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Assessment of Groundwater Sustainability in the Bawku East Municipality of Ghana

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Abstract

The sustainability of groundwater, which is the major source of potable water due to its general superiority in terms of natural quality and reliability in the semi-arid Bawku municipality had been assessed quantitatively using data on 760 boreholes, 79 hand-dug wells (HDWs), 8 mechanized boreholes, and water quality analysis of 25 boreholes and 10 HDWs. Analysis of drill logs revealed the existence of granitoids and Birimian metavolcanics as the main geological formations hosting structurally controlled aquifers. The estimated current annual water demand and abstraction were 6.52×10^6 and 2.8×10^6 m^3 respectively while the estimated annual recharge rate, permanent groundwater reserve and recoverable water reserve were 20.6×10^6 m^3, 799.02×10^6 m^3 and 319.61×10^6 m^3 respectively. The study showed that the current groundwater abstraction constitute only 13.6% of annual groundwater recharge, 35.02% of permanent groundwater reserve and meets only 42.9% of groundwater demand leaving a deficit of about 57.1% ($3.72\times10^6 m^3/yr$). Thus, aquifers meet current demand and have the capacity to be further developed to meet future needs sustainably. The observed gradual decrease in groundwater levels, annual rainfall figures and a corresponding increase in temperature (unfavourable climate change effects) coupled with the ever-increasing population may impact negatively on groundwater reserve in the near future if adaptive measures are not put in place. We recommend for further and more detailed studies including but limited to continuous monitoring of groundwater levels, yield, quality and isotopic studies of the resource in the municipality so as to ensure sustainable management to meet the socio-economic needs of the inhabitants.

Keywords: abstraction, groundwater, sustainability, Bawku, Ghana

1. Introduction

Water is required by humans to meet the demands of domestic, sanitation, agricultural, industry and urban development. About one-third of the world's population live in moderate to high water- stress countries (arid and semi-arid regions) with disproportionately high impacts on the poor (UNEP, 2002). In such regions, groundwater has been identified as the main source of potable drinking water for rural areas and peri-urban areas through hand-dug wells (HDWs), boreholes (BHs) fitted with hand-pumps and mechanized boreholes. This is due to the fact that groundwater is naturally available, generally of good quality and cheaper to develop as compared to surface water sources. The demand for potable water in Ghana, especially the rural and peri-urban and urban areas has been on the increase in the last two or more decades. This has been attributed to increase in population, agricultural and industrial activities at the local levels. Furthermore, the declaration of International Drinking Water and Sanitation Decade by the United Nations General Assembly and the government efforts to meet the Millennium Development Goals has led to massive investment in the water and sanitation sector leading to the provision of thousands of water points in the form of mechanized wells, boreholes and hand-dug wells to rural and urban centres across the country. This has led to massive exploitation of groundwater resources in Ghana, prompting stakeholders and environmentalist to begin to raise concerns about the sustainability of the resource, which requires proper management. Groundwater sustainability is the development and use of groundwater to meet both current and future beneficial purposes without causing unacceptable environmental consequences (Theis, 1940). According to Loucks et al. (1981), sustainability in water resource management means water resource systems that are managed to satisfy the changing demands put on them, now and into the future, without system degradation. Globally, the demand for water has increased over the years and this has led to water scarcity in many parts of the world, and this situation has been aggravated by the problem of water pollution or contamination even in areas where surface water resources are available. Thus, ensuring the continuous availability of groundwater resources in semi-arid regions which are water-stressed is a sure way of maintaining human livelihood as well as the ecosystem. According to Sanford (2002), quantification of recharge is a basic requirement for rational and sustainable exploitation of groundwater resource in the face of global climate change.

Northern Ghana comprises Upper West, Northern and Upper East Regions, and falls within the semi-arid to arid region of Ghana. These areas are characterised by combination of unfavorable climatic factors such as short and unreliable rainfall patterns, prolonged dry seasons, high average monthly temperatures, high potential evapotranspiration, which sometimes exceed annual precipitation (Dapaah-Siakwan & Gyau-Boakye, 2000) and ephemeral surface flow that had made groundwater, a hugely preferred source of potable water for domestic, agricultural and industrial purposes as compared to surface water sources. Groundwater is obtained via boreholes installed with submersible pumps, boreholes fitted with handpumps, hand-dug wells fitted with handpumps and developed springs at the source point. Previous studies in parts of the Upper East region had revealed the occurrence of borehole dry-ups (Wardrop, 1987; WRI/DANIDA, 1993; Thiery, 1990). According to Gyau-Boakye and Tumbulto (2000) the observed increase in abstraction of groundwater may have led to the declining groundwater levels and probably depletion of groundwater resources in some parts of Upper East region of Ghana. Estimated water coverage in rural areas is about 49% (WHO & UNICEF, 2000), implying that much more exploitation of groundwater to meet the demand for potable water supply, especially in rural and most peri-urban areas is inevitable and a major priority for the government. According to Bempah (2012), Ghana may be heading towards freshwater crisis mainly due to improper management of water resources, and environmental degradation which have led to reduced access to safe water supply to millions of people. This freshwater crisis is already evident in many parts of Ghana, varying in scale and intensity depending mainly on the time of the year. The lack of adequate knowledge and physical data pertaining to aquifer characteristics and behavior such as recharge, discharge, base flow and aquifer-dependent ecosystems, as well as important linkages between groundwater ecosystem services and human well-being had made groundwater resource planning and management an important and challenging task especially when the impacts of global and local climatic changes to climate are already evident in Ghana. This study therefore aimed at providing a quantitative estimate of the available groundwater resources in the Bawku municipality to ensure an efficient utilization, effective planning and sustainable management of aquifers to minimize the occurrence of any negative effect associated with groundwater over-abstraction.

1.1 Study Area

1.1.1 Location, Relief and Drainage

The Bawku Municipality (Figure 1) is one of the nine districts and municipalities in the Upper East Region of Ghana. It lies within latitudes 11°11′N and 10°40′N and longitudes 0°18′W and 0°06′E in the north-eastern corner of the region.

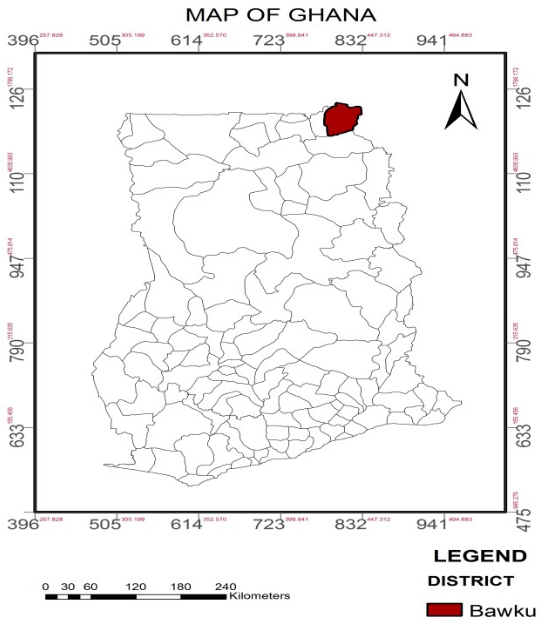
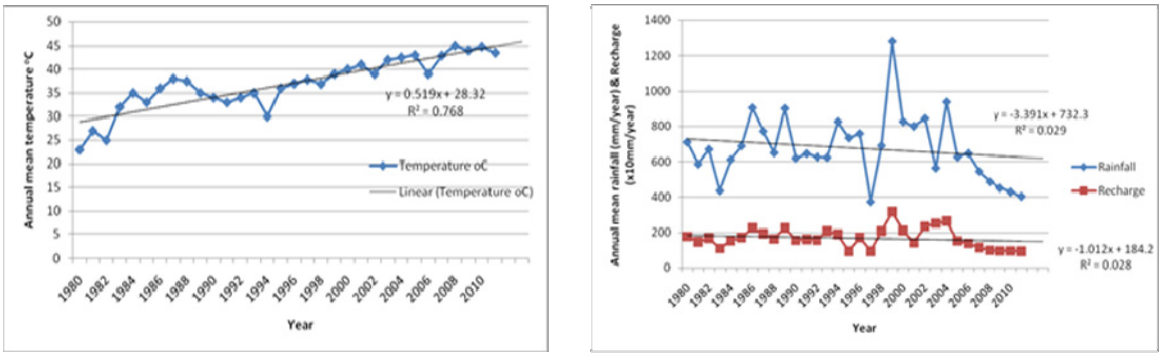


Figure 1. Map of Ghana showing Bawku Municipality

The area is bordered to the north by Republic of Burkina Faso, east by Bawku West District to the west by Republic of Togo and to the south by Garu-Tempane District. It covers an area of 1215.05 square kilometers which constitutes about 13.7% of the total land area of the Upper East Region. The relief of the municipality easily marks the highest point of the Upper East Region. In areas bordering the basins of the White Volta River and its tributaries, the relief is generally low and slightly undulating with heights of 120-150 metres above sea level. The rest of the municipality consists of a series of plateau surfaces, being remnants of prolonged periods of weathering and erosion of the scattered hills. The average height of the plateau is about 400 metres above sea level, but isolated peaks rise beyond 430 metres as in the case of Zawse hills. Drainage is enhanced in the municipality basically by the White Volta and its tributaries mainly from Tamne basin such as Kulupielea and Panabako Kayinchingo streams which are the main tributaries to the Volta Lake, Ghana's source of hydroelectric power.

1.1.2 Climate and Vegetation

The area falls under the Tropical Continental Climatic region which is influenced by two main air masses, namely the Southwest Monsoon and the Northeast Trade Winds. It is characterized by a single rainy season within a year, usually from May to October followed by prolonged dry season. The rainfall ranges from 110mm/year to 800mm/year with average evapotranspiration estimated to be about 890mm/year but may reach 1000 -1300 mm/year in wet years and 650mm/year in dry years. Between 1989 and 2005 rainfall has decreased from 1673.2mm to 769.5mm/year. Mean monthly temperatures range from 42°C in March to about 26°C in August with the average daily temperature ranging from 28°C in July to 32°C in April (Kwei, 1997). Within this climatic zone relative humidities are high during the rainy season (about 70 to 90%) which may fall to about 20% during the dry season. The vegetation is mainly of the Sahel Savannah type consisting of open Savannah with fire swept grassland separating deciduous trees (Dickson & Benneh, 1988). Parts of the forest reserves include Morago West, Kuka and the White Volta basin. These are protected areas by local authorities and the Municipal Assembly. It can be observed from Figure 2 (2a and 2b) that there is a general increase in temperature and a corresponding decrease in mean annual rainfall in the study area. The Climatic conditions render the municipality susceptible to bush fires in the dry season and thus exacerbate environmental degradation and poverty in the municipality.



(a) (b)

Figure 2. Variation of temperature (a) and rainfall and estimated recharge (b) in the study area

1.1.3 Soils, Geology and Hydrogeology

The distribution of soils in the study area is as shown in Figure 3. The most common soil type is the Lixisols which is well distributed in the entire study area. Liptosols are the next in terms of dominance, and can be located mainly in the extreme northern and southern parts of the study area; of lesser extent is the Acrisols located in parts of the northern section of the study area while Gleysols are commonly found along the various rivers and stream channels (Agyare, 2004). According to Martin (2006), the texture of the Lixisols generally vary from sandy-loam to silty-clay depending on the underlying parent materials, but the soils are generally characterised by higher clay content in the uppermost part of the profile and gradually becomes coarser as the depth increases.

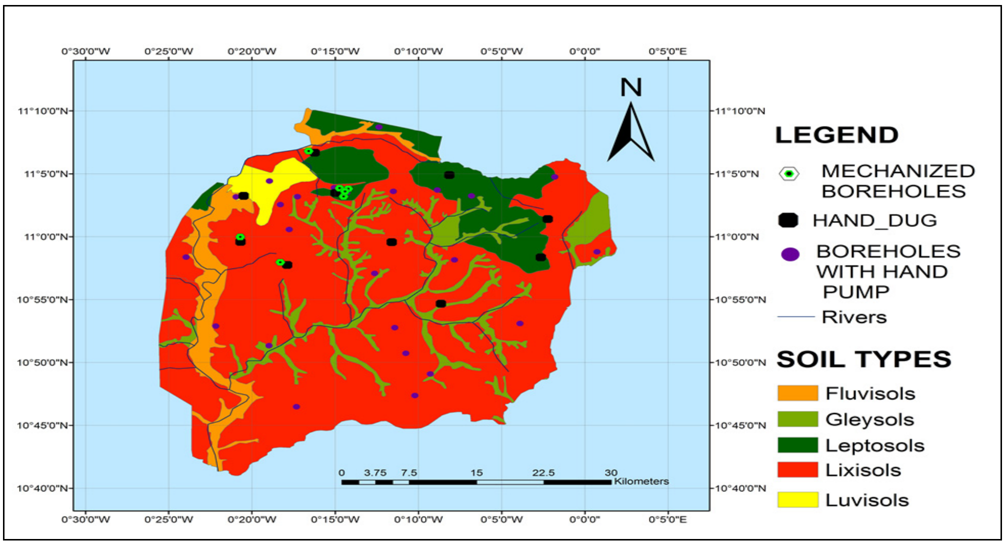


Figure 3. location, drainage and **s**oil distribution of the study area

The geology of the study area, according to Griffiths et al. (2000) is made up of two main rock types - the proterozoic (2134±1Ma), Birimian meta-volcanic and associated belt-type granitoids. The meta-volcanic rocks commonly occur in the north-western corner of the municipality (Figure 4) and overlie conformably on the Birimian meta-sedimentary. The formation consists of great thicknesses of basaltic-andesitic lavas, beds of agglomerate, tuff and tuffaceous sediments with the basic volcanics and pyroclastics altered largely to chloritised and epidotised rocks that are loosely grouped together as greenstones.

Figure 4. Geological map of the study area

Where the greenstones have been subjected to dynamothermal metamorphism, they have been converted to hornblende-schists and amphibolites. The rocks are usually fractured and sheared presenting mylonitic textures in places, and due to their intrusive relationship with belt-type granitoids, they are usually strewn with quartz veins. The water-bearing and yielding capacity is high due to the faults, fractures and quartz veins. According to Griffiths et al. (2000), the Birimian formation is greatly intruded by large masses of granites and basic intrusive of uncertain age but probably of post-Birimian and Pre-Tarkwaian age. According to Kesse (1985), the granitoids in Ghana are of two major types- The biotite-rich Cape Coast and Winneba granites (basin-type) and hornblende-biotite rich Dixcove granites (belt-type). The hornblende-biotite rich granitoids, which had intruded the Birimian meta-volcanic rocks, belong to the neo-proterozoic era (approximately 2128±1 Ma). It consists of hornblende granites (approximately 2134±1 Ma), granodiorites (2131±3 Ma) and quartz-diorites (2134±6 Ma). They are often well foliated, as well as magmatic and are potassium-rich, which come in the form of muscovite-biotite granite and granodiorites, porphyroclastic biotite gneiss, aplites and pegmatites. This granitic complex intruded along deep-seated faults in three distinct phases which follow one another from basic to acid gabbro-diorite-granites.

2. Material and Methods

2.1 Data Collection

The water consumption in different sectors of the municipality was estimated using data obtained from Ghana Statistical Service (GSS) 2010 population census and projected to 2012, Community Water and Sanitation Agency (CWSA), Water Research Institute (WRI), Ghana Meteorological Authority and Bawku Municipal Assembly. These data included population, population growth rate, rainfall, temperature, borehole drill logs and hand-dug wells, water quality, soil and geology, groundwater levels and settlement pattern. Information from these data were used for the analysis of future water demand trends, annual mean precipitation, groundwater recharge, transmissivity rates, groundwater storage reserve etc.

2.2 Estimation of Groundwater Abstraction and Reserve

The water discharge in the municipality was estimated using hand dug wells, boreholes fitted with hand pumps and mechanised boreholes. The discharge from the municipality groundwater aquifers was estimated using each of the three withdrawal parameters as given in Equation (1).

$$TD = GAP_n + D + T \tag{1}$$

where TD=total discharge from given discharge parameter, GAP=total number of a groundwater abstraction parameter, D= discharge rate, and T= time of extraction.

Issues on storage capacity of an area is one of the most frequently asked questions by private citizens, water resource planners and politicians alike because it seems easy to understand. It can be seen as how much reserve is underlying a given area. The groundwater storage capacity within the municipality was estimated using Equations 2 and 3 following Schoeller (1967);

$$Q_t = \alpha\theta HA \tag{2}$$

$$Q_r = \alpha\gamma HA \tag{3}$$

where Q_t = total groundwater storage, m^3, Q_r= recoverable groundwater storage, α = percentage of study area underlain by groundwater zone, γ = specific yield, θ = porosity, H = mean thickness of the saturated zone, m, A = extent of the study area, m^2.

2.3 Population and Water Demand Projections

2.3.1 Population Projections

The method for the population projections in the municipality was selected based on a statistical analysis of the past population census data. A regression analysis was carried out using 1984, 2000 and 2010 census data and it was realized that geometric regression had a higher correlation factor. The present and the future population projections were then estimated using Equation (4), from 2010 population census data as the base:

$$P_t = P_o\left(1+r\right)^t \tag{4}$$

where P_t = projected population at time t, P_o = initial population, r = population growth rate and t = time in years

The growth rate was calculated using Ghana's 2000 and 2010 population census Figures and Equation (5):

$$r = In^{\left[P_1/\ P_O\right]}\!\!\left/ _T \right. \tag{5}$$

where P_1 = present census population, P_o = last census population, T = time between the two census and r = growth rate.

The water demand was projected as the product of the per capita water demand at any point in time and the corresponding projected population. It was limited to 10 year design period because of the expected developmental project that will be established in the municipality, which may lead to rapid population growth. The assumptions made are as follows:

- The per capita water consumption for the urban dweller is 60 l/day.
- The per capita water consumption for the rural communities is 40 l/day.
- The population growth rate is the same for both the rural and the urban.

2.4 Estimation of Groundwater Recharge and Transmissivity

Quantifying recharge into an aquifer is probably the most difficult of all measurements in groundwater studies (Anornu et al., 2009) since any estimate is normally subjected to large uncertainties and errors. According to Martin (2006), groundwater recharge in the White Volta basin of Ghana is directly from precipitation, which was supported by the conclusions of Pelig-Ba (2009). Andreini et al. (2000), concluded that groundwater recharge rates ranged between 2.5% in the driest areas to about 12% in the wettest areas. According to Akiti (1986), The Bawku area falls within the hottest and driest part in the entire White Volta basin of Ghana and therefore, in this study, a recharge rate of 2.5% was assumed and used in estimating the approximate groundwater recharge. To determine the transmissivity of aquifers in the study area, the relation according to Driscoll (1986) as shown in Equation (6) below was used;

$$T = \frac{0.183Q}{\Delta s} \tag{6}$$

where T = Transmissivity in m^2/day, Q = Discharge in m^3/day and △s = Drawdown per log cycle for pumping test from semi-log plots.

2.5 Water Samples Collection

A total of thirty-five (35) groundwater samples from boreholes (25) and hand-dug wells (10) were collected in 0.5litre polythene bottles and their respective geographical locations (i.e. elevation, longitude and latitude) were measured. Sampling was carried out in accordance with protocols described by (Claasen, 1982) and (Barcelona et al., 1985). Sampling bottles were initially conditioned by washing with detergent, then with ten per cent (10%) nitric acid, and finally rinsing several times with distilled water. This was carried out to ensure that the sample bottles were free from contamination, which could affect the concentrations of various ions in the groundwater samples. Boreholes were pumped for at least five minutes to purge the aquifer of stagnant water so as to acquire fresh samples for analysis. Hand-held syringes fitted with a filter head with 0.45μm cellulose filter membrane were used to filter the water samples in the field. Two samples were collected at each site; one was acidified by adding 2% of concentrated nitric acid (HNO_3). The acidified water samples were used for metal analysis while the non-acidified water samples were used for physico-chemical analysis. The sampled waters were tightly capped and preserved in an ice-chest at a temperature of 4°C and transported to the laboratory of the Ghana Atomic Energy Commission at Kwabenya within the shortest time for analysis.

2.6 Sample Analysis

2.6.1 Physico- Chemical Parameters

Unstable hydrochemical parameters such as electrical conductivity (EC), pH and alkalinity were measured in situ (in the field) immediately after collection of samples, using a WTW field conductivity meter model LFT 91, WTW field pH meter model pH 95 and a HACH digital titrator respectively, that had been calibrated before use. Major ions such as Sodium (Na^+) and Potassium (K^+) were analysed in the laboratory using the flame photometer. Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) were analysed using the AA240FS Fast Sequential Atomic Absorption Spectrometer. The ICS-90 Ion Chromatograph (DIONEX ICS-90) was employed in the analysis of Chloride (Cl^-), Fluoride (F^-), Nitrate (NO_3^-), and Sulphate (SO_4^{2-}). Phosphate (PO_4^{3-}) was determined by the ascorbic acid method using the ultraviolet spectrophotometer (UV-1201). A multipurpose electronic DR/890 Colorimeter was used to measure the color, turbidity, total dissolved solids and a HACH SEN 523 pH meter was used to measure the pH and temperature. An electronic HACH SEN ION 5 conductimeter was used to measure the conductivity, salinity and total dissolved solids of all the samples.

3. Results and Discussion

3.1 Hydrogeology

The distribution of boreholes in the different geologic formations with some estimated aquifer characteristics are shown in Tables 1 and 2 respectively. Analysis of borehole data showed that currently, approximately 768 boreholes existed in the study area with about 96% success rate of drilling which is quite slightly higher than the average sub-Saharan African regional rate of 93% (Carter & Bevan, 2008). About 75% of the boreholes were drilled in the granitoids whilst the remaining wells were found within the Birimian meta-volcanic formation. Analysis of borehole logs revealed that groundwater occurrence in the meta-volcanics were structurally controlled (i.e. aquifers occurred in joints, sheared and fault zones), and also in weathered zones (especially in the granitoids) with an average over-burden thickness of 6m. The fractured zone aquifers were mostly confined or semi confined and contained relatively higher yielding capacities as observed in the estimated transmissivity (Table 1). There was an observed general increase in depth to aquifers from the north-western part towards the eastern boundary of the municipality varying between 5-18m. At the western part of the study area, however, clay layers were minimal suggesting a possible increase in groundwater recharge.

Table 1. Statistical summary of transmissivity and static water levels of boreholes

Formation	No, of Boreholes (analysed)	Static Water Level (m)		Transmissivity (m^2/day)	
		Range	Mean	Range	Mean
Meta-Volcanic	192	0.54 – 19.1	6.4	0.73-41.25	11.97
Granites	576	2.4 – 18.3	7.8	0.12-27.58	10.86

The yield of a well is an important hydrogeological parameter which can be used with other factors to determine the groundwater recharge potential of an area. From Table 2, it could be observed that wells drilled within the Birimian-Meta Volcanic rocks had higher average yields ranging from 0.78 to 21m^3/h compared to wells in granitoids formations with yield values ranging from 0.3-6m^3/h.

Table 2. Statistical summary depths and yields of boreholes

Formation	No, of Boreholes (analysed)	Depth (m)		Borehole yield (m^3/h)	
		Range	Mean	Range	Mean
Meta-Volcanic	192	28 - 76	39	0.78 - 21	4.6
Granites	576	31 -46	36.5	0.3 - 6	3.2

3.2 Groundwater Demand and Sustainability

Currently, the population of the inhabitants of Bawku as projected from the 2010 base year is 351,113 with a corresponding total water demand of $7.68\times10^6 m^3/yr$, which is made up domestic, livestock, institutions, small-scale and industries usages. Of this estimated total demand value, domestic water demand is about $5.65\times10^6 m^3/yr$ representing 73.6% of total water demand with local industries constituting about 2.03% (Figure 5). Available records from the community water and sanitation agency (CWSA) indicated that there are 760 boreholes fitted with hand pumps (Afridev) and assuming they were pumped for 8 hours in a day (which is the normal practice), then in a year, the estimated annual abstraction rate is 1.98×10^6 m^3. CWSA records also indicate that there are 79 hand-dug wells fitted with NIRA-85 hand pumps in the municipality with an average discharge of 10 l/min for 8 hours per day per year, and using equation (1) above, the estimated annual abstraction is 1.34×10^5 m^3 of groundwater abstraction per year for 8 hours pumping per day's discharge. The total estimated annual abstraction rate from eight (8) production (mechanized) wells was 6.65×10^5 m^3. Thus, the overall estimated abstraction of groundwater for various purposes in the municipality was estimated to be $6.67\times10^6 m^3$ per year. According to Pelig-Ba (2009), approximately 85% of the population in the study area depends on groundwater throughout the year for livelihood. This translated into about $6.52\times10^6 m^3/yr$ of groundwater demand constituting about 97.8% of the current total annual groundwater abstraction in the study area.

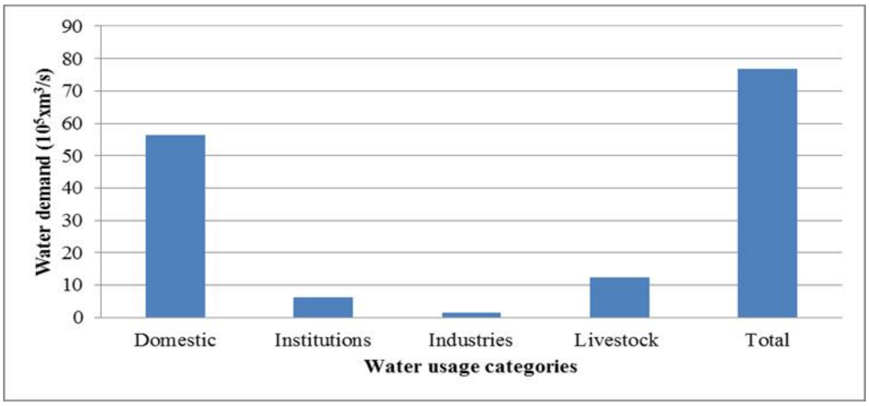


Figure 5. Estimated water demand for different usage categories in the Bawku Municipality

3.3 Groundwater Recharge and Sustainability

Determination of groundwater resource sustainability generally requires the development of significant knowledge in recharge processes and rates (Atobra, 1983). Recharge estimates from previous studies undertaken in the Birimian formations (metavolcanics and metasediments intruded with corresponding granitoids) in various parts of Ghana show that groundwater recharge values range from 2% to about 20% of the mean annual rainfall (Atobra, 1983; Bannerman & Ayibotele, 1984; Apambire, 1996; Frempong & Kortatsi, 1995; Kankam-Yeboah et al., 2005; Martin, 2006; Anornu et al., 2009). The variations had been attributed to climatic variations, geological settings, and changes in the land use, permeability and the storage characteristics in the subsurface, which may favor percolation of water to the aquifer systems. According to Andreini et al. (2000), the groundwater recharge rate in the White Volta basin of Ghana varied from 2.5% in the driest parts to about 7.5% in the relatively wet parts. According to Martin (2006), groundwater recharge is considered to be solely dependent on rainfall, and therefore since the study area fell within the driest part of the White Volta basin of Ghana, a recharge rate of 2.5% was assumed. This resulted in an estimated annual recharge to groundwater to be 16.91mm/yr, which was far smaller than what had been obtained in similar geologic settings elsewhere in southwestern Ghana by Kankam-Yeboah (2005). The estimated annual groundwater recharge of 16.91mm/yr translated into 20.6×10^6 m^3/yr, which far exceeds the current total groundwater demand of $6.52\times10^6 m^3$ per year. The relatively high estimated groundwater recharge compared to the estimated water demand of inhabitants in the area showed that recharge could currently be considered not to be a limiting factor, which agrees with the findings of Martin (2006). However from Figure 2, there was an observed significant increase in annual mean temperatures of about 0.519°C per year in the study area in the past thirty-three (33) years with corresponding gradual decrease in mean annual rainfall at a rate of 3.391mm/yr (representing 0.5%) and recharge at a rate of 1.012mm/yr (representing 6%).

3.4 Groundwater Storage and Sustainability

An attempt was made to quantify the volume of groundwater in storage based on borehole data using Equations 2 and 3. Using effective porosity and specific yield of 5% and 2% respectively (Asomaning, 1993; Acworth, 1987) for an area of 1166.45 km^2 with an estimated average aquifer depth of 13.7 m, the permanent storage and recoverable (or usable storage capacity) of groundwater of the municipality were estimated to be 799.02×106 m^3 and 319.61×10^6 m^3. This implies that there is reasonably enough groundwater available for future development, and therefore, there is little or no threat to the sustainability of groundwater resources in the study area.

3.5 Groundwater Sustainability in Terms of Water Quality

The results of the analysis of the physico-chemical parameters of 35 water samples (25 BHs and 10 HDWs) in the study area are as shown in Table 3. According to Amuzu (1974), groundwater quality data can provide information about the possible source(s) of minerals and how they came in contact with the groundwater as well as the general geochemistry of the host rock. Groundwater quality furthermore provides a basis to assess the suitability or otherwise, the wholesomeness of water for human consumption.

Table 3. Concentration of elements in the groundwater

Parameters	Minimum	Maximum	Mean	WHO (2011)
PH	6.5	8.7	7.3	6.5-8.5
Cond	225	789	560	250
Ca	1	47.5	20.9	200
Mg	7	103	33.1	150
Na	13	86	52	200
K	0.2	4.5	1.9	30
Fe	0	0.04	0.02	N/A
Mn	0.1	0.5	0.2	N/A
HCO_3	5.2	45	18.3	N/A
SO_4	0.1	58	0.5	400
NO_3	0.8	15	7.9	10
Cl	0.1	3	0.3	250
F	0.1	1.5	0.6	0.5-1.5

The analysis of the results showed that with the exception of nitrate concentrations in seven hand-dug wells and six boreholes (Figure 6), all the physico-chemical parameters fell within the permissible levels of WHO guideline. Generally, nitrate values ranged from 0.8 to 15 mg/l with a mean of 7.88 mg/l with about 70% and 24% of the hand-dug wells and boreholes respectively having nitrate values exceeding the WHO (2008) permissible limit of 10 mg/l required for human consumption.

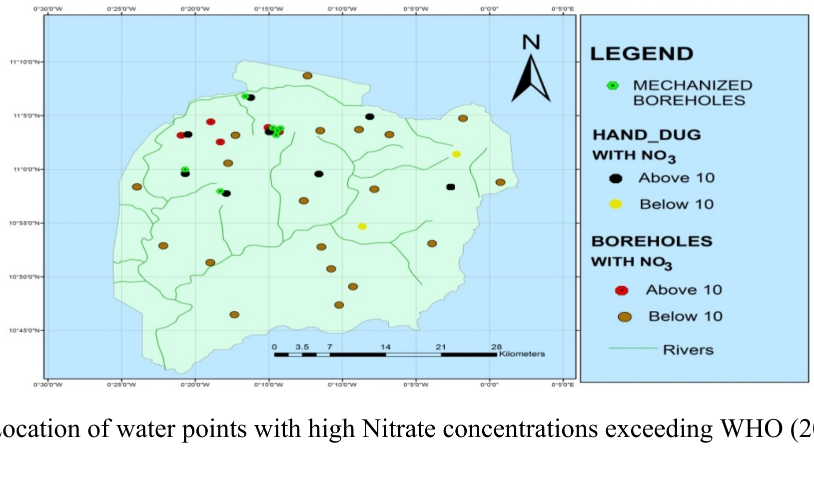


Figure 6. Location of water points with high Nitrate concentrations exceeding WHO (2008) GLV

The presence of high nitrates in majority of the HDWs as compared to BHs is a possible indication of organic pollution from infiltrating surficial waters from agricultural fields, which are utilizing the use of manure (cow dung) and chemical fertilizers rich in nitrates for intense crop-farming in the area. This is consistent with the findings of Akiti (1977) who observed similar elevated nitrate concentrations in boreholes in Tamne basin in Bawku in the upper east region of Ghana. According to McDonald and Kay (1988), the consumption of water with high nitrate concentrations (above 10mg/l) can result in the disease called Methaemoglobinemia (also known as Blue Baby Syndrome) which normally affect children, especially bottled-fed infants who are less than 3 months old (Super et al., 1981). This implies that in communities where nitrate levels are above permissible levels, very young infants may be vulnerable to this disease, and therefore, efforts in public health awareness creation must be carried out to farmers especially in rural areas on the potential risk involved in the use of such chemical for farming on the health of young children.

4. Conclusion

The occurrence of groundwater in the study was found to be structurally controlled and remains fundamental to the sustenance of life for the inhabitants due to challenges associated with surface water sources availability and quality during the greater part of the year. The current total groundwater abstraction of 2.8×10^6 m^3 constitute only about 13.6% the estimated direct annual groundwater recharge from precipitation, and a little less than 2% of the recoverable groundwater reserve within the municipality. This implies that annual recharge may not serve as a major limiting factor for future groundwater resource development in a sustainable manner in the study area. The current abstraction however, constitutes about 42.9% of the total groundwater demand leaving a demand deficit of about 57.1% (3.72×10^6 m^3/yr) rendering the municipality potentially water-stressed. The present study has provided encouraging results and has given a basis to carry out enhanced groundwater development to meet the socio-economic development of the inhabitant of the area. The unfavourable climate change factors in the form of declining annual rainfall and increasing temperatures, coupled with the impact of rapid urbanization could potentially impact adversely on the annual groundwater recharge to aquifers in the immediate future if adaptation measures are not put in place. This study could serve as a framework for the development of an efficient and sustainable groundwater utilization plan for the area. We recommend further and a much more advanced studies that may include but not limited to isotopic studies and land-use pattern that may be imperative to analyze the groundwater system in greater detail for the long-term sustainability of the resource.

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