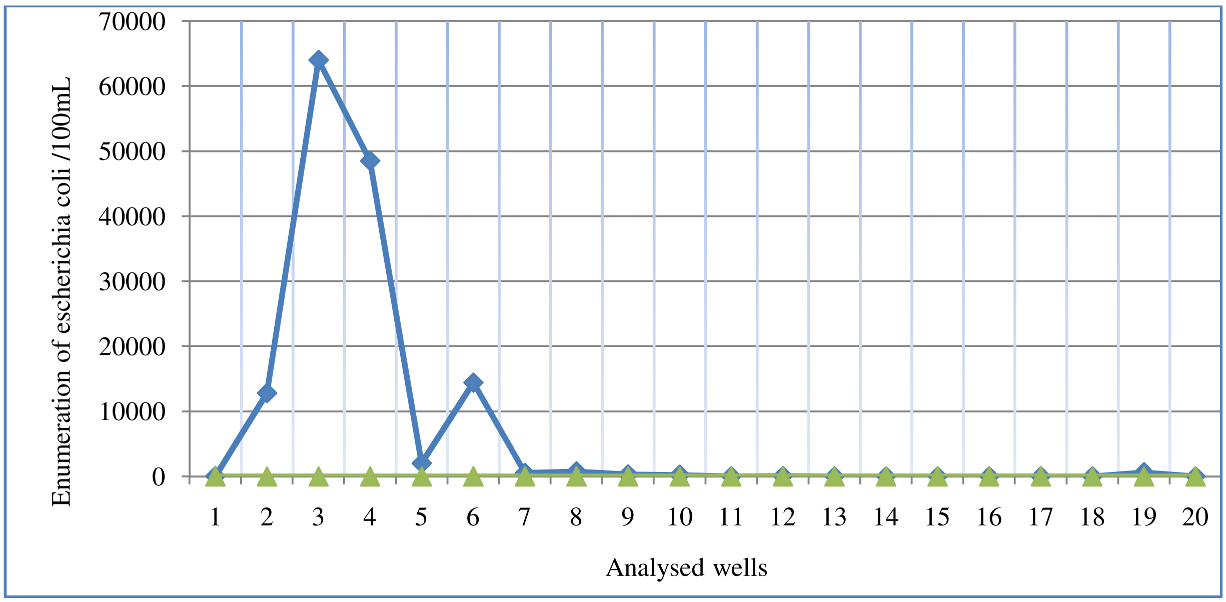

Figure-14
Number of E .coli in well water analyzed

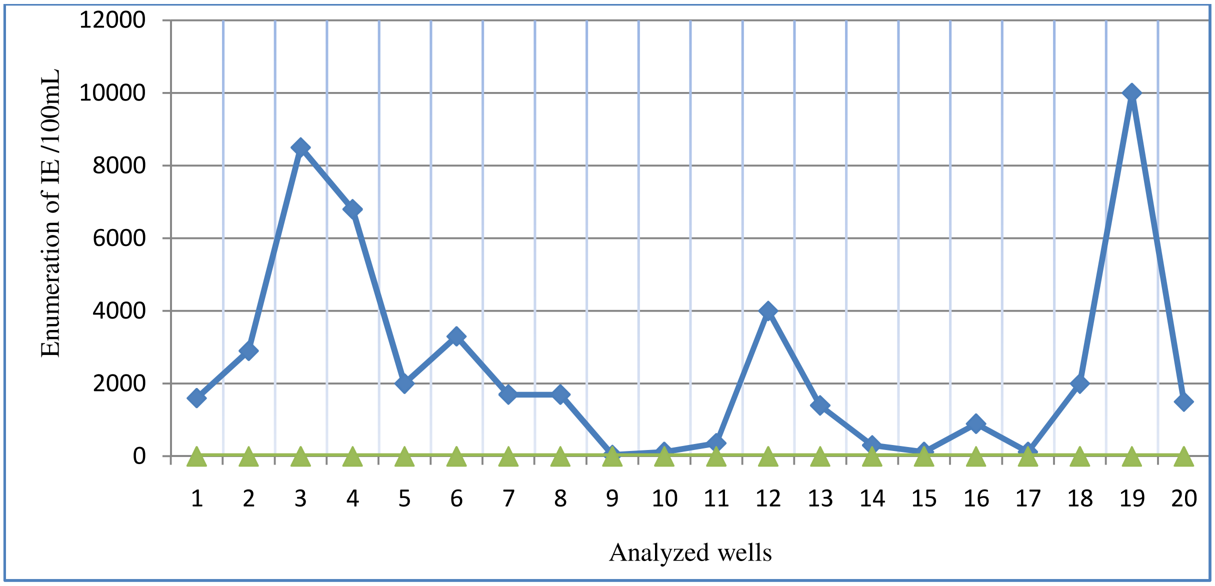

Figure-15
Number of IE in well water analyzed

Table-1
Origin of fecal contamination in well water analyzed

Numbers of wells	Thermotolérants coliforms/IE	Origin of fecal contamination (Origin of IE)
1	4.37	Human
2	8.13	Human
3	10.58	Human
4	10.23	Human
5	4.2	Human
6	7.48	Human
7	4.58	Human
8	4.7	Human
9	13	Human
10	4.16	Human
12	1.52	Both (animal and human)
19	0.33	Animal

Fecal contamination is generally of animal origin in wells away from the lake. In this region, runoff water stagnates on the roads and in homes for several days or weeks after the rains. We recommend that drainage channels of runoff water be built to prevent them from seeping into the soil with animal fecal germs.

Fecal contamination is 100% of human origin in wells near the lake. This is due to the shallowness of groundwater. We recommend that the population covers the insides of latrines, septic tanks and wells inside walls of wells with concrete to make them watertight.

Considering the omnipresence of germs in the water well studied, we recommend that people treat well water every two to three months with bleach. We recommend that the population covers wells and respect the minimum distance of 15m between septic tanks and wells. We urge the authorities at various levels to educate the population on hygiene through the media and expand the drinking water provision network.

Conclusion

This study of the pollution of wells in some areas of the town of Abomey-Calavi, allowed us to find out that all the water wells studied are polluted physically and chemically and bacteriologically. Indeed, the redox potential and dissolved oxygen of waters studied are not in accordance with recommended standards. PH, electrical conductivity, turbidity does not comply respectively in 55%, 40% and 35% in well water analyzed. All well water samples analyzed are contaminated with common germs, total coliforms, thermotolerant coliforms and IE. 60% of these waters are contaminated by *E. coli*. These results confirm those obtained by Bossou in 2002, Degbey in 2004 and El Haissoufi in 2011.

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