CHAPTER III
MATERIALS AND METHODS

3.1 SEA WATER INTRUSION ALONG COASTAL AQUIFERS

In coastal areas, saline water is the most common pollutant of the fresh groundwater aquifer. When coastal aquifers come in contact with the ocean, fresh water is discharged into the ocean. Sometimes this seaward flow of ground water decreases or even gets reversed due to the increased extraction of fresh groundwater. Thus the sea water enters into the aquifers. This phenomenon is called ‘sea water intrusion’ or ‘saline intrusion’ and occurs due to the density differences between seawater and freshwater. The saline intrusion can be classified into two groups according to the nature of occurrence. They are the saline intrusion of surface water such as that through the estuarine rivers and salinity intrusion into coastal aquifers. The present study deals with the salinity intrusion into the coastal aquifers.

Salt water intrusion into the confined and unconfined aquifers along the coastal belts of Indian territory is being increasingly reported (Cheng and Alexander 2003). The problem is particularly severe in the coastal belts of Tamil Nadu, Gujarat and Kerala. Due to the ever increasing demand for potable water by the increased population and industrial activities, the limited groundwater resources of this sensitive coastal zones are being more extensively utilized now a days, compared to the past few decades. In many places this has resulted in the gradual lowering of water table causing further sea water intrusion to the inland.

The coastal region of Kerala comprises about 10% of the total land surface of the state of Kerala, but supports 25% of its total population. This unusual population pressure with in the narrow long stretch of coastal alluvium imposes severe stress on per capita water availability of suitable quality and quantity (Nazimuddin et al. 2008). The major portion of groundwater along the coastal belt of Central Kerala is being tapped from the top unconfined sandy aquifer whose thickness varies from 3 to 27 m. Groundwater is mainly extracted from these aquifers through large number of existing open dug wells, filter wells and ponds (Basak and Nazimuddin 1986).

3.2 GHYBEN – HERZBERG PRINCIPLE

Seawater intrusion into coastal aquifers occurs when permeable formations outcrop into a body of seawater and when there is a landward hydraulic gradient. Seawater intrusion can be prevented by maintaining a head of fresh water above it. According to Ghyben – Herzberg principle the
interface will occur at a depth $h_s$ below the mean sea level (MSL) and is given by the equation

$$(h_s + h_f) \rho_f = h_s \rho_s$$

Once the pressure at the point of interface may be equal and

$$h_s = \rho_f / (\rho_s - \rho_f) h_f$$

Where $h_s$ - depth below where the interface occurs

$h_f$ - elevation of the groundwater table above the MSL

$\rho_f$ - specific weight of freshwater

$\rho_s$ - specific weight of seawater

taking the specific gravity of freshwater as 1 and that of seawater as 1.025 $h_s = 40 h_f$

That is, for a rise or fall of ground water table or piezometric head by 1 m will induce a fall or rise respectively of 40 m in the underlying salt water level, even though the response may be greatly delayed (Raghunath, 1987)

### 3.3 SALINITY

Salinity can be technically defined as the total mass in grams of all dissolved substance per kilogram of water, with all carbonate converted to oxide, all bromide and iodine replaced by chlorine, and all

<table>
<thead>
<tr>
<th>CATEGORY OF WATER</th>
<th>SALINITY (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh water</td>
<td>0.5</td>
</tr>
<tr>
<td>Brackish water – Oligohaline</td>
<td>0.5 – 3.0</td>
</tr>
<tr>
<td>Mesohaline – Meiomesohaline</td>
<td>3.0 – 8.0</td>
</tr>
<tr>
<td>Mesohaline-Pleioceansohaline</td>
<td>8.0 – 16.5</td>
</tr>
<tr>
<td>Polyhaline</td>
<td>16.5 – 30.0</td>
</tr>
<tr>
<td>Marine water</td>
<td>30.0</td>
</tr>
</tbody>
</table>
organic matter oxidized at 48°C (Sam F Atkinson et al. 1986).

Salinity is related to the mineral content or the dissolved solids contained in water. Water has been classified according to their dissolved solid content for various uses. Grading of water with respect to the salt concentration is given in the table 3.1 (Ramakrishnaiah et al. 2009). The classification of water based on salinity (Summers and Schwab 1970) is given in table 3.2

### Table 3.2: Grading of Water with Respect to Salt Concentration

<table>
<thead>
<tr>
<th>Classification</th>
<th>Salt Concentration (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>175</td>
</tr>
<tr>
<td>Good</td>
<td>175 – 525</td>
</tr>
<tr>
<td>Permissible</td>
<td>525 – 1400</td>
</tr>
<tr>
<td>Doubtful</td>
<td>1400 – 2100</td>
</tr>
<tr>
<td>Injurious</td>
<td>&gt;2100</td>
</tr>
</tbody>
</table>

### 3.4 Origin of the Research Problem

Situated at the southern part of the west coast of India, Kerala coastal tract is facing the serious problem of migration of salt water into the fresh water coastal aquifers. When coastal aquifers come into contact with the ocean, under natural conditions, fresh water is discharged into the sea. This submarine ground water discharge is an important part of the hydrological cycle. However, when reversal of the hydraulic gradient take place intrusion of saline water into the fresh water aquifers begins.

The increased demand for the fresh groundwater in coastal areas leads to a decrease in the seaward ground water flow which is necessary to maintain the balance between freshwater - seawater interface at safer depth. If the seaward flow is reduced, the interface moves inwards, that results in the contamination of the coastal freshwater aquifer system. This exerts a disastrous and almost irreversible impact on fresh water coastal aquifers, if the same is not managed timely and judiciously.

Large scale consumption of groundwater for agriculture, industry and domestic purpose together with intermittent monsoon failure and absence of storage reservoirs has often resulted in the reduction of recharge rate. The immediate result is the saline intrusion into the freshwater coastal aquifers. In addition to the anthropogenic activities, the potable water resources are being further deteriorated by seawater intrusion in to the fresh water especially during summer days. Under these circumstances a detailed investigation and evaluation of the coastal aquifer conditions of ‘Central Coastal Tract’ of Kerala during pre monsoon, monsoon and post monsoon periods is of much significance.

### 3.5 Scope and Relevance of the Study

Coastal areas are ecologically dynamic zones of great biological diversity, rich resource potential and high vulnerability towards degradation. These delicate ecosystems are badly affected by shoreline changes, pollution
and stress due to over population. The increased demand of fresh water for various purposes and changes in land use pattern leads to detrimental impact on the water quality of the region. Events like tsunami, sea erosion and hurricanes also adversely affect the fresh water aquifer. Deterioration in water quality will lead to many environmental problems ranging from human health hazards to agricultural hazards affecting the coastal environment. Thus study of saline intrusion and monitoring of water quality variation of this delicate segment, extending from Azhikkode of Thrissur district to Ponnani of Malappuram district of Central Kerala, South India is of much significance. The central Kerala coastal region is one of the fast developing region, which is environmentally very sensitive also. Extensive coastal land is being reclaimed for habitation and industries. Against this background, a detailed study is undertaken to understand the status of the aquifer.

The study area is located between North latitudes 10° 10’ 49” and 10° 46’ 53” and East longitudes 75° 54’ 06” and 76° 09’ 12”. Physiographically the area falls under the category of low lands or coastal plains. Survey of India topographical maps, No. S 49.N/13, 49.N/14, 58.B/2, 58.B/3, 58.B/4 (1:50,000) are used for the present study.

Several important pilgrim centers and centers of tourist attraction are located with in or adjacent the study area. The Mar Thoma shrine (10° 10’ 57” North latitude, 76° 10’ 02” East longitude) at Azhikode is an important holy place of the christian community. It is believed that at this place Saint Thomas, the disciple of Jesus Christ deported in India during AD 52. Another important muslim pilgrimage centre is the great historic Cheraman Musjid (10° 11’ 28” North latitude, 76° 10’ 42” East longitude). This is the first muslim church in India constructed during AD 652. The nearby Kodungallur Devi Temple (10° 11’ 42” North latitude, 76° 10’ 48” East longitude) is also famous for its ‘Bharani’ festival and find a place in history and described by ancient books of Sangha Kala is a very sacred place for Hindu community.

The world famous Sri Rama Temple (10° 25’ 49” North latitude, 76° 05’ 43” East longitude) of Triprayar is another Hindu pilgrimage centre, lying very close to the study area at Nattika. During the Malayalam month Karkkidakom thousands of devotees reaches here for ‘Nalambala Dharsam’, the famous pilgrimage tour. Another world famous Hindu pilgrimage centre is the Guruvayoor Temple (10° 30’ 27” North latitude, 76° 02’ 24” East longitude) which also lies very close to the study area at Chavakkad. This place is visited by large number of devotees during the entire seasons round the year. The Chavakkad Juma Musjid (10° 29’ 55” North latitude, 76° 02’ 55” East longitude) is also very famous for the Andu nercha, an yearly festival. The Palayoor Saint Thomas church (10° 29’ 43” North latitude, 76° 03’ 25” East longitude) is the sacred place for the people of the Christian community.
It is believed that Saint Thomas established a church here during the first century A.D. This place too is situated very near to the coastal area and visited by thousands of peoples every day.

Many other tourist hot spots are also situated in the study area. The Munakkal beach, (10° 10' 04" North latitude, 76° 10' 22" East longitude) Thalikkulam Snehatheeram, (10° 26' 10" North latitude, 76° 06' 30" East longitude). Chetuwa beach (10° 29' 03" North latitude, 76° 03’ 02" East longitude) and Palappetty beach (10° 41’ 25" North latitude, 75° 57' 10" East longitude) are some of the important tourist centers of great attraction falling within the study area.

Thus detailed studies of saline intrusion and critical evaluation of the aquifer conditions of this area during pre monsoon, monsoon and post monsoon seasons will help to ensure the water quality and thereby to avoid various health and agricultural hazards of this sensitive coastal belt characterised by high density of population.

3.6 OBJECTIVES OF THE PRESENT STUDY

The Main objective of the present study is to carry out a detailed investigation and critically evaluate of the aquifer conditions of the Central Kerala Coastal Tracts extending from Azhikkode in Thrissur district to Ponnani of Malappuram district of Kerala, south India during pre monsoon, monsoon and post monsoon periods.

- **Water Quality Analysis**: To carry out a detailed analysis of different physico-chemical parameters of the water samples collected from the open wells of the various sample stations of the different zones of the entire study area, during every month, at a specific date of pre monsoon, monsoon and post monsoon seasons.

- **Water Quality Index (WQI) Studies**: To calculate the Water Quality Index (WQI) for the water samples from different sampling stations of different zones using the estimated analytical data of various water quality parameters.

- **Quality – Depth Index (QDI) Studies**: To differentiate between the sensitive and insensitive salinity zones of the study area.

- **Water Table Fluctuation Studies**: To find out the variations in the depth to water table and to establish correlation with saline ingress during different seasons by collecting data at a specific date on monthly basis at different sample stations within the study area.

- **Rainfall Analysis**: To study and establish the correlation between rainfall recharge and water table fluctuations within the study area.
Soil Sample Analysis: To identify the influence of soil chemistry if any on the water quality scenario of the study area

Comparison of Saline Intrusion: To compare and establish the degree of saline intrusion between different zones within the study area

Correlation Studies: To test the significance of water quality parameters among different zones and seasons by conducting the two factor analysis of variance.

Rejuvenation: To suggest methods or techniques to improve the water quality of the entire study area and to suggest better management strategies for the coastal fresh water aquifers.

3.7 METHODOLOGY

Collection of water samples from pre fixed open wells located in various sampling zones of the entire study area during specific date of every month for pre monsoon, monsoon and post monsoon seasons, (for the period starting from February 2007 to January 2008) physico-chemical analysis of collected water samples, measurement of water table fluctuations, analysis of rainfall data, soil chemistry studies, calculation of Water Quality Index (WQI) and Quality-Depth Index (QDI) etc form the main part of the investigation methodology. Studies were conducted in the following order.

- Rapid reconnaissance survey for preliminary understanding of the terrain characteristics and its peculiarities.
- Collection of toposheets, maps and various other secondary data
- Preparation of the map of the study area and identification or deleniation of different zones and sampling stations.
- Collection of water samples at a specific date on every month and subsequent analysis of the samples for various physico-chemical parameters
- Measurement of water table fluctuations with in the study area every month during premonsoon, monsoon and post monsoon periods for the entire study area.
- Collection of soil samples from different locations of the study area by using standard techniques and its analysis
- Collection of rainfall data of the entire study area for the period of study.
- Calculation of Water Quality Index (WQI) for the entire study area
Representation of various analytical results and its comparison by preparing spatial diagrams using GIS technology (ArcGIS 9).

Differentiation of sensitive and insensitive sampling stations of each zone by the calculation of Quality–Depth Index (QDI).