Effects of ground water table fluctuation on salt water intrusion along the coastal belt of Malappuram district

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ABSTRACT

The ground water table fluctuation and its effect on salinity intrusion, ground water availability and its utilization pattern and quality of ground water for drinking and other purposes were studied in the coastal belt of *Chamravattom-Ponnani* region of Malappuram District. The study was conducted in six regions viz. Biyyam, *Puzhambram*, *Chamaravattom*, *Kadavanad*, Ponnani and *Puthuponnani*. The impact of socio-economic changes on salinity intrusion were identified and alternate strategies for better utilization of available water sources in coastal areas were also suggested.

Ground water table fluctuation and Total Dissolved Solid (TDS) content

The depth of water table in 41 observation wells was recorded once in 20 days (in monsoon season) and once in 10 days (in summer season). The ground water draw down was high in *Chamravattom* region (4.35 m below ground level) followed by *Puzhambram* and Biyyam. The yearly mean ground water table fluctuation observed in *Chamravattom* was 3.86 m followed by *Puzhambram* (2.75 m).

The study reveals that there exists a definite relationship between water table fluctuation and TDS. In some places (Biyyam and *Kadavanadu*), the TDS content was very high throughout the year. The TDS content observed in Biyyam region during summer period was more than seven times the maximum permissible limit (500 mg/l) in drinking water. The quality analysis of water samples show that the water in Chamravattom region is more suitable for drinking purpose compared to other five regions. The TDS content was less in Ponnani and *Puthuponnani* region though they are very near to the sea compared to other regions. This is due to the geological characteristics of the region.

Ground water availability and its utilization

The utilization of ground water is more in *Chamravattom* region (1.16 MCM). In *Puzhambram* and *Biyam* region, the percentage utilization of available ground water is very less, due to the contamination of well water. Only 16.8% of the available ground water was utilized by the people in *Puzhambram* region. The total availability of ground water in *Chamravattom*-Ponnani coastal belt is calculated to be 9.88 MCM, out of which 3.0 MCM is been utilized. The percentage utilization of available ground water resources in this region is only 30%.

Impact of socio-economic condition on salt-water intrusion

Due to increased population density, the fresh water bodies such as ponds, stream tributaries etc… were transformed into dry land. In Ponnani municipality, extend of paddy cultivation has reduced from 104 ha to just 6 ha in the past 25 years. The fresh water storage structures such as *cheeps* (VCBs) built across *Kanjiramukkuppuzha* and *Kannoli* canal were destroyed due to human interventions. The transformation of fresh water bodies into dry land enhanced the depletion of ground water table and thereby increasing the salt-water intrusion. About 30% of the people in Ponnani Municipality are lacking proper latrine facility, which is also a reason for the contamination of water in *Kannoli* canal and *Kanjiramukkuppuzha*.

The study reveals that the salinity intrusion and contamination of well water enhanced the following major changes occurred in the past years.

i) Drastic increase of population density (population density of the region is 5555per square kilometer)
ii) Over exploitation of ground water by digging more open wells to meet demand of the growing population.
iii) Transformation of paddy lands for other purpose (in Ponnani municipality alone, paddy cultivation has reduced to 6 ha from 104 ha during the past 25 years).

iv) Filling up of ponds, natural streams in between the dry lands and other water storage structures.
v) Out migration of sacred groves and other soil and water conservation plants such as vetiver, *panthanus* etc.
vi) Damage/removal of vented cross bars (cheeps) in *Kanjiramukkupuzha* and *Kannoli* canal.
vii) Lack of proper repair and maintenance of the vented cross bars (cheeps) across the natural streams flowing in between the dry lands in *Kadavanad*, Biyyam and *Puzhambram* region
viii) Water logging in low-lying area during monsoon season due to the filling up of natural drainage channels.
ix) Lack of proper toilet facilities for about 30 percent of population in Ponnani municipality.
x) Accumulation of waste from houses, hotels, factories, hospitals, coir mills, fish and meat market, fruits and vegetable shops, fish drying yards etc. in roads, *Kannoli* canal and other public places.
xi) Exposure of outlets of toilets and drainage system into *Kannoli* canal from the houses located on the banks of canal.

Digging open wells very close to septic tank and cemeteries due to the lack of awareness and limited space.

Alternate strategies for better utilization of available water resources

i) Rainwater harvesting to recharge ground water
ii) Roof top rainwater harvesting structures
iii) Construction of Vented Cross Bars (VCBs) in *Kanjiramukkupuzha*, *Kannoli* canal and other streams in the area
iv) Conservation of sacred/natural groves, ponds and natural streams
v) Controlled pumping to eliminate or reduce over draft to protect water quality. That is, maintain proper balance between water being pumped from the aquifer and the amount of water recharging.
vi) Conjunctive use of surface water and ground water.
vii) Control the number of wells per unit area.
viii) Proper awareness campaign to prevent construction of wells very close to the septic tank and cemeteries.
ix) Suitable solid waste management systems has to be implemented in Ponnani municipality in order to avoid the accumulation of waste from house holds, hotel, factories, coir mills and fish and meat markets on roads and other public places.
x) Necessary toilet facilities has to be provided for the 30 % of the population, who are lacking the facilities at present, in order to avoid the accumulation of human waste in canals (mainly *Kannoli* canal) and other public places. Latrines can be constructed with common septic tank for 10-15 families in colonies.
xi) Avoid the exposure of drainage channels from septic tanks, houses and hotels into the *Kannoli* canal.
xii) Provide suitable drainage facilities in low-lying areas to avoid water logging.
xiii) Mulching has to be done with plant residues and other organic wastes for coconut and other crops, so that moisture can be retained in the soil during dry periods.
xiv) For drying of fish, fish drum or '*choola*' has to be introduced to prevent the contamination of air and water through the traditional method of fish drying.

EFFECTS OF GROUND WATER TABLE FLUCTUATION ON SALT WATER INTRUSION ALONG THE COASTAL BELT OF MALAPPURAM DISTRICT

KERALA RESEARCH PRORGAMME
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The research report is arranged in four sections. The methodology adopted for the study is explained in section III. The findings of the study and alternate strategy for the better utilization of the available water sources are discussed in section IV.

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START

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I. INTRODUCTION

The increasing demand for water to meet drinking, domestic, agricultural and industrial need is placing greater emphasis on the development of ground water resources in coastal areas of Kerala. This is mainly due to high population pressure and unpotability of water along the large number of backwater near absence of perennial fresh water bodies in the coastal stretch of state, resulted almost complete dependence on ground water for making drinking and domestic needs of the vast majority of population living in the coastal area. Availability of ground water has therefore an important crucial factor for development and sustained living in the state in general and coastal belt in particular.

Salt water intrusion refers to the movement of salty water into freshwater aquifers or to the encroachment of saline water into fresh water estuaries. However, saline ground water can occur naturally in inland aquifers as well as in coastal areas, and has similar implications upon ground water use. Salt-water intrusion has been a major ground water resource problem in coastal environments for decades. Increasing population in these areas and resulting ground water consumption has added to the problem as the salt-water intrusion moves further inland in response to pumping. This critical problem requires proper management to protect our ground water resources.

The main problem encountered in the coastal belt is the deterioration of the quality of ground water due to the influence of the adjacent sea. This problem is severe during dry periods (April- May) of the year when the rainfall is zero. The ground water available in this period becomes unsuitable for domestic and irrigation purposes. This problem is less severe during monsoon season (June - November).

Another important factor that makes the well water saline is the depth of the wells in relation to the depth of the salt-fresh water interface zone along the coast. If the well bottom lies above the zone of interface, the chances of getting saline water through the wells are remote. On the other hand, if the well bottom falls within the zone of interface then wells may become permanently saline.

The salinity intrusion in coastal belts resulted a greater influence on the socio-economic status of the living community. Hence, much importance should be given to the socio economic aspects of the coastal region in detail. Alternate methods for the better utilization of the available water resource should also be thought off for long term planning. It is in this light, a group of researchers, comprised of Agricultural Engineers, has undertaken a research project titled ‘Effects of Ground Water Table Fluctuation on Salt Water Intrusion along the Coastal Belt of Malappuram District’ with the following objectives.

Objectives:

1. To study the ground water table fluctuation along the coastal belt of Chamravattom – Ponnani region of Malappuram district.
2. To estimate the extent of salinity intrusion in the coastal belt.
3. To assess the ground water availability along the coastal area.
4. To asses the ground water utilization pattern.
5. To assess the quality of water for potability and irrigation purpose.
6. To study the impact of socio-economic changes on salt-water intrusion along the coastal belt.
7. To suggest alternate strategies for better utilization of the available water sources in the coastal area.

II REVIEW OF LITERATURE

Basak and Nazimudhin (1984) conducted a study on the behavior of ground water in coastal belt of Malappuram district. The study was carried out through 41 permanent observation wells set up, by the ground water division of CWRDM, Kozhikode. Depth to ground water table and water quality parameters were recorded during pre-monsoon (April-May), monsoon (July-August) and post monsoon (December-January). The ground water utilization and present ground water use pattern along the coastal belt of the district were estimated. Ground water availability was calculated by multiplying the mean ground water level fluctuation with the area over which these mean fluctuations occur and the assumed specific yield of 0.20. The utilization of ground water in the area was found out by multiplying well density with the average draft in litres/day/well and corresponding area of each zone. The study concluded that the percentage utilization of ground water in the coastal belt was 20 per cent.

Wu et al; (1993) observed the seawater intrusion in the coastal area of Laizhou Bay. The study was conducted in two observation wells (No1&No.2) since from 1985. They reported that because of the excessive pumping of ground water from the coastal aquifer, ground water level in the study area have been dropping steady and the water table in the part near to the coast has become lower than the adjacent sea level, thereby giving rise to sea water intrusion. Now the transition zone (mixing zone) was increased up to 1.5-1.6 km wide. In 1985, the chemical quality of ground water from the No.1& No.2 pumping wells was very good. Chloride concentration was less than 70 mg/lit. But the chloride concentration was increased to 1700 mg/l in No.1 pumping well, 520 mg/lit. in the No.2 well on January 3, 1988 and 5140 mg/lit in the No.1 pumping well, 3500 mg/lit in No. 2 pumping well on December 20, 1989.

Nazimudhin and Basak (1998), reported the ground water availability and utilization in the coastal shallow aquifer at Aleppy district. The observations were carried out through the observation well network set up by C W R D M, Kozhikode. Ground water levels and its fluctuation and extent and pattern of ground water availability and utilization in the coastal belt of the district were studied and they concluded that there were three main ground water fluctuation zones along the coast with the annual fluctuation of 0.50, 1.00 and 2.00m .The total ground water availability in the top unconfined aquifer along the entire Aleppy coast was 39.59 million cubic meter and average utilization was of the order of 42 percent through an estimated number of 39,400 open wells scattered over the coast. Studies also showed that, seawater had an effect up to 150 m form the shore.

Nazimudhin and Basak (1998) reported the ground water resources in the coastal belts of Kerala. More than 400 observation wells in the various coastal belts of different districts were established for the study. Ground water levels and quality have been monitored for 3 to 4 years. Sample surveys were also carried out in each district for studying the ground water availability and utilization pattern. In each district, 2 sample areas of approximately 1 square kilometer were first identified and they were chosen based on the accessibility of the area, nearness to the shore, population density and distribution of wells in the area. The total availability of ground water was estimated as 454 million cubic meter, out of which 150 million cubic meter of ground water was utilized. Low pH, high iron content, high hardness, high TDS (total dissolved solids) and salinity were the common quality problems identified in the study area. The study also revealed that the width of sensitive zone for seawater in the various coastal belts vary from 100 to 500 m from the shore.

Jason (1993) explained about the salt-water intrusion caused by excessive pumping. The study conducted in the city of Laizhou in 1971, and in Longkou in 1979 illustrated that excessive pumping of ground water in these areas had caused salt-water intrusion. In the beginning the observations were taken from some specific, isolated spots (0.5km^2). Eventually the intrusion area spreads as increases in agriculture and industry persisted. In 1979, the salt-water intrusion area covered 16km^2, 39km^2 in 1982, 71km^2 in 1984, 196km^2 in 1987. By 1989, the salt-water intrusion area became a continuous zone covering an area of 238 km^2 in Laizhou. In the 1970's, the salt water intrusion area in the southwestern part of the study area increased by 4km^2 in each year. In the early 1980's, this number increased to 11.1km^2, and after the mid-1980s to 30km^2. This rapid increase reinforces the need for proper monitoring and controlling methods for salt-water intrusion. He suggested that recharge wells, recharge basins and barrier wells were very useful in maintaining the proper equilibrium between ground water recharge and pumping.

Yugun et al, (1995) conducted the hydrological and hydro geochemical studies for salt-water intrusion on the south coast of Laizhou Bay, China. In 1981, on the adjacent south coast, the intrusion of salt water originating from brine was observed. In this area, the salt-water intrusion was caused by the excessive pumping of fresh water in aquifers. More over, the simultaneous pumping of fresh water and salt water/brine formed a complicated ground water flow field. The data obtained form observation wells were used to analyze the origin of the salt water and brine, and the genesis of the bicarbonate/sodium water zone. All data suggested that the brine originated from ancient seawater and that the bicarbonate sodium water was formed by cation exchange.

The Endeavor consulting engineers (1986) described about the salt intrusion into rivers. The major reasons for increasing gravity of saltwater intrusion into river mouths were the increased subsidence of river beds in alluvial regions, enhanced in many cases by the exploitation of sand or gravel quarries along river beds; the requirements of water for irrigation, which is also generally increasing. A research carried on world wide in 1985 explained a few practical experiences for salt water intrusion control such as control of salt water intrusion in aquifers by recharge wells, reduction of salt water intrusion through locks by pneumatic barriers and use of concrete sills to prevent salt intrusion through locks.

Newport and Todd (1996) studied with the salt-water intrusion in coastal fresh water aquifers. The first step in correcting problems with salt-water intrusion is to evaluate the size and extent of the problems. This is commonly accomplished by the installation of monitoring wells, which are used to determine the boundaries of the salt/fresh water interface and the rate at which salinity levels are increasing. Using this data and information on the hydrologic and geologic properties of the contaminated aquifer, numeric and computer modeling is often incorporated into problem analysis in order to predict future conditions and to evaluate remediation alternatives. According to Newport (1977) and Todd (1974), the following methods for controlling salt-water intrusion in coastal aquifer systems can be adopted.

i) Reduce pumping
ii) Relocate wells
iii) Directly recharge aquifer.
iv) Fresh water recharge into wells paralleling the coast, creating a hydrodynamic barrier
v) Create a trough parallel to the coast by excavating encroaching salt water from wells
vi) Extracting sea water before it reaches wells
vii) Extraction/injection combination
viii) Construction of impermeable subsurface barriers.

In the national report on the implementation of “Agenda 21” of state of Quatar described about the development and rational use of water resources. According to the report, the renewable water resources were totally depleted and continue to cause lowering of the water table, deteriorating of water quality upcoming of highly saline water from deeper aquifer and resulting in a greater water cost. The previous works done in Quatar during early 1980 had suggested that artificial recharge of fresh water into the aquifer systems may be a possible solution to the prevailing water supply problems, in order to augment the diminishing ground water reserves and control environmental deterioration caused by salt water intrusion and soil degradation.

A study conducted by United States Geological Survey department on fresh water - salt water interaction along the Atlantic coast, the seaward movement of fresh water prevents salt water from encroaching coastal aquifers and the interface between fresh water and salt water was maintained near the coast or far below land surface. This interface is actually a diffuse zone in which fresh water and salt water mix is referred to as the zone of dispersion (or transition zone). Ground water pumping can reduce fresh water flow towards coastal discharge areas and cause salt water to be drawn towards the fresh water zones of the aquifer. Salt water intrusion decreases fresh water storage in the aquifers and in extreme cases, can result in the abandonment of supply wells. According to the study, salt-water intrusion occurs by many mechanisms, including lateral encroachment from coastal waters and vertical up coning near discharging wells.

Todd (1974) described the system approach for managing salt-water intrusion. If pumpage from a coastal aquifer exceeds the natural flow to the sea, salt water will continue to move inland until it reaches the pumping wells. The various strategies employed to retard salt-water movement includes.

i) Limiting pump age and time share pumping from a number of wells (a redesign of the well field may be necessary in some cases)
ii) Various means to control runoff of fresh water lost via fractures, karst and rivers, and
iii) Re-injection of wastewater near the salt-water interface to aid in maintaining a sufficient head of fresh water.

III. MATERIAL AND METHODS

The methodology followed in the study is described under the following tittles:

i) Establishment of observation well net work.

ii) Measurement of ground water table fluctuations.

iii) Quality analysis of ground water.

iv) Assessment of ground water availability and its utilization

v) Effect of salinity intrusion on socio economic status of the living community.

vi) Identification of alternate strategies for better utilization of the available water resources.

3.1 Establishment of observation well network.

The width of sensitive zone for seawater intrusion in various coastal belts normally varies form 100-500m from the seashore (Nazimuddin and Basak). Preliminary information about the intensity of salinity intrusion in the area were collected by interaction with local people and based on these informations, 41 observation wells were selected. The observation wells were spread over six different region viz. Biyyam, Puzhambram, Chamaravattom, Kadavanad, Ponnani and Puthuponnani of the Chamravattom – Ponnani coastal stretch. These observation wells were chosen based on the intensity of salinity intrusion, nearness to the seashore, accessibility and population density. For water quality analysis a representative sample of 15 observation wells (from 41 wells selected), which spread over the study area, were selected. Table 3.1 shows the details of observation wells selected from each region and the average distance of the wells form seashore. The location map of the study region and observation wells selected is shown in Fig 3.1

The study was conducted along the Chamravattom – Ponnani coastal belt of Malappuram district. This region occupies an area of 20.65 square kilometer, which includes Ezhuvathuruthy Panchayath and Ponnani municipality. The population density in this region is above 4500 per square kilometer, which is the highest in the state of Kerala.

Table 3.1 Details of observation wells selected for the study

Sl. No.	Name of the region	Area (ha)	No. of wells	Distance from sea shore (km)
1.	Biyyam	590	6	> 4
2.	Puzhambram	390	6	3-3.5
3.	Chamravattom	410	5	5-5.5
4.	Kadavanadu	225	10	1-1.5
5.	Ponnani	210	9	0.5-1.0
6.	Puthuponnani	240	5	< 0.5
	Total	2065	41	

3.2 Measurement of ground water table fluctuation

The variation of water level in wells depends mainly on nearness to sea shore and back water, daily withdrawal of water form wells, type of geological formation and the relative height from mean sea level. The depth to water level in the observation wells were measured from the ground level, with the help of a measuring tape, once in 20 days during monsoon season (June- December) and once in 10 days during summer season (January-May) for all the six regions selected for the study. The ground water table fluctuation behaviour along the coastal belt was assessed by analyzing the average depth to ground water level in the observation wells during the consecutive months.

3.3 Quality analysis of ground water

A detailed study on quality of well water from the observation wells was done to get an idea about the ground water quality of the coastal area. Salinity intrusion along the coastal area was assessed by measuring the level of total dissolved solids (TDS) contained in the water samples collected from the 15 observation wells, selected for this purpose. Water samples were collected monthly during monsoon season and fortnightly during summer season from these 15 observation wells. Quality of water samples collected from the observation wells was also tested for potability and irrigation purposes. For this, samples were tested for pH, suspended solids, total dissolved solids, chlorides of calcium sulphates, alkalinity, total hardness, iron, calcium, magnesium and E-coli.

3.4 Assessment of ground water availability and its utilization.

The ground water availability was estimated from the recorded water table fluctuation data obtained from the observation well network. The yearly average ground water table fluctuation of each region was calculated. Estimation of ground water availability was made by multiplying the mean ground water level fluctuation within the area over which these mean fluctuations occurred and the specific yield of 0.20 (Nazimudhin and Basak)

In order to find out the ground water utilization pattern, well density of the area was assessed through a field survey. The average withdrawal from these wells was observed in litres/day/well. The ground water utilization in each zone was found out by multiplying the well density (wells/square kilometer) with the average withdrawal from the wells in litres/day/well and the corresponding area of the respective region.

3.5 Effect of salinity intrusion on socio-economic status of the coastal belt.

The extent of salinity intrusion in the coastal area has got a great influence on the living status of the community. Similarly, the problem of salt-water intrusion has increased due to the intervention of human beings, in the form of conversion of paddy lands and ponds into dry lands, destruction of cheeps (Vented Cross Bars), unscientific digging of open wells etc, due to the increased population density.

Detailed socio-economic survey was conducted with the help of structured schedule and personal interviews with the local people in the study area and the following details were collected

1. Population (male, Female, Children Below 15 years, SC/ST)
2. Living condition (Status of houses such as concrete roof, Tile roof etc, Bathroom facilities)
3. Annual income
4. Electrification status of the houses
5. Availability of water for drinking and other purposes (Tap water, Own well, Public well, Tube well, Ponds and streams)
6. Details about well depth and drying period
7. Educational status (such as lower primary, upper primary, high school, pre degree, higher secondary, graduation and technical education)
8. Employment (labourers, government and private employees)
9. Operational holdings
10. Health care facilities

11. Industries
12. Details of irrigation and soil and water conservation practices

3.6 Alternate strategies for better utilization of available water sources.

Salt-water intrusion must be minimized/arrested for the better utilization of the available water sources. This can be done by raising the level of ground water table in the coastal region by adopting suitable methods to harness the plentiful rainwater. Over exploitation of ground water is another reason of draw down of water table and thus the entry of salt water. After analysing the technical data collected on water table fluctuation rate, ground water utilization and its availability, quality of ground water in the study area and based on the socio-economic conditions of the area suitable methods were suggested for the better utilization of the available water resources in the region.

IV RESULTS AND DISCUSSION

The result of the study is discussed in the following tittles.

i) Ground water table fluctuation of the region.

ii) Effect of ground water table fluctuation on total dissolved solids

iii) Ground water availability and its utilization pattern

iv) Socio-economic changes and salinity intrusion.

v) Alternate strategies for better utilization of the available water resources

4.1 Ground water table fluctuation of the region.

The data recorded on water table fluctuation in the observation wells indicated that, the depth to water table below ground level was increased from June to May in all the six regions. That is, the water level was found to be very near to the ground level during monsoon period and gradually lowered during dry period. Table 4.1 shows the average depth to water table below ground level recorded in meters from May 1998 to February 2000. The water table hydrograph corresponding to the data recorded is presented in Fig. 4.1 to 4.6

In all the six regions, water level was found to be increased gradually in the month of June due to the effect of heavy rainfall received during the monsoon seasons. In Biyyam region, the average depth to water level was decreased from 2.69 to 0.28m below ground level resulting ground water level fluctuation of 2.41m in the year 1998. In the same region the average ground water level fluctuation was recorded as 2.30m in 1999. The yearly mean ground water level fluctuation recorded in Biyyam region was found to be 2.36m (Table 4.2).

In Puzhambram region, the depth to water table below ground level was found to be decreased from 3.43 to 0.59 in May - June, 1998 and this gradually increased till the starting of next monsoon. The average ground water level fluctuation recorded in Puzhambram region was 2.84m in 1998. The water table was found to be lowered from 2.4 to 3.05 m below ground level in 1999 and then increased up to 0.4m below ground level in July. The average ground water level fluctuation and yearly mean ground water table fluctuation observed as 2.65 and 2.75m respectively.

Chamravattom region recorded the highest fall of ground water table (4.35 m) in May, 1998 among all the six regions. Then the ground water table was increased up to 0.4 m below the ground level in July. The average ground water level fluctuation recorded in this region during 1998 and 1999 were 3.95 and 3.77 m respectively. The yearly mean ground water level fluctuations observed in this region was 3.86m.

In Kadavanad region, the depth to water table below ground level was found to have the highest value of 1.78 m in May 1998 and the same was recorded as 1.59m in April 1999. Among the six study regions, Kadavannad was recorded a minimum drawdown of ground water level during peak summer period. The average ground water level fluctuation measured in Kadavanandu region was found to be 1.15m and 1.28m respectively in 1998 and 1999. The yearly mean ground water level fluctuation recorded in this region was 1.22 m, which was the lowest among the six regions.

In Ponnani region, the depth to water table below ground level was found to be 2.21m in May 1998; which was the lowest level of water table during the period of study. The water table went down to 1.97 m below ground level in April 1999 and increased to a level of 0.85m below ground level in July. The average ground water level fluctuation recorded in Ponnani region was 1.36 and 1.12 m in 1998 and1999 respectively. The yearly mean ground water table fluctuation observed in this region was 1.24 m

In Puthuponnani region the water table was found to be below 2.68 m from the ground level in May 1998 and suddenly it reached 0.77 m below the ground level in June. The average ground water table fluctuation of this region in 1998 was found to be 1.91m. During 1999, the highest drawdown of water table was recorded as 2.09m in April and the water table was found to be increased to 1.03m below the ground level in July and then recorded a decline in water table towards the end of the year. The average ground water level fluctuation observed in this region was 1.06m in 1999. The yearly mean ground water level fluctuation recorded in Puthuponnani region was 1.49m.

Table 4.2 Yearly mean ground water table fluctuation

Sl No.	Region	Average ground water level fluctuation (m)		Yearly mean ground water level fluctuation (m)
		1998	1999	
1	Biyyam	2.41	2.30	2.36
2	Puzhambram	2.84	2.65	2.75
3	Chamravattom	3.95	3.77	3.86
4	Kadavanad	1.15	1.28	1.22
5	Ponnani	1.36	1.12	1.24
6	Puthuponnani	1.91	1.06	1.49

Table 4.2 shows the average ground water level fluctuation during 1998 and 1999 and the yearly mean ground water level fluctuation of the six study regions. From Table 4.2, it is

clear that the highest yearly mean ground water level fluctuation of 3.86m was recorded in Chamravattom region compared to that of the other five regions. The Chamravattom region is located very near to the Bharathappuzha river. The depletion of ground water table in this region might be due to the increased sand mining in Bharathappuzha, closer to Chamravattom region. From the table, it was observed that in three regions viz, Kadavannad, Ponnani and Puthuponnani, the yearly mean ground water level fluctuation was below 1.50m and was found to be 1.22,1,24 and 1.49 m respectively. This increased level of water table in the above three regions might be due to the lesser utilization of ground water by the local people from their wells because of the poor quality of ground water in these area.

4.2 Effect of ground water table fluctuation on Total Dissolved Solids (TDS)

The study on water table fluctuation and salt-water intrusion reveals that there existed a definite relationship between these two factors. As the water level goes down, the amount of total dissolved solids (TDS) presented in water was found to be increased and vise versa. Table 4.3 shows the average amount of total dissolved solids presented in the water sample in milligram per liter (ml/l) collected from 15 observation wells spread in the six study regions.

From table 4.3, it was obvious that the amount of total dissolved solids presented in the water sample was high during summer period in all the six regions because of the low level of water table, which enhances the intrusion of saltwater towards these regions. In all the six regions, the TDS presented in the water sample was found to be higher than the permissible limit of 500 mg/l during summer period.

The highest value of TDS (3800 mg/l) was observed in Biyyam during May 1998 declined as the monsoon started. It was observed that except in June 1998 the amount of TDS presented in water sample was higher than the permissible limit of 500 mg/l, throughout the period of study. These results indicated the severe problem of contamination of ground water due to the saltwater intrusion in this region. Even though the area is located more than 4 km away from the sea. The presence of high amount of TDS in this region may be due to the nearness of Biyyam kayal, which is opened to the Arabian Sea through Kanjiramukkupuzha. More over, the fresh water storage structures such as vented crossbar (cheeps), which prevented the entry of saltwater up to a great extent, are now disappeared due to human intervention, which permitted the entry of salt water into this area.

Fig 4.7 shows the relationship between water table fluctuation and amount of TDS presented in the water sample in Biyyam region. From the figure it was observed that, as the depth to water table below ground level increased, the amount of TDS was also found to be increased. Highest value of TDS (3800 mg/l) was recorded when water table was 2.69 m below ground level in May 1998. Minimum value of TDS (460 mg/l) was observed, when water table was 1.28 m below ground level in June 1998.

In Puzhambram region, the highest value of TDS was 990 mg/l in May 1998 and was found to decrease in the following months due to the increased water level in monsoon period. Even though the observation wells in this region were located between 3-3.5 km away from the sea, the amount of TDS presented in the water samples were found to be more than the permissible limit throughout the year. The high amount of TDS presented may be due to the presence of Kanjiramukkupuzha, which has direct link with the sea. The fresh water storage structures such as ponds and other low-lying area were filled and transformed to other purposes due to the increased population density. This transformation of land causes rapid drainage during rainy season through the Kanjiramukkupuzha, without much ground water recharge. Thus the ground water level of this region fell below the safe limit, which allows the entry of saltwater since the region is directly connected to the sea through Kanjiramukkupuzha.

Fig.4.8 shows the relationship between water table fluctuation and maximum amount of TDS in Puzhambram region. Maximum amount of TDS observed in this region was 990 mg/l, when the ground water table was below 3.45 m. The TDS recorded in this region was minimum (640 mg/l) when the ground water table was below 0.59 m from the ground level. The TDS presented in water samples were found to be increased as the water level of the region declined.

The relationship between water table fluctuation and amount of TDS presented in water samples of Chamravattom region is presented in Fig 4.9. The highest amount of TDS was recorded as 880 mg/l in May 1998 when the water table of the region was 4.35m below the ground level. The TDS was found to be higher than the permissible limit during January-May, due to the depletion of ground water level. This may be due to the high utilization of ground water in the region and excess sand mining from the Bharathappuzha, which is very near to the Chamravattom region. The lowest amount of TDS recorded as 165 mg/l when the water table was 0.40 m below the ground level in June 1998.

In Kadavanadu region, maximum amount of TDS recorded was 2990 mg/l (Table 4.3), which is about six times of the permissible limit of TDS in water. Kadavanadu region was recorded the second highest amount of TDS among the six regions after Biyyam. The TDS content in Kadavanad region was higher than the permissible limit in all the months except June, July and August, even though the region is located about 1 – 1.5 km away from the sea. This high content of TDS may be due to the presence of Kanjiramukkupuzha flowing through this region, which has direct link between the sea and Biyyam kayal. In ancient days, Kadavanadu region was free from salt-water intrusion because of the presence of large number of fresh water storage structures across the Kanjiramukkupuzha. When time passes, the ponds and other low-lying area were filled and transformed for other purposes and the cheeps were damaged by human intervention and lack of proper repair and maintenance. This enhanced the depletion of the ground water level and thus the entry of salt water into this region.

The relationship between the ground water table fluctuation and TDS content in Kadavanadu region is shown in Fig.4.10. The highest value of TDS was recorded as 2990 mg/l against a water level of 1.78 m below ground level and lowest value of TDS recorded was 415 mg/l when the water level was 0.63m below the ground level.

The amount of TDS recorded in Ponnani region was 690mg/l in May 1998, which was found to be the lowest when compared to that of other five regions even though the distance from sea to this region is 0.5-1.0 km. This may be due to the characteristics of the geological formation of that area. The relationship between water table fluctuation and TDS content in Ponnani region is shown in Fig- 4.11. Highest value of TDS (690mg/l) was recorded against a water level of 2.21 m below ground level and lowest value of TDS was recorded as 220 mg/l when water level was 0.85m below ground level

In Puthuponnani region, the highest value of TDS recorded was 714mg/l in May 1998 and was found to be decreased as the rain started, due to increased water table in the region. The lowest value of TDS in Puthuponnani region was observed as 110mg/l, which was found to be the lowest among all the six regions, though it is located very near to the sea. Table 4.3 revealed that, Puthuponnani region observed less amount of TDS content compared to that of the other five regions, though the distance from the sea is less than 0.5 km. The TDS content in this region was found to be within the permissible limit except in the peak summer season. Here the factor of nearness to the sea was observed to have very little effect on salt-water intrusion. The lesser value of TDS in this region is due to the characteristics of the geological formations of the region. Fig 4.12 shows the relationship between water table fluctuation and TDS content in Puthuponnani region. The TDS content was found to be increased with the increased depth to water table. Highest amount of TDS recorded was 714 mg/l when the depth to water table was 2.68m and the lowest amount of TDS was recorded when the depth to water table was 0.77 m.

The study on the effect of ground water table fluctuation on salt-water intrusion revealed a definite relationship between depth of water table below ground level and salinity.

It was observed that lowering of ground water table in summer was associated with increase in salinity.

The result of water quality analysis for drinking purpose is shown in Table 4.4. The pH content was found to be within the permissible limit of 6.5-8.5 in 4 regions viz Biyyam, Chamravattom, Ponnani and Puthuponnani while it was higher than the permissible value in Puzhambram and Kadavanad regions. The well water in these two regions was more alkaline and people consuming it may get intestinal problems. The suspended solids, sulphate as $SO_{4,}$ alkalinity and iron content in the well water was observed within the permissible limit in all the six regions. The calcium content recorded was higher than the permissible limit in Puzhambram and Kadavanad region. This was found to be four times (1191.1mg/l) more than the permissible limit in Puzhambram region. The total hardness and calcium content in the well water was found to be within the permissible limits except in Puzhambram region. The hardness and calcium content observed in Puzhambram was 3.80and 100 respectively which is not suitable for drinking purpose without any water treatment. The Mg content in the water sample analysed was found to be more than the permissible limit in Puzhambram and Ponnani region and hence the water is not suitable for drinking in these regions. The E-coli presented in the well water was higher than the permissible limits in Kadavanadu, Ponnani and Puthuponnani regions and they were in the order of 24, 36 and 12 respectively.

The results of water quality analysis revealed that the well water in four regions viz, Puzhambram, Kadavanad, Ponnani and Puthuponnani was not suitable for drinking purpose, since the parameters tested were found to be higher than the permissible limit.

Puzhambram region was found to have highly contaminated well water. In this region, parameters such as p^H, chlorides as Ca, total hardness, calcium and magnesium were found to be higher than the permissible amount. The amount of TDS presented in the water sample was also higher than the permissible limit in the region (Table 4.3). Hence the well water in Puzhambram region is never suitable for drinking purpose. In Kadavanad region the P^H value, amount of chloride as calcium and E-coli presented in the well water were found to be higher than the permissible limits. The amount of TDS in the region was also very high and beyond the permissible limits (Table 4.3). Therefore the well water in Kadavanad region was also found to be not fit for drinking purpose. From Table 4.4, it was clear that the various parameters tested for water quality analysis were within the permissible limits only in Biyyam and Chamravattam region. But the amount of TDS in the well water in Biyyam region was observed as much higher than the permissible limit throughout the year except in June (Table 4.3). Among all the six regions, the well water only in Chamravattom region was found to be suitable for drinking purpose.

4.3 Ground water availability and its utilization pattern

The ground water availability and its utilization pattern for the six study region viz.; Biyyam, Puzhambram, Chamravattom, Kadavanad, Ponnani and Puthuponnani are tabulated in Table 4.5. Figure 4.13 shows the area of the study regions on which the average yearly mean ground water table fluctuation occurs.

From the table it was observed that highest ground water availability of 3.1652 MCM (Million Cubic Meter) was recorded in Chamravattam region, but the average utilization of ground water in this region was found to be 1.162350 MCM (36.72 percent of the available ground water). During summer periods, this region was affected by salinity intrusion and this prevented the people from taking more water from their open wells for domestic purposes. The ground water availability in Pazhambram region was found to be 2.1450 MCM and recorded the lowest ground water utilization pattern among the six study regions. In this region, the ground water utilization was observed as 0.359775 MCM, which accounted only 16.77 percent of the total available ground water resources. The lowest utilization of ground water in Puzhambram region is due to the salt-water intrusion in this region throughout the year. The amount of total dissolved solids in well water in this region was found to be more than the permissible limit throughout the year (Table 4.3). The well water in this region was found to be not suitable for drinking purposes and the people are dependent on pipe water for their domestic purposes. Biyyam region also recorded a lesser utilization of the available ground water .In this region 2.7848 MCM of ground water availability was observed, out of which only 0.730125 MCM (26.22%) was be utilized. In Kadavanad region, about 41.5 percent of the available ground water was found to be utilized. The ground water availability and utilization in this region was recorded as 0.549 and 0.227813 MCM respectively. In Biyyan and Kadavanad region also, people were not utilizing the well water for domestic purposes and are more dependent on the pipe water, which was available occasionally.

The highest percentage of utilization of available ground water was recorded as 47.18 in Ponnani region, though the region is very near to the seashore compared to Biyyam, Puzhambram, Chamravattom and Kadavanad regions. The ground water availability and its utilization observed in Ponnani was 0.5208 and 0.2457 MCM respectively. In Puthuponnani region also, the utilization of available ground water was found to be more compared to Biyyam, Puzhambram and Chamravattom, though the region is located less than 0.5 km from the sea. The ground water utilization in Puthuponnani region was observed as 0.27 MCM against an availability of 0.7152 MCM of ground water. The high ground water utilization in

Ponnani and Puthuponnani regions is due to the lesser amount of TDS in well water though this area is located very near to the sea compared to the other four regions. The less amounts of TDS in well water of Ponnani and Puthuponnani region may be due to the characteristics of their geological strata.

4.4 Socio- economic changes and its impact on salinity intrusion

The increasing demand for water to meet drinking, domestic agricultural and industrial purposes forced the society to exploit the available ground water sources all over the state. In coastal area, people are completely depending on ground water because of the unpotability of water in the lack of water sources and absence of any nearby perennial fresh water bodies. The increasing population density and demand of water resulted over exploitation of ground water sources and there by the depletion of ground water level in coastal region. Other factors such as transformation of paddy lands and other natural fresh water sources like ponds and streams, changes in land use pattern and ecological degradation were also enhanced the depletion of ground water level in this region. As a result of the low water table, salt water was extended into the well and other streams adjacent to the sea. The presence of salt water in these streams contaminated the well water near the banks of the stream even at a distance of 4-5 km away from the sea. Thus it is realized that, human interventions and social changes in the region deserve a major share of the causes for salt-water intrusion in the coastal region.

The socio- economic conditions of the study region is explained in following sections

4.4.1 Population

The study region is spread over Ponnani municipality and parts of Ezhuvathuruthy panchayath. The population density in this region is very high compared to that of other places in the state. The population density in Ponnani municipality was recorded as 5555 per square kilometers, which has the fourth place for the highest population density in Kerala. The male – female ratio in the region was found to be 1000:1090, which is higher than that in the state level (1000:1040). Majority of the people are in the backward community and about 2 % of them belongs to scheduled caste/tribe. Details of the people in different age groups, their educational status, details of educational institutions, occupation, details of land ownership, income of the people and tye of houses are tabulated in Table 4.6-4.12

Table 4.6 Percentage of people in different age groups.

Sl. No.	Age groups (years)	Percentage
1	0-10	7.03
2	11-20	23.02
3	21-30	25.60
4	31-40	16.00
5	41-50	13.65
6	51-60	6.60
7	61-70	6.40
8	>70	1.70

Table 4.7 Educational status of the people.

Sl. No.	Educational status	Percentage of people
1.	Lower primary	25.50
2.	Upper primary	20.50
3.	High school	33.00
4.	Higher secondary	4.30
5.	Degree	4.50
6.	Post graduate	0.50
7.	Technical	1.30

Table 4.8 Details of educational institutions

Sl. No.	Educational institutions	Number
1.	College	1
2.	High school	3
3.	Upper primary school	3
4.	Lower primary school	6
5.	Nursery school	4
6.	Anganavady	19
7.	Parallel colleges	6
8.	Typewriting institutes	4
9.	Tailoring institutes	12

Out of the 12 schools, 5 schools are under Government sector and 7 are aided schools.

Table 4.9 Details of occupation of the people.

Sl. No.	Occupations	Percentage of employed people in various occupations.
1.	Agriculture	5.00
2.	Manual labourers	25.25
3.	Fishing	24.00
4.	Gulf	9.65
5.	Public sector	9.65
6.	Business	10.85
7.	Teacher	3.60
8.	Other jobs	12.00

Table 4.10 Details of land ownership

Sl. No.	Area in cents	Percentage of people having land ownership
1.	< 10	40.0
2.	10-30	38.2
3.	31-50	10.3
4.	51-70	6.3
5.	71-90	2.6
6.	> 90	2.6

Table 4.11 Annual income of the people

Sl. No.	Annual income(Rs)	Percentage
1.	< 15000	85.00
2.	15000-25000	4.00
3.	25000-35000	2.15
4.	35000-45000	2.00
5.	45000-55000	4.10
6.	> 55000	2.75

Table 4.12 Details of houses

Sl. No.	Make of houses	Percentage
1.	Types of roof	
	i) Coconut leaves	30.0
	ii) Tiles	46.0
	iii)Concrete	24.0
2.	Types of well	
	i) Panamp	9.0
	ii)Clay and sand	10.0
	iii)Brick	79.0
	iv)Others	2.0
3.	Types of flooring	
	i) Clay and sand	31.0
	ii)Cement	48.0
	iii)Mosaic	10.0
	iv)marble	11.0

About 30% of the houses have no latrine facilities and more than 28% of the houses are not electrified

4.4.2 Changes in land use pattern

The land use pattern of the region was under drastic changes in the past 20-30 years in order to meet the demand of the ever-increasing population in the region. Paddy was the main crop in this region before 25 years and this was done even in lease basis also. Under Ponnani municipality the area of paddy cultivation was 104 ha before 25 years, but the cultivation is now only in 6 ha. This shows the extensive transformation of paddy land in this region in the past years, which lead to serious environmental problems in the area. In ancient days this paddy fields stored enormous quantity of fresh water during the rainy season and the water level of the region was kept under safe limit with respect to the near by sea level. As a result of the transformation of paddy lands, rainwater was flooded to the surrounding area creating excessive water logging and then drained into the sea. This caused the depletion of ground water table and enhanced the entry of saline water from sea to the area.

The crops grown in this region are coconut, arecanut, paddy, vegetables, banana, tapioca, pepper, jackfruit, cashew, mango, etc. Sesamum and tapioca were the major summer season crops in this region and now the area under this cultivation was reduced drastically and sesamum is not even cultivated now a days. The productivity of coconut in the banks of Kanoli canal in Ponnani municipality is very low because of the water logging in the area. Another reason for the less productivity is, majority of land is under the possession of those people whose main income is from sources other than agriculture. The irrigation in this region was found to be badly affected by low voltage of electricity, which prevents farmers from extensive cultivation.

The area was rich in biomass production in ancient years. Medicinal plants such as *muthanga*, vetiver etc. were extensively grown in this region. Similarly *panthanus*, which was used for making mat and other handicrafts was very common in the area. This *panthanus* was extensively used to protect stream bank and demarcate the boundary of individual land holdings. Now m*uthanga*, vetiver and *panthanus* were disappeared from this region. A large number of sacred groves were in this region in the past days. These sacred groves were good sources of biodiversity in the area and majority of them were disappeared. The outmigration of these sacred groves and other plants like *panthanus* and vetiver created serious ecological problems in this area. The presence of these plants and sacred groves accelerated the ground water recharge and retention of moisture in soil for a long time and ground water table was in higher level. Due to the increased population density and demand of land, the sacred grooves and other water conserving plants were destroyed extensively which causes low infiltration rate and ground water table. This lower level of water table accelerated the entry of salt water into the area.

Another major change during the past 15 to 20 years in the area was the transformation of low lying areas such as paddy field, ponds, streams etc. for other purposes like building construction, roads, cultivation of cash crops etc. As mentioned earlier the paddy field, which spreads over 104ha in Ponnani municipal area before 30 years, was decreased to a meager 6 ha. A large number of fresh water ponds located in Chamravattom and Kadavanad regions were filled for other purposes. Majority of the natural streams in Biyyam, Puzhambram and Ponnani region were completely transformed in to dry lands mainly for residential purposes. The low lying area such as paddy fields, ponds, natural streams existed in the region collected considerable amount of fresh water during monsoon period and were good source of water during summer season. Transformation of these water bodies into dry land resulted in the depletion of ground water table of the area. Another water storage structure used to prevent the entry of salt water to the streams was vented cross bars(cheeps) located in Kanjiramukkuppuzha, Kanolicanal and narrow streams of Biyyam kayal. These cheeps were completely destroyed due to the lack of proper repair and timely maintenance. This also enhanced the entry of salt water into the streams, which has direct link with the sea through Biyyam kayal. The presence of salt water in streams contaminated the surrounding well water in Biyyam and Puzhambram regions though the area was located far enough from the sea shore (3km). Table 4.13 shows the details of the land use pattern of the area.

Table 4.13 Details of the land use pattern

Sl. No.	Particulars	Area(ha)
1.	Dry land with house hold cultivation of coconut, aracanut, banana, vegetables, tapioca, pepper, jack fruit, mango, cashew etc	1900
2.	Paddy field	35
3.	Road	45
4.	Streams	45
5.	Ponds	4
6.	Waste land	1
7.	Public land	35
Total		2065

4.4.3 Water Resources.

The area is surrounded by Arabian Sea in the west and Bharathappuzha in the north. Kanjiramukkupuzha and Kanoli canal are the two main streams flowing through this area. Biyyam kayal is located very near to Puzhambram and Biyyam region. The Chamravattom region is located on the banks of Bharathappuzha. Besides these water resources, there were a large number of ponds and narrow streams in this area. But as time passed, these streams and ponds were transformed into dry lands due to the increased pressure of population. Another main water source in this area is open wells. The number of open wells in this area has drastically increased when compared to that in the past years. Even though the area is bestowed with an average annual rain fall of 2800mm and a good network streams, availability of drinking water is a serious problem to the people. The water in streams is not suitable for drinking and irrigation purposes due to its salinity and contamination. This forced the local people to depend more on ground water and hence every body started digging of open wells without any consideration of well spacing. When the number of wells increased, more water was drawn from the area, resulted in depletion of ground water table and intrusion of seawater. When water level of the area goes down, Kanjiramukkupuzha and Kanolicanal were affected by salinity intrusion. Hence water in these streams became contaminated throughout the year and this facilitated intrusion of salt water in near by wells, though they are located far away (more than 3km) from the sea. Another reason for intrusion of salt water to the streams was destruction of vented cross bars (cheeps) located in several places of Kanjiramukkupuzha and Kanolicanal. These cheeps were good barriers for preventing the entry of salt water in ancient days.

Even though there are 4700 open wells in the area, about 74 percent of the population is depending on pipe water for drinking purpose. There are about 750 house hold water connections and 500 public taps in Ponnani municipality alone. Availability of pipe water was also at stake as there will not be any water supply for about 10-15 days a month. Most of the time pumping was carried out late at night due to shortage of voltage during daytime. This not only caused difficulty for the people in collecting water but also wastage of water through faulty pipe outlets.

In Ponnani municipality, majority of the wells were located close to the septic tank due to limited space. Also some of the wells were located within the premises of the cemetery in this region. As a result, well water in this area is becoming more contaminated. The well water on the banks of Kannoli canal is not suitable for domestic purposes due to the deposition of house hold waste and hotel waste into the canal. Water related disease like cholera (in rainy season) and dysentery (in summer season) were found very common in Ponnani because of the consumption of highly polluted water. About 30% of the wells were dried up in the region during April-May months. It was observed that more than 60% of people in the region were lacking drinking water for a period of more than 6 months in a year. Rain water harvesting methods so far not adopted in this area. About 40 % of the population is using pump sets (0.5-1.0 HP) for domestic as well as agricultural purposes. Though water logging is experienced for more than 75 percent of the population, any drainage facilities or soil and water conservation practices were not adopted in the region. The average depth of well recorded in the region is shown in Table 4.14

Table 4.14 Average depth of well

Sl. No.	Depth (m)	Percentage of wells
1.	2-4	10
2.	4-5	71
3.	5-6	7
4.	6-8	9
5.	>8	3

4.4.4 Health and Sanitation

The details of hospitals and health care institutions in the region are shown in Table 4.15

Table 4.15 Details of hospitals and health care institutions

Sl. No.	Particulars	Government sector Nos.	Private sector Nos.	Total Nos.
1.	Alloppathy	3	2	5
2.	Dental hospital	-	1	1
3.	Ayurvedic	1	3	4
4.	Naturopathy	-	1	1

The diseases such as intestinal, dental and bronchitis were very common in this region as else where in Kerala. The major diseases found in Ponnani are philariasis and water born diseases. There is one leprosy eradication centre and one philaria eradication centre located in Ponnani. During 1996-97, about 10,500 cases were reported in the taluk hospital in Ponnani affected by water born diseases.

The involvement of voluntary organizations such as Muslim Service Society, M.E.S., Jesis, Pramot, Selas and Piaka are be very helpful to the local people for their health care. Ponnani was the first ‘rabies free’ municipality in Asia, which was a joint venture of Ponnani municipality and Jesis through the programme called ‘zero rabies’. One of the major problems identified during field survey was lack of sufficient staff and equipment in taluk hospital, leprosy eradication centre philaria eradication centre.

Sanitation is an essential component for a healthy life. Availability of latrine and drainage facilities and disposal of sewage are the necessary arrangements to protect public health. The survey conducted in the area reveals that more than 30 percent of the population was not having proper latrine facilities. Non-availability of fund and space for latrine were the reason for lack of toilet facilities for one third of the population.

About 6250 houses in Ponnani municipality were closely located without enough space for disposal of wastes. Wastes from houses, hotels, hospitals, factories, coir mills and fish and meat markets were accumulated on roads and other public places. No scientific methods of waste disposal were adopted by the municipality so far. Due to the lack of sufficient latrine facilities for 30 percent of the population human wastes are deposited on public places and even in canals. Another reason observed for contamination of well water in the area was the nearness of wells to septic tanks and cemetery, due to the lack of sufficient space and awareness of the people. Philariasis, which spreads through mosquitoes, was one of the major problems found in Ponnani compared to other parts of the state. Water logging in drainage channels due to its unscientific construction, formation of small water bodies in low lying areas of coastal region during rainy season, accumulation of waste water from houses and hotels, open over head tanks, holes in the lids of septic tank, absence of net on the riser pipe of septic tank etc... were some of the reasons for the drastic growth of mosquitoes in the area. Unscientific methods of fish drying and disposal of waste from fruits and vegetable shops to roads and canals cause the increase in population of bees and microorganisms. More over, the outlets of toilets and drainage system of houses located on the banks of Kannoli canal were drained into the canal. These factors were adversely affected the quality of well water in the region.

The field level survey and interaction with local people reveals that salinity intrusion and contamination of well water has enhanced by the following major changes occurred in the past ten years.

xii) Drastic increase of population density (population density of the region is 5555per square kilometer)

xiii) Over exploitation of ground water by digging more open wells to meet demand of the growing population.

xiv) Transformation of paddy lands for other purpose (in Ponnani municipality alone, paddy cultivation has reduced to 6 ha from 104 ha during the past 30 years).

xv) Filling up of ponds, natural streams in between the dry lands and other water storage structures.

xvi) Out migration of sacred groves and other soil and water conservation plants such as vetiver, *panthanus* etc.

xvii) Damage/removal of vented cross bars (cheeps) in Kanjiramukkupuzha and Kannoli canal.

xviii) Lack of proper repair and maintenance of the vented cross bars (cheeps) across the natural streams flowing in between the dry lands in Kadavanad, Biyyam and Puzhambram region

xix) Water logging in low lying area during monsoon season due to the filling up of natural drainage channels.

xx) Lack of proper toilet facilities for about 30 percent of population in Ponnani municipality.

xxi) Accumulation of waste from houses, hotels, factories, hospitals, coir mills, fish and meat market, fruits and vegetable shops, fish drying yards etc. in roads, Kannoli canal and other public places.

xxii) Exposure of outlets of toilets and drainage system into Kannoli canal from the houses located on the banks of canal.

xxiii) Digging open wells very close to septic tank and cemeteries due to the lack of awareness and limited space.

4.5 Alternate strategies for better utilization of the available water resources.

The intrusion of salt water into fresh water supplies has become cause for concerned within the last century and the population in the coastal area has risen sharply and placed greater demands on fresh ground water reserves. Salt water intrusion causes many problems in these areas, perhaps the most severe being the limitation of potable drinking water. The drinking water standards established in 1962 requires that drinking water should not contain more than 500mg/l of total dissolved solids (TDS), a common measure of salinity. Seawater contains approximately 30000mg/l of TDS. Therefore, it is evident that even a small amount of seawater can cause drinking water problems when mixed with fresh water reserves. Also, salinity in irrigation water can be detrimental to agriculture, reducing yields and killing crops with low tolerances to salt. Salt-water intrusion becomes a problem in coastal areas where fresh water aquifers are hydraulically connected with seawater. When large amounts of fresh water are withdrawn from the aquifers, hydraulic gradient encourages the flow of seawater towards the pumped well or wells. This will be increased if sufficient recharging of ground water is not take place.

In the present study, a major cause for salt-water intrusion was the changes both social and geographical occurred in the region due to the increased population pressure in the past years. Our intension is to reduce the extent of salt-water intrusion and contamination of the available ground water resources in the region. To achieve the goal, the following suggestions were put forth in the light of the study conducted in the region.

4.5.1 Rainwater harvesting.

Rainwater harvesting is the simple, easier and cost effective method to get sufficient water for domestic and other purposes. There are several methods to harvest the rainwater. One method of rain water harvesting is to adopt suitable land management works such as rain pits, trenches, terracing etc so that the rain water will collect in this structures and allow it to infiltrate to the ground. That is, catch the water where it falls. Rainwater can also be harvested by planting suitable plants such as vetiver, *panthanus* and other grasses, which can prevent soil erosion. Another method of rainwater harvesting is roof top rain water harvesting. The roof top rainwater harvesting can be done either to recharge to the ground water or to collect the water in a separate structure/tank made for this purpose. In order to recharge the ground water, the rooftop rainwater will be collected and guided into the recharge pits or into the abandoned well. The sketch of a recharge pit into which the roof top rainwater can be guided is shown in Fig 4.14. One of the major reasons for saltwater intrusion in coastal region is the depletion of ground water level due to the excess drawing of fresh water form the area for our domestic and other purposes. The encroachment of salt water can be reduced if sufficient ground water recharging is done. By harvesting the rainwater, either through the traditional methods such as rain pits, trenches, terracing and agrostology or through guiding the roof top rainwater into the recharging pits, the ground water table in that region can be increased. The increased water level will retard the encroachment of salt water to that area. These rainwater-harvesting methods can be adopted in all the six study regions viz., Biyyam, Puzhambram, Kadavannad, Chamravattom, Ponnani and Puthuponnani. Chamravattom region is more suitable for traditional methods of water harvesting structures such as trenches and terracing compared to the other five regions.

4.5.2 Roof-top-rain water harvesting structures.

In areas such as Puzhambram, Biyyam and Kadavanad, the area where TDS content in well water is beyond the permissible limit for majority of time in a year, the possible method of getting drinking water is the roof top rain water harvesting structures. Roof-top-rain water has to be collected and guided into storage tanks made up of ferrocement. PVC pipes (4 or 6 inches), divided into two equal halves, can be used as the rainwater guiding structures. The ferrocement tanks can be constructed either as under ground tanks or on the top of foundation provided on the ground. If the ferrocement tank is constructed below the ground, a hand pump can be provided to draw water. Roof-top-rain water harvesting structures with ferrocement tanks having capacities of 10000-100000 liters can be constructed for single house or a group of two or more adjacent house as required. Since the annual average rainfall of the area is 2900mm, it is estimated that an amount of 14500 liters can be harvested from an area of 5 m^2.

4.5.3 Construction of vented cross bar(VCB, cheap)

Vented cross bars (VCBs) or cheeps are the small temporary check dams built across streams such that large volume of water can be stored in the streams during summer period. This will help to maintain the ground water table of the surrounding area in a better level in dry period and thus the encroachment of salt water can be reduced to a great extent. The investigation during the study reveals that VCBs constructed across the Kanjiramukkupuzha and Kanolicanal were destroyed and this enhanced the direct entry of salt water into Puzhambram, Kadavannad, Biyyam and Ponnani region. It is recommended to reconstruct the old cheeps and one new cheep near the Biyyam Kayal. There are some narrow streams in between the dry lands in Ponnani, Puthuponnani and Kadavanad regions and on the sides of Kanolicanal. If cheeps are constructed across these streams, it could to minimize the intrusion of salt water to these regions.

4.5.4 Conservation of sacred groves, ponds, natural streams and other low-lying area.

Ponds, natural streams and paddy fields are considered as good water sources, which help to maintain the ground water table of the surrounding area. Now days, due to the increased population density and demand of land, the old age water sources such as ponds, natural streams and paddy fields were filled and transformed into dry lands for other purposes. Also a large number of sacred groves were disappeared in the past years causing serious environmental problem. The transformation of paddy fields, ponds and other natural streams should be stopped and the present sacred groves has to be conserved in order to recharge more fresh water to ground water reserve and minimize the possibility of entry of salt water to the fresh water zone. It is necessary to renovate the ponds located in the premises of temples and mosques to keep them in better condition for storing large quantity of water.

As the result of investigation the following methods are also recommended for better management of ground water:

i) Controlled pumping to eliminate or reduce over draft to protect water quality. That is, maintain proper balance between water being pumped from the aquifer and the amount of water recharging.

ii) Conjunctive use of surface water and ground water.

iii) Control the number of wells per unit area.

iv) Proper awareness campaign to prevent construction of wells very close to the septic tank and cemeteries.

v) Suitable solid waste management systems has to be implemented in Ponnani municipality in order to avoid the accumulation of waste from house holds, hotel, factories, coir mills and fish and meat markets on roads and other public places.

vi) Necessary toilet facilities has to be provided for the 30 % of the population, who are lacking the facilities at present, in order to avoid the accumulation of human waste in canals (mainly Kannoli canal) and other public places. Latrines can be constructed with common septic tank for 10-15 families in colonies.

vii) Avoid the exposure of drainage channels from septic tanks, houses and hotels into the Kannoli canal.

viii) Provide suitable drainage facilities in low-lying areas to avoid water logging.

ix) Mulching has to be done with plant residues and other organic wastes for coconut and other crops, so that moisture can be retained in the soil during dry periods.

x) For drying of fish, fish drum or '*choola*' has to be introduced to prevent the contamination of air and water through the traditional method of fish drying.

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Appendix I

Calculation of ground water table fluctuation, Ground water utilization and availability of Biyyam region

Table I: Depth to water table below ground level (m)

Well No:	1998								1999												2000	
	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb
1	2.65	0.25	0.30	0.65	0.89	1.57	1.70	1.95	2.20	2.38	2.60	2.95	2.61	0.21	0.41	0.49	0.49	0.95	1.25	1.20	1.21	1.25
2	2.88	0.28	0.35	0.72	0.95	1.60	1.82	2.05	2.30	2.51	2.75	3.05	2.59	0.85	0.43	0.53	0.65	0.86	1.70	1.37	1.38	1.65
3	2.94	0.41	0.45	0.78	1.22	1.85	1.89	1.90	1.92	2.06	2.39	2.62	2.95	0.50	0.52	0.52	0.53	1.15	0.85	1.32	1.25	0.85
4	2.58	0.28	0.30	0.47	0.61	1.05	1.18	1.55	1.73	1.81	1.87	2.21	2.80	0.25	0.26	0.71	0.65	1.15	1.00	0.82	0.97	1.15
5	2.61	0.27	0.30	0.49	0.65	1.03	1.19	1.32	1.50	1.70	2.00	2.19	2.60	0.17	0.29	0.39	0.21	0.70	0.70	0.77	0.80	0.75
6	2.49	0.17	0.18	0.39	1.04	1.50	1.62	1.80	1.90	2.05	2.30	2.44	2.73	0.50	0.70	0.31	0.63	0.96	1.30	1.47	1.47	1.56
Average	2.69	0.28	0.31	0.58	0.89	1.43	1.57	1.76	1.93	2.09	2.32	2.58	2.71	0.41	0.43	0.50	0.52	0.96	1.13	1.16	1.18	1.20

Average water table fluctuation in 1998 = 2.69 - 0.28
= 2.41 m

Average water table fluctuation in 1999 = 2.71-0.41
= 2.30 m

Yearly mean ground water table fluctuation $= \frac{2.41 + 2.30}{2}$
= 2.36 m

Ground water utilization

Ground water utilization = Well density x Avg. withdrawal of water in lpd per well x Area of the zone

Well density = 225/sqkm

Avg withdrawal of water = 550 lpd per well

Area of the zone = 5.90 sqkm

Ground water utilization = 225 x 550 x 5.90

= 0.730125 MCM

Ground water availability

Ground water availability = Mean ground water table fluctuation x Area over which these mean fluctuation occurs x 0.20 (Specific yield)

= 2.36 x 5.9 x 0.2

= **2.7848 MCM**

BLOCK 2 :- Details of family Member

No	Name	Age	Sex	Marital Status	Education	Technical education	Reason for school drop out	Occupation	Receiving pension or not	Persistant Diseases	Handicapped Or not	Annual income

BLOCK-3 Details of land ownership

Sl. No	Name	Survey No	Area (Cent)	Outside or inside the panchayath	Irrigated or not	Major crops										Productivity Of major crops	No.of damaged coconut trees	Annual Income
						Code		Code		Code		Code		Code				
						P	Up	P	Up	P	Up	P	Up	P	Up			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19

P – productive Up – Un productive

(5) Inside; Outside (6) Yes; No (7 to 16) Coconut; Aracanut; Pepper; Tapioca; Banana; Fruit trees; Vegetables; Cashew; Others

(18) No of Coconut trees

BLOCK – 4. Availability of Water

1. Source of drinking water: 1. Pipeline 2. Own well
   3. Public well 4. Tube well
   5. Pond 6. Stream
   7. Neighboring well 8. Others

2. Source of water for other purposes.

3. Method adopted for usage: 1. direct 2. Boiled

4. Drying of well 1. yes 2. No.
   If yes, period of drying

5. Depth of well

6. Scarcity of drinking water: 1. Yes 2. No

7. Whether adapted any rain water harvesting techniques: 1. yes 2. No.
   If yes specify the method

8. Use of pump-set : 1. yes 2. No

If yes H.P.

Time for daily usages the pump set: 1. For Agriculture
2. For domestic

BLOCK 5- Irrigation, Soil and Water Conservation

1. Irrigation: 1. yes 2. No

2. Water Availability: 1. yes 2. No 3. insufficient

3.Water source 1. well 2. pond 3. tube well 4. river/stream
5. Canal 6. Others

4. Irrigation details

Crop	Area (Cent)				Months	Internal	Other details
	Canal	Pipe	Drip	Sprinkler			

5. Whether experiencing water logging problem during monsoon : 1. yes 2. No
6. Whether doing any drainage practice : 1. yes 2. No.
7. Loss (Rs) due to salt water intrusion
   1. Coconut:
   2. Plantain:
   3. Paddy:
   4. Others:
8. Topography: 1. Plain 2. Sloping 3. Mixed
9. Soil conservation practices: 1. yes 2. No.
10. Whether implementing following practices
    Mulching
    Basin preparation
    Terracing stone pitched Terracing
    Rain pits
    Check dam
    Bunding
    Bio degeneration
    Contour trenches
    Others specify

Appendix-II

Structured schedule used for the survey

BLOCK 1 – General Informations

1. Grama panchayath / Municipality
2. Ward number
3. Village
4. House Number
5. Survey Number
6. House Name
7. Name of family head
8. Occupation of family head
9. Religion: 1. Hindu 2. Christian 3. Muslim 4. Others
10. Caste: 1. Backward 2. Forward 3. S.C 4. Others
11. If SC/ST, then residing at: 1. Colony 2. Outside colony
12. Distance from sea shore:

    1. below 500m 2. 500-1km 3. 1-2km 4. above 2km
13. Details of Houses:

    Roof: 1.Thatched 2.Asbestos 3.Tiles 4.Concrete 5.Others

    Wall: 1. *Panamb*/Thatched 2. Clay 3.Wood 4.Brick 5. Others

    Floor: 1. Clay 2.Current 3.Mosaic 4.Marble 5. Ceramic tiles
14. Electrified or not: 1. Yes 2. No
15. Ownership: 1. Own 2. Rented
16. If rented, whether own house in there or not: 1. yes 2. No
17. Having own land but not having own house
18. Not having land or houses.

Table 4.1 Average depth of water table below ground level (m)

Sl No.	Region	1998								1999												2000	
		May	June	July	Aug	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul	Aug	Sept	Oct.	Nov.	Dec.	Jan.	Feb.
1	Biyyam	2.69	0.28	0.31	0.58	0.89	1.43	1.57	1.76	1.93	2.09	2.32	2.58	2.71	0.41	0.43	0.50	0.52	0.96	1.13	1.16	1.18	1.20
2	Puzhambram	3.43	0.59	0.62	0.83	1.31	1.54	1.76	2.07	2.40	2.57	2.83	3.05	1.96	0.80	0.40	0.81	0.85	0.96	1.16	1.20	1.24	1.27
3	Chamravattom	4.35	0.40	0.66	0.94	1.24	1.22	1.46	2.11	2.08	2.83	3.62	4.05	2.08	0.76	0.28	0.64	0.88	1.08	1.10	1.12	1.15	1.19
4	Kadavanadu	1.78	0.63	0.68	0.90	1.28	0.98	1.02	1.11	1.21	1.32	1.48	1.59	1.03	0.69	0.31	0.55	0.80	1.12	1.13	1.22	1.23	1.28
5	Ponnani	2.21	0.85	1.02	1.14	1.34	1.56	1.60	1.64	1.72	1.77	1.83	1.97	1.19	1.00	0.85	0.92	1.12	1.10	1.35	1.52	1.68	1.79
6	Puthuponnani	2.68	0.77	1.10	1.22	1.39	1.59	1.63	1.72	1.78	1.85	1.95	2.09	1.35	1.65	1.03	1.08	1.28	1.35	1.85	1.65	1.78	1.98

Table 4.4 Ground water quality analysis for drinking purpose (permissible limit of each parameter is shown in brackets)

Sl. No.	Region	pH (6.5-8.5)	Suspended solids (30mg/l)	Chlorides as Ca (250 mg/l)	Sulphate as SO4 (150mg/l)	Alkalinity (300mg/l)	Total hardness (300)	From Fe (0.30)	Calcium Ca (75)	Magnesium Mg (30)	E.Coli (10/100ml)
1.	Biyyam	7.9	23.6	148.90	2.1	110.0	250	0.11	56.0	26.84	9
2.	Puzhambram	8.9	12.4	1191.10	1.7	110.0	380	0.10	100.0	31.72	8
3.	Chamravattom	7.4	19.5	85.10	1.9	82.5	140	0.12	32.0	14.60	9
4.	Kadavanad	8.7	16.8	255.20	1.8	110.0	200	0.11	48.1	19.52	24
5.	Ponnani	7.8	25.2	113.00	2.2	82.5	290	0.13	56.11	36.60	36
6.	Puthuponnani	7.5	21.5	141.80	2.0	82.5	200	0.12	44.1	21.96	12

Table 4.3 Total dissolved solids presented in the water samples (mg/l) (Maximum permissible limit is 500 mg/l)

		1998								1999			
Sl. No.	Region	May	June	July	Aug.	Sept.	Oct	Nov.	Dec.	Jan	Feb	Mar.	April.
1.	Biyyam	3800	460	700	760	810	890	910	930	980	1980	3680	3740
2	Puzhambram	990	640	720	740	770	780	790	805	810	825	870	940
3	Chamravattom	880	165	170	178	198	260	280	390	518	605	780	850
4	Kadavanad	2990	415	430	480	550	640	640	645	650	1020	2860	2940
5	Ponnani	690	220	280	305	320	320	335	460	510	530	565	610
6	Puthuponnani	714	110	118	185	280	370	410	495	515	558	595	638

Table 4.5 Ground water availability and utilization pattern

Sl. No.	Name of region	Area Sq. km	Yearly average ground water table fluctuation (m)	Well density per sqkm	Average withdrawal of water l/day/well	Ground water availability MCM	Ground water utilization MCM	Percentage utilization
1.	Biyyam	5.90	2.36	225	550	2.7848	0.730125	26.22
2.	Puzhambram	3.90	2.75	225	410	2.1450	0.359775	16.77
3.	Chamravattom	4.10	3.86	225	1260	3.1652	1.162350	36.72
4.	Kadavanad	2.25	1.22	225	450	0.5490	0.227813	41.50
5.	Ponnani	2.10	1.24	225	520	0.5208	0.245700	47.18
6.	Puthuponnani	2.40	1.49	225	500	0.7152	0.270000	37.75
	Total	20.65				9.8800	2.995763	30.32