Groundwater utilization in Ghana

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Abstract Ghana has over 56 000 groundwater abstraction systems comprising boreholes, hand-dug wells and dugouts. The yields of aquifers which these systems tap are generally low. Apart from the Keta basin, borehole yields hardly exceed 6 m$^3$ h$^{-1}$. Except for low pH (3.5-6.0), high iron values (1-64 mg l$^{-1}$) in a few cases and high salinity values (5000-14 584 mg l$^{-1}$) in some coastal aquifers, groundwater quality is generally considered good for domestic and agricultural purposes. Groundwater is mainly used for domestic purposes primarily for drinking. Indeed, it serves as the most cost effective potable water supply for some urban centres and most rural communities. On a smaller scale, groundwater is used for watering livestock in the upper and northern regions of Ghana and in the Accra Plains. The use of the groundwater for irrigation purposes is limited due to its low yield. However, in the southeastern part of Ghana, notably, the Anlo District of the Keta basin, shallow hand dug wells with depths not exceeding 5 m in the Recent sand are used to irrigate shallots and other vegetable farms. In the upper and northern regions, dug outs along alluvial channels are used for dry season vegetable farming. In the Accra Plains of Southern Ghana, a pilot project for carrying out dry season vegetable farming with borehole water is currently being carried out. Crop yields of 5 t ha$^{-1}$ and 3 t ha$^{-1}$ in the cases of cabbage and onions have been realized. These compare favourably with 2-5 t ha$^{-1}$ and 5-8 t ha$^{-1}$ for cabbage and onions grown in Ghana under similar agronomic practice but under more favourable climatic conditions and irrigation by river water. Recently, the interest has been shown in using groundwater for mineral and spring water production. A factory at Medie, near Accra in the southern part of Ghana has started its mineral water production using borehole with a yield of 778 m$^3$ day$^{-1}$.

INTRODUCTION

Ghana has ample surface water resources. However, these resources are unable to satisfy the water demand for socio-economic development everywhere in the country. Indeed there are only ten major perennial rivers notably the River Volta (the largest river), the Bia, Tano, Ankobra, Pra, Ochi-Nakwa, Amisa, Ayensu, Densu and Tordzie (Fig. 1). Some perennial springs also exist in the forested highland areas of the country, e.g. the Volta region has 143 inventoried perennial springs (WRRI, 1993b). Unlike the Volta region, the exact number in other regions is unknown since a national inventory has not been undertaken. Inspite of their number, these springs are either located in areas remote from settlements or have such low discharge rates that they could not
support large settlements. The rest of the surface water resources are ephemeral and collect into pools for about six months during the dry season. Furthermore, some of the main rivers especially those taking their sources from the mining areas are found to be contaminated with heavy metals. For example, River Ankobra is contaminated with arsenic and mercury (Osafo, 1989). In addition, these surface water bodies host many water-borne diseases such as bilharzia, typhoid, cholera, guinea worm, etc. and are therefore unsafe for domestic use unless treated.
Rainwater harvesting is another widely used technology for water storage and supply. Nevertheless, the rainfall pattern has become so erratic that the system cannot be relied upon.

The provision of groundwater has therefore become the most cost effective means of water supply for the scattered rural communities and some urban areas. This has led to the drilling of over 10,000 boreholes and over 45,000 hand-dug wells in the country.

Initially, groundwater was used mainly for domestic purposes especially for drinking. However, the need for increased agricultural production to feed ever growing population coupled with the erratic pattern of the rainfall has made the diversity of groundwater use a necessity. Other uses of groundwater include dry season irrigation, livestock watering, fish farming, poultry and cottage industries.

The purpose of this paper therefore is to give a general overview of groundwater use in Ghana.

HYDROGEOLOGICAL SETTING

Ghana can be divided into two main hydrogeologic provinces. These are the Basement Complex comprising the Precambrian crystalline igneous and metamorphic rocks and the Paleozoic consolidated sedimentary formations (Fig. 1). The Basement Complex which is subdivided into Birimian, granite, Dahomeyan, Togo and Tarkwaian rock formations consist mainly of gneiss, phyllites, schists, migmatites, granite-gneiss and quartzites.

The consolidated sedimentary formation which underlies the Volta basin consist mainly of sandstones, shale, arkose, mudstone, sandy and pebbly beds and limestones. The Basement Complex and the Voltaian formation cover 54% and 45% of the country respectively.

The Cenozoic and Mesozoic sediments form the remaining 1% of the rock cover. They consist of unconsolidated alluvial sediments, beach sand, red continental deposits of mainly alternating limonitic sand, sandy clay gravels, marine shale, limestone and glauconitic sandstone.

The rocks of the basement complex and the Voltaian formation have little or no primary porosity. Groundwater occurrence is thus associated with the development of secondary porosity as a result of jointing, shearing, fracturing and weathering. This has given rise to two main types of aquifers; the weathered zone aquifer and the fractured zone aquifers. The weathered zone aquifers usually occur at the base of the thick weathered layer. The weathered layer varies from 0 m (at outcrops) to about 100 m. It is thickest in the wet forested southwestern part of the country where it reaches an average thickness of 60 m and thinnest in the semi-arid zone in the extreme northeast where the mean thickness is 10 m. The fractured zone aquifers usually occur at some depth beneath the weathered zone. Both type of aquifer are normally discontinuous and limited in area. Due to the sandy clay nature of the weathered overburden, the groundwater occurs mostly under semi-confined or leaky conditions.

The Cenozoic and Mesozoic sediments occur mainly in the extreme south eastern and part of the country (Fig. 1). Three aquifers occur in this formation. The first aquifer is unconfined and occur in the Recent sand very close to the coast. It is between 2 m and 4 m deep and contain fresh meteoric water. The intermediate aquifer is either semi-confined or confined and occurs mainly in the Red Continental deposits of sandy clay
and gravels. The depth of this aquifer varies from 6 m to 120 m, and it contains mostly saline water. The third aquifer is the limestone aquifer. It varies in depth between 120 m and 300 m. The groundwater in this aquifer which occurs under artesian condition is fresh.

Recharge to all the aquifer systems is mainly by direct infiltration of precipitation through fracture and fault zones along the highland fronts and also through the sandy portions of the weathered zone. Some amount of recharge also occur through seepage from ephemeral stream channels during the rainy seasons.

GROUNDWATER ABSTRACTION AND DISTRIBUTION

Groundwater is abstracted from all geological formations in Ghana. There are over 56,000 abstracting systems made up of approximately 10,500 boreholes, 45,000 hand dug well and some dug out over the country. The regional distribution of borehole and the estimated annual abstraction of groundwater based on 12 h of pumping per day is given in Table 1.

Apart from the Volta region, where an inventory on hand dug wells had been undertaken by the Water Resources Research Institute of Ghana under the DANIDA sponsored Rural Drinking Water Supply and Sanitation Project in the Volta region, (WRRI, 1992), limited data exist on hand dug wells in the country. However, it appears the distribution of hand dug well follows the same pattern as boreholes. From the Volta region Inventory, it can be inferred that hand dug well yield varies from 0 (dry well) to 26 m$^3$ day$^{-1}$ with a mean of 6 m$^3$ day$^{-1}$. The total abstraction by hand dug well per year is thus estimated to be $1.1 \times 10^8$ m$^3$.

Table 1 Distribution of boreholes in the regions.

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of boreholes</th>
<th>Abstraction (m$^3$ a$^{-1}$)</th>
<th>Region</th>
<th>Number of boreholes</th>
<th>Abstraction (m$^3$ a$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper east</td>
<td>1680</td>
<td>$17.0 \times 10^6$</td>
<td>western</td>
<td>700</td>
<td>$6.8 \times 10^6$</td>
</tr>
<tr>
<td>Upper west</td>
<td>1350</td>
<td>$11.2 \times 10^6$</td>
<td>eastern</td>
<td>950</td>
<td>$22.1 \times 10^6$</td>
</tr>
<tr>
<td>Northern</td>
<td>1340</td>
<td>$21.0 \times 10^6$</td>
<td>central</td>
<td>925</td>
<td>$11.4 \times 10^6$</td>
</tr>
<tr>
<td>Brong-Ahafo</td>
<td>855</td>
<td>$13.0 \times 10^6$</td>
<td>Volta</td>
<td>1140</td>
<td>$22.4 \times 10^6$</td>
</tr>
<tr>
<td>Ashanti</td>
<td>1310</td>
<td>$13.1 \times 10^6$</td>
<td>Greater Accra</td>
<td>210</td>
<td>$2.5 \times 10^6$</td>
</tr>
</tbody>
</table>

GROUNDWATER QUALITY

The quality of groundwater is generally good for multipurpose use except for the presence of low pH (3.5-6.0) waters, high level of iron, manganese and fluoride in certain localities as well as high mineralization with TDS in the range 2000-14,584 mg l$^{-1}$ in some coastal aquifers particularly in the Accra Plains (Amuzu, 1978). Low pH waters are found mainly in the forest zones of southern Ghana.

About 30% of all boreholes in Ghana have iron problems (Ayibotele, 1985). High iron concentrations in the range 1-64 mg l$^{-1}$ have been observed in boreholes in all
Table 2 Chemical analysis of water samples in the geological formations of Ghana (all values except pH are in mg l\(^{-1}\)).

<table>
<thead>
<tr>
<th></th>
<th>Gneiss formations</th>
<th>Granitic formations</th>
<th>Phyllites</th>
<th>Sandstone and shale</th>
<th>Sand and gravel</th>
<th>Lime-stone</th>
<th>Quartzite</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.5</td>
<td>6.99</td>
<td>6.83</td>
<td>6.95</td>
<td>7.64</td>
<td>7.53</td>
<td>7.7</td>
</tr>
<tr>
<td>Total dissolved salts</td>
<td>4888</td>
<td>387.38</td>
<td>211.19</td>
<td>533.45</td>
<td>424.66</td>
<td>632.04</td>
<td>946.77</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>595</td>
<td>49.38</td>
<td>32.09</td>
<td>25.08</td>
<td>26.10</td>
<td>68.72</td>
<td>58.08</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>207.2</td>
<td>19.06</td>
<td>15.67</td>
<td>7.57</td>
<td>9.12</td>
<td>33.50</td>
<td>36.14</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>720</td>
<td>47.99</td>
<td>11.67</td>
<td>262.55</td>
<td>125.39</td>
<td>134.45</td>
<td>296.77</td>
</tr>
<tr>
<td>Chloride (Cl)</td>
<td>1790</td>
<td>73.48</td>
<td>9.90</td>
<td>70.42</td>
<td>42.04</td>
<td>173.56</td>
<td>196.86</td>
</tr>
<tr>
<td>Sulphate (SO(_4))</td>
<td>1800</td>
<td>10.60</td>
<td>7.16</td>
<td>65.17</td>
<td>11.18</td>
<td>101.19</td>
<td>77.25</td>
</tr>
<tr>
<td>Bicarbonate (CO(_3))</td>
<td>34</td>
<td>81.17</td>
<td>104.14</td>
<td>97.49</td>
<td>189.29</td>
<td>154.59</td>
<td>149.66</td>
</tr>
<tr>
<td>Total iron (Fe)</td>
<td>0.1</td>
<td>1.01</td>
<td>2.15</td>
<td>1.95</td>
<td>0.645</td>
<td>1.84</td>
<td>0.467</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>0.05</td>
<td>0.44</td>
<td>0.39</td>
<td>0.17</td>
<td>0.10</td>
<td>0.22</td>
<td>0.16</td>
</tr>
<tr>
<td>Fluoride (F)</td>
<td>0.25</td>
<td>0.35</td>
<td>0.315</td>
<td>0.775</td>
<td>0.57</td>
<td>0.60</td>
<td>1.76</td>
</tr>
<tr>
<td>Nitrate nitrogen (NO(_3))</td>
<td>0.5</td>
<td>1.605</td>
<td>0.59</td>
<td>0.75</td>
<td>0.135</td>
<td>2.22</td>
<td>1.79</td>
</tr>
<tr>
<td>Total hardness</td>
<td>2340</td>
<td>172.49</td>
<td>123.70</td>
<td>70.76</td>
<td>222.77</td>
<td>230.35</td>
<td>229.94</td>
</tr>
</tbody>
</table>

Iron originates partly from the attack of low pH waters on corrosive pump parts and partly from the aquifers. The percentage of Iron derived from the aquifers is however unknown (Asare & Boateng, 1992). High fluoride values in the range 1.5-5.0 mg l\(^{-1}\) on the other hand are found in boreholes located in the granitic formation of the upper east and west regions (Pelig-Ba, 1989). The mean values of chemical analyses of many water samples in the various geological formation in Ghana are presented in Table 2.

The waters in many hand dug wells look turbid and polluted as they contain high levels of nitrate in the range of (30-60) mg l\(^{-1}\) and abundant coliform (WRRI, 1992). This is probably due to improper construction and inadequate protection of the wells sites from surface runoff and animal droppings.

USES OF GROUNDWATER

In Ghana, the purpose of groundwater use is largely determined by the quantity of groundwater available, its quality and the unavailability of other alternatives.

Groundwater use for domestic and drinking purposes

Due to the low yield of boreholes and the relatively good quality of the groundwater compared to surface sources, boreholes in almost all regions with the exception of the
Greater Accra regions are exclusively used to supply water for drinking and other domestic purposes. The estimated total annual abstraction of groundwater for drinking and other domestic purposes by means of borehole is $1.38 \times 10^8$ m$^3$. In the Greater Accra region, the groundwater quality is poor due to high level of salinization of water in the gneiss which underlies most part of the region and there is a good coverage of pipe-borne water supply system. As a result, the use of borehole for drinking water supply is limited to only small farming communities.

Due to the high level of pollution of hand dug wells only about 50% of the total are used for drinking purposes while about 66% are used for both drinking and other domestic purposes. The estimated annual abstraction by hand dug wells for domestic purposes is therefore $7.3 \times 10^7$ m$^3$.

The total estimated groundwater abstracted for domestic purposes including drinking is $2.11 \times 10^8$ m$^3$ a$^{-1}$. This forms 84% of the total annual groundwater abstraction.

**Groundwater for irrigation**

The use of groundwater for irrigation is limited to mainly the southern Volta region, the upper regions and the Accra Plains.

In the southern Volta region, particularly in the Keta basin (Fig. 2), more than 60% of the shallow hand dug wells in the Recent sand are used solely for irrigation. These wells have depth ranging between 1 m and 5 m and are spaced less than 100 m apart. The abstraction rate of these wells vary in the range of 1.0-22.6 m$^3$ day$^{-1}$ with a mean of 2.7 m$^3$ day$^{-1}$ (WRRI, 1992). Low powered irrigation pumps are fitted on these wells to irrigate large hectares of shallots and other vegetable farms all the year round. Shallot is solely produced in this region and without the use of the shallow groundwater, its production would be limited.

In the upper regions of Ghana, groundwater is extracted by dug out from alluvial channels along the courses of ephemeral streams during the dry season. This water is used with the application of water cans and buckets to irrigate between 0.04 and 0.1 ha vegetable farms.

In the Accra Plains, about 70% of the boreholes are drilled for agricultural purposes and 33% of the number are used for irrigation (Kankam-Yeboah, 1987). Irrigation is limited to watering moderate to high salt tolerate vegetables such as cabbage, onion, tomatoes and carrot. Pilot Irrigation with Groundwater Project carried out by the Water Resources Research Institute has realized crop yields of 5 t ha$^{-1}$ and 3 t ha$^{-1}$ for cabbage and onion respectively. This compares well with 2-5 t ha$^{-1}$ and 5-8 t ha$^{-1}$ for cabbage and onion grown in Ghana under similar agronomic practices but under more favourable climatic conditions and irrigation by river water (Andah, 1993).

There is currently a plan underway to irrigate 60 ha of pineapple plantation with $5 \times 10^5$ m$^3$ a$^{-1}$ of groundwater. This amount of groundwater is to be abstracted from granitic formation using between 20 and 30 boreholes or large diameter wells using hydro-fracturing techniques (Zahn, 1993).

**Livestock and poultry watering**

This use of groundwater is restricted to the upper, northern and the Greater Accra regions. In the upper and northern regions, animals are not restricted but are allowed to
range in search of food and water. Watering troughs are constructed between 5 m to 10 m from the boreholes. Spillways are constructed from the drainage aprons of the borehole to the watering troughs. Spilled water from the boreholes collect in these troughs for use by livestock mainly goat, sheep, cattle and pigs. About 70% of Ghana’s livestock is produced in these regions and it is watered exclusively using groundwater.

In the Greater Accra region, the livestock are restricted to the farm premises. Mechanized wells are used to supply their water requirement. In addition to using groundwater for livestock, several large scale poultry farmers use groundwater for their operations.

**Fish farming**

The use of groundwater for fish farming has not been very extensive, however, trials on four farms in the Accra Plains have been very successful. In one particular case about 40 t of tilapia have been harvested annually from a single pond (Kankam-Yeboah, 1987).
Spring and mineral water production

Interest in spring and mineral water production is growing steadily. The assessment of the potential for spring and mineral water production in Ghana has been completed (WRRI, 1993a). The results show that the potential is high. The potential exists in the northeastern part of mid Volta region where numerous springs exist which can be protected for spring water production. Also the Keta basin of southern Volta region has very high potential for mineral water production. The limestone aquifer which has very good quality water and yields between 720 m$^3$ day$^{-1}$ and 960 m$^3$ day$^{-1}$ to a borehole can be utilized for this purpose.

In the Accra Plains, the potential exists mainly along the foothills to the northeast. Already a borehole at Medie within the Accra Plains is being used for the production of mineral water. The borehole yields 778 m$^3$ day$^{-1}$ of groundwater and its quality is good for drinking purposes by WHO Standard (WRRI, 1989). There are other areas which may have high potential but their potentials have not been assessed.

CONCLUSION

In Ghana, about 84% of the groundwater abstracted is used for domestic purposes, primarily drinking. On a smaller scale groundwater is used for agricultural purposes mainly for irrigation, livestock watering and poultry. The potential and interest in using groundwater for mineral and spring water production in Ghana is high.

REFERENCES


