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# WATER QUALITY AND SYNDICATED LEAD BURDEN OF A COMMUNITY DRINKING WATER SUPPLY IN NIGERIA

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**Abstract**

*Inability of the Zaria municipal water works to satisfy the water demands of Ahmadu Bello University (ABU) community necessitated the construction and commissioning of the ABU water treatment works in 1981. Against the background that wholesome and potable water had been declared a Human Right by the Human rights Commission of the United Nations in 2002, this study assesses the water quality status of the drinking water produced by the ABU water treatment plant from 2008 – 2010. This assessment focussed on some parameters of general properties and some heavy metals using standard methods of analyses. The average values of these parameters measured at the house level water samples over the study period were, pH 6.7, TDS 66.0, TOC 2.3, $NO_3^-$ 1.4, $PO_4^{3-}$ 0.1, $Cl^-$ 0.5, $SO_4^=$ 42.0, $Zn^{2+}$ 0.04, $Pb^{2+}$ 0.035mgl$^{-1}$ and conductivity 102.0µScm$^{-1}$. With these results, ABU drinking water supply complies with the Nigerian (Nigerian Industrial Standards NIS 554, SON 2007), USEPA, World Health Organization - WHO and European Union - EU standards except for its lead content. High lead concentration as recorded in this study is a source of worry in view of the health implication of lead in drinking water and the involvement of the Ahmadu Bello University Health Services in protecting the source water for over a decade through managing quality of drainage water from Samaru Village into the source water being treated.*

**Key words:** *ABU drinking water, lead concentration, Samaru, standards*

## Introduction

The physiological importance of water to the human body is wide ranging and it is no doubt that water is one of the most basic and critical components of human life. Clean and healthy water is a fundamental requirement of the human body that cannot be replaced. Hence the popular saying "Water sustains life". Good quality drinking water is primarily sourced from rainfall or from surface water such as streams, rivers, springs and lakes. Where these do not exist or where they exist in quantities that cannot adequately support the dependent populations, ground water resources are exploited in the form of wells and boreholes to provide this vital body requirement. This is why water has and continues to be the centre of ancient and present day civilizations (Shaibu-Imodagbe, 2011).

From the point of view of use, water is a renewable but finite resource already stressed by the demands of today's global population. With global population exceeding 6 billion people, the stress becomes alarmingly increasing. On its part, potable water becomes still more limiting because of rapid ecosystem destruction and aggravated pollution of water resources in many world regions, widespread water scarcity, global incompatible human activities on the world's hydrosphere (UNU, 2001).

Recently, incoming rain water is no more as pure as before. This is because gaseous contaminants like sulphur, nitrogen oxides and even carbon dioxide of anthropogenic sources make rain water acidic and contaminate soil and surface water bodies. This is further compounded by decomposing materials and their microbial populations rendering even these surface waters unfit for drinking. These have serious consequences for the dependent populations including humans due to the capacity of the modified water to spread diseases, notably water borne diseases. These have continued to pose the greatest health challenges in most developing countries like Nigeria because water borne diseases have been identified to be among the five most important causes of mortality and morbidity in these developing countries up till recent times (Reiff, 1995). In support of this, Snyder and Merson (1982) reported that annual diarrhoeal cases in developing countries average 875 million cases and 4.6 million deaths. In the same vein, Reiff (1995) noted that between 1st January 1991 and 30th December 1993, there were 950,000

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reported cases of cholera and 9,000 deaths in developing countries.

By 2002, the United Nations Committee on Economic, Cultural and Social Rights, on behalf of the United Nations took the unprecedented step of agreeing on a General Comment on water as a human right. They declared that water is fundamental for life and health and that the human right to water is indispensable for leading a healthy life in dignity as it is a prerequisite to the realization of all human rights. Thus, safe, and secure drinking water became a human right as declared for the first time and approved by 147 countries on the $4^{th}$ December, 2002. The declaration further required that drinking water be treated as a social and cultural good and not primarily as an economic commodity (ENS, 2002). Many treatment methods have evolved over the years to rid surface source waters of the natural and anthropogenic contaminants. These include age long practices like boiling and conventional treatment methods involving processes of coagulation, flocculation, sedimentation, filtration, disinfection and residual disinfection to supply safe drinking water to households (USEPA, 1990; Vrijenhoek, *et al.,* 1998). Conventional water treatment in public drinking water supply incorporating disinfection is an improvement to surface water sources in providing wholesome and potable drinking water to the public. In fact, the disinfection process in this water treatment method is considered the most important step in drinking water treatment and one of the public health triumphs of the $20^{th}$ century. This is because disinfection serves as the main barrier against the transmission of water borne diseases (Schoeny, 2010).

The area in which the university is situated is drained by the Samaru stream and River Kubanni. The Samaru stream is a tributary of the River Kubanni and its flow is mostly drainage water from the northern part of Samaru village which empties into the River Kubanni. A man made reservoir of the River Kubanni provides source water for treatment by the ABU water treatment plant as drinking water for the university community.

The quality of inflow from Samaru stream had long been identified as a major contributor to the quality of source water being treated by the ABU water works (Anon, 2004). This is why the university health services had been involved in managing the inflow into the Samaru stream for over a decade now. Previous works had identified appreciably high levels of trace and heavy metals in the Kubanni sediment, (Tukura *et al.*, 2011) in freshwater crab (2009) and in Zaria wells and boreholes, (Musa *et al.,* 2004). Against this background, this study attempts to identify how far the ABU water treatment plant provides safe drinking water to the academic community by comparing the water quality indices with national and international standards.

Lead is one of the three most toxic heavy metals that have the ability to lay dormant and have long-term negative impacts on health, causing hepatitis, anaemia, nephritic syndrome, brain damage, mental deficiency, anorexia, vomiting, malaise and encephalopathy (Deng *et al.,* 2006).

Meanwhile, some 1.1 billion people are reported to lack access to safe drinking water. As the global population increase from over 6 to 8 billion people, 3 billion people (38%) are estimated to live in water stressed countries (Postel, 2000). By the $5^{th}$ Annual Water for the Poor report released by the US States' Department late 2010, only 7.2% of Nigerians have access to pipe borne water in a country that is the World's $6^{th}$ largest producer of crude oil (Nwokeoma, 2011).

The hypothesis under test in this study is that being a university community and a relatively well informed community, the quality of drinking water produced by its treatment plant is of standard quality, meeting national and international standards in terms of general quality and heavy metal content.

## Materials and Methods

### *Study Area*

The Ahmadu Bello University is located opposite Samaru Village in Zaria, Kaduna State of Nigeria, (Figures 1 and 2). It was established in 1962 and is one of the first generation universities in Nigeria.

This study assesses the quality of drinking water produced by the Ahmadu Bello University (ABU) water treatment plant commissioned in 1981 when the Zaria municipal water supply was found to be incapable of meeting the drinking water needs of the Ahmadu Bello University community. The A.B.U. water treatment plant is located within the university premises at an elevation of 655 meter MSL on latitude $11^0$ 08' 25.60"N and longitude $7^0$ 39' 19.65"E. The treatment plant was designed to produce 13.640$m^3$ per day on full development over 3-phases. It presently has five (5) sand gravity filters, five (5) bottom hopper type sedimentation tanks, one (1) liming unit and one (1) disinfecting unit. It also has a clear water well of 1,500 $m^3$ capacity, with three (3) high lift pumps. Close to the Kubanni reservoir is the raw water intake house with two (2) low-lift pumps. The water treatment plant schematic is by a single train, one disinfection segment conventional water treatment. Part of the treated water is sent to the booster station which has two (2) tanks – concrete (capacity 110$m^3$) and steel tanks (capacity 117$m^3$) for subsequent distribution to houses on higher elevations. The other part is sent to the elevated tank near the University Senate building to supply most academic areas, students' hostels and some residential houses. At the moment, water is distributed intermittently to areas on high elevations from the booster station. Daily output is presently 4,800$m^3$ per day (Anon, 2004).

***Sampling***

One hundred and ten (110) sets of water samples were taken in sterilized plastic half litre containers for chemical analysis of general properties over the period of 2008 and 2010. These samples were taken during the distinct climatic conditions of the year in the study location. These were at the hottest months of the year (Feb and March, 2008, 2009, 2010), on the establishment of the rains (June and July, 2008, 2009, 2010) at periods of peak rainfall (August and September, 2008, 2009, 2010) and in the cool Harmattan period (November and December, 2008, and 2009). During these months five replicates of each sampling set were made. This gave 30 sets of samples each for the hottest, establishment of rains and peak rainfall periods of the year while there were only 20 sets of samples during the harmattan months. A total of 110 sets of samples were thus obtained for the experiment. In each set, water samples were taken of the raw water (from the Kubanni reservoir), water after sedimentation, water after chlorination and water at the booster station. A sample was also taken of water supply to residences at Area 'E' quarters (AREA E20). These samples were stored in coolers with melted ice for preservation.

***Sample Analyses***

Over the period 2008 into 2010, the sampled waters were subjected to some general chemical analyses including pH, residual chlorine, conductivity, total dissolved solids, salinity, nitrate, phosphate, chloride, sulphate and heavy metals content. Among the heavy metals determined in the samples were iron, chromium, lead, cadmium and manganese These analyses were conducted in accordance with standard procedures as in Standard Methods for the Examination of Water and Wastewaters, 20th edition (APHA, 1998). The heavy metals were further analysed using a Perkins Elmer Atomic Absorption Spectrophotometer.

***Statistical Analyses***

The values obtained in the analyses were subjected to descriptive statistics to determine a measure of their central tendency and the standard error.

**Results and Discussion**

Results of some of the general chemical parameters of the sampled waters are presented in Table 1.

***pH***

The mean pH values for the sampled waters ranged between 6.7 and 8.0 for the house level water and the water in the booster station respectively. This shows that the finished drinking water is slightly acidic to weakly alkaline in nature. The higher value at the booster station is likely due to the equalization of the liming agent and the calcium hypochlorite during storage in the booster station. On the other hand, the low pH value at the house in Area 'E' may have arisen because of the formation of biofilms due to intermittent flow in the distribution system and distribution failures. These biofilms are organic, living or dead capable of undergoing decomposition to create intermediate products (Jakubovics, 1998;; LeChevallier, 2000). The processes of formation of these intermediate products has tendency to acidify the medium. When compared with national and international standards, these values are well within acceptable limits (6.5 – 8.5) of the Nigerian (SON) and international standards (USEPA, WHO, and EU).

***Dissolved Solids***

The Total Dissolved Solids concentrations were between 50.50$mgl^{-1}$ and 70$mgl^{-1}$, as against the 500$mgl^{-1}$ as the maximum contaminant level required by the Nigerian drinking water standards (SON, 2007) and the USEPA (2011) standards or the 600$mgl^{-1}$ required by the WHO (2005). This shows that the observed dissolved solids concentrations in the ABU treated water are well within the acceptable limits. The increasing levels in the booster station to the house level could be attributed to the biofilms formation during storage in the booster tanks and as a result of intermittent flows in the distribution system to the residential area - Area E (Jakubovics, 1998; LeChevallier, 2000). On decomposition and mineralization consequent upon the flow characteristics in the distribution system, these biofilms add to the total dissolved solids

***Conductivity***

The mean conductivity of the water samples ranged from 66µScm$^{-1}$ to 131µScm$^{-1}$at 25 $^{0}$C compared to 1000µScm$^{-1}$ as the permitted maximum by the Nigerian Water quality standards. It is evident that these values are considerably low in comparison with the critical limit of 4000µScm$^{-1}$ for waters of high salt content with a possibility of inducing salinity. The higher value at chlorination stage could be as a result of the calcium hypochlorite used as disinfectant in the chlorinated water sample. This is also in line with the chloride content being highest in this stage of drinking water treatment. Despite this, the values are still considerably lower than the maximum permitted levels under various standards. Therefore, the ABU treated water is within acceptable drinking water quality with respect to this parameter.

***Salinity***

All the water samples had below detection salinity status using standard method as described in the 20$^{th}$ edition of Standard Methods for the Examination of Waters and Wastewater (APHA, 1998). Thus salinity status in the treated drinking water is so minimal to be detected, thereby positively contributing to high quality drinking water quality produced by the treatment plant.

***Total Organic Carbon***

The average Total Organic Carbon (TOC) content measured ranged from 2.25mgl$^{-1}$ to 6.65mgl$^{-1}$ with the highest values recorded in the raw water; while the least values were recorded for the chlorinated water sample. There was a gradual decline in the concentrations as raw water was progressively treated along the treatment line. It reduced to 2.25 mg in the chlorinated water and increased in the booster station to 2.40mgl$^{-1}$ which gradually decreased to the house level with 2.30mgl$^{-1}$. This trend is due to the removal of dissolved solids in the filtered water after coagulation with alum in to the chlorination stage. Increased level in TOC in the booster station is traceable to biofilms formation due to fluctuating water levels in the storage tanks as reported by Jakubovics (1998) and LeChevallier (2000). The decreasing level of TOC into the house level could be due to frictional losses, and flow characteristics resulting in mineralization of the dissolved organic carbon. This is likely responsible for the increase in the mean total dissolved solids which increased from 55.0 to 66.0mgl$^{-1}$ from booster station to house level.

***Residual Chlorine***

Average residual chlorine in the water samples ranged from 0.01mgl$^{-1}$ to 0.05mgl$^{-1}$. The lowest mean value was recorded for the water sample from house water supply, while the highest mean value was obtained in the water sample after chlorination. This is not unexpected as the residual chlorine decrease in content due its use in the reactions along the distribution system. The generally low concentrations however, are a dangerous development because the adequacy of such concentrations of the residual disinfectant is in doubt in safeguarding water in the distribution network against recontamination especially when distribution failures occur.

***Nitrate Concentration***

Average nitrate concentration was from 0.80mgl$^{-1}$ to 3.00mgl$^{-1}$. The highest concentration was obtained from raw water while the least concentration of 0.80mgl$^{-1}$ was obtained in the samples after chlorination and booster station. The highest value for the raw water is consistent with the high mobility of nitrogen in the environment which immediately oxidises to nitrates. The decrease in the sample after sedimentation could be traced to the flocculation process while the slight increase in the house level sample is probably either due to biofilms created because of the periodical distribution of water or external inflow into the distribution network as a result of distribution failures. Despite this, the average values of nitrates in the treated water samples are considerably lower than the range of values in national drinking water standards (50mgl$^{-1}$) and those of international standards (10 mgl$^{-1}$ MCL and MCLG for the USEPA, 50mgl$^{-1}$ for the WHO and EU standards).

***Sulphate Concentration***

Mean sulphate concentration ranged from 23.00mgl$^{-1}$ in the sedimentation water sample to 42.00mgl$^{-1}$ for house level water in Area 'E'20. The higher values in the household sample could be attributable to biofilms created in the distribution network due to periodical water distribution in the mains (Jakubovics, 1998; LeChevallier, 2000). It is also possible that soil solution in flows from soil surroundings and growing rootlets at weak pipe joints with other distribution failures may account for increased sulphates at house level. Despite this, these values are considerably lower than the maximum allowed sulphate level in the national drinking water standards (100mgl$^{-1}$) as well as those of the international standards for drinking water with maximum concentration of 250mgl$^{-1}$ (USEPA and EU) and 500mgl$^{-1}$ (WHO).

***Phosphate Concentration***

Average phosphate values for the water decreased down the treatment line to the household after boiling. The concentrations ranged from 0.30mgl$^{-1}$ in the raw water to 0.10mgl$^{-1}$ in the house level in Area "E". This is probably due to the fact that phosphorus is relatively immobile unlike nitrogen and is in high demand by biofilms as an essential element. As a result, the growth of biofilms as reported by Jakubovics, (1998); LeChevallier, (2000) will cause depletion of available phosphate in the medium.

***Heavy Metals***

Table 2, shows the mean concentrations of the heavy metals determined in the water samples from treatment to house level in Area "E". Among these seven heavy metals determined, chromium, cadmium, manganese and copper were neither detected in the raw water nor in the various stages of treating the water. Also there was no detected level of these heavy metals in the finished drinking water supplied to the residences.

***Iron content***

Table 2 results show that iron was only detected in the raw water. This was removed during treatment stage in sedimentation tanks after flocculation. This is why it was not detected in the sample after chlorination. This is in line with most conventional water treatment plants (USEPA, 1990).

***Lead content***

The mean concentration level of lead in the sampled water ranged from 0.035 to 0.040mgl$^{-1}$. The higher mean concentration (0.040mgl$^{-1}$) was obtained in the raw water samples which decreased to 0.035mgl$^{-1}$ after the chlorination stage. From this stage the concentration was unchanged in the booster station and at house level. The higher mean concentration in the raw water is indicative of the raw water being the source of lead in the drinking treated by the water works. This could be due to the drainage water from Samaru village which is loaded with lead wastes from de-commissioned automotive batteries that are poorly disposed of in the mechanical workshops in Samaru. It is also likely that dry and wet deposition of lead particulates from vehicular emissions (from leaded petroleum fuel) may contribute to the lead loading of the source water to the treatment plant. When compared to national and international standards, these mean concentrations are higher than the permitted lead levels of 0.010mgl$^{-1}$. As reported by Deng *et al,* (2006) this has implication for health of the consumers of the treated water as lead is implicated in the damage to the brain, mental deficiency, kidney (nephritic syndrome) hepatitis, anaemia, anorexia, vomiting, malaise, encephalopathy and nervous system of humans especially children. This is despite the fact that the University Health Services had been involved in the management of drainage water quality from Samaru village into the Kubanni reservoir for over a decade. It is hereby recommended that drainage flow from Samaru village need be diverted or detained to be treated using organic adsorbents before discharge to the Kubanni reservoir for abstraction as source water.

***Zinc content***

Mean concentrations of zinc recorded for the water samples ranged from 0.01mgl$^{-1}$ in the raw water to 0.05mgl$^{-1}$ at the house level water. As earlier pointed out, due to intermittent flow in the distribution system, biofilms are formed, which bio-accumulate essential elements including micronutrients like zinc. The decay and mineralization of these biofilms could be responsible for increased levels within the distribution mains to the house level. However, the levels in the treated water are far lower than the maximum level in drinking water (4mgl$^{-1}$) as required under the WHO standards. Zinc is an element of exceptional biological and public health importance as its deficiency retards growth in children, delay sexual maturity, increase susceptibility to infection, diarrhoea, birth defects and contribute to death of children worldwide.

## Conclusion

From the results of the analyses of Ahmadu Bello University water treatment plant drinking water supply, it was found to treat drinking water to a standard that is generally within limits of acceptability of prevailing national and international standards except for the lead level in the drinking water produced. It is likely this high lead is washed into the source water from poorly disposed de-commissioned lead batteries in automotive workshops in adjacent Samaru village. Also, lead particulates from leaded fuels used in vehicles are dry and wet deposited and subsequently washed to the source water. This creates a lead burden for the water treatment plant. Due to the health implications of lead, runoff from Samaru village need to be specially treated to remove lead before discharge to the source water. It is by so doing that wholesome and potable water to the university community be guaranteed and hence contribute towards an increase in the number of Nigerians with access to safe drinking water.

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Table 1: Mean Values of Some Chemical Parameters of Conventionally Treated Drinking Water from A. B. U. Water Treatment Plant

| Parameter | Raw Water | Sedimentation water | Chlorinated water | Booster Station water | House Level water (Area E) | Standard Error SE |
|---|---|---|---|---|---|---|
| pH | 7.8 | 7.6 | 7.8 | 8.0 | 6.7 | 0.23 |
| Total Dissolved Solids | 50.5 | 50.5 | 51.50 | 55.00 | 66.00 | 2.94 |
| Salinity | ND | ND | ND | ND | ND | - |
| Total Organic Carbon (TOC $mgl^{-1}$) | 6.65 | 4.40 | 2.25 | 2.40 | 2.30 | 0.86 |
| Residual Chlorine ($mgl^{-1}$) | ND | ND | 0.05 | 0.03 | 0.02 | 0.01 |
| Conductivity (µS/cm @ $25^0$C) | 83.50 | 102.50 | 131.00 | 121.00 | 102. | 8.26 |
| Nitrates ($mgl^{-1}$) | 3.00 | 2.40 | 0.80 | 0.80 | 1.40 | 0.44 |
| Phosphates ($mgl^{-1)}$ | 0.30 | 0.15 | 0.25 | 0.15 | 0.10 | 0.04 |
| Chloride ($mgl^{-1}$) | 12.30 | 0.80 | 12.65 | 0.50 | 0.50 | 2.91 |
| Sulphate ($mgl^{-1}$) | 40.00 | 23.00 | 22.50 | 24.50 | 42.00 | 4.35 |

ND – Not detected; SE - Standard Error

Table 2 - Mean Heavy Metals' Content of ABU Treated Drinking Water

| Parameter ($mgl^{-1}$) | Raw Water | Sedimentation water | Chlorinated water | Booster Station water sample | House Level water (Area E) | Standard Error SE |
|---|---|---|---|---|---|---|
| Chromium (Cr) | ND | ND | ND | ND | ND | - |
| Lead (Pb) | 0.040 | 0.040 | 0.035 | 0.035 | 0.035 | 0.001 |
| Zinc (Zn) | 0.010 | 0.035 | 0.025 | 0.030 | 0.050 | 0.007 |
| Cadmium (Cd) | ND | ND | ND | MD | ND | |
| Iron (Fe) | 3.45 | ND | ND | ND | ND | |
| Manganese (Mn) | ND | ND | ND | ND | ND | |
| Copper (Cu) | ND | ND | ND | ND | ND | |

ND; Not detected

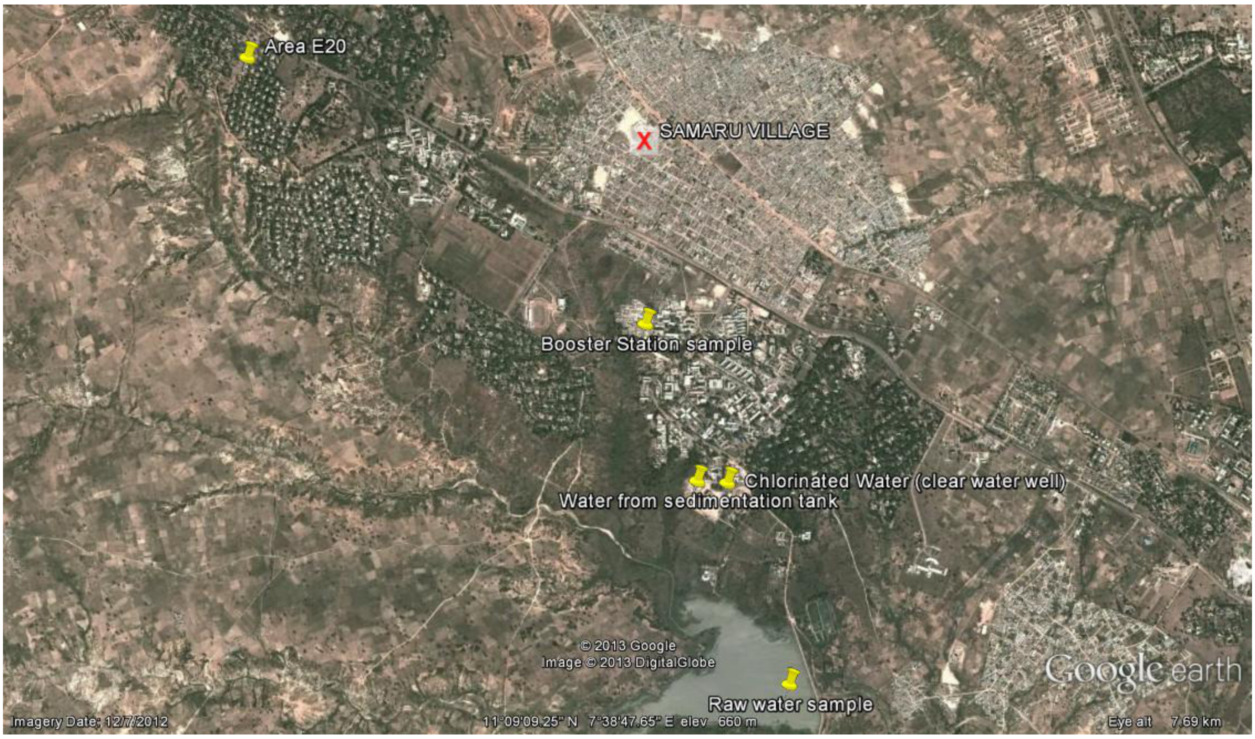


Image View Coordinates 11°09'09.25" N 7°38'47.65" E

Figure 2 Google Map of Ahmadu Bello University Drinking water Treatment and Distribution system showing the Sampling Points