Hydrogeochemical distribution and characteristics of groundwater in Weligama area – in Southern Sri Lanka

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\textbf{ABSTRACT}

Groundwater table behavior and physico-chemical properties of the aquifer system in Weligama bay area were studied selecting 43 dug wells distributed over an approximately 15 km\textsuperscript{2} area. Weligama is located in 80\textdegree 22’ Lat and, 5\textdegree 97’ long; main river basin of the area is Polwattumodara Ganga. Continuous monitoring conducted from May to November 2005 pertaining to groundwater levels, Electrical conductivity, total dissolved solids and salinity helped to prepare hydrogeological map and hydrogeochemical map of the area using the GIS package MAPINFOW. Most of the dug wells distributed in the area are shallow and 3-5 m in depth and 0.5- 1.5 m diameter. According to results of the chemical analysis in groundwater prepared major cations of Na\textsuperscript{+}, K\textsuperscript{+}, Mg\textsuperscript{2+} and Ca\textsuperscript{2+} distribution maps in the shallow groundwater. The maps clearly indicate that distribution of the major cations in the groundwater is associated with aquifer characteristics. The Mg\textsuperscript{2+}: Ca\textsuperscript{2+} ratio of the groundwater in between 0.5-0.7 in the coastal line where available calcareous sandstone, the ratio between 0.7- 0.9 in the western region where groundwater available in the hard rock and rest of the region ration more than 0.9 where groundwater available in the alluvium aquifer.

\textbf{Key Words :}

\textbf{INTRODUCTION}

According to the world water budget 97.2\% of water in the hydrosphere is brackish in oceans, and almost 2.15\% of the left out is tied up as north and south glaciers, leaving relatively little portion as fresh water sources located in surface or subsurface reservoirs. Groundwater resource is the largest reservoir of usable water recourse available in the hydrological cycle,
which consists only 0.9% of the fresh water reserve.

Even rainwater on arrival dissolves chemicals of various kinds, particularly in industrialized areas with substantial air pollution. Once atmospheric precipitation reaches the ground, it reacts with soil, rock, and organic debris, dissolving more chemicals naturally, leaving aside the pollutants generated by human activities. Streams, rivers, lakes have historically been used as disposal sites for untreated wastewater and sewage, which makes the surface waters unsuitable for drinking purposes without proper cleaning.

Rocks and soils through which groundwater passes provide a natural filter for the removal of many undesirable contaminants and can be of great benefit in water purification. Indeed, the development of groundwater for drinking water supplies over the past few decades has been instrumental in decreasing the incidence of serious water borne diarrhoea diseases in developing countries and as a result major benefit in improving public health is achieved. Nevertheless the quality of groundwater cannot always be guaranteed due to geo chemical reactions in the host aquifers can lead to the natural build up of trace elements derived from the rocks and soils which can be harmful if presents in sufficiently high quantities.

Groundwater quality may be described in different ways but one of the most important aspects is the assessment of natural groundwater quality with the balance of ions. Therefore the groundwater monitoring and quality assessment are important aspects for its utilization for human consumption.

The objectives of the present study are to identify the hydrogeochemical distribution in the shallow groundwater aquifer in Weligama bay area, Southern Sri Lanka. Dissolved chemicals in shallow groundwater and understand their distribution pattern along with the geological information that may be applied to the analysis of water-quality characteristics of surface and shallow groundwater:

**Area of Investigation**

**Topography**

The Weligama area is located in 80° 22' latitude, and 5° 97' longitudes, in the southern coastal belt of Sri Lanka (Figure 1). The southern part of the study area forms extremely flat coastal plain but south western coastal region is slightly high, reaching a maximum elevation of about 10 m above mean sea level. Generally, mean sea level of the central region of the area is between 1 to 5 m. Main river basin of the area is River Polwathumodara
Ganga. It flows through the division with a meandering, of about 160ha land extent. Delta of the Polwathumodara ganga is very large and tidal sea water can easily be intruded through the river. During the Tsunami disaster sea water wave flowed more than 2 km upstream through the Polwathumodara ganga.

Figure 1. Study area in Weligama

Weligama town is the largest urban city in the study area, which is located 146km away from Colombo and it’s in southern margin of Indian Ocean. This area falls within the WL4 agro ecological region which is defined as an area where 75% expectancy of the annual rainfall exceeding 2400 mm. Annual rainfall of the area is between 1875 mm-2500 mm. In Annual mean temperature of the area is 25°C and relative humidity is 75%-80%. Rains come mainly from southwest monsoon and an as inter monsoon rains during the intermonsoon periods. According to the topography the area is a flat low land near the coastal zone and maximum elevation of the area around 25m from MSL.

A part of the population in Weligama urban council area and suburb meets their drinking water needs through the main water distribution system from Hallala (National water Supply and Drainage Board), but most of the households use shallow groundwater from open dug wells for drinking and domestic activities.
Geology and Hydrogeology of the area

Dominant rocks of the Weligama area are Precambrian metamorphic hardrock covered by Quaternary sedimentary deposits. Basement consists with Precambrian rocks of the highland complex and consists of granite sills with-biotite gneiss. Topsoil of the area mainly consists of sandy clay. The top unconfined alluvium aquifer is distributed in the river basin area and in the coastal line. Water bearing sand in top of the section is more often fine and lower section usually has coarse sand with small portion of gravel. In general, the aquifer consists of calcareous sand and along the river basin aquifer consists of sandstone. Recharge of the aquifer takes place mainly from precipitation in northern region of the catchments area. The top quaternary sandy aquifer and the surface soils of the coastal margin of Weligama bay area is very permeable. Here, the hydro geological conditions are very favorable for salt-water intrusion. Therefore, along the coastal belt, alluvial and coastal sand deposits dominate and form higher-yielding local aquifer systems.

MATERIALS AND METHODS

For the study, control-monitoring network of 43 dug wells distributed in Weligama Pradesiya Shaba division is selected. Locations of the dug wells were identified with a GPS. Continuous monitoring of the water levels in the dug wells was conducted and the water quality with respect to Electrical Conductivity (EC), Total Dissolved Solids (TDS) and salinity were measured using portable EC/pH meters at three to four week intervals. In order to identify hydrogeological features in the unconfined sandy/ sandstone aquifer the water levels of the monitoring dug wells were measured. GIS package MAPINFO was used to plot the hydrogeological and hydrogeochemical maps.

Fig. 2 : Groundwater Monitoring network map in Weligama
Sampling procedure: 25 wells were selected for water sampling from the network of 43 dug wells. 200ml of settled unfiltered water samples was collected for the determination of major cations. Atomic Absorption Spectrometer was used to determine $\text{Ca}^2+$, $\text{Mg}^2+$, $\text{Na}^+$, $\text{K}^+$ ions.

Classification of water bearing formation according to the chemical analysis

For water flowing through Calcareous formations the $\text{Mg}^2+/\text{Ca}^2+$ ratio is normally in the range between 0.5-0.7. The range 0.7-0.9 is commonly associated with groundwater available in the hard rocks (Table 1). Ratios exceeding 0.9 are sometimes found in fresh groundwater from Sandy alluvium formations. More often they indicate the admixture of sea water or brine. In brackish waters an increase of this ratio along the flow path may be caused by the precipitation of calcium carbonate or calcium sulfate, under high concentration of Ca ions.

<table>
<thead>
<tr>
<th>Ratio or order</th>
<th>Range</th>
<th>Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Mg}^2+/\text{Ca}^2+$</td>
<td>0.5-0.7</td>
<td>Calcareous formations</td>
</tr>
<tr>
<td></td>
<td>0.7-0.9</td>
<td>Hard rock</td>
</tr>
<tr>
<td></td>
<td>&gt; 0.9</td>
<td>Alluvium</td>
</tr>
<tr>
<td>$\text{Na}^+/\text{K}^+$</td>
<td>Around 47</td>
<td>Sea water</td>
</tr>
<tr>
<td></td>
<td>&lt; 10</td>
<td>Fresh water</td>
</tr>
<tr>
<td>$\text{Ca}^2+ &gt; \text{Mg}^2+ &gt; \text{Na}^+$</td>
<td>carbonate water</td>
<td></td>
</tr>
<tr>
<td>$\text{Na}^+ &gt; \text{Mg}^2+ &gt; \text{Ca}^2+$</td>
<td>Chloridic water</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 Groundwater Identification based on the ionic compositions. (Mandel, 1981)

RESULTS AND DISCUSSION

Well characteristics

Most of the monitoring dug wells distributed in the area are shallow and are in the range of 1-7 meter in depth. However, more than 50% of the total depths of the dug wells are in the range of 3-4 meters. Wells which are sandwiched in between the coastal line and Polwathumodera ganga are very shallow and they are in range of 1-3 m in depth. The diameter of most of the wells are in the range of 1-1.5 meter.
Hydrogeological characteristics

Groundwater level near the coastal area lies closer to the ground surface and in between 0-0.99m (Figure 3). Groundwater level has been slightly increased in north-eastern and north-western regions. Recharge areas of the study area are north-eastern and North-Western region and discharge area indicate in the costal area. Hydraulic gradient of the groundwater in central and western section of the study area is changing from 0.002-0.0007. But hydraulic gradient of the western area is higher than central region. Due to low hydraulic gradient in the central region groundwater flow from land side is low and sea water intrusion easily forced in to the aquifer and equilibrium can damage very easily. According to the hydro isograph, discharge area of the study area lies with the the Pollathomodara ganga.

According to the data received during the period total dissolved solids levels are not changing in the study area. In coastal areas, TDS values are high due to intrusion of sea water with the tsunami wave (Figure 4). Here, a very favorable sandy fresh water aquifer lens was available and it’s now converted to be saline due to the tsunami waves. Availability of fresh water in this aquifer system depends on the thickness and the hydrogeological characteristics of the aquifer.

Hydrogeological, geological, morphological, and climatic information and chemical analyses helped to reconstruct the path of geochemical distribution in shallow groundwater. Sequence of processes through which water acquired its chemical composition was evident and this process is to be interpreted with reference to geohydrological and hydrogeological data.

Fig. 3: Groundwater contour map in May to October 2005

![Groundwater contour map](image1.png)

Fig. 4: Total Dissolved solid distribution in groundwater in October 2005

![TDS distribution](image2.png)
Ca concentration in the groundwater

A calcium concentration in the groundwater is high in Weligama area (Figure 5). Along the coastal region and in the river basin area, unconfined aquifer consists with calcite sand stone which is very permeable. Observations of the dug wells constructed in the area According to the hydrogeological characteristics of the region main discharge area is associated with the Polwathumodara ganga region, due to which Ca dissolves in the groundwater and contribute to the aquifer Mg concentration in central region of the area indicates high values (Figure 6). Mg values are high in the river basin area due to availability of calcite sand stone. But in western region the Mg concentration indicates low values compare to the central region, where metamorphic hard rock is dominant.

Fig. 5: Ca distribution in groundwater

Potassium normally occurs in very low concentrations in well water (Figure 7). If water contains high levels of potassium, it may be due to the contribution from fertilizer, detergent, or from other contaminant. In the central part of the area K levels are much higher compared to other parts of the study area. Excessive evaporation and probable influence of salinity may have contributed to high levels of K. High Potassium concentration observed in the north and north eastern regions is associated with the intense agricultural activities and usage of high dozes of fertilizer and pesticides.
In North Eastern and South region of the area Na+ concentrations are much higher (Figure 8). In the surrounding coastal area Na concentration is higher and exceeds 2 mg/l. According to the analysis, the Na concentration is low generally throughout the Weligama area.

**Groundwater bearing formations according to the chemical analysis**

Distribution of Groundwater bearing formations map of the area according to the cation ratios is given in Figure 9. In Weligama area top unconfined aquifer mainly consists with alluvium sandy formation and calculated $\text{Mg}^{2+}/\text{Ca}^{2+}$ is more than 0.9. (Figure 9).
Along the coastal area and through Polwattumodera ganga river basin consists of calcarceous sand stone, where Mg/Ca ratio varies in the range of 0.5 - 0.7. The field observations conducted in central and western regions helped to demarcate the sandy soil embedded on the hard rock. Due to which concentration of Mg\(^{2+}\)/ Ca\(^{2+}\) is low and water bearing formation can be identified as a hard rock. (Figure 9).

CONCLUSIONS

1) Groundwater discharge area in the study area is Polwattumodera ganga and coastal line. Recharge is low value due to low hydraulic gradient.

2) Calcium concentration is high due to calcarceous unconfined aquifer and Mg\(^{2+}\)/ Ca\(^{2+}\) is 0.5 to 0.7.

3) There exist two groundwater bearing formations in the Polwattumodara basin Ganga and in the eastern and western part of the Weligama bay which could be classified as:
   i. Unconsolidated alluvium groundwater bearing formation where Mg2+/Ca2+ ratio is more than 0.9.
   ii. Consolidated crystalline hard rock aquifer

4) In the coastal area due to high concentration of Ca calcarceous aquifer is formed. The effect of salinity and the presence of carbonate rock in the areas could possibly contribute to such formation.

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REFERENCES