Research Article

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AN APPRAISAL OF SOME WATER RESSOURCES IN THE CITY OF YAOUNDE (CAMEROON): WATER ADDUCTION POTENTIALITIES, PHYSICO-CHEMISTRY AND CONSEQUENT ECO-SANITARY REPERCUSSIONS

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Abstract

People on globe are under tremendous threat due to undesired changes in the physical, chemical and biological characteristics of air, water and soil. Due to increased human population, industrialization, use of fertilizers and man-made activity water is highly polluted with different harmful contaminants. Natural water contaminates due to weathering of rocks and leaching of soils, mining processes etc. A systematic study was carried out to explore the physicochemical characteristics and quality of water in the Yaounde III municipality, particularly in the Obili and Damas neighbourhood. Water samples from wells, streams and springs were collected in August 2018 and analysed for pH, turbidity, oxygen concentration, color, temperature, acidity, alkalinity, pH, conductivity, salinity, suspended solids, used for testing of water quality. Also, the quality of drinking water was checked at regular time intervals, because due to the use of contaminated drinking water, human population suffered from varied water borne diseases. The availability of good quality water was an indispensable feature for preventing diseases and improving quality of life. Physico-chemical analysis showed that the waters of the sampled stations were slightly basic, slightly acidic and averagely oxygenated with very small thermal amplitude, and averagely turbid and murkier. Some water analysis reports with physico-chemical parameters have been given for the exploring parameter study. Guidelines of different physico-chemical parameters were used for comparing the value of real water sample. The qualities of water in these municipalities are not suitable for drinking purposes and basic hygienic rules are highly recommended.

Keywords: physico-chemical, water borne disease, conductivity, resistivity, alkalinity.

Résume

Les habitants du globe sont extrêmement menacés par des modifications indésirables des caractéristiques physiques, chimiques et biologiques de l'air, de l'eau et du sol. En raison de l'augmentation de la population humaine, l'industrialisation, l'utilisation d'engrais et l'eau, des productions artificielles sont fortement polluées par différents contaminants nocifs. L'eau naturelle est contaminée par l'altération des roches et la lixiviation des sols, les processus miniers, etc. Une étude systématique a été menée pour explorer les caractéristiques physico-chimiques et la qualité de l'eau dans la municipalité de Yaoundé III, en particulier dans les quartiers d'Obili et de Damas. Des échantillons d'eau de puits, de cours d'eau et de sources ont été collectés en Août 2018 et analysés pour déterminer leur pH, turbidité, leur concentration en oxygène, leur couleur, leur température, leur acidité, leur alcalinité, leur conductivité, leur salinité et leurs solides en suspension. En outre, la qualité de l'eau potable a été contrôlée à intervalles réguliers, car du fait de son utilisation, la population humaine souffrait de diverses maladies d'origine hydrique. La disponibilité d'une eau de bonne qualité est un élément indispensable pour prévenir les maladies et améliorer les conditions de vie. Les analyses physico-chimiques ont montré que les eaux des stations échantillonnées étaient légèrement basiques, légèrement acides, moyennement oxygénées, avec une très faible amplitude thermique, et moyennement troubles et plus troubles. Certains rapports d'analyse de l'eau avec des paramètres physico-chimiques ont été fournis pour l'étude des paramètres d'exploration. Les directives de différents paramètres physico-chimiques ont été utilisées pour comparer la valeur d'un échantillon d'eau réel. Il a été conclu que la qualité de l'eau dans ces municipalités n'était pas adaptée à la consommation humaine et des règles d'hygiène de base ont été recommandées dans ces quartiers.

Mots-clés: physico-chimique, maladie d'origine hydrique, conductivité, résistivité, alcalinité.

1. INTRODUCTION

Human life depends to a large extent, on water. It is used for an array of activities; principal among these being for drinking, food preparation, as well as for sanitation purposes. In as much as safe drinking water is essential to health, a community lacking a good quality of this commodity will be saddled with a lot of health problems which could otherwise be avoided (Miller, 1997). Water is a fundamental resource, integral to all environmental and social processes. There is a growing concern everywhere that in the coming century, cities will suffer imbalances in quality water supply, consumption, and population. Many regions of the world are already limited by the amount and quality of available water. According to World Health

Organization (WHO, 2003), in the next thirty years alone, accessible water is unlikely to increase more than ten percent (10%) but the earth's population is projected to rise by approximately one-third. Unless the efficiency of water use rises, this imbalance will reduce quality water services, reduce the conditions of health of people and deteriorate the environment and the world. The world's population size and the rapid urbanization growth is increasingly a major issue in the world especially in developing countries. Cairn cross (2002), showed that by the year 1975, about 74% of the urban population in the developing world had access to safe water, the figure increased to about three hundred million (79%) in 1985 partly because of the International Water Decade which was an improvement, however, there were still 21% of the people who were still not having access to safe water. The rapidity with which cities are growing is frightening in the sense that human population with its associated sanitation problems will grow faster than increases in the amount of accessible quality water (Ackson *et al*, 2001). This means that per capita availability of quality water will decrease in the coming century.

Although, many international conferences as well as researchers have gone on in the past, little by way of success has been chalked so far. Report from World Health Organization (2002) indicates that over 2.6 billion people were still suffering from the effect of poor water around the world. It is based on this that Heads of states and governments met and signed the Millennium Declaration at the 2000 UN Millennium summit to end the sufferings from the effects of poor water quality across the globe, as a matter of urgency (WHO, 2002). The growing demands for adequate quality water resources create an urgent need to link research with improved water management, better monitoring, assessment, and forecasting of water resources and sanitation issues with much emphasis on the roles of stakeholders (UNESCO/WHO , 1978). It must however be emphasized that adequate water quality needs seem to have improved greatly in some regions and countries especially in the developed world, but for poor nations this is still a major issue (Stockholm International Water Institute, SIWI, 2001). As observed by WHO-UNICEF (2004), while in 2002, countries like Japan, Australia, Austria, Switzerland and Sweden had achieved hundred percent, others, such as countries in sub Saharan Africa are far below 50%. For instance, Guinea 6%, Liberia 7%, Niger 4%, Togo 15%, Ghana 46%,Cameroon, 19% (Zubia, Mosood,2015).

According to Schaffter and Parriaux, 2002; Saeed *et al*, 2014; Said *et al*, 2014 , the main source of water in these regions includes untreated rain water from roofs, polluted rivers and streams, unprotected wells and bore holes. He went further to show that there is little to choose between sub saharan rural and urban since the rural to some extent has only to deal with the quality while the urban has both the quantity and quality to deal with. Water related health problems are a growing human tragedy, and according to WHO (2003), it kills more than 5 million people a year with infants being the most affected. The problems also prevent millions of people from leading healthy lives, and undermine developmental efforts by burdening the society with substantial socio-economic costs for treatment of water-borne diseases. This problem is of great significance in cities in developing countries, where polluted water, water shortages, and unsanitary living conditions prevail. Information from WHO (2002), notes that, although access to water has improved greatly, access to safe water is still a major issue. The source quoted that about some 1.1 billion people rely on unsafe drinking water sources in developing countries and the lowest drinking water coverage rates are in sub Saharan Africa (58%) with a corresponding low sanitation coverage rates (36%) which leads to many deaths especially among children through diarrhoea among other water-related diseases. To meet the 2015 target of the United Nations Millenium Development Goals (MDGs) on access to safe drinking water therefore, will require that countries create the political will and resources to manage water especially in growing urban cities in sub Saharan Africa (Chilton, Smith-Carington,1984). Sources of water available to mankind are: atmospheric water (precipitate), surface water (including rivers, streams, ponds, etc), and ground water. The potability of water from any of these sources is determined by the water quality (Miller, 1997). With 97% of all freshwater found on the earth being stored underground, accessing ground water in the quest for potable water is a laudable venture. Groundwater is accessed by way of sinking wells and boreholes to reach the water table (Chilton, Smith-Carington, 1984). Water-related diseases are responsible for 80% of all illnesses/death in developing countries. Globally, 4 billion cases of diarrhoea are reported every year causing 1.8 million deaths, out of which about 90% are children under age five (WHO,2003).

Potable water is defined as water that is free from pathogens, low in compounds that are acutely toxic or that have grave long-term effects on human health (Fewtrell *et al*, 2005). Potable water should be free from compounds that can cause change in the 'normal' colour, taste (e.g. high salinity) and odour. Wells are normally located in valleys where the groundwater table is relatively high (4 – 10m below ground level) and infiltration of rain and river water plays a main part in the groundwater recharge. Boreholes however, draw water from deep (20 – 80 m or more) aquifers (Pritchard *et al;* 2008).

This project sought to assess the water quality of some wells, springs and streams in the Yaounde III municipality, precisely at the Obili and the Damas neighbourhood.Physicochemical parameters were determined.World population continues to increase at an alarming rate and will reach 8, 5 billion by 2025. Contrary to this population increase, it is estimated that 10,000 people die every day from water borne diseases. A primary concern of people living in developing countries is that of obtaining clean drinking water. In Africa and Asia, most people in rural areas depend on ground and surface water for sustenance. Water quality has a direct impact on public health. More than 80% of deaths is caused due to water borne diseases (United Nations, 1994, USEPA,2000).

The water supply system and quality in the Yaounde III municipality is insufficient as per demand of consumers due to increase population in these municipalities day by day and development. The population of the Obili and Damas neighbourhood shows an increasing trend of using wells, springs and to a limited extent stream water sources, mostly driven by the unreliable and quality compromised tap water supply and in part due to the perception and expectation of pure and safe drinking water. With the increasing demand and insufficient supply, it seems that in the near future, the urban dwellers would not have an option other than properly treating springs and well water to satisfy their demands. Thus it's high time to check the quality of these water sources and some measures taken. However, very few studies have been carried out to assess their quality and there are no agencies that regularly monitor their quality.

Safe drinking water is a fundamental right of human being. However, is the water that we drink safe? The answer is obviously “NO” as shown by the death statistics from water borne diseases, according to WHO which accounts to more than 3.4million people. Driven by the perception of purity, people switch to treat water their own way. The question is not: why to check the quality of these water sources, it is: why not? People have the right to know the quality of water that they perceive to be pure. Hence, this case study is justifiable. The main objective of this research is to analyse the physical and chemical quality of water in the Yaoounde III municipality. The specific objectives are: to locate and analyse selected water quality parameters of some sources, and carry out physico-chemical analysis on samples of these water sources from the Yaounde III municipality. To carry out observations and identify impacts of each source to the Yaounde III municipality. To verify the perception of the population on water pollution and the transmission of water related diseases. To propose solutions to remedy some of the problems caused by these water sources to the Yaounde III municipality denizens.

2. MATERIALS AND METHODS

2.1 MATERIALS

In order to successfully carry out this research, certain materials were used, with the most important ones being: Writing material which consisted of ball point pen and several A4 papers as well as an exercise book; A mobile phone for storing the contacts of resource persons, as well as making calls between each other; Writing pad: This served as the principal equipment for jotting down information obtained and observed on the field; A mobile phone camera of brand itel p12, used for taking pictures of those aspects on the field which were of particular interest to me.; A 13GPS of brand to obtain coordinates at the site; A mic recorder for saving important conversations with resource persons; Boots which permitted me access those areas which seemed quite difficult to reach; A computer of mark e-machines that allowed for the accomplishment of research and typing the data obtained from the field; Use of plastic containers, double capping polyethylene bottles and a thermos flask to collect samples from the sight; Use of indicators and an Alcohol thermometer at the site

This study was carried out in the center region of Cameroon, Yaounde. Yaounde is located in the forest region of the southern plateau between latitudes 3º30’, and 3º58’North and longitudes11º20’ and 11º 40’ East, with an altitude of about 750m .The relief is undulating and extends over several hills high of about 25 to 50 metres above the plateau . This region is characterized by a peculiar equatorial climate called the Yaoundéen climate which is hot and humid, which varies slightly over time characterised by an average rainfall of 1576 mm per year ,average temperatures of 24.44°C which varies very little. We have 4 seasons of unequal importance and duration which varies from one year to another as follows: a LDS (from mid November to mid March), a SRS (mid 15 March to ending June), a SDS (from July to mid August) and a LRS (mid August to mid November). However, the above climatic sequence is seriously perturbed by climate change and global warming.

2.2 METHODOLOGY

Quarters were randomly selected in the Yaounde III municipality, and due to lack of resources and limited time, Damas and Obili were selected at random as study units for these theses. Also, public places such as hospitals, were also considered. For the objectives of these studies to be attained, important research methods and instruments were used, including primary, secondary, qualitative and quantitative data collection. Primary data collection was done through the use of structured questionnaires to households in the Yaounde III municipality through informal interviews, telephone interviews and email data collection. Two structured questionnaires were prepared for the primary data collection. One for the selected houses in the study area or municipality and the other for quarter heads in the municipality. Two types of data variables were used, dependent and independent variables. Secondary information was also collected from census, survey report and internet. Much of the data in this study area is qualitative in nature. Qualitative approach includes virtually any information that can be captured that is not numerical in nature. Here, the aim is to explain, define and interpret a complex situation through the use of observation, interviews and written documents, watching, asking and examining to understand the use of the aquatic resources. This study was qualitative in the sense that it used open-ended questionnaires. The purpose of using open-ended questionnaires in this study area was to: Understand what is like to be in a particular situation, articulate the views of people, and gain understanding of underlying reasons and motivation. Uncover prevalent trends in thought and opinion. Quantitative research is about numbers and the counting and measuring of things in other words data is in the form of numbers and statistics. In quantitative approach methods for data collection are developed. The research was quantitative method and employed the use of closed-ended questionnaires. The purpose of using closed-ended questionnaires in this study was to: Quantify data and generalize results from a sample to the population of interest. Measure the incidence of various views and opinions in a chosen sample; Collect data from a large population; Collect numerical data for data representation and analysis. The choice of Yaounde III was influenced by the authors own opinion on how people become contaminated with water borne diseases and on how people move around with containers looking for good quality water(Figure 1 and 2).

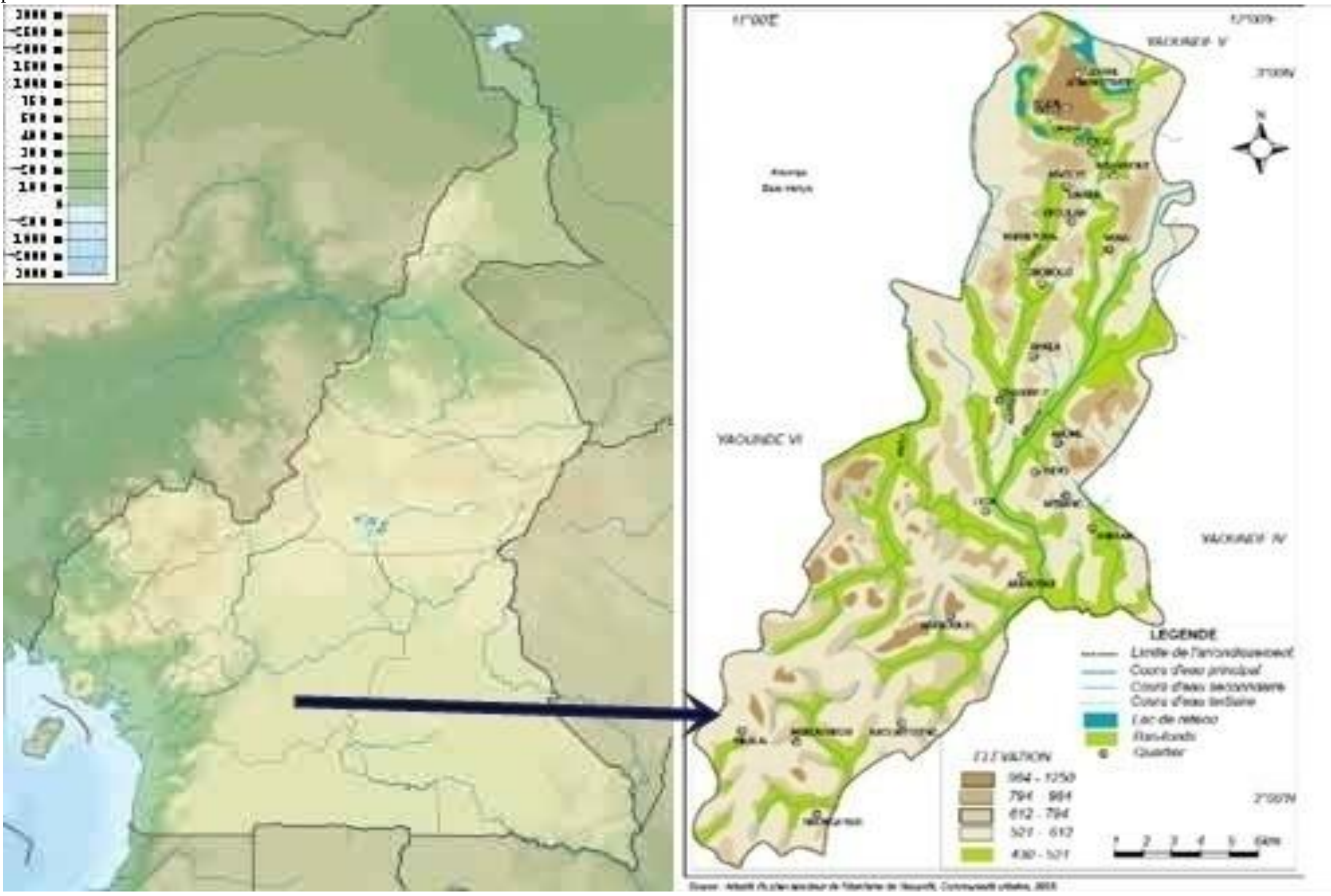

Figure 1: Map of Cameroon with map of the Yaounde III municipality

Figure 2: Map showing different sampling stations at the Obili and Damas neighbourhood

2.2.1 SAMPLING STATIONS

There were six sampling stations, three in Obili, and three in Damas, Yaounde. Damas is found in the Yaounde III municipality with geographical coordinates of 03°48’47.7’N and 11°29’00.4’’ E and an altitude of 691 m. This study site is characterized by stagnant water, streams and wells with few taps. Different water samples were collected from a spring, a stream and a well at the damas neighbourhood as seen in figure 3 below. Damas Well is located at Rue Damas at an altitude of 712.704346m and with coordinates E 11°29.654′ and N03°49′.616″.This well is 12m deep and characterised by macrophytes.The principal source of pollution in this sampling station originates from the fact that the water source is exposed and not protected and also sorrounded by houses around the stations as can be seen in figure 3A below.Damas Spring is located at Rue Damas and characterised by the presence of clay soil and some sediments, at an altitude of 715.518066m and with coordinates E11°29.643′ and N03°49.673′. This water source has a depth of 30cm and 0.5m wide.This water source receives waste from households around the station and can be seen in figure 3C below.Damas Stream stream is located at Rue Damas with an altitude of 703.748413m, and coordinates E11°29.636′ and N03°49.613′.It is 15cm deep and 40cm wide and receives waste from households around the station, most especially from toilets whose drainage is connected directly to the stream as can be seen in figure 3D below.It is characterised by debris and some sediments. Obili is one of the quarters found in the Yaounde III municipality. It is bounded by Oleazoa, Nsimeyong,Melen and biyem-Assi.Its characterised by few springs, many streams and few wells and taps. Different water samples were collected from a spring, a stream and a well at the obili neighbourhood as seen below in figure 4 below.Obili Well is loacted at an altitude of 722.65454m and with coordinates E11°29.418′ and N03°51.173′ . The water depth at this station is 12m as shown in fig4B below and is marked by the presence of loam soil. Obili Spring is found at an altitude of 711.997864m and have coordinates E11°29.390′ and N03°51.206′.This station is characterised by the presence of clay soil and some sedimentary rocks as can be seen in fig4B below.Obili Stream is found at an altitude of 707.241943m and with coordinates E11°29.394′ and N03°51.122′.This station is 13cm deep and markd by the presence of debris and waste from households that highly pollutes the stream as shown in figure 3-5 below.

Figure 3: Different sampling stations at the Damas neighbourhood.

Figure 4 and 5: Different sampling stations at the Obili neighbourhood

2.2.2 DETERMINATION OF PHYSICO-CHEMICAL PARAMETERS

Physico-chemical analysis was carried out both on the field and in the laboratory following the recommendations of (Rodier, 1996) and (APHA, 1998). For those carried out in the laboratory, sampling was always done using double capping polyethylene bottles of 250 and 1000mL before being transported to the laboratory in an insulated cooler. Temperature was measured at the field using an alcohol thermometer graduated in 1/10ºC. 2/3 of the thermometer was immersed into the stream, wells and spring samples for 2minutes and the temperature values read and recorded.Suspended solids, turbidity and colour were measured in the laboratory by colorimetric analysis using a spectrophotometer of mark HACH DR/2010 at wavelengths of 810nm, 450nm and 455nm respectively. To measure these parameters, 25mL of distilled water was used to calibrate the apparatus thereafter, 25mL of sample water was poured into the spectrophotometer tube cell and the results read on the screen of the apparatus at the respective wavelengths of the parameters measured. Their values were expressed in mg/L for suspended solids, Formazine Turbidity Unit (FTU) for turbidity and Pt.Co (platinum cobalt) for colour. Electrical conductivity, resistivity, salinity and TDS, were measured using a multi-parameter of mark HANNA HI 9829 with a resolution value of 0.01. Two thirds of the electrode was dipped into the water sample for about 2 minutes and the values were read on the screen. The results obtained for these different parameters were expressed in µS/cm (micro Siemens per centimeter), Ω/cm (ohm per centimetre), PSU (Practical Salinity Unit) and mg/L respectively.Carbon dioxide was measured in two stages. The first stage was in the field and consisted in the fixing of carbon dioxide. Here ,20 mL of NaOH N/20 was measured using a measuring cylinder and poured into a 200mL volumetric flask to which 2 to 3 drops of phenolphthalein indicator were added, producing a characteristic pink colour, the flask was completed with water sample to the 200th millimetre mark on the flask. The mixture was then transferred into a 250mL double capping polyethylene bottle and transported to the laboratory in an insulated cooler.

The second phase was done in the laboratory where 50mL of the mixture was titrated with HCl N/10 until the disappearance of the pink colour. A control experiment was conducted where distilled water was used in the place of the water sample and titrated with HCl N/20, and the amount of CO2 was obtained from the formula;CO_2 (mg/L) = (burette decrease of control sample - burette decrease of test sample) x17.6. Measurement of dissolved oxygen also involved two stages. The first stage being on the field and involved the fixation of dissolved oxygen by collecting 123mL of our water sample in a Winkler's bottle to which was added 1mL of MnCl2 and then 5 minutes later 1mL of KOH+KI solution known as Winkler's reagent. This led to the formation of a white precipitate and the solution was homogenised by gently swirling the bottle which was closed firmly and transported to the laboratory in an insulated cooler. The second phase was carried out in the laboratory where 1mL of concentrated H_2SO_4 was added to the mixture to dissolve the white precipitate formed. Fifty milliliters of the fixed sample was then collected using a measuring cylinder and poured into a beaker and 2 to 3 drops of starch indicator was added. This led to the formation of a blue black coloration. The mixture was then titrated against an N/80 sodium thiosulphate solution until the decolourisation of the blue black colour. The amount of oxygen gas in the sample was expressed in mg/L and calculated using the formula; O_2 (mg/L) = (Final burette reading -initial burette reading) × 2. Alkalinity was determined in the laboratory by volumetric analysis. 50 mL of the water sample was poured into a beaker, to which 2 to 3 drops of red green methyl bromocresol colour indicator was added and the solution titrated against a N/50 H_2SO_4 solution.The results for alkalinity were expressed in mg/L and calculated thus;Alkalinity (mg/L) = change in burette's reading ×20.

2.2.3 WATER PROBLEMS FACED IN THESE LOCALITIES

There are a lot of water difficulties encountered in the neighbourhood of Damas. This is seen through the fact that out of about 2000 habitats, more than half possesses Wells which is used in cooking, and some treated wells are used as drinking water sources, as there is rarely water flow from taps in this quarter. Also, there are about eight underground water sources but not clean as its not treated, which some households used for laundry, cooking and even drinking carried by people. In this quarter, more than half of the population depends on wells for survival, most especially laundry, while those who are fortunate to have taps can then sale water to those who cannot afford taps, who further use this water as drinking or portable water. People do not mostly depend on streams as it is highly polluted. The water difficulties at Obili are not as intense as those in Damas as there is constant water flow in this quarter, though with a population greater than that of Damas. Out of about 25000 habitats in the Obili neighbourhood, not up to a quarter possess wells. The few springs or underground water sources are mostly used by those who cannot afford water bills (CAM WATER). So many around the spring sources further treats the spring and use it as a source of drinking water, most especially those springs that are well preserved. Most households depend on taps for survival, few on wells and springs. People rarely depend on stream because of its high level of pollution, due to the population. The total number of wells, streams and springs with the number of people using the said sources were estimated on table 3 below;

Table 1: Estimated water sources and the % using the sources in the sampled localities.

1. Quarter	Water Source	Number Of Source	% Using This Source
-Obili	-Wells	45	40
	-springs	06	45
	-streams	08	05
-Damas	-wells	167	95
	-springs	08	80

	-streams	10	3

A direct observation of conditions of individual wells, springs and streams was made to ascertain any possible sources of contamination of the water other than contamination from on-site sanitation systems. Factors like the major uses of the water, the depth, water levels, and nearness to a possible source of contamination like septic tanks, public toilets, private toilet pits and gutters were looked out for. At each site a sanitary inspection was made during the sampling period. The sanitary inspections involved the use of unstructured questionnaire based on the individual state of the water sources. Interviews at each water source, ten regular users of the water sources were interviewed. Interviewees were asked about the uses they put the water fetched from these sources to, they were asked about their perception on the quality of the water, as well as whether they had experienced any illness they could link to the use of the water in their various activities. Also, health centres around these vicinities were visited and some statistics collected. All the physicochemical variables and the estimated percentage of water borne diseases in these localities were analysed using Microsoft excel 2007.

3. RESULTS AND DISCUSSION

The results gotten from different sampling stations in the Yaounde III municipality, precisely from wells, streams and springs in the Damas and Obili neighbourhood, after analysis. It also describes the health statistics related to water borne disease in the neighbourhood for the past five consecutive years. The results obtained are as well analysed as to why they are the way they are and the possible causes of the results obtained. Table 4-7 below shows the different diseases and causative agents, water adduction sources and usage, data for water borne diseases and the physico-chemical results obtained for different parameters and from different sampling stations.

Table 4: Present Some of Such Diseases and Their Causative Agents

Disease	Causative agent
-Bacterial dysentery	*Shigella dysentera*
-Typhoid fever	*Salmonella typhi*
-Para typhoid fever	*Salmonella paratyphi*
-Cholera	*Vibrio cholera*
-Dysentery	*Entamoeba histolytica*
-Infantile paralysis(poliomyelitis)	Polio virus
-Hepaptitis	Hepatitis virus

Table 5: Estimated Water Sources And The % Using The Sources In The Sampled Localities.

1.Quarter	-Water Source	-Number Of Source	% Using This Source
-Obili	-Wells	45	40
	-springs	06	45
	-streams	08	05
-Damas	-wells	167	95
	-springs	08	80
	-stream	10	3

Table 6: Statistics for Water Borne Diseases for 5 Consecutive Years in Damas and Obili

Year	DC Damas-Cholera	Ddy Damas-Dysentery	DD Damas Diarhoea	Dt Damas-Typhoide	OC Obili-Cholera	Ody Obili-Dysentery	OD Obili Diarhoea	Ot Obili Typhoide
2014	50%	90%	60%	70%	30%	65%	45%	60%
2015	10%	85%	65%	45%	6%	45%	60%	65%
2016	4%	75%	60%	80%	1%	50%	65%	70%
2017	2%	73%	80%	90%	1%	55%	75%	73%
2018	1%	70%	95%	93%	0%	60%	80%	80%

Table 7: Results of physicochemical parameters obtained from different water sources.

Parameter/Unit	Obili Spring (Os)	Obili Stream (Ost)	Obili Well (Ow)	Damas Spring (DS)	Damas Stream (DSt)	Damas Well (Dw)
pH(UC)	7.13	7.8	6.23	6.52	7.44	6.57
Alkalinity(mg/L)	14	54	16	06	22	06
Oxygen(%)	65.2	65.7	65.9	66.1	64.8	66.7
CO_2(mg/L)	14.08	15.84	12.32	12.32	14.08	15.84
Temperature(°c)	27	24	25	26	24	24
Suspended solids(mg/L)	0.11	10.6	35	77	130	0.1
Turbidity(FTU)	0.9	06	0.4	12	03	04
Colour(Pt.Co)	03	17	19	05	09	04
Salinity(PSU)	0.17	0.37	0.09	0.16	0.23	0.13
TDS(mg/L)	159	339	82	153	216	120
Conductivity(µs/cm)	317	678	164	306	433	238
Resistivity(Ohm/cm)	3145	1475	6098	3268	2309	4184

As presented in figure 6 below, the highest pH (Hydrogen potential) value was 7.44CU and was obtained at the Damas stream (Dst), while the least pH value was 6.23CU and was obtained at the Obili well (Ow).

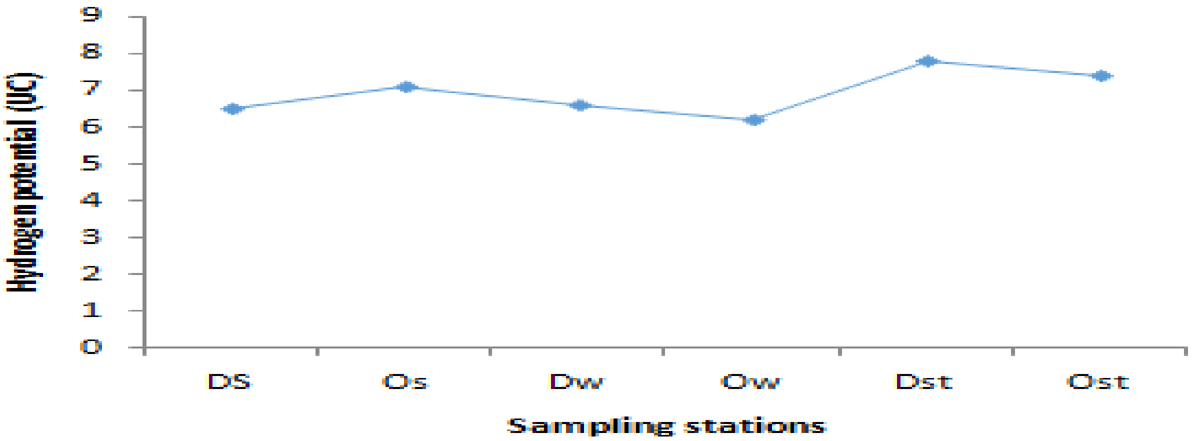

Figure 5: Variation of water pH

Figure 7 below reveals the value of alkalinity which varies from 06mg/L through 54mg/L to 22mg/L, with the highest value of 54mg/L recorded at the Obili stream (Os) and the least values recorded at the Damas spring (DS) at 06mg/L and Damas well (Dw) at 06mg/L.

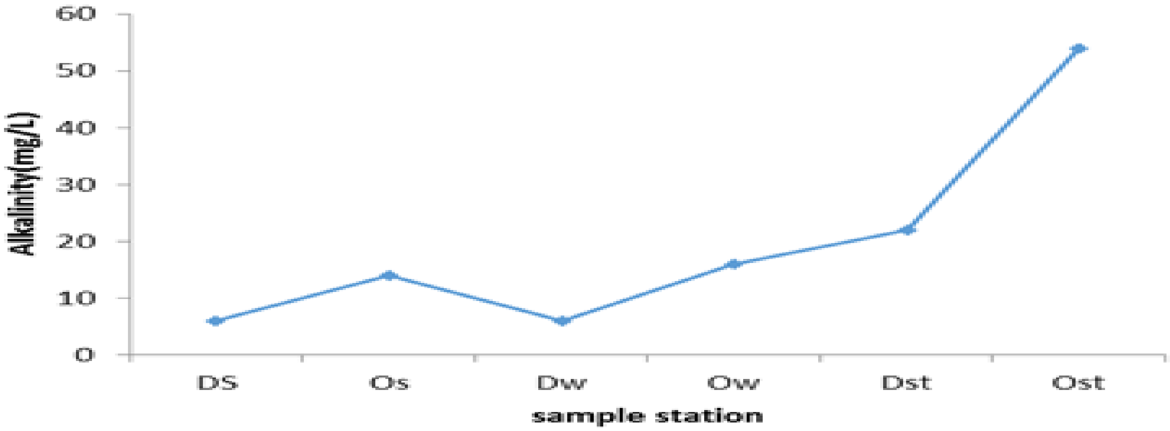

Figure 6: Variation of water Alkalinity

As shown on figure 8 below, dissolved oxygen varied through 64.8%, 65.9% to 66.7%. The highest value of 66.7% was obtained at the Damas well (Dw) and the least value of 64.8% was obtained at the Obili stream (Ost).

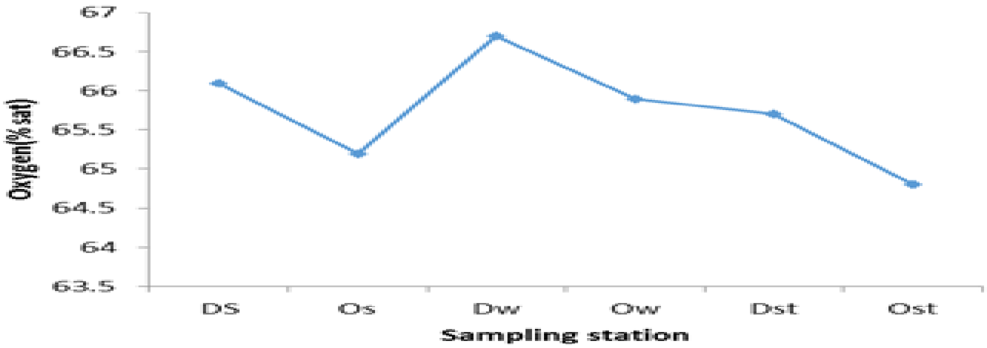

Figure 7: Variation of dissolved Oxygen

According to figure 8 below, dissolved carbon dioxide varied between 12.32mg/L through 14.08mg/L to 15.84mg/L, with the highest values of 15.84mg/L of dissolved carbon dioxide recorded at the Obili stream, and also, 15.84mg/L was recorded at the Damas well, and the least values of 12.32mg/L recorded at the Ow and Dst.

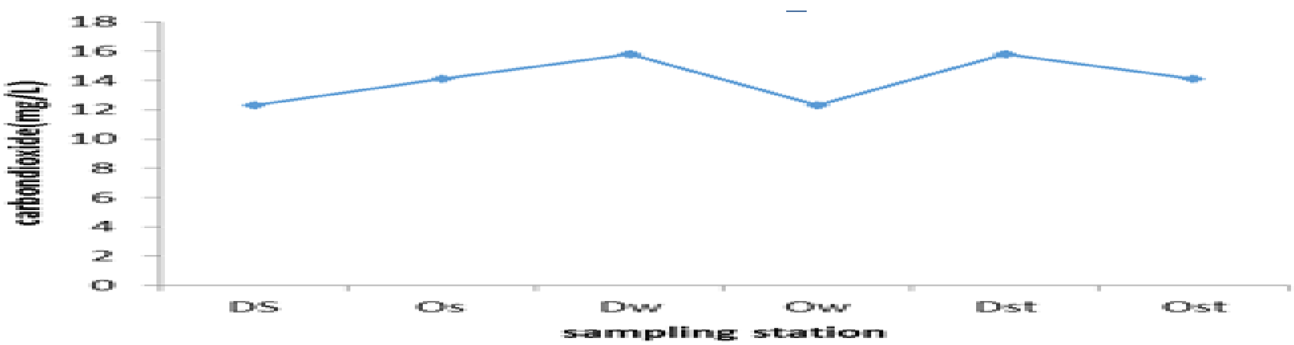

Figure 8: Variation of dissolved CO_2

As presented on figure 9 below, water temperature varied between 24°C, through 25°C to 27°C, with the highest temperature value of 27°C recorded at the Os, while the least temperature of 24°C was recorded at the Ost,Dst.

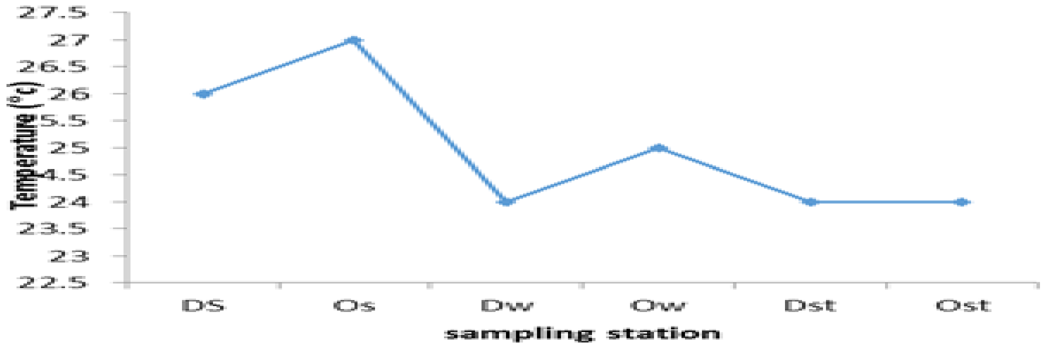

Figure 9: Variation of water temperature

As shown in figure 10 below, suspended solids varied from 0.25mg/L, through 77mg/L to 130mg/L. The highest value of 130mg/L was recorded at Dst and the least value of 0.1mg/L was recorded at the Os.

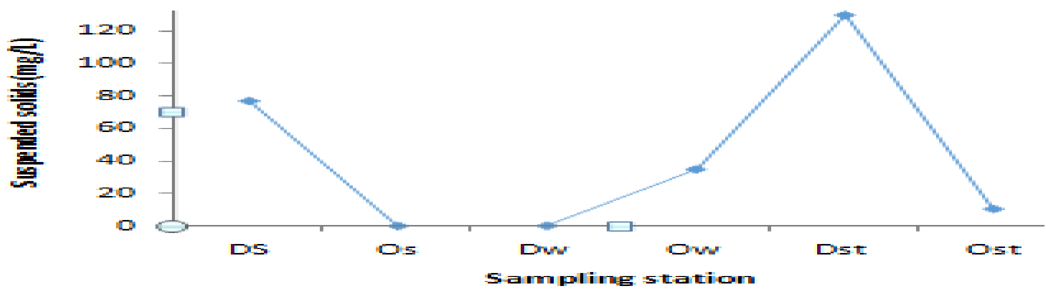

Figure 10: Variation suspended solids (SS)

As indicated in figure 11 below, turbidity varied from 0.4FTU through 6FTU to 12FTU, with the highest turbidity value of 12FTU recorded at the Dst, and the least value of 0.4FTU recorded at the Ow.

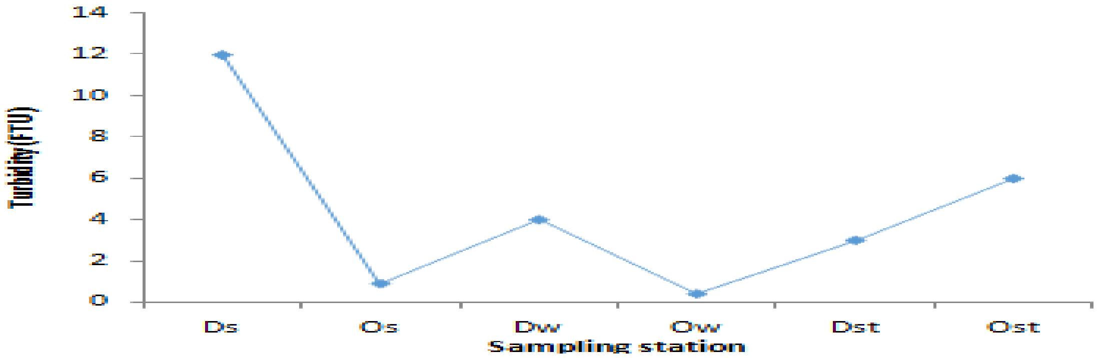

Figure 11: Variation of turbidity

As indicated on figure 12 below, colour varied between 03Pt.Co, through 09Pt.Co to 17Pt.Co. The highest value of 17 Pt.Co was recorded at Ost, and the least value of 03 was obtained at Os.

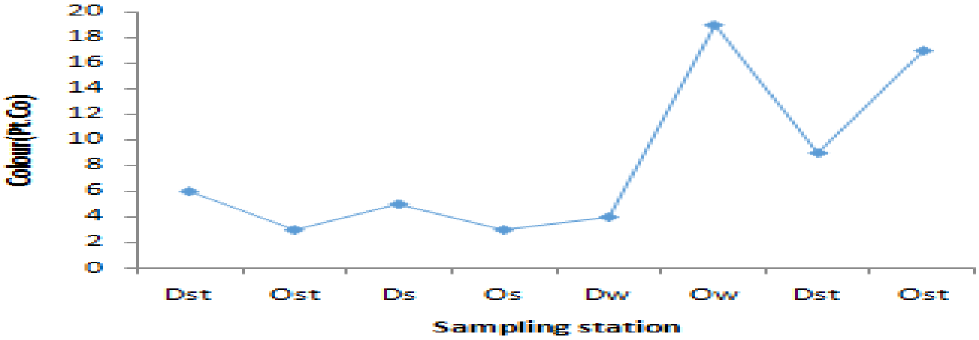

Figure 12: Variation of water colour

As shown in figure 13, salinity varies from 0.09PSU, through 0.16 to 0.37 PSU. The highest salinity value of 0.37PSU was recorded at the Ost, While the lowest salinity value of 0.09PSU was recorded at the Ow.

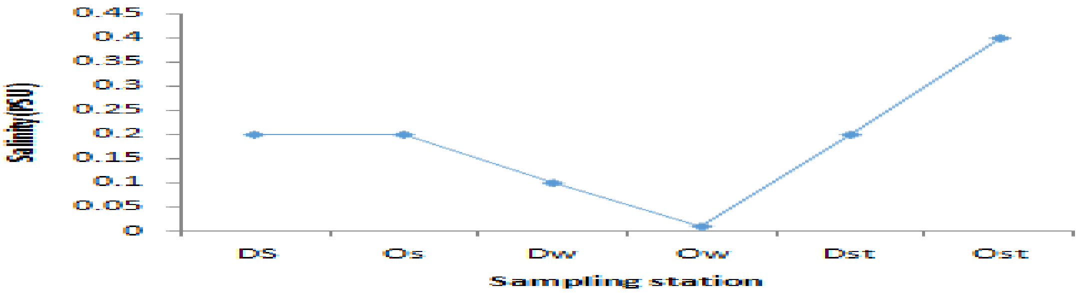

Figure 13: Variation of salinity (PSU)

As shown in figure 14 below, TDS varied between 82mg/L through 153mg/L to 339mg/L. The highest TDS value of 339mg/L was recorded at the Ost, while the least value of 82mg/L was recorded at the Ow.

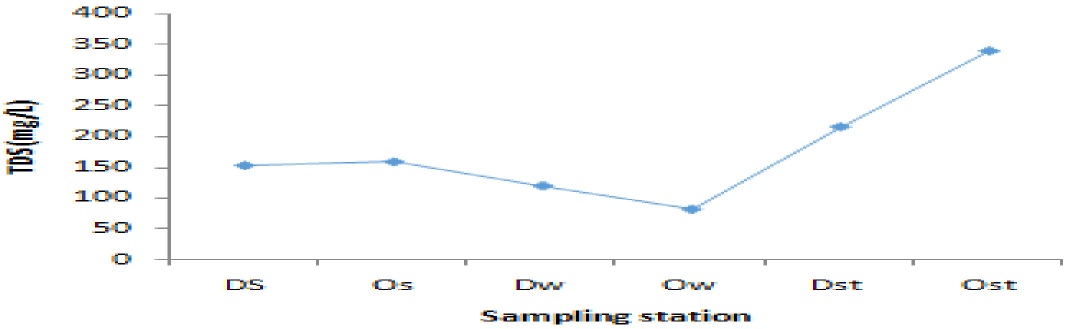

Figure 14: Variation of Total Dissolved Solids (TDS)

According to figure 15 below, conductivity varied between 168µs/cm through 306µs/cm to 678µs/cm. The highest value of conductivity at 678µs/cm was recorded at Ost, while the lowest value of 164µs/cm was obtained at the Ow (Obili well).

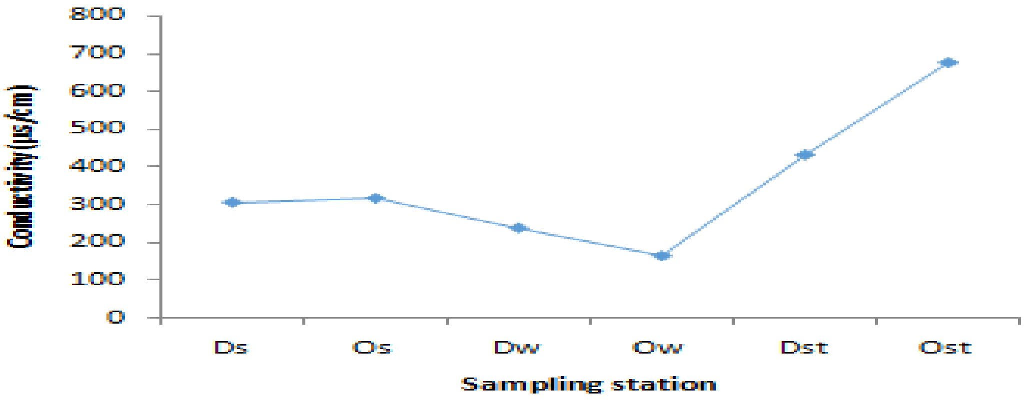

Figure 15: Variation for conductivity(µs/cm)

As shown in figure 16 below, resistivity varies from 1475Ω/cm through 2309Ω/cm to 6098Ω/cm. The highest resistivity value of 6098Ω/cm was recorded at the Ow, while the least value of resistivity of 1475Ω/cm was obtained in the Ost.

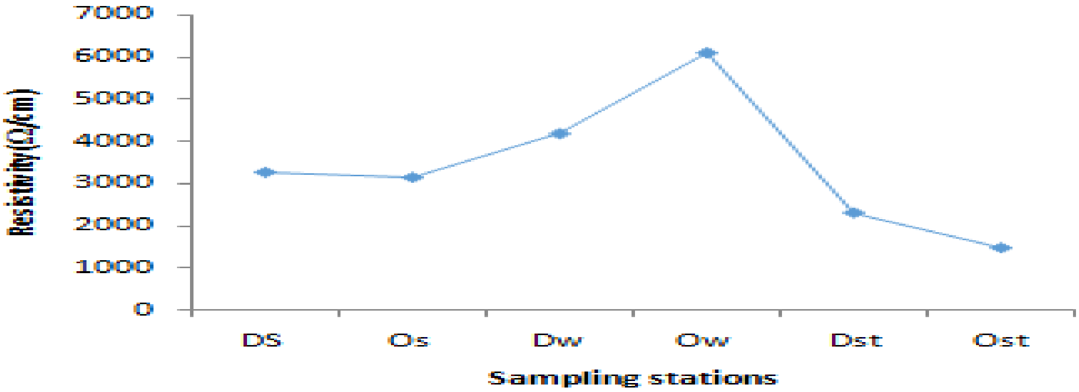

Figure 16: Variation of electrical resistivity

The most prominent water borne diseases observed in these localities according to this report was typhoid fever, while the least water borne disease was Cholera. Other water borne diseases observed were Diarrhoea and dysentery. From the statistics below, diarrhoea, typhoid fever and dysentery has become a call for concern so far as the health results obtained from the health centres is concerned. The statistics in these municipalities according to the SAREF foundation health centre at Obili, Yaounde and the Saint Elizabeth health centre, Damas, Yoaunde, were as seen in table 6 below;As seen in figure 18 below, in the year 2014, the most renowned water borne disease which affected about 90% of the denizens in the damas neighbourhood according to the Saint Elizabeth health centre statistics is dysentery (Ddy), while the least renowned water borne disease which affected about 30% of the population in that municipality (Oc), was registered at the SAREF health centre at obili(Figure 17).

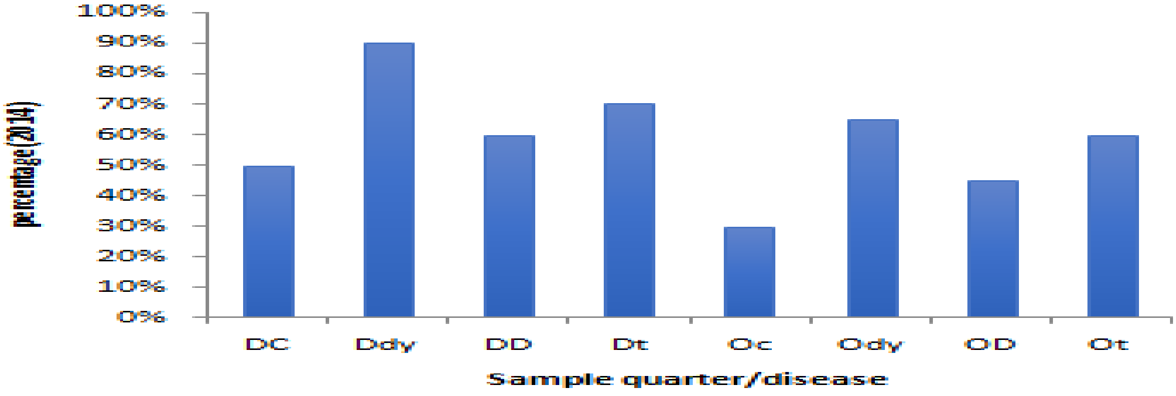

Figure 17: Variation of water borne diseases

As seen in figure 18 below, in the year 2015, the most prominent water borne disease which affected up to 85% of the population at the Damas neighbourhood according to the Saint Elizabeth health center was dysentery, while the least renowned water borne disease with records of 6% was obtained at the Obili neighbourhood, in the name of Cholera.

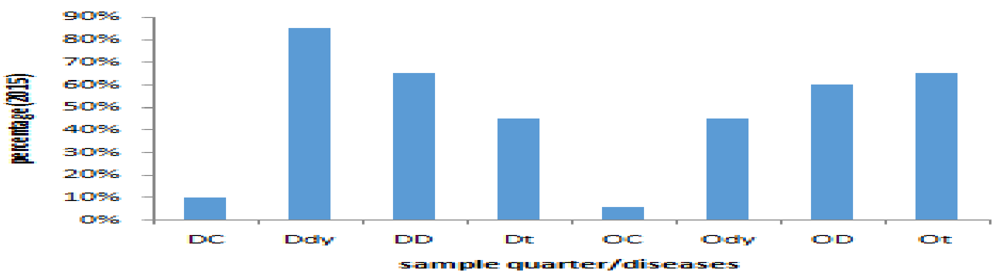

Figure 18: Variation of water borne diseases

As seen in figure 19 below, in 2016, the highest value of water borne disease at 80%, was recorded in damas, according to Saint Elizabeth health centre (Dt), while the least results of 1% were obtained at the Obili neighbourhood according to SAREF health center.

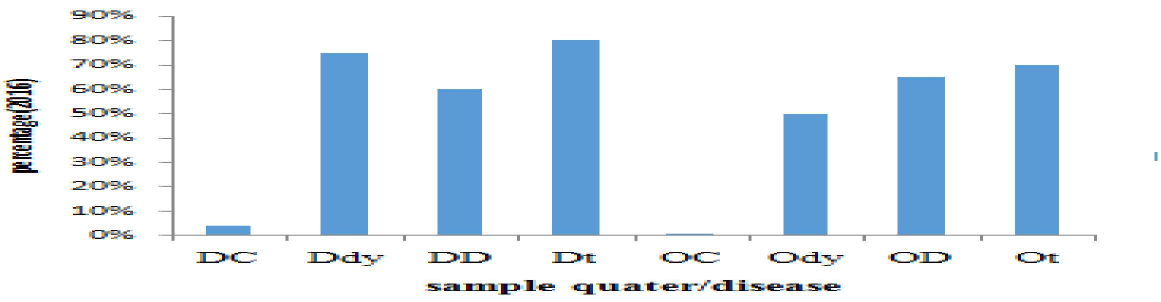

Figure 19: Variation of water borne diseases

As seen in figure 20 below, the highest value of 90% for typhoid fever was recorded at Damas according to Saint Elizabeth health center records, 2017, while the least water borne disease value of 1% for cholera, was recorded at the Obili SAREF foundation health centre.

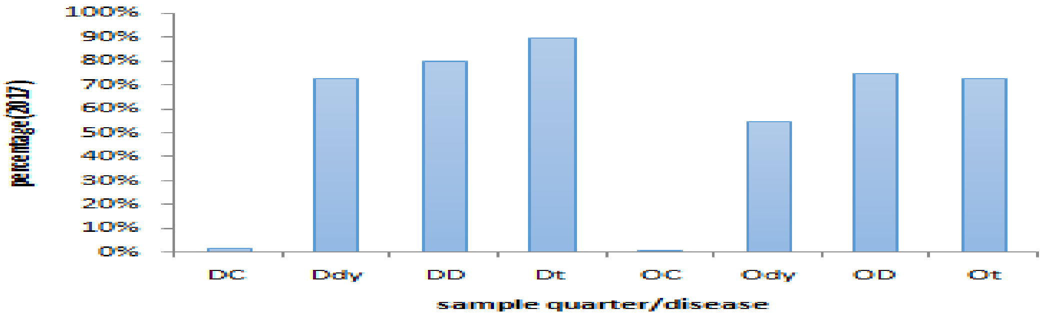

Figure 20: Variation of water borne disease

Some few cases of water washed diseases or water scarce diseases (diseases which thrive in conditions with freshwater scarcity and poor sanitation) were also reported in these localities. Control of water-washed diseases depends more on the quantity of water than the quality Examples of water washed diseases found out in these localities were scabies, Yaws, Relapsing fever, Trachoma, Conjunctivitis and Skin ulcers. A reliable, safe water supply plays an important role in disease prevention, especially by facilitating personal, domestic, and food hygiene. They may be divided into the following three groups:Diseases transmitted by the faecal–oral route, such as hepatitis A, bacillary dysentery, and many diarrhoeal diseases; these are transmitted by water and also by other means, such as food or hands. Improved hygiene therefore contributes to their control. Infections of the skin and eyes, such as trachoma, skin infections, and fungal skin diseases. The prevalence of these diseases is related to poor hygiene. Infections carried by lice or mites, such as scabies (mites), and louse-borne epidemic typhus (caused by Rickettsia prowazeki and transmitted largely by body lice). Good personal hygiene can assist in control

We discuss the results from the findings of the study. From the findings of the study, the researcher compares the results obtained from the analysed samples with the standard reference, most especially with the WHO and UN standard reference of water quality.Conductivity in all the water samples analysed are below the maximum limits of 1000 µS/cm as can be seen in table 4 above. The values ranged between 164 and 6678 µS/cm, high value was recorded from Sampling point Ost and low value at Sampling point Ow. Conductivity in water is a measure of all ions dissolved (soluble salts) .The low conductivity values indicate low mineralized water. Turbidity measurements in water are a key test of water quality as high turbidity in water may indicate ineffectiveness in filtration. The turbidity of the samples analysed varied between 0.4-12NTU which falls within 5NTU recommended values by WHO, except sample Ost. and the Ds which is higher and more turbid and more murkier. The lowest values were found at Ow and Os, which are least turbid (Basavara, 2011).

Alkalinity is another parameter in water quality study; it is the acid neutralizing capacity of water and a function of all titratable bases present in water. The alkalinity values ranged between 06-54mg/L. The values were found to be below the prescribed limit of 500 mg/L. The highest alkalinity value recorded at the Ost, which indicates it has a good buffering capacity, indicating that water must have flown through limestone region (Calciium carbonate) containing carbonates which generally have high alkalinity. Conversely, areas rich in granites and some conglomerates and sandstones may have low alkalinity and therefore, poor buffering capacity. This high alkalinity could be due to the introduction of basic wastes into the water body but also due to the high values of dissolved CO_2 recorded.

pH is among the most important parameters in operational water quality study and is the measurement of acid base equilibrium in water. From the results, the highest values was recorded at Dst. and lowest at Ow .which falls within the recommended levels of 6.5-8.5 by WHO, meaning no case of acidity or alkalinity which could be accompanied by adverse effects. The temperature is one the most essential parameters in water. It has significant impact on growth and activity of ecological life and is greatly affects the solubility of oxygen in water. The values obtained ranged from 24°C to 27°C. The highest value was found to be 27°C. According to WHO,2002, limit of temperature is 15-25°C. The marked increase in temperature in the Ds and Os can be as a result of pressure from underground source because increase in pressure leads to increase in temperature with depth. As a result, deep circulating ground water becomes warm when in spring form. Also, the temperature of the Ow was high, indicating that the well could be an Artesian well.

Chlorides are common constituents of all natural waters. Higher value of it imparts a salty taste to water making it unacceptable for human consumption. The values of chlorides range from 0.09-0.37mg/L. In the present study values of chlorides was found to be below the pre-subscribed limit of 250 mg/L. When salinity exceeds1,000mg/l, aquatic organisms are adversely affected. Fresh water species are generally restricted to salt levels of less than 3,000mg/L. According to Australian Drinking Water guidelines, salinity levels from 0-600mg/L are classified as good quality, from 600-900mg/L classified as fair, 900-1200mg/L classified as poor and greater than 1200mg/L is unacceptable(unpalatable).CO_2 was found within the range of 12.32-15.84mg/L. This value depends upon alkalinity and hardness of water according to International Journal of Mineral Processing and Extractive Metallurgy 2017. Surface water usually contains about 10ppm of free carbon dioxide. High amount of Carbon dioxide such as in the Dw indicates that the water is acidic as carbon dioxide in water gives carbonic acid.

It was found out that, colour values ranged between 03-19Pt.Co, which is within WHO permissible limit of 15Pt.Co, but for 19Pt.Co at the Ow and 17Pt.Co, at the Ost. Colour in these water stations could have been due to the presence of colour organic matter associated with the humus fraction of soil or the presence of iron and other metals, either as natural impurities or as corrosion products. Also, the relatively high water colour in the named sampled stations could be due to the presence of waste that are introduced in the drainage basin. It could also be due to intense biological activity that results from the process of eutrophication. From results obtained, it was observed that, the value of suspended solids varies between 0.1-130mg/L. According to the results obtained, high concentrations above the WHO recommended value affect the test of drinking water quality (Szewzyk,2000). The high suspended matter of 130mg/L in the Dst. and Dw may be due to the presence of organic material such as algae, and inorganic material such as silt and sediment. The TDS in all the water samples were far below the WHO maximum allowable limit of 1000mg/L. The high values of 339mg/L at Ost. indicates a greater amount or quantity of dissolved organic and inorganic content. Also, primary sources for TDS in the Ost are from agricultural and residential run offs. The most common constituents in this source could be calcium, phosphates, sodium etc, while naturally occurring TDS could result from weathering and dissolution of rocks and soils. Total dissolved solids indicate the salinity of groundwater. This could also be obtained by

The higher values of dissolved oxygen obtained at sampling station 66.7% could be due to more intense water oxygenation resulting from water agitations during periods of rainfall. Baldy *et al.*,1995). Aquatic life is put under stress if the dissolved oxygen level in water drop below 5.0mg/L. Oxygen levels below 1-2mg/L leads to large fish kills.Resistivity is the reciprocal of conductivity. From the studied sampling stations, the highest resistivity value was obtained at the Ow of 6098 ohms/cm, which indicate that this particular sampling station is bound to have low conductivity level. The least resistivity value of 1475ohm/cm was recorded at the Ost sampling station, which indicates that this water body could conduct electric current; this also indicates that this water will have high concentration of dissolved salts, hence, low resistivity. More than half of the population of the Damas neighbourhood and $1/5^{th}$ of the population in the obili neighbourhood use dug wells with Open or poorly covered well heads, which poses the commonest risk to well-water quality, since the water may then be contaminated by the use of inappropriate water-lifting devices by consumers, which further leads to water borne diseases and water washed disease (Szewzyk *et al*, 2000). The most serious source of pollution in these sample areas is contamination by humans and waste from latrines, septic tanks, and farm manure, resulting in increased levels of microorganisms, including pathogens in water. Dug wells are generally the worst groundwater sources in terms of faecal contamination, and bacteriological analysis serves primarily to demonstrate the intensity of contamination and hence the level of the risk to the consumer. The commonest physical defects leading to faecal contamination of dug wells are associated with damage to, or lack of, a concrete plinth, and with breaks in the parapet wall and in the drainage channel. However, the most hazardous gross faecal contamination is most commonly associated with latrines sited too close to the well. Emergency relocation of either the latrines or the water source is essential when such serious problems are encountered. The majority of open dug wells are contaminated, with levels of at least 100 faecal coliforms per 100mL, according to WHO unless very strict measures are taken to ensure that contamination is not introduced by the bucket. Also, water borne diseases results from using springs which most people believed is a good source in the sampled quarters most especially Damas, as the spring is not fenced and protected (Patil *et al*; 2012, Musa *et al*; 2013). It is difficult to define protection zones for individual tube wells as the resources are rarely available for a full study of the properties of the aquifer or for comprehensive pumping test (Dahiru M. and O. I., Enabulele ; 2015, El-Amier.2015).

The purpose of this chapter is to provide solutions in order to remediate contamination of water sources which further leads to water related diseases in these neighbourhoods. It is recommended that Solar water disinfection process should be adopted in this locality, where portable water is purified using solar energy to make biologically contaminated (e.g. bacteria, viruses, protozoa and worms) water safe for drinking, using heat from the sun to heat water to 70-100˚C for a short period of time. This affects pathogens present in in water and reduces the occurrence diseases caused by these pathogens. Also, the following hygiene practices should be considered in the municipality to prevent water borne and water washed diseases(Lu, 1990; Lukubye and Andama, 2017).All children, women, and men in the community should use safe water sources for drinking and food preparation, Adequate water should be used for hygiene purposes such as bathing, household cleanliness, and clothes washing. Water should be efficiently used and not wasted. Wastewater should be properly drained away. Improved water sources should be used hygienically and be well maintained. There should be no risk of contamination of water sources from nearby latrines, wastewater drainage, cattle, or agricultural chemicals. Simple purification procedures, e.g. chlorination, should be carried out on the water source if necessary. If necessary, water should be filtered to remove any solid material, guinea worm, before consumption. Drinking-water should be collected in clean vessels without coming into contact with hands and other materials. Water should be transported in a covered container. Adequate amounts of water should be available and used for personal and domestic hygiene. (It is estimated that a minimum of 30–40 litres per person per day are needed for personal and domestic hygiene.).Hands should be washed with soap or ash before food is prepared or eaten. Vegetables and fruits should be washed with safe water, and food should be properly covered. Utensils used for food preparation and cooking should be washed with safe water as soon as possible after use and left in a clean place. All men, women, and children should use latrines at home, at work, and at school. The stools of infants and young children should be safely disposed of. Household latrines should be sited in such a way that the pit contents cannot enter water sources or the groundwater table. Hand-washing facilities and soap or ash should be available, and hands should always be washed after defecation and after helping babies and small children. Household wastewater should be disposed of or reused properly. Measures should be taken to ensure that wastewater is not allowed to create breeding places for mosquitoes and other disease vectors or to contaminate safe water (Venugopal, 1994, Vidyasagar, 2007).

A community dug well with a windlass whereby one bucket is suspended over the well in a narrow opening is an improvement on each individual using his or her own bucket. Water quality should be greatly improved by the installation of a hand-pump and the fitting of a sanitary cover to an open dug well, access being restricted by a lockable sanitary lid, which prevents any contamination of the well by buckets. However, even this relatively costly improvement may fail to reduce contamination significantly unless the well lining is made watertight down to the dry-season water-table. If faecal contamination persists, the community may have to resort to pot chlorination, but this requires considerable organization and management to be successful; effective physical protection of the source is Provision of water for domestic purposes in adequate quantities and quality will contribute to reducing the incidence of diseases transmitted by the faecal– oral route and other transmissible diseases. Water quality deals with the physical, chemical, and biological characteristics in relation to all other hydrological properties. The quality of ground water depends on various chemical constituents and their concentration, which mostly can be derived from the geological data of the particular region. There are different sources through which groundwater becomes contaminated and these includes organic wastes, industrial effluents, urban runoff, agricultural activities, geological factors as well as othersMany chemical substances emitted into the environment from anthropogenic sources pose a threat to the functioning of aquatic ecosystems and to the use of water for various purposes. The need for strengthened measures to prevent and to control the release of these substances into the aquatic environment has led many countries to develop and to implement water management policies and strategies based on, amongst others, water quality criteria and objectives. To provide further guidance for the elaboration of water quality criteria and water quality objectives, The precautionary principle should be applied when selecting water quality parameters and establishing water quality criteria to protect and maintain individual uses of waters. In setting water quality criteria, particular attention should be paid to safeguarding sources of drinking-water supply. In addition, the aim should be to protect the integrity of aquatic ecosystems and to incorporate specific requirements for sensitive and specially protected waters and their associated environment, such as wetland areas and the surrounding areas of surface waters which serve as sources of food and as habitats for various species of flora and fauna. Water-management authorities in consultation with industries, municipalities, farmers' associations, the general public and others should agree on the water uses in a catchment area that are to be protected. Use categories, such as drinking-water supply, irrigation, livestock watering, fisheries, leisure activities, amenities, maintenance of aquatic life and the protection of the integrity of aquatic ecosystems, should be considered wherever applicable. Water-management authorities should be required to take appropriate advice from health authorities in order to ensure that water quality objectives are appropriate for protecting human health. In setting water quality objectives for given water body, both the water quality requirements for uses of the relevant water body, as well as downstream uses, should be taken into account. In trans boundary waters, water quality objectives should take into account water quality requirements in the relevant catchment area. As far as possible, water quality requirements for water uses in the whole catchment area should be considered.

Under no circumstances should the setting of water quality objectives (or modification thereof to account for site-specific factors) lead to the deterioration of existing water quality. Water quality objectives for multipurpose uses of water should be set at a level that provides for the protection of the most sensitive use of a water body. Among all identified water uses, the most stringent water quality criterion for a given water quality variable should be adopted as a water quality objective. Established water quality objectives should be considered as the ultimate goal or target value indicating a negligible risk of adverse effects on use of the water and on the ecological functions of waters. The setting of water quality objectives should be accompanied by the development of a time schedule for compliance with the objectives that takes into account action which is technically and financially feasible and legally implementable. Where necessary, a step-by-step approach should be taken to attain water quality objectives, making allowance for the available technical and financial means for pollution prevention, control and reduction, as well as the urgency of control measures. The setting of emission limits on the basis of best available technology, the use of best environmental practices and the use of water quality objectives as integrated instruments of prevention, control and reduction of water pollution, should be applied in an action-oriented way. Action plans covering point and diffuse pollution sources should be designed, that permit a step-by-step approach to water pollution control which are both technically and financially feasible.

Both the water quality objectives and the timetable for compliance should be subject to revision at appropriate time intervals in order to adjust them to new scientific knowledge on water quality criteria, to changes in water use in the catchment area, and to achievements in pollution control from point and non-point sources. The public should be kept informed about water quality objectives that have been established and about measures taken to attain these objectives. Also, the upgrading of unprotected wells, streams and the construction of protected wells for community use should be strongly promoted. Many tens of millions of families worldwide still depend on private and public dug wells; technical assessment and improvement of these wells is therefore very important. The area immediately surrounding the tube well should be managed in such a manner as to reduce the risk of contamination. Latrines should be located downhill from the well and a minimum of 10 metres away from it, sources of pollution, such as open dug wells, within 15–20 metres of the tube well should be filled in, and animals should be kept at least 10 metres away.

5. Conclusion

The following precautionary measures will help to ensure that spring water is of a consistently high quality: A surface drainage ditch should be located uphill from the source so as to intercept surface-water runoff and carry it away from the source. The location of the ditch and the points at which the water should be discharged are a matter of judgement, based on factors such as topography, subsurface geology, land ownership, and land use. The location of the fence should be selected in the light of the considerations mentioned above. The fence should exclude livestock from the surface-water drainage system at all points uphill of the source. Providing for access to the tank for maintenance; unauthorized removal of the cover should be prevented by fitting a suitable locking device. Designing the cover in such a way as to prevent contamination from entering the storage tank. Monitoring the quality of the spring water by means of periodic checks for contamination. A marked increase in turbidity or flow immediately after a rainstorm is a good indication that surface runoff is reaching the spring.

Water from a protected spring may be supplied to small communities either directly or via a distribution system. Such systems may not be disinfected because the water is bacteriologically safe and chlorination is expensive. Where spring-fed water supplies do require disinfection, either because it is mandatory under local legislation or because of inadequate quality, this is generally done on a continuous basis: chlorine is added either as the water enters the conduction pipe from the spring box, or as it leaves a storage tank to enter the distribution network. Artesian springs should be protected by a box with walls extending above the maximum static head; a strong sanitary cover should also be provided. To conserve water and increase the productivity of an artesian well, the casing must be sealed into the confining stratum, otherwise water may be lost through leakage into lower-pressure permeable strata at higher elevations. Where local water supplies are known to be contaminated or have not been tested, household treatment should generally be recommended. Faecal contaminated water can be treated by: Boiling, filtration (candle filters, Stone filters, Sand filters), Settling and Coagulation. In order to carry out further investigations, it would be interesting to study the construction of ECOSAN (Ecological sanitation) sustainable toilets to troubleshoot sanitation problems in these municipalities. Complete the biological analysis of water to better characterize it for consumption purposes.

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