EXAMINING THE POTENTIAL OF USING SPRING WATERS FOR DOMESTIC AND IRRIGATION FARMING ACTIVITIES: CASE STUDY OF LIWONDE, MALAWI.


* University of Malawi - Chancellor College, P.O Box 280 Zomba, Malawi.

* Corresponding author contact details: University of Malawi, Chemistry Department, P.O. Box 280, Zomba, Malawi. E-mail: russelchidya@gmail.com. +265 (0) 999 317 176; Fax: +265 (0) 1 524 046

ABSTRACT

Springs are an important source of water for various purposes including domestic, irrigation, recreation, and fishing. Liwonde is one the areas in Malawi that have both hot and cold spring water sources. However, no data is clearly established on the potential use, water quality, and management of these spring water resources. This study, therefore, intended to explore the potential of using springs for domestic and irrigation farming activities. Specifically, the study aimed at identifying sites that provide spring waters and assessing the socio-economic values and governance systems. Data was collected through observation, field visits and key informant interviews. Twelve hot and cold springs were identified in the area and water discharge was determined by use of bucket method. Water samples were collected for water quality parameter analyses including pH, EC, TDS, hardness, alkalinity, Na, Mg, Ca, and K. Water quality indices such as Sodium Adsorption Ratio (SAR), Magnesium Hazard Ratio (MHR), Residual Sodium Carbonate (RSC), and percent sodium (%Na) were determined. The study revealed that spring waters are substantially used for domestic purposes. Furthermore, commercial and small-scale farming activities were observed at some sites where crops such as vegetables, rice, and maize are grown. The results showed that several sites (>80%, n=12) were characterised by poor sanitation and management systems of the springs. Preliminary results on physico-chemical analyses revealed that several springs contain levels of SO$_4^{2-}$ (25.92-115.80 mg/L) Cl (19.52-191.36 mg/L) Mg (0.07-9.83 mg/L), Ca (1.69-24.34 mg/L), Na (129.50-189.83 mg/L), Cu (0.03-0.22 mg/L), and Mn (0.0-0.03 mg/L) below the World Health Organisation (WHO) limits, hence suitable for drinking. However, based on RSC (>2.83) and %Na (>87%), the some sites were deemed not suitable for irrigation use due to high levels of Na, CO$_3^{2-}$, and HCO$_3^-$.

The highest discharge obtained was 824.08 cm$^3$/s followed by 433.94 cm$^3$/s. The discharge of some springs were noted to decrease during dry season due to low aquifer recharge. However, the perennial outflow of water at several sites suggest a large capacity of the underground aquifer system that could be used for large-scale irrigation farming. The study has shown that the springs are poorly managed and underutilised. This calls for integrated approach in spring water use and management systems. Further studies are needed on hydrology and the aquifer systems of springs in the area.

Key words: Liwonde; Malawi; multiple use of spring waters; springs; water quality.

1.0 INTRODUCTION

1.1 Sources and management of water

Water is a finite natural resource and is essential for the well being of mankind and for sustainable development (GWP, 2010). The most important pools of water sources from human point of use are the surface and ground waters. Surface water comprises water that
flows across the land in the form of rivulets, springs, streams and rivers or it collects to form ponds, lakes and seas. In contrast, groundwater is located in aquifers underground and relates to surface water through percolation, wells, boreholes and springs. Boreholes as a low-cost technology option for domestic water supply are considered as ‘safe sources’ of drinking water. Similar to other developing nations, boreholes are the major and most preferred source of drinking water in Malawi. Despite the concerted efforts by national and international organisations to protect water resources, human health and aquatic life continue being at risk due to water quality problems. Various natural and anthropogenic factors, for example, contaminate groundwater because of deep percolation from intensively cultivated fields, disposal of hazardous wastes from industries, sewage disposal and surface impoundments (Kass et al., 2005; GWP, 2010).

Integrated Water Resources Management (IWRM) is a critical foundation for sustainable development, achievement of the MDGs and for balancing increasing demands on water resources. Water is at the centre of MDGs numbers 1, 3 and 7, and indirectly linked with the other MDGs. Malawi, with a population of about 13.2 million, registers water availability per capita of 1273 m³/a (NSO, 2008; GWP, 2010). The existence of rivers, Lake Malawi, Lake Chilwa and other smaller lakes provide fresh water resources. However, climate variability, poor agricultural practices, rapid population growth, inappropriate discharge of wastes, poor water use and management of catchment areas pose daunting challenges which could result in access to water resources being strained in the near future (GWP, 2010).

1.2 Characteristics and the role of spring waters

A spring is formed when the ground water, which is under pressure, flows out through a natural opening in the ground. The amount of water that flows from springs depends on many factors, including the size of the caverns within the rocks, the water pressure in the aquifer, the size of the spring basin, and the amount of rainfall. The quality of water discharged by springs can vary greatly because of factors such as the quality of the water that recharges the aquifer and the type of rocks. Springs provide base flow for many streams and rivers that are used for boating, recreation, fishing, swimming, scuba diving, and snorkeling. Springs provide water for public supply, irrigation farming, industrial, domestic, and thermoelectric power purposes (Spechler and Schiffer, 1995; WHO, 2008).

A study by UNEP and GPF showed that Malawi has several hot and cold springs. Further, earlier work conducted in Liwonde revealed that the area has both hot and cold springs. However, there is no established data on the exact location and capacity of these springs. No attempt has been made to assess the socio-economic use, management and governance systems of the springs. There is also a need to determine the physico-chemical characteristics of the spring waters and their implications for domestic and irrigation use.

1.3 Aim and specific objectives of the study

This study intended to identify and explore the potential of using cold and hot spring waters for domestic and irrigation farming activities. Specifically, this research study intended to:

a) To assess the socio-economic use and governance systems of spring water resources.

b) To study the physico-chemical characteristics of spring water resources and their implications for domestic and irrigation use.

c) To examine the water discharge and capacity of springs to support large-scale domestic and irrigational farming activities.

2.0 MATERIALS AND METHODS

2.1 Description of the study area - Liwonde
The study area is situated in Southern Malawi between latitude 15° 02 – 15° 07’ S and longitude 35° 10’ – 35° 15’ E. It lies at an elevation of 470 – 531 m above the sea level. The area (Liwonde) experiences a tropical climate, and receives a relatively low rainfall (mm/a). It is one of the hottest areas in Malawi with mean maximum temperature of 39 °C. The area under study lies in the Shire river plain and is partly surrounded by mountains (Sajidu et al., 2007). The geology of this area is varied with its basement complex composed of metamorphic rocks and charnockitic granulalities of Precambrian origin.

2.2 Water sample and socio-economic data collection

Several hot and cold springs (12) were identified in the study area and these sites were denoted. These springs were connected to a borehole except at SW6, SW10, SW11 and SW12. Water samples from the identified sites (Table 1) were collected in triplicate using 1 L cleaned plastic bottles. The samples were transported and preserved in accordance with standard methods (APHA, 1998; WII, 2008). Field visits, observations, key informant interviews and literature review were employed to investigate the socio-economic activities making use of springs in the study area.

<table>
<thead>
<tr>
<th>Sampling site</th>
<th>GPS location</th>
<th>Site description</th>
</tr>
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<tbody>
<tr>
<td>SW1</td>
<td>0740204 8333590</td>
<td>Spring connected to a borehole (in Kaudzu Vge) near Liwonde railway line station</td>
</tr>
<tr>
<td>SW2</td>
<td>0741295 8331905</td>
<td>Spring connected to a borehole (in Kalonjere Vge) near Liwonde plots</td>
</tr>
<tr>
<td>SW3</td>
<td>0740810 8331811</td>
<td>Spring connected to a borehole in Kalonjere Vge, at Liwonde plots near mosque</td>
</tr>
<tr>
<td>SW4</td>
<td>0740449 8331865</td>
<td>Spring connected to a borehole (Kalonjere Vge - at Liwonde LEA School)</td>
</tr>
<tr>
<td>SW5</td>
<td>0740023 8328851</td>
<td>Spring connected to a borehole in Malindima Vge across Mtubwí School</td>
</tr>
<tr>
<td>SW6</td>
<td>0740362 8329046</td>
<td>Hot spring in Mlwo Vge surrounded by field gardens</td>
</tr>
<tr>
<td>SW7</td>
<td>0741344 8328302</td>
<td>Spring connected to a borehole in Mlwo vge</td>
</tr>
<tr>
<td>SW8</td>
<td>0740444 8328526</td>
<td>Spring connected to a borehole at Mtubwí School in Malindima Vge</td>
</tr>
<tr>
<td>SW9</td>
<td>0740510 8327831</td>
<td>Spring connected to a borehole in Mlwo Vge near the tarnecked road to Zomba</td>
</tr>
<tr>
<td>SW10</td>
<td>0737989 8332984</td>
<td>Hot spring A near Shire river and railway line bridge</td>
</tr>
<tr>
<td>SW11</td>
<td>0737977 8332970</td>
<td>Hot spring B near Shire river and railway line bridge</td>
</tr>
<tr>
<td>SW12</td>
<td>0737972 8332827</td>
<td>Hot spring C near Shire river and railway line bridge</td>
</tr>
</tbody>
</table>

SW: spring water sampling, LEA: Local Education Authority Vge: village. E: easting. N: northing

2.3 Physico-chemical analyses and discharge measurement

A field pH meter (EUTECH Instruments, Malaysia) was used to measure pH, whilst water temperature, electrical conductivity (EC) and total dissolved solids (TDS) were measured using field meter (No. 59, MARTINI instruments, USA). Turbidity was measured using a potable turbidimeter (DRT-15CE, HF Scientific, USA). Both pH, EC, TDS and turbidity were measured on site. Total hardness (due to Ca<sup>2+</sup> and Mg<sup>2+</sup> ions), CO<sub>3</sub><sup>2-</sup>, and HCO<sub>3</sub> were measured in the laboratory by titrimetric method. Ion-Selective Electrode (ISE) method was used to measure Cl<sup>-</sup> ions (APHA, 1998). SO<sub>4</sub><sup>2-</sup> and PO<sub>4</sub><sup>3-</sup> ions were determined by turbidimetric and method with the aid of a UV/Vis spectrophotometer (model no. 6405, England). An Atomic Emission Spectrometer (Agilent 4100 MP-AES, USA) was used to measure Na, K, Ca, Mg, Cd, Cu, Zn and Mn. Discharge of springs flowing through boreholes was determined by use of volumetric method with a bucket at an average height of 70 cm.

2.4 Irrigational water quality indices:

Sodium Adsorption Ratio (SAR), percent sodium (%Na), Magnesium Hazard ratio (MHR), Residual Sodium Carbonate (RSC), and Sodium adsorption Ratio (SAR) used to classify irrigation water were computed using the following equations (Bauder et al., 2008):

\[
\text{Na\%} = \frac{(\text{Na}^+ + \text{K}^+) \times 100}{(\text{Ca}^{2+} + \text{Mg}^{2+} + \text{Na}^+ + \text{K}^+)} \quad [1]
\]

\[
\text{MHR} = \frac{\text{Mg}^{2+}}{(\text{Ca}^{2+} + \text{Mg}^{2+}) \times 100} \quad [2]
\]
\[
RSC = \left(\text{CO}_3^{2-} + \text{HCO}_3^-\right) - \left(\text{Ca}^{2+} + \text{Mg}^{2+}\right)
\] [3]
\[
\text{SAR} = \sqrt{\frac{Na^+}{\frac{1}{2}(\text{Ca}^{2+} + \text{Mg}^{2+})}}
\] [4]

2.5 Statistical analysis

The social-economic data was evaluated by repeated reading and content analysis. Data obtained on water quality and discharge were entered into Microsoft Excel (Windows 2007) worksheets to compute means, and standard deviations. Pearson Correlation Coefficient (two-tailed at 95%) was employed to detect relationships for the test parameters.

3.0 RESULTS AND DISCUSSION

3.1 The socio-economic activities and spring water management

Twelve cold and hot springs were identified in the study area and most of them (75%, n=12) were associated with boreholes. Preliminary results revealed that spring waters are fairly used for domestic purposes such as washing, bathing, cooking and drinking. Furthermore, small-scale subsistence and commercial farming activities were observed at some sites where crops such as vegetables, rice, and maize are grown. At some sites the spring waters are used for moulding of bricks, watering of nursery beds, and fishing pond. However, the major problems observed include poor sanitation and management of the springs. This calls for integrated approach in spring water usage and management. Further studies are needed on the aquifer systems and construction of water pipeline and reservoirs.

3.2 The physico-chemical characteristics of the springs

The physico-chemical and discharge data of the investigated spring waters are summarized in Tables 2 and 3. The results have shown that the spring water are slightly basic with a pH range of 7.7 – 9.1. Most sites (67%, n=12) registered pH values above the WHO (2008) standard limit in drinking water. The spring waters are slightly alkaline due to high levels of carbonates (CO\(_3^{2-}\)) and bicarbonates (HCO\(_3^-\)). Both EC and TDS values were within the WHO and MBS (2005) limits in drinking water (Table 2). However, springs near Shire river showed slightly high EC and TDS, depicting high ionisation and dissolution of minerals. Water temperature values at sites SW6 (38 °C), SW8 (30.3 °C), SW10 (39.7 °C), SW11 (41.3 °C) and SW12 (40.3 °C) showed that they are hot springs, influenced by geothermal effects originating from deeper parts. All sites except SW11 and SW12 registered turbidity values below the WHO (2008) limit of ≤5.0 NTU, hence suitable for domestic use. High turbidity levels at SW11 and SW12 were attributed to washing and bathing activities.

The highest water discharge (824.08 cm\(^3\)/s) was obtained at SW3, a site serving >500 households. Interviews with key informants showed that the discharge of some springs decrease during dry season due to low aquifer recharge. However, the perennial spring outflow at several sites suggest large capacity of the underground aquifer system that could be used for large-scale irrigation farming and domestic activities. Based on WHO (2008) hardness classification, all samples registered ‘soft class’ (0-70 mg/L CaCO\(_3\)) (Table 3). The SO\(_4^{2-}\), Cl\(^-\), Mg, Ca, Na, Cu, and Mn registered values below WHO (2008) limits at all sites, hence the water generally considered safe for domestic use. However, due to presence of Cd and relatively high levels of Na at some sites there is a need for further water quality studies to justify this claim. Results on the suitability of water for irrigation showed that the springs fall under different classes. Based on SAR, sites SW1 to SW4 fell under excellent ‘S1 class’ (0-10) whilst the other sites registered ‘good’ (SAR 10-18), doubtful (SAR 18-26) and ‘unsuitable classes’ (SAR>26). However, based on RSC and %Na classifications by Bauder et al., (2008) all the sites were unsuitable for irrigation due to elevated levels of CO\(_3^{2-}\), HCO\(_3^-\) and Na\(^+\) ions that tend to affect irrigable soil properties.
4.0 CONCLUSION AND RECOMMENDATIONS

This study has shown that springs in the study area have both socio-economic value and capacity to support large-scale farming and domestic use for human development. However, the major challenges faced include poor sanitation, governance and management systems of the springs. Further, physico-chemical analyses indicated that some springs are of poor quality. This calls for integrated approach aimed at sustainable use and management of the springs. Further studies are needed on hydrology and aquifer systems of area.

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REFERENCES


