



GLOBAL JOURNAL OF RESEARCHES IN ENGINEERING
CIVIL AND STRUCTURAL ENGINEERING
Volume 12 Issue 3 Version 1.0 Year 2012
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Water Resources Assessment of the Manya Krobo District

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GJRE-E Classification : FOR Code: 090509



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Water Resources Assessment of the Manya Krobo District

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Abstract - The study on water resources assessment carried out in the Upper Manya Krobo district of the Eastern region, Ghana with the sole objective of identifying feasible options for water supply augmentation to communities in the district. The methodology consisted of inventory of boreholes and hand dug wells, rivers, streams, pipe schemes. Surveys conducted on the hydrogeology, geomorphology and buildings (roof) to determine the prospect of constructing underground dams and rain harvesting schemes. Interviews as well as sampling of groundwater and laboratory measurements determined the quality status of groundwater. Also carried out was limited pumping test. The results showed that groundwater potential is generally low. Borehole yield varies from 0.48 m³h⁻¹ to 12.00 m³h⁻¹ with mean of 3.4 m³h⁻¹ and standard deviation of 2.97 respectively. Generally, the southern half of the district seems to have relatively higher yields than the northern half. Except for the high iron concentration, which is mostly outside the WHO (2006) guideline values, other chemical constituents were generally low and within the WHO (2004), guideline limits. The potential for rain harvesting is high, however, in a few communities; sheds would need to be provided for the dual purposes of school, community centre, etc on one hand and rain harvesting system on the other. The geology and geomorphology of the district are suitable for underground dam construction, however, more detailed hydrogeological investigations are required prior to construction.

Keywords : Ghana, Groundwater, Rain harvesting, underground dams, Upper Manya District.

I. INTRODUCTION

Upper Manya Krobo district is one of the districts that benefited from the District Based Water and Sanitation Component (DBWSC) of the Water and Sanitation Sector Programme Support (WSSPS) Phase II in the Eastern Region. It has been implemented with Community Water and Sanitation Agency, Eastern Region Office, as the facilitators. During the implementation of the programme in the districts, some challenges were observed to be militating against the success of the programme. These included low success rate, low yield and poor water quality. These challenges prevented the achievements of the expected targets of water delivery and coverage in the district, which according to the Millennium Development Goals, should reach at least 75 % by 2015. Currently, about 52 % of communities have access to potable water supply in the whole of the

Eastern Region. After much cogitation and deliberation, it was realized that most of the water supply projects in the Eastern Region were put in place without due reference to the source of supply and the amount of replenishment to the underlying groundwater reservoirs leading to low yields, water shortages and deterioration water quality. As a first step to address the challenges mentioned above, this research had the objective of water resource inventory and source identification for water supply to communities in the Upper Manya Krobo district.

II. THE STUDY AREA

The Upper Manya Krobo district is located to the East of Ghana between latitude 6.17°N and 6.55°N and longitude 0.10°W and 0.33°W. Figure 1 presents the location map of the study area. The geomorphology consists of undulating topography with alternating series of ridges and valleys. The ridges attained elevations between 350 m and 600 m, mostly separated by long narrow strike valleys in which small streams flow for most parts of the year. The district falls under the Equatorial Climatic Zone. The climatic conditions of the area are characterized by high temperatures, ranging from 26° C in August to about 32° C in March. The area has two rainfall regimes, with the first rainy season starting from May and ends in July with heaviest rainfall occurring in June. The second rainy season starts from September and ends in October or early November. The annual rainfall varies between 1200 mm and 1450 mm with a mean value of 1250 mm (Benneh and Dickson, 2004; WARM, 1998). Relative humidity is generally high throughout the year.

a) Size and distribution of population

The population of the district according to the 2000 population and housing census was 18,741. Out of this, 9,400 were females and 9,341 were males. With a growth rate of 2.5%, the estimated population of the district stood as 25,205 as at the end of the year 2012.

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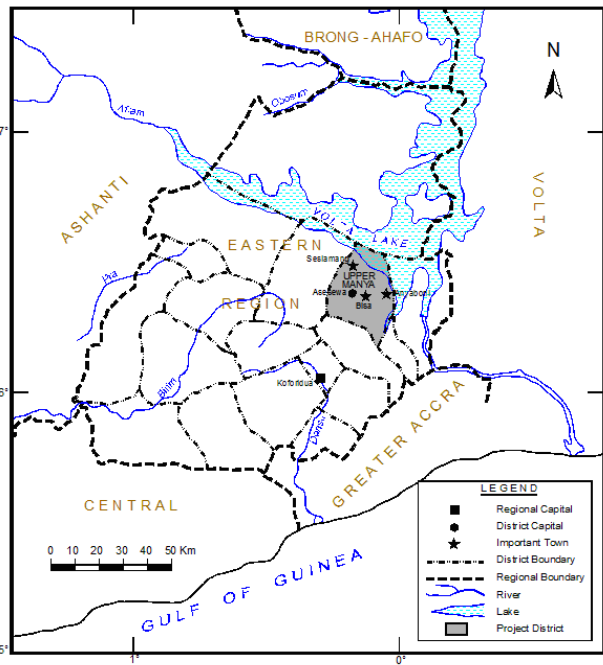


Fig. 1 : Location map of the Upper Manya District

b) Land use and socioeconomic issues

The major economic activity in the district is rain fed agriculture using the slash and burn method. Also, petty trading and small-scale industry for dehydrating cassava dough and extracting palm kernel oil form part of the economic activities in the district. Food crops like maize, cassava, plantain and vegetables are cultivated throughout the district. Livestock farming is undertaken at the household level. In communities along the Volta Lake, extensive fishing in the lake is their major occupation. As the effect of these activities on water resources intensified with increases in human and livestock populations, settlements, farming (using the “slash and burn” method and under shorter rotation periods), the use of agrochemicals, fishing and charcoal production more land is being used in the district.

c) Geological Setting

The Voltaian Formation mainly underlies the Upper Manya Krobo district as a sedimentary basin that has more or less concentric distribution of sediments because of its overall gently synclinal form (Wright *et al.* 1985). The sediments of the Voltaian system range in age from Upper Proterozoic to Paleozoic and include facies interpreted as products of two ancient glaciations, one in the infra-cambrian and the other in the Upper Ordovician (Wright *et al.*, 1985). The rocks are commonly flat-bedded with a mean dip of about 5° except at the eastern flank approximating a tectonic contact with the Buem Formation (Mason, 1963). The Voltaian System has three main divisions, which are the Lower, Middle and Upper Voltaian units (Junner and Hirst, 1946; Grant, 1967; Annan Yorke and Cudjoe, 1971; Affaton *et al.*, 1980). Nonetheless, the

predominate rock that has underlain the Upper Manya Krobo district is Upper Voltaian unit. The sediments, probably typify mosassic deposit that accompanied the uplift in the Pan African event (Grant, 1967). The sediments consist primarily of sandstones and conglomerates that contain pebbles of granite and other igneous rocks and quartzite fragments. The sandstones weather mainly to sandy clay and fine sand in the numerous valleys. The Obosum and Oti Beds form only 2% of the total rock cover of the Upper Manya district and occur as discontinuous unit along the bank of the Volta Lake (Fig. 2).

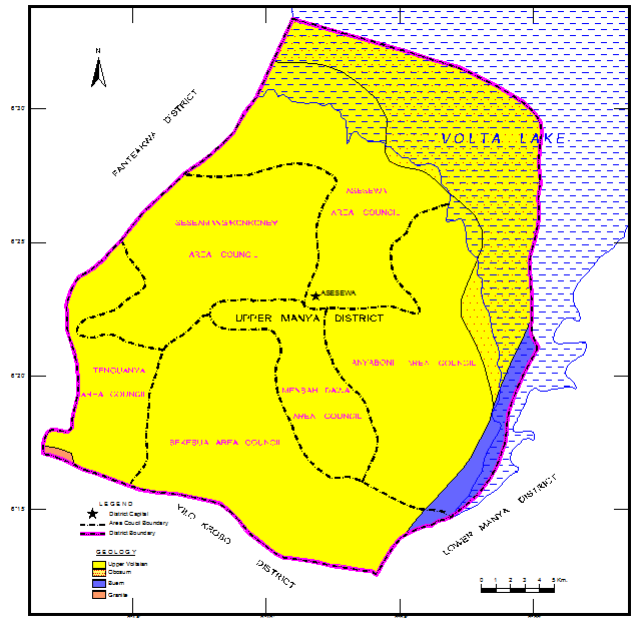


Fig. 2 : Geological map of the Upper Manya Krobo District

III. MATERIALS AND METHODOLOGY

The methodology considered was principally made of desk study, interviews, field measurement, laboratory analyses, map preparation and reporting.

The desk study involved re-evaluation of relevant literature notably hydrogeological and hydrological reports; geological and topographic maps, drilling logs and borehole records. Borehole records and hydrogeological information were collected from Water Research Institute (WRI), Community Water and Sanitation Agency (CWSA), the Adventist Development and Relief Agency (ADRA). Hydro meteorological and hydrological data were collected from Ghana Meteorological Services Agency (GMSA) and Hydrological Services Department (HSD) of the Ministry of Water Resources, Works and Housing respectively.

Hydrometeorological data (rainfall and temperature) were obtained for two (2) meteorological stations (Anyaboni and Asewesa) in the study area. The Upper Manya Krobo District Assembly provided data on

the water resources and environmental plan for the district. All the information gathered were collated, analysed and presented as the background of the study area. Additionally, field data sheets were designed based on information gathered from the desk study to obtain further primary data.

Field Reconnaissance survey was carried out in the entire district between September 8th and 25th, 2008 and 248 boreholes, 24 hand-dug wells and 41 ephemeral streams were inventoried. Survey of roofs was also carried out in 42 communities in the district, which had low groundwater and surface water potentials to determine the suitability of the roofs for rain harvesting and the volume of rain water that each roof could harvest annually. Interviews were also conducted on a sample of the communities with regards to the adequacy of water supply, water quality problems, sanitation facilities etc. The field work also involved careful ground observations to delineate areas, which by their geological history and geomorphology could be suitable for underground dam construction. Based on the results of the desk study and field reconnaissance survey, 13 boreholes were sampled for water quality of which 2 of them were pump tested to ascertain their yields and analysis carried out using Jacob Cooper methodology.

The boreholes sampled were randomly selected and distributed in such a way that they represented the whole district. Sampling protocols described by Claasen (1982) and Barcelona *et al.* (1985) for chemical water quality determination were strictly adhered to during the sample collection. Samples collected into 4:1 acid-washed polypropylene containers after three-pore volumes purge. Each sample meant for trace metal determination immediately filtered on site through 0.45 μm pore size on acetate cellulose filters. The filtrate transferred into 100 cm^3 polyethylene bottles and immediately acidified to $\text{pH} < 2$ by the addition of MerckTM ultra pure nitric acid. Samples for anions analyses collected into 250 cm^3 polyethylene bottles without preservation. All samples were stored in an ice-chest at a temperature of $< 4^\circ\text{C}$ and transported to the Potable Water Quality Laboratory of the Water Research Institute in Accra for analyses, which was carried out within three days.

Temperature, pH and electrical conductivity were measured '*in situ*' using WTW-Multiline P4 Universal Meter. Chemical analyses of the samples were carried out using appropriate certified and acceptable international standard methods (APHA, 1998; Global Environmental Monitoring System/Water Operational Guide, 1988). An ionic balance was computed for each chemical sample and used as a basis for checking analytical results. In accordance with international standards, results with ionic balance error greater than 5% were rejected (Freeze & Cherry, 1997; Appelo & Postma, 1999).

IV. RESULTS AND DISCUSSIONS

a) Groundwater Resources Evaluation

Data on 248 boreholes, 24 hand-dug wells in the district were collected and analysed, and results revealed complex hydrogeological conditions. Much of the primary porosity of the bedrocks in the Upper Voltaian formation has been destroyed due to consolidation and cementation (Kesse, 1985). The formation, therefore, have very little intergranular pore-space and are thus characterized by insignificant primary porosity and permeability. The rocks however, are fractured and weathered as they occur close to the surface. Cavities along joints, bedding and cleavage planes frequently act as channels for groundwater transmission and storage. Where these fissures are prevalent, incessant, interconnected and/or filled with permeable material, percolation and circulation of significant quantity of water do occur.

The pumping test analysis indicated that the trend lines of most of the field data cut below the zero on the residual drawdown axes (Fig. 3) suggesting that the aquifers are generally discrete and limited in extent. Depth to water varied throughout the district but was generally shallow, ranging from 0.5 m to 18.3 m with mean and median values of 6.4 m and 4.2 m respectively. The depth of boreholes varied from 22 m to 84 m with mean and median values of 35 m and 25 m respectively. Data on potentiometric heads indicate that the potentiometric surface resembles that of the land surface elevation. Groundwater generally occurs under semi-confined conditions, but confined conditions also exist at a few places. Static water levels (SWL) ranged from 1.0 m to 20 m below the land surface. Transmissivities values were between 0.3 and 70.0 m^2d^{-1} . This range is consistent with transmissivity values obtained in similar geological formation in the Afram Plains (Buckley, 1986; Minor *et al.*, 1995). Estimated well yields range from 0.25 to 12.00 m^3h^{-1} with mean 3.2 m^3h^{-1} and standard deviation 3.5 respectively. The median yield is 1.6. m^3h^{-1} . The histogram in Fig. 4 shows that the yields of the boreholes were discontinuous and not normally distributed. In such situations, non-parametric statistics needs to be applied (UNESCO/WHO/UNEP, 1996; Caritat, 1998). Therefore, the use of the median is more robust than the mean in describing the central tendency of the yield distribution (Caritat, 1998). The low median value, suggests that generally the yields of majority of boreholes in the Upper Manya Krobo district are low. Nonetheless, boreholes are apparently higher yielding and more numerous in the areas underlain by the Upper Voltaian than those of the Obosum and Oti beds areas. Spatially, relatively higher yields were obtained in the southern half of the district than in the northern half.

RESIDUAL DRAWDOWN GRAPH

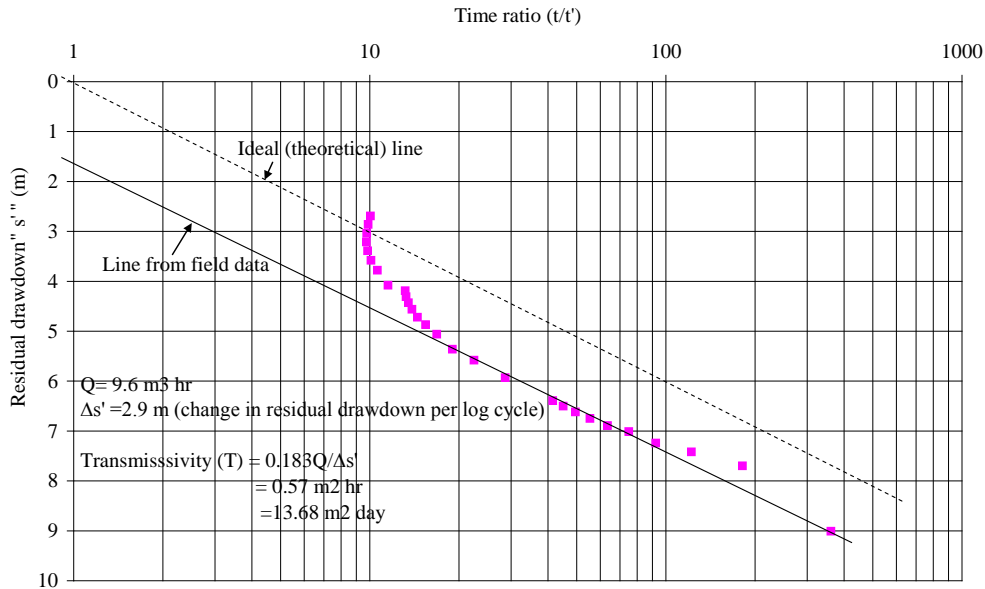


Fig. 3 : Pumping test analysis using Cooper-Jacob time-drawdown and residual drawdown methods.

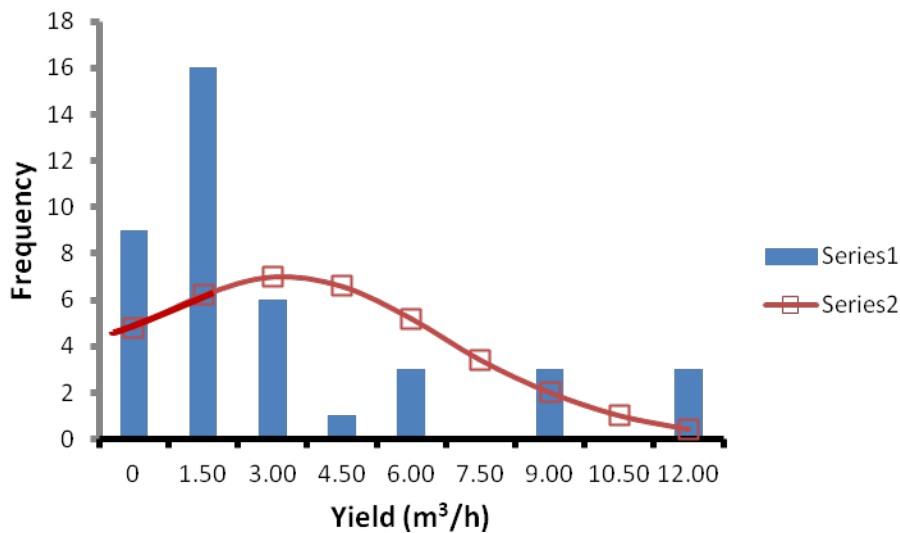


Fig. 4 : Frequency distribution of yield within the Upper Manya Krobo District

b) *Hydrochemistry of groundwater in Upper Manya district*

The results and the summary statistics of the physico-chemical parameters and chemical constituents in groundwater in the Upper Manya District (Tables 1 & 2 respectively) are mostly non-parametric (UNESCO/WHO/UNEP, 1996; Caritat, 1998). It is, therefore, more useful to use the median (non-parametric statistics) instead of the mean.

Groundwater temperature in the district ranged from 26.4°C to 30.0°C with a median of 27.6°C (Tables 1 & 2). The groundwater was slightly acidic with pH in the range 5.5-7.0 pH units with median 6.3 pH units (Tables

1 & 2) as compared to natural water pH range of 4.5-9.0 pH units (Langmuir, 1995). EC levels varied from 76 $\mu\text{S cm}^{-1}$ to 1198 $\mu\text{S cm}^{-1}$, with median 240 $\mu\text{S cm}^{-1}$. Groundwater in the district was relatively turbid with turbidity values ranging from 0.2 to 68 NTU and a mean value of 13 NTU. The alkalinity of the groundwater values varied largely ranging from 6.0 mg/l^1 to 432 mg/l^1 , with a mean value of 114.6 mg/l^1 .

Table 1 : Results of the physico-chemical parameters and constituents in groundwater in the Upper Manya District.

Community	Sampled ID	Temp	pH	Cond	TDS	Turb.	Tot.alk	Hard	Ca	Cl	NO ₃	PO ₄	SO ₄	Na	K	F	HCO ₃	Mg	Mn	Fe	Zn
Akatawiah	UM1	27.6	6.6	440	242	-	160	164	30.5	31	1.37	0.94	27.1	19	8.5	<0.005	195	21.3	0.64	4.68	0.010
Agome Bisa	UM2	27.8	5.7	127	69.9	0.3	18.0	44.0	16.0	18	5.27	1.10	38.0	13	9.4	<0.005	22.0	1.0	0.017	0.011	0.019
Kabu	UM3	27.5	5.8	136	74.8	6.8	18.0	25.0	8.8	21	7.78	1.72	18.8	16	5.3	<0.005	22.0	0.7	0.072	0.358	0.021
New Anyaboni Quarters	UM4	27.3	5.9	678	373	68	150	240	68.2	45	1.68	1.48	42.1	14	5.8	<0.005	183	16.9	0.617	5.23	0.005
Kwabia Asaasehene	UM5	28.5	7.0	1198	659	0.2	432	560	120	114	1.03	1.56	35.6	35	5.9	<0.005	527	63.2	0.279	0.047	<0.005
Sesame Sisi	UM6	28.0	5.6	164	90.2	12	22.0	30.0	8.8	28	2.79	1.57	20.7	16	11	<0.005	26.8	1.9	0.212	0.285	0.042
Akateng Manya	UM7	30.0	5.5	76	41.8	2.3	6.0	48.0	16.4	17	1.83	3.38	17.4	1.8	0.8	<0.005	7.3	1.7	0.043	0.113	0.019
Akrusu Saisi	UM8	28.6	6.9	930	512	3.5	252	332	97.0	87	0.741	1.60	37.3	50.5	6.9	<0.005	307	21.7	0.579	0.298	<0.005
Abrese Akwenor	UM9	27.2	6.9	438	241	6.2	182	116	29.7	21	1.03	1.72	19.0	57	13	<0.005	222	10.1	0.408	0.870	<0.005
Brepon Kpeti	UM10	27.3	5.5	135	74.3	0.5	6.0	16.0	4.0	21	8.89	0.800	35.3	22.2	7.8	<0.005	7.3	1.5	0.108	0.113	0.005
Dawatrim	UM11	27.5	6.6	406	223	4.7	128	146	33.7	27	1.06	0.780	47.3	29	4.4	<0.005	156	15.0	0.578	1.09	<0.005
Takorase	UM12	26.4	6.3	226	124	44	40.0	68.0	11.2	11	1.00	1.57	54.5	17	4.9	<0.005	48.8	9.7	0.376	3.45	<0.005
Agbletsom	UM13	27.6	6.5	240	132	7.1	76.0	72.0	20.8	9.9	1.00	1.85	26.4	19	3.2	<0.005	92.7	4.9	0.332	0.543	0.005

Table 2 : Statistical summary of chemical parameters and constituents of groundwater in the Upper Manya Krobo district compared with the limits recommended for drinking water.

Parameter	Upper Manya		Median	WHO (2006) Guideline	GCWL Guideline
	Range	Mean			
Temperature	26.4 – 30.0	27.8	27.6		
pH-unit	5.5 - 7.0	6.2	6.3	6.5-8.5	6.5 - 8.5
Conductivity	76 – 1198	400	240		
TDS	41.8 – 659	220	132	1000	1000
Turbidity	0.2 - 68.0	13.0	5.45	5.0	0-15.0
Total alkalinity	6.0 – 432	114.6	76		
Tot. Hardness	16 – 560	143	72		
TSS	1.0 - 41.0	15.7	10.2		
Cl ⁻	9.9 – 114	34.6	21	250	600
SO ₄ ²⁻	17.4 – 54.5	32.2	35.3	250	400
HCO ₃ ⁻	7.3 – 527.0	139.8	92.7		
NO ₂ -N	0.041 - 0.145	0.073	0.070	0.3	
NO ₃ -N	0.74 - 8.89	2.73	1.37	10	10
PO ₄ ²⁻	0.78 - 3.38	1.54	1.57		
Na ⁺	1.8 – 57	24	19	200	
K ⁺	0.8 - 12.5	6.63	5.9	30	
Ca ²⁺	4.0 – 120	35.8	20.8	200	
Mg ²⁺	0.7 - 63.2	13.1	9.7	150	
Fe ²⁺ (Total)	0.011 - 5.23	1.314	0.358	0.3	0.3
Mn ²⁺	0.017 - 0.64	0.328	0.332	0.5 (P)	
Zn	0.005-0.042	0.016	0.005		
F ⁻	Below detection	Below detection	Below detection	1.5	1.5

c) Hydrochemical facies

The chemical trend of groundwater in the Upper Manya Krobo district was derived using the Piper trilinear diagrams (Piper, 1944). Four main water types (labelled A-D) characterized the district. In the first type (A), alkaline earth and weak acids, dominate the chemical properties of the groundwater, that is the groundwater consists mainly of low salinity calcium bicarbonate (Ca (HCO₃)₂). This water type designated (A) occurs principally at Agbetsom, Akatawiah, Akusu Saisa, Dawatrim, Kwabia Asaasehene and New Anyaboni Quarters. The second type (B and D) consists of mixed water type where no particular ion pair exceeds

50 %. This water type is found mainly at Takorase and Abrese Akwenor. Alkali and strong acids dominate the chemical properties of the third water type (C) that is, this water type has Na as the main cation and Cl or SO₄ as the principal anion and mainly found at Seseame Sisi, Agome Bisa, Brepon Kpeti and Kabu. In the fourth water type (E), non-carbonate hardness (permanent hardness) exceeds 50%. In other words, Mg²⁺ and Ca²⁺ are the main cations and SO₄²⁻ is the key anions, dominating the chemical properties of the water. This water type occurs principally at Akenteng Manya area.

d) Quality of groundwater in the Upper Manya Krobo district

Groundwater has good quality for domestic use if it is soft, low in total dissolved solids (TDS) and free from poisonous chemical constituents as well as bacteria (Karanth, 1994; Kortatsi *et al.*, 2008). The quality of groundwater in the Upper Manya district evaluated in terms of physico-chemical and bacteriological parameters would ascertain whether the water is soft, low in TDS, free from deleterious chemical constituents and bacteria.

Water is considered soft if the total hardness is between 0 -75 mg l⁻¹ of CaCO₃; moderately hard if the total hardness is between 75-150 mg l⁻¹ of CaCO₃, hard if the total hardness is between 150-300 mg l⁻¹ of CaCO₃ and very hard if the total hardness is greater than 300 mg l⁻¹ of CaCO₃. Total hardness values of the groundwater ranged from 16 mg l⁻¹ to 560 mg l⁻¹ of CaCO₃ with a median value of 143 mg l⁻¹ of CaCO₃ suggesting that about half the boreholes are soft to moderately hard.

WHO (2004) guideline value is 0.3 mg l⁻¹, suggesting that the majority of the well in the Manya Krobo district have iron problem. On the contrary, manganese (Mn²⁺) concentration in the groundwater is generally low. Its range was 0.02 - 0.64 mg l⁻¹, with a median value of 0.33 mg l⁻¹ as against the WHO (2004) provisional upper limit of 0.5 mg l⁻¹ signifying that a larger proportion of the boreholes are potable with regards to Mn²⁺.

The presence of high Fe²⁺ and Mn²⁺ concentrations in water do not particularly pose physiological problems. However, they have the ability of producing aesthetic or sensory effect due to discoloring of water, i.e. high Fe²⁺ concentrations results in reddish brown coloration, while high Mn²⁺ concentrations results in black coloration. These sensory effects can lead to the total rejection of the boreholes. It also results in staining of laundry and sanitary wares (WHO, 2004). Very distinct reddish brown coloration in water pertained in some abandoned boreholes in some communities during sampling period. The reddish colouration might probably have led to the abandonment of the boreholes. Other trace metals measured only have background concentrations. Bacteriological survey of boreholes in the Upper Manya district suggests that the boreholes are generally free from *E. coli* and total coli form but some hand-dug wells contain bacteria due to unhygienic conditions around the hand-dug wells (CSIR-WRI, 2009).

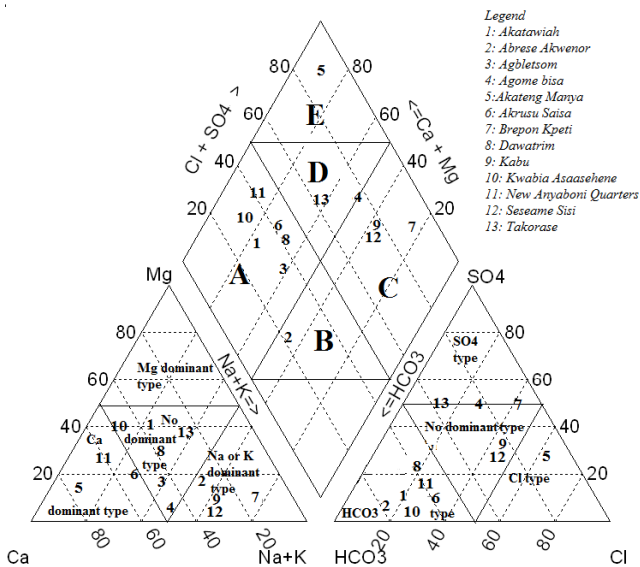


Fig. 5 : Piper (Trilinear) diagram of groundwater from Upper Manya Krobo District.

The TDS of the groundwater is in the range 41-659 mg l⁻¹ with a median 132 mg l⁻¹ while the WHO (2004) recommended upper limit for drinking water is 1000 mg l⁻¹. This implies that the water quality is good with respect to TDS. Similarly, all the major ions (calcium, magnesium, sodium, bicarbonate, sulphate, and chloride) are within the WHO (2004) limits for drinking water. Nitrate (NO₃-N) levels are generally low with values in the range 0.74- 8.89 mg l⁻¹ and median 1.37 mg l⁻¹ and, therefore, within the WHO guideline value of 10 mg l⁻¹ (Table 2). Iron concentration in the groundwater in the district is relatively high. It is in the range 0.01- 5.23 mg l⁻¹ with a median 0.36 mg l⁻¹. The

e) Rainwater Harvesting

Generally, rainwater harvesting requires simple arrangement to collect, store, treat and to distribute the captured rainwater. Rainwater offers additional advantages in water quality for domestic use. It is naturally soft (unlike well water), contains almost no dissolved minerals or salts, is free of chemical treatment, and is a relatively reliable source of water for households. Rainwater collected and used on site can supplement or replace other sources of household water. Rainwater can be drunk if properly stored and suitably treated.

f) Availability of rain for collection (harvesting)

The annual rainfall in the area is in the ranges 120-160 cm with a mean of about 130cm and median 125 cm (Dickson and Benneh, 2004). Fig.s 6. & 7. present the mean annual rainfall distributions for the respective stations. The data covered a period 1939-1996. The rainfall pattern is bimodal, with the major peak in June and minor peak in October. In August, there is a minor dry spell.

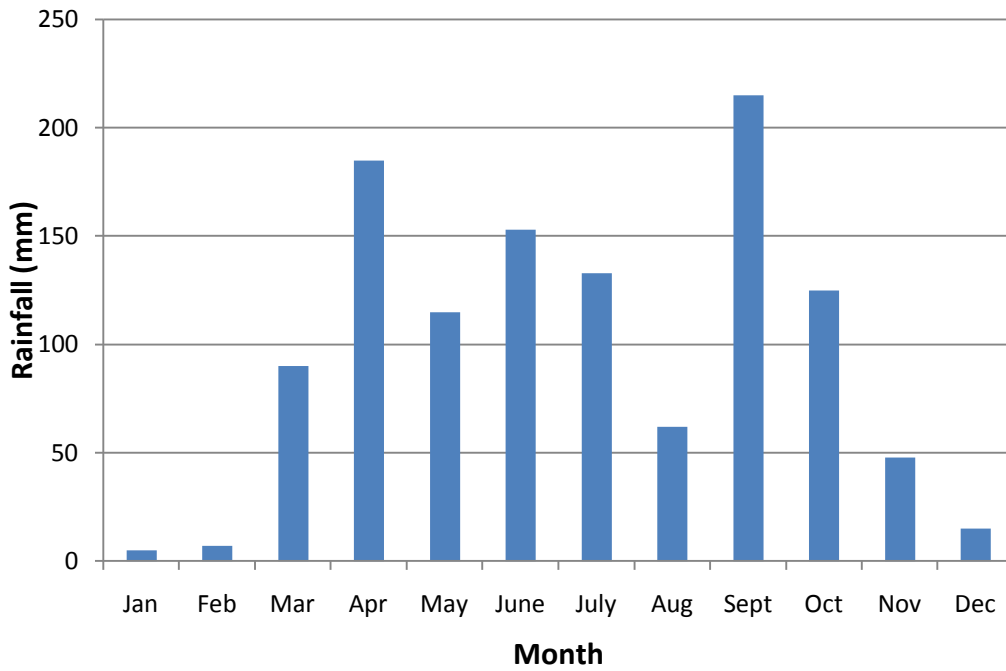


Fig. 6 : Mean monthly rainfall distribution pattern at Anyaboni.

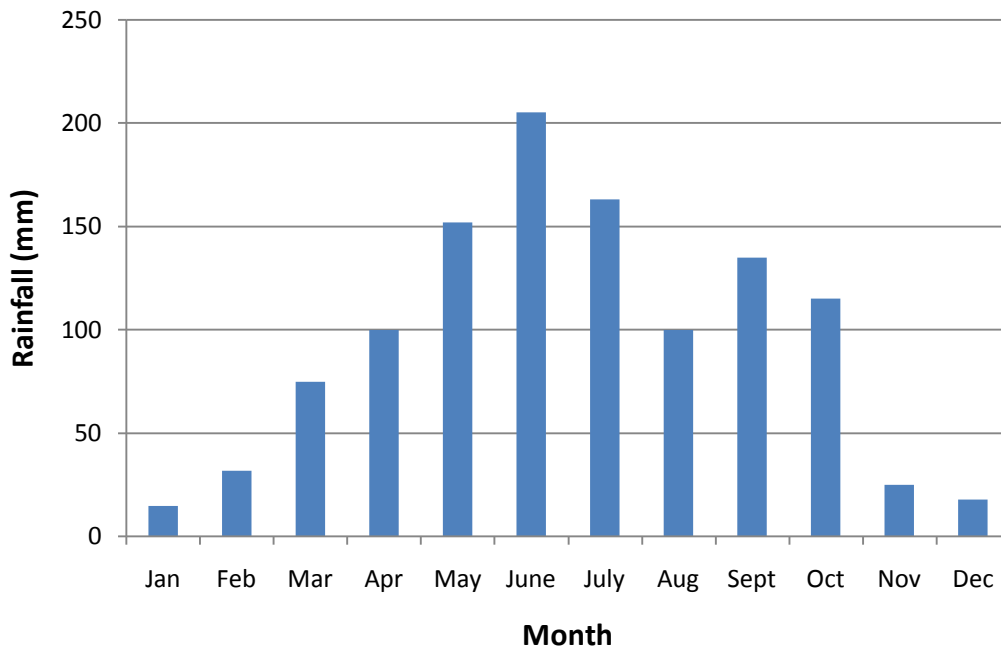


Fig. 7 : Mean monthly rainfall distribution pattern at Asesewa.

Assumption for computation of the volume of rainwater expected to harvest.

The following assumptions were made for the computation of the volume of water that can be harvested by buildings (roofs) currently available and the projected population that the rain harvested system can serve.

- Mean annual rainfall of 1.2 m;
- Rainfall available for harvesting is only 70 per cent of the mean annual precipitation since there are partial losses due to interception, evaporation etc.

- Daily per capita consumption of 25 litres;
- Duration of usage of 366 days;
- Average household size of 5 persons.

Using the criteria above the volume of rainwater likely to be harvested annually from metallic roofs, the average number of persons to be served by the expected harvested volume of water and the estimated average current population coverage of settlement within the various area councils have been computed and presented in Table 3.

Table 3 : Rain Water Potential of Selected Communities

Area Council	Average number of persons expected to be served by estimated volume of water.	Average estimate of current harvested population of the settlement
Anyaboni Bisa	464.26	379.75
Mensah Dawa	332.00	142.55
Sekesua	384.25	286.30
Konkoney Sisiamang	452.45	208.25
Ternguanya	655.20	357.70
Asesewa	204.11	284.20

The results indicate that the estimated annual harvested rainwater from approximately 43 major settlements within the Upper Manya district varies from 807.77 to 10,143.00 m³. The results also suggest that 76.8 % or thirty three (33) of the settlements could harvest water to suffice the inhabitants with water for their daily needs annually. The remaining twelve (12) communities or 23.2 % had few metallic roofed buildings. In these poor communities, funds used for the search for groundwater and the drilling of unproductive boreholes can be channelled into the provision of sheds or pavilions, which can be utilised dually as community centres, schools etc. on one hand and rain harvesting system on the other hand. With such basic infrastructure provision, enough volume of water can be obtained to provide for the needs of these settlements. Another solution would be to utilise raw water from the Volta Lake for their requirements.

Problems that may militate against rain harvesting in the Upper Manya Krobo district.

Most buildings in Upper Manya Krobo district were unsuitable for rainwater harvesting. Structural modification of buildings particularly attaching a gutter system will be necessary to make them suitable for rainwater harvesting. The cost of such modification will be beyond the financial means of most families living in the district. Additionally, some villagers living in houses roofed with straws would probably not have the means and resources to adopt such rainwater harvesting technique.

The next problem is how to store rainwater for dry season. Currently, in the communities visited, storing rainwater in vessels for later use will be practically impossible, for it will require a large number of containers. Various techniques of water storage are available but the most feasible option is to build large underground concrete tanks. Again, investment cost for storage system can be prohibitive for most households in the district. Pollution may also be a major problem in spite of the fact that rainwater in rural areas as the Upper Manya district remote from atmospheric and industrial pollution is practically clean except for some dissolved gases it may pick up while it precipitates through the atmosphere. Rainwater often contains

dissolvable atmospheric gases proportionate to their abundance. It also contains sediments, dust, bird droppings, aerosols, particulates, and anthropogenic gases that may result from biomass and fossil fuel burning. These are often the main sources of rainwater pollution. Since rainwater is not pure water, some precautions have to be observed before the water is consumed. Sediments removal and further water purification could be carried out by using slow sand filtration system with activated charcoal. Slow sand filter is low energy consuming process that has great adaptability in components and application; also, its maintenance requirement is minimal.

g) Underground dams

Underground dams (sand storage dam) construction is another option considered for the Upper Manya district. Underground dams can be constructed anywhere water resources are scarce and hydrogeological and geomorphological conditions are favourable (Onder and Yilmaz, 2005).

h) Criteria for underground dam site selection

The underground dam cannot be constructed just anywhere. The following appropriate conditions are necessary (dos Santos and Frangipani, 1978):

- An aquifer with high effective porosity, sufficient thickness and great areal extent;
- An impermeable bedrock layer under the aquifer;
- Sufficient groundwater inflow to the underground area;
- An underground valley where an underground barrier can be built.

i) Feasibility of Underground Dam construction in the Upper Manya District

The availability of numerous ephemeral springs and streams as well as the favourable geomorphology and geology satisfy the criteria for sand storage dam construction in the Upper Manya Krobo district. Therefore, in addition to rain harvesting system recommended for the Upper Manya district, construction of sand storage dam is also a feasible option for the district. However, there is the need to conduct more detailed hydrogeological and

bacteriological investigations to determine the conditions that exist underground, the type of microbes that may be available in the stored water, nutrient levels and the types of microbes that exist underground to purify the water.

V. CONCLUSIONS

The option for water supply augmentation include the provision of additional boreholes, rain harvesting and sand storage (underground) dam construction. In spite of the fact that, groundwater potential is generally low in the Upper Manya district, intensive groundwater exploration in some localities particularly in the southern half of the district where boreholes are relatively higher yielding than the north should result in adequate yield for existing water supply augmentation. Generally, the quality of groundwater encountered is physiologically safe for drinking purposes. The only perennial yielding spring (Ternguanya), could be protected for supply of water to nearby settlements.

The potential exists for harvesting clean rain water in substantial quantities to supplement water supply from current sources. However, existing metallic roofs need modification for rain harvesting. In communities with thatch buildings, rain harvesting schemes can be effective when installed on institutional and church buildings in the rural communities. Individual household schemes with ferro-cement tanks may also be considered for rural communities with no other option for water supply. This is because the size of storage system required for using harvested rainfall to meet the full demand of an average rural community may be too prohibitive and not cost-effective.

Detailed designs, especially of receptacles and storage facilities are required to plan for an effective programme to pursue this option; while educational programmes to reawaken the populace on the importance and benefits of harvesting rain water at the local level; is required.

The geology and geomorphology of this district are apparently suitable for under ground dam construction. However, more detailed hydrogeological investigations are required prior to construction.

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