Water Source and Water Demand Needs Assessments for Bonwire.

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Abstract

This work assessed the water supply source and water demand of Bonwire, a town in the Ashanti Region of Ghana. The work was done to solve an identified water threat in Bonwire. The assessment was done via the identification and discharge quantification of water sources; the physicochemical and biological assessments of the source(s); estimation of water needs and a comparison of the supply and demand in Bonwire, and to recommend this assessment to the local government and Donor Agencies. The methodology for the work was site reconnaissance and desk studies, water discharge measurement via area-velocity method, field sampling and laboratory testing. The ions were analysed by ICP-AES and IC. The current water demand was estimated as 274 m^3d^{-1}.The two sources of water identified for Bonwire were four (4) rivers and groundwater from two (2) boreholes. The discharge measurements and borehole yields indicated that the total discharge for Bonwire is 14,239 m^3d^{-1} of which rivers contribute about 99%. Inspite of the large river discharges, the physicochemical properties finger the river waters as unpotable, because the rivers are contaminated with contaminants (nitrates, sulphates, coliform) and hardness. The groundwater source which is the only potable source has a daily discharge of 86 m^3d^{-1}, which is in a deficit of 188 m^3d^{-1} for the current water demand. It was concluded that there was a water threat in Bonwire. It was therefore recommended that contamination of the rivers should be controlled; a hydrogeological assessment for additional borehole drilling should be conducted, and the possibility of treating the rivers for supplying water to Bonwire and the Municipality should be considered.

Keywords: Water Supply, Water Demand, Water Threat, Contaminants, Coliform, Water Hardness, Hydrogeological Assessment

1. Introduction

A lot of work has been done to improve rural water coverage in Ghana in the last few years, and records indicate that Rural water coverage increased from 58% (2000) to 74 % (2008) (Joint Monitoring Programme of the WHO/UNICEF, 2010). This is to ensure that Ghana meets the Millennium Development Goals (MDGs) 1, 3 and 7.

However, according to the Rural Supply Network (2010), there still exists a water supply deficit in rural areas. This water supply deficit is due to the unavailability of funds, system breakdowns, poor post-construction maintenance and servicing (Nyarko et al., 2010) and, government inaction and inadequate water sources within the rural areas.

Water deficit occurs when the sources of water available to a locality are unsuitable in quality and quantity in comparison with the water demands of the locality (Gleick, 1996). The assessment of a supply source is done with a thorough understanding of the hydrology and physicochemical properties of the source. The water demand is estimated using demographic properties and makeup, water use requirements and the variation in water usage (Punmia et al, 2005). The condition for the existence of water deficit means that a locality could have water sources that have discharges meeting demand, but still have a deficit if the source does not meet established chemical and biological standards. Bonwire is a very prominent town in the Ashanti Region of Ghana, but it has a severe water supply problem. With a population of 5,085 in 2000 projected to increase to 7,099 in 2013 (Ghana Statistical Service, 2005), the town has only two hand pump boreholes which are continually under pressure (Site Reconnaisance, April 2013). To reduce the pressure on the borehole, the townsfolk use the often polluted streams as a source of water supply. The dearth of water and the commuting distances by inhabitants to search for water disrupts economic activities and causes water borne diseases like guinea worm, trachoma, bilharzias which militate against the Millenium Development Goals (MDGs). This work therefore aims at assessing the water needs of Bonwire, via the identification and discharge quantification of water sources; the physicochemical and biological assessments of the source(s); estimation of water needs and a comparison of the supply and demand in Bonwire, and to recommend the assessment to the local government and Donor Agencies about funding for the development of a water supply scheme if need be to stem the tides of economic and human resource loss due to the consumption of contaminated and polluted water.

2. Background of Study Area

2.1 Location and economic activities

The study area, Bonwire, 6° 47'N 1° 28'W is a small town located in the Ejisu-Juaben Municipal of the Ashanti Region of Ghana(http://ejisujuaben.ghanadistricts.gov.gh). Bonwire is the fourth largest town in the Ejisu-Juaben Municipality (http://ejisujuaben.ghanadistricts.gov.gh), with a current population of 7099(Ghana Statistical Service, 2005). Bonwire is noted for its beautiful woven Kente, which attracts tourists, enhances Ghana's Gross Domestic Product (UN Country Profile, 2002) and strengthens the Asante identity (Opoku-Dwomoh, 2006). Besides Kente, the people of Bonwire engage in other livelihood activities like farming, animal husbandry and trading. Crops grown in the community include: cocoyam, tomatoes, cassava maize, rice, oil palm and plantains (http://ejisujuaben.ghanadistricts.gov.gh).

2.2 Climate, vegetation, topography and geology

Climate and vegetation of the area is that of the middle belt in Ghana, which experiences tropical rainfall, i.e. bi-modal rainfall pattern and wet semi-equatorial climate. It is characterized by double maxima rainfall lasting from March to July and again from September and normally ends in the latter part of November. The mean annual rainfall is 1200mm which is ideal for minor season cropping.

Temperatures range between 20°C in August and 32°C in March. Relative humidity is fairly moderate but quite high during rainy seasons and early mornings. The fair distribution of temperature and rainfall patterns enhances the cultivation of many food and cash crops throughout the Municipality thus making Ejisu Juaben Municpality food sufficient (http://ejisujuaben.ghanadistricts.gov.gh).

The Municipal lies within the semi-deciduous forest zone, which does not differ much in appearance from the Rain Forest. Most of the trees shed their leaves during the dry season, but not at the same time for all the trees of the same species (http://ejisujuaben.ghanadistricts.gov.gh). .

The area is of Pre-Cambrian rock of Birimian and Tarkwain formation which rises from about 240m to 300m above sea level. The type of rock underlying the study area is identified as the Voltaain rock formation (http://ejisujuaben.ghanadistricts.gov.gh). The study area is generally undulating and is drained by a number of streams notable among them are the Abumekum, Abutia, Aboyensua and Japimu (Site Reconnaissance).

2.3 Sources of water in Bonwire

The main sources of water supply predominant in Bonwire are surface water (rivers and streams), atmospheric water in the form of rain and ground water.

Abumekum, Abuatia, Abuyensua and Japimu are the rivers that drain Bonwire. According to Berner and Berner (1987), the four rivers are liable to pollution because they are open to the environment.

Rain water does not contain contaminants but may only be infested by other elements in air or atmosphere and therefore need to be disinfected before use. The mean annual rainfall in Bonwire is about 1200 mm which is ideal for minor season cropping as a result of climatic changes and seasonal drought. However rain water is not dependable because it cannot be harvested at will to meet demand requirement and also because it requires large storage space, which is expensive to construct.

Rainfall that infiltrates the soil and penetrates to the underlying soil strata is called ground water (Wilson, 1990).The community currently has three boreholes, one of which is dysfunctional. A pumping test undertaken by Community Water and Sanitation Agency (CWSA) shows that, the yield of the remaining two boreholes within the community (near the lorry station) is 70 $Lmin^{-1}$ and the second borehole has a yield of 20 $Lmin^{-1}$ which is too low to be pumped over a long distance. According to the CWSA, the average depth for water abstraction from the confined aquifers of Bonwire is between 50 – 70m. Thus it is assumed that a borehole drilled to a depth of 60m will be able to intersect the confined aquifer for water abstraction.

The issue of water coming under serious threat has been an outstanding issue in modern Bonwire. According to

Berner and Berner (1987), the possible factors that may threaten the availability and usage of water in Bonwire include pollution from human activities like farms on the river banks, overexploitation and droughts.

3. Methods

3.1 The demographic characteristic

The assessment required the analysis of the basic demographic characteristics like the population size, structure, and growth rate. This data was used to calculate the current as well as the projected population size. This data played an important role in the estimation of water demand for Bonwire.

Data from the 2000 National Population and Housing Census was used to calculate the current and projected population using the Geometric Growth formula (Punmia et. al, 2005):

$P_n = Pc\ (1 + r)^n$ ….. [1]

Where:

P_n: Projected population

P_c: Current population

n: Projected year (design period)

r : Growth rate

The current water demand as well as the projected water demand were estimated from the CWSA design guideline (CWSA, 2005).

3.2 Discharge measurement

The discharge measurements were done in April 2013. Site accessibility and flow influenced discharge measurements. Dimensions (depth and width) of water features were measured by dip stakes and tape measure. Flow velocities were determined by measuring the time of travel of leaves over a 4m distance on the stream surface (Brassington, 2007; Weight, 2001). The product of velocity and area measurements yielded discharge for the streams(Schwartz and Zhang, 2003).

3.3 Field sampling of rivers

Samples were collected using bucket and line at accessible sites of the study area. At each sample location, samples were filtered through a 0.45um filter paper, into two (2) 50ml vials. On-site pH of filtered samples were determined. Stored samples for metal analyses were acidified with 5ml of 10% HNO_3. The samples were then labelled and sent to the Ghana Water Company Limited (GWCL) for storage and analyses. The cations were measured by Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES) and the anions ($SO4^{2-}$, Cl^-, NO_3^-) by Ion Chromatography (IC). Duplicates and blank samples were used to check the consistency of the laboratory testing methods.

4 Results and Discussions

4.1 Catchment stream discharge

The discharge values for the four rivers in the study area are presented in Table 1. From the table of discharges, Abuatia and Abuyensua rivers recorded maximum and minimum discharges of 73.8 and 8.4 Ls^{-1} respectively. The total discharge for the four streams in Bonwire is 163.9 Ls^{-1} which translates to a daily stream discharge of 14,153 m^3d^{-1}

Table 1. Bonwire river discharge

Sample Code	**River**	**Discharge, Ls^{-1}**
S1	Abemekum	48.4
S2	Abuatia	73.8
S3	Abuyensua	8.4
S4	Japimu	33.3
Total discharge, Ls^{-1}		**163.9**

A pumping test undertaken by Community Water and Sanitation indicates that, the yield of the functioning borehole within the community (near the lorry station) is 1.2 Ls^{-1} whilst the second boreholes has a yield of 0.3 Ls^{-1}. Assuming a pumping time of 16 hours for both boreholes, yields a borehole discharge of 86 m^3d^{-1}.

The total discharge for the Bonwire township is 165.37Ls^{-1}, which translates to a total daily source supply of 14,239m^3d^{-1} of which the rivers contribute about 99% of the discharge. The total source supply can only be relied on assuming that the physicochemical properties of streams and the groundwater are to acceptable standards and therefore potable.

4.2 Water demand estimation

The population of Bonwire for 2000 is 5085. Using a population growth rate of 2.6%, the geometric growth formula in equation 1, the projected population for 2013 and 2028 using a design period of 15 years (CWSA guideline), yields the data in table 2. Refer to the CWSA guidelines and detailed computations of demand at Appendix A.

Table 2. Bonwire population and projections

Year	Population
2000	5085
2013	7099
2028	10433

The current and 15 year population water demands are 274 and 397 m^3d^{-1} respectively.

4.3 Demand and supply comparison

A comparison of the source and demand indicates that the source discharge is far in excess of the demand for the township, and surface water contributes 99% of the supply source. The caveat however is that, this assessment is valid only if both sources (river and groundwater) are potable, and this can only be done after an analysis of the physicochemical state of the water sources.

4.4 Physicochemical characteristics of water sources

The physicochemical characteristics of the streams and European Commission Water Quality Directive (Brassington, 2007) are presented in Table 3.

Table 3. Streams physicochemical characteristics and EC standards

Parameter	**Unit**	**Streams**				**EC Directive 80/778/ EEC standards**
		Abumekum	Abuatia	Abuyensua	Japimu	
Total Coliform	No./100ml	44	43	50	47	0
pH	pH units	7.5	7.3	7.4	7.8	6.5 – 8.5
NO_3	mgL^{-1}	71	63	60	58	50
Fe	ugL^{-1}	450	550	400	380	200
SO_3	mgL^{-1}	320	410	300	248	250
Cl	mgL^{-1}	240	246	257	250	400
$CaCO_3$ Hardness	mgL^{-1}	280	243	270	258	500
TDS	mgL^{-1}	600	610	540	600	500
Colour	N/A	brownish	clear	clear	brownish	colourless

In terms of pH, Table 3 indicates that the rivers in Bonwire are all neutral and conform to the EC standard. From the laboratory results obtained from the four streams, Aboyensua and Abuatia had the maximum and minimum values of 50 mgL^{-1} and 43mgL^{-1} for coliform bacteria respectively. Japimu had the greater nitrate concentration of 71 mgL^{-1}. Abumekum recorded a maximum $CaCO_3$ hardness of 280 mgL^{-1}, whilst the chloride content of the four rivers varied slightly with Abuatia having the maximum of 257 mgL^{-1} and Aboyensua with a minimum of 240 mgL^{-1}.

A comparison of the streams with EC Directive indicate that the stream properties except for pH, chloride and $CaCO_3$ hardness are objectionable.

The source of the nitrates could be from runoff containing fertilizer from farmlands that are on the banks of the rivers. Another source is from animal droppings that wash into drains that finally find their way to the streams. Nitrate concentrations above the recommended limits are dangerous to pregnant women and pose a serious health threat to infants under 3 months of age because of the ability of nitrates to cause Methaemoglobinaemia or "Blue Baby Syndrome" in which the blood loses its ability to carry sufficient oxygen. Distillation and reverse osmosis units can remove nitrates and nitrites (Saskatchewan Watershed Authority, 2003).

Leaching and runoff from ammonium sulphate fertlisers on farms, decaying plant and animal matter may be the source of sulphate into the rivers. Excess sulphate levels may have a laxative effect on new users and produce an objectionable taste. Regular users tend to become accustomed to high sulphate levels. High amounts of various sulphate salts may give drinking water an offensive taste. Excess sulphates can also give water and offensive taste at

concentrations ranging from 250 to 1,000 mgL^{-1}. High concentrations of sulphate may interfere in the efficiency of chlorination in some water supplies. Also, sulphate salts may increase the corrosive properties of water

(Saskatchewan Watershed Authority, 2003).

The source of the coliform could be from animal and / or human waste that has been washed or deposited into the streams. Coliforms are indicative organisms that suggest the presence of feacal matter in the streams. Feacal matter contains microorganisms like bacteria, protozoa, and viruses; some algae and helminths (worms) that cause waterborne related diseases. For this reason, water containing coliform is non-potable for human consumption.

The borehole chemical characteristics are also presented in Table 4. The groundwater parameters in Table 4 as compared to the EC directive show that the borehole is potable, as it meets all the quality standards.

Table 4. Borehole physicochemical characteristics and European Commission Directive standards

Parameter	**Unit**	**Borehole**	**EC Directive 80/778/ EEC standards**
Coliform	No./100ml	0	0
pH	pH units	7.2	6.5 – 8.5
Na	mgL^{-1}	160	175
K	mgL^{-1}	2.2	12
Ca	mgL^{-1}	9.2	250
Mg	mgL^{-1}	0.2	50
SO_3	mgL^{-1}	246	250
NO_3	mgL^{-1}	43	50
Cl	mgL^{-1}	210	400
F	mgL^{-1}	0.71	1.5
HCO_3	mgL^{-1}	150	1000
Fe	ugL^{-1}	100	200
$CaCO_3$hardness	mgL^{-1}	255	500
Colour	N/A	Colourless	Colourless

The physicochemical analysis of the sources indicates that currently, groundwater is the only non-treatable potable source that Bonwire can rely on. For the groundwater source however, it has a discharge of 86 m^3d^{-1} which is in deficits of 188 and 311 m^3d^{-1} for the current and 15 year water demands respectively. Recollecting that there are only two (2) boreholes which give a total discharge of 86 m^3d^{-1}, the extra boreholes required to meet demand are 4 and 8 boreholes for 2013 and 2028 respectively.

However, if funding is procured to treat the rivers, the water threat could be eliminated, and even that, the townsfolk need to be educated and entreated to reduce and eliminate the pollutant loading to the river sources, to reduce the cost of treatment.

5. Conclusions and recommendations

From the analysis, it is concluded that the two key sources of water for Bonwire are groundwater and river sources. The discharge of the rivers far outweigh the groundwater source, but the abundant river source is contaminated with agricultural pollutants and harmful microorganisms and can only be made potable via treatment. The groundwater is however potable but does not meet the water demand of Bonwire.

In view of the analysis, the following are recommended to the local government (Municipal Assembly) and donor/funding agencies:

- The Municipal Assembly should inform and educate the Bonwire townsfolk about the state of the rivers in Bonwire, and the water borne diseases that can be contracted from the consumption and usage of river water for domestic and economic activities.
- Farmers in Bonwire should be advised to stop farming along river banks.
- Hydrogeological assessments should be conducted in Bonwire and additional boreholes should be drilled to meet water demand of the town. In addition, the townsfolk should own a part of the water supply system, to ensure the replacement of parts for sustainable functioning of the boreholes.
- Considering the discharge of the four (4) rivers, a cost benefit analysis of the possibility of treating the rivers for supply both to Bonwire and surrounding towns should also be explored, for the generation of revenue for the Bonwire and the Municipal Assembly. This approach will alleviate poverty and create jobs for Bonwire and other towns in the Ejisu Juaben Municipality.

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APPENDIX A

Table A1: CWSA Design Guidelines

Criteria	**CWSA Guideline**	**Design Value**
1. Domestic Demand		
a. Standpost Demand for 80% of population	20lcd	20lcd
b. House connection for 20% of population	60lcd	60lcd
2. Industrial and Commercial Demand (…% of 1)	10%	10%
3. Unaccounted for Losses (…% of 1+2)	8-10 %	10%
4. Design Period for Distribution	10years	10years
5. Design Period for Transmission	15years	15years
6. Design Period for Source Capacity	15years	15years
7. Peak Hour Demand Factor	2.5	2.5
8. Peak Day Demand Factor	1.2	1.2
9. Population per Tap outlet	300	300
10. Service Reservoir Capacity (…% of Daily Demand)	35-40%	36.4%

Population Projections

The present population P_0 = 7099

The projected population is computed as follows:

$$P_n = Po (1+ r) n$$

Where;

Pi = Design Projected Population

Po = Present Population= 7,099

r = Regional Population Growth Rate=2.6%

n = Projected Design Period =15 years

15 year projected Population $P_{15} = 7{,}099\ (1 + 0.026)^{15} = 10{,}433$

Table A2**.** Population and projections

BONWIRE	**POPULATION**
2000	5085
2013	7099
2028	10433

Water Demand Projections

Present Water Demand (2013)

Domestic = 7,099 x [(60 x 0.2) + (20 x 0.8)] = 198,772lpd

Commercial +Industrial Provision=10 % (198,772) = 19,877lpd

Provision for Market days 10 % (198,772) = 19,877 lpd

Provision for Hospital (100 beds @ 100 liters per bed per day) = 10,000 lpd

Physical Losses 10% x (198,772 + 19,877 + 19,877 + 10,000) = 24,852 lpd

Total = 198,772 + 19,877 + 19,877 + 10,000 + 24,852 = 273,378 lpd Say 274m^3d^{-1}

15 years Projected Water Demand (2013)

Domestic = 10,433 x [(60 x 0.2) + (20 x 0.8)] =292,124lpd

Commercial +Industrial Provision=10 % (292,124) = 29,212

Provision for Market days 10 % (292,124) = 29,212

Provision for Hospital (100 beds @ 100 liters per bed per day) = 10,000 lpd

Physical Losses 10% x (292,124+ 29,212+ 29,212 + 10,000) = 36,055 lpd

Total =292,124+ 29,212+ 29,212 + 10,000 + 36,055 = 396,603 lpd Say 397m^3d^{-1}