Kerala State Council for Science, Technology & Environment

REPORT

ENVIRONMENTAL MONITORING PROGRAMME ON WATER QUALITY

CWRDM

Centre for Water Resources
Development & Management

ENVIRONMENTAL MONITORING PROGRAMME ON WATER QUALITY

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27.05.2009

MESSAGE

I am glad to know that the Kerala State Council for Science, Technology & Environment (KSCSTE) is publishing a report in "Environmental Monitoring Programme on Water Quality" in the State in connection with the World Environment Day 2009. It is an ambitious project undertaken by the Council with the objective to cover all the 44 river basins of Kerala under the water quality monitoring work. The authentic information generated by the study will facilitate the formulation of long term planning and implementation of strategies to combat the problems of poor water quality on life and property.

I congratulate KSCSTE and CWRDM for undertaking the Environmental Monitoring Project on Water Quality and bringing out reports as part of the dissemination of the study results. I hope the study report will be a major milestone in the conservation and development of Water Resources in the State.

V.S. Achuthanandan

FOREWORD

Sustained and equitable development in all walks of life is essential for the survival and growth of all living things. A myriad of environmental problems are being faced by the country at large and the State of Kerala in particular due to ignorance and indifference of those concerned. The attitudes and approach towards the environment has to be changed drastically. Environmental protection and development must be interdependent and indivisible and the resultant issues have to be dealt with scientifically. In keeping with national guidelines on environmental protection and conservation of resources the Government has been taking measures to arrest the degradation of our environment and concurrently to promote the economic development.

The Kerala State Council for Science, Technology and Environment (KSCSTE) has launched the project on 'Environmental Monitoring' with the objective of monitoring the primary components of our environment. The KSCSTE already launched such projects in the area of water quality and soil quality. There is no organised mechanism existing in Kerala on the water quality monitoring informations of various waterbodies. This project on 'Environmental Monitoring Programme on Water Quality for the State of Kerala' aims to generate water quality data and use the same for practical application in the management of water quality.

In this case river basin is taken as the unit for detailed study and in the first phase three river basins of Kerala, viz., Kabbini, Periyar and Neyyar are being monitored. The network is already being expanded to cover 15 river basins which will be further expanded. The programme also focuses on developing water quality indices for different water bodies which can be used to identify the problem areas and also to suggest management action plans.

The KSCSTE is the co-ordinating agency for this major project with Centre for Water Resources Development and Management (CWRDM) as the implementing agency. The Council has also included same educational institutions in the programme so that the students, teachers and their services can be utilised for the project.

I wish to record my appreciation to Dr.M.S.Valiathan, former Executive Vice President of KSCSTE for suggesting this programme. I also congratulate Dr.Kamalakshan Kokkal, Project Co-ordinator, Dr. P.S. Harikumar, Principal Investigator and the entire project team for their sincere efforts to achieve the objectives.

I am confident that the report will be useful for planners, decision makers, scientists and public at large and help the Government in the long term planning for sustainable development of water resources and their utilisation.

Sd/-
Dr.E.P.Yesodharan
Executive Vice President
KSCSTE

Thiruvananthapuram
29.05.2009

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EXECUTIVE SUMMARY

There is no organized system exist in Kerala on the water quality information of various water bodies especially on a river basin approach. The water quality monitoring of the selected water bodies will help the departments and agencies like Kerala Water Authority, Pollution Control Board, Academic Institutions, district administration, local bodies, government departments and public to get information on the water quality status especially in a spatial manner through geographical information system.

The project entitled on **"Environmental Monitoring Programme on Water Quality"** is being co-ordinated by Kerala State Council for Science, Technology and Environment (KSCSTE) and implemented by Centre for Water Resources Development and Management (CWRDM). The outbreak of arsenic problem in West Bengal due to groundwater contamination was an eye-opener to all concerned and was a driving force. In this context, Kerala State Council for Science Technology and Environment, Government of Kerala has initiated the project.

The water quality information systems are being developed to manage the water quality from a point or nonpoint source of pollution. The project on **"Environmental Monitoring Programme on Water Quality"** aims to incorporate water quality data generation and to use the data for practical application for production of usable information to be used in the management of water quality. The water quality monitoring is being done on a river basin scale. Samples are being collected both from surface and groundwater sources. Groundwater sampling stations were fixed after conducting a sanitary survey in the panchayats.

In the first phase of the project, three river basins of Kerala viz. Kabbini, Periyar and Neyyar were monitored. The network has been presently expanded with basins such as Chaliyar, Kadalundi, Meenachil, Karamana, Anjarakandi, Pamba, Muvattupuzha, Bharatapuzha, and Chalakudy. The secondary data already available and primary data which is being generated through different ongoing schemes are also being used.

The project focuses on developing water quality and biological indices for different water bodies, which can be utilised to identify the problem areas and to suggest management action plans.

Biological indicators show the degree of imbalance that has been caused while chemical methods measure the concentration of pollutants responsible. Since biota can integrate the environmental effects of water chemistry, aquatic communities like phytoplankton reflects the average ecological condition and therefore may be used as indicators of water quality. In the above context, as part of the project on Environmental Monitoring Programme on Water Quality, the biological monitoring was invariably included.

The short, fast-flowing, monsoon-fed rivers of Kerala often encounter salinity intrusion into their lower stretches during the summer months. When the fresh water flow reduces, two major problems can encounter in these water bodies: (i) salinity propagates more into the interior of the river and (ii) the flushing of the system becomes less effective. The pollution of the rivers is more severe in downstream. Majority of the Rivers in Kerala has Biochemical Oxygen Demand within 10 mg/l. Bacteriological contamination is one of the major water quality problems of the Kerala Rivers.

We are reporting the salient results of the water quality monitoring of Periyar, Kabbini and Neyyar in the following sections:

Periyar River basin

Water quality analysis indicates that iron, alkalinity and phosphate were on a higher side in the downstream of the river. The Dissolved Oxygen (DO) values varied between 6.27mg/l to 8.47 mg/l. Biochemical Oxygen Demand (BOD) varied between 0.34mg/l & 2.07 mg/l. Bacteriological analysis confirmed the presence of total coliform and E.Coli in almost all the samples. Biological analysis showed the high nutrient enrichment in the downstream towards the Manjummal region (according to the chlorophyll value) and comparatively high pollution index value (Palmer's pollution index) was recorded towards the downstream.

Canadian Council of the Ministers of the Environment (CCME) Water Quality Index of Periyar river was calculated for 34 stations during the four seasons (post-monsoon-2005, pre-monsoon-2006, pre-monsoon-2007 and post- monsoon -2007). Fifteen parameters, which include pH, turbidity, colour, total dissolved solids, alkalinity, total hardness, calcium, magnesium, chloride, nitrate-N, sulphate, iron, total coliforms and faecal coliforms and dissolved oxygen, were used for the calculation.

The index values of most of the stations are in the range of 65-79, which indicates that the upstream part of the River stations have fair water quality, which means that they are occasionally threatened. However, six stations in the downstream showed marginal water quality, which indicate that they are frequently threatened.

Classification of different stations in Periyar River reveals that most of the stations fall under the class C, that implies that the water in these stations can be used as drinking water with conventional treatment and disinfection. About 13 stations are in the class E, and water can only be used for irrigation, industrial cooling and waste disposal.

The results of the study revealed higher concentration of trace metals in surface layers than in deeper ones. The spatial variation of trace metals showed more contamination in the downstream at Pathalam industrial site. The present study highlighted severe trace metal contamination in sediments of Periyar estuary with increased rate of deposition.

Kabbini River

Kabbini River, one of the three east flowing rivers of Kerala, is an important tributary of the river Cauvery. Kabbini and its tributaries constitute a powerful river system in the landscape of Wayanad.

CCME WQI for Kabbini River indicates that none of the samples is coming under excellent water quality (range 95-to 100)). Thirteen samples had values between 80 and 94 reflecting minor

degree of threat or impairment only. Eight samples had CCME index between 65 and 79 indicating occasional threat or impairment through anthropogenic activity. The WQI indicated that Panamarampuzha, Kabbinipuzha, Byrakkuppa, Choottakadavu Valliyurkavu and Banasurasagar reservoir had minor degree of threat or impairment. At these stations, the Kabbini River receives untreated domestic or municipal effluents.

Neyyar

Neyyar originates from Agasthyakudam hills, flows through Neyyattinkara Taluk and joins Arabian sea near Poovar. It has a total length of 56 kms.

CCME water quality index indicates that 69% of the sampling stations are **Good** in quality. Four sampling stations came under the classification **Fair** ie, samples from Pantha, Spillway, Neyyattinkara-1 and Mavilakadavu. Of these in Pantha and Spillway the rate of flow was very low. Spillway is a bathing and washing area. Neyyattinkara-1 is a waste dumping site and in addition, activities such as bathing and washing take place. Salinity intrusion and faecal contamination are the major problems faced by Mavilakadavu. Two downstream stations (Arumanoor and Poovar Bridge) are coming under the class **Marginal**. This is due to salinity intrusion. Near Poovar bridge, sand mining and faecal contamination due to sewage are the major environmental problems. Poovar Pozhikara-I(bathing and washing) and II (tourism) are under the class **Poor**. Salinity intrusion is the common problem in these areas.

Biological Analysis

The dynamics in the structure and composition of the biota over different seasons is a key to the prevailing ecological and environmental status of the water body. The biological water quality of the water was ascertained through diversity index, Palmer's pollution index, family biotic index and genus richness at various levels. It was observed that the streams receive much stress from sewage and organic effluents. More anthropogenic impacts are reflected by the biota in river Neyyar which is a west flowing river than in Kabbini which is east flowing.

One of the major environmental problems faced by rivers of Kerala is due to the disposal of untreated municipal sewages. This may result in the organic pollution of the rivers. All the calculated indices report the organic pollution in the rivers considered. The algal community structure and their seasonal dynamics indicated the pollution enhancement in rivers after the offset of monsoon rain. In the post monsoon season, the runoff from tributaries and canals joining the river bring organic matter in adequate amounts. The sewage channels also contribute to the organic pollution load in the river. The study points out that Neyyar is more prone to organic pollution compared to that of Kabbini. Neyyar is connected with an elaborate network of canals like Vandichirathode, Kulathoorvaliathode, Maruthurthode, Athiyanurthode, Thalayilthode, Kottukalthode and Venganurthode flowing through residential areas and substantial inflow of organic matter is obvious which is reflected by different levels of biota pertaining in the river. Whereas Kabbini is relatively virgin and it takes more time for the organic contaminants to concentrate in as amount as reflected by the biota. The seasonal variation in the water quality is better affirmed by a biological angle of investigation and it is proved that biotic indices like Diversity index, Palmer's algal genus index, and family biotic index are performing more consistently in assessing the quality status of the river.

Groundwater quality problem of Kerala is mainly associated with bacteriological contamination, which is found to be in more than 90 % of the open wells, is due to the interference of man. The load of untreated sewage and solid waste is also contributing to the pollution of groundwater. Other localized water quality problems are associated with excess iron, chloride low pH and excess fluoride. In the shallow aquifers of some coastal areas, salinity problems are reported. Problems due to industrial effluents, burial grounds, municipal landfills, municipal sewage etc are seen in a few locations of Kerala.

Managing and protecting surface and groundwater is essential for sustaining life. A continuous water quality monitoring program and proper water safety plan are essential to preserve and improve the water quality.

Chapter 1

KABBINI RIVER BASIN

1.1 INTRODUCTION

We are witnessing what must surely be the greatest of all mans struggles – the struggle to control his environment. One of the most important environmental areas is the quality of life giving water. In a place like Kerala gifted with torrential monsoon, water quality concerns have always been sidelined because of readily available good quality water. In a high range station, like Wayanad which is relatively untouched by urbanization and industrialization it is a general belief that there is no undue stress over the water resources therein and this has led to lack of proper attention to quality assessments.

Wayanad has an agricultural economy and has an extensive area under cultivation. The livelihood of the bulk population depends on agriculture and in order to increase the productivity, blind usage of fertilizers, herbicides, pesticides, insecticides, mineral oils, fungicides, acaricides, vertebrate targets, bactericides, seed treatment chemicals, plant growth regulators, rodenticides etc. are in progress for the past so many years. Such indiscriminate activities have led to the deterioration of the terrains environment. The water bodies serve as sinks to these agrochemicals which ultimately reach biomass and have its impact on molecular tissues, organs, individuals and communities. For the sustainable management of water resources the impacts of agrochemicals on the water bodies need to be evaluated time and again. The continuing pollution of surface and groundwater especially with pesticides causes problems not only on the availability of good drinking water but also generate economic and social pressures due to increasing conflicts between land use and the demand for the protection of water resources.

The water quality assessment of the surface and ground water resources of Kabbini river basin is discussed in this report.

1.2 KABBINI RIVER BASIN

The Wayanad district stands on the southern tip of Deccan plateau and the main reason for its chief glory is the majestic Western Ghats with lofty ridges interspersed with dense forest, tangled jungles and deep valleys. The terrain is generally rugged. Of the total geographical area, 78787 ha come under forests. The district is covered by loamy and clayey soils with high base saturation; shows wide variation in depth and texture; the soil is rich in organic content due to thick vegetation. Some basic information on the district are given below.

Latitude and Longitude	:	11^0 26' 28''- 11^0 48' 22'' N and 75^0 46' 38'' - 70^0 26' 11''E
Altitude	:	700 – 2100 m asl
Area	:	2,131 sq. km
Average rainfall	:	2,500 mm per year.
Population	:	786627 as per 2001 census (provisional Figs)

Only 3.79% of the Wayanad is urbanized. Agriculture is the main stay of the economy. The climate, terrain and soil of the area are suitable for growing a variety of perennial plantation crops and spices. The crop raised in the uplands are tea, coffee, rubber, coconut, tapioca, cashewnut, cardamom, ginger, pepper, cassava etc. Paddy, banana and areca nut are cultivated in the plains.

The Kabbini is one of the three east flowing rivers of Kerala. It is a perennial tributary of the Cauvery river and constitutes a powerful river system in the landscape of Wayanad. Kabbini river is formed by the confluence of Panamaram rivulet originating from Lakkidi and Mananthavady rivulet originating from Thondarmudi peak, 6 km north of Panamaram town. Almost the entire Wayanad is drained by the Kabbini and its tributaries, namely, Panamaram, Mananthavady, and Thirunelli before it joins river Cauvery at Thirumakudal Narasipur in Karnataka and thereafter transversing through Tamil Nadu, it finally empties into the Bay of Bengal. The Banasura Sagar Dam is built over a tributary of the Kabbini for the purpose of irrigation and even for meeting the purpose of drinking water requirements of and adjoining areas.

1.3 MATERIALS AND METHODS

The network of sampling stations in the river course was finalised considering the locations of major pumping stations, upstream and downstream locations of discharge of industrial effluents, sewage, major fishing and recreation zones, stretches generally not subject to pollution and the areas of wetland habitats. Samples from few of the identified stations were subjected to biological analysis. In selecting the wells for sampling, Panchayath and Municipalities of different thaluks and also the locational peculiarities were considered. The details of sampling stations are given in Tables 1.1 and 1.2 and locations are given in Figs 1.1 and 1.2. All the water quality parameters were analyzed as per the standard procedure given in APHA (1996). Water samples for bacteriological examination were collected in 100 ml sterilized bottles and were immediately kept in iceboxes, for physico-chemical and pesticide analysis (selected sites). Each sample was collected in 1 litre polyethylene bottle. Six soil samples were also collected in polyethylene bottles during the pre-monsoon season of 2007. It was air-dried and analysed.

Details of number of water samples collected from the basin during the study are furnished below.

Surface water samples:

Pre-monsoon 2006:	21 Nos
Post-monsoon 2006:	21 Nos
Pre-monsoon 2007:	20 Nos
Monsoon 2007:	20 Nos
Post-monsoon 2007:	20 Nos

Groundwater samples:

Monsoon 2006:	125 Nos
Pre-monsoon 2007:	69 Nos

Table 1.1: Details of sampling stations along the river course

Station code	Station	Description
KBS01	Panamarampuzha	Near KWA pump house, pumping for irrigation
KBS02	Mananthavadipuzha	Near KWA pump house
KBS03	Koodalkadavu	Washing, bathing, drinking sources for domestic animals
KBS04	Kuruva Island	Tourist area, forest area, effluent discharge from outside sources
KBS05	Bavalipuzha	Near hydrology project station
KBS06	Kabanipuzha	Near road, paddy field and metal crush factory
KBS07	Byrakuppa	Ferry, sand mining activities
KBS08	SALP school	Downstream of Thirunelli town
KBS09	Thirunelli	Temple-pilgrimage activities
KBS10	Wayanad Wildlife Sanctuary	Inside forest, Thekepally Wild Life Sanctuary
KBS11	Begoor Bridge	Near forest area
KBS12	Mananthavady Town	Upstream of Mananthavadipuzha
KBS13	Choottakadavu	Downstream of Mananthavadipuzha, Housing board
KBS14	Valliyurkavu	Under bridge, temple accompanied by Oottupura and marriage hall nearby
KBS15	Periya	Agriculture area surroundings
KBS16	Panamaram Bridge	Educational complex nearby
KBS17	Muthanga	Near KWA pump house, hydrology project
KBS18	Kalpetta	School, church
KBS19	Vythiri puzha	Bridge
KBS20	Banasurasagar , D/S	Reservoir
KBS21	Banasurasagar Reservoir	Reservoir

1.4 FINDINGS AND DISCUSSION ON RIVER WATER QUALITY

1.4.1 Temporal changes in water quality parameters

The surface water samples were collected during the three seasons, namely pre-monsoon, monsoon and post-monsoon. The samples were analysed and the data complied.

The maximum and minimum concentrations of different parameters are shown in Tables 1.3 to 1.7 Data for five seasons from 2006-2007 (pre-monsoon of 2006, pre-monsoon, monsoon and post-monsoon of 2007) were available for the study.

Table 1.2 Details of groundwater sampling locations

Sl.No.	PANCHAYATH / MUNICIPALITY	NO. OF WELLS SAMPLED	
1	Kalpetta Municipality	4	KALPETTA BLOCK
2	Vythiri	5	
3	Meppadi	5	
4	Pozhuthana	5	
5	Muttil	5	
6	Mooadupainu	5	
7	Vengappally	5	
8	Padinjarethara	5	
9	Kaniyambetta	5	
10	Thariyodu	4	
11	Kottathara	5	
12	Ambalavayal	5	SULTHAN BATHERY BLOCK
13	Nenmeni	4	
14	Meenangadi	5	
15	Noolpuzha	5	
16	Sulthan Bathery	5	
17	Poothadi	5	
18	Pulpally	5	
19	Mullankolly	5	MANANTHAVADY BLOCK
20	Vellamunda	5	
21	Panamaram	5	
22	Edavaka	4	
23	Thondarnadu	4	
24	Manandavadi	5	
25	Thirunelli	5	
26	Thavinjal	5	

1.4.2 Physico-chemical analysis

The characteristics of surface water depend on many factors like atmospheric gases, rock minerals undergoing weathering in the drainage basin, surface water run-off, decomposition products of animal and plant material and industrial and municipal wastes. In a district like Wayanad, experiencing heavy rain fall and with large area under agriculture, the major problems are soil erosion and heavy storm water flows.

Fig. 1.1 Surface water sampling stations along the Kabbini river course

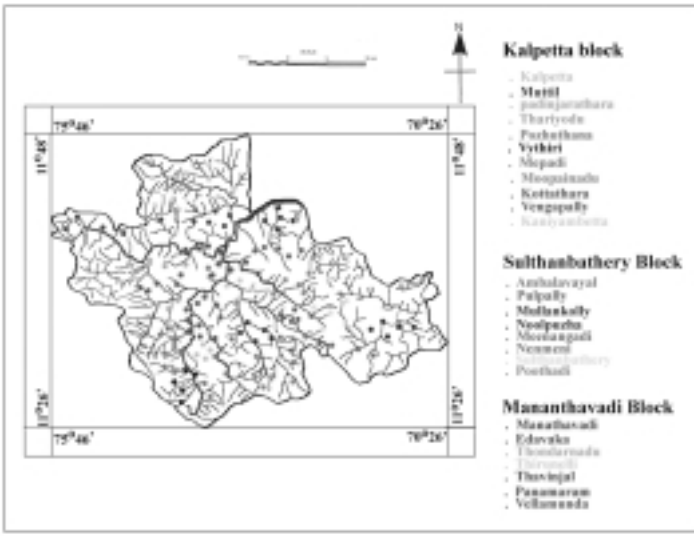


Fig. 1.2: Groundwater sampling locations in the Kabbini river basin

When analysing the physico-chemical and biological data of surface water, it was found that pH during the pre-monsoon 2006 and the post-monsoon 2006 ranged from 7.1-8.2 and 7.3 - 8 respectively. The pH of the samples was comparatively low in the pre-monsoon and post-monsoon 2007 indicating a decreasing trend as shown in Fig.1.3. The values of pH for all seasons were well within the values prescribed by BIS. It can be noted that the water of the river had a pH above 7, at most of the stations, which could be due to the bicarbonate alkalinity. The average pH was found to be 7.3.

Table 1.3: Maximum and minimum concentration values of Kabbini river (Pre - monsoon 06)

Parameters	Minimum	Maximum
Temperature	23.60	32.20
pH	7.10	8.20
EC, (µs/cm)	38.20	283.00
Colour, (Hazen)	3.00	24.00
Turbidity, (NTU)	1.00	8.00
TDS, (mg/l)	16.00	129.00
Total Alkalinity, ($CaCO_3$ mg/l)	28.00	108.00
Total Hardness,($CaCO_3$ mg/l)	20.00	124.00
Calcium Hardness, (mg/l)	10.00	56.00
Calcium, (mg/l)	1.94	16.52
Magnesium, (mg/l)	4.00	22.40
Sodium, (mg/l)	0.01	0.27
Potassium, (mg/l)	1.20	10.40
Iron, (mg/l)	0.20	4.00
Chloride, (mg/l)	8.52	39.76
Sulphate, (mg/l)	0.10	30.40
Nitrate, (mg/l)	0.02	1.77
Phosphate, (mg/l)	ND	0.52
Dissolved oxygen, (mg/l)	4.87	8.00
Biological oxygen demand, (mg/l)	0.20	2.87

ND-Not Detected

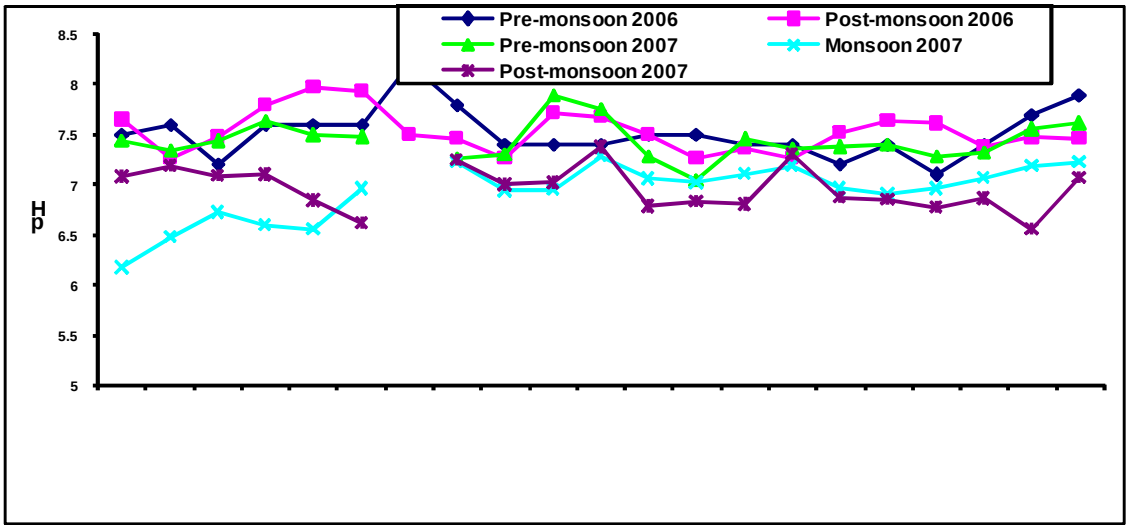


Fig. 1.3: Variation in pH along Kabbini River

Table 1.4: Maximum and minimum concentration values of Kabbini river (Post-monsoon 06)

Parameters	Minimum	Maximum
Temperature	20.40	29.60
pH	7.26	7.97
EC, (µs/cm)	25.80	326.00
Colour, (Hazen)	6.00	27.00
Turbidity, (NTU)	2.00	30.00
TDS, (mg/l)	16.51	208.64
Total Alkalinity, ($CaCO_3$ mg/l)	16.00	80.00
Total Hardness,($CaCO_3$ mg/l)	6.00	118.00
Calcium Hardness, (mg/l)	6.00	60.00
Calcium, (mg/l)	2.40	24.00
Magnesium, (mg/l)	0.49	14.09
Sodium, (mg/l)	2.80	15.20
Potassium, (mg/l)	0.30	2.90
Iron, (mg/l)	0.01	0.14
Chloride, (mg/l)	14.40	71.99
Sulphate, (mg/l)	0.88	9.72
Nitrate, (mg/l)	0.17	1.31
Phosphate, (mg/l)	0.11	0.20
Dissolved oxygen, (mg/l)	6.47	8.40
Biological oxygen demand, (mg/l)	0.40	4.67

Table 1.5: Maximum and minimum concentration values of Kabbini river (Pre - monsoon 07)

Parameters	Minimum	Maximum
Temperature	22.10	33.20
pH	7.05	7.90
EC, (µs/cm)	30.20	363.00
Colour, (Hazen)	1.00	9.00
Turbidity, (NTU)	ND	7.91
TDS, (mg/l)	19.33	232.32
Total Alkalinity, ($CaCO_3$ mg/l)	16.00	100.00
Total Hardness,($CaCO_3$ mg/l)	20.00	132.00
Calcium Hardness, (mg/l)	12.00	60.00
Calcium, (mg/l)	4.80	24.00
Magnesium, (mg/l)	1.94	17.50
Sodium, (mg/l)	3.30	15.30
Potassium, (mg/l)	0.68	5.40
Iron, (mg/l)	0.01	0.55
Chloride, (mg/l)	3.70	29.61
Sulphate, (mg/l)	1.87	7.57
Nitrate-N, (mg/l)	0.10	9.40
Phosphate-P, (mg/l)	0.01	0.53
Dissolved oxygen, (mg/l)	5.00	8.20
Biological oxygen demand, (mg/l)	0.40	4.60

ND-Not Detected

Table 1.6: Maximum and minimum concentration values of Kabbini river (Monsoon- 07)

Parameters	Minimum	Maximum
Temperature	18.60	23.60
pH	6.17	7.28
EC, (µs/cm)	20.60	73.00
Colour, (Hazen)	1.00	25.00
Turbidity, (NTU)	0.75	29.96
TDS, (mg/l)	13.18	46.72
Total Alkalinity, ($CaCO_3$ mg/l)	16.00	116.00
Total Hardness,($CaCO_3$ mg/l)	12.00	56.00
Calcium Hardness, (mg/l)	8.00	24.00
Calcium, (mg/l)	3.20	9.60
Magnesium, (mg/l)	ND	7.78
Sodium, (mg/l)	0.32	16.00
Potassium, (mg/l)	0.80	5.40
Iron, (mg/l)	ND	0.80
Chloride, (mg/l)	5.67	22.69
Sulphate, (mg/l)	0.34	9.36
Nitrate-N, (mg/l)	0.01	0.73
Phosphate-P, (mg/l)	6.10	44.00
Dissolved oxygen, (mg/l)	5.51	11.68
Biological oxygen demand, (mg/l)	3.73	11.08

ND-Not Detected

Plate 1.1: Water sampling of Kabbini river

Table 1.7: Maximum and minimum concentration values of Kabbini river (Post – monsoon 07)

Parameters	Minimum	Maximum
Temperature	20.40	29.60
pH	6.56	7.37
EC, (µs/cm)	27.40	365.00
Colour, (Hazen)	3.00	22.50
Turbidity, (NTU)	1.00	23.00
TDS, (mg/l)	17.54	233.60
Total Alkalinity, ($CaCO_3$ mg/l)	8.00	76.00
Total Hardness,($CaCO_3$ mg/l)	12.00	116.00
Calcium Hardness, (mg/l)	12.00	60.00
Calcium, (mg/l)	4.80	24.00
Magnesium, (mg/l)	ND	13.61
Sodium, (mg/l)	2.80	22.80
Potassium, (mg/l)	ND	5.60
Iron, (mg/l)	0.05	0.59
Chloride, (mg/l)	8.51	28.36
Sulphate, (mg/l)	0.56	13.92
Nitrate-N, (mg/l)	0.39	3.06
Phosphate-P, (mg/l)	0.15	20.90
Dissolved oxygen, (mg/l)	3.46	8.00
Biological oxygen demand, (mg/l)	0.11	4.11

ND-Not Detected

Plate 1.2: Fixing Dissolved Oxygen at Sampling site

Plate 1.3 : Groundwater sampling of Kabbini basin

Plate 1.4: Sanitary survey and groundwater sampling in Kabbini basin

Physical parameters like turbidity and colour showed wide variation in all seasons (Figs. 1.4 and 1.5). The turbidity of the samples was less during pre-monsoon 2006. Only at Panamarampuzha (KBS 01) and Banasurasagar catchment area (KBS 21) showed slightly high values greater than 5 NTU (BIS limit). During the post–monsoon, many sites showed high values (ranging between 2 and 30) (Fig. 1.12). In the post-monsoon 2006 Panamarampuzha, recorded a turbidity of 30 NTU, which is one of the KWA pumping site for drinking water. Turbidity problems were found to be more prominent in the monsoon season. Turbidity of the samples were comparatively high during the monsoon of 2007 (Fig. 1.13) and it decreased during the post-monsoon of 2007. Average turbidity was found to be 5.07 NTU. The color of the samples was found to be on higher side during both the seasons in 2006. Only three stations had low value of colour (5 Hazen) during the pre-monsoon, and no station had a value less than prescribed by BIS for drinking water during the post-monsoon of 2006.There was improvement in colour in the pre-monsoon of 2007. In the monsoon of 2007 the values of colour were again high and maximum was found at Muthanga (25 Hazen units). During the post-monsoon the colour was again high. The colour of the samples was generally high because the river receives considerable run-off from high the lying terrains during the rains, which are very frequent in the region. The average colour for all the seasons is 9 Hazen units. Values above 20 Hazen units were also found at a few stations as shown in Fig. 1.4. In the post-monsoon of 2007 colour varied from 3 to 22.5 Hazen units.

TDS was found to be within BIS limits (500 mg/l) at all stations both during the pre-monsoon of 2006 (16 to 129 mg/l) and the post-monsoon of 2006 (16.5 to 208.64 mg/l). The TDS at the Wayanad Wildlife Sanctuary (KBS 10) was comparatively high in all seasons, except during the monsoon of 2007. It is because this upstream area is a source of drinking water for animals. The average TDS was found to be 45.39 mg/l. The sites which showed high values are identified as centers of developmental activities like tourism, urbanization, paddy cultivation, or the downstream reaches of important discharge stations.

Alkalinity did not show any general trend. The alkalinity values ranged from 28 to 208 mg/l and 16 to 80 mg/l in the pre- and post-monsoon 2006 and it may be noted that all the surface water samples have values within the prescribed BIS limit of 200 mg/l comparatively low alkalinity was found during the monsoon and the post-monsoon of 2007.

During the pre-monsoon of 2006 all the surface water sampling stations had low hardness (ranging from 17 to 60 mg/l as $CaCO_3$). Samples collected from the Wayanad wild life sanctuary (KBS 10) indicate high values of hardness in all seasons. At locations such as SALP School, Thirunelli (KBS 09), Choothatukadavu (KBS 13), Periya (KBS 15), Vythiripuzha (KBS 19) and Banasurasagar reservoir (KBS 21) soft water (0 to 17 mg/l as $CaCO_3$ was found. During the post-monsoon of 2006, samples from stations such as Wayanad Wild Life Sanctuary (KBS 10) showed hard water, and samples from the rest of the places were slightly hard. It was noted that Kabbini river basin generally has low to moderate hardness values which can be due to the nature of weathering of calcarious minerals. During the pre-monsoon of 2006 and 2007, the total hardness was comparatively high, which could be because of the reduction in flow (Fig. 1.6). The average value of total hardness during the five seasons is found to be 22.87 mg/l.

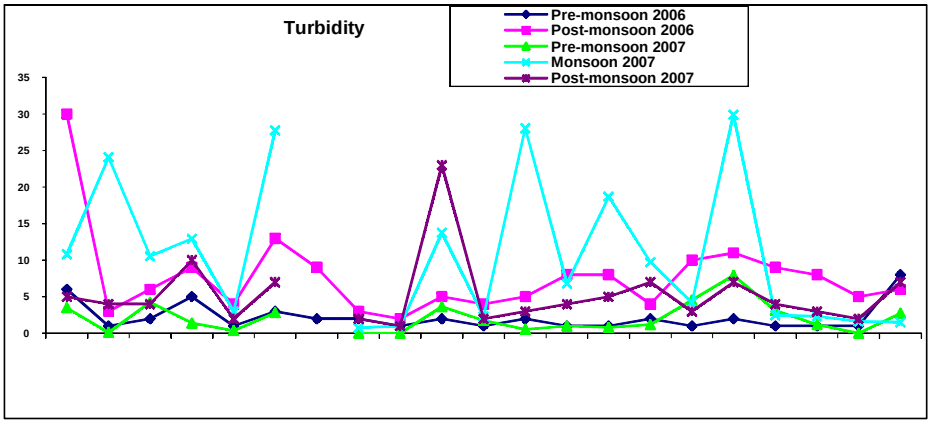


Fig. 1.4: Variation in turbidity along the Kabbini river

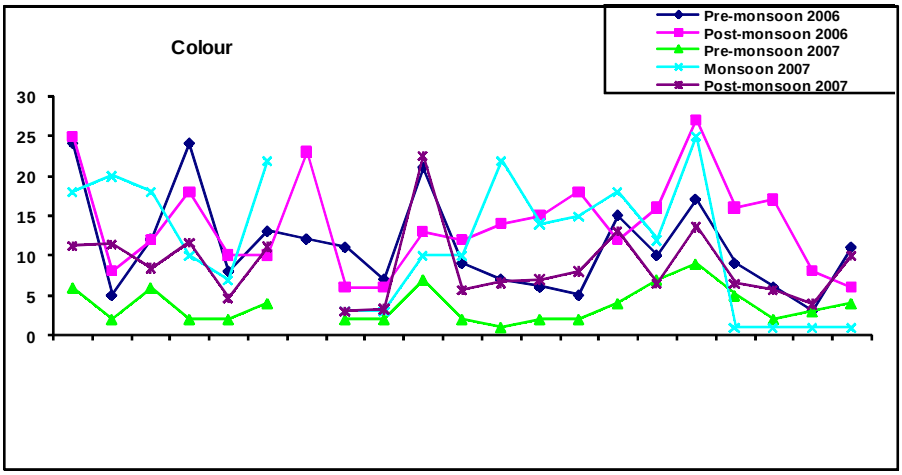


Fig. 1.5: Variations in colour along the Kabbini river

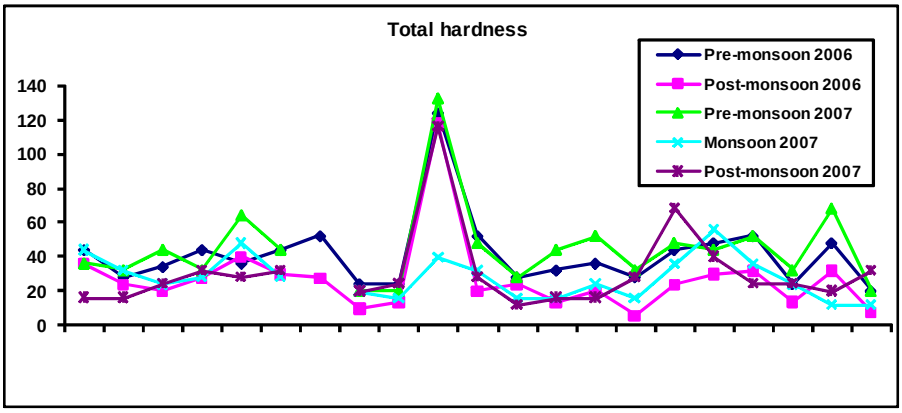


Fig. 1.6: Variations in total hardness along the Kabbini river

The concentration of cations like Ca, Mg, Na, K recorded low concentrations and within the BIS limits during all the five seasons. The average of Ca, Mg, Na, K for the five seasons was 6.67, 4.29, 4.78 and 2.22 mg/l respectively. The concentration of anions like Chloride, Sulphate, Nitrate-N and Phosphate-P was also very low, the averages being 13.9, 3.9, 0.9 and 0.09mg/l respectively. Wayanad Wildlife Sanctuary had comparatively high value of chloride and sulphate (Figs. 1.7 and 1.8).

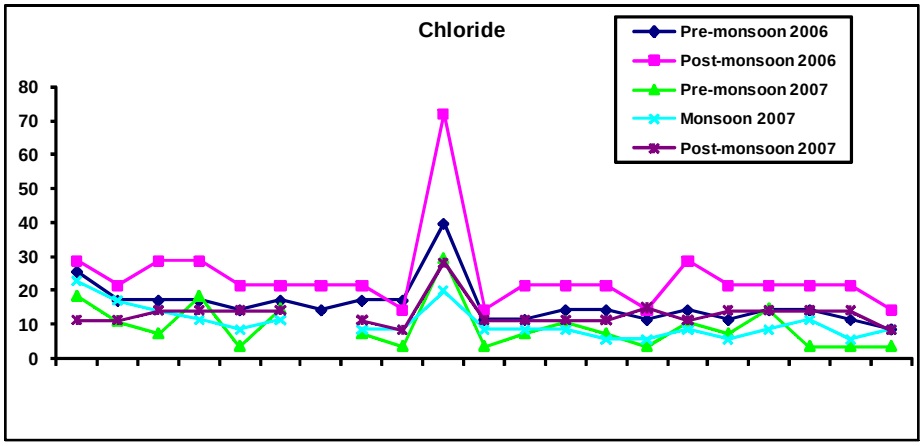


Fig. 1.7: Variation in chloride along the Kabbini river

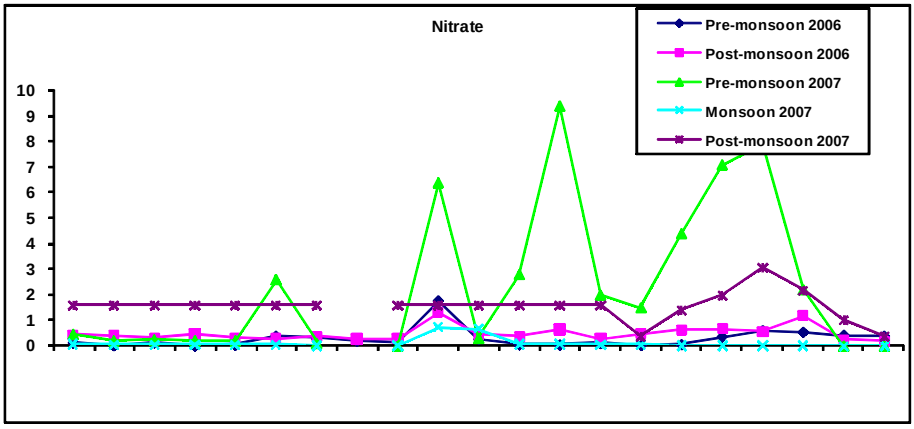


Fig. 1.8: Variations in nitrate-N along the Kabbini river

It is reported (Fig. 1.9) that the concentration of iron is relatively low and ranges from not detected levels to 0.27 mg/l during the pre-monsoon of 2006 and not detected levels to 0.14mg/l during the post-monsoon of 2006. During the pre-monsoon of 2006, only from two sites namely Mananthavadipuzha and Wayanad Wildlife Sanctuary, a concentration of less than 0.3 mg/l was reported. There was no observable trend in concentration, and in the other season's values higher than BIS permissible limits of 0.3mg/l were reported from KBS02-KBS06. The average concentration of iron has been 0.35 mg/l.

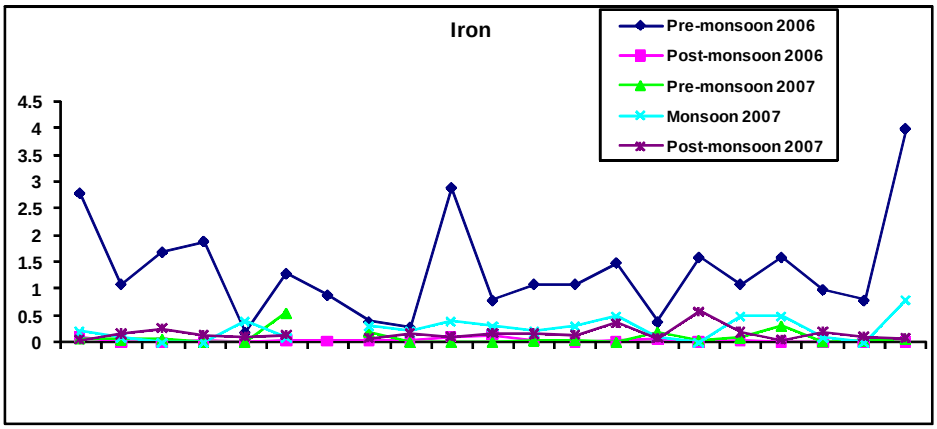


Fig. 1.9: Variations in iron along the Kabbini river

Dissolved oxygen concentration ranged from 5.87 to 8 and 6.47 to 8.4 mg/l during the pre-monsoon and post-monsoon of 2006 respectively. The concentration of DO was greater than 5 mg/l as required for fresh aquatic life in the pre-monsoon and monsoon -2007. During the post-monsoon of 2007, at certain sites the concentration was less than 5 mg/l. Similarly, the biological oxygen demand varied from 0.2 to 2.87 and from 0.4 to 4.67 mg/l during the pre-monsoon and post-monsoon of 2006 respectively. During the pre-monsoon and post-monsoon of 2007 the values were fair but in the monsoon of 2007, the BOD was quite high when compared to other seasons. It could be because of the high organic load in the river as it receives a lot of forest and agricultural runoff in the monsoon.

The microbial analysis showed that during the pre-monsoon and post-monsoon of 2006, 81% and 57 % of the samples reported E.Coli respectively. In 2007, all the samples were positive for E.Coli during all the three seasons as shown in Fig. 1.11.

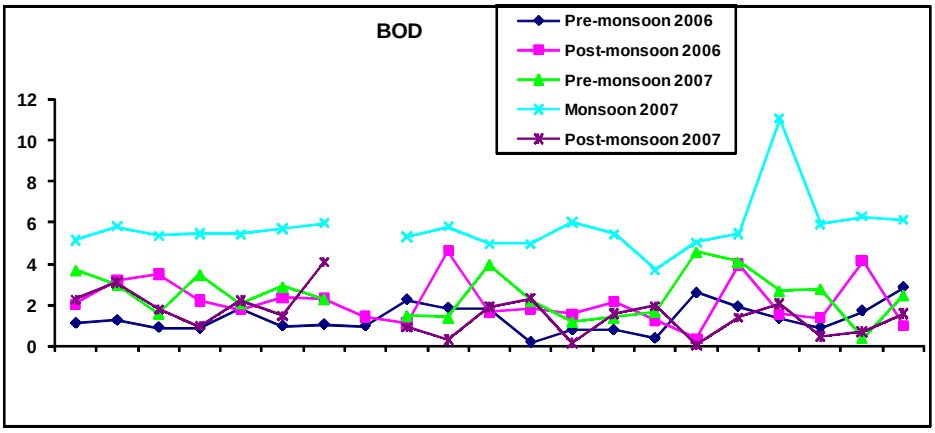


Fig. 1.10: Variations in BOD along the Kabbini river

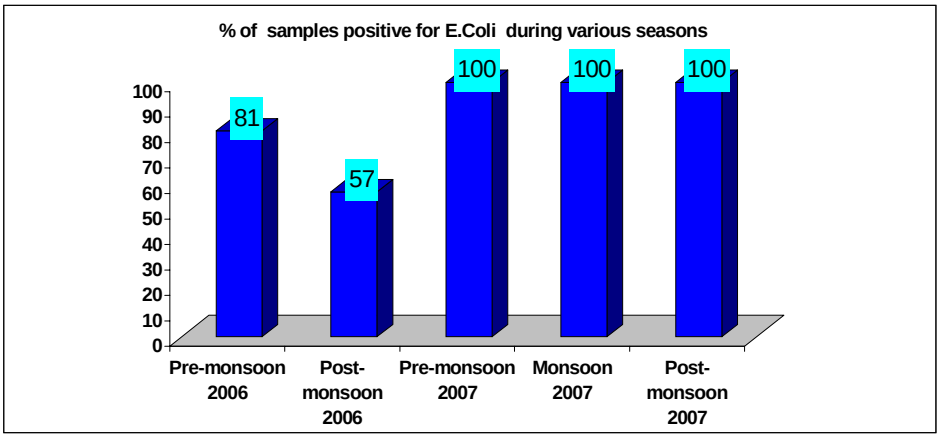


Fig. 1.11: Variation in percentage of samples collected from the Kabbini river- tested positive for E.coli

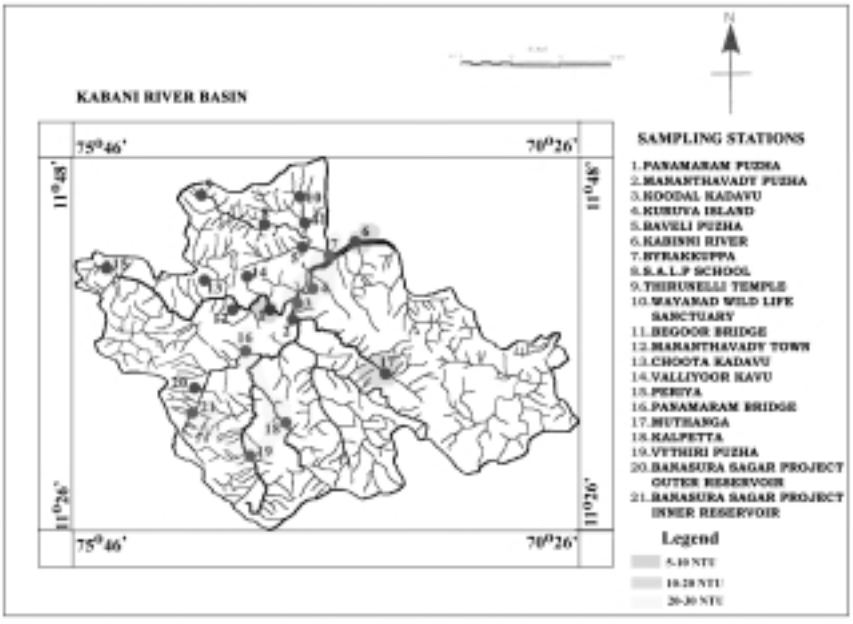


Fig. 1.12: Turbidity at various sampling sites of the Kabbini river during the Post – monsoon 2006

1.5. RIVER WATER QUALITY INDEX

Water Quality Index (WQI) can be defined as a rating which reflects the composite influence of the overall quality of a number of quality characteristics or water quality parameters. Water quality indices facilitate quantification, simplification and communication of complex analytical data. WQI can be used to monitor water quality changes, make comparisons of water quality and to decide the suitability of a particular stretch of water for different purposes. The formulation of

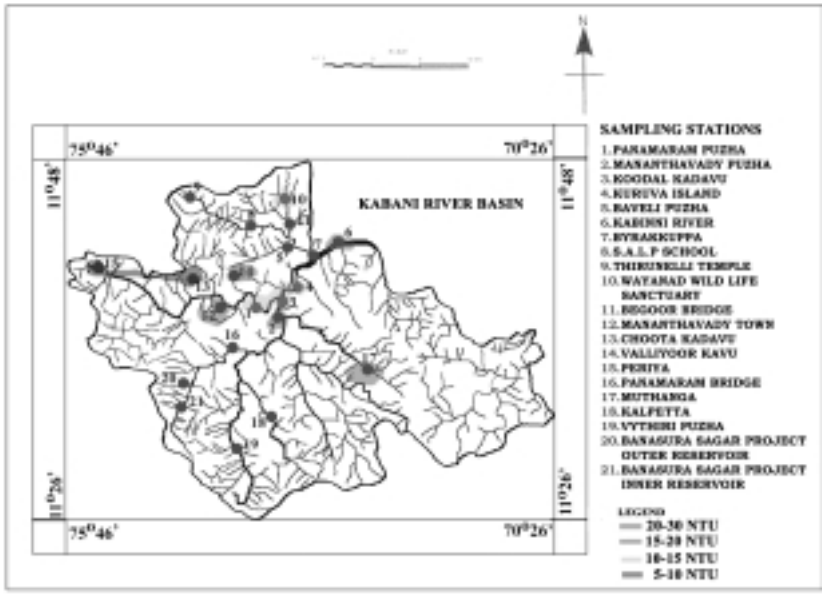


Fig. 1.13: Turbidity at various sampling sites of the Kabbini river during the monsoon- 2007

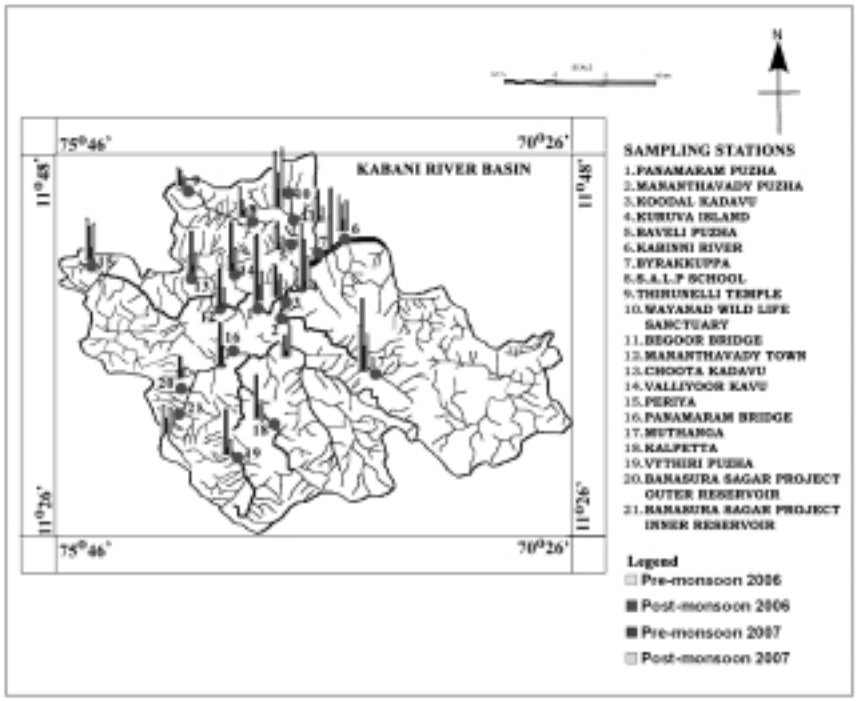


Fig. 1.14: Colour at various stations of the Kabbini river during the pre-monsoon- 2006 and the post-monsoon- 2007

water quality index depends on the intended use of water. The water quality index, which is useful for reflecting the suitability of water for human consumption, is attempted (CCME-Canadian Council of Ministers of the Environment WQI). An attempt has also been made to categorize various sites into the classes recommended by the CPCB, and assign their best designated use.

1.5.1 CCME WQI

CCME WQI was developed in response to the pressure felt by 'Environment Canada' for the consistent, regular and understandable reporting of water quality to the Canadian people. CCME assigns a value between 0 and 100 to reflect the quality of water without undergoing the exercise of weighting different variables that exceed an objective or guideline. The index has the advantage of treating all variables that are retained with equal importance. The CCME WQI has been has been arrived at as per the procedure given in CCME Water Quality Index 1, User's Manual (CCME). The variables selected are assigned a limit either based on the Bureau of Indian Standards or the World Health Organization drinking water standards.

The CCME WQI is based on the following three attributes of water quality, that relate to water quality objectives:

1. Scope - How many? - The percentage of water quality variables that do not meet objectives in at least one sample during the time period under consideration, relative to the total number of variables measured. In the present case a total number of 15 variables were selected.

   F_1 = (Number of failed variables / Total number of variables) x 100

2. Frequency - How often? - The number of individual measurements that do not meet objectives, relative to the total number of measurements made in all samples for the time period of interest. Here it is 44 (Sampled three times) in most of the sites and 45 in three sites.

   F_2 = (Number of failed test/ Total number of tests) x 100

3. Amplitude - The amounts by which measurements that do not meet the objectives departs from those objectives.

   F_3 = Nse / (0.01nse+0.01) ; F_3 is calculated in three steps

   Excursion = (failed test value $_i$ / objective $_j$)-1; when the variable should not be higher than the objective

   Excursion = (objective $_j$ / failed test value $_i$)-1; when the variable should not be lower than the objective

   Nse =" (excursion \ total no. of tests)

   CCME WQI =100-{" (f12+f22+f32)/1.732}

CCME WQI categorizes the water into various types based on the value of the index as given in Table 1.8.

CCME WQI for the five seasons indicates that the river has departed from its natural conditions to a large extent. The comparison of WQI of major stations does not indicate any major variations

The CCME WQI for the five seasons are given in Table 1.8

Table 1.8: CCME WQI for the five seasons

Station Code	Stations	CCME WQI	Specification
KBS01	Panamarampuzha	37.16	Poor
KBS02	Mananthavadypuzha	41.06	Poor
KBS03	Koodalkadavu	38.94	Poor
KBS04	Kuruva Island	37.50	Poor
KBS05	Bavalipuzha	40.70	Poor
KBS06	Kabani puzha	35.92	Poor
KBS07	Byrakkuppa	38.65	Poor
KBS08	SALP School	45.09	Marginal
KBS09	Thirunelli	40.87	Poor
KBS10	Wayanad Wildlife Sanctuary	35.35	Poor
KBS11	Begoor Bridge	41.61	Poor
KBS12	Mananthavady Town	39.14	Poor
KBS13	Choottakadavu	36.23	Poor
KBS14	Valliyurkavu	37.98	Poor
KBS15	Periya	40.61	Poor
KBS16	Panamaram Bridge	35.78	Poor
KBS17	Muthanga	37.84	Poor
KBS18	Kalpetta	37.41	Poor
KBS19	Vythiripuzha	36.06	Poor
KBS20	Banasurasagar, D / S	43.54	Poor
KBS21	Banasurasagar Reservoir	39.05	Poor

(Fig. 1.15). The low value of WQI is due to heavy bacterial contamination and high concentration of water quality characteristics like colour and turbidity. Only SALP School site has marginal quality which also points to frequent threats (Fig. 1.16).

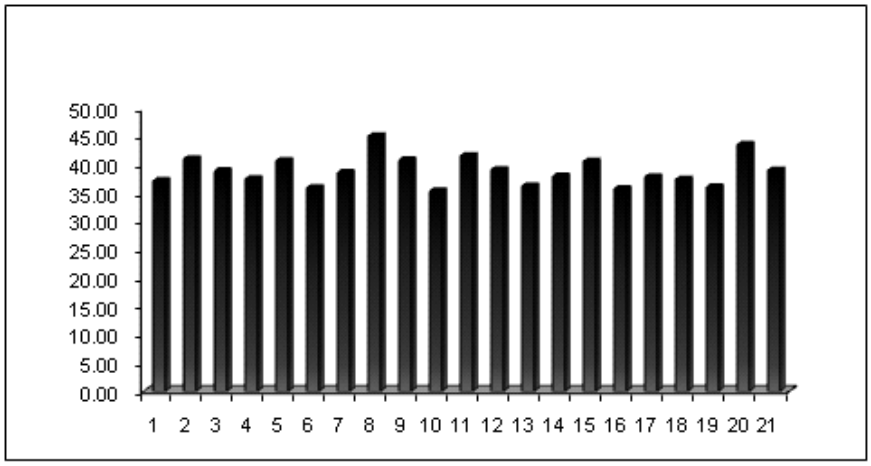


Fig. 1.15: Variations in CCME WQI along the Kabbini river

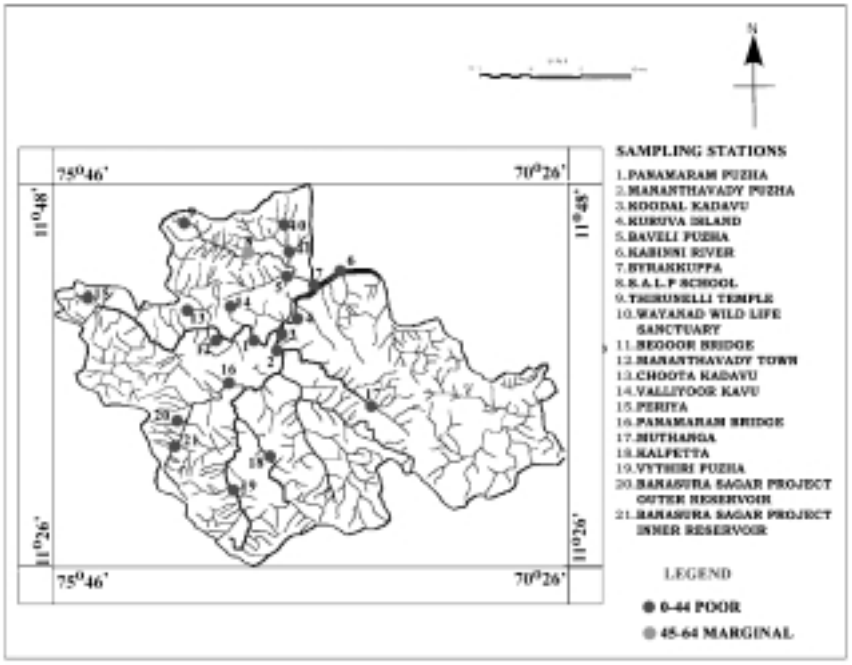


Fig. 1.16: CCME WQI of the Kabbini river

1.5.2 CPCB Classification

The Central Pollution Control Board (1979) has adopted a scheme of classification and zoning of water bodies. The water quality criteria for this classification and the designated best use of each class are given in Table 1.9 and 1.10.

Table 1.9: Scheme for zoning and classification of Indian rivers, estuaries and coastal waters

Designated Best Use	Class of Water	Criteria
Drinking water source without conventional treatment but after disinfection	A	1. Total Coliform organisms MPN/100ml shall be 50 or less 2. pH between 6.5 and 8.5 3. DO 6 mg/l or more 4. BOD 2 mg/l or less
Outdoor bathing (organized)	B	1. Total Coliform organisms MPN/100ml shall be 500 or less 2. pH between 6.5 and 8.5 3. DO 5 mg/l or more 4. BOD 3 mg/l or less
Drinking water source with conventional treatment followed by disinfection	C	1. Total Coliform organisms MPN/100ml shall be 5000 or less 2. pH between 6 and 9 3. DO 4 mg/l or more 4. BOD 3 mg/l or less
Propagation of wild life, fisheries	D	1. pH between 6.5 and 8.5 2. DO 4 mg/l or more 3. Free Ammonia (as N) 1.2 mg/l or less
Irrigation, industrial cooling, controlled waste disposal	E	1. pH between 6 and 8.5 2. EC at 25^0 C µs max. 2250 3. Sodium Absorption Ratio maximum 26 4. Boron, maximum 2mg/L

In pre-monsoon (2006), nine stations could be classified as Class 'B' and 12 stations as Class 'C'. During the post-monsoon (2006) two stations fell under Class 'A', eight under Class 'B' and 11 under Class 'C'. In the pre-monsoon (2007) and the post-monsoon (2007) the quality of the water stretch was worse (Fig. 1.17). All the samples had normal pH; in certain cases DO and BOD were out of range but more severe since majority of the samples were in Class 'C' and 'D'. During the post-monsoon (2007), there was again improvement in the condition of the water stretch. It is the total number of was Coliforms (MPN /100 ml) that is responsible for pushing the stations in to either of the Class 'B' or 'C' 'D' in majority of the cases. It is also noteworthy that certain sites are KWA pumping stations. None of these sites fall under the CPCB class 'A' which implies that water from this source can be used for drinking only after conventional treatment.

Table 1.10: CPCB quality classes for different stations

Station Code	Stations	Class				
		Pre-Monsoon 2006	Post-Monsoon 2006	Pre-Monsoon 2007	Monsoon Monsoon 2007	Post-Monsoon 2007
KBS01	Panamarampuzha	B	B	B	D	B
KBS02	Mananthavadypuzha	B	B	B	D	C
KBS03	Koodalkadavu	B	B	C	D	B
KBS04	Kuruva Island	B	A	A	D	C
KBS05	Bavalipuzha	B	B	C	D	B
KBS06	Kabani puzha	C	C	C	D	B
KBS07	Byrakkuppa	C	C	-	-	-
KBS08	SALP School	C	A	C	D	C
KBS09	Thirunelli	B	C	B	D	C
KBS10	Wayanad Wildlife Sanctuary	C	C	C	D	D
KBS11	Begoor Bridge	B	C	C	D	C
KBS12	Mananthavady Town	C	C	C	C	C
KBS13	Choottakadavu	C	B	C	D	C
KBS14	Valliyurkavu	C	C	B	D	C
KBS15	Periya	B	B	B	C	C
KBS16	Panamaram Bridge	C	C	B	D	C
KBS17	Muthanga	C	C	D	D	B
KBS18	Kalpetta	C	B	C	D	C
KBS19	Vythiripuzha	C	B	C	D	C
KBS20	Banasurasagar D / S	B	C	B	D	B
KBS21	Banasurasagar Reservoir	C	C	B	D	B

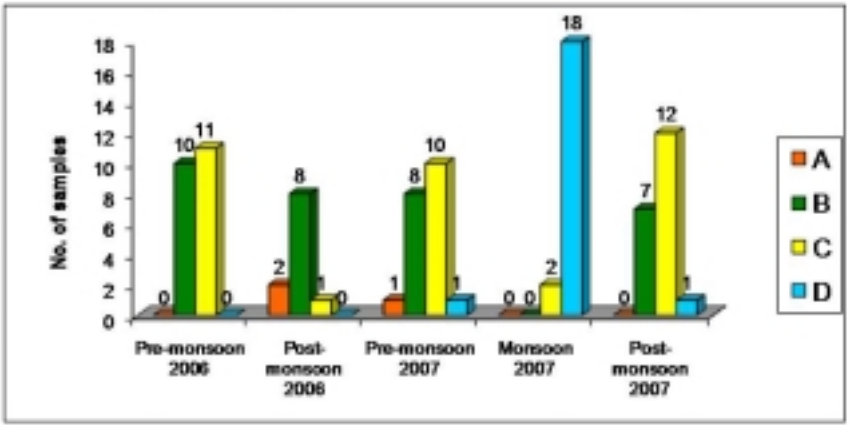


Fig. 1.17: Comparison of number of stations under each class the during the pre- monsoon and post-monsoon

1.5.3 Palmers Algal Genus Index

Palmer has prepared a list of algae tolerant to organic pollution and derived an index to evaluate the organic pollution status of the water. Palmer's modified algal genus index for the periods before and after monsoon is presented in Table 1.11. The variation in the index is graphically represented in the Fig. 1.18.

Table 1.11: Palmer algal genus index at different stations during different seasons

Sl. No	Station	Index Value for	
		Post-monsoon	Pre-monsoon
1	Koodalkadavu	24	30
2	Bavali	13	18
3	Perikallur	28	29
4	Thirunelli	5	12
5	Mananthavady	16	24
6	Periya	17	27
7	Panamaram	16	20
8	Muthanga	18	10
9	Banasurasagar	17	20

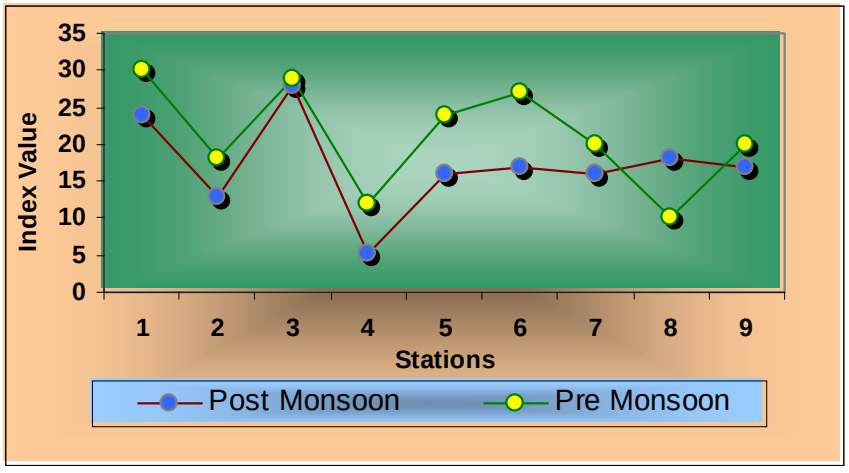


Fig. 1.18: Seasonal variation in the Palmer's algal genus index

Number of pollution tolerant species increases from winter to summer season and a subsequent increase in the index values is noticed, except in Muthanga. The higher index values at Koodalkadavu, Perikallur, Mananthavady, Periya, Panamaram and Banasurasagar denote high organic load at these stations in the pre-monsoon season. At Koodalkadavu, where two major tributaries meet, higher index values are observed in both the seasons. A tendency of the index value to increase in the pre-monsoon season shows the nutrient influx due to the increasing organic load in the stream water.

1.6. BIOLOGICAL ANALYSIS OF RIVER SYSTEM

1.6.1 Data base

Analysis of the aquatic communities along with the background information on the ecological requirements of various species can indicate the conditions of an aquatic environment. Thus the biological aspects of investigation are of vital significance as far as the assessment of the state of aquatic environments is concerned.

In the present monitoring programme, Kabbini river is also studied from the angle of biological quality criteria. The study mainly compared to the pre-monsoon, monsoon and post-monsoon seasons of 2007. A total of nine stations were selected for the study including one reservoir (Banasurasagar), two stations adjacent to townships (Panamaram and Mananthavady) and rest distributed in different regions along the course of the river. The details of the stations selected for biological analysis are given in Table 1.12 and their locations are shown in Fig. 1.19. Sampling was carried out in the post-

Table 1.12: Details of stations selected for biological analysis

Sl. No	Place	Description
1	Koodalkadavu	Confluence of two major tributaries
2	Bavalipuzha	Washing and bathing ghat
3	Perikallur	Sand mining
4	Thirunelli	Virgin area
5	Mananthavady	Township
6	Periya	Virgin stream
7	Panamaram	Township
8	Muthanga	Forest area
9	Banasurasagar reservoir	Reservoir

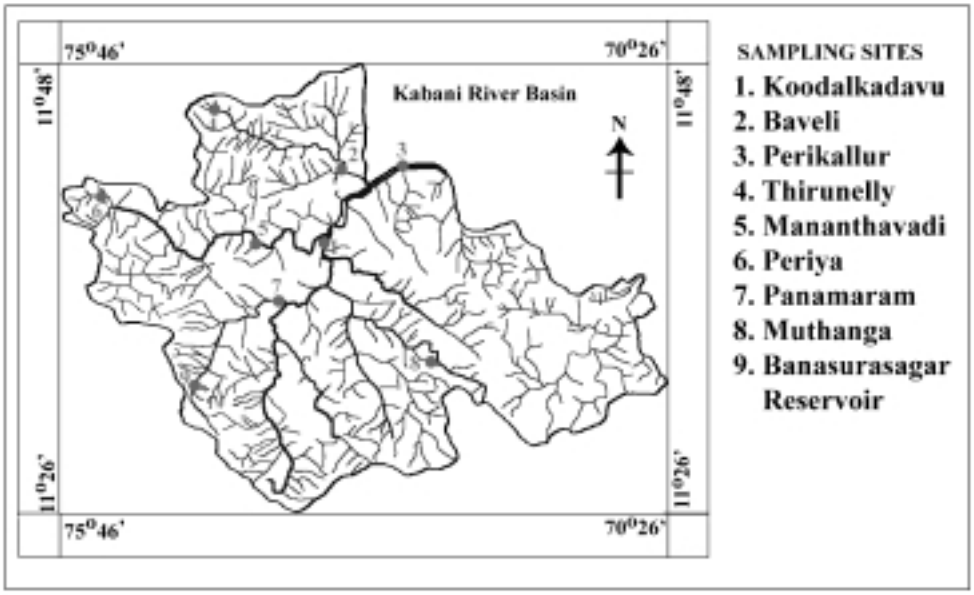


Fig. 1.19: Map showing the locations of biological sampling stations

monsoon (January 2007) and the pre-monsoon (April 2007) and the monsoon (September 2007) seasons. The analysis was carried out following the standard techniques for collection, preservation and identification. A quantitative assessment was done with Lackey's drop method for pre-monsoon and monsoon seasons. Different levels of aquatic biota analyzed are: Phytoplankton, Zooplankton and Macro-invertebrates (benthic organisms), and a comparative biological assessment has also been attempted. The results are interpreted and the areas are characterized and the quality status ascertained in the light of genus richness, abundance and presence of indicator species of different kinds of pollutants.

1.6.2 Phytoplankton

The phytoplankton community is composed of members from *Chlorophyceae*, *Cyanophyceae*, *Bacillariophyceae* and very minor representations from class *Chrysophyta* and *Euglenophyta*. Some species of Diatoms show clear dominance over the others and some environmental conditions prevailing there will be due to the rearrangement of this community. The phytoplankton taxa identified from the river in different seasons are given in Tables. The number of each alga per liter of the sample is given for both pre-monsoon and monsoon seasons.

The variation in the algal community structure in different seasons is diagrammatically shown in Figs. 1.20, 1.21, and 1.22. The percentage of each class to the total number of genera is represented. It is evident that members of *Bacillariophyceae* and *Chlorophyceae* form predominant components in the community. In the monsoon season, with heavy runoff, incidence of *Chlorophycean* and *Cyanophycean* decreases and some diatoms still remain. However, the numerical abundance of diatoms is quite high in both seasons and the diatoms are the dominant class in the algal community of the river.

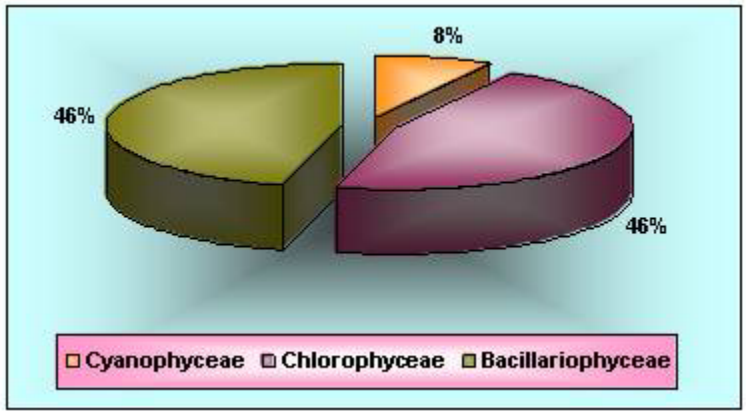


Fig. 1.20: Algal community structure of Kabbini river (post-monsoon- Jan 07)

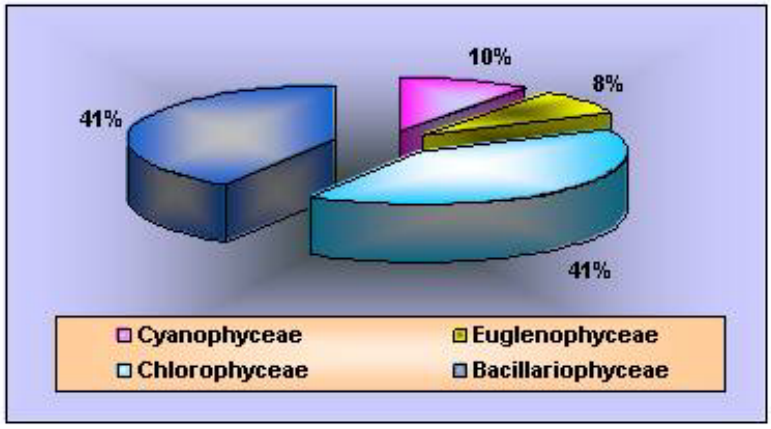


Fig. 1.21: Algal community structure of Kabbini river (pre-monsoon- April 07)

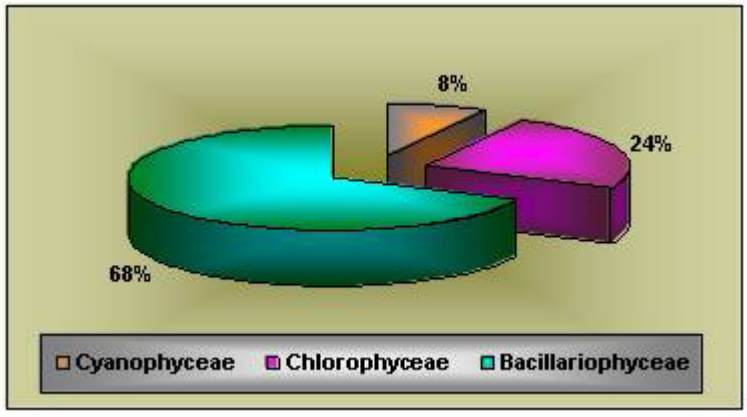


Fig. 1.22: Algal community structure of Kabbini river (monsoon- Sept 07)

The *Cyanophyceae* or Blue green algae genera reported from different stations are Oscillatoria, *Anabaena, Anacystis, Gleotrichia* and *Lyngbia*. The density of blue green algae was maximum during the pre-monsoon followed by the post-monsoon season, and was least in the monsoon season. Density of *Anabaena* and *Anacystis* increases in summer at Koodalkadavu and Panamaram, and it indicates the impact of sewage input at Panamaram. *Anabaena* showed the highest incidence in all the seasons. *Oscillatoria* was reported in the post-monsoon season only. *Gleotrichia* and *Lyngbia* were reported only in the pre-monsoon at Koodalkadavu and Banasurasagar respectively. The high density of blue green algae in the summer season is a clear evidence of the nutrient enrichment in the river. The presence of Euglenophytes also supports this as three genera of Euglenophyta are reported uniquely in summer season. Abundance of *Trachelomonas* is notable at Koodalkadavu, Panamaram and Banasurasagar reservoir which proves the nutrient enrichment and organic load in the water in summer months.

Chlorophyceae, the green algae was represented by a total of 17 species in the pre-monsoon and post-monsoon. A reduced number of 6 species was noted during the monsoon season. A heavy influx of rain water in the monsoon had affected the abundance of green algae. The population was dominated by *Scenedesmus quadricauda, Centritractus* sp, *Cosmarium monomazum* and *Staurastrum chaetoceras* in the pre-monsoon and *Scenedesmu sp., Staurastrum sp* and *Closterium sp* in the post-monsoon season. In monsoon, considerable number of *Staurastrum chaetoceras, Micrasterias sp* and *Tetradon sp* are identified in the Banasurasagar reservoir. The species unique to summer are *Scenedesmus bijugatus, Coelastrum cambricum, Golenkinia sp, Microspora sp, Centritractus sp*, and some filamentous forms like *Oedogonium and Microspora*. At Perikallur, Panamaram, Koodalkadavu, and Banasurasagar reservoir, higher abundance of green algae are found in this season.

Considering the diatoms, most of the genera were reported throughout the year. However, an increase in the total number of individuals had been noted in the summer season. The highest abundance is shown by *Synedra, Asterionella, Cymbella* and *Navicula* at Koodalkadav, *Asterionella* and *Navicula* at Perikallur, and *Cyclotella* and *Melosira* at Banasurasagar. Even during the period of heavy rainfall, considerable number of diatoms was reported from the river. *Nitzschia*, an organic pollution tolerant species, was reported at Koodalkadav in summer indicating organic load in the river. High density of *Asterionella* and *Synedra* also supports this.

In the light of the phytoplankton analysis, the stations given special attention are: Koodalkadavu, Panamaram and Banasurasagar. The phytoplankton community composition of these stations in the summer season is given in Figs. 1.23 to 1.26.

It is evident that the flowing water is populated dominantly by the diatoms. The reservoir, where water is stagnant, green algae has considerable dominance in terms of diversity. Even then, the total number of individuals is far below than that of the diatoms. In the monsoon season also more stable and diverse algal biota was obtained from the reservoir. The percentage of Euglenoid species in the reservoir and at Panamaram indicates the organic enrichment of stream water. The sewage from the minor township may have enhanced the algal growth giving rise to a more stable community. Its impact is also apparent at Koodalkadavu where the stream from Panamaram confluence with that from Mananthavady. A combined effect of the nutrients bought from these tributaries is clearly reflected at Koodalkadavu.

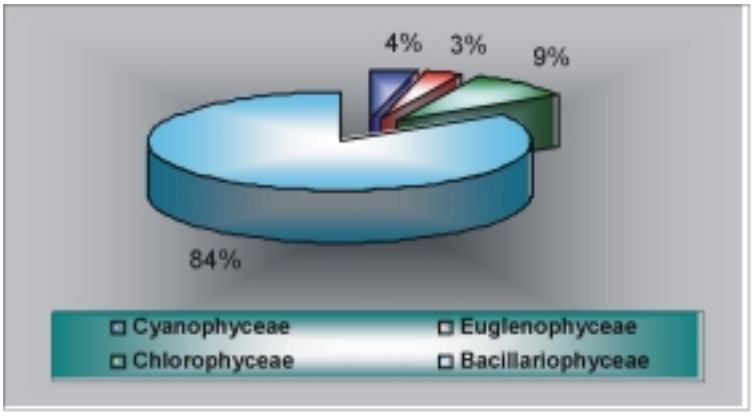


Fig. 1.23: Algal community composition in summer at Koodalkadavu

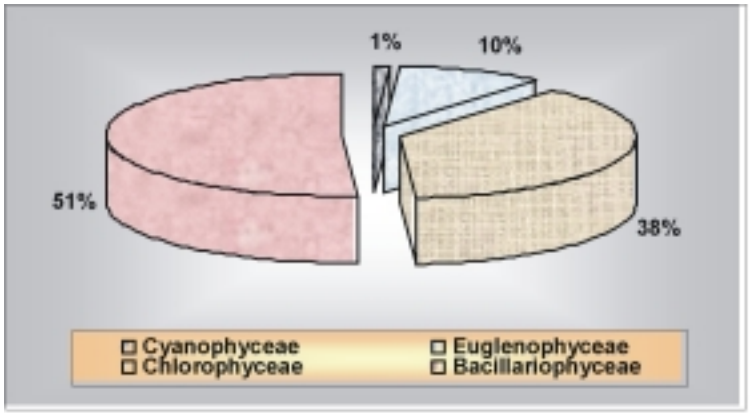


Fig. 1.24: Algal community composition in summer at Panamaram

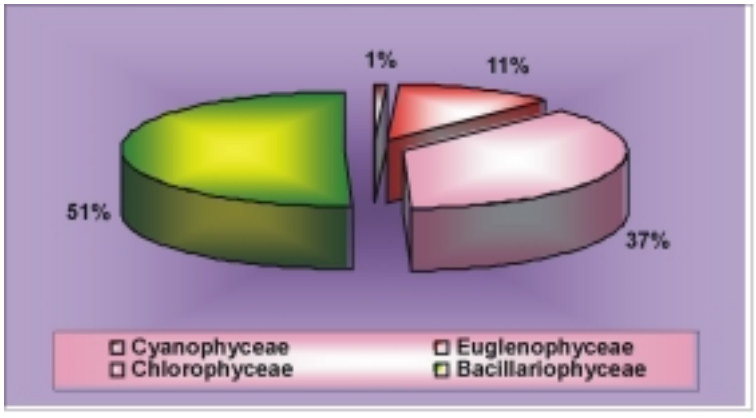


Fig. 1.25: Algal community composition in summer at Banasurasagar reservoir

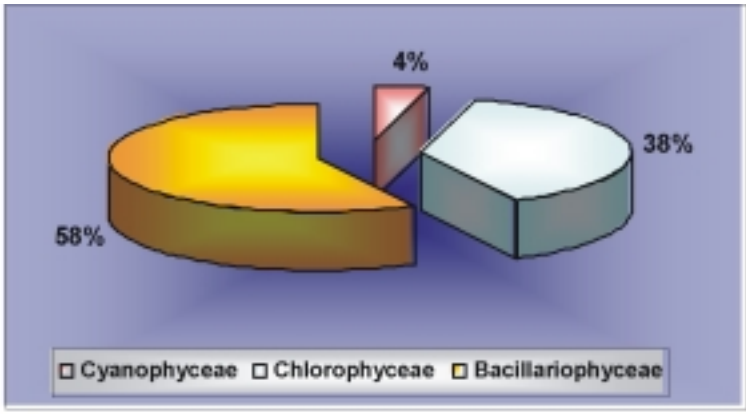


Fig. 1.26: Algal community composition in monsoon at Banasurasagar reservoir

1.6.3 Zooplanktons

Another important component of the aquatic biota is the planktonic animals which are the primary consumers in the aquatic food chain. Their density and abundance is the key to the degree of productivity of the water body. The sample for fauna analysis is collected with the manual technique of filtering 20 liters of water through organdie cloth of 60 micro meter mesh size. The organisms collected from the Kabbini river mainly belongs to Protozoa, *Ciliophora, Rotifera, Ostracoda, Cladocera, Crustacaea* and *Insecta*.

A total of 18 and 13 zooplankton genera were reported in the post-monsoon season and pre-monsoon season respectively. In the monsoon, only seven genera were reported. This pattern shows the variation in productivity of the system. Plenty of Protozoan and Rotifers are found in the post-monsoon season. It is at Panamaram that the highest diversity of animals is noted in the post-monsoon season.

1.6.4 Benthic Macro Invertebrates

The organisms inhabiting the river bed can reflect the quality of the substratum of the water body. They are regarded as the most efficient and informative bio-indicators of water pollution. The benthic community of the Kabbini river in different seasons was identified.

Ten species of benthic fauna were reported in the post-monsoon season which belong to Nemata, Insecta and Mollusca, while eleven were reported in the summer season. In the pre-monsoon, pollution tolerant species of class Oligochaeta are numerous, replacing some insect species especially at the stations where organic pollution is suspected. At Panamaram, *Chironomus* and *Tubifex* are abundant indicating the low oxygen conditions at the bottom of the river as a result of high degree of organic degradation going on. The Goodnight and Whitley index calculated for the Koodalkadavu station shows an increase from 33 in the post-monsoon to 83 in the pre-monsoon, which is a clear indication of the organic matter enrichment in the summer season.

In the present study, it is revealed that the plankton community of the river is always dominated by the class Bacillariophyceae followed by Chlorophyceae and Cyanophyceae, which is characteristic of a dynamic lotic system. It is also observed that at Banasurasagar, which is a reservoir, the class Chlorophyceae shows a characteristic dominance over other classes of planktons. Analyzing the biota, the vulnerable spots identified are Koodalkadavu, Perikallur, and Panamaram. Increase in organic content load is noticed at these stations which are located near the townships and impact of fertilizers may also be a factor. However, detailed information of the aquatic biota of the Kabbini river has been generated which may be useful for further investigations dealing with the biological quality monitoring of the river water.

1.7. SEDIMENT CHARACTERSTICS

1.7.1 Sediment sampling

Sediment samples were collected from six locations and the details are given in Table 1.13.

Table 1.13: Details of sediment sampling stations

Sl no	Sample Code	Stations
1	KBS03	Koodalkadavu
2	KBS05	Bavalipuzha
3	KBS06	Kabani puzha
4	KBS12	Mananthavady town
5	KBS13	Choottakadavu
6	KBS15	Periya

1.7.2 Findings and Discussion

The maximum and minimum concentration of different Parameters are shown in Table 1.14.

The pH of the samples ranged from 7.16 to 7.91 . The maximum value was recorded at the Choottakadavu (Fig. 1.27). The EC values are very low in the case of samples. Koodalkadavu sampling station recorded high value for EC (28 µS/cm). The EC values ranged from 16.4 µS/cm to 28 µS/cm. The alkalinity values ranged from 80 to 140 mg/kg. Choottakadavu had the maximum value (Fig. 1.28).

The chloride values ranged from 450 mg/kg to 850 mg/kg. The maximum value was found at Kabinipuzha (Fig. 1.29). The total hardness values vary from 80 mg/kg to 210 mg/kg. Kabinipuzha station had the maximum concentration for total hardness (Fig. 1.30). The concentration

Table 1.14: sediment samples – Maximum and minimum values (Pre-monsoon -2007)

Parameters	Maximum	Minimum
pH	7.91	7.16
EC,(micro siemens/cm)	28	16.4
Alkalinity, (mg/kg)	140	80
Sulphate, (mg/kg)	1200	145
Chloride, (mg/kg)	850	450
Total Hardness, ($CaCO_3$ mg/kg)	210	80
Total Organic Carbon, mg/kg	0.88	0.08
Nitrate-N, (mg/kg)	340	180
Phosphate-P, (mg/kg)	145.2	24.3
Calcium, (mg/kg)	64	26
Magnesium, (mg/kg)	11	2.5
Sodium, (mg/kg)	29316.5	5683.85
Potassium, (mg/kg)	108.45	42.35
Fe, (mg/kg)	23.05	1.55
Zn, (mg/kg)	2.4	ND

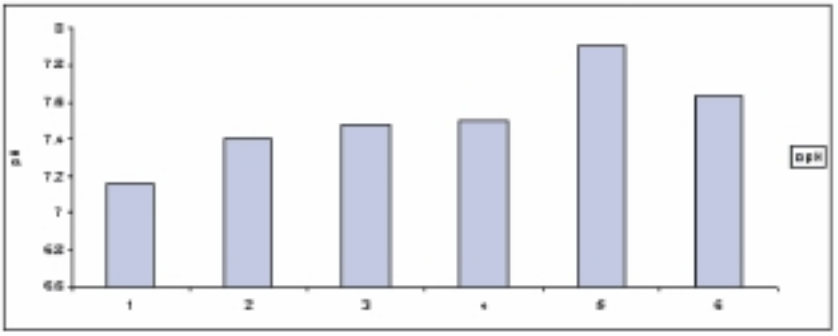


Fig. 1.27: Variation of pH in the sediment samples from the Kabbini basin

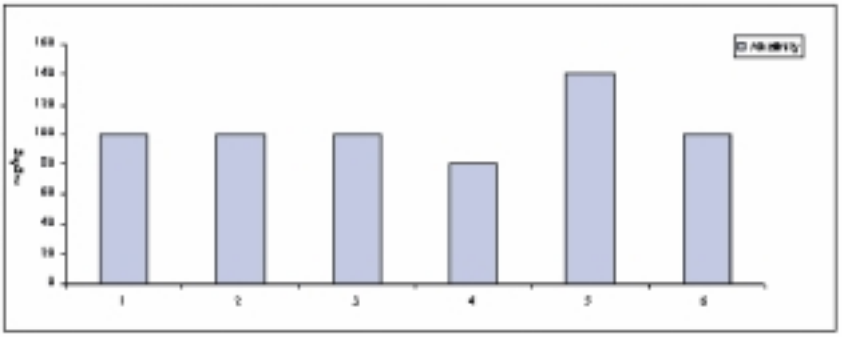


Fig. 1.28: Variations of alkalinity in the sediment samples from the Kabbini basin

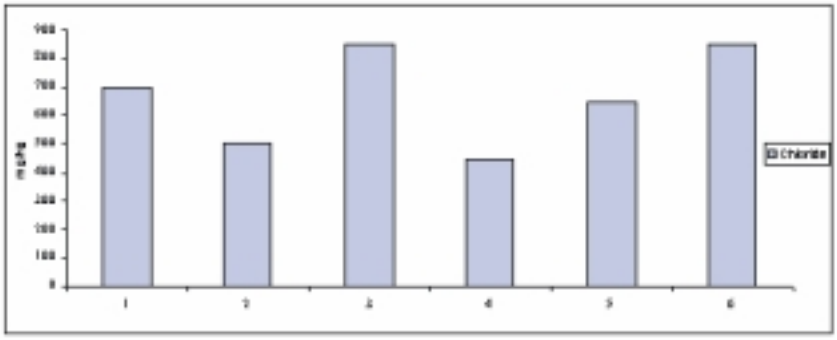


Fig. 1.29: Variation of chloride in the sediment samples from the Kabbini basin

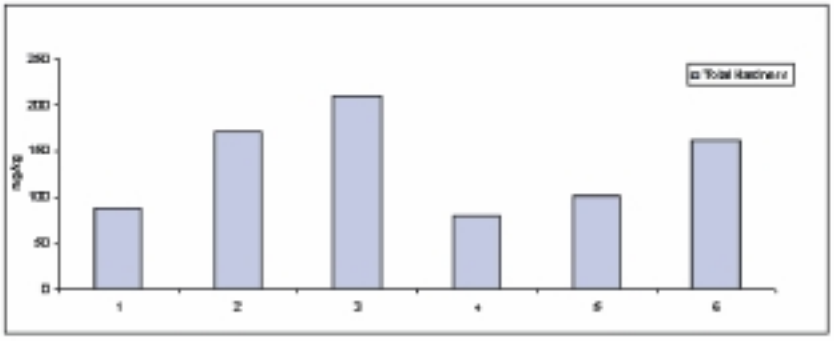


Fig. 1.30: Variations of total hardness in the sediment samples from the Kabbini basin

of Ca ranges from 26 mg/kg to 64 mg/kg (Fig. 1.31). The maximum concentration was found at Choottakadavu. The Mg concentration ranged between 3 mg/kg to 11 mg/kg. The highest concentration was found at Periya.

Na concentration in samples ranged from 5683.85 to 29316.5 mg/kg as given in Fig. 1.32. At Periya the maximum concentration was observed. The concentration of K in samples ranged between 42.35 mg/kg to 108.45 mg/kg. The maximum value was found at Bavali puzha.

The inorganic phosphorus values in samples ranged from 24.3 mg/kg to 145.2 mg/kg. The maximum concentration was found in the sampling station at Periya (Fig. 1.33). The TOC concentration varied from 0.08 mg/kg to 0.88 mg/kg. The maximum concentration was found at Periya (Fig. 1.34). The concentration of Nitrate –N was found to be high in all samples, maximum value of 340 mg/l was found at Kabani puzha.

The heavy metal analysis of the samples revealed high concentration of Fe. The value of Fe ranged from 1.55 to 23.05 mg/l, with an average of 7.69 mg/kg. The maximum concentration was found at Periya (Fig. 1.35).

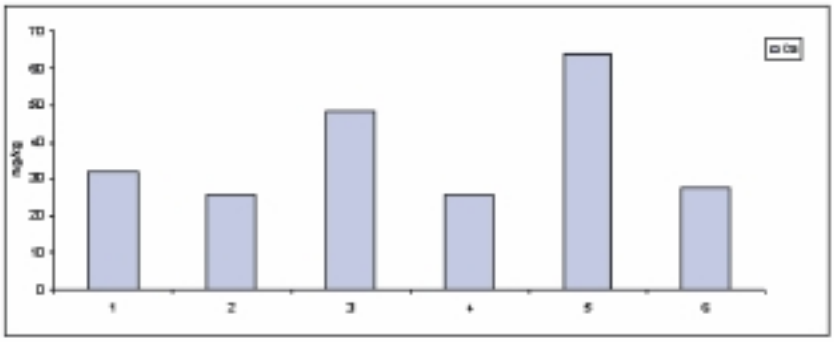


Fig. 1.31: Variations of Ca in the sediment samples from the Kabbini basin

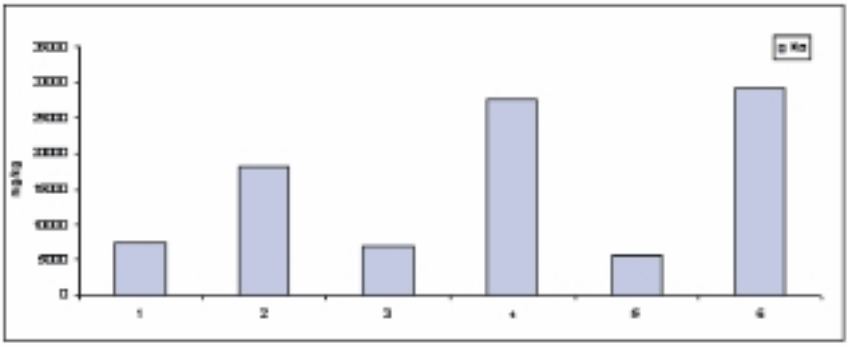


Fig. 1.32: Variations of Na in the sediment samples from the Kabbini basin

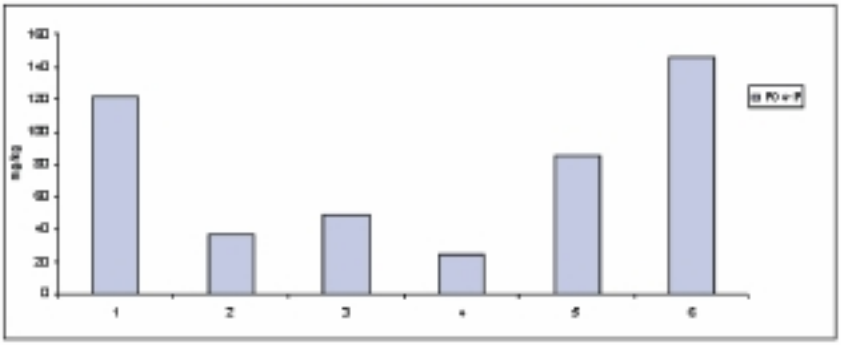


Fig. 1.33: Variation of inorganic phosphorous in the sediment samples from the Kabbini basin

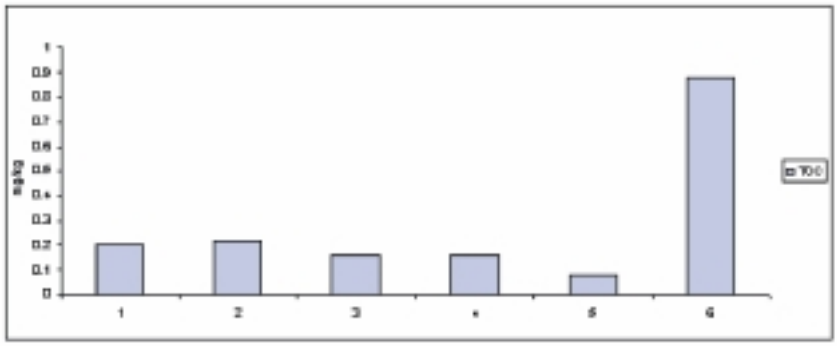


Fig. 1.34: Variations of TOC in the sediment samples from the Kabbini basin

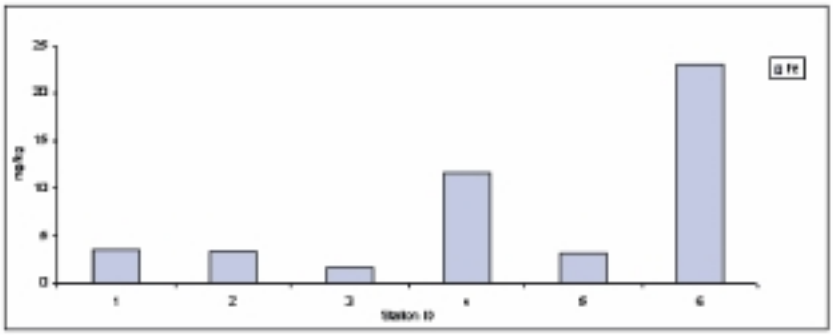


Fig. 1.35: Variations of Fe in the sediment samples from the Kabbini basin

The concentration of Zn varied from 1.65- 2.4 mg/l. The other metals, i.e., Mn, Cu and Pb showed comparatively low concentrations. Their average concentrations were 71.56 mg/kg, 7.69 mg/kg and 2.07 mg/kg, respectively.

1.8. ASSESMENT OF GROUNDWATER QUALITY OF KABBINI BASIN

1.8.1 Surveillance of Sampling Locations

The objective of the surveillance was to collect and collate information regarding the sampling location and its surroundings. This was done to identify specific points of risks to the water body. For this purpose, a questionnaire was prepared containing 44 questions each having quantitative or qualitative significance. The findings of the survey using questionnaire are presented in Fig. 1.36 to 1.49.

1.8.2 Findings of the Survey

Based on the data collected from the entire basin, 90% of the houses have their dugwells either lined with concrete, brick, and laterite or with laterite cutting. Ninety percentages of the households of not face water shortage during the summer and 65% have other sources like streams, dams etc. nearby which keep the water level in their wells high throughout the year.

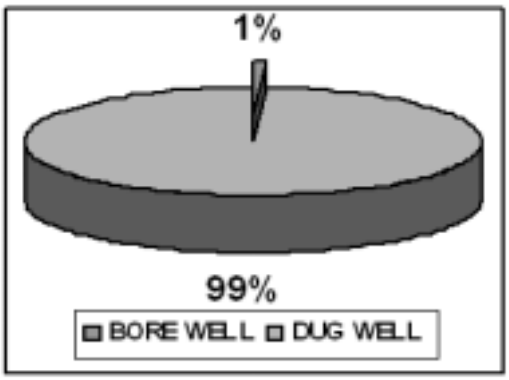


Fig. 1.36: Types of well from which samples

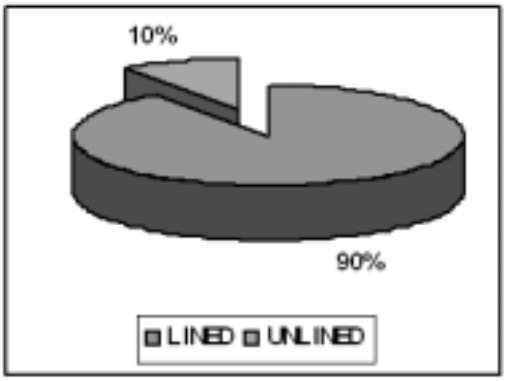


Fig. 1.37: Types of well construction

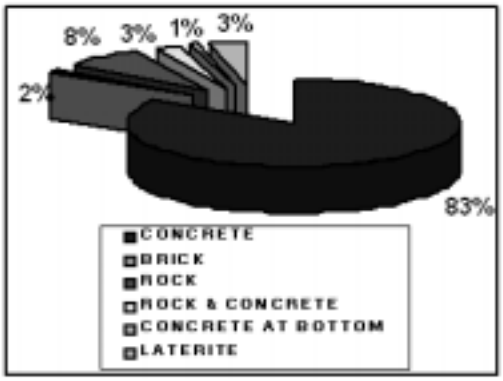


Fig. 1.38: Types of well lining

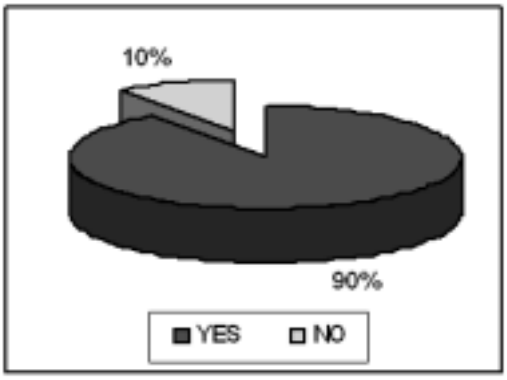


Fig. 1.39: Availability of water Throughout the year

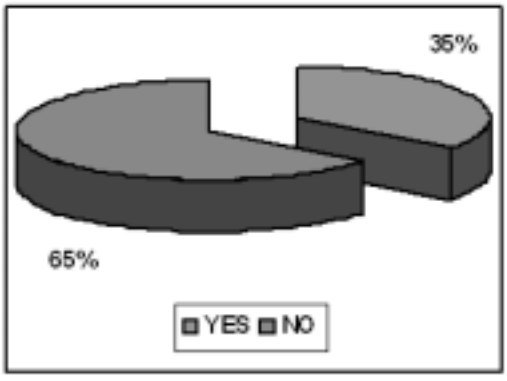


Fig. 1.40: Presence of other water sources near the well

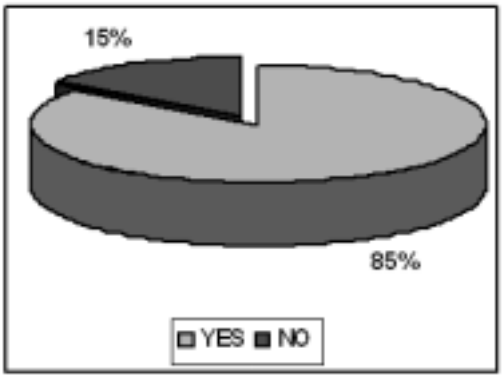


Fig. 1.41: Presence of Cultivated area near the well

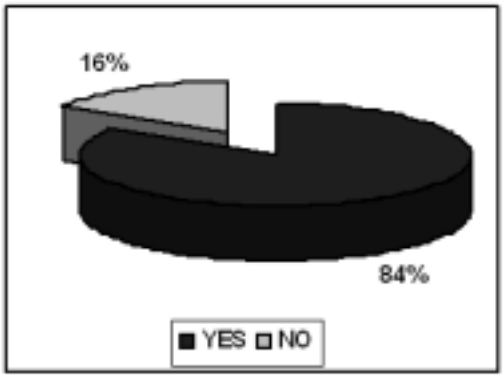


Fig. 1.42: Presence of paddy field near the well

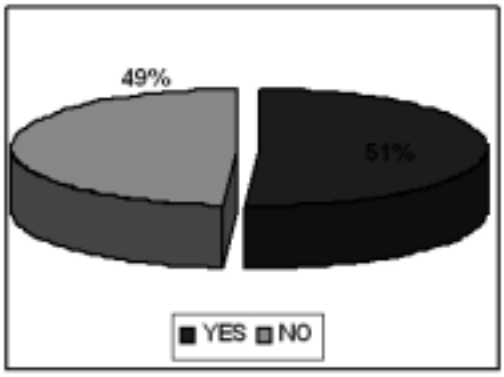


Fig. 1.43: Use of fertilizers

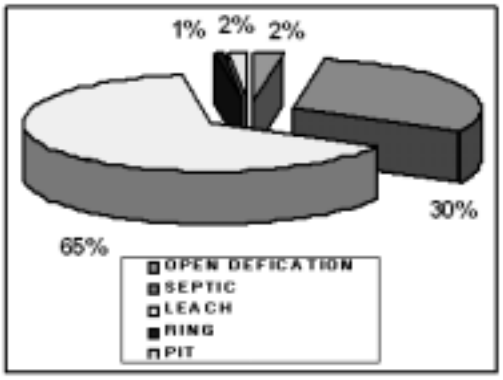


Fig. 1.44: Type of latrine

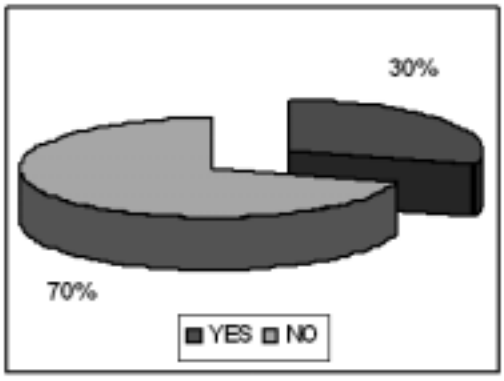


Fig. 1.45: Use of pesticides

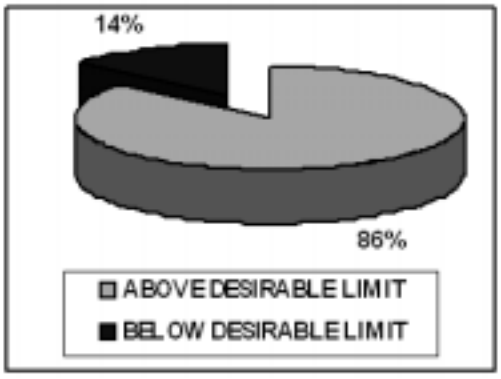


Fig. 1.46: Distance of latrine from the well

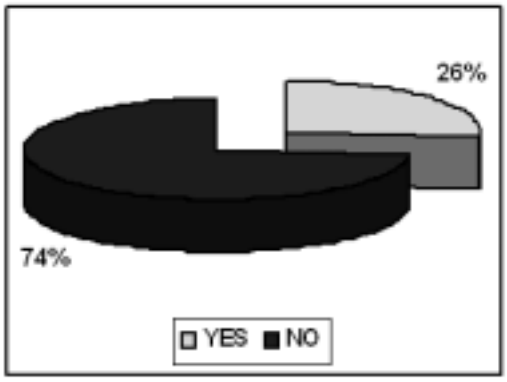


Fig. 1.47: Cattles reared

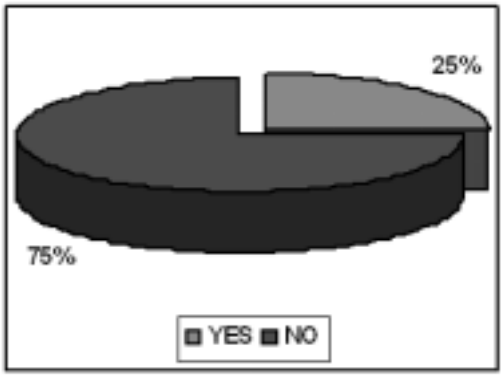


Fig. 1.48: Usage of bleaching power

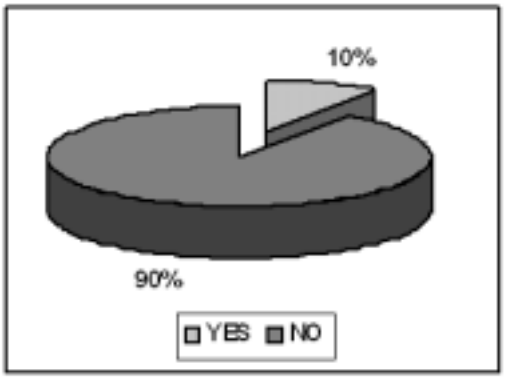


Fig. 1.49: Noticeable changes in quality of water

Eighty five percent of wells are surrounded by cultivated area in the form of paddy, tea, coffee, spices and other mixed crops. Inorganic fertilizers are applied by 51% and at least 30% use pesticides (organochlorines, carbamates or organophosphorous).

Five percent of houses do not have leach or septic/latrine tanks and have only pit type latrines or have to opt for open defecation. Around 14% of the septic, leach or pit type latrines are within the limit of 10 m from the wells. Only 26% families rear cattle.

Generally, the families apply bleaching powder only when the Panchayath supplies them or when they come to know about water borne diseases elsewhere. Twenty five percent of them disinfected the well water during the monsoon. Only 10% of the families admitted having some problems with their well water and none of the families reported any water borne diseases.

In accordance with the analytical data, it is found that the concentration of potassium ion is much higher in certain places than the average concentration of K^+ ions for ground water samples. These are regions of intense cultivation as seen from the survey data. There is a positive correlation between concentration of NO_3^- and K^+ in such regions, but because nitrate is easily assimilated by plants or because of other denitrification processes the concentration of NO_3^- is not prominent.

It is also found that majority of the groundwater samples (85%) have pathogenic contamination because only 25% people bleached their wells during the monsoon season. The problem is severe where the well to latrine tank/pit distance is less than 10 m. Survey data suggest intense use of pesticides and when selected samples were analysed, organochlorine pesticides were detected. These samples were collected from cultivated zones growing paddy, banana, arecanut etc.

1.8.3 Physico-chemical and bacteriological Analysis of monsoon 2006

The maxima, minima and average values of ground water samples during the monsoon of 2006 are given in Table 1.15.

Analysis of the water quality data indicates that pH, nitrate, iron, turbidity, color, total hardness, calcium and chloride are certain critical water quality parameters exceeding the desirable limit as per drinking water standards.

Table 1.15: Maximum and minimum values of ground water samples (Mon 2006)

Parameters	Maximum	Minimum
pH	8.8	5.24
EC, (micro siemens/cm)	1194	6.6
Salinity, (ppt)	0.6	ND
Colou,r, (Hazen)	73	ND
Turbidity, (NTU)	36	ND
TDS, (mg/l)	764.16	4.22
Total Alkalinity, ($CaCO_3$ mg/l)	170	4
Total Hardness, ($CaCO_3$ mg/l)	328	8
Ca Hardness, (mg/l)	224	4
Calcium, (mg/l)	89.6	1.6
Magnesium, (mg/l)	29.16	ND
Sodium (mg/l)	47.2	1.2
Potassium, (mg/l)	43.2	0.1
Iron, (mg/l)	0.51	ND
Chloride, (mg/I)	426	6.01
Sulphate, (mg/l)	46.08	0.04
Nitrate-N, (mg/l)	20.6	ND
Phosphate-P, (mg/l)	0.13	ND
Total Coliform, MPN/100ml	2400	3
Faecal Coliform, MPN/100ml	2400	3

The values of pH ranged from 5.25 - 8.8. Sixteen samples showed pH below 6.5 and only 2 samples showed pH above 8.5 (Fig. 1.50). The acidic nature of the water may be due the acidic nature of the soil or due to the aquifer origin. The alkalinity could be due to the presence of excess bicarbonate.

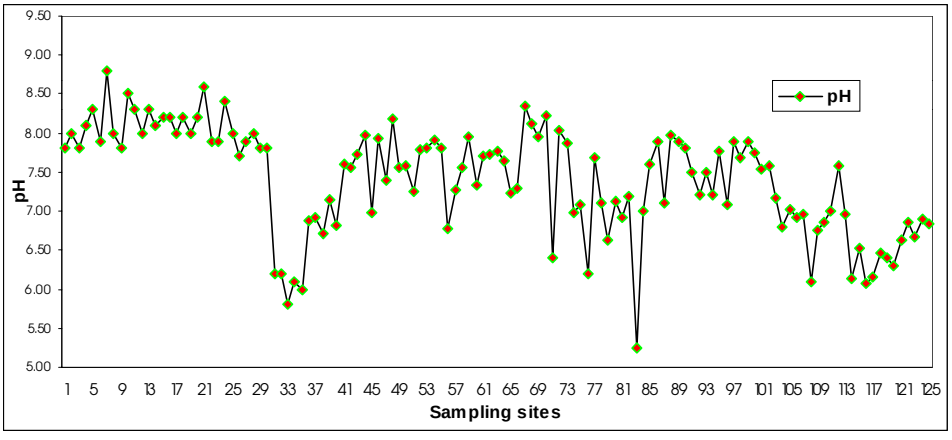


Fig. 1.50: Variation in pH values of groundwater samples from Kabbini basin

Turbidity and colour (Fig. 1.51 and 1.52) are found to be high (> 5 NTU) prescribed by BIS) at eight sites, namely Mepadi, Moopainadu, Pozhuthana, Noolpuzha, Kalpetta Municipality and Pulpally. The high values of turbidity and colour are found in regions of cesspools and areas experiencing overflow from paddy fields. Damage to or lack of concrete plinth and cracks in parapet walls lead to the entrance of runoff water in to the well. Wells without proper concrete casing also face the problem of intrusion of turbid water from nearby water sources through holes and burrows created by rodents and crabs. Sites KRG16 and KRG21 have high value of iron (> 0.3 mg/l, BIS limits) which may be the cause of high color. Color and turbidity in other samples could be due to the presence of suspended organic colloidal matter.

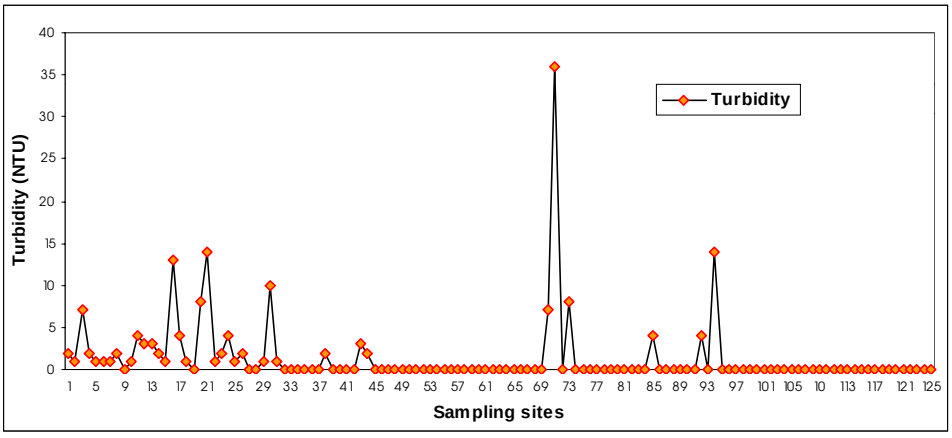


Fig.1. 51: Variation in turbidity of groundwater samples from Kabbini basin

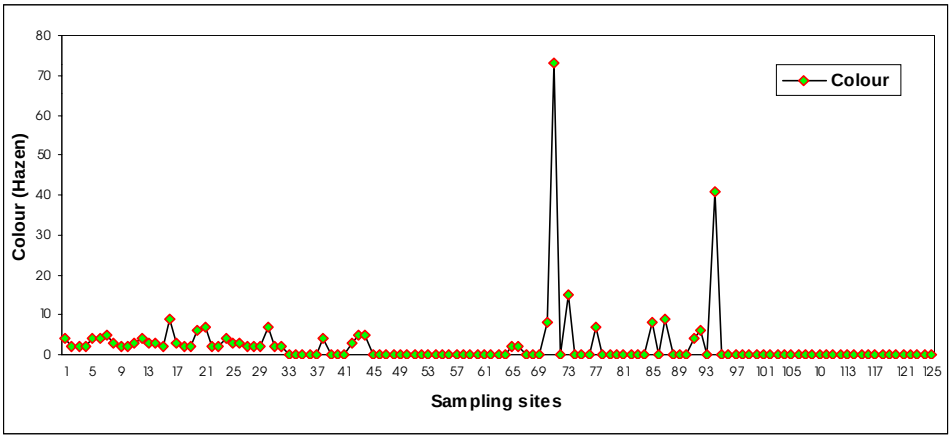


Fig. 1.52: Variation in colour of groundwater samples from Kabbini basin

Total Dissolved Solids concentration ranged from 4.22 to 764.16 mg/l as shown in Fig. 1.53. The groundwater samples KRG69 (Noolpuzha) and KRG97 (Mullankolly) have TDS values higher than the prescribed by BIS. Several processes are responsible for such wide variation in TDS

values, such as movement of groundwater through rocks containing solute mineral matter, concentration by evaporation etc. The agrochemicals from cultivated area and other pollutants such as untreated sewage and waste deposits affect soil and surface water and these finally seep down to the ground water system at a rate depending on the soil type these processes also contribute to TDS. The leachates from nearby pits may also be contributing to high TDS values. The EC of the sample ranged from 6.6 to 1194 µ siemens/cm. As suggested by Pearson's correlation matrix, Ca^{2+}, Mg^{2+}, Na^{+}, SO_4^{2-}, HCO_3, Cl^{-}, and K^{+} are the major ions contributing to EC.

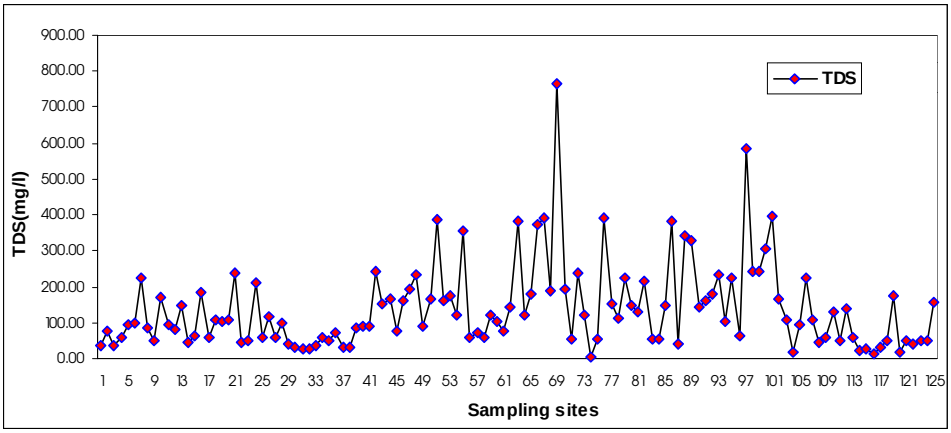


Fig. 1.53: Variation in total dissolved solids of groundwater samples from Kabbini basin

Hardness in the groundwater sample is primarily due to the presence of calcium and to a less extent that of magnesium. Total hardness value varies from 8 to 328 mg/l. Only one site, namely Noolpuzha Panchayath (KRG69) has total hardness above the BIS value of 300mg/l. The groundwater of the basin can be classified under 'hard water' in general and such water hampers lather formation when soap is used. The correlation matrix indicates a positive relation between salinity and hardness, indicating that chloride is the common contributor to both.

Parameters like sodium and potassium ranged from 1.2 to 47.2mg/l and 0 to 43.2 mg/l respectively. The concentration of calcium and magnesium are within the limits set by BIS. However Ca values exceeding 75mg/l were found Noolpuzha (KRG69) and Thirunelly (KRG86) as depicted in Fig. 54. Ca and Mg show positive correlation, and increase in one parameter is invariably accompanied by the increase in the other because of their common mineral origin. Comparatively high value of Na (>20 mg /l) is found at 10 sites (42, 51, 63, 66, 69, 76, 79, 86, 97, 100). On an average the K^{+} ion concentration in the groundwater sample is only 2.3 mg/l, if the 6 stations having K^{+} greater than 15 mg/l are not considered. Kalpetta Municipality (KRG7), Vengapally (KRG24), Padinjarathara (KRG36), Sulthan Bathery (KRG46), Ambalavayal (KRG76), Thirunelly (KRG89) and Panamaram (KRG105) have potassium concentration higher than sodium concentration. This could be due to seepage of K^{+} ion from potash fertilizers in to water as these areas are cultivated and subject to fertilizer application. The positive correlation between Na^{+} and K^{+} suggests that the area has mineral origin, containing both the ions in a definite proportion.

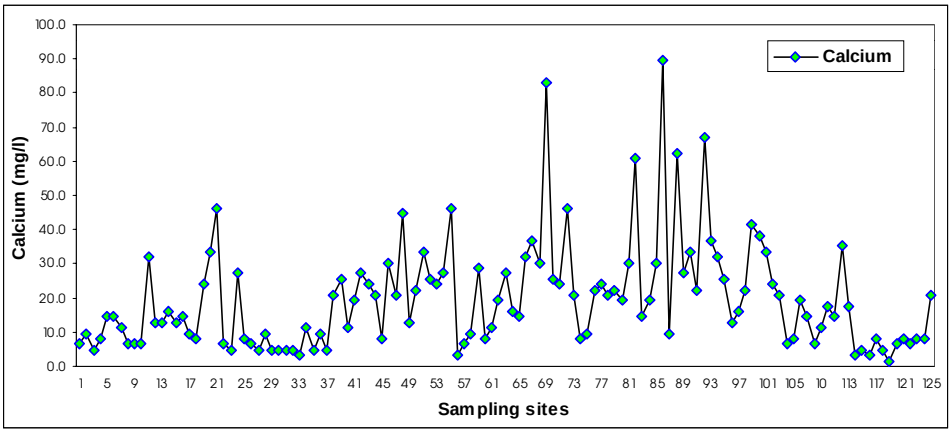


Fig. 1.54: Variation in calcium of groundwater samples from Kabbini basin

The concentration of nitrate-N varies from 0 to 20.6 mg/l (Fig. 1.55); nitrate-N concentration is higher than BIS limit of 10 mg/l for the samples from Meenangadi (52), Poothadi (KRG63), Noolpuzha (KRG66), Ambalavayal (KRG76) and Thirunelly (KRG88). The cause for this may be natural or man-made (such as the usage of nitrate fertilizers in the region, decomposition of human and animal wastes and soil organic matter and their mixing with groundwater body or fixation of atmospheric nitrogen by micro organisms). Nitrate usually remains loosely bound in the soil and they are easily washed off with storm discharges. Chloride concentration ranged from 6 to 426 mg/l. Noolpuzha (KRG69) alone has chloride values exceeding BIS limits. The average value of chloride is only 22.5 mg/l, if high concentration (>100 mg/l) in 6 site are not considered. The concentration of phosphate and sulphate ranged from 0 to 0.13 and 0 to 46.8 mg/l. The concentration of both the ions is very less in majority of the samples and is of no major concern. The sampling stations were the parameters exceeding BIS drinking water limits, are presented in Fig. 1.56.

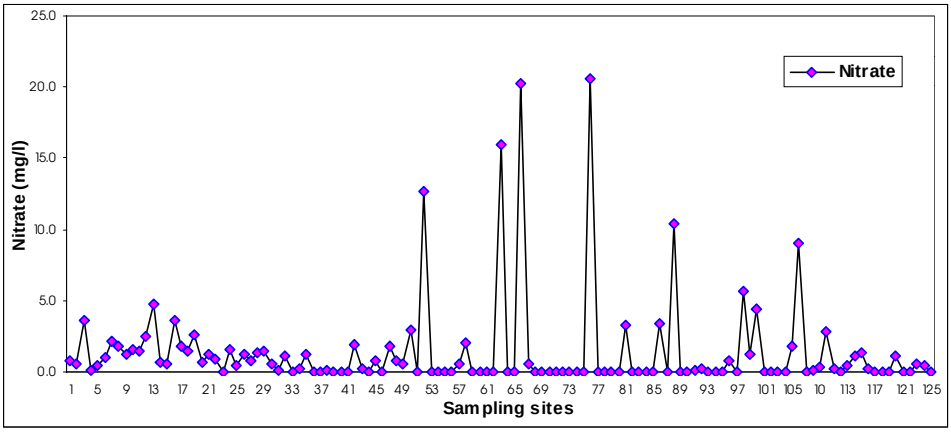


Fig. 1.55: Variation in nitrate - N of groundwater samples from Kabbini basin

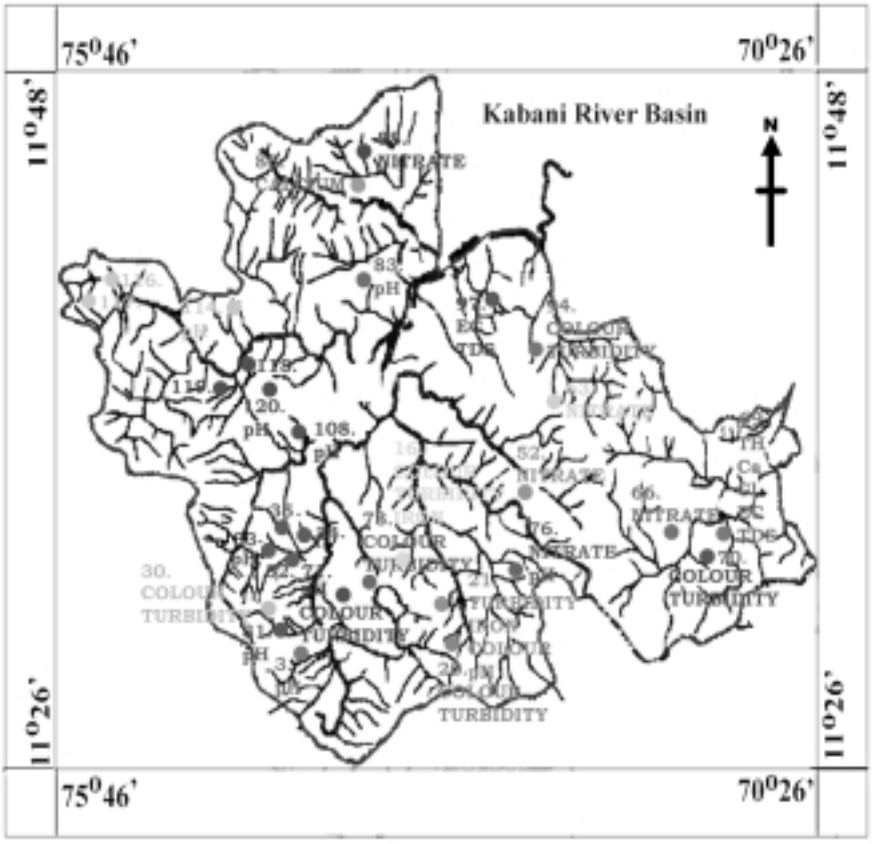


Fig. 1.56: Groundwater sampling sites where the water quality parameters exceeded the limit as per prescribed by BIS for drinking water quality standards.

One of the major groundwater quality problems identified is bacteriological contamination. Out of 125 samples, 84.8% showed faecal contamination. The sources could be either the garbage from households of organic origin deposited by house hold activities or the leachates from the tanks or pits situated nearby.

Pesticide analysis shows the presence of organochlorine pesticides in all the 5 samples analysed. Aldrin, DDD, DDE, Lindane, Endo- alpha and Endo-beta were detected in the groundwater samples (Table 1.16).

1.8.4 Groundwater Type

The nature of ground water is related to the soluble products of rock weathering, decomposition and changes with respect to time and space. The concentration of an ion in water depends upon the nature of the rock mineral, its solubility and weatherability in fresh or carbonated water (due to dissolution of atmospheric Carbon dioxide in rain water, i.e., pH dependent), climate and local topography. The main rock minerals forming the earth surface are oxides of Silicon (quartz),

Table 1.16: Maximum and minimum values of ground water samples (Pre - monsoon 2006)

Parameters	Maximum	Minimum
pH	7.54	5.5
EC, (micro siemens/cm)	1066	16.2
Salinity, (ppt)	0.4	ND
Turbidity, (NTU)	6.3	ND
TDS, (mg/l)	682.24	21.89
Total Alkalinity, (mg/l)	152	0.5
Total Hardness, (mg/l)	340	12
Ca Hardness, (mg/l)	260	8
Calcium, (mg/l)	104	3.2
Magnesium, (mg/l)	26.2	ND
Sodium (mg/l)	84	1.2
Potassium, (mg/l)	34	0.3
Chloride, (mg/I)	907.56	6.83
Sulphate, (mg/l)	96.28	ND
Nitrate-N, (mg/l)	10.4	ND
Phosphate-P, (mg/l)	0.46	ND
Total Coliform, MPN/100ml	≤ 2400	4
Faecal Coliform, MPN/100ml	≤ 2400	4

Aluminum, Iron (Magnetite), Sulphides (Chlorite and Pyrites), Carbonates (Magnesite and dolomite) etc. These minerals on weathering releases simple radicals or ions such as Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, HCO_3^{-}, SO_4^{2-}, NO_3^{-}, PO_4^{3-}, H^{+}, Cl^{-} etc. A mineral in contact with ground water represents a geochemical system consisting of a solid phase and solution phase. If the solution does not initially contain any of the minerals, then in equilibrium exists between the phases and some of the minerals will dissolve to provide their component to the solution. It is inferred from this that in an unpolluted environment, groundwater quality can be correlated with the minerals present in the bedrock or aquifer.

The major water types are given in Table 1.17 and from the chemical analytical parameters, the groundwater of Kabbini river basin has been classified as having Ca-Mg-HCO_3-Na-Cl as the dominant type (Fig. 1.57). The source of Ca-Mg-HCO_3 is generally calcareous sedimentary rocks such as calcite, dolomite or magnesite. Weathering of igneous silicate rocks may also be responsible for the water type because it introduces appreciable concentration of Ca-Mg-Na. Some inland rocks could be responsible for the contribution of Na-Cl to the groundwater.

Table 1.17: Concentration of pesticides in groundwater

Sample Code	Panchayath	Pesticide	Concentration µg/l (ppb)
KBG/77	Ambalavayal	Aldrin, Endo-alpha	0.0395 0.0742
KBG/83	Mananthavady	Lindane Aldrin	0.0428 0.034
KBG/111	Vellamunda	Aldrin	0.0451
KBG/113	Thavinjal	Lindane, Aldrin, DDE, Endo Beta, DDD	1.2910 0.1492 0.1428 0.1700 0.0071
KBG/115	Thavinjal	Lindane, Aldrin, Endo Beta, DDD	0.0107 0.0174 0.0029 0.0307

1.8.5 Physico-chemical and bacteriological Analysis of pre-monsoon 2007

An attempt has been made to interpret the groundwater quality based on the field data collected during the pre-monsoon of 2007

The maximum and minimum values of ground water samples during the monsoon of 2006 and Pre-monson 2006 are given in Table 1.15 and 1.16.

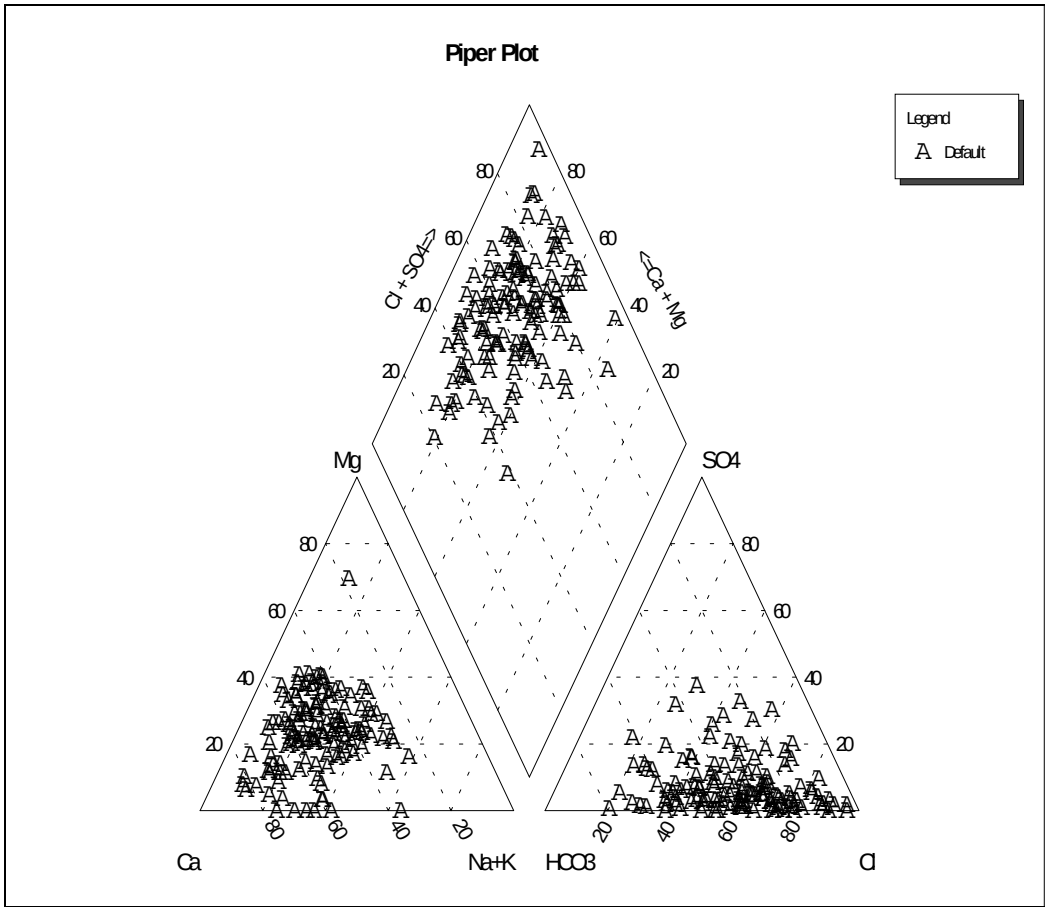


Fig. 1.57: Piper plot showing the groundwater chemistry of Kabbini river basin

The pH is one of the most important parameters of water quality study. The groundwater samples were generally found to be slightly acidic (5.5 to 7.5). The maximum value of pH (7.5) was recorded at Noolpuzha station (69) and the minimum value of 5.5 was recorded at Vengapally station (6). Many samples (57.57 %) reported pH values lower than the BIS limit of 6.5 as seen from Fig. 1.58.

The value of EC ranged from 16.2 µS/cm to 1066 µS/cm. The average value of EC was found to be 219.29 µS/cm. The maximum value for EC was recorded at Noolpuzha station (KRG69). The TDS values for groundwater ranged from 10.37 mg/l to 682.24 mg/l. The average TDS value of groundwater was reported to be 140.51mg/l. The maximum value of TDS (682.24 mg/l) was recorded at Noolpuzha station (KRG69). Samples collected from Noolpuzha (KRG69) and Meenangadi (KRG52) showed TDS values greater than the BIS limit of 500mg /l (Fig. 1.59). Comparatively, high value of TDS was reported at Poithana (KRG 29), Thariyod (KRG 33), and Meenangadi (KRG 50).

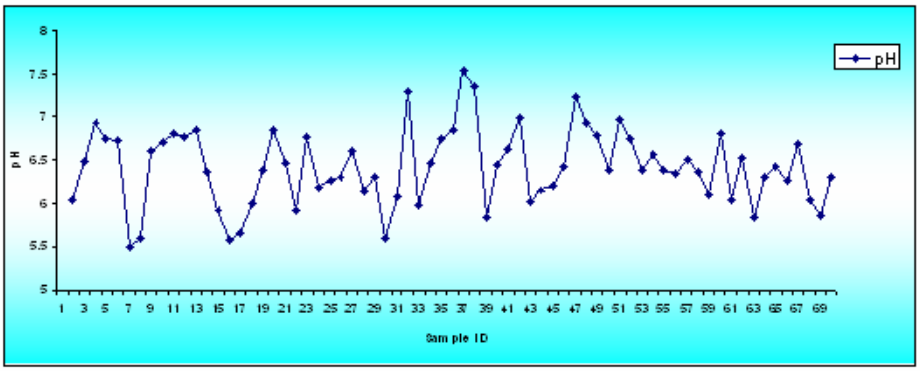


Fig. 1.58: Variation of pH in groundwater samples - Kabbini basin

The turbidity values of groundwater samples varied from not-detectable levels to 6.3 NTU. The maximum value of turbidity was determined at Thondarnadu station (69).

The sulphate values of groundwater samples ranged from not detected levels to 96.28 mg/l. The average value was found to be 5.68 mg/l. The maximum concentration was found in a sample collected from the Thariyod Panchayath (96.28 mg/l).

Chloride concentration of groundwater samples varied from 10.25 mg/l to 907.56 mg/l. The maximum limit of chloride set by BIS is 250 mg/l. The average value of chloride was 36.94 mg/l. The maximum concentration of chloride was found in a sample collected from the Noolpuzha station (KRG 69) which was also above the permissible concentration prescribed by BIS 200 mg/l (Fig. 1.60).

The limit set by BIS for alkalinity is 200 mg/l. The alkalinity values of groundwater samples ranged from 0.5 mg/l to 152 mg/l. Alkalinity of all the groundwater samples are found to be within the desirable limit. The maximum value was obtained for a sample collected from Noolpuzha (Fig. 1.61).

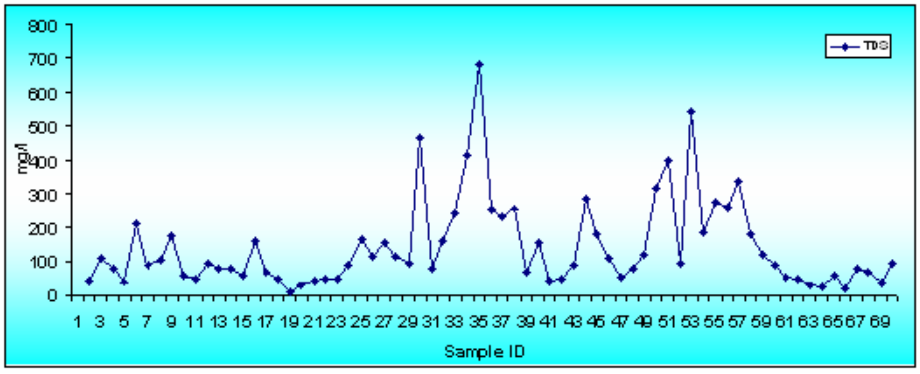


Fig. 1.59: Variation of TDS in groundwater samples - Kabbini basin

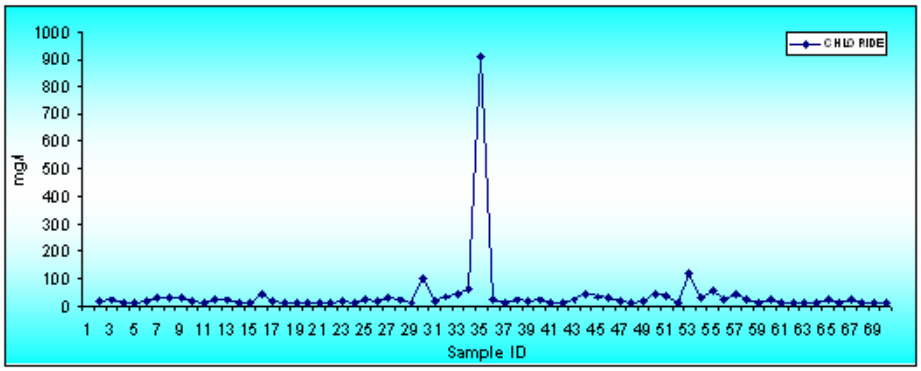


Fig. 1.60: Variation of chloride in groundwater samples - Kabbini basin

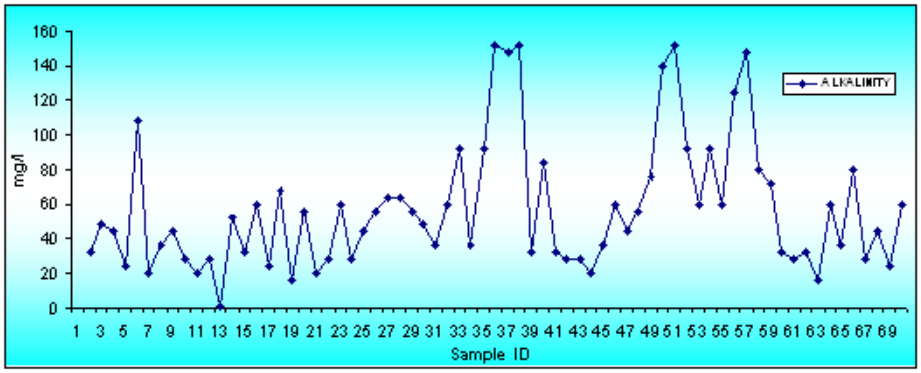


Fig. 1.61: Variation of alkalinity in groundwater samples - Kabbini basin

The maximum permissible limit for total hardness in drinking water is 200 mg/l. In the present study, the values ranged from 12 mg/l to 340 mg/l. The average value for total hardness was reported as 72.94 mg/l. Sample collected from Noolpuzha (KRG 69) station had the highest concentration for total hardness. The Noolpuzha (KRG 69), Kalpetta(KRG 34), and Meenangadi (KRG 50, KRG 52) showed considerable deviation from the BIS limit of 200 mg/l (Fig. 1.62).

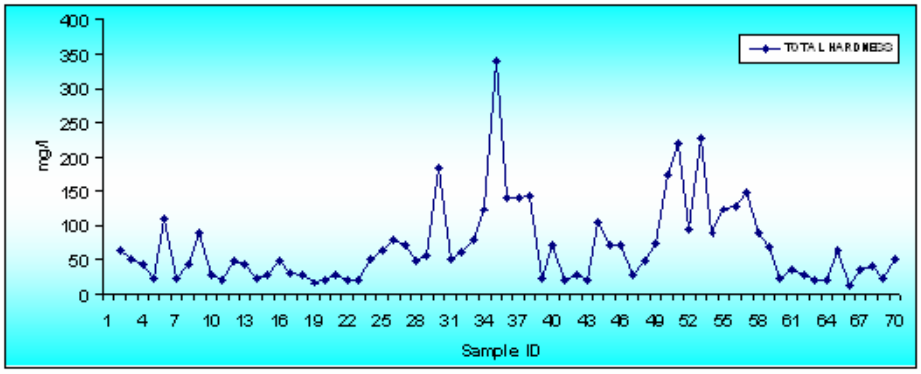


Fig. 1.62: Variation of total hardness in groundwater samples - Kabbini basin

The desirable limit set for calcium by BIS is 75 mg/l. In the present study, the concentration of Ca ranged from 3.2 mg/l to 104 mg/l. The average value for Ca was 58.85 mg/l. Noolpuzha (KRG 69) station showed the highest concentration for Ca (104 mg/l), which was also higher than the BIS limit. The maximum desirable limit set by BIS is 30 mg/l. The concentration in all the water samples was found to be within the desirable limit. The concentration of Mg ranged from ND to 26.2 mg/l. The maximum concentration was found at Thirunelli (26.2mg/l). The average Na concentration reported was 14.46 mg/l. The Na concentration ranged from 1.2 mg/l to 84 mg/l. The maximum concentration was found for a sample collected from Noolpuzha station (KRG 69). The K values for groundwater samples ranged from 0.3 mg/l to 34 mg/l. The average value of K was 3.42 mg/l. The maximum value was found at Kalpetta Municipality.

The Phosphate-P values of groundwater samples ranged from not detectable levels to 0.46 mg/l (Fig. 1.63). The average value of phosphate was found to be 0.08 mg/l. The average concentration of Nitrate-Nitrogen was reported as 0.37 mg/l. The concentration ranged from not detectable level to 0.92 mg/l (Fig. 1.64). The maximum value was found at Ambalavayal.

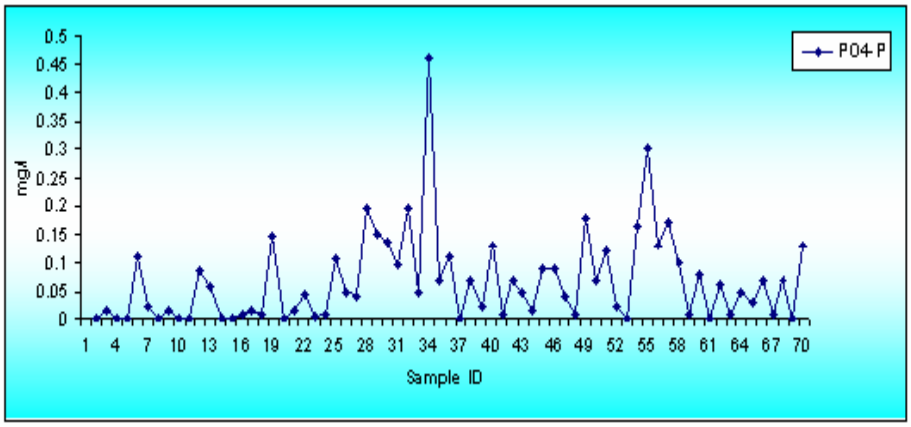


Fig. 1.63: Variation of phosphate in groundwater samples - Kabbini basin

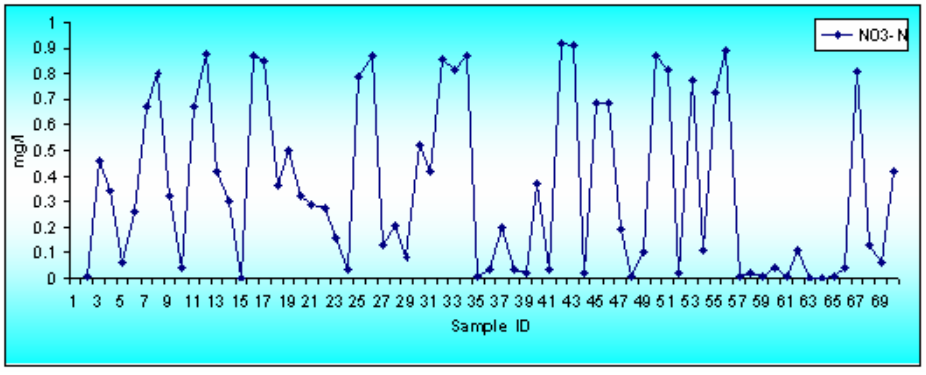


Fig. 1.64: Variation of nitrate- N in groundwater samples – Kabbini basin

All the samples were found to be bacteriologically contaminated. The bacteriological pollution can be mainly attributed to faecal sources. Fig. 1.65 gives the percentage of samples positive for E.coli. Parameters, which exceed BIS permissible limits, are shown in Fig. 1.66.

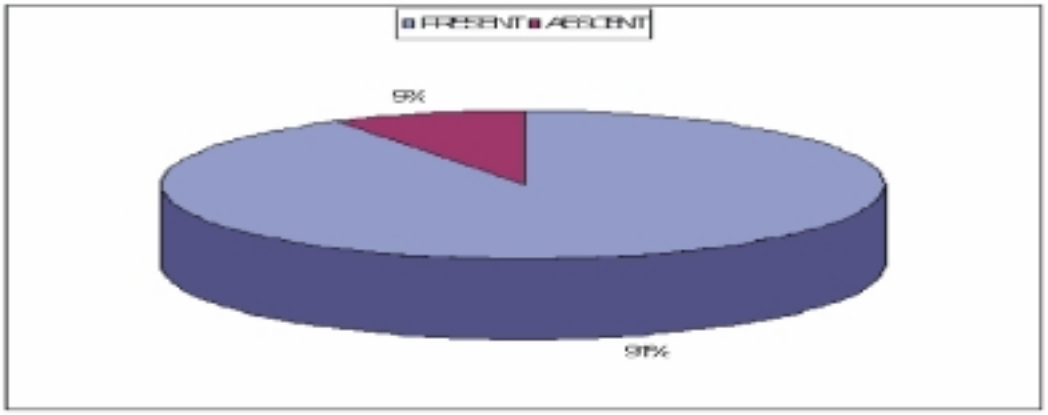


Fig. 1.65: Percentage of samples positive for E.coli - Kabbini basin

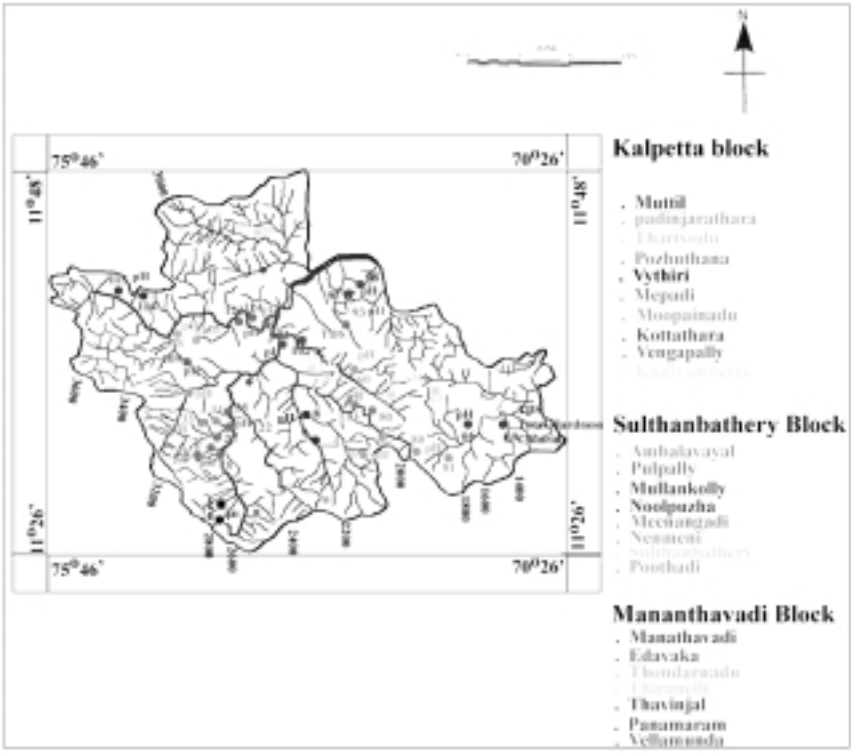


Fig. 1.66: Groundwater sampling sites where the parameters exceeded the limit prescribed by BIS for drinking water standards

Table 1.18: Percentage of wells under different water types

Sl. No.	Water Type	% of Samples
1	Ca-Mg-Na-HCO3-Cl	21.6
2	Ca-Mg-Cl-HCO3	18.4
3	Ca-Na-Mg-Cl	17.6
4	Ca-Na-HCO3- Cl	8.8
5	Ca-HCO3-Na	8
6	Ca-Mg-Cl-Na	6.4
7	Ca-Na-Cl	3.2
8	Na-Ca-Cl-HCO3-SO4	3.2
9	Ca-Mg-HCO3	3.2
10	Ca-Cl	2.4
11	Ca-Mg-Na-HCO3	0.8
12	Ca-Na-HCO3 Cl	0.8
13	Na-Ca-K-Cl	0.8
14	Ca- Mg-Na-K-HCO3-Cl	0.8
15	Na-Cl-SO4	0.8
16	Ca—Na-Mg-Cl-SO4	0.8
17	Ca-Mg-Cl-HCO3-SO4	0.8
18	Ca-Na-K-Mg-Cl	0.8
19	Ca-K-HCO3	0.8

1.8.6 Groundwater Type

The nature of ground water is related to the soluble products of rock weathering, decomposition and changes with respect to time and space. From the chemical analytical parameters obtained based on the field data for the period of observation, the groundwater of Kabbini river basin has been classified as having Ca-CO_3-Cl—HCO_3 and Na-Ca-CO_3-Cl as major type (Tables 1.19 and Fig. 1.67).

1.8.7 Comparison of Groundwater Quality of different seasons

A comparison of ground water quality of two different seasons, namely the monsoon (2006) and the pre-monsoon (2007) has been attempted. It was found that during the monsoon season, relatively less number of samples have low pH values. There is a decreasing trend from the monsoon to the pre-monsoon as seen from the Fig. 1.68. The average value of pH in the monsoon was 7.4, where as it was 6.3 in the pre-monsoon.

Table 1.19: Number of wells under different water types

Sl.No	Water Type	% of Samples
1	Ca-Cl-CO3	1
2	Ca-CO3-Cl	6
3	Ca-CO3-Cl-HCO3	9
4	Ca-CO3-HCO3	1
5	Ca-CO3-HCO3-Cl	6
6	Ca-HCO3-Cl-CO3	1
7	Ca-HCO3-CO3-Cl	3
8	Ca-HCO3-CO3-Cl-SO4	1
9	Ca-Mg-CO3-Cl	3
10	Ca-Mg-CO3-HCO3	3
11	Ca-Mg-CO3-HCO3-Cl	4
12	Ca-Mg-Na-CO3-HCO3	1
13	Ca-Na-CO3-Cl	3
14	Ca-Na-CO3-Cl-HCO3	4
15	Ca-Na-CO3-HCO3	6
16	Ca-Na-CO3-HCO3-Cl	4
17	Ca-Na-Mg-CO3-Cl	1
18	Ca-Na-Mg-CO3-Cl-HCO3	3
19	Ca-Na-Mg-CO3-HCO3-Cl	4
20	K-Na-Ca-CO3-Cl	3
21	Mg-Ca-CO3-HCO3-Cl	1
22	Mg-Na-Ca-CO3-HCO3	1
23	Na-Ca-Cl-CO3	1
24	Na-Ca-Cl-CO3-HCO3	6
25	Na-Ca-CO3-Cl	9
26	Na-Ca-CO3-HCO3	1
27	Na-Ca-HCO3-Cl-CO3	1
28	Na-Ca-Mg-CO3-Cl-HCO3	3
29	Na-Cl-CO3-HCO3	1
30	Na-Mg-Ca-CO3-Cl	1
31	Na-Mg-Ca-CO3-HCO3-Cl	1
32	SO4-CO3	1

The turbidity of the samples was not significant in any of the seasons, except for samples Noolpuzha (KRG 70), Kalpetta (KRG 71, KRG 73), Pulpally (KRG 94) in the monsoon and the pre-monsoon (Fig. 1.69).

There is no observable trend in TDS. For samples from Noolpuzha (KRG 69) total dissolved solids in both the seasons were found to be above the permissible limits of 500 mg/l set by BIS. Similarly, the sampling from Mullankolly (KRG 97) in the monsoon and Pulpally (KRG 93) in the pre-monsoon gave TDS values of 583.04 and 543.36 mg/l, respectively (Fig. 1.70).

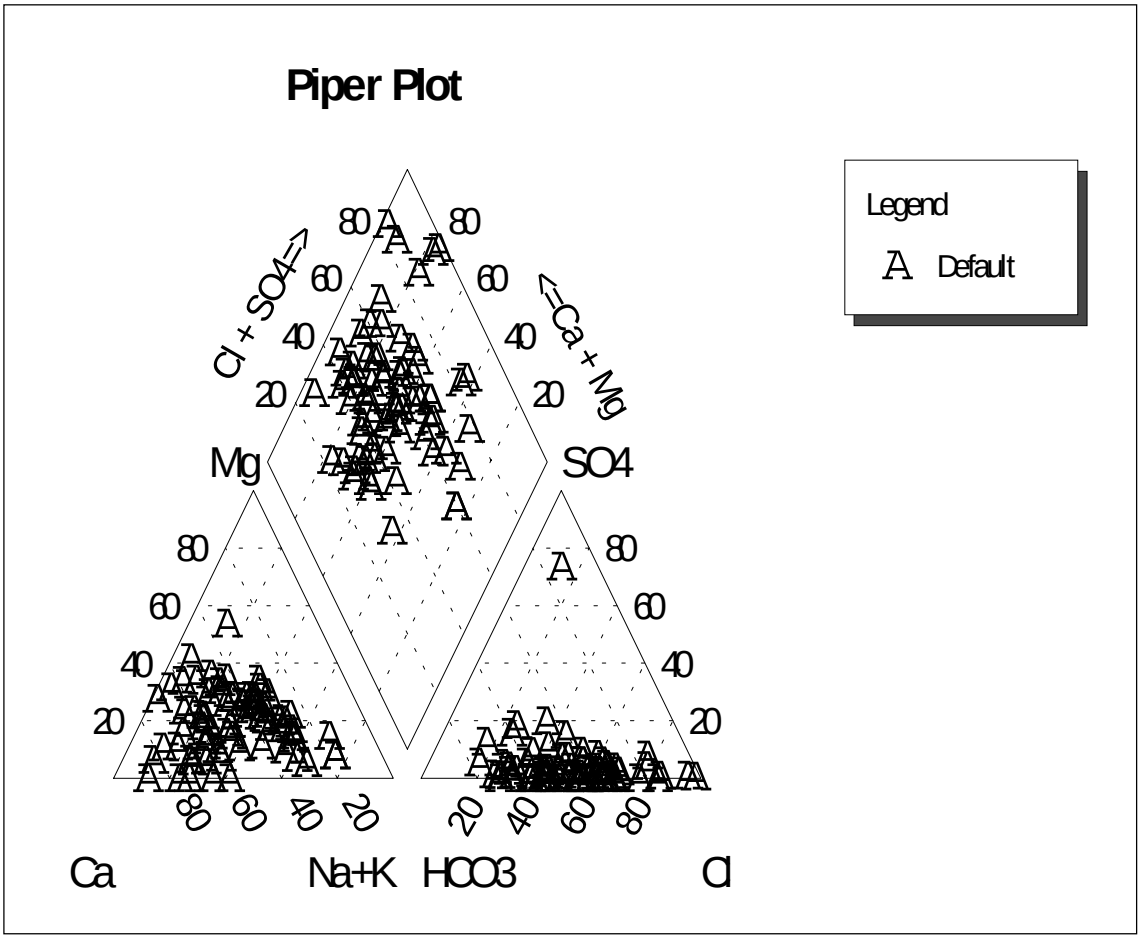


Fig. 1.67: Piper plot showing the ground water chemistry of Kabbini basin

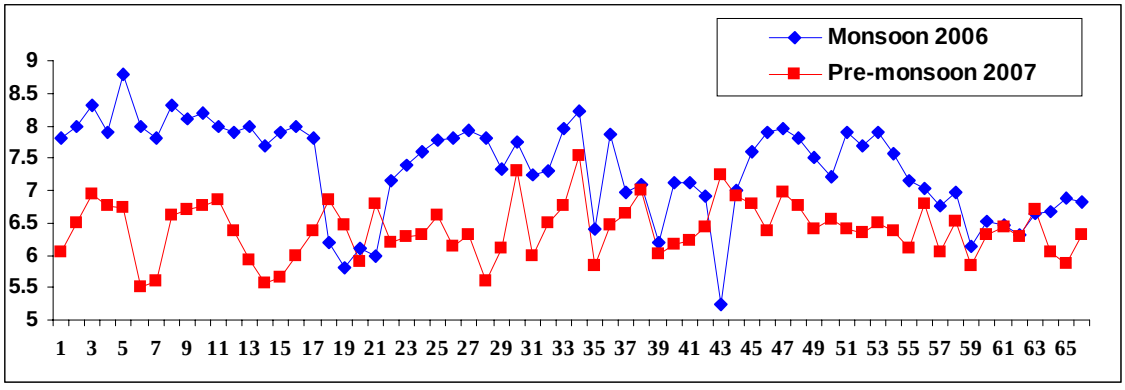


Fig. 1.68: Seasonal variations in pH in groundwater samples - Kabbini basin

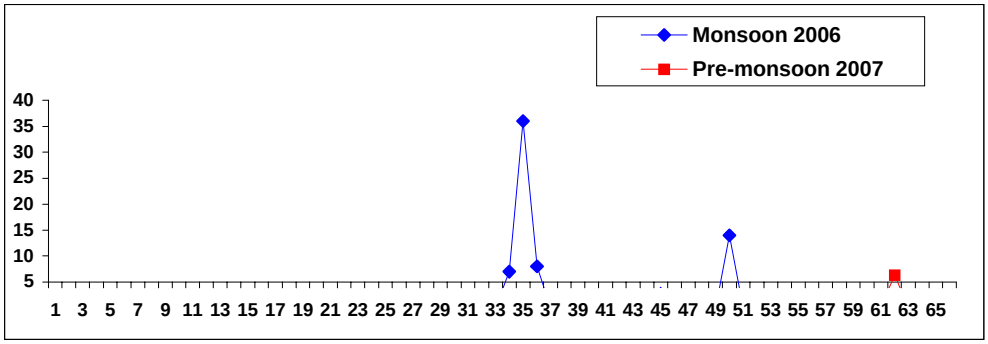


Fig. 1.69: Seasonal variations in turbidity of groundwater samples - Kabbini basin

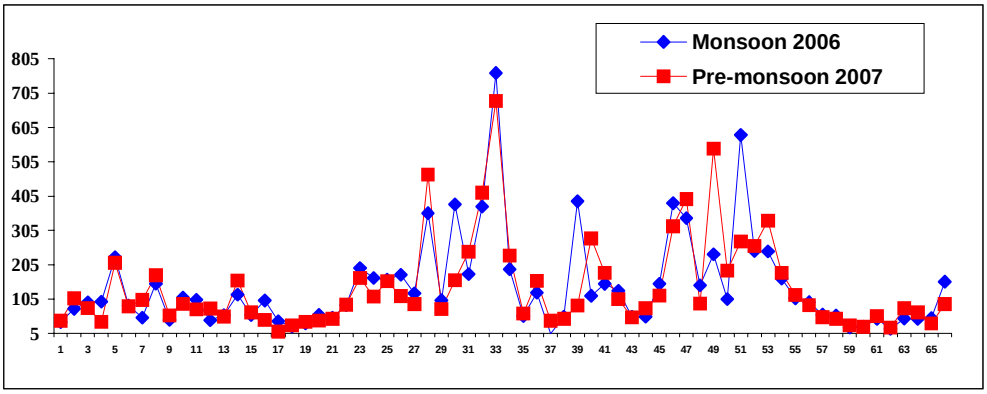


Fig. 1.70: Seasonal variations in TDS of groundwater samples - Kabbini basin

Total alkalinity of the samples showed an increasing trend from the monsoon to the pre-monsoon as shown in Fig. 1.71. The average concentrations of alkalinity in the monsoon and the pre-monsoon are 40.41 mg/l and 54.67 mg/l respectively. All the samples were found to have alkalinity within the desirable range of 200 mg/l.

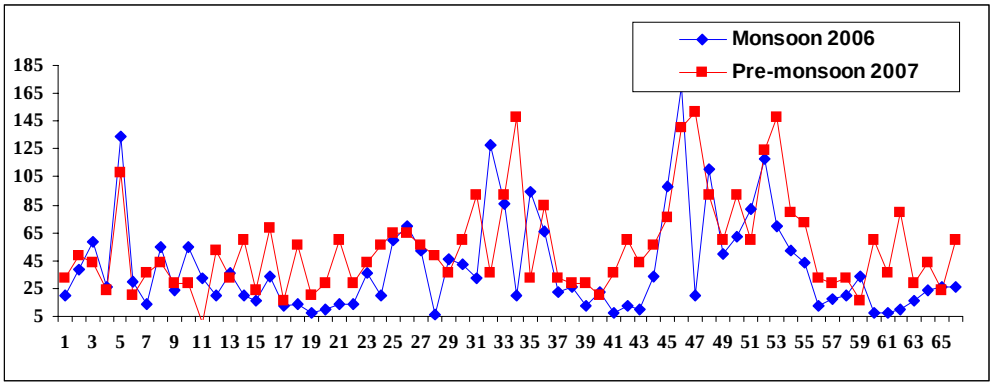


Fig. 1.71: Seasonal variations in total alkalinity of groundwater samples - Kabbini basin

Total hardness of the samples showed no trend. Sample Noollpuzha (69) reported hardness higher than the BIS prescribed limit of 300 mg/l in both the seasons (Fig. 1.72). The water samples collected from Kaniyambetta (KRG 55), Mananthavadi (KRG 86), Thirunelly and (KRG 88) pulpally (KRG 93) may be classified as very hard. (>180) mg/l). The concentration of cations like Ca, Mg (Fig. 1.73 and 1.74) were well within the prescribed limits and did not exhibit a detectable trend. The average concentration of Ca in the monsoon was 19.3 mg/l and in the pre-monsoon, it is found to be 18.1 mg/l. The average value of Mg was 5.8 and 5.3 mg/l in the monsoon and the pre-monsoon respectively. Na and K concentrations were also low in both the seasons. The average concentration of Na was 10 mg/l in the monsoon and 13.4 mg/l in the pre-monsoon. The average concentration of K ranged from 3.6 in the monsoon to 3.9 in the pre-monsoon.

The concentration of anions like Sulphate, Nitrate-N and Phosphate-P was found to be low, but the Chloride concentration at Noolpuzha (KRG 69) was 420 mg/l in the monsoon and 907.57 mg/l in the pre-monsoon. These values are higher than the permissible limit for chloride prescribed by BIS of 250 mg/l (Fig. 1.75).

All samples were found to be bacteriologically contaminated; 55% samples in the monsoon and 61% samples in the pre-monsoon were found to be contaminated with E-coli as seen from Fig. 1.76.

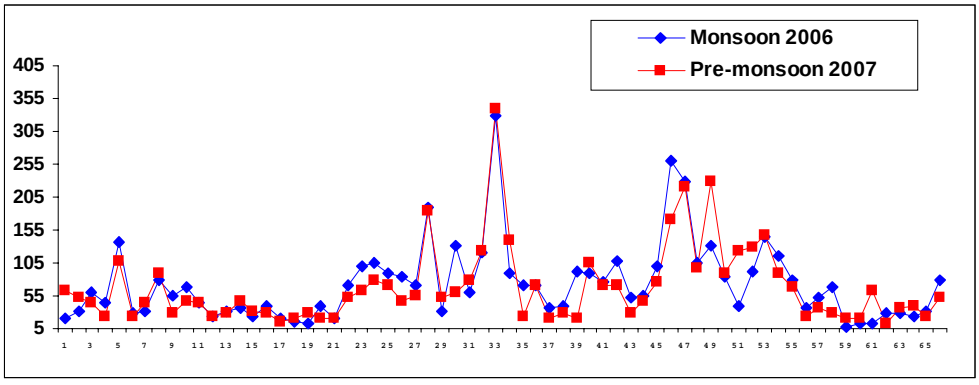


Fig. 1.72: Seasonal variations in total hardness of groundwater samples - Kabbini basin

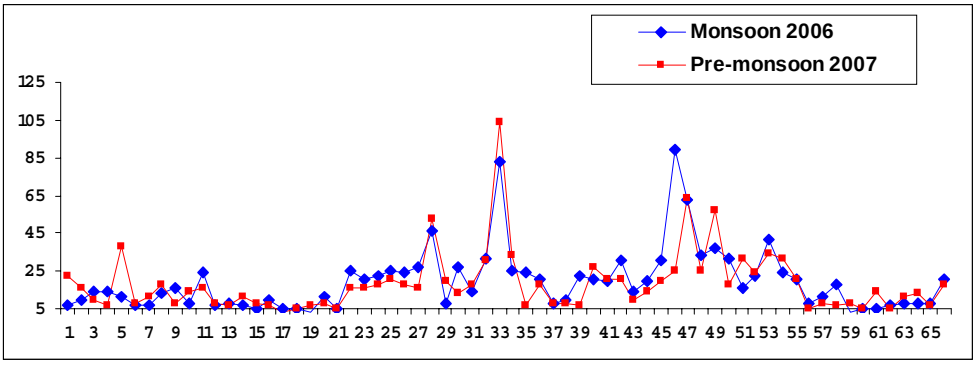


Fig. 1.73: Seasonal variations in Calcium of groundwater samples - Kabbini basin

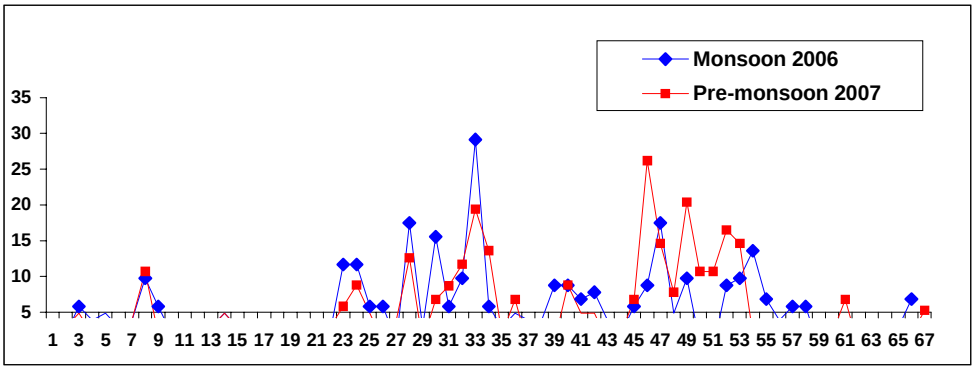


Fig. 1.74: Seasonal variations in Magnesium of groundwater samples - Kabbini basin

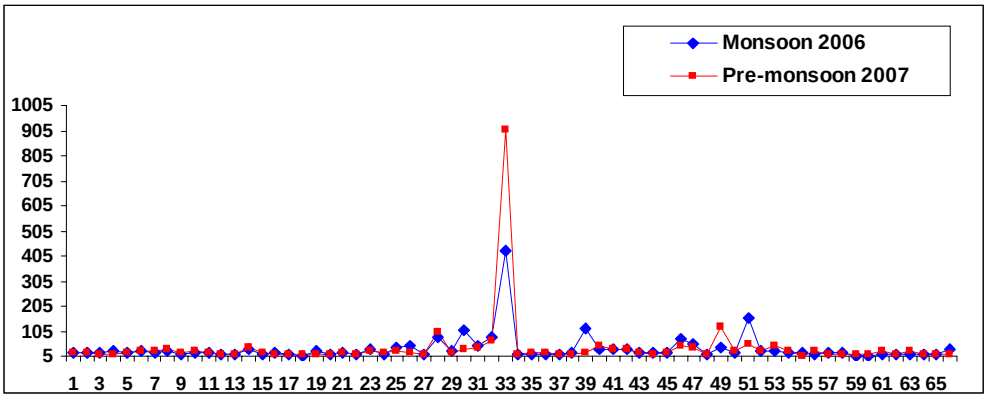


Fig. 1.75: Seasonal variations in Chloride of groundwater samples - Kabbini basin

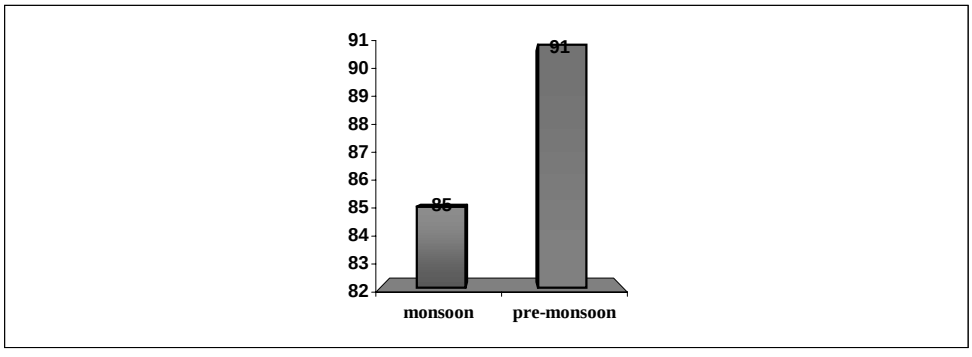


Fig. 1.76: Percentage of well water samples positive for E.coli in the Kabbini basin during different seasons

1.9. SALIENT FEATURES OF THE STUDY

The salient features of the study are given below:

- Water quality problems of Kabbini river is mainly associated with turbidity, colour and coliforms.
- The analyse of river water samples indicate that the Wayanad Wildlife Sanctuary is the most contaminated site.
- All the surface water samples are bacteriologically contaminated and in most of the cases, E.Coli is tested to be positive.
- In the case of groundwater, pH, alkalinity, Mg, Sulphate and Nitrate are within the desirable limit for drinking water.
- The groundwater samples from Noolpuzha recorded maximum concentration for most of the parameters.
- Of the total groundwater samples, 91 percent are bacteriologically contaminated and are tested positive for E.Coli.
- The water type is dominated by Ca, Mg, Na, Cl and CO_3 ions.
- CCME WQI suggests that all surface water sampling stations have poor water quality, which is due to the physical and bacteriological contamination.
- From the phytoplankton analysis it is evident that members of *Bacillariophyceae* and *Chlorophyceae* form predominant components in the community.
- In the monsoon season, with heavy runoff, incidence of *Chlorophycean* and *Cyanophycean* decreases and some diatoms still remain.
- Abundance of *Trachelomonas* is notable at Koodalkadavu, Panamaram and Banasurasagar reservoir which proves the nutrient enrichment and organic load in the water in summer months.
- *Nitzschia*, an organic pollution tolerant species, was reported at Koodalkadav in summer indicating organic load in the river. High density of *Asterionella* and *Synedra* also supports this.
- At Panamaram, *Chironomus* and *Tubifex* are abundant indicating the low oxygen conditions at the bottom of the river as a result of high degree of organic degradation going on.
- The Goodnight and Whitley index calculated for the Koodalkadavu station shows an increase from 33 in the post-monsoon to 83 in the pre-monsoon, which is a clear indication of the organic matter enrichment in the summer season.

Analyzing the biota, the vulnerable spots identified are Koodalkadavu, Perikallur, and Panamaram.

1.10. CONCLUSIONS

The Kabbini river basin is comparatively less polluted at present. Developmental activities like urbanization, tourism and interference with natural course of river water have not yet resulted in any uncontrollable water problems, though signs of change in the health of surrounding ecosystems are slowly becoming evident.

In certain wells, concentration of chemical parameters like Ca, Cl, pH, iron etc are beyond the BIS limits. Yet, majority of groundwater samples are free from chemical contamination and have only low concentration of ions which is basically because the area is fairly rain-fed and dilution effects are prominent. Surface water is also free from contaminants due to the absence of heavy industry and associated infrastructure. High turbidity value is detected in surface water and at some groundwater sites; however, such problems can be eliminated by simple procedures such as sedimentation and flocculation. Pathogenic pollution of both ground and surface water sources is a very common occurrence. Microbial contamination can be treated by boiling, filtration or chemical disinfection. The importance of bleaching should be made known to the people because the data from the survey indicate that most of the people are reluctant to disinfect their wells. Contamination of the biosphere by excessive use of pesticide is a major problem faced in Wayanad. The concentration of pesticides in water can be treated to a great extent through methods like carbon adsorption. This may also help in removing color, objectionable odour and taste. Analyzing the biota, the vulnerable spots identified are Koodalkadavu, Perikallur, and Panamaram.

Chapter 2

PERIYAR RIVER BASIN

2.1. INTRODUCTION

River Periyar is the longest river in Kerala, with a length of 244 km within the State. It possesses the highest water potential among the river basins of Kerala. The river is formed by the confluence of rivulets originating from the Sivagiri Hills at an elevation of 1,830m above MSL. After flowing for about 48 km, the Periyar is joined by the Mullayar, then it turns west to flow into the Periyar Lake at Thekkady, which is an artificial reservoir created in 1895 by constructing a dam across the river. The famous Wildlife Sanctuary and tourist place Thekkady is situated near the Mullaperiyar dam. The largest hydro- electric project of the state, namely Idukki with its arch dam is on this river. Pallivasal, Chenkulam, Panniyar, Neriyamangalam and Lower Periyar are the other hydro electric projects in Periyar. Mullaperiyar, Bhuthathankettu, Mattupetty, Munnar, Idukki, Cheruthoni, Kulamavu, Irattayar, Lower Periyar, Edamalayar, Chenkulam, Anayirangal and Ponmudi are the important dams across this river. The important tributaries of the Periyar are the Muthirapuzha, Mullayar, Cheruthoni, Perinjankutty and the Edamalayar. On its way to Lakshadweep Sea the river is enriched with water of minor tributaries like Muthayar, Perunthuraiar, Chinnar, Cheruthony, Kattappanayar and Edamalayar at different locations. At Aluva, the river bifurcates into the Marthandavarma and the Mangalapuzha branches. The Mangalapuzha branch joins Chalakkudy river and empties into the Lakshadweep sea at Munambam, and the Marthandavarma branch flows southwards, through the Udhyogamandal area and joins the Cochin backwater system at Varapuzha. The Cochin backwater system is a part of the Vembanad wetland, a tropical estuary on the south west coast of India. It has a natural opening at Cochin. The Cochin backwater and lower reaches of the river are subject to tidal influence.

River Periyar is significant from the point of view of energy and industry; Idukki and several other hydroelectric projects are located in this river and the lower reach of the basin is the hub of industrial and commercial activities (Table 2.1). Twenty five percent of the industries of the state are located along the banks of River Periyar and the concentration of these industries is within a stretch of 5 km in the Eloor- Edayar area, which is only 10 km north of Cochin port. These industrial complexes depend on the river for intake of process water and disposal of effluents.

The river also provides water for irrigation and domestic use all along its course, besides supporting a rich fishery. The Cochin Corporation, in the vicinity of river mouth has an intake point upstream of Aluva to meet its water supply; this point is generally free from salinity intrusion.

Table 2.1 : Details of Major Industries in Kochi

Name of Industry	Raw Materials Used	Products	Total Effluent Discharge, ML / day	Point of Disposal
Fertilizers and Chemicals Travancore Ltd, Udyogamandal, Aluva	Sulphur, Rockpowder, Naphtha, Hydrochloric Acid	Ammonia, Ammonium Sulphate, Sulphuric acid, Ammonium Phosphate, Phosphoric Acid, Super Phosphate, Ammonium chloride	8800	Periyar river
Indian Aluminium Company Ltd, Eloor	Alumina, Petroleum Coke, Pith, Aluminium Flouride	Aluminium Ignate, Aluminium Extusions, Aluminium Wire Rod	7090	Periyar river
Periyar Chemicals Ltd, Edavar,Kochi	Caustic Soda, 30% Carbon Monoxide, Sulphuric Acid	Fermic Acid, Sodium Sulphate,	22	Periyar river
United Catalyst India Ltd Edayar	Copper ,Zinc, Sulphuric Acid, Caustic Soda, Ammonia, Graphite	Catalyst for Fertilizer and Petrochemical industries	537	Periyar river
Cominco Binani Zinc Ltd, Binanipuram, Aluva	Zinc Concentrate	Zinc, Sulphuric acid, Cadmium	5330	Periyar river
Indian Rare Earths Ltd , Udyogamandal	Monozite sand, Caustic soda, Hydrochloric Acid, Chlorine, Nitric Acid	Trisodium Phosphate, Rare Earth Chloride Rare Earth Oxide,	2405	Periyar river
Travancore Cochin Chemicals Ltd, Aluva	Common Salt, Sulphur, Zinc Dust, Sulphur Dioxide,	Caustic Soda, Sodium Sulphate, Liquefied Chlorine, Hydrochloric Acid, Bleach Liquor	6579	Periyar river
Hindustan Insecticide Ltd , Udyogamandal, Aluva	Benzene, Alcohol, Oleum, Chlorine	DOT Tech, BHC, DDT (50%), BHC (50%)	620	Periyar river

Barrages are constructed downstream at Manjummal and Paathalam to arrest salinity intrusion to upstream reaches.

2.2. MATERIALS AND METHODS

Water samples were collected during three seasons (pre-monsoon, monsoon and post-monsoon) from the Periyar river from October 2005 to October 2007. Initially 24 stations were identified but later 11 more stations were added in 2007 recognizing the need for better data base. The stations with code numbers, frame of references and other details are given in Table 2.2. The locations and names of sampling stations are given in Fig 2.1. Groundwater samples were also

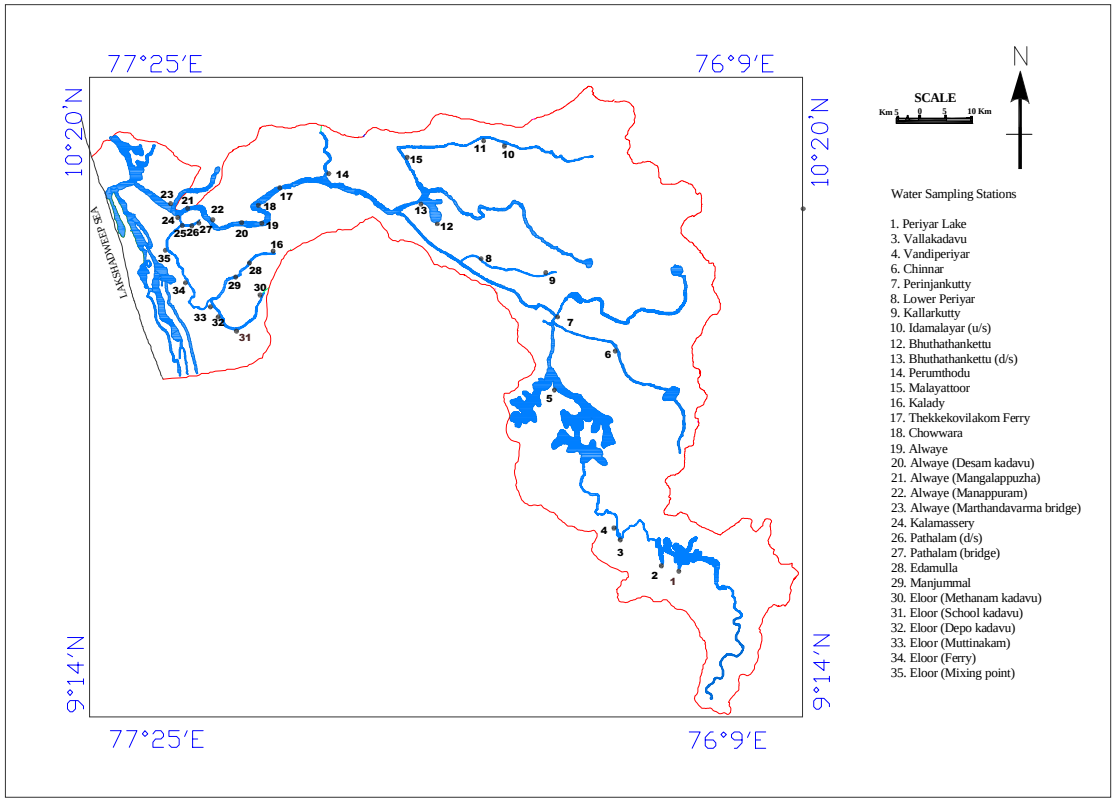


Fig. 2.1: Surface water sampling stations along Periyar river basin

collected from the Periyar river basin during the monsoon of 2006 and the pre-monsoon of 2007. The groundwater sampling stations are shown in Fig 2.2. A total of 151 groundwater samples were collected during the season. During the pre-monsoon of 2007, 46 samples were again collected from the Idduki district. The groundwater sampling was carried out during the monsoon of 2006 in all the Panchayath in eight selected blocks (Angamaly, Parakkadavu, Alangad, Vazhakkulam, Adimali, Devikulam, Kattappana and Nedumkandam) in Ernakulam (Table 2.3) and Idukki districts (Table 2.4).

A survey of household sanitation facilities was conducted to find out the hygienic condition, to identify the pollution sources, and to understand the soil characteristics and points of contamination of water. Water samples were collected in pre cleaned non-reactive plastic containers and were transported to the laboratory. The surface and groundwater samples were analysed for various physico-chemical parameters such as pH, temperature, electrical conductivity, colour, turbidity, total dissolved solids, total alkalinity, total hardness, calcium hardness, magnesium, calcium, iron, sodium, potassium, chloride, iron, sulphate, nutrients (nitrate-N, phosphate-P) and for certain heavy metals at selected surface water stations. Select groundwater samples were subjected to pesticide analysis (Aldrin, Dieldrin, DDD, DDE, Endo-alpha, Endo-beta and Lindane).

Table 2.2: Details of sampling stations

Sample Code	Name Of The Station	Details
PRS01	Thekkady	Tourist place, Boating , Forest, Animal grazing
PRS02	Mullaperiyar	Dam site, Tiger reserved area, Deep forest
PRS03	Vallakadavu	Near bridge
PRS04	Vandiperiyar	Bathing area, Domestic sewage, Dumping site of markets
PRS05	Idukki (Dam site)	Largest hydro eletric power station, Dam site, Deep forest
PRS06	Chinnar	Tea plantations
PRS07	Perinjankutty	A new bridge is under Construction ,Tributary of Periyar
PRS08	Pambala Dam	Dam site, Coloured, Turbid and bottom was clay
PRS09	Kallarkutty	Dam site, Coloured, Turbid and bottom was clay
PRS10	Idamalayar (U/S)	Dam site, Forest, Undisturbed station
PRS11	Idamalayar (D/S)	Dam site
PRS12	Bhuthathankettu (U/S)	Dam site, Near Thattekkad bird sanctuary
PRS13	Bhuthathankettu (D/S)	Dam site
PRS14	Perumthodu	Deep forest, Animal grazing
PRS15	Malayattoor	Bathing ghut, Sand mining area, International pilgrim centre,
PRS16	Kalady	Under kalady Adisankara bridge, Bathing centre, Waste of vegetables dumped here, Near KWA pump house , Vehicle servicing centre
PRS17	Thekkekovilakam Ferry	Ferry
PRS18	Chowwara	Washing and bathing, Washing of vehicles
PRS19	Aluva	Under railway bridge
PRS20	Aluva (Desam kadavu)	Washing and bathing
PRS21	Aluva (Mangalapuzha)	Washing and bathing, Near Aluva bridge, residential area
PRS22	Aluva (Manappuram)	Washing and bathing, Washing of vehicles, Pilgrimage centre
PRS23	Aluva (Bridge)	Washing and bathing, Heavy traffic, residential area
PRS24	Kalamassery	Near bridge with heavy traffic, Pump house
PRS25	Pathalam (U/S)	Industrial area, Near regulator cum bridge, Rarely colour change noted
PRS26	Pathalam (D/S)	Downstream of regulator
PRS27	Pathalam (bridge)	Near bridge
PRS28	Edamulla	Industrial area
PRS29	Manjummal	Industrial area
PRS30	Eloor (Methnam kadavu)	Industrial area ,Washing and bathing,
PRS31	Eloor (School kadavu)	Industrial area, Washing and bathing,
PRS32	Eloor (Depo kadavu)	Industrial area, Washing and bathing,
PRS33	Eloor (Muttinakam)	Industrial area, Washing and bathing,
PRS34	Eloor (ferry)	Industrial area
PRS35	Varappuzha	Tributries of Periyar joined there

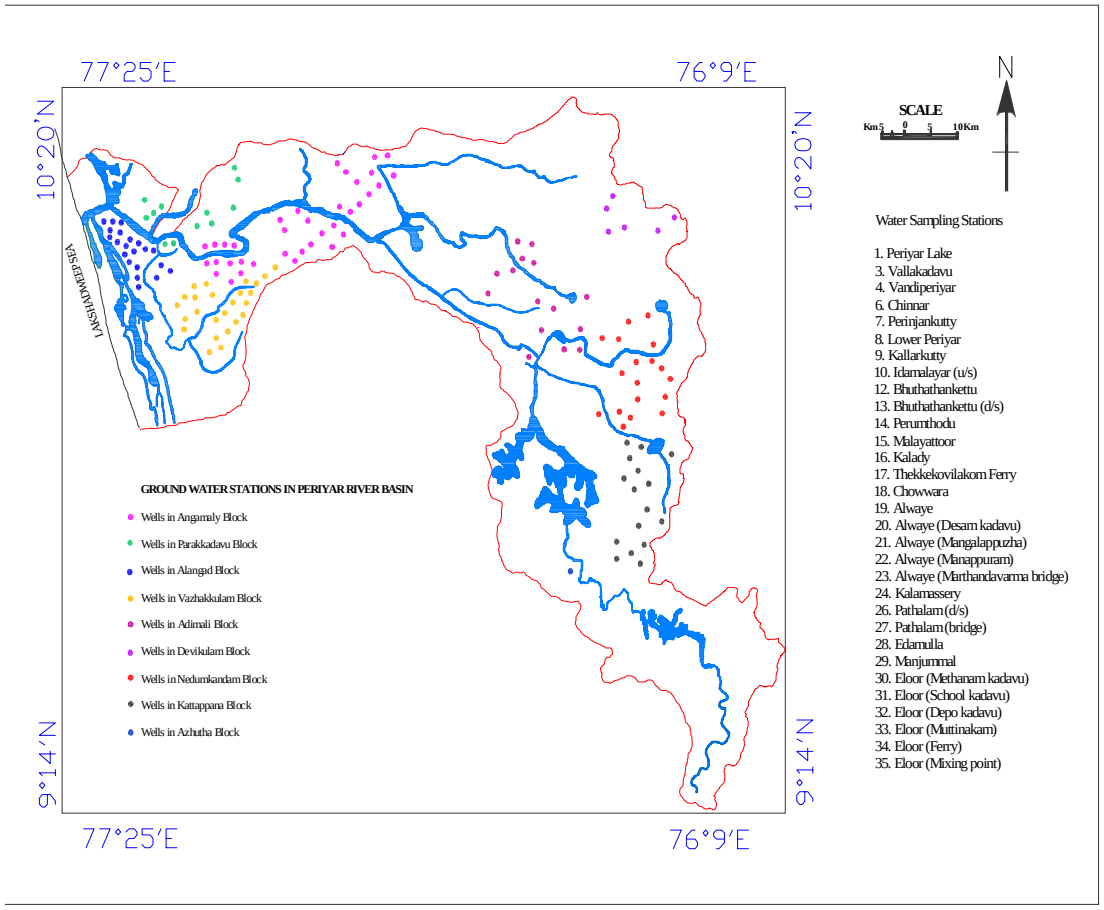


Fig. 2.2: Groundwater sampling stations along Periyar river basin

Microbiological analysis for total coliform, faecal coliform and Escherichia coli was also done. Samples were analyzed for biological parameters (macro-organisms and micro-organisms), which can help in identifying the extent of pollution. Sampling and analysis were carried out as per the standard procedures given in the Standard Methods for the Examination of Water and Wastewater (APHA, 1996).

2.3. FINDINGS AND DISCUSSION ON RIVER WATER QUALITY

2.3.1 Temporal changes in Water Quality Parameters

Physico-chemical parameters of the water samples from the Periyar river were analyzed for the period from October 2005 to October 2007. Water was sampled from different sites along the course of the river. The maximum, minimum and average concentration of different physico-chemical parameters is given in Tables 2.5- 2.9.

Table 2.3: Groundwater sampling stations in Ernakulam district

Block	Panchayath	No. of Samples	
Angamaly	Mookkannoor	4	36
	Thuravoor	4	
	Manjapra	4	
	Karukutty	4	
	Ayyampuzha	3	
	Sreemoolanagaram	4	
	Kanjoor	4	
	Kalady	4	
	Mala - Neeliswaram	5	
Parakkadavu	Puthanvelikkara	3	9
	Chengamanadu	2	
	Parakkadavu	4	
Alangad	Karumaloor	4	21
	Varapuzha	4	
	Alangad	5	
	Eloor	4	
	Kadungalloor	4	
Vazhakkulam	Vazhakkulam	4	25
	Vengola	5	
	Choornikkara	4	
	Edathala	4	
	Keezhmadu	4	
	Kizhakkambalam	4	
Total Samples			95

Table 2.4: Groundwater sampling stations in Idduki district

Block	Panchayath	No. of Samples	
Adimaly	Adimaly	5	15
	Pallivasal	4	
	Vellathooval	3	
	Konnathadi	3	
Devikulam	Chinnakkanal	2	6
	Shanthampara	4	
Nedumkandam	Nedumkandam	3	18
	Pampadumpara	3	
	Rajakkad	3	
	Rajakumari	3	
	Senapathy	3	
	Udumbanchola	3	
Kattappana	Erattayar	3	16
	Kattappana	3	
	Kanchiar	4	
	Ayyapancoil	3	
	Upputhara	3	
Azhutha	Elappara	1	1
Total Samples			56

Plate 2.1: Groundwater sampling in the Periyar river basin

Plate 2.2: Groundwater sampling and survey of sanitation facilities in the Periyar river basin

Table 2.5: Maximum and minimum values of Periyar river (Post-monsoon 2005)

PARAMETERS	Maximum	Minimum
Temperature ^{o}C	29.90	26.20
pH	6.97	6.36
EC, Micromhos/cm	98.40	26.00
Colour, Hazen	25.00	4.00
Turbidity, NTU	14.00	2.00
TDS, mg/l	62.98	16.64
Total Alkalinity, mg/l	28.00	12.00
Total Hardness, mg/l	24.00	8.00
Ca Hardness, mg/l	20.00	6.00
Chloride, mg/l	28.00	8.00
Sulphate, mg/l	4.16	0.72
Nitrate-N, mg/l	7.40	0.50
Phosphate-P, mg/l	0.09	ND
Ca, mg/l	8.00	2.40
Mg, mg/l	3.89	ND
Na, mg/l	8.00	2.40
K, mg/l	1.20	0.50
Iron, mg/l	0.25	0.02
DO, (mg/l)	8.67	6.27
BOD, (mg/l)	2.07	0.34

ND - Not Detected

2.3.2 Physico-chemical analysis

pH is considered as an ecological factor and is the result of interaction of various substances in solution in water and also of numerous biological phenomenon. The variation in pH is an important parameter in water body since most of the aquatic organisms are adapted to an average pH and do not withstand abrupt changes. The value of pH varied from 6.37(Eloor Methanamkadavu) to 6.97 (Edamalayar and Buthathankettu D/S) during post-monsoon season of 2005. Samples collected from Eloor Methanam kadavu and Depokadavu were not within the limit prescribed by BIS. During pre- monsoon of 2006, low values of pH were reported from Eloor Methanam kadavu and Ferry which comes under the industrial belt. Almost all samples are found to be acidic. During pre-monsoon of 2007 minimum value of pH was reported from Manjummal which also come under the industrial belt and high value was reported from Mullaperiyar probably due to the cold and damp nature of water. The pH of samples during the pre-monsoon of 2007 is given in Fig 2.15.

Table 2.6: Maximum and minimum values of Periyar river (Pre-monsoon 2006)

Parameters	Maximum	Minimum
Temperature ^{o}C	33.4	28.5
pH	7.1	5.7
EC, Micromhos/cm	373	28.6
Colour, Hazen	5	2
Turbidity, NTU	8	1
TDS, mg/l	238.72	18.304
Total Alkalinity, mg/l	22	10
Total Hardness, mg/l	46	8
Ca Hardness, mg/l	26	6
Chloride, mg/l	89.46	8.52
Sulphate, mg/l	3.88	0.04
Nitrate-N, mg/l	1.68	0.31
Phosphate-P, mg/l	0.087	ND
Ca, mg/l	10.4	2.4
Mg, mg/l	6.318	0.486
Na, mg/l	24.8	0.8
K, mg/l	1.8	ND
Iron, mg/l	0.9	0.01
DO, (mg/l)	11.8	1.6
BOD, (mg/l)	4.73	0.06

ND - Not Detected

pH values of the samples during the monsoon of 2008 varied from 6.74 (Aluva Marthandavarma and Kalamasseri) to 7.15 (Kallarkutty). pH of all samples were within the limit prescribed by BIS. Seasonal variation of pH is given in Fig 2.3.

The appearance of colour in water is caused by absorption of certain wavelengths of normal light by coloured substances, by scattering of light by suspended particles and by degradation of organic matter. In addition inorganic iron can also impart colour to water. Colour from iron is referred to as apparent colour. Seasonal variation of colour is depleted in Fig 2.4; comparatively, higher colour was found during the pre-monsoon of 2007. During the post-monsoon and pre-monsoon of 2006, values obtained for colour were not objectionable. But in the pre-monsoon of 2007, colour concentration showed a wide variation from 3 Hazen to 395 Hazen at Lower Periyar as shown in Fig 2.16. Only nine stations showed colour values within the BIS limit of 5 Hazen.

Table 2.7: Maximum and minimum values of Periyar river (Pre-monsoon 2007)

PARAMETERS	Maximum	Minimum
Temperature ^{o}C	37.20	24.20
pH	8.42	5.65
EC, Micromhos/cm	3660.00	21.70
Colour, Hazen	395.00	3.00
Turbidity, NTU	209.00	1.00
TDS, mg/l	2342.40	13.89
Total Alkalinity, mg/l	122.00	12.20
Total Hardness, mg/l	400.00	8.00
Ca Hardness, mg/l	120.00	4.00
Chloride, mg/l	1350.00	8.00
Sulphate, mg/l	157.60	0.96
Phosphate-P, mg/l	0.41	ND
Ca, mg/l	48.00	1.60
Mg, mg/l	68.04	0.00
Na, mg/l	860.00	3.00
K, mg/l	22.00	0.50
Iron, mg/l	1.15	ND
Manganese, mg/l	0.10	ND
Copper, mg/l	0.02	ND
DO, (mg/l)	8.60	2.40
BOD, (mg/l)	4.60	0.26

ND - Not Detected

Also in the post-monsoon of 2007, the maximum value of 25 Hazen was observed at three stations namely Eloor (Depo Kadavu), Chowwara and Perumthodu, the minimum value of 3 Hazen was observed at Eloor (mixing point). Only for three stations, the colour concentration was favourable, i.e., below 5 Hazen. Colour was found to be generally high during the pre-monsoon of 2007. During the monsoon of 2008 colour of the water sample shows the high values in all sites except four stations (Malayattoor, Idamalayar U/S, Bhuthathankettu U/S and Kalamasseri). Colour varies from 1.4 Hazen (Idamalayar U/S) to 72.1 Hazen (Kallarkutty).

Turbidity shows the physical status of river. The suspended particles, soil particles, effluents, TDS, and microscopic organisms increase turbidit of water at different sites of the river. During the post monsoon of 2005 only four samples (Manjummal, Eloor, Methanam Kadavu, School

Table 2.8: Maximum and minimum values of Periyar river (Post-monsoon 2007)

Parameters	Maximum	Minimum
pH	6.94	5.99
EC, Micromhos/cm	96.70	21.30
Colour, Hazen	25.00	3.00
Turbidity, NTU	27.44	ND
TDS, mg/l	61.89	13.63
Total Alkalinity,mg/l	36.00	12.00
Total Hardness, mg/l	36.00	10.00
Ca Hardness ,mg/l	28.00	6.00
Chloride, mg/l	32.00	8.00
Sulphate, mg/l	9.08	0.44
Nitrate-N, mg/l	5.80	ND
Phosphate-P, mg/l	0.51	ND
Ca, mg/l	11.20	2.40
Mg, mg/l	5.83	ND
Na, mg/l	10.80	3.20
K, mg/l	2.90	0.50
Iron, mg/l	0.54	0.01
DO(mg/l)	8.40	5.00
BOD(mg/l)	4.62	0.40

ND - Not Detected

Kadavu, and Depo Kadavu) showed values above the limit prescribed by BIS. During pre-monsoon of 2006 the value of turbidity was very low compared to other stations. During the pre-monsoon of 2007 high value of turbidity was reported from Lower Periyar (209 NTU) which may be due to flushing of sediment from Kallarkutty Dam. Desilting of reservoir directly affected the water quality in the downstream reaches of the river, and impact of sediments can extend up to many hundreds of kilometers from the dam. During the post monsoon of 2007 high value of turbidity was reported from the Thekkekovilakam Ferry (27.44 NTU), and 13 stations showed values above the desirable limit of 5 NTU. During the monsoon season of 2008, 12 samples showed values within the limit, 19 samples were found to have values above the desirable limit. The maximum value obtained was 21 NTU at Kallarkutty and turbidity was absent in sample collected from Perinjankuty, Idamalayar U/S, and Bhuthathankettu downstream. The turbidity of various samples collected during the pre –monsoon and post-monsoon of 2007 is shown in Fig 2.17 and 2.18.

Electrical conductivity is an index to represent total concentration of salts. High level of electrical conductivity indicates the pollution status as well as tropic level of aquatic body. During

Table 2.9: Maximum and minimum values of Periyar river (Monsoon 2008)

Parameters	Maximum	Minimum
Temperature(0 c)	26.60	26.10
pH	7.15	6.74
EC (micro siemens/cm)	200.00	30.10
Colour (Hazen)	72.10	1.40
Turbidity (NTU)	21.00	1.00
TDS, (mg/l)	128.00	0.00
Total alkalinity	36.00	0.00
Total Hardness(mg/l)	64.00	16.00
Calcium Hardness (mg/l)	40.00	8.00
Chloride(mg/I)	116.40	7.76
Sulphate(mg/l)	17.20	1.64
Nitrate(mg/l)	3.09	ND
Phosphate-P,(mg/l)	0.56	ND
Calcium (mg/l)	16.00	3.20
Magnesium (mg/l)	10.69	ND
Sodium (mg/l)	13.60	2.40
Potassium (mg/l)	5.80	0.30
Iron (mg/l)	0.96	0.03
Mn(mg/l)	0.35	0.02
D.O	9.04	2.44
B.O.D	4.22	0.13

ND - Not Detected

Table 2.10: Heavy metal concentration in selected sites of Periyar river water during pre-monsoon 2007

Parameters	**Manganese**	**Copper**
PRS04	0.014	ND
PRS 08	0.010	0.008
PRS 09	0.093	0.022
PRS15	0.010	ND
PRS16	0.013	0.008
PRS17	0.002	ND
PRS18	0.011	ND
PRS20	0.016	ND
PRS23	0.008	ND
PRS24	0.007	ND
PRS27	0.003	ND

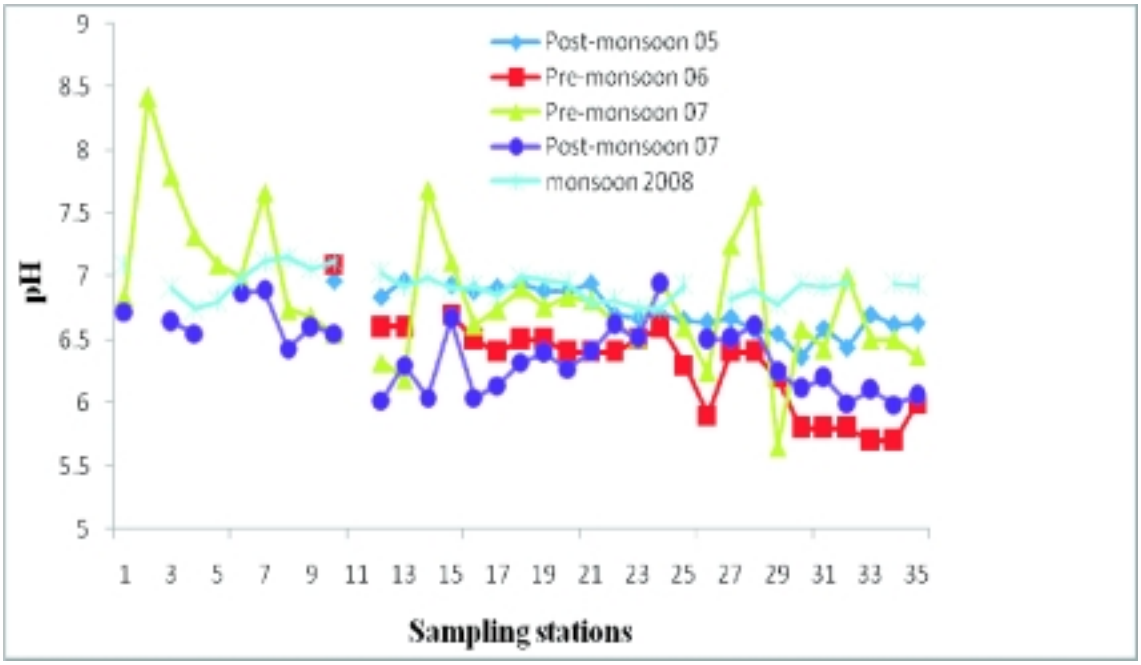


Fig 2.3: Variation in pH at various stations of Periyar river

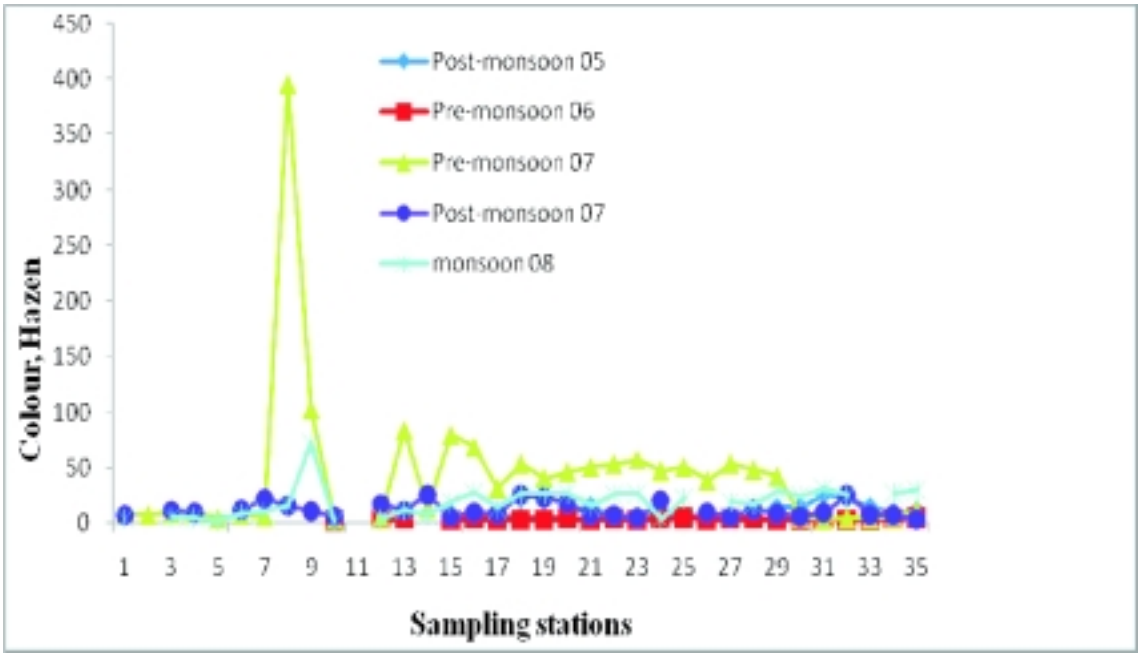


Fig 2.4: Variation of colour at various stations of Periyar river

pre-monsoon of 2005 the value of EC varied from 26 to 98.4µs/cm. During the season low value was reported from Edamalayar which is the upstream station of Periyar river basin and high value was reported from Pathalam upstream. During the pre-monsoon of 2006 the value was varied from 28.6 (Edamalayar) to 373 µs/cm (Eloor ferry). The EC values varied from 21.7 (Bhuthathankettu Downstream) to 3660.0 µs/cm (Eloor Ferry) during the post-monsoon of 2007. The highest value reported from Eloor ferry may be due to the saline intrusion from Cochin estuary. In the pre-monsoon seasons EC values were found to be increases from 2005 to 2007. During the post-monsoon season of 2007 the value varied from 21.30 to 85.7 µs/cm. High value of 85.7 µs/cm was observed for the sample collected from the Eloor mixing point which is the downstream sample of Periyar river basin. During the monsoon season of 2008, the electrical conductivity values varied from 30.1 (Idamalayar upstream) to 200 µs/cm (Aluva Manappuram).

Total dissolved solids consisted of inorganic salts, small amount of organic matter and dissolved materials. High value of TDS may induce unfavourable physiological reactions in the transient consumer and it indicated that the water is highly mineralized and which is in turn unstable apart from portability, for industrial applications also. The TDS values of samples collected during the pre-monsoon of 2005 and 2006, the post- monsoon of 2007 and the monsoon of 2008 were below the desirable limit of 500 mg/l. But in the pre-monsoon season of 2007 six stations showed TDS values above the desirable limit. The highest value of 2342.42 mg/l was observed from the sample collected from the Eloor Ferry. The variation of TDS was showed in the Fig.2.6.

Alkalinity is characterized by the presence of all hydroxyl ions and hydrolysis of salts such as carbonates and bicarbonates of calcium and magnesium. Alkalinity values of all the samples were below the limit of 200 mg/l during all the five seasons, but comparatively high values were found during the pre-monsoon of 2007 in the downstream stretches of Periyar river basin Fig 2.7.

Hardness is a measure of capacity of water to react with soap. It is not caused by a single substance, but by a variety of dissolved polyvalent metallic ions predominantly calcium and magnesium. Total hardness varied both seasonally and spatially. Comparatively, high hardness content was recorded in almost all the stations during the pre-monsoon of 2007. Water of six stations in the pre-monsoon of 2007 can be classified as very hard (concentration >180 mg/l as calcium carbonate); these stations are closer to the sea mouth (Fig. 2.8).

Analysis of major cations like sodium, potassium, calcium and magnesium revealed that the concentrations of these ions are in the desirable range during all the seasons, with an exception of six stations in the Eloor region which is surrounded by industries. Calcium concentration has an increasing trend from the post-monsoon of 2005 to the post-monsoon of 2007 as shown in Fig. 2.9. During the monsoon season of 2008 the values were found to be low may due to dilution effect.

Heavy metal analysis of the samples like iron, manganese and copper were also carried out. Iron concentration of 14 samples collected during the pre-monsoon of 2007 showed very high values. These values were noticed in general, and particularly in the case of samples collected from the upstream stations of the river. During pre monsoon of 2007 the maximum value of iron obtained was 1.15 mg/l (Lower Periyar). This high concentration may be attributed to the opening of the gates of Kallarkutty dam. Out of 34 samples analysed during the pre-monsoon of 2007, 14

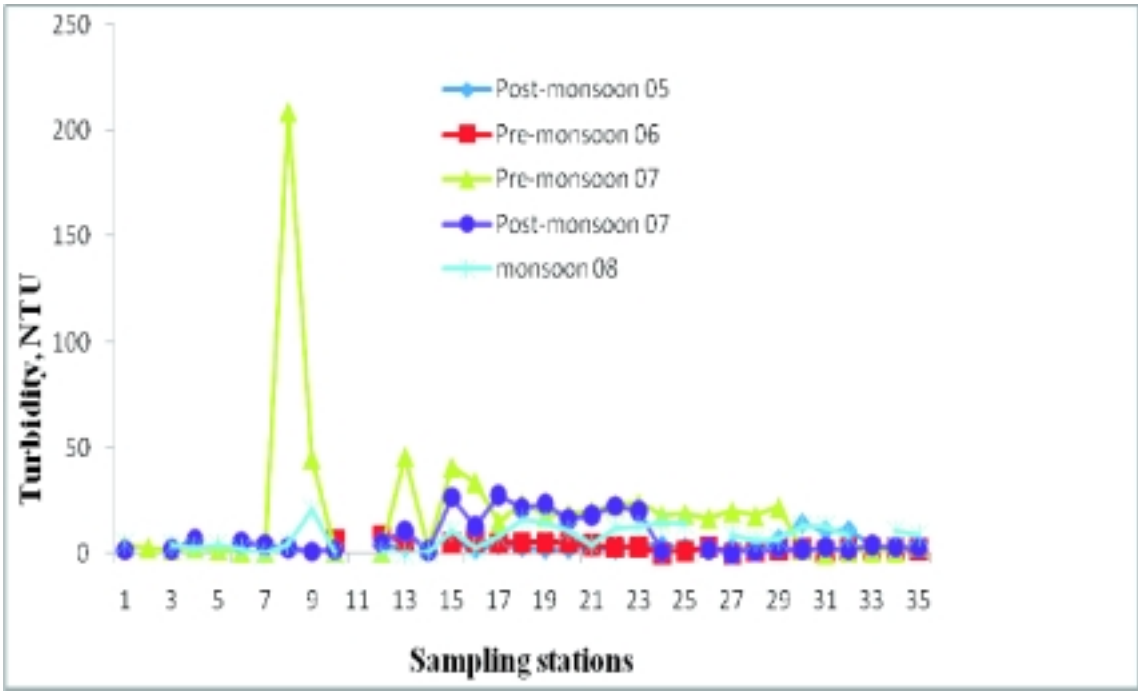
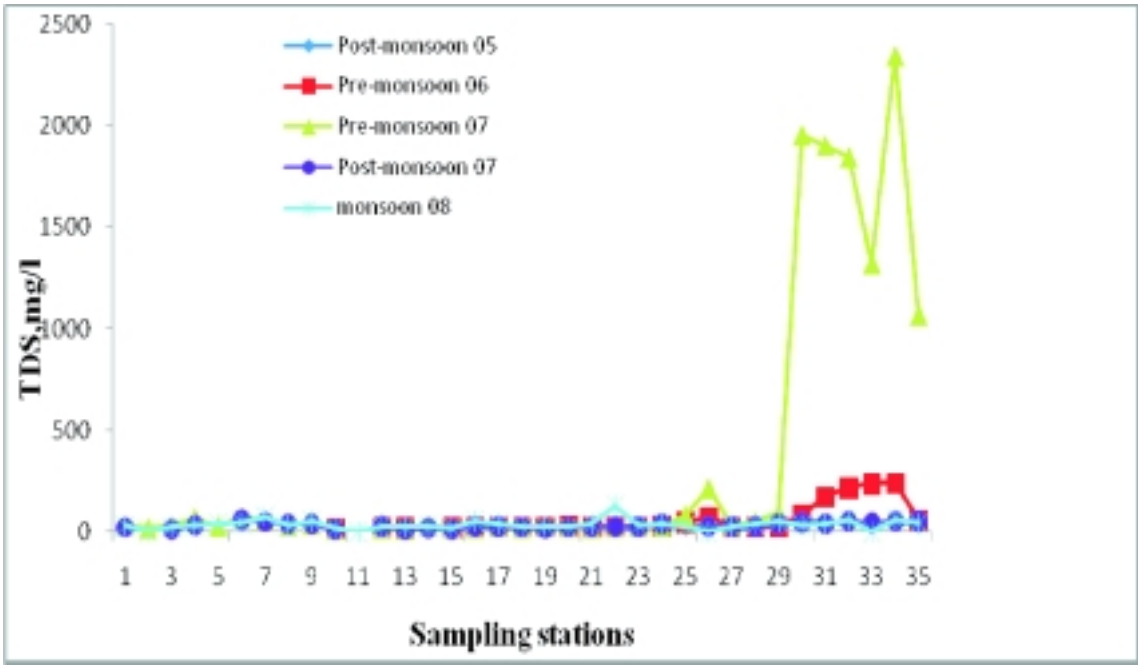


Fig 2.5: Variation of turbidity at various stations of Periyar river



2.6: Variation of TDS at various stations of Periyar river

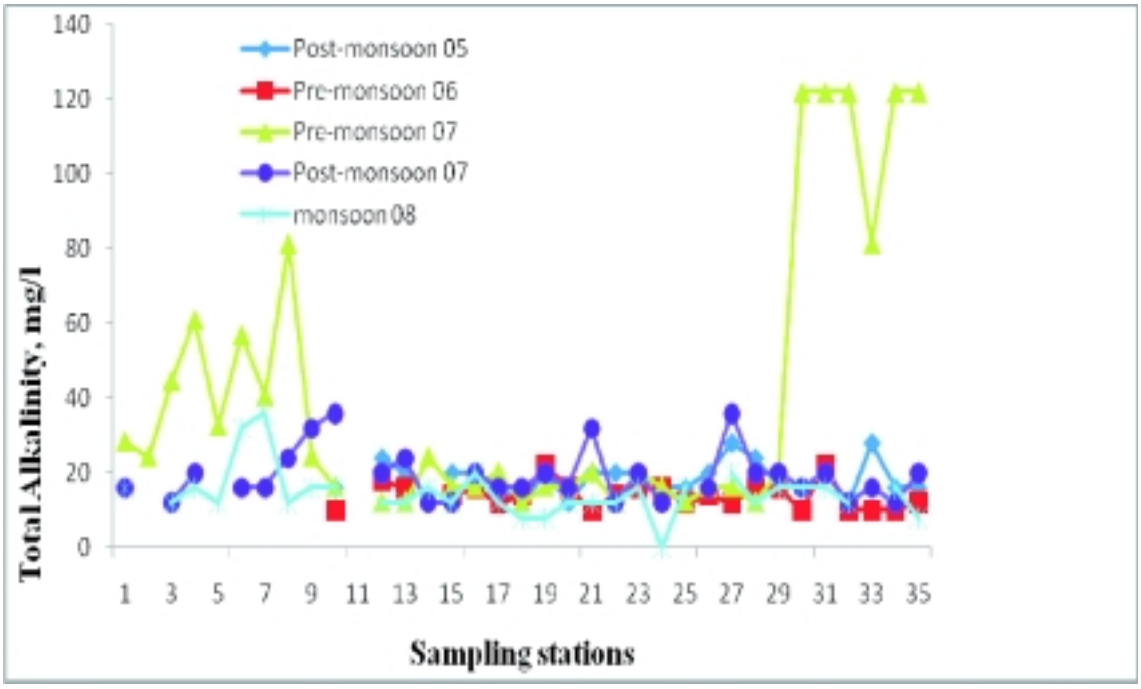


Fig 2.7: Variation of total alkalinity at various stations of Periyar river

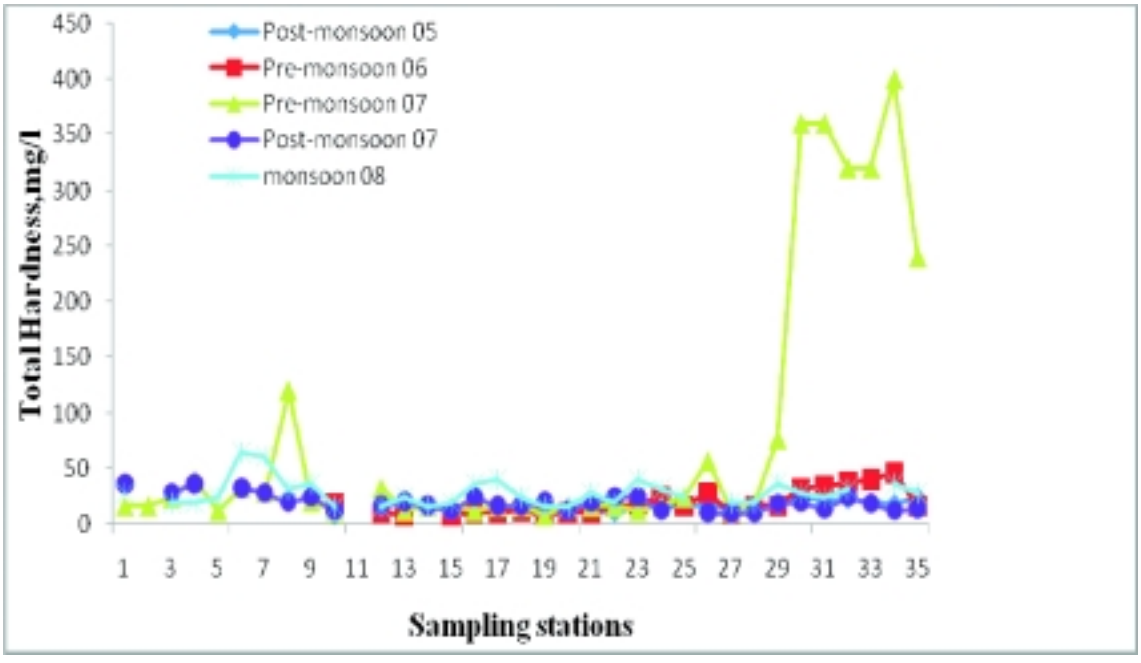


Fig 2.8: Variation of total hardness at various stations of Periyar river

stations showed values above the permissible limit of 0.3 mg/l. During the post monsoon of 2007 maximum value of 0.54 mg/l was reported at Malayattur and the minimum value 0.012 mg/l at Aluva (Mangalapuzha). Nine stations showed values above the permissible limit. During monsoon 2008, 18 samples showed value greater than 0.3 mg/l which is the limit prescribed by BIS. Highest value of 0.96 mg/l was observed for the sample collected from Kalamassery. Variation in Iron concentration is evident from the Fig. 2.10.

The concentration of manganese and copper were found to be low during the pre-monsoon of 2007. Values of manganese were within the limits of drinking water standards except one sample collected from Malayattur (0.1mg/l) During the monsoon 2008 the value of Manganese varied from 0.0169 (Buthathankettu downstream) to 0.35 mg/l (Malayattor which is an international pilgrim centre). Three stations showed values above the permissible limit of 0.1mg/l (Malayattur, Manjummal, Eloor Ferry).

Chloride is one of the anions which determine the total salinity of water and make a quantitative accumulation of this anion over a period of time is an indicative of anthropogenic pollution. High chloride content in water bodies harms metallic pipe and structures as well as agricultural crops. Among the samples collected from the Periyar, only six samples were found to have higher chloride values during the pre-monsoon of 2007, which could be due to salinity intrusion. During this season, maximum value obtained was 1350 mg/l (Eloor Ferry) and minimum value at Mullaperiyar 8.00 mg/l. The value was found to be very low during the monsoon of 2008 may be due to dilution effect. The variation in chloride concentration is given in Fig. 2.11.

In the post-monsoon of 2005 and the pre-monsoon of 2006, the concentration of sulphate was insignificant. Its concentration increased in the pre-monsoon of 2007 and again decreased in the post-monsoon of 2007 as shown in Fig 2.12. Comparatively high values were found in sites Aluva (Marthandavarma), Kalamassery and Pathalam (upstream) during the pre-monsoon of 2007.

Nitrate and phosphate concentrations in the river were found to be very low. Comparatively high concentration of nitrate-N (5.4 and 5.48 mg/l) was reported from Eloor Ferry and Eloor Mixing Point during the post-monsoon of 2007. During the monsoon of 2008 high value for nitrate N was observed for the sample collected from Malayatoor which is an international pilgrim centre (3.094 mg/l).

Dissolved oxygen is necessary to sustain aquatic biota and it also provides a self purification capacity to water. Biodegradation of dissolved, suspended and deposited organic materials depends on oxygen, as also on the respiration of aquatic biota. If the river is heavily loaded with organic materials, the amount of oxygen consumed may be more than what can be absorbed through water-air interface so that the oxygen content quickly falls. Dissolved oxygen values of most of the samples were above the minimum requirement in pre monsoon 2005 as given in Fig. 2.13. In the pre-monsoon of 2006, low DO was observed for the sample collected from Kalamassery. DO concentration was comparatively low during pre-monsoon of 2007, 14 samples showed DO less than 5 mg/l. During the monsoon 2008 sample collected from Kalady showed low DO value. Biological Oxygen Demand of the samples during all the seasons was below 5mg/l.

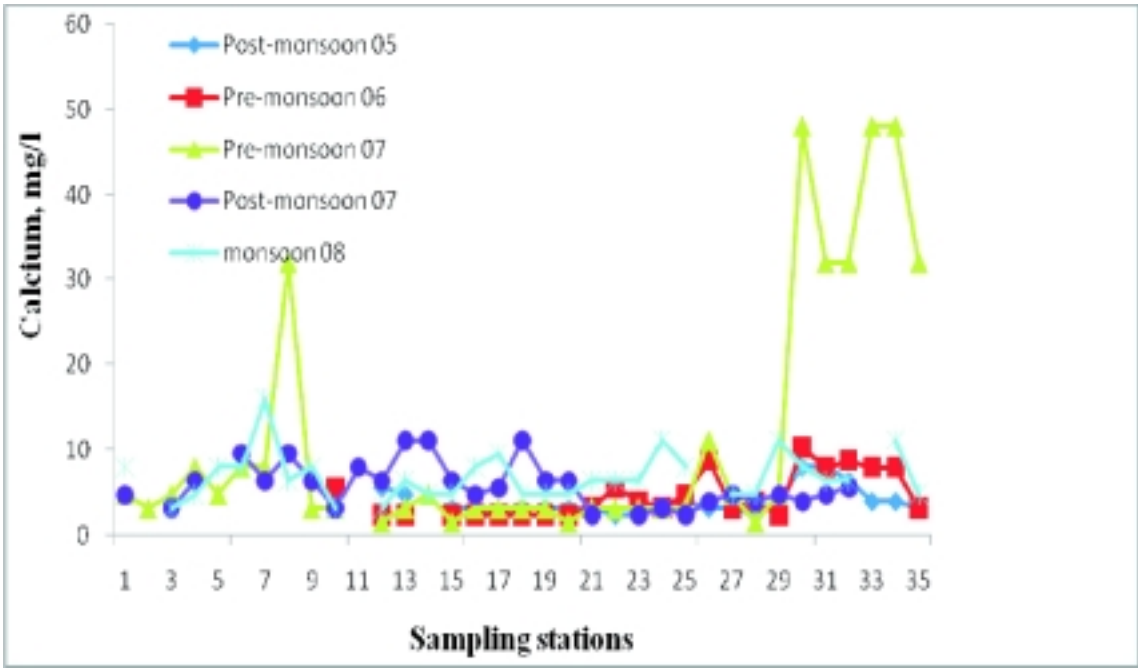


Fig 2.9: Variation of calcium at various stations of Periyar river

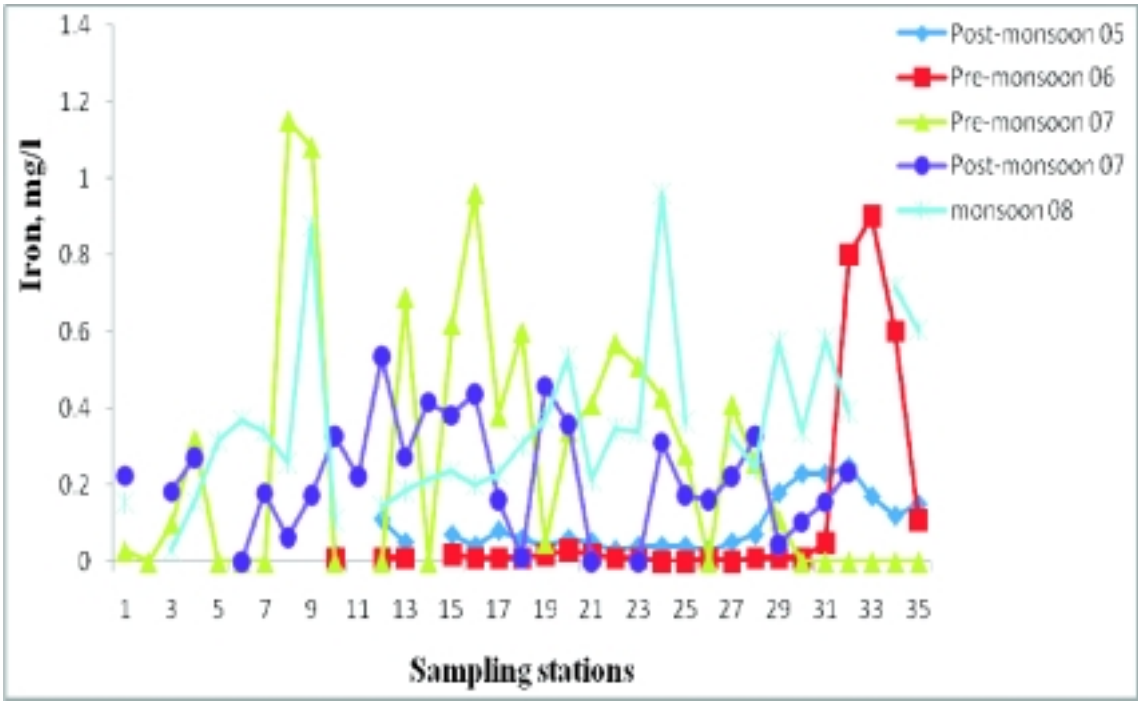


Fig 2.10: Variation of iron at various stations of Periyar river

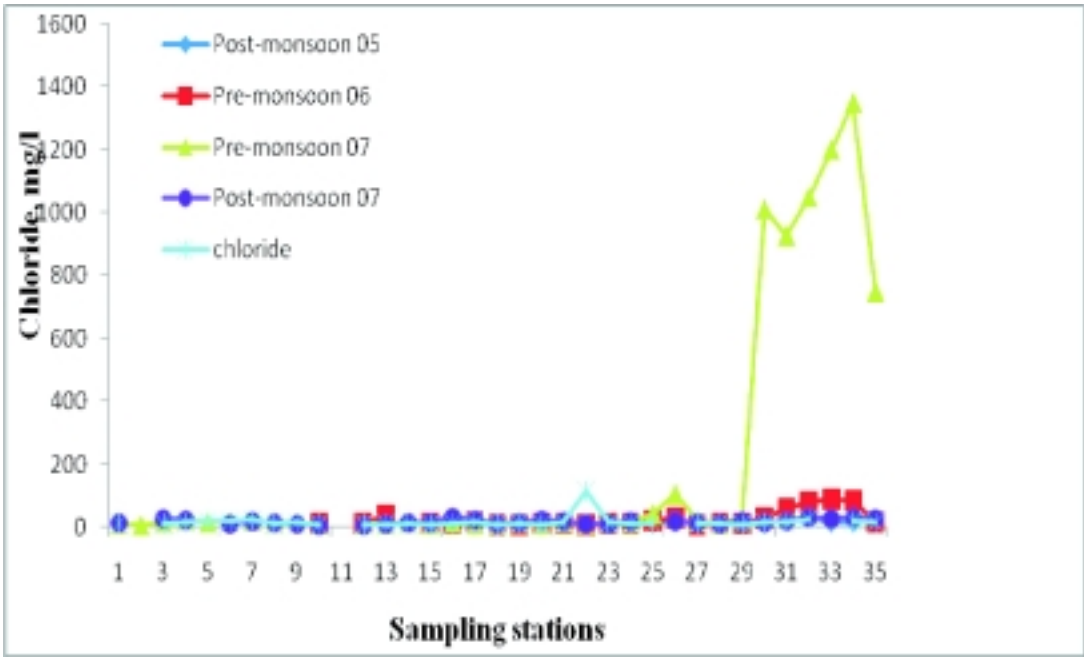


Fig 2.11: Variation of chloride at various stations of Periyar river

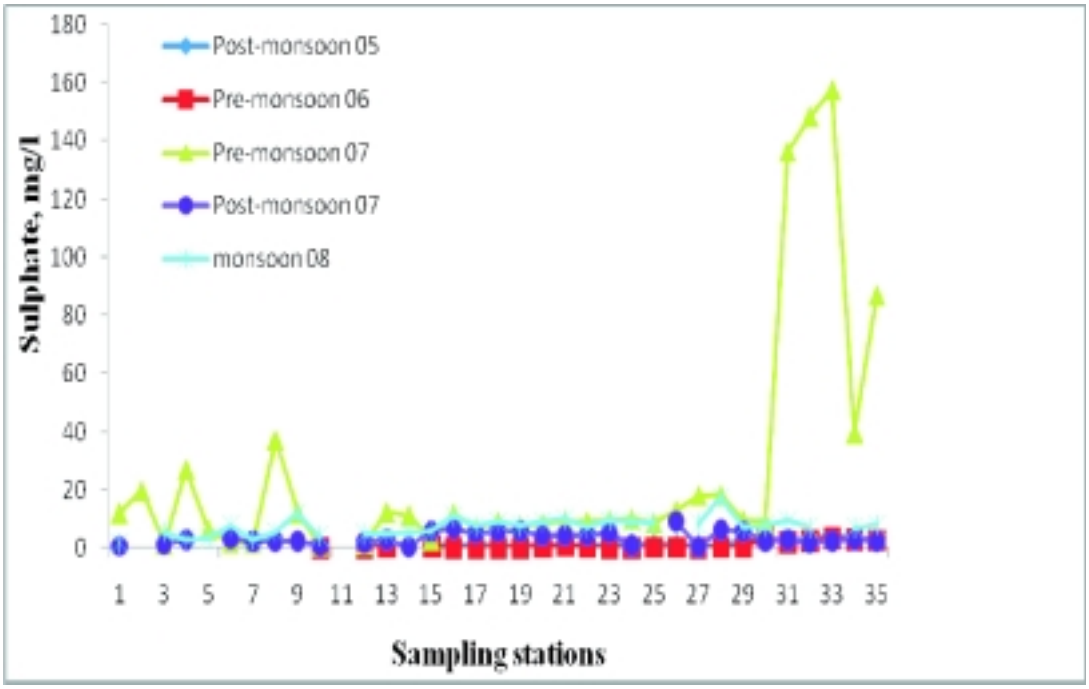


Fig 2.12: Variation of sulphate at various stations of Periyar river

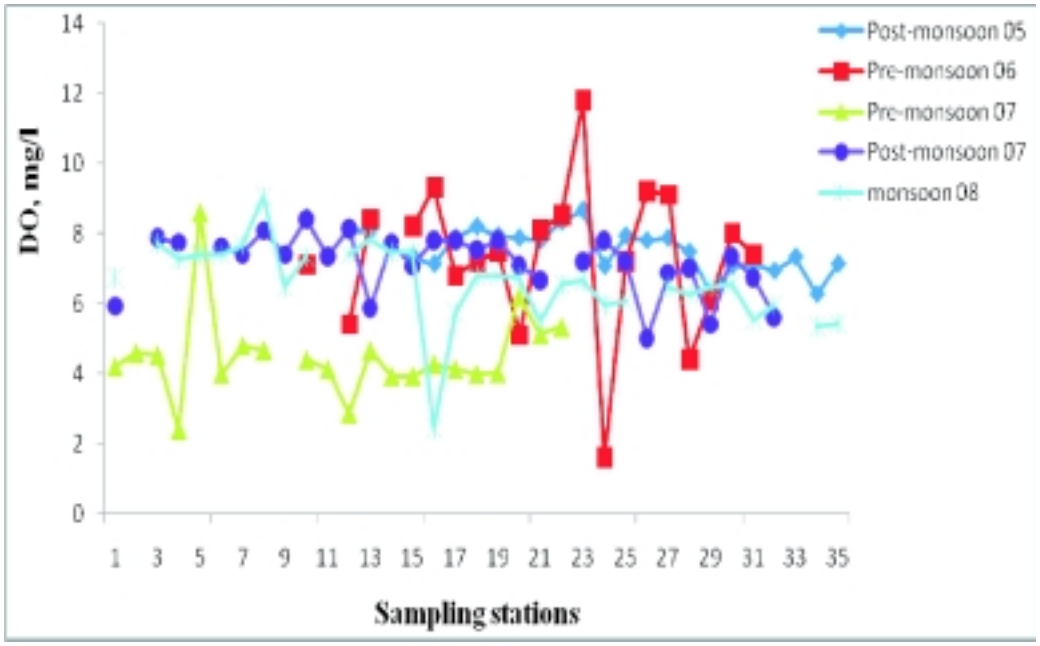


Fig 2.13: Variation of DO at various stations of Periyar river

Bacteriological analysis of the samples clearly indicated microbial contamination in the river. Almost all the stations showed higher index for total coliforms. The percentage of samples tested positive for E.Coli is shown in Fig. 2.14.

2.3.3 Investigations on specific problems

The stretch between Angamaly and Kochi is a highly industrialized zone in the Periyar river basin. The Eloor - Edayar region of Cochin estuary presents a typical example of industrial pollution. It is situated 17 km north of Eranakulam town area, Eloor is an island of 11.21 sq km in which most of the industries of the area are situated. The Eloor - Edayar region, about 20 km from the point where the Periyar river meets the Lakshadweep Sea, is the industrial hub of Kochi. There are more than 247 chemical industries, including Hindustan Insecticide Limited (HIL), Fertilizers and Chemicals Travancore Ltd (FACT), Indian Rare Earths Ltd, Travancore Cochin Chemicals, Cochin Minerals and Rutile Ltd (CMRL) etc. These industries take considerable amount of fresh water from Periyar river and also discharge effluents treated or partially treated. Two emergency surveys were conducted in the Eloor region on 12 Sept 2006 when a change of colour due to pollution was observed. Heavy metal analysis of four samples collected has provided information on the extent of pollution in this area.

2.3.3.1 Sampling of 12 September 2006

The sampling was carried out in the wake of the reports of colour change and fish kills in the Eloor region of Periyar river. Water quality characteristics of the samples are presented in Table 2.11.

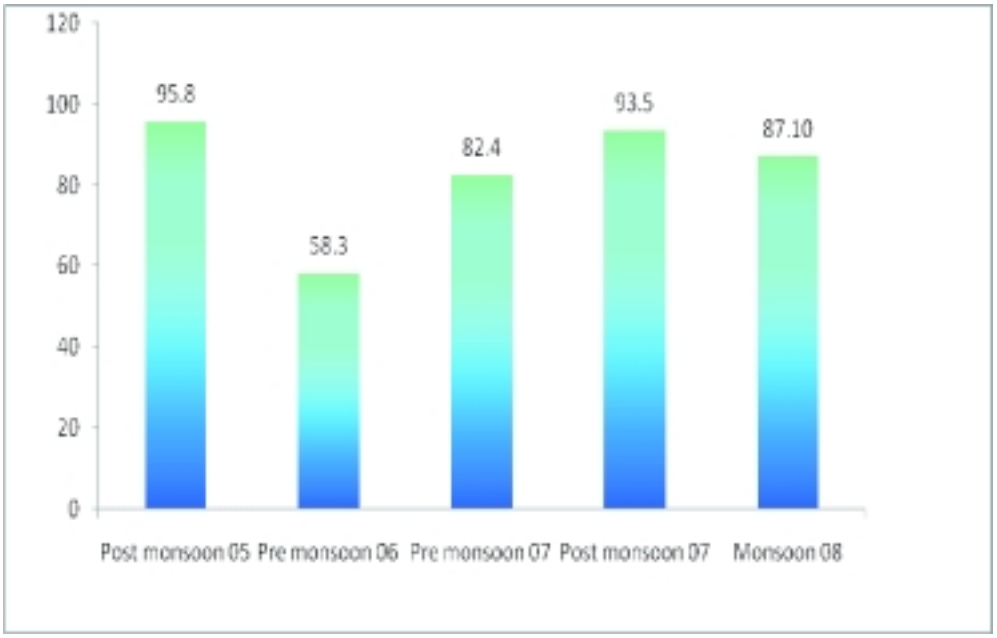


Fig 2.14: Percentage of samples tested positive for the presence of E.coli

Table 2.11: physico-chemical characteristics of water samples

Parameters	01/PR	02/PR	03/PR	04/PR
pH	7.8	6.9	6.9	4.7
EC, (micro siemens/cm)	83.7	196.9	50.9	392
Colour, (Hazen)	15	17	19	34
Turbidity, (NTU)	8	10	10	75
TDS, (mg/l)	40	93	24	816
Total Hardness, (mg/l)	18	24	20	116
Calcium Hardness, (mg/l)	10	16	8	60
Calcium, (mg/l)	4	6.4	3.2	24
Magnesium, (mg/l)	1.944	1.944	2.916	13.608
Sodium, (mg/l)	10.4	24	4.4	68.8
Potassium, (mg/l)	1	1	1	8.8
Iron, (mg/l)	0.14	0.19	0.26	17
Chromium, (mg/l)	0.013	0.014	0.013	0.061
Manganese, (mg/l)	0.13	0.08	ND	1.47
Lead, (mg/l)	ND	ND	ND	0.003
Chloride, (mg/l)	2.1	3.8	1.2	5.8
Nitrate-N, (mg/l)	0.94	1.13	ND	0.08
Phosphate-P, (mg/l)	0	0.02	0	0.14

Iron concentration showed a maximum value of 17 mg/l. Maximum value recorded for Chromium was 0.061mg/l which is above the BIS limit of 0.05 mg/l and the values for Manganese ranged between 0.08 mg/l and 1.47mg/l while BIS limit is 0.1mg/l.

2.3.3.2 Sampling on 12th December 2007

On 18 Dec 2007, the water of Periyar again showed discoloration. The colour suddenly changed to red. The discoloration occurred at Pathalam Bund near Eloor which houses the Udyogamandal Industrial Estate. The details of sampling sites are given in Table 2.12 and Fig 2.20.

Table 2.12: Details of sampling location

Station ID	Site details
E/01	Pathalam regulator cum bridge
E/02	Eloor Methanam Kadavu
E/03	Edayar near southern minerals and metals
E/04	Catalyst Kadavu near Periyar chemicals ltd.

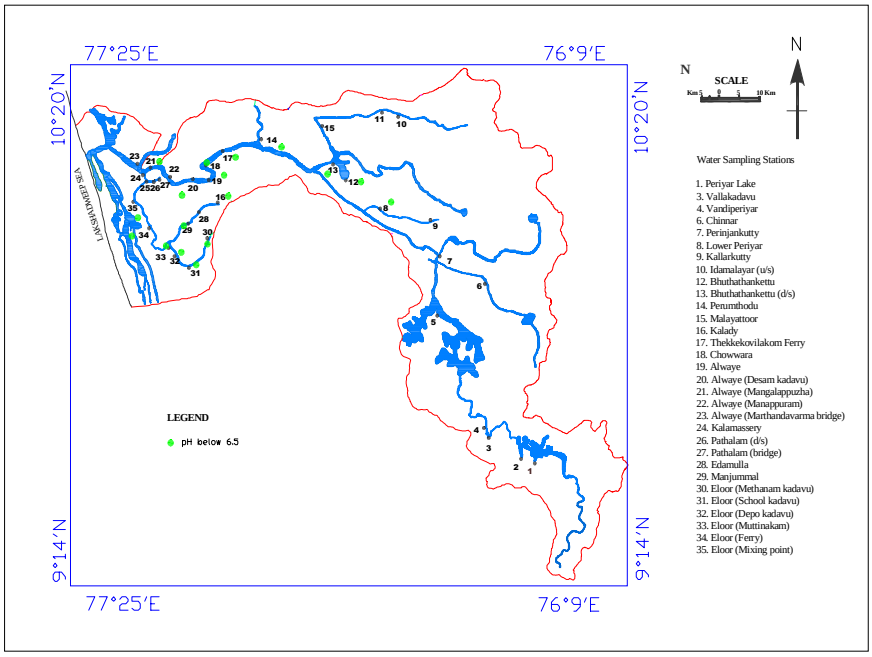


Fig 2.15: Spatial variation of pH along Periyar river (pre-monsoon 2007)

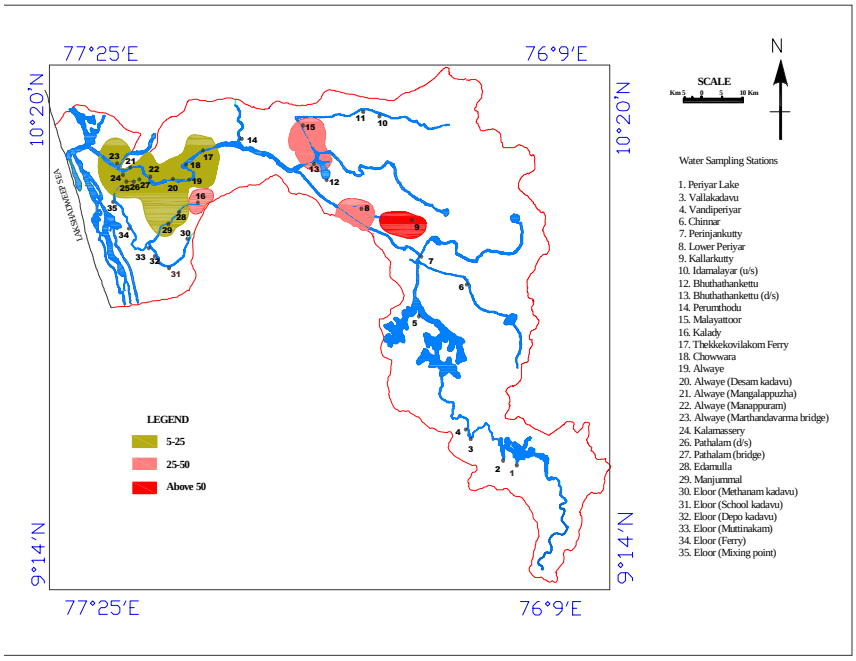


Fig 2.16: Change in colour at different stations in Periyar river during (Pre-monsoon 2007)

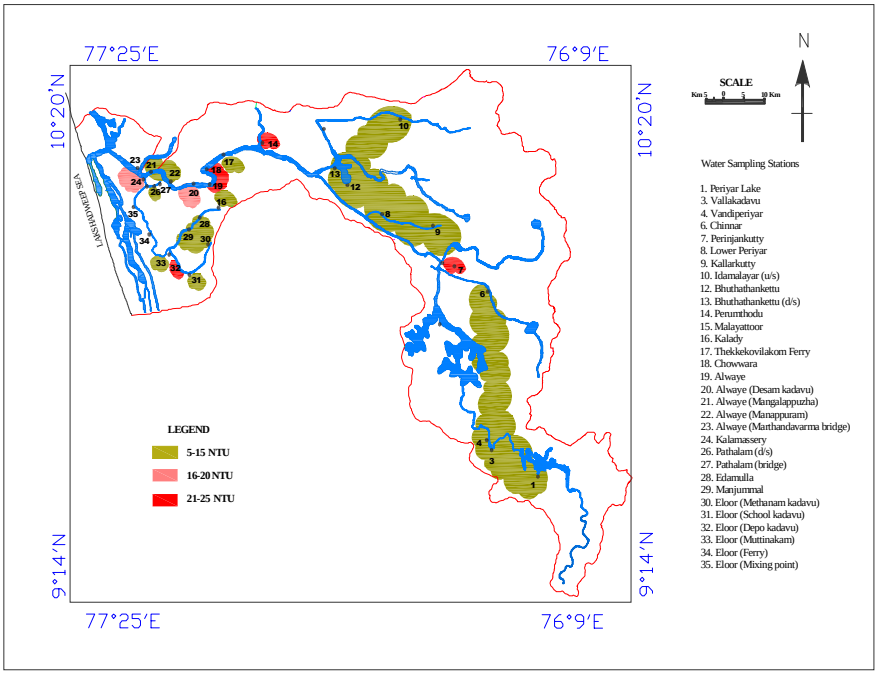


Fig. 2.17: Spatial variation of turbidity along Periyar river (pre-monsoon 2007)

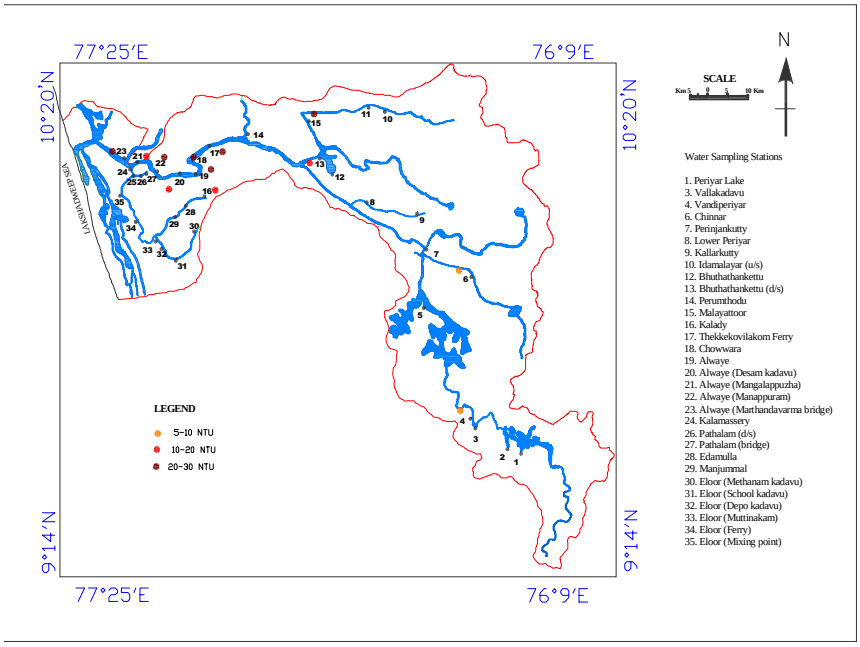


Fig. 2.18: Spatial variation of turbidity along Periyar river (post-monsoon-2007)

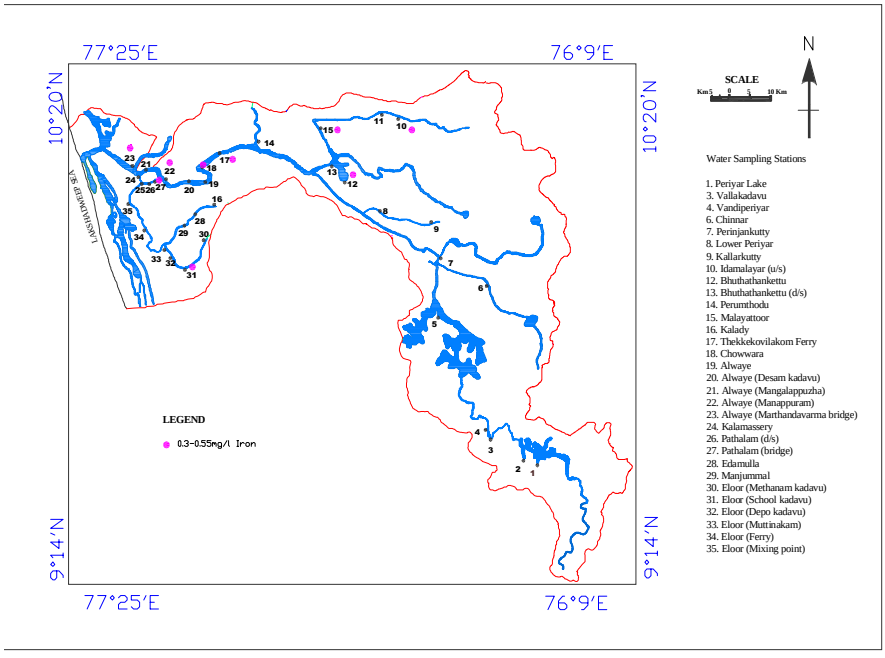


Fig. 2.19: Iron concentration at different stations in Periyar river (pre-monsoon 2007)

Fig 2.20: Site map of Eloor industrial zone showing the sampling sites

Plate 2.3: Downstream of Bhuthathankettu

Plate 2.4: Paathalam dam

Plate 2.5: Reddish water in the vicinity of Eloor- Edayar region of Periyar river

Physico-chemical parameters of water samples collected from Eloor region on 20 Dec 2007 were analysed. The results are presented in Table 2.13.

The values of pH of the samples varied from 6.31 to 6.76. Sample collected from Site 2 was found to be slightly acidic.

Table 2.13: Water quality characteristics of samples from Eloor region of Periyar river

PARAMETERS	E/01	E/02	E/03	E/04
pH	6.54	6.31	6.76	6.71
EC, Micromhos/cm	112.00	240.00	117.90	91.90
Colour, Hazen	8.20	6.80	35.10	13.20
Turbidity, NTU	5.00	3.00	34.00	7.00
TDS, mg/l	71.68	153.60	75.46	58.82
Total Alkalinity, mg/l	20.00	20.00	20.00	16.00
Total Hardness, mg/l	20.00	56.00	20.00	56.00
Ca Hardness, mg/l	16.00	44.00	8.00	36.00
Chloride, mg/l	7.88	35.48	11.83	23.65
Sulphate, mg/l	1.92	3.80	4.56	0.76
Nitrate-N, mg/l	0.20	1.20	ND	ND
Phosphate-P, mg/l	0.02	ND	ND	0.01
Ca, mg/l	6.40	17.60	3.20	14.40
Mg, mg/l	0.97	2.92	2.92	4.86
Na, mg/l	4.40	8.80	4.80	6.00
K, mg/l	1.90	1.10	1.10	1.00
Iron, mg/l	0.09	0.09	1.50	0.29

Colour of these samples varied from 6.8 to 35.1 Hazen. For all samples, a reported value of colour was higher, i.e. greater than the desirable limit of 5 Hazen.

Turbidity varied from 3 to 34 NTU. Turbidity values were highly correlated with iron (0.9975). At Stations 3 and 4, the value was above the limit and a high value was reported at Station 3.

Concentration of iron varied from 0.09 to 1.5 mg/l. High value was reported at Station 3 and it was beyond the BIS limit. Dissolved iron showed good correlation with colour (0.9968) and turbidity.

The high value of colour and iron was reported at Station 3, i.e. from Edayar region. Alkalinity values ranged from 16 to 20 mg/l. Total hardness varied from 20 to 56mg/l. High value was reported at Station 2 and 4. Maximum value of calcium was reported at Station 2 and minimum at Station 3. It ranged from 3.2 to 17.6 mg/l. Value of chloride ranged from 7.88 to 35.48 mg/l. High value was reported at Station 2.

The samples were found to be contaminated with iron, turbidity and colour. Oxidation of dissolved iron particles in water might have changed soluble iron in to red brown solid particles of ferric hydroxide, which might be the reason for the red coloration. The source of iron can be from the effluents discharged by the industries. Some of the industries located near Periyar river are listed below:

Hindustan Insecticides Limited - One of the major producers of DDT; Other products include endosulfan, malathion and mancozeb.

Travancore Cochin Chemicals - Their primary products include caustic soda, chlorine, hydrochloric acid and sodium hypochlorite.

Merhcem Limited - A leading manufacturer of rubber chemicals, agrochemicals, water treatment chemicals and speciality chemicals.

FACT - Their main interests lie in fertilisers, petrochemicals and pharmaceuticals

Table 2.14 .Sampling details of Periyar industrial area

Station Code	Stations	Location	
		Latitude	Longitude
PR01	Boat Jetty	N 09° 59´ 4.5´´	E 76° 16´ 20.4´´
PR02	Eloor Ferry	N 10° 04´ 46.56´´	E 76° 16´ 56´´
PR03	Methanam	N 10° 05´ 45.18´´	E 76° 17´ 5.46´´
PR04	Eloor (Plywood Company)	N 10° 05´ 30.6´´	E 76° 17´ 44.34´´
PR05	Eloor	N 10° 05´ 13.68´´	E 76° 17´ 52.14´´
PR06	Binanipuram Zinc	N 10° 05´ 3.18´´	E 76° 17´ 57.12´´
PR07	Indian Rare Earth Ltd	N 10° 05´ 0.06´´	E 76° 17´ 54.24´´
PR08	Fact	N 10° 05´ 50.88´´	E 76° 17´ 57.18´´
PR09	TCC (Outlet)	N 10° 04´ 37.2´´	E 76° 17´ 6´´
PR10	TCC (Near)	N 10° 04´ 37.68´´	E 76° 18´ 15.6´´
PR11	Navalli Rubber Company	N 10° 04´ 36.96´´	E 76° 18´ 29.82´´
PR12	Pathalam Upstream	N 10° 04´ 36.72´´	E 76° 18´ 30.36´´
PR13	Fact Petrochemicals Outlet	N 10° 04´ 7.62´´	E 76° 18´ 27.18´´

Plate 2.6: Periyar river with reddish water

Plate 2.7: Discoloured Periyar river

Cochin Minerals and Rutile Ltd (CMRL): It manufactures 70 tons per day of synthetic rutile (an intermediate in the manufacture of Titanium dioxide) through chloride route and roughly 90 tons of other by-products per day. Ferrous chloride is produced as a byproduct which is a toxic waste. These iron particles can be oxidized and may lead to the formation of red brown ferric hydroxide.

2.3.3.3 Sampling of 13th March 2008

An emergency surface water sampling in the industrial area of Periyar river basin was conducted on 13 March 2008 as the river water got colored due to industrial effluents during that period. Nine sediment samples were collected. Maximum, minimum and average of physico-chemical and bacteriological analyses of the water samples are given in Table 2.15. The Table shows the details of the sampling stations is presented below.

The pH varied from 3.59 (Indian Rare Earth Ltd) to 7.4 (Boat Jetty) with an average value of 6.38. Colour of all the samples exceeded the potability limit prescribed by BIS. But the concentration of iron lies within the permissible limit.

Turbidity of only one sample (Pathalam Upstream) exceeded the limit of 5 NTU. The EC and TDS showed high values in most of the stations, which reflect high concentration of the dissolved ions. Further analysis revealed that most of the samples are contaminated with high concentration of the ions like Ca, Mg, Na, K and chloride.

Parameters like total alkalinity exceeded the limit and it ranged from 400 mg/l to 800 mg/l. The water is also found to be extremely hard in these areas. It ranged from 400 to 4000 mg/l with an average value of 1200 mg/l.

The concentration of sulphate was comparatively low and only one sample, from Eloor Ferry was found to exceed the prescribed limit. It had an average value of 100.31 mg/l.

Nutrients like PO_4-P and NO_3-N were found to have very low concentration throughout the area.

The salinity of most of the samples were much high. The maximum value (17.6 ppt) was found at Boat Jetty.

The DO of most of the samples were below 5mg/l. and the BOD of all the samples were reported below 3mg/l.

Microbiological analysis revealed that most of the samples were contaminated with the presence of coliforms. But Indian Rare Earth Ltd, the coliform count was below 3 MPN. This shows the presence of some toxic substances which are harmful to coliforms.

The water quality in the industrial area of Periyar river basin is very poor due to the excess concentration of different dissolved ions. If the effluent discharge continues like this, the assimilative capacity of the river will be lost.

2.4. WATER QUALITY INDEX

Water quality index may be defined as a rating reflecting the composite influence of a number of water quality parameters. It provides a convenient means of summarizing complex water quality

Table 2.15: Water quality parameters- maximum and minimum of industrial stretches of Periyar river

Sl. No.	Parameters	Minimum	Maximum
1	Temperature	28.5	31.7
2	pH	3.59	7.4
3	EC (micro siemens/cm)	86.1	28900
4	DO(mg/l)	4	6.06
5	BOD(mg/l)	0.5	2.33
6	Colour (Hazen)	8.4	15.8
7	Turbidity (NTU)	2.3	22
8	TDS, (mg/l)	55.36	18582.7
9	Total Alkalinity(mg/l)	400	800
10	Total Hardness(mg/l)	400	4000
11	Calcium Hardness (mg/l)	200	800
12	Calcium (mg/l)	80	320
13	Magnesium (mg/l)	0	780.8
14	Sodium (mg/l)	4.4	15306
15	Potassium (mg/l)	0.7	335
16	Iron (mg/l)	0.02	0.18
17	Chloride(mg/I)	237.05	10777.5
18	Sulphate(mg/l)	3.68	282.4
19	Nitrate-N,(mg/l)	0.02	2.48
20	Salinity(ppt)	ND	17.6
21	Phosphate-P,(mg/l)	ND	0.05

data. The index generally produces a number between 0 and 100. Higher the index better the quality, lower the value higher the pollution. An attempt was made to classify the river based on the water quality index.

2.4.1 Tiwari and Mishra Water Quality Index

Tiwari and Mishra (1986) have developed a WQI which can be calculated from the formula given below:

$WQI = [\Sigma q_i W_i] / [\Sigma W_i]$

Where,

$q_i = 100(\mathbf{V}_i/S_i)$

$q_{DO} = 100 \{(VDO – 14.6) / (5.0 – 14.6)\}$

$q_{pH} = 100 \{(VpH – 7.0) / (8.5 – 7.0)\}$

$W_i = K/S_i$

And, here

q_i = quality rating for the i^{th} water quality parameter (i=1, 2, 3,…N)

V_i = measured value of the i^{th} parameter at a given sampling station,

S_i = the standard of permissible value for the i^{th} parameter,

The 'standard' permissible values for various pollutants in drinking water, recommended by WHO, are given in the Table 2.16, these are parameters considered.

Table 2.16: WHO standards and unit weights of water quality parameters

Parameters	Recommended Unit Standard (S_i)	Unit weight (W_i)
pH	7.0 – 8.5 (avg. 7)	0.005
Turbidity, (NTU)	5.0	0.2
Total Dissolved Solids, mg/l	500	0.002
Dissolved Oxygen, mg/l	>5	0.2
Biochemical Oxygen Demand, mg/l	<5	0.2
Calcium, mg/l	75	0.0133
Magnesium, mg/l	50	0.02
Hardness (as CaCO3), mg/l	100-500 (avg. 300)	0.0033
Chloride, mg/l	200	0.005
Nitrate-N, mg/l	45	0.022
Sulphate, mg/l	200	O.005
Sodium, mg/l	200	0.005
Specific Conductance, µS/cm	300	0.003

It is well known that, the more harmful a given pollutant is, the smaller is its permissible value for the standard (V_s) recommended for drinking water. So, the "weights" for various water quality parameters are assumed to be inversely proportional to the recommended standards for the corresponding parameters, namely $W_i = K/S_i$ (where W_i is the unit weight for the parameter P_i (i = 1, 2, 3…) and K is the constant for proportionality. For the sake of simplicity, K is assumed as 1 for pH, assuming the same unit weight as that for chlorides, namely 0.005.The unit weight Wi, obtained from the above equation with K = 1, are shown in the third column of table below. As per the WQI devloped by Tiwari and Mishra, values above 100 indicate pollution.

The water quality index of Periyar River has been calculated for 35 stations during the pre-monsoon of 2007 and also during the post-monsoon of 2007. For calculating the Water Quality Index of Periyar River, a set of 12 parameters are selected, which includes pH, turbidity, total dissolved Solids, dissolved oxygen, biochemical oxygen demand, calcium, Magnesium, Hardness, chloride, sulphate, sodium, specific conductance and total coliforms. The water quality index is given in Tables 2.17 and 2.18.

2.4.2. NSF Water Quality Index

The National Sanitation Foundation (NSF) created and designed a standard index known as the Water Quality Index (WQI) and it is one of the most widely used. The overall results of nine separate tests (DO, pH, BOD, faecal coliform, temperature, total phosphates, nitrates, turbidity and total solids) can be used to determine, if a particular stretch of river is healthy based on the score as given in Table 2.19.

NSF water quality index is calculated for 34 stations of Periyar river during the pre-monsoon of 2007 (Table 2.20) and for 31 stations during the post-monsoon of 2007 (Table 2.21) and monsoon 2008 (Table 2.22). Among these, 18 stations considered during the pre-monsoon and one station (Vallakadavu) considered in the post-monsoon of 2007 showed an average rating. This implies that water from these stations has less diversity of aquatic organisms, and has frequent increase in algae growth. Rating value of 15 stations ranged between 71 and 90 (Good Water Quality) during the pre-monsoon, 24 stations during the post-monsoon of 2007 and 30 stations during monsoon 2008. This means that the water stretch is able to support a high diversity of aquatic life and it is also suitable for all forms of recreational activities involving direct contact with water.

2.4.3 CCME Water Quality Index

The CCME Water Quality Index (WQI) is a simple mathematical tool for reporting water quality data. The index can inform about the ability of surface and ground waters to support various beneficial water uses, and the possible threats to those uses due to human activities. In contrast to traditional reports on water quality that usually consists of variable-by-variable statistical summaries, the CCME WQI provides one number representing a broad overview of the suitability of water quality data for a particular use, based on a set of objectives.

The index consists of three factors that ultimately yield a number between 0 and 100, which is further classified to describe the quality of water as shown in Table 2.23.

Table 2.17: Tiwari and Mishra Water Quality Index for the pre-monsoon of 2007

Code	Name of the station	WQI
PRS01	Thekkady	58.81
PRS02	Mullaperiyar	77.99
PRS03	Vallakkadavu	47.85
PRS04	Vandiperiyar	68.67
PRS05	Idukki (Dam)	39.94
PRS06	Chinnar	63.85
PRS07	Perinjankutty	44.14
PRS08	Lower Periyar	1310.02
PRS09	Kallarkutty	318.24
PRS10	Idamalayar (Upstream)	46.13
PRS11	Idamalayar (Downstream)	not taken
PRS12	Bhuthathankettu (Upstream)	42.16
PRS13	Bhuthathankettu (Downstream)	317.77
PRS14	Perumthodu	60.22
PRS15	Malayattoor	307.29
PRS16	Kalady	245.32
PRS17	Thekkekovilakam Ferry	146.98
PRS18	Chowwara	179.91
PRS19	Aluva	148.82
PRS20	Aluva (Desam Kadavu)	167.42
PRS21	Aluva (Mangalapuzha)	178.69
PRS22	Aluva (Manappuram)	167.64
PRS23	Aluva (Marthandavarma)	186.89
PRS24	Kalamassery	141.98
PRS25	Pathalam (Upstream)	153.84
PRS26	Pathalam (Downstream)	137.91
PRS27	Pathalam (Bridge)	154.18
PRS28	Edamulla	149.539
PRS29	Manjummal	173.43
PRS30	Eloor (Methanam Kadavu)	64.49
PRS31	Eloor (School Kadavu)	47.82
PRS32	Eloor (Depo Kadavu)	57.13
PRS33	Eloor (Muttinakam)	53.06
PRS34	Eloor (Ferry)	58.45
PRS35	Eloor (Mixing Point)	71.33

Table 2.18: Tiwari and Mishra Water Quality Index for the Post-monsoon of 2007

Code	Name of the station	WQI
PRS01	Thekkady	66.24
PRS02	Mullaperiyar	58.23
PRS03	Vallakadavu	37.75
PRS04	Vandiperiyar	135.66
PRS05	Idukki (Dam)	-
PRS06	Chinnar	113.71
PRS07	Perinjankutty	148.05
PRS08	Lower Periyar	133.38
PRS09	Kallarkutty	148.43
PRS10	Idamalayar (Upstream)	217.05
PRS11	Idamalayar (Downstream)	-
PRS12	Bhuthathankettu (Upstream)	209.07
PRS13	Bhuthathankettu (Ddownstream)	148.66
PRS14	Perumthodu	205.35
PRS15	Malayattoor	223.23
PRS16	Kalady	253.20
PRS17	Thekkekovilakam Ferry	228.79
PRS18	Chowwara	259.78
PRS19	Aluva	215.95
PRS20	Aluva (desam Kadavu)	225.61
PRS21	Aluva (Mangalapuzha)	256.63
PRS22	Aluva (Manappuram)	192.70
PRS23	Aluva (Marthandavarma)	195.70
PRS24	Kalamassery	108.60
PRS25	Pathalam (Upstream)	-
PRS26	Pathalam (Downstream)	65.71
PRS27	Pathalam (Bridge)	82.00
PRS28	Edamulla	81.25
PRS29	Manjummal	98.82
PRS30	Eloor (Methnam Kadavu)	84.45
PRS31	Eloor (School Kadavu)	65.71
PRS32	Eloor (Depo Kadavu)	82.00
PRS33	Eloor (Muttinakam)	81.25
PRS34	Eloor (Ferry)	98.82
PRS35	Eloor (Mixing Point)	84.45

Table 2.19: Score and their specification

Range	Specification
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very Bad

Table 2.20: NSF WQI for the pre-monsoon of 2007

Station Code	Name of the station	WQI	Specification
PRS01	Thekkady	69	Average
PRS02	Mullaperiyar	74	Good
PRS03	Vallakadavu	82	Good
PRS04	Vandiperiyar	60	Average
PRS05	Idukki (Dam)	86	Good
PRS06	Chinnar	74	Good
PRS07	Perinjankutty	78	Good
PRS08	Lower Periyar	54	Average
PRS09	Kallarkutty	46	Fair
PRS10	Idamalayar (Upstream)	82	Good
PRS11	Idamalayar (Downstream)	-	-
PRS12	Bhuthathankettu (Upstream)	72	Good
PRS13	Bhuthathankettu (Downstream)	68	Average
PRS14	Perumthodu	71	Good
PRS15	Malayattoor	84	Good
PRS16	Kalady	63	Average
PRS17	Thekkekovilakam Ferry	60	Average
PRS18	Chowwara	67	Average
PRS19	Aluva	68	Average
PRS20	Aluva (Desam Kadavu)	60	Average
PRS21	Aluva (Mangalapuzha)	65	Average
PRS22	Aluva (Manappuram)	79	Good
PRS23	Aluva (Marthandavarma)	69	Average
PRS24	Kalamassery	73	Good
PRS25	Pathalam (Upstream)	73	Good
PRS26	Pathalam (Downstream)	69	Average
PRS27	Pathalam (Bridge)	78	Good
PRS28	Edamulla	65	Average
PRS29	Manjummal	74	Good
PRS30	Eloor (Methanam Kadavu)	61	Average
PRS31	Eloor (School Kadavu)	69	Average
PRS32	Eloor (Depo Kadavu)	74	Good
PRS33	Eloor (Muttinakam)	66	Average
PRS34	Eloor (Ferry)	70	Average
PRS35	Eloor (Mixing Point)	64	Average

Table 2.21: NSF WQI for the post-monsoon of 2007

Station Code	Name of the station	WQI	Specification
PRS01	Thekkady	79	Good
PRS02	Mullaperiyar	-	-
PRS03	Vallakadavu	91	Excellent
PRS04	Vandiperiyar	78	Good
PRS05	Idukki (Dam)	-	-
PRS06	Chinnar	71	Good
PRS07	Perinjankutty	86	Good
PRS08	Lower Periyar	77	Good
PRS09	Kallarkutty	79	Good
PRS10	Idamalayar (Upstream)	76	Good
PRS11	Idamalayar (Downstream)	-	-
PRS12	Bhuthathankettu (Upstream)	67	Medium
PRS13	Bhuthathankettu (Downstream)	79	Good
PRS14	Perumthodu	79	Good
PRS15	Malayattoor	83	Good
PRS16	Kalady	78	Good
PRS17	Thekkekovilakam Ferry	73	good
PRS18	Chowwara	62	Medium
PRS19	Aluva	64	Good
PRS20	Aluva (Desam Kadavu)	68	Good
PRS21	Aluva (Mangalapuzha)	68	Medium
PRS22	Aluva (Manappuram)	81	Good
PRS23	Aluva (Marthandavarma)	76	Good
PRS24	Kalamassery	75	Good
PRS25	Pathalam (Upstream)	-	-
PRS26	Pathalam (Downstream)	82	Good
PRS27	Pathalam (Bridge)	79	Good
PRS28	Edamulla	81	Good
PRS29	Manjummal	76	Good
PRS30	Eloor (Methanam Kadavu)	74	Good
PRS31	Eloor (School Kadavu)	75	Good
PRS32	Eloor (Depo Kadavu)	67	Medium
PRS33	Eloor (Muttinakam)	76	Good
PRS34	Eloor (Ferry)	67	Medium
PRS35	Eloor (Mixing Point)	66	Medium

Table 2.22: NSF WQI for the monsoon of 2008

Sample	Name of the Station	WQI	Specification
PRS01	Thekkady	79	Good
PRS02	Mullaperiyar	–	–
PRS03	Vallakadavu	83	Good
PRS04	Vandiperiyar	83	Good
PRS05	Idukki (Dam)	81	Good
PRS06	Chinnar	82	Good
PRS07	Perinjankutty	81	Good
PRS08	Lower Periyar	77	Good
PRS09	Kallarkutty	77	Good
PRS10	Idamalayar (Upstream)	88	Good
PRS11	Idamalayar (Downstream)	–	–
PRS12	Bhuthathankettu (Upstream)	80	Good
PRS13	Bhuthathankettu (Downstream)	79	Good
PRS14	Perumthodu	78	Good
PRS15	Malayattoor	75	Good
PRS16	Kalady	65	Medium
PRS17	Thekkekovilakam Ferry	72	Good
PRS18	Chowwara	74	Good
PRS19	Aluva	74	Good
PRS20	Aluva (Desam Kadavu)	74	Good
PRS21	Aluva (Mangalapuzha)	71	Good
PRS22	Aluva (Manappuram)	75	Good
PRS23	Aluva (Marthandavarma)	72	Good
PRS24	Kalamassery	81	Good
PRS25	Pathalam (Upstream)	78	Good
PRS26	Pathalam (Downstream)	–	–
PRS27	Pathalam (Bridge)	76	Good
PRS28	Edamulla	81	Good
PRS29	Manjummal	75	Good
PRS30	Eloor (Methanam Kadavu)	76	Good
PRS31	Eloor (School Kadavu)	71	Good
PRS32	Eloor (Depo Kadavu)	75	Good
PRS33	Eloor (Muttinakam)	–	–
PRS34	Eloor (Ferry)	74	Good
PRS35	Eloor (Mixing Point)	73	Good

Scope (F_1)

The scope factor represents the number of variables, in percent, that fail to meet the prescribed objectives, even if only once during the sampling period: F_1 = (failed variables / total variables) x 100

Frequency (F_2)

The frequency factor represents the percentage of individual measurements that do not meet the objectives:

F_2 = (failed measurements / total measurements) x 100

Amplitude (F_3)

The amplitude factor represents the amount by which failed measurements do not meet the objectives. It is calculated in three steps,

nse= Σexcursions/N

N= total number of tests

F_3 = nse / (0.01nse + 0.01)

where *nse* is the *n*ormalized *s*um of the *e*xcursions from the objectives.

CCME WQI =100-{v (f12+f22+f32)/1.732}

This score can be further simplified by assigning it to one of the five descriptive categories. These categories are given below.

Excellent: (CCME WQI Value 95-100) - water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels. These index values can only be obtained, if all measurements are within objectives virtually all of the time.

Good: (CCME WQI Value 80-94) - water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.

Fair: (CCME WQI Value 65-79) - water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.

Table 2.23: CCME WQI and their specifications

Excellent (95–100)	Conditions are very close to natural or pristine levels
Good (80–94)	Minor degree of threat or impairment
Fair (65–79)	Occasionally threatened or impaired
Marginal (45–64)	Frequently threatened or impaired
Poor (0–44)	Almost always threatened or impaired

Marginal: (CCME WQI Value 45-64) - water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.

Poor: (CCME WQI Value 0-44) - water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

CCME Water Quality Index of Periyar river is calculated for 34 stations during the four seasons (post-monsoon-2005, pre-monsoon-2006, pre-monsoon-2007 and post- monsoon -2007). Fifteen parameters, which include pH, turbidity, colour, total dissolved solids, alkalinity, total hardness, calcium, magnesium, chloride, nitrate-N, sulphate, iron, total coliforms and faecal coliforms and dissolved oxygen, were used for the calculation. The CCME WQI values are listed in Table 2.24 and are presented in Fig 2.21.

The index values indicate that the quality of water is really bad as majority of the samples come under the 'poor' range. Mullaperiyar is comes under 'fair' specification water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels. The water quality index of the river stretch is presented in Fig 2.21.

2.4.4 CPCB Classification

The Central Pollution Control Board established a scheme for classification and zoning of water bodies in 1979. Based on this, any water body can be designated for some particular best use which is termed as designated best use. The water quality criteria for this classification include

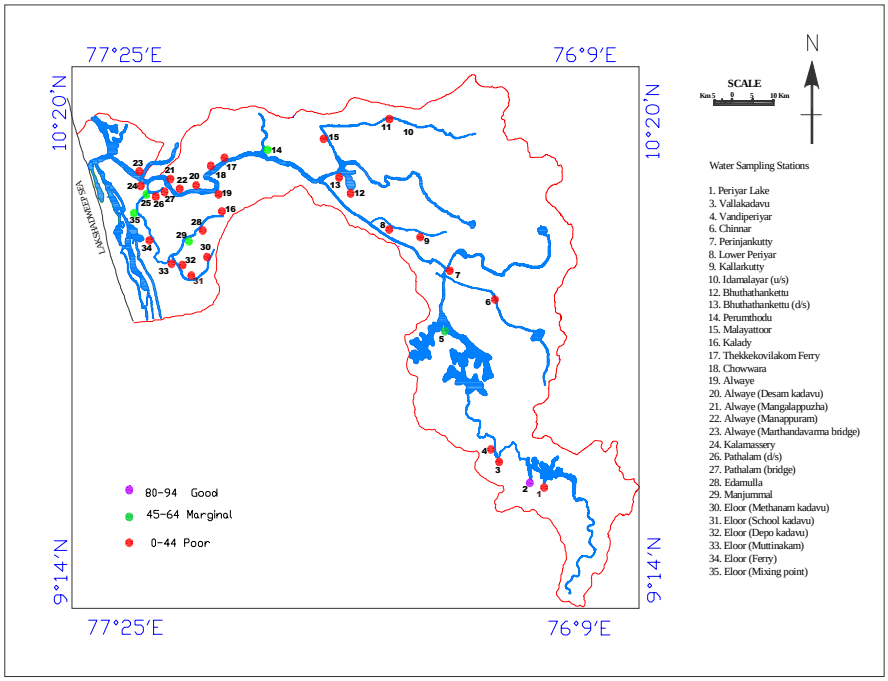


Fig 2.21: CCME WQI for Periyar river

Table 2.24: CCME WQI of Periyar river basins

Code	Name of the Station	WQI	Specification
PRS01	Thekkady	40	POOR
PRS02	Mullaperiyar	75	FAIR
PRS03	Vallakadavu	40	POOR
PRS04	Vandiperiyar	36	POOR
PRS05	Idukki (Dam site)	45	MARGINAL
PRS06	Chinnar	36	POOR
PRS07	Perinjankutty	36	POOR
PRS08	Lower Periyar	36	POOR
PRS09	Kallarkutty	38	POOR
PRS10	Idamalayar U/S	38	POOR
PRS11	Idamalayar D/S	_	_
PRS12	Bhuthathankettu U/S	38	POOR
PRS13	Bhuthathankettu D/S	35	POOR
PRS14	Perumthodu	38	POOR
PRS15	Malayattur	37	POOR
PRS16	Kalady	35	POOR
PRS17	Thekkekovilakam Ferry	34	POOR
PRS18	Chowwara	34	POOR
PRS19	Aluva	35	POOR
PRS20	Aluva (Desam kadavu)	34	POOR
PRS21	Aluva (Mangalapuzha)	35	POOR
PRS22	Aluva (Manappuram)	37	POOR
PRS23	Aluva (Marthandavarma)	38	POOR
PRS24	Kalamassery	38	POOR
PRS25	Paathalam U /S	39	POOR
PRS26	Paathalam D/S	38	POOR
PRS27	Paathalam (bridge)	37	POOR
PRS28	Edamulla	37	GOOD
PRS29	Manjummal	39	POOR
PRS30	Eloor (Methanam kadavu)	29	POOR
PRS31	Eloor (School kadavu)	29	POOR
PRS32	Eloor (Depo kadavu)	29	POOR
PRS33	Eloor (Muttinakam)	32	POOR
PRS34	Eloor (Ferry)	30	POOR
PRS35	Eloor (mixing point)	33	POOR

parameters like pH, DO, BOD, most probable number of coliforms/100ml, free ammonia-N, EC, sodium absorption ratio and boron. The CPCB class and designated best use are given in Table 2.25. The CPCB class of various sites and the number of samples falling in each class are given in Table 2.26 and Fig 2.22 respectively.

Table 2.25: Use based classification of waters of Indian rivers and coastal waters

SI No.	Beneficial uses	Classification
1	Drinking water and domestic supplies without treatment, but with disinfection	A
2	River bathing, swimming and water contact sports.	B
3	Source of raw water for municipal supplies- consumed only after conventional water treatment	C
4	Propagation of wildlife, animal husbandry and fisheries	D
5	Agriculture, industrial cooling and washing, hydropower generation and controlled waste disposal	E

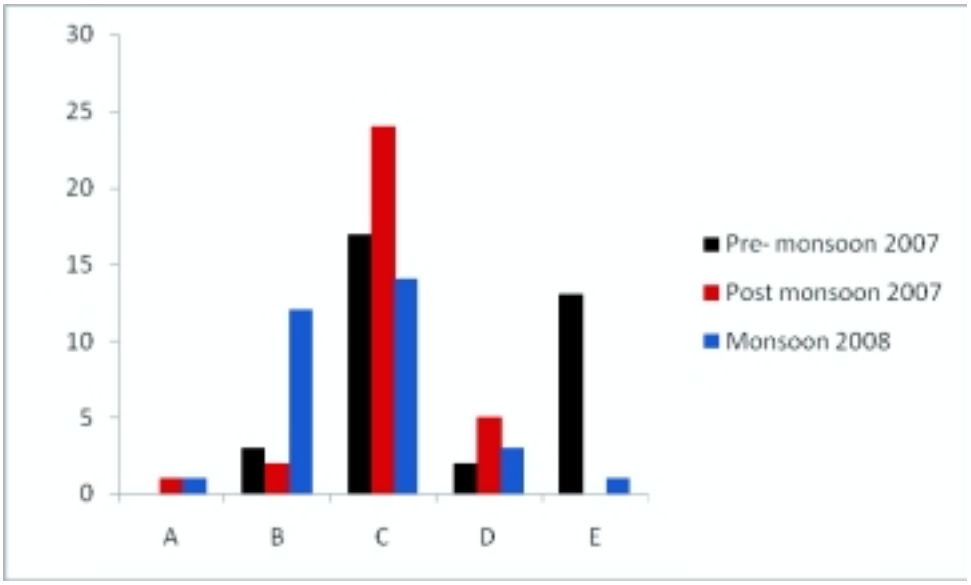


Fig 2.22: Number of samples in each class during the pre-monsoon and post-monsoon 2007 and monsoon 2008

Table 2.26: Designated Use of Periyar River as per CPCB classification

Code	Name of the station	Pre-monsoon 2007	Post-monsoon 2007	monsoon 2008
PRS01	Thekkady	C	C	C
PRS02	Mullaperiyar	C	Not taken	Not taken
PRS03	Vallakadavu	C	C	B
PRS04	Vandiperiyar	E	C	B
PRS05	Idukki (Dam)	B	C	C
PRS06	Chinnar	C	C	B
PRS07	Perinjankutty	C	D	D
PRS08	Lower Periyar	E	C	D
PRS09	Kallarkutty	E	D	B
PRS10	Idamalayar U/S	C	C	C
PRS11	Idamalayar D/S	C	Not taken	Not taken
PRS12	Bhuthathankettu U/S	C	D	B
PRS13	Bhuthathankettu D/S	C	D	A
PRS14	Perumthodu	E	A	C
PRS15	Malayattur	D	B	C
PRS16	Kalady	E	C	E
PRS17	Thekkekovilakam Ferry	E	C	C
PRS18	Chowwara	C	C	C
PRS19	Aluva	C	C	C
PRS20	Aluva (Desam Kadavu)	D	C	C
PRS21	Aluva (Mangalapuzha)	C	C	C
PRS22	Aluva (Manappuram)	B	C	C
PRS23	Aluva (Marthandavarma)	C	C	D
PRS24	Kalamassery	C	B	B
PRS25	Paathalam (Upstream)	B	Not taken	B
PRS26	Paathalam (Downstream)	C	C	Not taken
PRS27	Paathalam (Bridge)	C	C	C
PRS28	Edamulla	E	C	B
PRS29	Manjummal	E	C	B
PRS30	Eloor (Methanam Kadavu)	E	C	C
PRS31	Eloor (School Kadavu)	E	C	B
PRS32	Eloor (Depo Kadavu)	E	C	C
PRS33	Eloor (Muttinakam)	E	D	Not taken
PRS34	Eloor (Ferry)	C	C	B
PRS35	Eloor (Mixing Point)	E	C	B

Classification of different stations in Periyar river reveals that most of the stations fall under class C, which implies that the water in these stations can be used as drinking water with conventional treatment and disinfection. About 13 stations are in class E in the pre-monsoon of 2007 and this water can only be used for irrigation, industrial cooling and waste disposal. During the post-monsoon, Perumthode alone is in class A, which means this water, can be used without any treatment. Kalamasseri comes under class B; all other stations are in the class C and D. In monsoon 2008 only Bhuthathankettu downstream comes under class A, 12 stations comes under class B, 14 stations comes under class C, three stations comes under class D and Kalady comes under class E. In the post-monsoon of 2007 and monsoon 2008 the river stretch is better than the pre-monsoon of 2007 as seen from the Fig.2.22

2.5. SEDIMENT

The analytical data of sediment analysis of ten samples collected from various surface water stations during the post-monsoon of 2007 are presented in Tables 2.27 and 2.28.

The pH values of the samples were found to be acidic with a minimum of 4.54 at Thekkekovilam Ferry. The electrical conductivity was found to be maximum for samples collected from Eloor Mixing Point and minimum for the sample collected from Thekkekovilam Ferry. The concentration of anions like chloride and sulphate were found to be low but very high concentration of phosphate was detected in all samples. The concentration of sodium was found to be very high but there was no corresponding increase in of value of potassium. The values of Kjeldal nitrogen and inorganic carbon were found to be low. The heavy metal concentration of sediments was not found to be very high, though this was reported.

Table 2.27: Physico-chemical and heavy metal characteristics of Periyar river (post-monsoon- 2007

Parameters	PRS4	PRS7	PRS8	PRS12	PRS15
pH	5.47	5.33	6.73	5.86	5.92
EC, (µS/cm)	80.6	57.4	33.4	51.1	65.2
Chloride, mg/kg	7.04	14.08	7.68	1.6	6.28
Sulphate, mg/ kg	17.6	35.2	19.2	4	32.4
Phosphate-P, mg/ kg	1940	940	1130	1320	1260
Sodium, mg/ kg	315	400	60	360	200
Potassium, mg/ kg	25	10	23	20	33
Inorganic Carbon, mg/ kg	0.7581	1.0573	0.5187	1.2369	0.9177
Kjeldal Nitrogen, mg/kg	140	140	70	70	70
Cupper, mg/ kg	0.125	0.474	0.287	0.606	0.253
Cadmium, mg/ kg	0.033	0.044	0.037	0.032	0.056
Lead, mg/ kg	0.365	0.439	0.309	0.421	0.503
Manganese, mg/ kg	6.172	4.357	6.307	1.056	3.66
Iron, mg/ kg	409.299	549.48	725.541	509.43	620.695

ND - Not Detected

Table 2.28: Physico-chemical and heavy metal characteristics Periyar river (post-monsoon 2007)

Parameters	PRS16	PRS17	PRS22	PRS23	PRS35
pH	6.09	4.54	5.46	6	5.26
EC, (µS/cm)	18.04	41.5	119.1	81.8	276
Chloride, (mg/kg)	24	6.4	13.44	2.88	34.56
Sulphate, (mg/kg)	60	16	33.6	7.2	86.4
Phosphate-P, (mg/kg)	1260	1365	1680	1080	1210
Sodium, (mg/kg)	250	200	100	350	400
Potassium, (mg/kg)	18	20	12	20	45
Inorganic Carbon, (mg/kg)	1.0573	0.6783	0.3192	0.2793	0.5785
Kjeldal Nitrogen, mg/kg	140	70	70	70	140
Cupper, (mg/kg)	0.238	ND	1.009	0.009	0.132
Cadmium, (mg/kg)	0.028	ND	0.046	0.001	0.046
Lead, (mg/kg)	0.322	ND	0.811	ND	0.2
Manganese, mg/kg	6.614	ND	9.547	0.403	0.665
Iron, (mg/kg)	620.695	ND	727.468	0.803	139.998

ND - Not Detected

A total number of seven sediment samples were taken from different industrial areas of Periyar river during the pre-monsoon of 2007 and analysed for different physico-chemical parameters like pH, EC, PO_4-P, NO_3-N, organic carbon, total hardness, calcium hardness, alkalinity, sodium, potassium, Kjeldal nitrogen, Sulphate, chloride and heavy metals. The sampling details are given in Table 2.29. The maxima, minima and the average concentration values for the same are presented in Table 2.30 and 2.31.

Table 2.29 Details of sampling locations

Sl. No	Station code	Stations	Location	
			Latitude	Longitude
1	PR01	Boat Jetty	N 09° 59´ 4.5´´	E 76° 16´ 20.4´´
2	PR02	Eloor Ferry	N 10° 04´ 46.56´´	E 76° 16´ 56´´
3	PR03	Methanam	N 10° 05´ 45.18´´	E 76° 17´ 5.46´´
4	PR04	Eloor (Plywood Company)	N 10° 05´ 30.6´´	E 76° 17´ 44.34´´
5	PR05	Eloor	N 10° 05´ 13.68´´	E 76° 17´ 52.14´´
6	PR06	Binamipuram Zinc	N 10° 05´ 3.18´´	E 76° 17´ 57.12´´
7	PR07	Indian Rare Earth Ltd	N 10° 05´ 0.06´´	E 76° 17´ 54.24´´
8	PR08	Fact	N 10° 05´ 50.88´´	E 76° 17´ 57.18´´
9	PR09	TCC (Outlet)	N 10° 04´ 37.2´´	E 76° 17´ 6´´
10	PR10	TCC (Proximity)	N 10° 04´ 37.68´´	E 76° 18´ 15.6´´
11	PR11	Navalli Rubber Company	N 10° 04´ 36.96´´	E 76° 18´ 29.82´´
12	PR12	Paathalam (Upstream)	N 10° 04´ 36.72´´	E 76° 18´ 30.36´´
13	PR13	Fact Petrochemicals (Outlet)	N 10° 04´ 7.62´´	E 76° 18´ 27.18´´

Table 2.30: The Maximum and minimum concentration of the sediment from Periyar Industrial area in Periyar

Parameters	Max	Min
pH	7.47	5.16
EC, S/cm	11650	421
Alkalinity, mg/kg	2800	320
Chloride, mg/kg	57600	960
Sulphate, mg/kg	1588.8	227.2
Calcium Hardness, mg/kg	60000	4000
Total Hardness, mg/kg	76000	10000
Na, mg/kg	9900000	6500
K, mg/kg	800000	750
PO_4-P, mg/kg	4800	520
NO_3-N, mg/kg	47.52	ND
Kjeldal Nitrogen, mg/kg	420	140

ND - Not Detected

Table 2.31: Heavy metal concentration in the sediment of Periyar river

Parameters	Cd, mg/kg	Ni, mg/kg	Cu, mg/kg	Fe, mg/kg
PR1	7.175	74.025	62.05	54413.4
PR3	29.275	66.7	59.15	72109.25
PR4	6.8	55.5	42.75	51132.43
PR5	5.1	47.05	34.275	44143.55
PR6	5.1	1.375	14	10131.78
PR7	7.025	69.4	48.65	50172.8
PR10	1.925	29.9	17.075	28625.73

The pH ranged from 5.16 to 7.47. The least value was found at Eloor. EC was very high in all the samples. The average concentration was 2932 mg/l. Alkalinity of all the samples was also found to be very high. It ranged from 320 mg/kg to 2800 mg/kg with an average value of 811.43 mg/kg.

The ions like chloride, sulphate, sodium and potassium reported high concentration in all the samples. The hardness of the samples was also on the higher side.

A nutrient like PO_4-P was found to be very high in all the samples. It ranged from 520 mg/kg to 4800 mg/kg with an average value of 2040.71 mg/kg. The maximum value was found at Indian Rare Earth Ltd. The maximum concentration of NO_3-N was found at Binanipuram.

The heavy metal analysis of the sediment samples indicated very high concentration (Table 2.31) which may be due to discharge of effluents containing these toxic substances.

2.6. HYDRO-BIOLOGY OF PERIYAR RIVER BASIN

2.6.1 Biological Features

Sampling of Periyar river was carried out in the post-monsoon, the pre-monsoon, and the monsoon seasons. The analysis was carried out following standard techniques for collection, preservation and identification reported by APHA (American Public Health Association). A quantitative assessment was done with Lackey's drop method for pre-monsoon and monsoon seasons. Different levels of aquatic biota analyzed are phytoplankton, zooplankton and macro-invertebrates (benthic organisms) and a comparative biological assessment was carried out. The results are interpreted and the areas characterized and the quality status is ascertained in the light of genus richness, abundance and presence of indicator species to different kinds of pollution.

The phytoplankton community is composed of members from Chlorophyceae, Cyanophyceae, Bacillariophyceae and very minor representations from class Chrysophyta and Euglenophyta. Some species of Diatoms show clear dominance over others and some environmental conditions prevailing may be responsible for these community rearrangements. Palmer has prepared a list of algae tolerant to organic pollution and derived an index to evaluate the organic pollution status of the water. Twelve stations were identified for biological monitoring during the monsoon (June 05), the post-monsoon (Oct 05) and the pre-monsoon (May 06). The stations such as Thekkady, Vandiperiyar, Perinjankutty and Kallarkutty were added during Feb 07 and Oct 2007 for the next one year, namely Feb 07 and Oct 07. The stations selected were based on the catchment and downstream features of the river basin. The details of selected stations are given in Table 2.32 and Fig 2.23.

Biological assessment is useful for measuring the ecological quality of aquatic ecosystems, since biological communities integrate the environmental effects of water chemistry. The most pollution tolerant genera and species of four groups of algae were recorded from three sites on the river. Nygaard and Palmer's biotic indices have been used for the assessment of quality of the river. Phytoplankton encountered in the water body reflects the saprobic condition and, therefore, may be used as an indicator of water quality.

2.6.2 Primary productivity

Chlorophyll concentration in the fresh water region of river (Edamalayar to Pathalam) was compared to that of downstream (backwaters). Chlorophyll value ranged from 0.297mg/l during the monsoon season to 556.4 mg/l during the pre monsoon (May 06). It is noticed that high chlorophyll value is reported from Chowara and less from Mixing Point, during June 05 October 05 and May 06. Minimum value is reported from the upstream as well as downstream stations in different

Table 2.32: Details of the stations selected for Biological sampling

Station No.	Name of Station	Description Of Sites
1	Thekkady	Reservoir, Tourist Place
2	Vallakadavu	Reservoir
3	Vandiperiyar	Receives Sewage
4	Perinjamkutty	
5	Kallarkutty	Reservoir
6	Idamalayar	Reservoir
7	Bhuthathankettu	Reservoir
8	Malayattur	Pilgrim Centre
9	Kalady	Receives Sewage
10	Chowwara	Industrial Zone
11	Aluva	Receives Sweage
12	Aluva Manappuram	Pilgrim Centre, Receives Sewage
13	Paathalam	Industrial Zone
14	Edamulla	Industrial Zone
15	Manjummal	Industrial Zone
16	Eloor Methaanam Kadavu	Industrial Zone
17	Eloor	Mixing Point

seasons. The values are shown in Table 2.33. The chlorophyll values indicate that the chlorophyll content is increasing towards the downstream of the river. The variation in chlorophyll content is shown in Fig 2.24.

Plankton:

Plankton includes micro/macro organisms, which move at the mercy of currents. They occupy a central position in the aquatic food chain and are the indices of water quality. They are divided in to macro-and micro- planktons. Some of the planktons are very good indicators of pollution.

Macro-plankton:

Macro- planktons are represented mainly by crustaceans and rotifers.

Micro- plankton:

Micro-planktons include both zoo- and phytoplankton. Many of them feed on algae and bacteria and in turn are fed by numerous invertebrates and fish. In the Periyar river, zooplankton is represented by Rotifera and Protozoa.

Phytoplankton:

Phytoplanktons include class Chlorophyceae, Cyanophyceae and Bacillariophyceae.

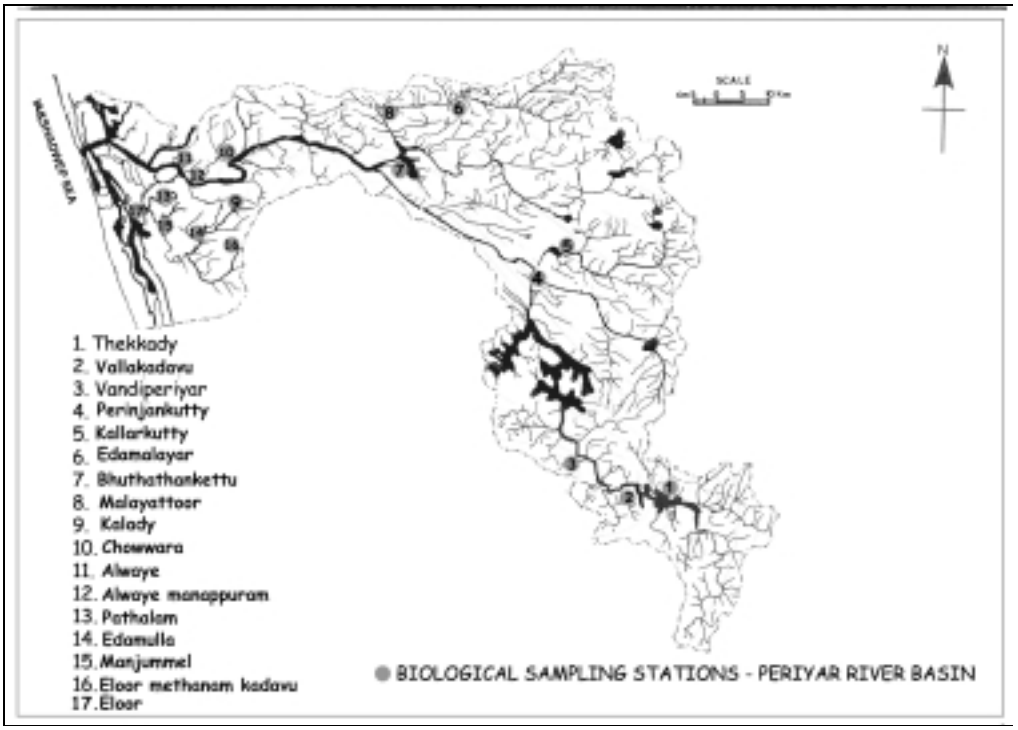


Fig 2.23: Biological sampling stations along the Periyar river

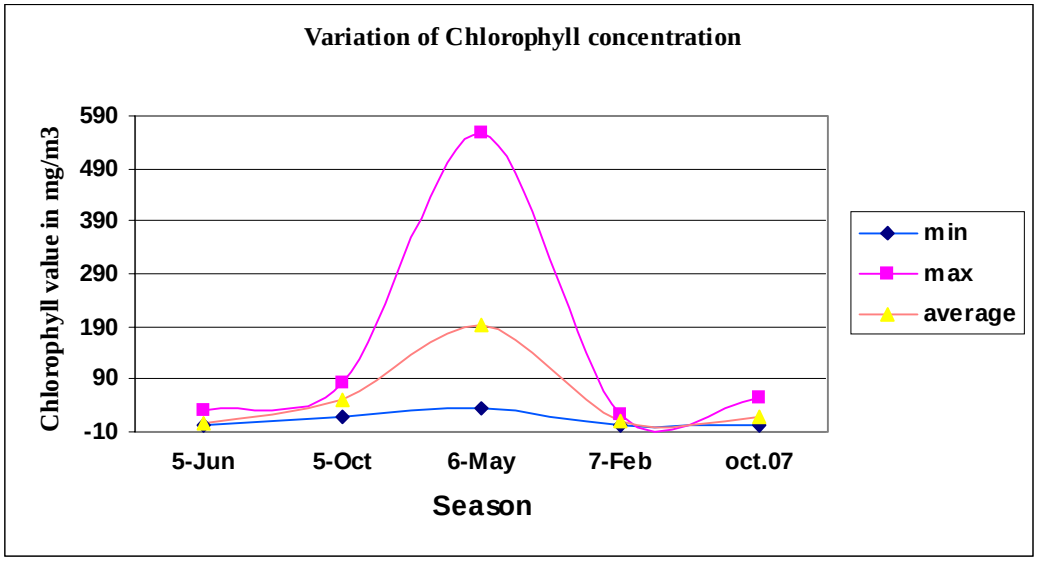


Fig 2.24: Variation of chlorophyll concentration along the Periyar river during different seasons

Table 2.33: Chlorophyll concentration in samples collected from different stretches of Periyar river

Sl. No.	Sampling stations	Chlorophyll, mg/l				
		Jun 05	Oct 05	May 06	Feb 07	Oct 07
1	Edamalayar	0.38	44.94	350.78	11.41	4.85
2	Bhuthankettu	0.46	63.97	111.13	8.00	3.24
3	Malayattur	NT	41.26	ND	10.61	9.18
4	Kalady	NT	34.26	70.08	ND	4.55
5	Chowwra	NT	63.00	36.40	20.55	16.09
6	Aluva	3.42	55.50	123.57	16.25	8.93
7	Aluva Manappuram	0.30	63.17	289.40	13.88	6.66
8	Paathalam	ND	66.35	145.60	9.22	17.03
9	Edamulla	ND	83.82	556.49	9.22	22.75
10	Manjummal	29.96	54.92	275.33	8.17	13.26
11	Methanam Kadavu (Eloor)	ND	17.21	81.45	8.04	41.77
12	Mixing point (Eloor)	3.92	18.43	99.35	1.06	53.39
13	Minimum	0.30	17.21	36.40	1.06	3.24
14	Maximum	29.96	83.82	556.49	20.55	53.39

ND - Not Detected

2.6.3 Importance of benthic organisms

Macro- invertebrates and macrobenthos can serve as excellent diagnostic indicators of aquatic pollution. Degraded water quality affects macro-invertabrates (Hynes, 1962) including benthic organisms.

Density of the benthic organisms is calculated by using the formula:

$$\text{Benthos (organisms / m}^2\text{)} = n / a * 10^4$$

Where,

n = number of organisms per sample

a= area of the sampler.

From the above formula, benthic population density is found to be high at Bhuthathankettu (195 organisms / m^2). Most of the benthic organisms come under the family Chironomideae, which indicates organic pollution load. Malayattoor, Chowara and Pathalam also represents the Chironomidae family. It is also noted that during Oct 07, Vallakadavu (Upstream) reported the

presence of Oligocheates (river limbet) showing dominance over other benthic organisms. A population density of 820 / m^2 indicates the evidence of organic pollution load.

Common benthic organisms reported from the river bed of Periyar river:

- Leech
- Poriferan shell
- Unio crassus
- Bristle worm
- Oilgocheates worms
- Ablabesmyia larva
- Viviparus viviparous
- River limbet (Ancylus flucialitis)
- Blader snail (Physa fontalis)

2.6.4 Palmer's Algal Index

Algal and water samples were collected from twelve sites in the Periyar river. A list of algae tolerant of organic pollution can be employed as a pollution index. An algae can be used in this manner only if they are present in sufficient quantity (>5% of the population or rare algae would not count, but uncommon, common and abundant algae would count). The individual pollution index factors are added up. The Palmer's Pollution Index for different stations is listed in Table 2.34 and the variation is indicated in Fig 2.25. A high score (>20) might indicate high amounts of organic pollution. A low (<15) or moderate (between 15 and 19) score might be interpreted as less organically polluted but should not be interpreted as evidence of little or no pollution since other factors such as pH or toxic wastes may be present.

2.6.5 Inferences

Malayattur, which is a pilgrimage centre on the banks of Periyar river, reported high Palmer's index value during different seasons. This indicates high organic contamination at this station. It supports the presence of most pollution tolerant genera like Ankistrodesmus, Scenedesmus, Oscillatoria, Anabaena, Synedra and Navicula and Rotifer like Philodina, a pollution indicator. Arcella, a pollution tolerant form is also reported at this station. The presence of organic pollution tolerant family Chironomidae at this station also supports the load of organic pollution.

Paathalam and Edamulla stations are in the industrial area of Periyar river basin. Plankton reported are Chlorella, Scenedesmus, Oscillatoria, Synedra and mastigophora like Euglena. Presence of less pollution tolerant genera Pediastrum is also noted but it is clear that this area is dominated by pollution indicator genera. Snails and Calms have been taken as indicators of organic pollution. Here also, members of Chironomidae and Oligochaetae are reported. The presence of Chironomidae is dominant at Kalady (under the bridge), which receives untreated municipal effluents.

The assessment of pollution indices indicates that stations of Bhoothankettu, Aluva Manappuram, Chowara, Manjummal and Eloor Ferry (Mixing Point) are facing problems due to

Table 2.34: Palmer's Algal Pollution Index values for different sampling stations of Periyar river

Sl. No	Sampling Station	Palmers Algal Pollution Index				
		Periyar River Basin				
		Jun 05	Oct 05	May 06	Feb. 07	Oct 06
1	Edamalayar		10	3	18	1
2	Bhuthankettu	19	11	7	3	12
3	Malayattur	7	22	2	16	9
4	Kalady	ND	11	21	15	ND
5	Chowwra	ND	14	16	15	ND
6	Aluva	18	15	5	11	14
7	Aluva Manappuram	17	14		19	9
8	Paathalam	20	9	14	14	10
9	Edamulla		21	14	3	10
10	Manjummal	19	16	17	1	0
11	Methanam kadavu (Eloor)		14	17	11	13
12	Mixing point (Eloor)	18	13	10	18	18

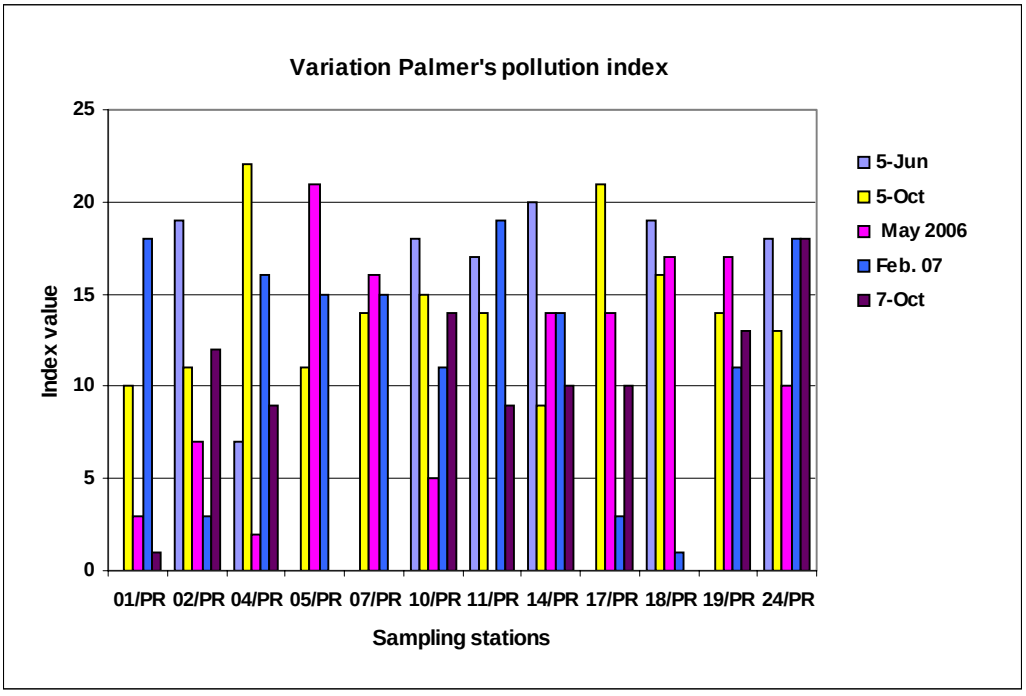


Fig 2.25: Variation of Palmer's Pollution Indices along Periyar River

disposal of organic waste. Except for Bhuthankettu, all other stations are on the downstream of Periyar river. The raw municipal effluents may be the major contributers to organic load at these stations. Bhuthankettu station is in the catchment area of the dam; the pollution at this station is contributed by the surface runoff from adjacent areas. The station is also being used for bathing / washing purposes. Micro-plankton composition of some of the above sites is shown in the Figs 2.26-2.30.

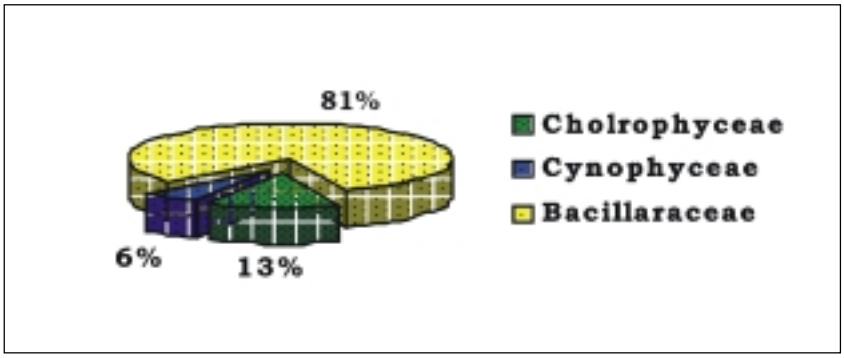


Fig 2.26: Micro-plankton density at Edamulla (May-06)

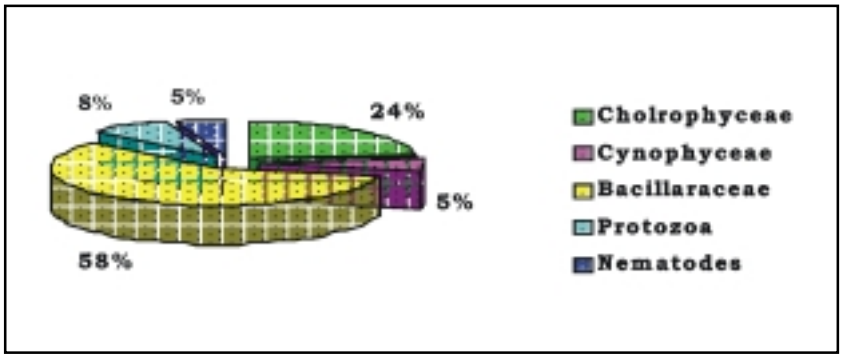


Fig 2.27: Micro-plankton density at Kalady (May 06)

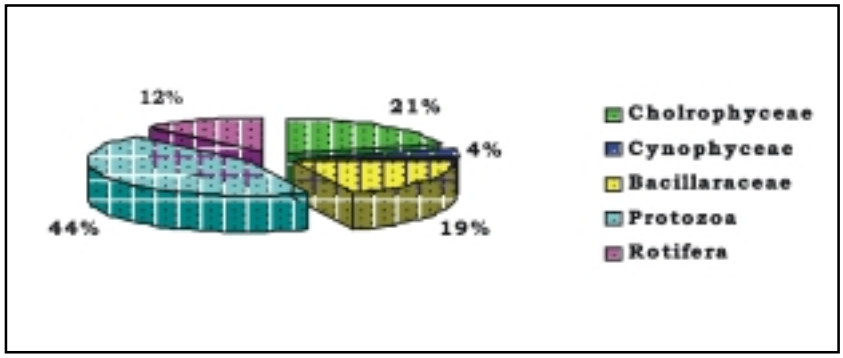


Fig 2.28: Micro-plankton density at Chowwara (May 06)

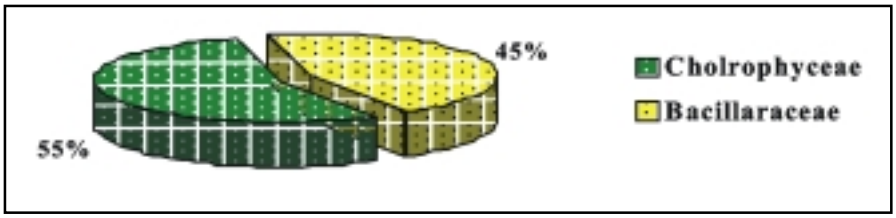


Fig 2.29: Micro-plankton density at Manjummal (May-06)

Fig 2.30: Micro-plankton density at Malayattur (Oct-07)

2.7. GROUNDWATER SAMPLES

Groundwater is the key source of drinking water in the basin. The major types of soil in the basin include alluvial and laterite. The soil type plays a major role in determining the predominant ions in water. In this study, an attempt has been made to monitor the quality of groundwater in the Periyar river basin.

2.7.1 Survey of sanitation facilities

Surveillance is an investigative activity undertaken to identify and evaluate factors associated with any aspect. In the present case it is drinking water our concern. It has a role to play public health by promoting improvement to the quality, quantity, coverage cost and continuity of water supplies. A sanitary inspection was carried out to identify and evaluate the system deficiencies, sources of contamination and hygienic conditions of the area. The survey was based on a questionnaire, which includes details of the well, geology of the area, agricultural crops, fertilizers used, type of latrine, etc.

Findings of the survey (Figs 2.31-2.38) reveal that of the wells selected for sampling, about 94% are of open type and the remaining 6%, bore wells and springs. Of these, 94% open wells, and 60% of the wells are lined. The lining details are: 42% -laterite cutting, 29% - concrete cutting, 15% - laterite and 14% - rock cutting. In 82% of the wells, electric pump is being used for lifting water and in 18% pulley is used. Seventy percentage of the houses covered by the survey use fertilizers for various crops and 63% use pesticides in addition to the fertilizers. Majority of latrines have leach pits or septic tanks.

The sanitary inspection was found to be useful for the adequate interpretation of the laboratory results. An attempt to relate the survey results with water quality analysis showed good correlation.

Artrodesmus

Euastrum

Closterium

Closterium

Gyrosigma

Micrasterias

Plate 2.8(a): Selected plankton species found in the Periyar river basin

Arcella

Calonies

Daphnia

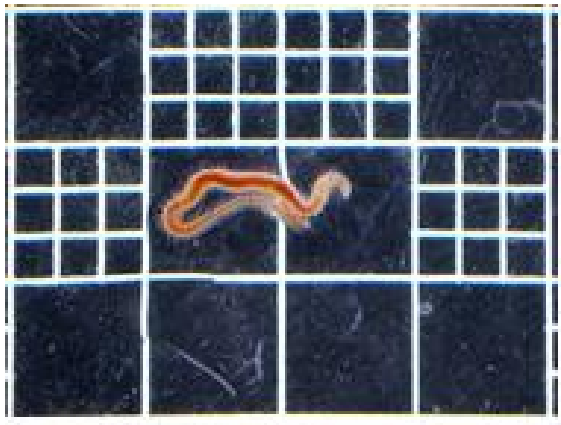
Cypris

Cyclops

Plate 2.8(b): Selected plankton species found in the Periyar river basin

Chironomus

Stylaria



Oligocheates

Plate 2.9: Pollution tolerant benthic species

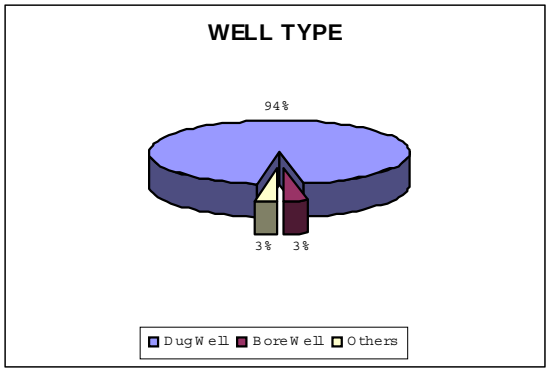


Fig 2.31: Type of sampled wells

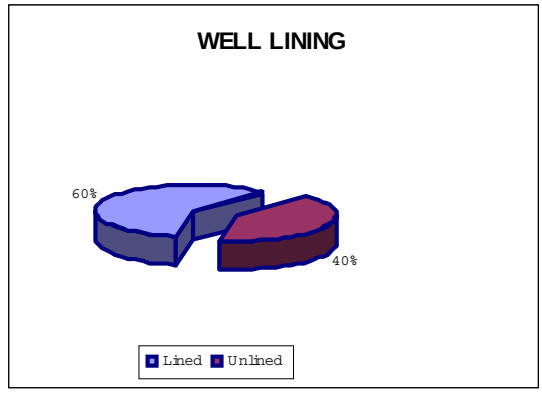


Fig 2.32: Type of well lining

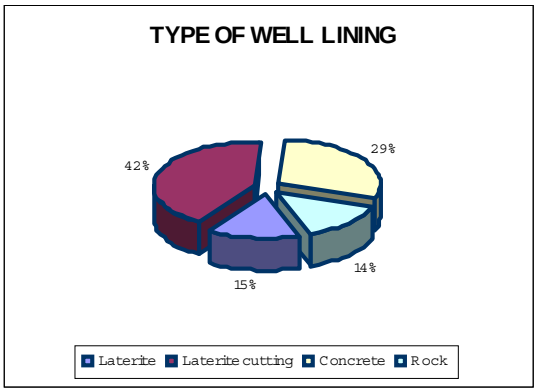


Figure 2.33: Type of well lining

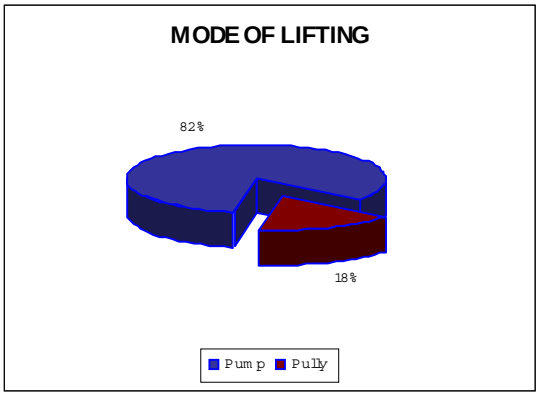


Fig 2.34: Mode of lifting

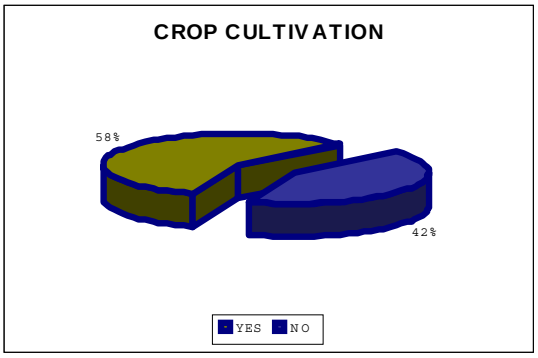


Fig 2.35: Crop cultivation in the area

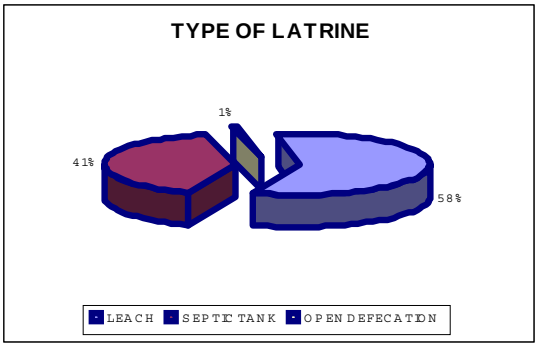


Fig 2.36: Type of latrine

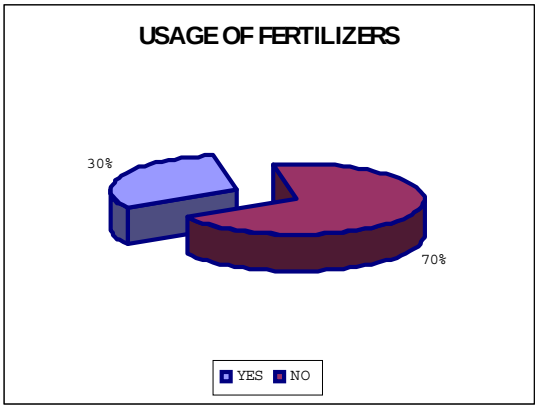


Fig 2.37: Use of fertilizers

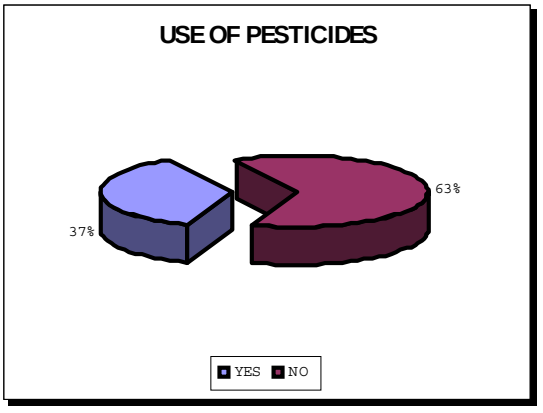


Fig 2.38: Use of pesticides

Nitrate (NO_3-N) values of seven samples were much above the desirable limit. Although there are many sources of nitrogen (both natural and anthropogenic) that could potentially lead to the pollution of groundwater with nitrates, the anthropogenic sources are the ones that most often cause rise in nitrate level above the desirable level in water. Waste materials are one of the anthropogenic sources of nitrate contamination of groundwater. Many local sources of potential nitrate contamination of groundwater exist such as, sites used for disposal of human and animal sewage, industrial wastes related to food processing and some poly resin facilities and sites where handling and accidental spills may lead to accumulation of nitrogenous materials. Septic tanks are another source of nitrogen contamination of groundwater. Groundwater contamination is usually related to the density of septic systems. In densely populated areas, septic systems can represent an important local source of nitrate contamination in groundwater. From the results of survey it is observed that in all the cases the distance between the well and the latrine is below the minimum safe distance. In addition to that nitrogenous fertilizers and pesticides are used for agricultural purposes.

2.7.2 Interpretation of Groundwater Quality (monsoon – 2006)

The maximum, minimum and average concentration of different physico-chemical analysis of groundwater samples are presented in Table 2.35.

pH is an important parameter in groundwater chemistry since many of the solution processes, water/rock interactions (mineral solubility and adsorption properties), gas solubilities, and biochemical reactions are pH sensitive. The variation in pH values of the samples was not significant and most of the samples were found to be acidic. Only 30% of the samples had values within the BIS limit for drinking water (Fig 2.39). Nine samples showed Hazen colour values above the desirable limit, BIS limit being 5 Hazen. Nitrate-N values of seven samples were found to be greater than 10 mg/l. Turbidity values of all the samples, except one collected from Santhanpara Panchayath (16 NTU), were below 5 NTU. Sample collected from Senapathi Panchayath showed a value of 0.38 mg/l for Iron. Values obtained for all other parameters like alkalinity, hardness, calcium hardness, calcium, magnesium, sodium, potassium, chloride, sulphate and phosphates were within the desirable limit for drinking water for all samples. Among the samples, the one collected from Pampadumpara Panchayath (PRG133) showed values for parameters like EC (1600 µS/cm), salinity (0.8 ppt), TDS (1024 mg/l) (Fig 2.40) and nitrate-N (16.9 mg/l). The presence of high values for certain parameters in this particular well may be due to the leaching of nutrients from a leach pit located in the vicinity of the well.

Microbiological examination of drinking water is important (Figs 2.41 and 2.42), since the principle risk associated with water supplies is that of infectious diseases which is related to faecal contamination. Coliform organisms have long been recognized as a suitable microbial indicator of drinking water quality because they are easy to detect. An examination shows that almost all the groundwater samples were microbiologically contaminated. Only 28 % of the samples can be considered as safe for drinking purpose. E.Coli was reported in 62 % samples (Fig 2.43).

2.7.3 Interpretation of Groundwater Quality (pre-monsoon -2007)

Sampling details are given in Table 2.36. The maximum and minimum values of physico-chemical analysis are presented in Tables 2.37.

Table 2.35: Maximum and minimum values of physic-chemical characteristics of groundwater (monsoon 06)

Parameters	Maximum	Minimum
pH	7.88	4.05
EC, Micromhos/cm	1600.00	17.20
Colour, Hazen	45.00	ND
Turbidity, NTU	16.00	ND
TDS, mg/l	1024.00	11.01
Total Alkalinity, mg/l	178.00	4.00
Total Hardness, mg/l	164.00	6.00
Ca Hardness, mg/l	122.00	4.00
Chloride, mg/l	135.68	3.61
Sulphate, mg/l	120.00	0.20
Nitrate-N, mg/l	16.90	ND
Phosphate-P, mg/l	1.90	ND
Ca, mg/l	48.80	1.60
Mg, mg/l	22.36	0.49
Na, mg/l	39.20	1.20
K, mg/l	74.00	0.40
Iron, mg/l	0.38	ND

The pH value of most of the samples was found to be within the limit of desirable range set by BIS for drinking water. Samples collected from 22 sites showed values greater than 6.5 (Fig 2.44). The maximum value for pH (7.7) was found Neddumkandam Panchayath (PRG132) and minimum (5.35) was found Udambamchola Panchayath (PRG128). Turbidity values of all the samples, except two collected from Udambamchola Panchayath(5.43NTU) and Erattayur Panchayath (101.03 NTU) were below the BIS limit for drinking water (5 NTU). The values obtained for all other parameters like total alkalinity, total hardness, calcium hardness, calcium, sodium, potassium, chloride, sulphate, nitrate-N and phosphate-P were within the desirable limit for drinking water for all the groundwater samples. Concentration of magnesium was higher than the BIS limit of 30 mg/l for six sites (Fig 2.45). Ayappankovil Panchayath(PRG143) showed the maximum value of 63.18 mg/l and at the ESTATE the minimum value of 1.94 mg/l was reported. The presence of high values of certain variables for this particular well may be due to the leaching of nutrients from a leach pit located in the vicinity of the well. Bacteriological analysis of the

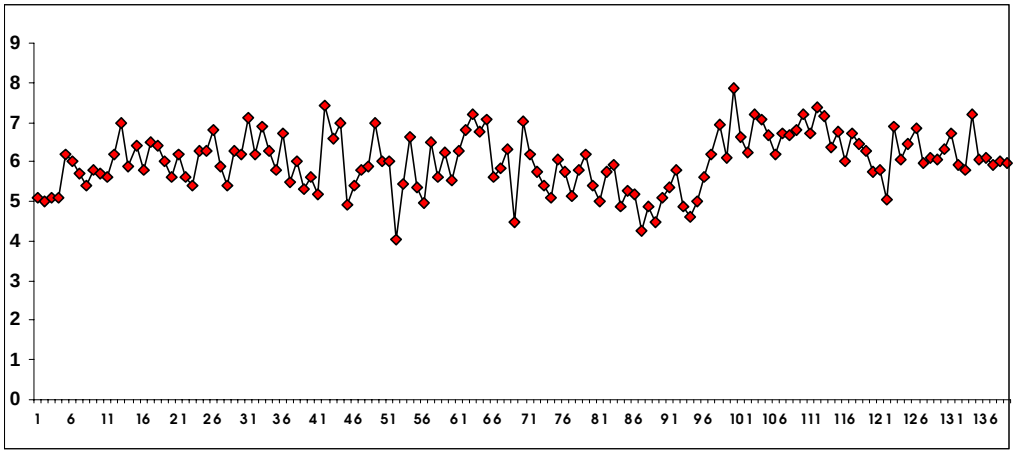


Fig 2.39: Variation in pH of groundwater

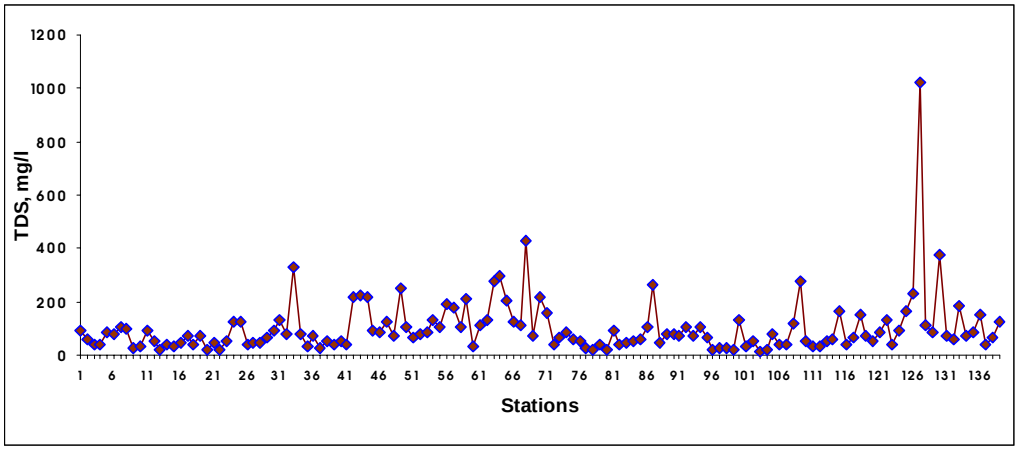


Fig 2.40: Variation in TDS of groundwater

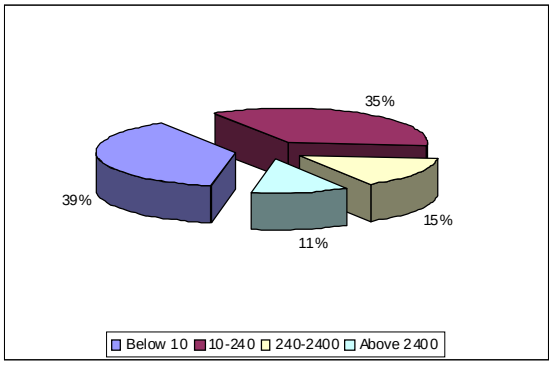


Fig 2.41: Percentage distribution of total coliform in well water

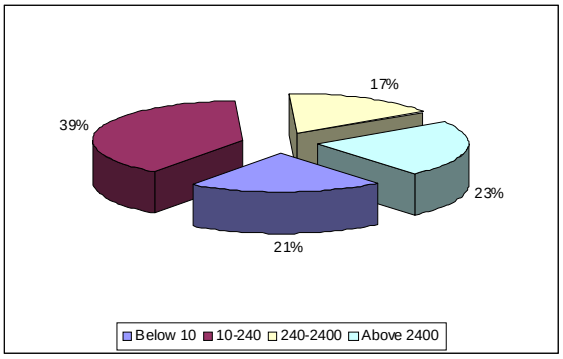


Fig 2.42: Percentage distribution of faecal coliform in well water

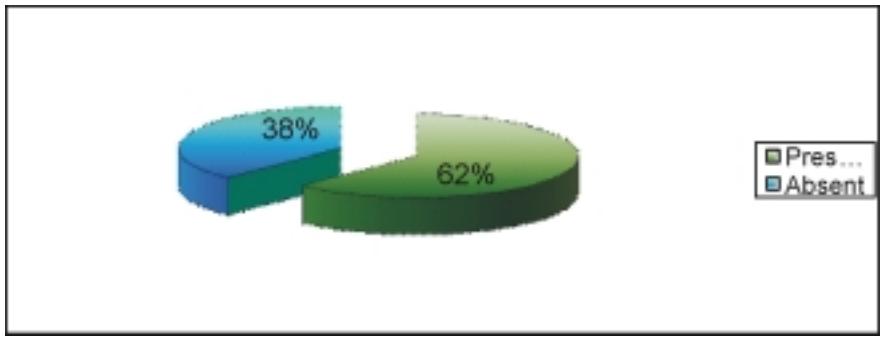


Fig 2.43: Percentage distribution of E. Coli in the Well water

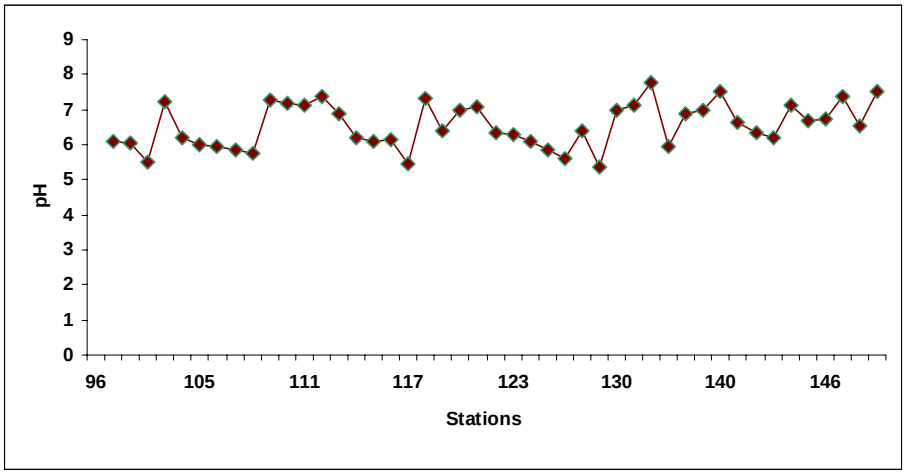


Fig 2.44: The variations of pH values in groundwater samples

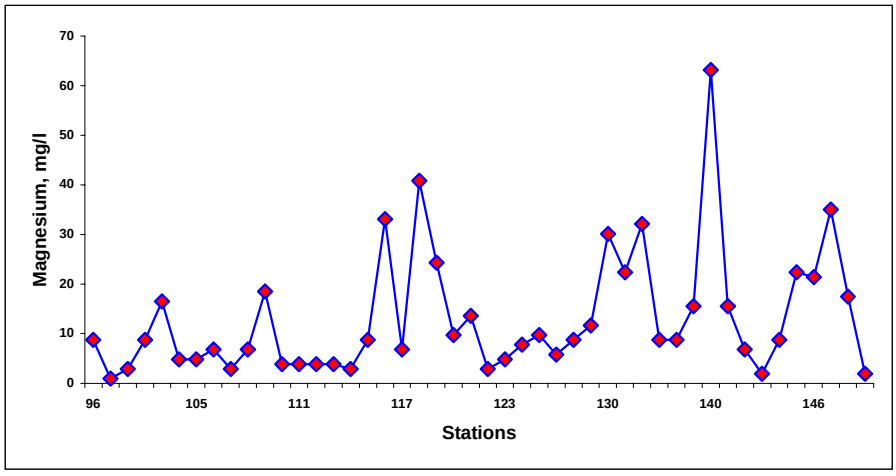


Fig 2.45: Variation of concentration of magnesium in groundwater samples

Table 2.36: Groundwater sampling stations in Idduki district (pre-monsoon 2007)

Block	Panchayath	No. of Samples	
Adimaly	Adimaly	5	15
	Pallivasal	4	
	Vellathooval	3	
	Konnathadi	3	
Devikulam	Chinnakkanal	2	6
	Shanthampara	4	
Nedumkandam	Nedumkandam	3	18
	Pampadumpara	3	
	Rajakkad	3	
	Rajakumari	3	
	Senapathy	3	
	Udumbanchola	3	
Kattappana	Erattayar	3	16
	Kattappana	3	
	Kanchiar	4	
	Ayyapancoil	3	
	Upputhara	3	
Azhutha	Elappara	1	
Total Samples			56

samples clearly indicated microbial contamination; 54% of the samples showed the presence of E.coli (Fig 2.46).

2.7.4 Pesticide analyses

Idukki, one of the mountainous districts of Kerala state, is famous for its spices, tea and rubber cultivation. Major agricultural crops of the area include cardamom, coffee, tea, nutmeg, cashew etc, and the agricultural practices generally depend upon the application of pesticides.

Table 2.37: Maximum and minimum values of physico- chemical analysis of groundwater (pre-monsoon 07)

Parameters	Maximum	Minimum
pH	7.77	5.35
EC, Micromhos/cm	737.00	31.80
Turbidity, NTU	101.03	0.06
TDS, mg/l	471.68	20.35
Salinity, (ppt)	0.20	0.10
Total Alkalinity, mg/l	144.00	16.00
Total Hardness, mg/l	468.00	16.00
Ca Hardness, mg/l	208.00	8.00
Chloride, mg/l	124.00	8.00
Sulphate, mg/l	39.20	0.04
Nitrate-N, mg/l	0.83	0.01
Phosphate-P, mg/l	0.13	0.01
Ca, mg/l	83.20	3.20
Mg, mg/l	63.18	0.97
Na, mg/l	35.20	2.00
K, mg/l	7.00	0.30

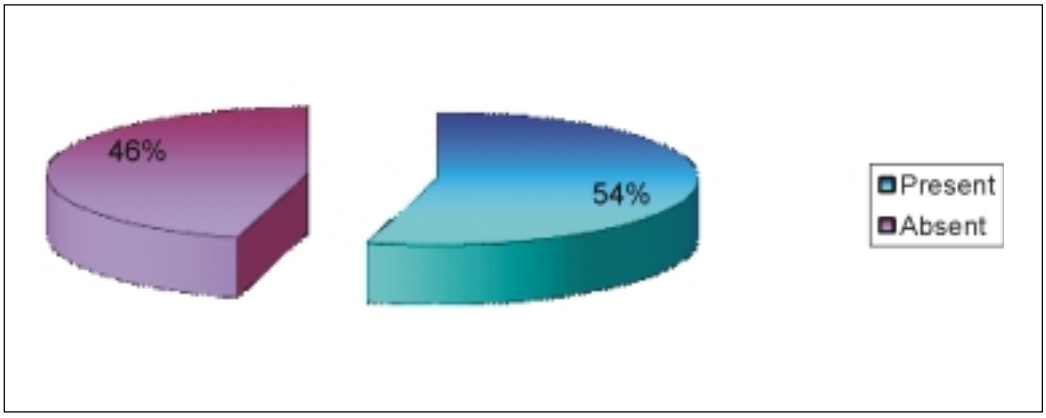


Fig 2.46: Percentage of faecal coliforms in samples collected

Water sources serves as sinks for these chemicals. A study of the concentration of pesticides in groundwater is important, since it is the fresh water source of most of the people.

Pesticides are biologically active chemicals. They can enter in to water by a number of ways, such as runoff, deposition from air and by direct sprays. Most of the modern pesticides fall into two broad categories: chlorinated hydrocarbons and organo-phosphates. The former include DDT, BHC, dieldrin, aldrin, methoxychlor etc. Chlorinated hydrocarbons have low to moderate acute toxicity and affect mainly the central nervous system. Heptachlor, aldrin and dieldrin show parasympathetic failures.

Groundwater samples were collected from intensive agriculture areas of Idukki district and were analyzed for pesticides during the monsoon of 2007. The analysis carried out for four selected groundwater samples collected from Idukki district indicated the presence of pesticides in all the samples and the concentration ranged from 0.1041 µg/l to 1.3198 µg/l for Aldrin, 0.5393 µg/l to 1.279 µg/l for Dieldrin and 0.0961µg/l to 0.6244 µg/l for Endo sulfan-beta. Water sample collected from Vellathooval Panchayath (PRG108) showed high concentration for all pesticides, (Table 2.38).

Table 2.38: Pesticide concentration in selected groundwater samples

SL. No.	Parameters	Sample Code			
		PRG 134	PRG151	PRG126	PRG108
1	Aldrin (µg/l)	1.3198	0.9288	0.1041	0.8022
2	Dieldrin (µg/l)	0.7012	1.279	0.5637	0.5393
3	DDE (µg/l)	ND	0.0965	0.1424	0.0931
4	DDD (µg/l)	ND	0.0437	0.007	0.475
5	Endo-alpha (µg/l)	ND	0.0912	0.0756	0.0912
6	Endo-beta (µg/l)	ND	0.1507	0.0961	0.6244
7	Lindane (µg/l)	ND	0.0087	0.0278	0.0076

All these wells are located close to fields in which pesticides have been applied. Groundwater may contain pesticides that are leached out from the fields by rain and irrigation water. Leaching of pesticides depends in part on the amount applied per unit area per unit year; where, when and how it is applied; the solubility of the compound: how strongly it is held by the soil; and how quickly it breaks down in the root zone.

2.7.5 Irrigation Quality of Groundwater (Monsoon 2006)

The suitability of water for irrigation is dependent upon such factors as soil texture and composition, crops grown and irrigation practice, in addition to the chemical characteristics of water. The quality of irrigation water is judged not by the total amount of salts but by the kind of salt it contains. Classification of irrigation water is an expression of quality of water in terms of one or more variables. It presents the criteria for evaluating the suitability of irrigation water.

Irrigation parameters of groundwater samples were determined and classified based on Magnesium Hazardous Ratio (MHR), Soluble Sodium Percentage (SSP), Kelly's Ratio (KR) and Sodium Adsorption Ratio (SAR).These parameters and their specifications are given in Table 2.39. Suitability of water for agricultural purpose, based on irrigation parameters for groundwater samples, is represented in Tables 2.40 to 2.44.

Table 2.39: Irrigation parameters and their specifications

Sl. No.	Irrigation Parameters	Calculation	Specification
1.	Magnesium Hazardous Ratio	MgX100/(Ca+Mg)	<50:Suitable >50: Unsuitable
2.	Soluble Sodium Percentage	NaX100/(Na+Ca+Mg)	<20:Excellent 20 - 40: Good 40 - 60: Permissible 60 – 80: doubtful >80:Unsuitable
3.	Kelly's Ratio	Na/ (Ca+Mg)	<1:Suitable 1 – 2: Marginal >2: Unsuitable
4.	Sodium Adsorption Ratio	Na/ε(Ca+Mg/2)	0 - 10:Excellent 10 – 18: Fair >20: Poor

An attempt to classify the groundwater samples based on irrigation quality revealed that most of the samples come under 'excellent class' according to Soluble Sodium Percentage (SSP) and Sodium Adsorption Ratio (SAR). Kelly's Ratio (KR) also points towards the suitability of groundwater samples for irrigational purpose. But, Magnesium Hazardous Ratio of 42% makes it unsuitable for irrigation.

2.7.6 Groundwater Types

The major ion composition is used to classify groundwater into various types based on dominant cations and anions. Groundwater samples collected from the Periyar river basin were classified into various water types. Water quality interpretation was attempted by plotting on the tri-linear or Piper diagram. On this diagram, the relative concentrations of major ions in percent (Meq/L) are plotted on cation and anion triangles, and then locations are projected to a point on a quadrilateral representing both cations and anions.

Table 2.40: Classification of groundwater of Periyar river basin based on irrigational quality

Sample ID	M.H.R	Specific-ation	S.S.P	Specification	S.A.R	Specific-ation	K.R	Specific-ation
PRG01	48	Suitable	14	Excellent	3.43	Excellent	0.11	Suitable
PRG02	61	Unsuitable	10	Excellent	4.38	Excellent	0.09	Suitable
PRG03	33	Suitable	9	Excellent	2.46	Excellent	0.07	Suitable
PRG04	33	Suitable	10	Excellent	2.77	Excellent	0.08	Suitable
PRG05	32	Suitable	8	Excellent	1.19	Excellent	0.07	Suitable
PRG06	27	Suitable	14	Excellent	2.34	Excellent	0.10	Suitable
PRG07	83	Unsuitable	9	Excellent	3.32	Excellent	0.08	Suitable
PRG08	50	Unsuitable	9	Excellent	2.25	Excellent	0.08	Suitable
PRG09	28	Suitable	5	Excellent	1.11	Excellent	0.04	Suitable
PRG10	28	Suitable	6	Excellent	1.38	Excellent	0.05	Suitable
PRG11	43	Suitable	14	Excellent	3.15	Excellent	0.11	Suitable
PRG12	17	Suitable	31	Good	3.75	Excellent	0.13	Suitable
PRG13	43	Suitable	9	Excellent	2.04	Excellent	0.08	Suitable
PRG14	0	Suitable	56	Permissible	1.26	Excellent	0.03	Suitable
PRG15	11	Suitable	15	Excellent	1.48	Excellent	0.08	Suitable
PRG16	21	Suitable	6	Excellent	0.94	Excellent	0.05	Suitable
PRG17	47	Suitable	6	Excellent	1.75	Excellent	0.05	Suitable
PRG18	48	Suitable	7	Excellent	1.81	Excellent	0.06	Suitable
PRG19	21	Suitable	8	Excellent	1.18	Excellent	0.06	Suitable
PRG20	24	Suitable	11	Excellent	1.50	Excellent	0.08	Suitable
PRG21	24	Suitable	5	Excellent	1.18	Excellent	0.04	Suitable
PRG22	16	Suitable	62	Good	6.20	Excellent	0.18	Suitable
PRG23	0	Suitable	42	Permissible	0.95	Excellent	0.03	Suitable
PRG24	54	Unsuitable	8	Excellent	2.86	Excellent	0.07	Suitable
PRG25	130	Unsuitable	7	Excellent	3.54	Excellent	0.07	Suitable
PRG26	30	Suitable	9	Excellent	1.81	Excellent	0.07	Suitable
PRG27	21	Suitable	16	Excellent	2.35	Excellent	0.10	Suitable
PRG28	13	Suitable	33	Good	3.74	Excellent	0.11	Suitable
PRG29	61	Unsuitable	4	Excellent	1.18	Excellent	0.04	Suitable
PRG30	60	Unsuitable	10	Excellent	3.07	Excellent	0.08	Suitable

Table 2.41: Classification of groundwater of Periyar river basin based on irrigational quality

Sample ID	M.H. R	Specific-ation	S.S.P	Specification	S.A.R	Specific-ation	K.R	Specific-ation
PRG32	37	Suitable	15	Excellent	2.91	Excellent	0.11	Suitable
PRG33	32	Suitable	36	Good	4.53	Excellent	0.23	Suitable
PRG34	49	Suitable	16	Excellent	4.68	Excellent	0.12	Suitable
PRG35	44	Suitable	6	Excellent	2.02	Excellent	0.05	Suitable
PRG36	25	Suitable	7	Excellent	0.89	Excellent	0.06	Suitable
PRG37	63	Unsuitable	4	Excellent	1.80	Excellent	0.03	Suitable
PRG38	33	Suitable	14	Excellent	3.15	Excellent	0.10	Suitable
PRG39	61	Unsuitable	6	Excellent	2.32	Excellent	0.05	Suitable
PRG40	61	Unsuitable	10	Excellent	4.12	Excellent	0.09	Suitable
PRG41	24	Suitable	20	Good	5.09	Excellent	0.11	Suitable
PRG42	73	Unsuitable	7	Excellent	1.48	Excellent	0.07	Suitable
PRG43	48	Suitable	25	Good	4.04	Excellent	0.18	Suitable
PRG44	37	Suitable	11	Excellent	1.53	Excellent	0.10	Suitable
PRG45	75	Unsuitable	8	Excellent	2.62	Excellent	0.07	Suitable
PRG46	86	Unsuitable	5	Excellent	1.67	Excellent	0.04	Suitable
PRG47	44	Suitable	34	Good	11.52	Excellent	0.20	Suitable
PRG48	43	Suitable	11	Excellent	2.59	Excellent	0.09	Suitable
PRG49	30	Suitable	36	Good	4.33	Excellent	0.23	Suitable
PRG50	46	Suitable	11	Excellent	1.90	Excellent	0.09	Suitable
PRG51	40	Suitable	13	Excellent	2.59	Excellent	0.10	Suitable
PRG52	44	Suitable	17	Excellent	4.42	Excellent	0.13	Suitable
PRG53	50	Unsuitable	14	Excellent	3.38	Excellent	0.11	Suitable
PRG54	18	Suitable	21	Good	2.01	Excellent	0.14	Suitable
PRG55	38	Suitable	26	Good	4.71	Excellent	0.17	Suitable
PRG56	48	Suitable	13	Excellent	2.81	Excellent	0.10	Suitable
PRG57	41	Suitable	21	Good	3.10	Excellent	0.16	Suitable
PRG58	50	Unsuitable	24	Good	5.63	Excellent	0.17	Suitable
PRG59	25	Suitable	38	Good	4.21	Excellent	0.21	Suitable
PRG60	109	Unsuitable	2	Excellent	0.72	Excellent	0.02	Suitable

Table 2.42: Classification of groundwater of Periyar river basin based on irrigational quality

Sample ID	M.H.R	Specific-ation	S.S.P	Specification	S.A.R	Specific-ation	K.R	Specific-ation
PRG61	36	Suitable	13	Excellent	1.92	Excellent	0.10	Suitable
PRG62	6	Suitable	15	Excellent	1.02	Excellent	0.10	Suitable
PRG63	28	Suitable	31	Good	3.62	Excellent	0.21	Suitable
PRG64	27	Suitable	38	Good	4.37	Excellent	0.23	Suitable
PRG65	17	Suitable	45	Permissible	4.23	Excellent	0.22	Suitable
PRG66	40	Suitable	31	Good	5.69	Excellent	0.19	Suitable
PRG67	94	Unsuitable	13	Excellent	3.75	Excellent	0.11	Suitable
PRG68	45	Suitable	59	Permissible	9.44	Excellent	0.31	Suitable
PRG69	130	Unsuitable	7	Excellent	2.98	Excellent	0.07	Suitable
PRG70	74	Unsuitable	23	Good	5.57	Excellent	0.19	Suitable
PRG71	47	Suitable	23	Good	4.15	Excellent	0.17	Suitable
PRG72	49	Suitable	10	Excellent	2.90	Excellent	0.08	Suitable
PRG73	16	Suitable	33	Good	3.56	Excellent	0.13	Suitable
PRG74	50	Unsuitable	24	Good	6.72	Excellent	0.17	Suitable
PRG75	11	Suitable	24	Good	1.95	Excellent	0.11	Suitable
PRG76	51	Unsuitable	12	Excellent	3.21	Excellent	0.10	Suitable
PRG77	41	Suitable	5	Excellent	1.39	Excellent	0.05	Suitable
PRG78	18	Suitable	13	Excellent	2.33	Excellent	0.08	Suitable
PRG79	31	Suitable	10	Excellent	1.76	Excellent	0.08	Suitable
PRG80	24	Suitable	12	Excellent	3.13	Excellent	0.08	Suitable
PRG81	32	Suitable	28	Good	4.90	Excellent	0.16	Suitable
PRG82	55	Unsuitable	7	Excellent	2.15	Excellent	0.06	Suitable
PRG83	66	Unsuitable	9	Excellent	3.52	Excellent	0.08	Suitable
PRG84	55	Unsuitable	11	Excellent	3.44	Excellent	0.09	Suitable
PRG85	40	Suitable	16	Excellent	3.59	Excellent	0.12	Suitable
PRG86	35	Suitable	36	Good	6.74	Excellent	0.19	Suitable
PRG87	36	Suitable	9	Excellent	1.42	Excellent	0.07	Suitable
PRG88	0	Suitable	251	Good	5.69	Excellent	0.03	Suitable
PRG89	30	Suitable	28	Good	5.43	Excellent	0.15	Suitable
PRG90	70	Unsuitable	16	Excellent	6.06	Excellent	0.13	Suitable

Table 2.43: Classification of groundwater of Periyar river basin based on irrigational quality

Sample ID	M.H.R	Specific-ation	S.S.P	Specific-ation	S.A.R	Specific-ation	K.R	Specific-ation
PRG91	43	Suitable	24	Good	5.56	Excellent	0.16	Suitable
PRG92	59	Unsuitable	21	Good	5.25	Excellent	0.16	Suitable
PRG93	24	Suitable	40	Good	7.10	Excellent	0.16	Suitable
PRG94	44	Suitable	32	Good	8.42	Excellent	0.20	Suitable
PRG95	14	Suitable	33	Good	3.08	Excellent	0.13	Suitable
PRG96	78	Unsuitable	2	Excellent	1.33	Excellent	0.02	Suitable
PRG97	28	Suitable	9	Excellent	1.94	Excellent	0.07	Suitable
PRG98	28	Suitable	10	Excellent	2.22	Excellent	0.08	Suitable
PRG99	61	Unsuitable	4	Excellent	1.80	Excellent	0.04	Suitable
PRG100	60	Unsuitable	10	Excellent	2.00	Excellent	0.09	Suitable
PRG101	17	Suitable	19	Excellent	2.29	Excellent	0.10	Suitable
PRG102	50	Unsuitable	12	Excellent	3.46	Excellent	0.10	Suitable
PRG103	40	Suitable	4	Excellent	1.41	Excellent	0.03	Suitable
PRG104	13	Suitable	10	Excellent	1.07	Excellent	0.06	Suitable
PRG105	61	Unsuitable	19	Excellent	5.39	Excellent	0.15	Suitable
PRG106	69	Unsuitable	6	Excellent	2.00	Excellent	0.05	Suitable
PRG107	80	Unsuitable	6	Excellent	2.79	Excellent	0.06	Suitable
PRG108	48	Suitable	22	Good	4.99	Excellent	0.16	Suitable
PRG109	81	Unsuitable	24	Good	5.55	Excellent	0.20	Suitable
PRG110	36	Suitable	11	Excellent	1.98	Excellent	0.09	Suitable
PRG111	31	Suitable	9	Excellent	1.57	Excellent	0.07	Suitable
PRG112	84	Unsuitable	5	Excellent	2.39	Excellent	0.05	Suitable
PRG113	68	Unsuitable	8	Excellent	2.56	Excellent	0.07	Suitable
PRG114	61	Unsuitable	5	Excellent	2.06	Excellent	0.05	Suitable
PRG115	61	Unsuitable	14	Excellent	4.12	Excellent	0.11	Suitable
PRG116	61	Unsuitable	22	Good	4.04	Excellent	0.18	Suitable
PRG117	23	Suitable	32	Good	3.77	Excellent	0.17	Suitable
PRG118	60	Unsuitable	17	Excellent	3.11	Excellent	0.14	Suitable
PRG119	38	Suitable	36	Good	4.86	Excellent	0.23	Suitable
PRG120	46	Suitable	13	Excellent	2.95	Excellent	0.11	Suitable

Table 2.44: Classification of groundwater of Periyar river basin based on irrigational quality

Sample ID	M.H.R	Specific-ation	S.S.P	Specific-ation	S.A.R	Specific-ation	K.R	Specific-ation
PRG121	73	Unsuitable	16	Excellent	3.85	Excellent	0.14	Suitable
PRG122	91	Unsuitable	6	Excellent	2.53	Excellent	0.06	Suitable
PRG123	46	Suitable	12	Excellent	2.44	Excellent	0.10	Suitable
PRG124	72	Unsuitable	24	Good	6.85	Excellent	0.19	Suitable
PRG125	20	Suitable	34	Good	4.06	Excellent	0.15	Suitable
PRG126	50	Unsuitable	8	Excellent	2.24	Excellent	0.07	Suitable
PRG127	61	Unsuitable	13	Excellent	3.21	Excellent	0.11	Suitable
PRG128	100	Unsuitable	29	Good	9.76	Excellent	0.23	Suitable
PRG129	50	Unsuitable	9	Excellent	2.65	Excellent	0.08	Suitable
PRG130	68	Unsuitable	19	Excellent	6.16	Excellent	0.15	Suitable
PRG131	76	Unsuitable	19	Excellent	4.81	Excellent	0.16	Suitable
PRG132	42	Suitable	37	Good	5.75	Excellent	0.23	Suitable
PRG133	53	Unsuitable	21	Good	4.47	Excellent	0.16	Suitable
PRG134	76	Unsuitable	13	Excellent	3.49	Excellent	0.11	Suitable
PRG135	117	Unsuitable	9	Excellent	2.98	Excellent	0.08	Suitable
PRG136	43	Suitable	53	Good	8.57	Excellent	0.28	Suitable
PRG137	61	Unsuitable	16	Excellent	4.84	Excellent	0.13	Suitable
PRG138	61	Unsuitable	12	Excellent	3.76	Excellent	0.10	Suitable
PRG139	90	Unsuitable	22	Good	7.14	Excellent	0.18	Suitable
PRG140	68	Unsuitable	11	Excellent	3.23	Excellent	0.10	Suitable
PRG141	79	Unsuitable	11	Excellent	3.60	Excellent	0.10	Suitable
PRG142	56	Unsuitable	25	Good	6.05	Excellent	0.18	Suitable
PRG143	88	Unsuitable	8	Excellent	4.35	Excellent	0.07	Suitable
PRG144	69	Unsuitable	9	Excellent	3.09	Excellent	0.08	Suitable
PRG145	43	Suitable	32	Good	7.41	Excellent	0.20	Suitable
PRG146	31	Suitable	26	Good	4.70	Excellent	0.15	Suitable
PRG147	68	Unsuitable	5	Excellent	1.46	Excellent	0.04	Suitable
PRG148	54	Unsuitable	34	Good	6.28	Excellent	0.23	Suitable
PRG149	79	Unsuitable	18	Excellent	5.11	Excellent	0.15	Suitable
PRG150	57	Unsuitable	19	Excellent	4.40	Excellent	0.15	Suitable
Estate	44	Suitable	4	Excellent	1.44	Excellent	0.04	Suitable

The different distribution patterns of groundwater samples of Periyar river basin collected during monsoon 2006 are shown in Fig 2.47. Different groundwater types are given in the table 2.45.

Table 2.45: Ground water types in monsoon 2006

Groundwater type	No of samples
Na-Ca-Mg-Cl	5
Ca-Na-Cl-HCO3	8
Mg-Ca-Na-Cl-HCO3	6
Mg-Na-Ca-Cl-HCO3	7
Na-K-Ca-Mg-Cl	1
Mg-Na-Ca-K-Cl-HCO3	1
Ca-Mg-Na-HCO3-Cl	2
Mg-Na-HCO3-Cl	3
Mg-Ca-Na-Cl-HCO3-SO4	1
Na-Mg-Ca-Cl-HCO3	9
Ca-Na-Mg-Cl	1
Ca-Mg-Na-Cl	1
Ca-Mg-HCO3-SO4-Cl	2
Ca-Na-Mg-Cl-HCO3	5
Ca-Mg-Na-HCO3-SO4	1
Ca-Mg-Na-HCO3	2
Na-Mg-Cl	4
Na-Mg-Cl-HCO3-SO4	1
Mg-Na-Ca-HCO3-Cl	3
Mg-Ca-Na-HCO3-Cl	2
Mg-Na-Cl-HCO3	5
Ca-Mg-Na-Cl-HCO3	2
K-Na-Ca-Cl	1
Na-Mg-Ca-HCO3-Cl	1
Na-Mg-Ca-K-Cl-HCO3	1
Na-Ca-Cl-HCO3	5
Ca-Cl-HCO3	5
Mg-Ca-Cl	2
Na-Ca-Mg-HCO3-Cl-SO4	1
HCO3-Cl	2
Ca-Mg-K-Na-Cl-HCO3	1
Ca-Mg-HCO3-Cl	5
Ca-Cl	2

Groundwater type	No of samples
Na-Ca-K-Cl	1
Na-Mg-Ca-Cl	4
Na-Ca-Cl-SO4	1
Mg-Ca-HCO3-Cl	3
Ca-Na-HCO3-Cl	2
Mg-Na-Cl-SO4-HCO3	1
Na-Cl-HCO3	1
Mg-Ca-Na-Cl	1
Na-Cl	2
Ca-Na-HCO3-SO4-Cl	2
Ca-Mg-HCO3-Cl-SO4	1
Ca-Mg-Na-HCO3-Cl-SO4	1
Ca-Na-Mg-Cl-SO4	1
Ca-HCO3	2
Ca-SO4-Cl	1
Ca-Mg-HCO3-SO4	1
Na-Ca-Mg-Cl-HCO3-SO4	1
Ca-Na-HCO3-SO4	1
K-Ca-Cl-HCO3-SO4	1
Mg-Ca-Cl-HCO3	1
Ca-Na-Mg-HCO3	1
Ca-Na-HCO3	1
Mg-Na-Ca-Cl	1
Na-Ca-Cl-SO4-HCO3	1
Mg-Na-Cl	1
Ca-Na-Mg-HCO3-Cl	1
Ca-Na-Cl-SO4-HCO3	1
Ca-HCO3-Cl	1
Ca-Mg-K-Na-Cl	1
Na-Ca-HCO3-Cl	1
Na-Ca-Cl	2
Ca-Na-Cl	1
Na-Mg-Ca-Cl-SO4-HCO3	1

The water type of samples collected during pre monsoon 2007 is given in Table 2.46 and the Piper plot, which shows the dominating ions in water, is given in Fig 2.48.

The data clearly points towards the presence of Ca^{2+}, Mg^{2+} and Na^{+} as the predominant cations and Cl and HCO_3^- as the dominating anions. Calcarious rocks such as calcite, dolomite and magnetite are the major source of $Ca^{2+,}$ Mg^{2+} and HCO_3^- and igneous silicate rocks are the major source of Na^{+} and Cl^- on the earth crust. Water type is basically dependent on geochemistry of the area.

Table 2.46: Groundwater type

96/P-ID	Mg-Ca-Cl-HCO3
100/P-ID	Ca-Mg
101/P-ID	Ca-Mg-Na-Cl-HCO3
105/P-ID	Ca-Mg-Na-Cl-HCO3
106/P-ID	Mg-Ca-Cl-HCO3
107/P-ID	Ca-Mg-Na-Cl-HCO3
108/P-ID	Mg-Ca-Cl-HCO3
109/P-ID	Ca-Mg-Cl
110/P-ID	Ca-Mg-Na-Cl-HCO3
111/P-ID	Ca-Mg-Cl-HCO3
112/P-ID	Mg-Ca-Cl-HCO3
113/P-ID	Ca-Mg-Cl-HCO3
114/P-ID	Mg-Ca-Cl-HCO3
115/P-ID	Ca-Mg-Cl-HCO3
116/P-ID	Ca-Mg-Cl
117/P-ID	Ca-Mg-Na-Cl
97/P-ID	Ca-Na-Cl-HCO3
118/P-ID	Mg-Ca-HCO3
119/P-ID	Ca-Mg-Cl-HCO3
120/P-ID	Ca-Mg-Cl-HCO3
121/P-ID	Ca-Mg-Cl
122/P-ID	Mg-Ca-Cl-SO4-HCO3
123/P-ID	Ca-Mg-Cl-HCO3
124/P-ID	Mg-Ca-Na-Cl-HCO3
125/P-ID	Mg-Ca-Na-Cl
126/P-ID	Mg-Ca-Cl-HCO3
127/P-ID	Ca-Mg-Na-Cl
98/P-ID	Ca-Mg-Na-Cl-HCO3
128/P-ID	Mg-Na-Cl
130/P-ID	Ca-Mg-Na-Cl
131/P-ID	Mg-Ca-Cl-HCO3
132/P-ID	Ca-Mg-Cl-HCO3
133/P-ID	Mg-Ca-Na-Cl
137/P-ID	Mg-Ca-Na-Cl
139/P-ID	Mg-Ca-Na-Cl
140/P-ID	Mg-Ca-Cl
141/P-ID	Mg-Ca-Na-Cl-HCO3
142/P-ID	Ca-Na-Mg-Cl-HCO3
99/P-ID	Mg-Ca-Cl-HCO3
143/P-ID	Na-Ca-Cl
144/P-ID	Mg-Ca-Na-Cl-HCO3
145/P-ID	Mg-Ca-Na-Cl
146/P-ID	Mg-Na-Ca-Cl
148/P-ID	Mg-Ca-Na-Cl
149/P-ID	Mg-Ca-Na-HCO3-Cl
Estate	Na-Cl-HCO3

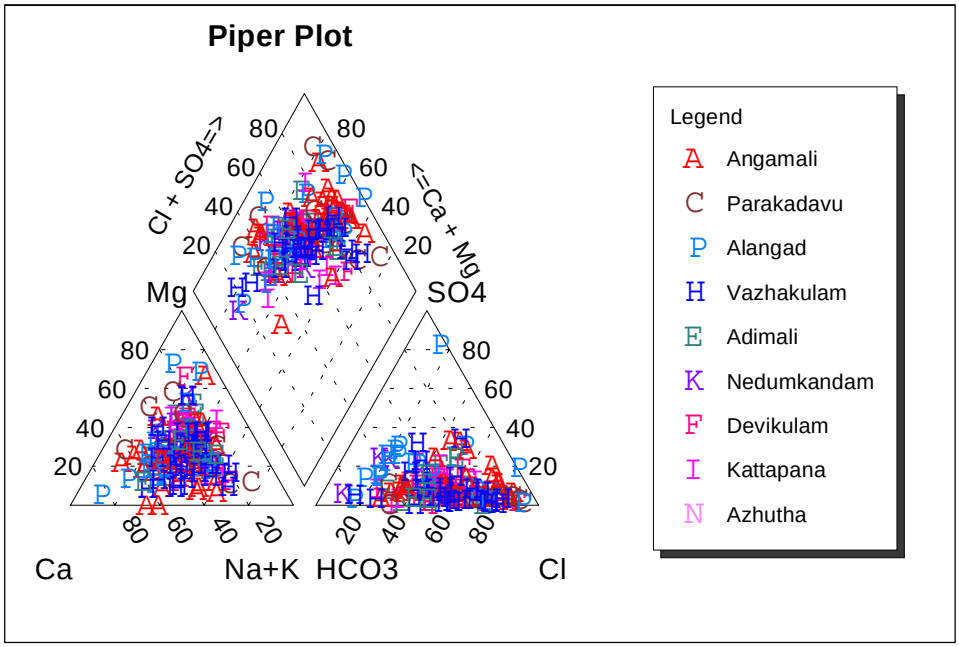


Fig 2.47: Piper diagram of groundwater (monsoon-2006)

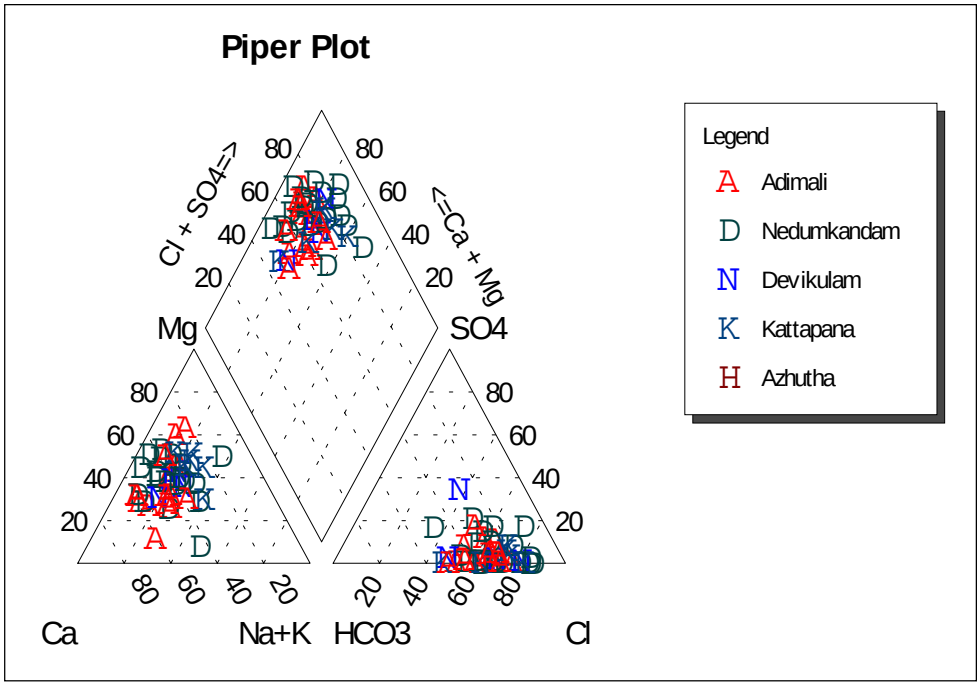


Fig 2.48: Piper plot for water type of groundwater samples (pre-monsoon 2007)

2.8 CONCLUSIONS

Surface water samples were collected from 35 stations along the stretch of the river during the period from 2005 October to 2007 February. The results of analysis are given below:

- Most of the physic-chemical water quality parameters exceed the desirable limits of the downstream stations during all the seasons.
- Bacteriological analysis clearly indicates the microbial contamination of the river.
- The analytical results of an emergency survey conducted in the downstream stations of the river reveal the extent of heavy metal pollution due to the flushing of industrial effluents directly to the river.
- Water Quality Index of the different stations of the river was calculated using three indices viz, Tiwari and Mishra Water Quality Index, CCME Water Quality Index and NSF Water Quality Index. Pollution in the downstream due to anthropogenic activities is indicated from the values obtained. Only a few stations are found to be in the desirable category of drinking water and the water samples at all other stations can be used for drinking only after proper treatment.
- Classification of the river based on CPCB criteria reveals that most of the upstream stations are under the Class C which implies that water at these stations can be used for drinking purpose only after conventional treatment and disinfection. Stations at the downstream area are under Class D which indicates that water in this stretch is not suitable for drinking, but can be used for irrigation and industrial cooling.

Ground water samples were collected from selected wells representing the entire Periyar river basin during the monsoon of 2006. The following conclusions are drawn based on the analytical results:

- pH analysis points to the fact that the ground water samples are acidic in nature; as per the quality standards of BIS, 70% of the samples are not fit for drinking.
- The contamination of well water by nitrate (3.9 % of sampled wells) is observed in some cases and it is due to the proximity of wells to the septic tanks or leach pits.
- Microbiological contamination is another major problem observed, more than 90% of the wells are bacteriologically contaminated due to feacal pollution and this situation warrants for immediate and periodical disinfection of the wells.
- Pesticide analysis carried out for four selected groundwater samples from Idukki district indicated the presence of pesticides in all the samples and the concentration ranged from 0.1041µg/l to 1.3198µg/l for Aldrin, from 0.5393µg/l to 1.279µg/l for Dieldrin and from 0.0961µg/l to 0.6244µg/l for Endo sulfan-beta. The wells in which high pesticide content is observed are located near the agricultural fields.
- Study of groundwater chemistry using Piper diagram revealed that the common ions noticed in all the water types are calcium and sodium.

Surface water samples were collected from 17 stations along the stretch of the river for biological analysis during the monsoon, pre-monsoon and post-monsoon seasons. The results of analysis are given below:

- Most of the benthic organisms come under the family Chironomideae, which indicates organic pollution load was identified from Malayattur, Chowwara and Paathalam
- Vallakadavu (Upstream) reported the presence of Oligocheates (river limbet) showing dominance over other benthic organisms.
- Malayattur, which is a pilgrimage centre on the banks of Periyar river, reported high Palmer's index value during different seasons which indicates high organic contamination. It supports the presence of most pollution tolerant genera like Ankistrodesmus, Scenedesmus, Oscillatoria, Anabaena, Synedra and Navicula and Rotifer like Philodina, a pollution indicator.
- Plankton reported from Paathalam and Edamulla was Chlorella, Scenedesmus, Oscillatoria, Synedra and mastigophora like Euglena.
- The presence of Chironomidae is dominant at Kalady (under the bridge), which receives untreated municipal effluents.
- The assessment of pollution indices indicates that stations of Aluva Manappuram, Chowara, Manjummal and Eloor Ferry (Mixing Point) are facing problems due to disposal of organic waste.

Chapter 3

NEYYAR RIVER BASIN

3.1. BACKGROUND

Many countries in the world are facing water scarcity problems and many of these problems are related to the pollution of the available water resources. The rapid population growth and the asserted pollution of rivers and groundwater sources have put much stress on the water resources to meet the needs of increasing population. Scientific monitoring of the quality of water resources is the first and most essential step for the wise and sustainable management of these resources.

There is a growing need of potable water for domestic, industrial and agricultural use. Due to the peculiar geomorphologic and hydro geological conditions prevailing in Kerala, the residence time of water in the stream channels is considerably low. Besides this, the unscientific ways of utilising the rivers and lakes, and the indiscriminate discharge of untreated industrial effluents, domestic and municipal wastes and sewage to water sources cause pollution and the degradation of the quality of water and the fresh water aquatic ecosystems themselves.

Through the water quality in the upstream stretches of rivers of Kerala are generally good and potable, the quality deteriorates as the rivers traverse through the thickly populated midland and more thickly populated lowland areas. Some of the streams in the highland region however are found to be contaminated due to the application of agro-chemicals, especially insecticides in the estates with monocrops in the Western Ghats. Contamination is often found in the stretches in the midland, especially near bathing ghats and locations used for washing cloths.

The water quality of downstream reaches of rivers are obviously good due to several reasons, such as discharge of waste water from thickly populated areas, dumping of solid wastes, effluent discharge from industries non-point pollution due to application of agro-chemicals in paddy fields, and also due to the other anthropogenic activities like coconut husk processing and sand mining. The report gives a vivid picture of the water quality status along the course of Neyyar river from the upstream stretches to the downstream stretches.

Around two-third of the population of the state depend on open wells for meeting their domestic water requirements. Majority of these wells are bacteriologically contaminated. Moreover, there are several areas in the state, where ground water is affected by iron, low pH, salinity, fluoride, etc. Therefore, ground water quality monitoring is of paramount importance and an attempt has

been made to monitor a network of wells during different seasons of the year, the results of which exercise is presented in this report.

Sediment samples from different locations were also collected and subjected to analysing for ascertaining the physico-chemical characteristics, apart from analyzing the samples collected from the field, an attempt has been made to discuss and interpret the results. Several standard methods have been made use of to attain the Water Quality Indices to help in having a general idea about the water quality status. Biological features of the water body have served as an indicator of water quality status. The continuous monitoring programme and water quality status report will be useful from the following angles.

1. To understand the major sources and causes of pollution
2. To identify critical areas requiring immediate attention
3. To adopt methods and techniques to stop/ control pollution of water sources.
4. To report to appropriate waste water / effluent treatment procedures
5. To have as a reference material while planning for future developed activities.
6. To create awareness among all those concerned.

The present report on Neyyar is one among the three reports already drafted, other two being on Kabbini and Periyar rivers.

3. 2. NEYYAR RIVER BASIN

Neyyar originates from the Agasthyakudam hills, flows through Neyyattinkara taluk and joins Lakshadeep Sea near Poovar. It has a total length of 56 km. The main tributaries are Kallar and Karavaliyar. Streams like Vandichirathode, Kulathoorvaliyathode, Maruthoorthode, Athiyannurthode, Thaliyalthode, Kottukalthode and Venganoorthode joins the main stream. There is an irrigation project constructed in 1973 at Kallikkadu near Kaattakkada, which is about 29 km from Trivandrum city. Neyyar wild life sanctuary in this basin is a famous tourist place. The drainage map of Neyyar basin is given in Fig.3.1.

The total area of Neyyar river basin is 128 sq.kms. It lies between 80º17’2” N and 80º 53’2” N, and 76º 40’2” E and 70º 17’2” E. The area of river basin is spread over six blocks and one Muncipality. A total of 41 Panchayats are there in these blocks.

3. 3. MATERIALS AND METHODS

The network of sampling stations in the river course areas finalized considering the localities of major pumping stations, upstream and downstream locations of discharge of industrial effluents/ sewage, major fishing and recreation zones, stretches generally most prone to pollution and the wetland habitats. The relevant details of sampling stations thus selected in the Neyyar river course are given in Table 1, along with their frames of reference and code numbers. Fig.3.2 shows the surface water sampling stations in the river course. Samples from a few stations were also subjected to biological analysis (Table 3.1).

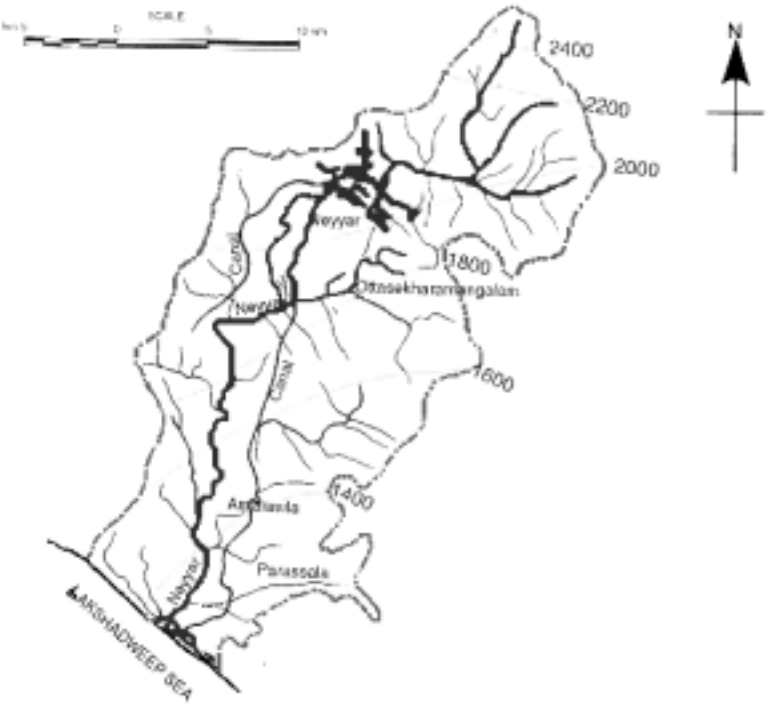


Fig. 3. 1: Drainage map of Neyyar river basin

Fig. 3. 2: Surface water sampling stations along the Neyyar river course

Table 3.1: Details of sampling stations along the river course

Code No:	*Station*	*Location*	*Description*
01/N	Anamukham-I:	N 8° 30´ 0.2´´ E 77° 12´ 7.7´´	Rocky bed ; narrow channel; Mixed vegetation ;rubber plantation
02/N	Anamukham-II (BS)	N 8° 29´ 59.7´´ E 77° 12´ 09.1´´	Narrow channel with organic bed; rubber plantation
03/N	Mayam	N 8° 31´ 44.1´´ E 77° 10´ 16.8´´	Relatively undisturbed organic bed.
04/N	Koompichalkadavu (B S)	N 8° 30´ 49.9´´ E 77° 11´ 22.7´´	Ferry, small drainage joins stream;organic bed; rubber; coconut
05/N	Pantha	N 8° 31´ 28.1´´ E 77° 09´ 59.0´´	Small drainage joins the river; a bridge across; rubber
06/N	Marakkunnu	N 8° 32´ 29.9´´ E 77° 08´ 29´´	Side of the reservoir ; residential buildings on the banks ; domestic waste water discharge
07/N	Daivapuram I	N 8° 31´ 56.9´´ E 77° 08´ 57´	Margin of the reservoir, Rubber
08/N	Daivapuram II(B S)	N 8° 31´ 43.3´´ E 77° 09´ 14.4´´	Margin of the reservoir, Rubber
09/N	Spillway	N 8° 31´ 55.8´´ E 77° 08´ 44.5´´	Water (reservoir)tourism, bed with small to large pebbles, washing and bathing ghat, shallow stream, comparatively less flow
10/N	Perinjamkadav	N 8° 32´ 0.5´´ E 77° 08´ 6.8´´	Steep channel with rock bed, a natural weir , small at site scale excavation of sand, faecal contamination , Mixed vegetation with settlement
11/N	Kallikkad	N 8° 31´ 46.6´´ E 77° 07´ 38.9´´	Faecal contamination, bathing and washing ghat; hollow brick manufacturing unit; Mixed vegetation with settlement.
12/N	Mylakkara	N 8° 31´ 38.6´´ E 77° 07´ 36´´	Cattle grazing; faecal contamination, a small bund; washing and bathing ghat, pump house near by; mixed vegetation.
13/N	Keezharoor	N 8° 28´ 0.5´´ E 77° 05´ 22.4´´	Rocky bed; temple site; washing and bathing ghat; pump house nearby; Mixed vegetation with settlement.
14/N	Pazhamala Temple	N 8° 26´ 57.3´´ E 77° 06´ 05´´	Temple near by, Pump house ; washing and bathing ghat; mixed vegetation.
15/N	Mandapathinkadavu	N 8° 29´ 33.3´´ E 77° 07´ 26.5´´	Pump house nearby; a small weir nearby; mixed vegetation especially banana
16/N	Mampazhakkara	N 8° 26´ 27´´ E 77° 05´ 58.1´´	Pump house nearby; Mixed vegetation with settlement.
17/N	Aruvippuram	N 8° 25´ 37.0´´ E 77° 05´ 28.0´´	Pump house nearby; faecal contamination; Mixed vegetation with settlement; Coconut dominated.

Code No:	*Station*	*Location*	*Description*
18/N	Neyyattinkara I	N 8° 24.0´ 21.6´´ E 77° 05´ 32.0´´	Domestic waste dumped; banks unstable; washing and bathing ghat, mixed vegetation with settlement.
19/N	Neyyattinkara II	N 8° 23´ 52.2´´ E 77° 05´ 40.9´´	Faecal contamination; washing and bathing ghat; dense riparian vegetation; Mixed vegetation with settlement.
20/N	Amaravila Bridge	N 8° 23´ 24.8´´ E 77° 05´ 54.0´´	Rocky bed, washing and bathing ghat; Mixed vegetation with settlement
21/N	Pirayummood Bridge (B S)	N 8° 22.0´ 50.4´´ E 77° 05´14.0´´	Shallow stream; washing and bathing ghat; faecal contamination; Mixed vegetation with settlement
22/N	Mavilakadavu	N 8° 20.1´ 29.6´´ E 77° 05´ 22.1´´	Bathing ghat; faecal contamination; Mixed vegetation with settlement
23/N	Arumanoor	N 8° 19.0´ 53.7´´ E 77° 04´ 54.9´´	Ferry; banks unstable; Mixed vegetation with settlement; Coconut dominated.
24/N	Poovar Bridge	N 8° 19´ 9.7´´ E 77° 04´ 35.2´´	A small rivulet joining the main stream; faecal contamination; sand mining; Urban/ agglomerated settlement; Coconut dominated.
25/N	Poovar Pozhikkara I (B S)	N 8° 18.0´ 40.5´´ E 77° 04´ 26.1´´	Just above the estuary; washing and bathing ghat; channel with mixed riparian vegetables; Urban/ agglomerated settlement.
26/N	Poovar Pozhikkara II (B S)	N 8° 18.0´ 33.4´´ E 77° 04´ 40.7´´	Estuary; tourist resort nearby; boating and tourism activities; severely eroding coast; Urban/ agglomerated settlement; Coconut dominated.

Abbreviation Used: BS- Biological Station.

One ground water sample was selected from each of the wards of all the Panchayats in the Thiruvananthapuram district for estimating the water quality parameters. A few sediment samples were also collected from the basin to determine the quality status. In addition to water quality monitoring data, important geomorphologic features, vegetation and groundwater level fluctuations were also collected. Information on anthropogenic activities and demographic features were also collected from available sources.

Water samples were collected from a network of 26 stations in the Neyyar river, during the monsoon (2006), pre-monsoon (2007) and post-monsoon (2007) seasons. Among the 26 stations, nine were identified for biological analysis. Ground water samples were also collected from 15 Panchayats and one Municipality in the basin, during the monsoon 2007, pre-monsoon (2007), and post-monsoon (2006) seasons. In order to find out the hygienic condition a sanitary survey was also conducted in the basin. A total of 64 ground water samples were collected during each seasons depending on well characteristics, sources of pollution and soil type. The map showing groundwater sampling stations are given in Fig. 3.3.

Fig. 3.3: Ground water sampling stations in the Neyyar basin

The containers used for sampling were pre-cleaned, non reactive plastic bottles of 1 litre capacity and sterilized bottles of 100ml capacity for physico chemical and microbiological analysis respectively. Specially designed glass bottles were used for DO & BOD sampling. Parameters like pH, temperature and electrical conductivity were measured in-situ. Also, the samples for the analysis of dissolved oxygen were fixed at the spot (plate 3.1 to 3.3).

The samples were transported to the laboratory and analyzed for various physico chemical parameters, such as color, turbidity, total dissolved solids (TDS), total alkalinity, total hardness, calcium hardness, magnesium, calcium, iron, sodium, potassium, chloride, sulphate and nutrients (Nitrate-N, Phosphate-P),microbiological content, total coliforms, faecal coliforms and Escherichia coli, and biological content, chlorophyll, macro and micro planktons. Analyses were carried out following the standard procedures given in the Standard Methods for the Examination of Water and Wastewater (APHA, 1996).

Plate 3.1: Surface water sampling from Anamukham station

Plate 3.2: Surface water sampling from Poovar Station

Plate 3.3: In-situ analysis of water samples

3.4. FINDINGS AND DISCUSSION ON RIVER WATER QUALITY

3.4.1 Temporal Changes in Water Quality Parameters

The surface water samples collected during the 3 seasons namely pre-monsoon, monsoon, and post-monsoon were analyzed and the data compiled. The maximum and minimum of different parameters are given in Tables 3.2 to 3. 4.

3. 4.2. Physico-chemical Analysis

The samples collected from the Neyyar river during monsoon (2006), pre-monsoon (2007) and post-monsoon (2007) were analyzed for the physico-chemical parameters, like temperature, pH, EC, salinity, color, turbidity, TDS, total alkalinity, total hardness, Ca, Mg, Fe, Na, K, Cl^-, $SO4^{2-}$, PO4-P, NO3-N, DO and BOD.

The pH values during the monsoon and pre-monsoon seasons were found to be somewhat neutral, except in the samples from downstream reaches, which were slightly alkaline during the monsoon season and were slightly acidic in the pre-monsoon, but within the range prescribed by BIS, (Fig 3.4). However most of the samples were found to be acidic in nature during the post-monsoon season. The pH varied between 5.93 and 7.26. Minimum value for pH was noticed at the Spillway (09/N). This site is a bathing and washing ghat and the flow is comparatively low. The pH of 14 samples was found to be below 6.5. The low pH may be due to the decomposition of debris and organic matter in the river.

Table 3.2: Maximum and minimum concentration values of Neyyar river (pre-monsoon 2007)

Parameters	Maximum	Minimum
Temperature,0C	36.1	26.1
pH	7.87	6.6
EC, microsiemens/cm	29100	55.4
Colour, Hazen	33	2
Turbidity, NTU	26	0
Salinity, ppt	4.2	0
TDS, mg/l	18624	35.456
Total Alkalinity, mg/l	64	16
Total Hardness, mg/l	880	8
Calcium hardness, mg/l	240	4
Magnesium, mg/l	155.52	ND
Calcium, mg/l	96	1.6
Iron, mg/l	1.49	ND
Sodium , mg/l	2240	4.4
Potassium, mg/l	70.00	1.10
Chloride, mg/l	4400	8
Sulphate, mg/l	432	ND
Phosphate-P, mg/l	0.05	ND
Dissolved oxygen, mg/l	9.28	4.81
BOD, mg/l	4.54	0.27

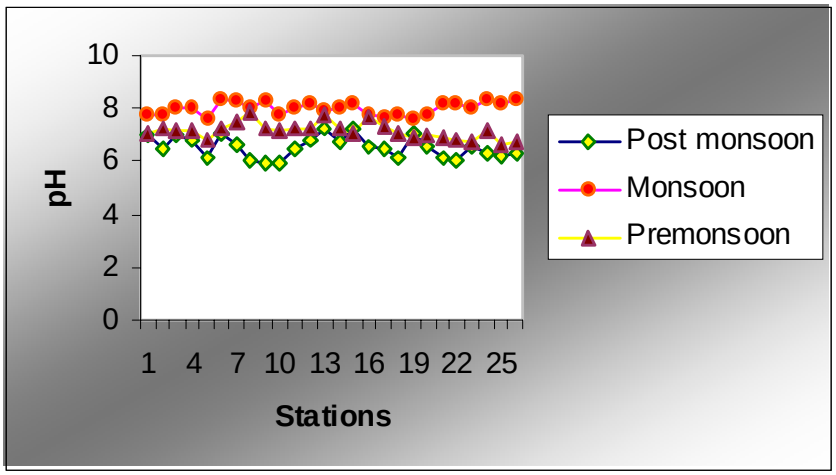


Fig. 3.4: Variation of pH along Neyyar river

Table 3.3: Maximum and minimum values of Neyyar river monsoon 2007

Parameters	Minimum	Maximum
Temperature,^{0}C	28.10	32.30
pH	7.60	8.40
EC, micro siemens/cm	27.10	39000.00
Colour, Hazen	1.00	15.00
Turbidity, NTU	1.00	11.00
Salinity, ppt	0.10	19.40
TDS, mg/l	17.34	24960.00
Total Alkalinity, mg/l	28.00	84.00
Total Hardness, mg/l	4.00	4400.00
Calcium hardness, mg/l	4.00	720.00
Magnesium, mg/l	0.00	894.24
Calcium, mg/l	1.60	288.00
Iron, mg/l	0.01	0.29
Sodium , mg/l	1.20	4000.00
Potassium, mg/l	0.90	310.00
Chloride, mg/l	5.76	14976.00
Sulphate, mg/l	0.24	1882.00
Nitrate-N, mg/l	0.22	0.81
Ammoniacal Nitrogen, mg/l	0.03	35.76
Phosphate-P,mg/l	0.01	0.03
Dissolved oxygen, mg/l	5.44	8.53
BOD, mg/l	0.40	3.07

The samples up to Pirayummoodu had low value for EC. However from Mavilakadavu (22/N) onwards, an increase in the values of EC was observed and the trend continued towards the downstream reaches and attained the highest value at Poovar Pozhikara (26/N). The values were much high during the pre-monsoon season, except at 26/N, which station recorded a low value of E.C, compared to the post-monsoon. This may be due to the dilution of water due to mid summer rains. The observation clearly brings out the impact of intrusion of saline water into the fresh water zones. In the post-monsoon, the electrical conductivity is very low compared to other seasons. An increasing trend in the concentration towards the downstream stations was noticed. The highest value of 2660 µs was found at Poovar II, which is in an estuarine stretch. This high value is due to the salinity intrusion from the sea. The area has considerable tourism activities, including boating. As expected TDS follows the same trend as EC in all seasons, as TDS is directly proportional to EC (Fig 3.5).

Table 3.4: Maximum and minimum values of Neyyar river (Postmonsoon2007)

Parameters	Maximum	Minimum
Temperature,0C	30.9	22.2
pH	7.26	5.93
EC, micro siemens/cm	2660	25
Colour, Hazen	8.8	1
Turbidity, NTU	6	1
Salinity, ppt	0.9	0.1
TDS, mg/l	1710.38	16.075
Total Alkalinity, mg/l	44	16
Total Hardness, mg/l	236	8
Calcium hardness, mg/l	52	6
Magnesium, mg/l	44.712	0.486
Calcium, mg/l	20.8	2.4
Iron, mg/l	0.06	0.02
Sodium , mg/l	390	4.8
Potassium, mg/l	12.6	0.8
Chloride, mg/l	688	8
Sulphate, mg/l	66.8	0.28
Nitrate-N, mg/l	4.21	0.61
Phosphate-P, mg/l	12.2	0
Dissolved oxygen, mg/l	9.6	5.06
BOD, mg/l	5.93	0.2

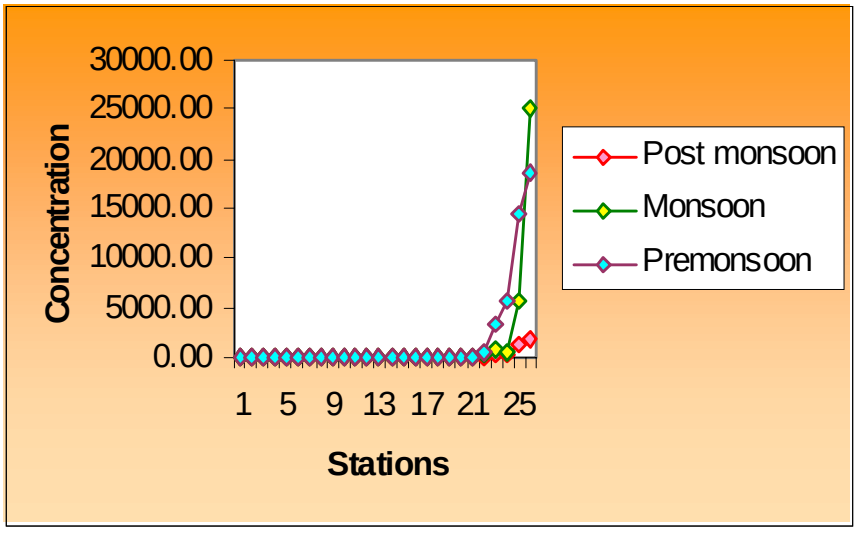


Fig. 3.5: Variation of TDS along Neyyar river

Salinity also has been gradually increasing towards the downstream reaches from Mavilakadavu (22/N). During the monsoon, salinity value was found to be the highest (19 ppt) at Poovar Pozhikkara I (25/N). This may be due to the salinity intrusion from the sea during the period of high tide. But, the concentration comes down to 4.2 ppt during the pre-monsoon due to heavy mid summer rains. But in the post-monsoon, the values were found to be very low, it ranging from 0 to 0.90 ppt, which indicates the effects of monsoon rain on the dilution of water. The over all observations indicate that during the high tide, the influence of saline water intrusion is high as expected. However, data for short time intervals during a tidal period, and even during tides of different magnitudes would have provided more precise information.

Out of the 26 samples collected, only six samples had colour within the permissible range during the pre-monsoon season, where as only 5 samples (from Aruvippuram, Neyyattinkara-I & II, Amaravila and Pirayummodu) were found to be coloured during the monsoon. In post-monsoon the color of the samples ranged from 1 to 8.8 Hazen. The high value is found at Mylakkara (17/N), which is a washing and bathing ghat. The flow rate is also comparatively low at this station in the post-monsoon season. About seven samples were found to be highly colored during this season. The variation of colour along the Neyyar river is depicted in Fig 3.6

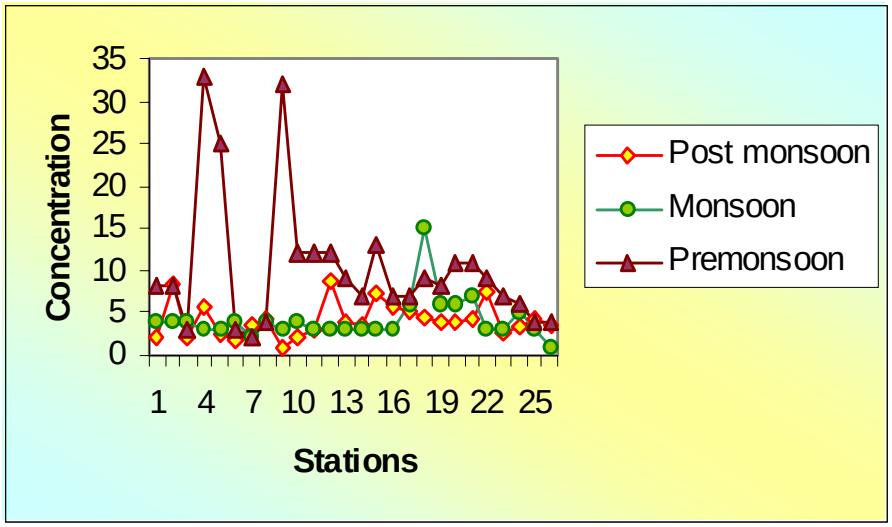


Fig. 3.6: Variation of color along Neyyar river

In general turbidity is found to be low during the three seasons. Only samples from sample Mylakkara (12/N) and Neyyattinkara-1(18/N) during the monsoon and samples from Koompichal (04/N), Pantha (05/N), Daivapuram-II(08/N) and Spillway(09/N) during the pre-monsoon and sample from Keezharoor (13/N) during the post-monsoon were found to exceeded the limit (Fig 3.7).

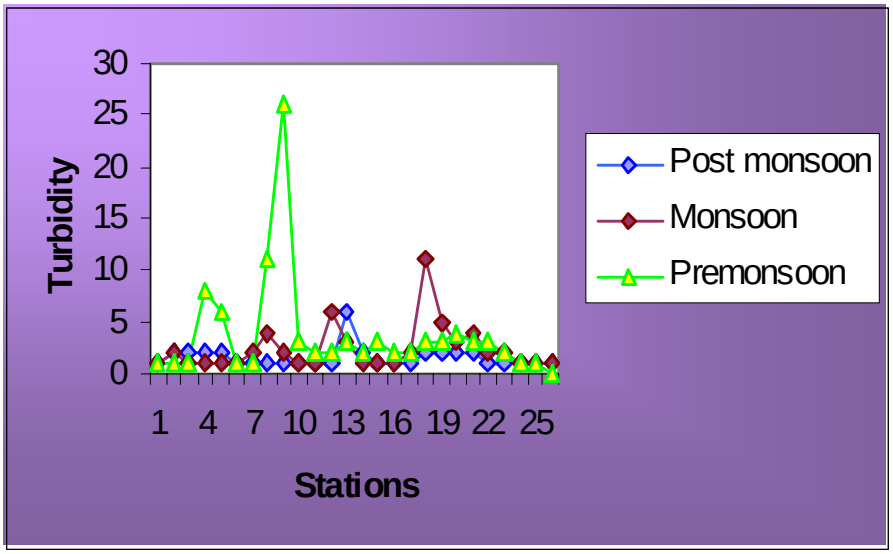


Fig. 3.7: Variation of Turbidity along Neyyar river

Alkalinity is important in determining the ability of a stream to neutralize acidic pollution from rainfall or wastewater. Present study brings to light that alkalinity values are very less all along the river during all the seasons. All samples show alkalinity values below the range prescribed by BIS.

The hardness values were beyond the limits for samples from the down stream stations like Poovar Bridge, during pre-monsoon and Poovar Pozhikkara-I and II during the monsoon and pre-monsoon seasons. During the post- monsoon it ranged from 8mg/l (Anamukham II) to 236mg/l (Poovar II) and the values were found to be within the permissible limit prescribed by BIS.

The calcium and magnesium values were found to increase towards the downstream reaches of the river. The magnesium concentration is dominated when compared to that of calcium in the downstream stations at Arumanoor, Poovar Bridge and Poovar Pozhikara-I and II during the pre-monsoon season. But during the monsoon season, the values were found to be very low compared to the pre-monsoon except at Poovar Pozhikara, where high values of magnesium and calcium namely 894.24mg/l and 288.00 mg/l respectively, were observed. This may be due to the impact of estuarine processes. During the post-monsoon, the values were much low compared to the other seasons. As in the case of other seasons, the concentration of magnesium is dominated in the down stream stations namely Poovar bridge, Poovar Pozhikkara I and II. Only two samples had the concentration above the BIS limit, ie, at Poovar Pozhikkara I (35.96mg/l) and Poovar Pozhikkara II (44.71 mg/l). All the samples had the concentration of Ca within the permissible limit.

The concentration of iron during the monsoon and post-monsoon was found to be very less and below the permissible limits. However during pre-monsoon, the concentration was high. The concentration at Koompichal, Pantha, Spillway, Perinjamkadavu and Mylakkara exceeded the potability limit. Of these, Koompichal and Pantha had shown concentrations as high as 1.22 &

1.49 mg/l respectively. This may be due to the concentration of sediments caused due to the reduction in discharge.

In the case of sodium, the values were very less during the monsoon and pre-monsoon seasons up to Pirayummoodu Bridge. From Mavilakadavu onwards, the values show sudden rise and the maximum value is observed at Poovar Pozhikara-II (26/N). At this station, the value is as much as high as 4000 mg/l during the monsoon and it reduced to 2240mg/l during the pre-monsoon season, as expected. During the post -monsoon the values are very low; the values ranged between 6mg/l (Mayam) and 390mg/l (Poovar II). The high value may be due to the salinity intrusion from the sea during the high tide.

The concentration of potassium is very low during all the seasons, except at Poovar Pozhikkara, where a high value of 310 mg/l is observed during monsoon season, showing the characteristic property of an estuary. Chloride concentration is very low at the up stream stations and high in the down stream stations during all the seasons. This may be due to the sea water intrusion in to the stream. The maximum concentration is found at Poovar II i.e. 14976 mg/l, 4400mg/l and 688mg/l during the monsoon, pre-monsoon and post-monsoon respectively. It may be due to the salinity intrusion from the sea (Fig 3.8).

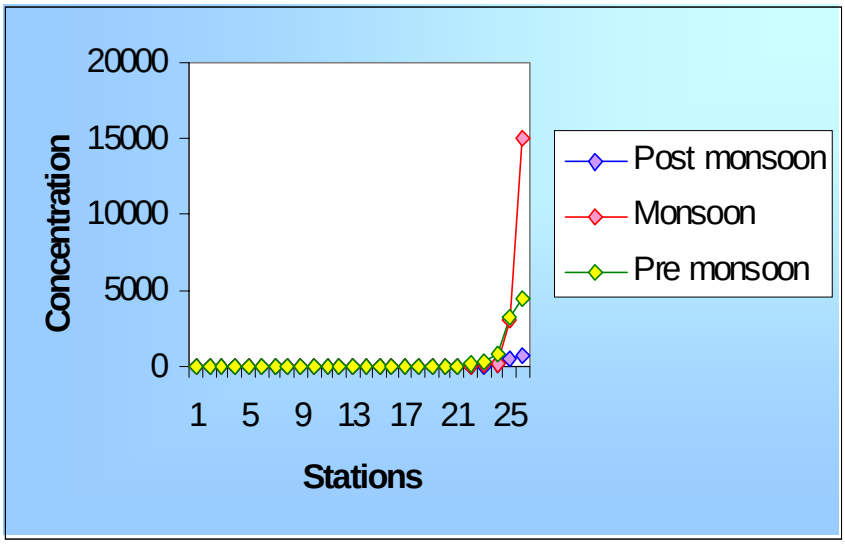


Fig. 3.8: Variation of Chloride along Neyyar river

The phosphate values of all the samples during all the seasons are found to be very low. This may be due to the pollution caused by detergents, sewage, drainage and industrial effluents.

The concentration of sulphate was also found to be very low up to Pirayummoodu Bridge. From Mavilakadavu onwards, the concentration increased and at Poovar Pozhikara, which is very close to the sea, it attained the highest value during the monsoon and pre-monsoon seasons. In comparison, the concentration is very low during the post- monsoon season; however all values

are under the permissible limit. The maximum value is found at Poovar Pozhikara-I and II during the monsoon season namely 444 and 1882mg/l respectively.

The Biochemical Oxygen Demand (BOD) is an important parameter for ascertaining the quality of river water. The DO ranges from 4.81 to 9.28 mg/l during the pre-monsoon from 5.44 to 8.53mg/l during the monsoon and from 5.06 mg/l (Pirayummoodu Bridge) to 9.6 mg/l (Poovar II) during the post-monsoon season. BOD at most of the stations is very low during both the seasons. But some stations showed values above 3mg/l during pre-monsoon and post-monsoon seasons. (Fig. 3.9).

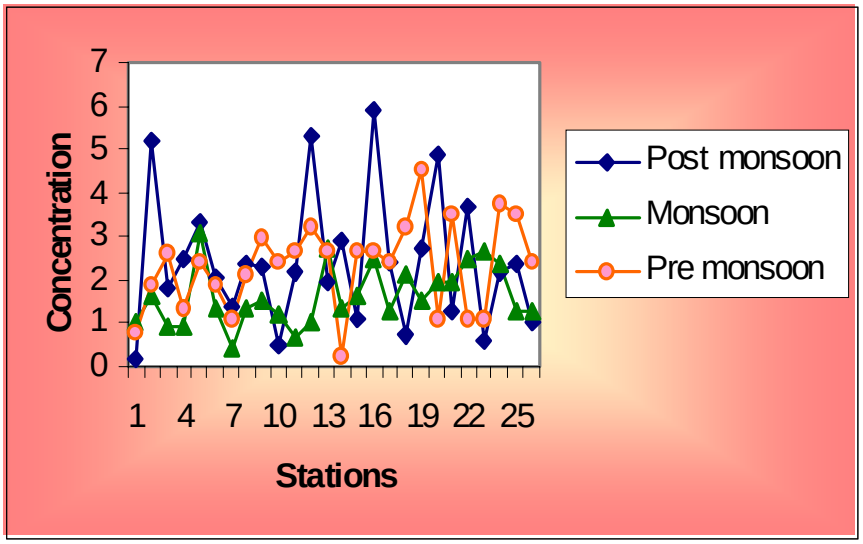


Fig. 3. 9: Variation of BOD along Neyyar river

3.4.3 Bacteriological Analysis:

Bacteriological analysis indicates that the Neyyar river is contaminated with coliforms especially with faecal coliforms. E.Coli is present in Neyyar most of the samples collected during the three seasons.

3.5. RIVER WATER QUALITY INDEX AND CRITERIA

Water quality index may be defined as a form of average derived by relating a group of variables to a common scale and combining them into a single number. The group should contain the most significant parameters of the data set, so that the index can describe the overall position and reflect change in a representative manner.

A water quality index thus fulfills the requirements of a simple classification but additionally provides information on within- class variation in water quality in a timely and efficient manner, facilitating the early detection of fluctuations in water quality and providing additional information of value to the operational management for river water quality.

In order to understand the quality of water of Neyyar river CCME (Canadian Council of Ministers of Environment) water quality index was calculated using the analytical data of three seasons. Twelve parameters used for the determination are: pH, turbidity, TDS, total alkalinity, total hardness, calcium, magnesium, chloride, sodium, sulphate, total coliform and faecal coliform

3.5.1 CCME Water Quality Index of Neyyar River

Canadian Council of Ministers of Environment (CCME) water quality index has been worked out for the Neyyar river using the seasonal analytical data. The results are presented in Fig 3.10 and Table 3.5

Fig. 3.10: CCME, Water Quality Index of Neyyar river.

According to CCME water quality index, none of the samples have shown Excellent or Good water quality specification. Most of the samples come under Poor water quality. Only one station, namely Mayam has the water quality specification as Fair. About 61% of the sampling stations have Poor water quality. The presence of coliforms is the major problem for this decline in water quality. Human and animal excrete all along the banks of the river are the main reason for the faecal contamination of the river. At most of the stations, the water is acidic due to the decomposition of the debris during the post monsoon season and this also contributes to the decline in the quality of water. Sand mining and tourism as well as salinity intrusion from the sea are some other causative factors for the deterioration of quality of water in the down stream stations.

Table 3. 5: CCME Water Quality Index of Neyyar river

Station Code	Station Name	WQI	Specifications
01/N`	Anamukham I	45	Marginal
02/N	Anamukham II	44	Poor
03/N	Mayam	67	Fair
04/N	Koompichal	48	Marginal
05/N	Pantha	38	Poor
06/N	Marakunnu	43	Poor
07/N	Daivapuram I	46	Marginal
08/N	Daivapuram II	62	Marginal
09/N	Spillway	53	Marginal
10/N	Perinjamkadavu	43	Poor
11/N	Kallikkad	45	Marginal
12/N	Mylakkara	45	Marginal
13/N	Keezharoor	52	Marginal
14/N	Pazhamala Temple	45	Marginal
15/N	Mandapathinkadavu	44	Poor
16/N	Mampazhakkara	42	Poor
17/N	Aruvippuram	40	Poor
18/N	Neyyattinkara I	40	Poor
19/N	Neyyattinkara II	42	Poor
20/N	Amaravila Bridge	42	Poor
21/N	Pirayummoodu Bridge	41	Poor
22/N	Mavilakadavu	39	Poor
23/N	Arumanoor	37	Poor
24/N	Poovar Bridge	34	Poor
25/N	Poovar Pozhikkara I	26	Poor
26/N	Poovar Pozhikkara II	28	Poor

3.5.2 Water Quality Criteria of Neyyar River In Relation To Irrigation Standards

Impurities in water, which have a negative impact on agricultural production, affect plant growth and soil characteristics. For example, sodium, because of its large radius of hydration, causes clay soils to disperse. When clay soils are dispersed, the soil pore size reduces and

permeability of water greatly decreases. The dispersive effect results from the +ve sodium being adsorbed on negatively charged clay surfaces, and replacement by other ions is also possible. The most abundant elements for this ion exchange process in natural waters are Ca^{++}, Mg^{++} and Na^{+}. Ca and Mg are more tightly bonded to clay surface than sodium and so are preferentially adsorbed. As the adsorption reactions are irreversible, equilibrium between the adsorbed and dissolved ions is approached, and the relative amounts of the adsorbed species will be a function of the amounts in solution. In most of the agricultural irrigation waters, the great bulk of the cations are Ca^{++}, Mg^{++} and Na^{+} and other ions can be neglected in determining the risk to soil dispersion. (World Water Mission Commission)

In order to study the suitability of water in Neyyar for agricultural purposes, the water quality parameters were compared with the standard specifications. The quality of irrigation water was assessed through Magnesium Hazard Ratio (MHR), Soluble Sodium Percent (SSP), Kelly's Ratio (KR) and Sodium Adsorption Ratio (SAR) etc. The standard specifications of important irrigational parameters are given in the Table 3.6.

Table 3. 6: Irrigation parameters and their standard specifications

Irrigation Parameters	Formula Used (all values in EPM)	Standard Specifications
Magnesium Hazards Ratio	$\frac{Mg \times 100}{[Ca+Mg]}$	<50% = suitable >50% = unsuitable
Soluble Sodium Percent	$\frac{Na \times 100}{[Ca+Mg+Na]}$	<20% = excellent 20-40 = good 40-60 = permissible 60-80 = doubtful >80 = unsuitable
Kelly's Ratio	$\frac{Na}{[Ca+Mg]}$	<1 = suitable 1-2 = marginal >2 = unsuitable
Sodium Adsorption Ratio	$\frac{Na}{\sqrt{\frac{Ca+Mg}{2}}}$	0-10 = excellent 10-18 = fair >20 = poor

The values for MHR, SSP, KR and SAR for the Neyyar during the three seasons are presented in tables 3.7 to 3.9.

Table 3. 7: Water quality criteria as per irrigation standards for the Neyyar (Pre-monsoon 2007)

	MHR		SSP		KR		SAR	
No:	Values	Spe	Values	Spe	Value	Spe	Value	Spe
01/N`	1.2587	Suitable	6.4275	Excellent	0.06869	Suitable	0.2444	Excellent
02/N	3.6834	Suitable	9.4633	Excellent	0.10452	Suitable	0.3075	Excellent
03/N	1.2587	Suitable	1.7546	Excellent	0.01786	Suitable	0.0899	Excellent
04/N	3.6834	Suitable	6.2795	Excellent	0.06700	Suitable	0.2414	Excellent
05/N	2.4861	Suitable	5.6333	Excellent	0.05970	Suitable	0.2137	Excellent
06/N	1.2587	Suitable	3.1919	Excellent	0.03297	Suitable	0.1173	Excellent
07/N	1.2587	Suitable	2.9337	Excellent	0.03022	Suitable	0.1075	Excellent
08/N	0.6333	Suitable	1.6319	Excellent	0.01659	Suitable	0.0832	Excellent
09/N	3.6834	Suitable	7.4420	Excellent	0.08040	Suitable	0.2365	Excellent
10/N	1.8763	Suitable	5.7878	Excellent	0.06143	Suitable	0.1790	Excellent
11/N	1.2587	Suitable	3.7041	Excellent	0.03847	Suitable	0.1369	Excellent
12/N	3.6834	Suitable	5.3283	Excellent	0.05628	Suitable	0.1656	Excellent
13/N	2.4861	Suitable	5.3910	Excellent	0.05698	Suitable	0.2040	Excellent
14/N	1.2587	Suitable	4.9614	Excellent	0.05220	Suitable	0.1857	Excellent
15/N	2.4861	Suitable	4.6567	Excellent	0.04884	Suitable	0.1749	Excellent
16/N	2.4861	Suitable	5.6333	Excellent	0.05970	Suitable	0.2137	Excellent
17/N	2.4861	Suitable	5.1475	Excellent	0.05427	Suitable	0.1943	Excellent
18/N	2.4861	Suitable	12.3651	Excellent	0.14110	Suitable	0.3572	Excellent
19/N	2.4861	Suitable	5.3910	Excellent	0.05698	Suitable	0.2040	Excellent
20/N	2.4861	Suitable	9.7910	Excellent	0.10854	Suitable	0.2748	Excellent
21/N	2.4861	Suitable	5.6333	Excellent	0.05970	Suitable	0.2137	Excellent
22/N	23.4269	Suitable	58.4421	Permissible	1.40628	Marginal	3.2804	Excellent
23/N	73.2216	Unsuitable	81.1434	Unsuitable	4.30318	Unsuitable	12.5363	Fair
24/N	88.6383	Unsuitable	84.3127	Unsuitable	5.37458	Unsuitable	19.3361	Poor
25/N	98.2866	Unsuitable	85.7291	Unsuitable	6.00728	Unsuitable	29.6241	Poor
26/N	98.3920	Unsuitable	88.2590	Unsuitable	7.51715	Unsuitable	38.2650	Poor

The values for MHR, SSP, KR and SAR for the Neyyar during the three seasons are presented in tables 3.7 to 3.9. The samples from the down stream stations like Arumanoor, Poovar Bridge, Poovar Pozhikara-I and II and the upstream stations like Mayam have shown high values of MHR during the pre-monsoon season and are unsuitable for irrigation purposes. In all other stations, the water is suitable for irrigation. In monsoon season, down stream stations like Mavilakadavu, Arumanoor, Poovar Bridge, and Poovar Pozhikara II and the upstream stations like Anamukham-II and Mayam are unsuitable for irrigation. In post-monsoon, the water samples from stations like Neyyattinkara-I, Amaravila Bridge, Mavilakadavu, Poovar Bridge, Poovar Pozhikara I and II are unsuitable for irrigation.

Table 3. 8: Water quality criteria as per irrigation standards (Monsoon- 2006)

	MHR		SSP		KR		SAR	
No:	Values	Spe	Values	Spe	Value	Spe	Value	Spe
01/N`	33.242	Suitable	42.050	Permissible	0.4205	Suitable	0.502	Excellent
02/N	66.575	Unsuitble	30.361	good	0.3036	Suitable	0.302	Excellent
03/N	66.575	Unsuitble	30.361	good	0.3036	Suitable	0.302	Excellent
04/N	49.897	Suitable	24.628	good	0.2463	Suitable	0.185	Excellent
05/N	33.242	Suitable	73.126	Doubtful	0.7313	Suitable	1.884	Excellent
06/N	0.000	Suitable	46.512	Permissible	0.4651	Suitable	0.348	Excellent
07/N	24.923	Suitable	52.109	Permissible	0.5211	Suitable	0.870	Excellent
08/N	33.242	Suitable	26.622	good	0.2662	Suitable	0.251	Excellent
09/N	49.897	Suitable	39.523	Permissible	0.3952	Suitable	0.369	Excellent
10/N	49.897	Suitable	43.260	Permissible	0.4326	Suitable	0.431	Excellent
11/N	49.897	Suitable	39.523	good	0.3952	Suitable	0.369	Excellent
12/N	49.897	Suitable	24.628	good	0.2463	Suitable	0.185	Excellent
13/N	33.242	Suitable	30.332	good	0.3033	Suitable	0.301	Excellent
14/N	0.000	Suitable	52.083	Permissible	0.5208	Suitable	0.615	Excellent
15/N	49.897	Suitable	46.563	Permissible	0.4656	Suitable	0.492	Excellent
16/N	33.242	Suitable	44.389	Permissible	0.4439	Suitable	0.553	Excellent
17/N	49.897	Suitable	49.502	Permissible	0.4950	Suitable	0.554	Excellent
18/N	33.242	Suitable	42.050	Permissible	0.4205	Suitable	0.502	Excellent
19/N	33.242	Suitable	39.506	good	0.3951	Suitable	0.452	Excellent
20/N	0.000	Suitable	54.455	Permissible	0.5446	Suitable	0.676	Excellent
21/N	33.242	Suitable	42.050	Permissible	0.4205	Suitable	0.502	Excellent
22/N	66.575	Unsuitble	65.959	Doubtful	0.6596	Suitable	2.322	Excellent
23/N	78.191	Unsuitble	76.325	Doubtful	0.7633	Suitable	6.175	Excellent
24/N	68.662	Unsuitble	75.809	Doubtful	0.7581	Suitable	5.007	Excellent
25/N	28.219	Suitble	92.253	Unsuitable	0.9225	Suitable	34.659	bad
26/N	83.580	Unsuitble	66.478	Doubtful	0.6648	Suitable	26.263	bad

With regard to SSP, none of the stations come under the group 'Excellent'. The down stream stations were found to be unsuitable and doubtful for irrigation during the monsoon and pre-monsoon seasons.

With regard to KR, the downstream stations are not found to be suitable for irrigation during the pre-monsoon. But, during the monsoon season, all samples except that of Poovar Pozhikara I and II are found to be suitable for irrigation. Kelly's Ratio of post- monsoon samples reveals that the water from the down stream stations like Arumanoor, Poovar Bridge, Poovar Pozhikkara I and II are unsuitable for irrigation purpose.

Table 3. 9: Water quality criteria as per irrigation standards (Post-monsoon 2007)

	MHR		SSP		KR		SAR	
No:	Values	Spe	Values	Spe	Value	Spe	Value	Spe
1	39.90	Suitable	51.10	Permissible	1.05	Marginal	0.93	Excellent
2	24.92	Suitable	68.52	Doubtful	2.18	Unsuitable	1.23	Excellent
3	33.24	Suitable	52.12	Permissible	1.09	Marginal	0.75	Excellent
4	33.24	Suitable	55.23	Permissible	1.23	Marginal	0.85	Excellent
5	49.90	Suitable	49.50	Permissible	0.98	Suitable	0.78	Excellent
6	33.24	Suitable	53.73	Permissible	1.16	Marginal	0.80	Excellent
7	33.24	Suitable	46.55	Permissible	0.87	Suitable	0.60	Excellent
8	33.24	Suitable	53.73	Permissible	1.16	Marginal	0.80	Excellent
9	24.92	Suitable	44.94	Permissible	0.82	Suitable	0.65	Excellent
10	24.92	Suitable	46.54	Permissible	0.87	Suitable	0.70	Excellent
11	33.24	Suitable	53.73	Permissible	1.16	Marginal	0.80	Excellent
12	24.92	Suitable	49.48	Permissible	0.98	Suitable	0.78	Excellent
13	39.90	Suitable	54.04	Permissible	1.18	Marginal	1.05	Excellent
14	24.92	Suitable	61.21	Doubtful	1.58	Marginal	1.26	Excellent
15	49.90	Suitable	53.35	Permissible	1.14	Marginal	0.91	Excellent
16	24.92	Suitable	60.37	Permissible	1.52	Marginal	1.22	Excellent
17	24.92	Suitable	61.21	Doubtful	1.58	Marginal	1.26	Excellent
18	59.90	Unsuitable	54.96	Permissible	1.22	Marginal	1.09	Good
19	19.93	Suitable	57.43	Permissible	1.35	Marginal	1.21	Excellent
20	62.40	Unsuitable	48.09	Permissible	0.93	Suitable	1.05	Excellent
21	49.90	Suitable	54.51	Permissible	1.20	Marginal	1.17	Excellent
22	57.04	Unsuitable	55.46	Permissible	1.25	Marginal	1.32	Excellent
23	28.49	Suitable	73.23	Doubtful	2.74	Unsuitable	2.89	Excellent
24	66.58	Unsuitable	67.36	Doubtful	2.06	Unsuitable	3.19	Excellent
25	73.92	Unsuitable	75.85	Doubtful	3.14	Unsuitable	8.87	Excellent
26	77.90	Unsuitable	78.28	Doubtful	3.60	Unsuitable	11.06	Fair

Sodium adsorption ratio shows that the down stream stations are poor in water quality for irrigation purpose during the monsoon and pre-monsoon seasons. During the post-monsoon, the condition improved considerably.

Overall assessment of the Neyyar river water shows that the water at the down stream stations are unsuitable for irrigation purposes.

3.6. BIOLOGICAL ANALYSIS OF RIVER SYSTEM

3.6.1. Data collection and Preliminary analysis

Biological analysis covers examination of plankton and benthic flora and fauna. Organisms present in the ecosystem can indicate its overall quality and pollution status and therefore biological analysis is gaining more importance. The flora and fauna present in specific ecosystems are the function of the combined effects of various hydrological, physical and chemical factors. Two such specific factors in the context of aquatic ecosystem are the density of water and abundance of dissolved and particulate nutrients. In the present monitoring programme, rivers are characterized by their biological quality criteria in different seasons viz, pre-monsoon, monsoon and post-monsoon. The stations located along the river course for biological monitoring given in Table 3.10 and map showing sampling stations are given in Fig 3.11.

Table 3.10: Stations selected for biological monitoring

Sl.No.	Station Code	Location
1	02/N	Anamukham
2	04/N	Koompichal
3	08/N	Daivapuram
4	09/N	Neyyar spillway
5	11/N	Kallikkadu
6	17/N	Aruvipuram
7	21/N	Pirayamudu
8	25/N	Puvar
9	26/N	Puvar Estuary

The sampling stations were fixed along different stretches of the river considering the spatial, aspects and the potential sources of pollution. The analysis was carried out following the standard techniques for collection, preservation and identification. A quantitative assessment was done with Lackey's drop method. Different levels of aquatic biota considered are micro phytoplankton, zooplankton and benthic macro invertebrates. The areas are characterized, the quality status ascertained and the interpretations made in the light of the genus richness and abundance and presence of indicator species with regard to different kinds of pollution.

Fig. 3.11: Biological sampling stations

The different classes of biota reported from Neyyar river are listed below.

1. Phytoplankton

Class: Cyanophyceae

1. *Oscillatoria sp.*
2. *Anabaena sp.*
3. *Anacystis sp.*
4. *Lyngbia sp.*
5. *Nostoc sp.*
6. *Chlorococcum sp.*
7. *Gleotrichia sp.*

Class: Chlorophyceae

1. *Closterium acutum*
2. *C. setaceum*
3. *C.acerosum*
4. *Coelastrum sp.*
5. *Staurastrum chaetoceras*
6. *Cosmarium granatum*

7. *Xanthidium sp.*
8. *Ankistrodesmus sp.*
9. *Closteriopsis sp.*
10. *Euastrum didelta*
11. *Clostridium sp.*
12. *Pandorina sp.*
13. *Eudorina* sp.
14. *Paediastrum duplex*
15. *P.tetras*
16. *Scenedesmus quadricauda*
17. *S.bijugatus*
18. *Chlorococcum sp.*
19. *Oocystis sp.*
20. *Golenkinia sp.*
21. *Centrosphaeria sp.*
22. *Trachelomonas sp.*
23. *Centritractus sp.*
24. *Microspora sp.*
25. *Mougeotia sp.*
26. *Tribonema sp.*
27. *Perenema sp.*

Class: Bacillariophyceae

1. *Surirella sp.*
2. *Opephora sp.*
3. *Amphipleura sp.*
4. *Pinnularia sp.*
5. *Meridion sp.*
6. *Cymbella sp.*
7. *Melosira sp.*
8. *Cocconeis sp.*
9. *Cyclotella sp.*
10. *Gomphonema* sp.
11. *Stauroneis sp.*
12. *Gyrosigma sp.*
13. *Synedra sp.*
14. *Fragillaria sp.*

15. *Nitzschia sp.*
16. *Amphora sp.*
17. *Navicula sp.*
18. *Ceratoneis sp.*
19. *Sidopleura sp.*

2. Zooplanktons

1. *Amoeba sp.*
2. *Difflugia sp.*
3. *Stylonchia sp.*
4. *Urostyla sp.*
5. *Trichocera sp.*
6. *Sinantherina sp.*
7. *Candona sp.*
8. *Daphnia sp.*
9. *Bosmina sp.*
10. *Macrothrix sp.*
11. *Alona sp.*
12. *Moina sp.*
13. *Cyclops sp.*
14. *Diaptomus sp.*
15. *Ablabesmyia sp.*
16. *Chaoborus sp.*
17. *Hydrachna sp.*
18. *Nocteleuca sp.*
19. *Planaria sp.*
20. *Rhabdolaimus sp.*

3. Benthic macro-invertebrates

1. *Chironomus sp.*
2. *Ablabesmyia sp.*
3. *Dero sp.*
4. *Stylaria sp.*
5. *Aulophorus sp.*
6. *Riffle beetle larva*
7. *Rithrogena sp.*
8. *Hydrachna sp.*
9. *River mussel*

The phytoplankton community is composed of members from Chlorophyceae, Cyanophyceae, Bacillariophyceae and very minor representation from class Chrysophyta. Some species of Diatoms show clear dominance over others and the environmental conditions prevailing there will be responsible for these community rearrangements. The phytoplankton community structure over different seasons is given in Figs. 3.12 & 3.13.

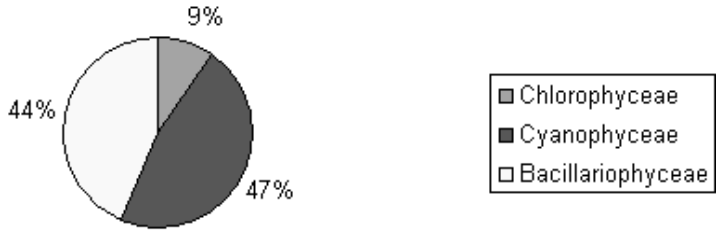


Fig. 3.12: Phytoplankton composition of Neyyar river, Monsoon (August 2007)

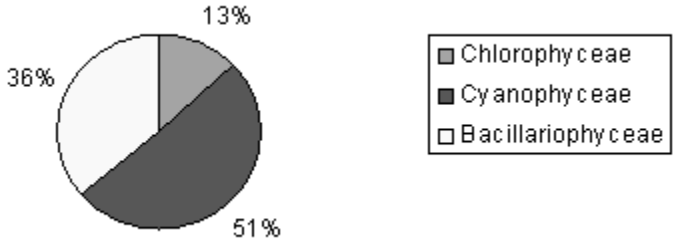


Fig. 3.13: Phytoplankton composition of Neyyar river – pre-monsoon (March 2007)

Based on the biological monitoring, it can be concluded that the Neyyar river has considerable threat from sewage and other domestic wastes. The organic load in the river bed is high, several canals and streams carry the sewage into the river. Some potent pollution indicators like *Chironomus, Tubifex* and other Oligochaetan worms are reported in the river bed near Neyyatinkara Township and also at Poovar where the river enters the Lakshadweep Sea. The biota analysis of the river clearly shows that the quality deterioration becomes more drastic in summer.

The phytoplankton community shows a distinct dominance by Bacillariophyceae (Diatoms), which is characteristic of a flowing system like river. The abundant presence of diatom species like *Melosira, Cyclotella* and *Synedra* indicates that the water is devoid of any chemical pollutants like those from untreated industrial effluents. However, presence of species like *Nitzschia* and *Navicula* indicates deterioration in water quality due to organic contamination.

The algal wealth of primary producers (Chlorophyceae) is an indication of the fair productive nature of the stream. The presence of desmids, a class of single celled chlorophyceans (*Cosmarium, Euastrum, Closterium* etc) is also an indication of better quality of water. However, the minor representation of the class Cyanophyceae (blue green algae like *Oscillatoria, Anabaena* and *Anacystis*), especially during and towards summer is a clear indication of nutrient enrichment of water in the river. These species are reported from areas near townships of considerable sewage discharge, and point out the weak eutrophic nature of river water.

3.6.2 Palmers Algal Genus Index

Palmer has prepared a list of algae tolerant to organic pollution and derived an index to evaluate the organic pollution status of the water. Palmer's modified algal genus index is calculated herein based on the genus identified from the Neyyar. The index values reported for various seasons are given in table 3.11. The seasonal variation in the index values is shown in Fig 3.14.

Table 3.11: Palmers Pollution Index Value

Sl. No.	Station Code	Index Value	
		Monsoon	Pre-monsoon
1	2/N	11	15
2	4/N	26	20
3	8/N	8	30
4	9/N	14	23
5	11/N	15	23
6	17/N	6	12
7	21/N	13	30
8	25/N	10	21
9	26/N	0	0

The index value shows an increasing trend towards summer. This indicates the increase in the organic content in the river due to the sewage inputs at various stretches along the course of the river. The identified spots where the aquatic flora and fauna face serious environmental stress are, Koompichal, Neyyatinkara and Poovar.

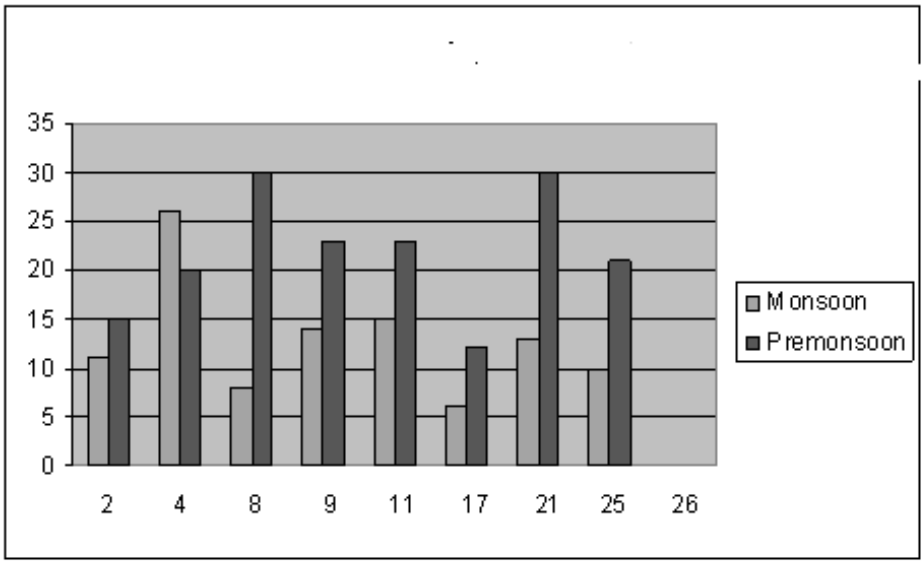


Fig. 3.14: Seasonal variation in Palmer's Algal Genius Index

3.7. SEDIMENT CHARACTERISTICS

Sediment quality of any aquatic environment could be a reliable indicator of the all over status and the long term impacts of water pollution. A total of 11 sediment samples were collected from different parts of Neyyar and analysed for the parameters such as pH, EC, Total hardness, Ca hardness, alkalinity, phosphate, sulphate, total organic carbon, Ca, Mg, Na, K and heavy metals like Fe, Mn, Cu, Pb, Ni and Cd. The maximum and minimum values are given in Table 3.12.

The pH of most of the upstream samples was acidic. However towards the down stream reaches, it became slightly alkaline at Poovar II (N/25), where it is 5.84. The concentration of EC was found to be very low in almost all the samples. But, the down stream stations like Poovar Pozhikara-I and II were having a slight high EC which is an estuarine area. Alkalinity is very high in the estuarine area and it is of the order of 400mg/kg. The chloride content of the sediment samples was comparatively very low except in the estuarine stretch.

Hardness is somewhat high in all the samples. The maximum value of 14800 mg/Kg was found at Amaravila Bridge (N/20). Obviously, the concentration of calcium (9600 mg/kg) and magnesium (1263 mg/kg) also was much high at this site. Rest of the stations have the concentration of these parameters was comparatively very low.

The phosphate concentration of the sample collected form Koompichalkadavu (N/04) is very high of the order of 2530 mg/kg. This may be due to the agricultural run off from the nearby rubber plantation.

Concentration of sulphate is comparatively low at all the stations, the maximum value being at Arumanoor (N/23).

Table 3.12: Chemical characteristics of sediment samples from Neyyar river

Parameters	Maximum	Minimum
pH	9.03	5.80
EC, microsiemens/cm	727.00	6.06
Alkalinity, mg/kg	400.00	40.00
Chloride, mg/kg	680.00	0.00
Total Hardness, mg/kg	14800.00	360.00
Calcium Hardness, mg/kg	9600.00	200.00
Calcium, mg/kg	3840.00	80.00
Magnesium, mg/kg	1458.00	19.44
Phosphate, mg/kg	2530.00	2.40
Sulphate, mg/kg	350.00	98.40
Total organic carbon,%/kg	6.30	0.00
Total Organic Matter,%/kg	10.86	0.00
Sodium, mg/kg	448.00	20.00
Potassium, mg/kg	126.00	18.00
Iron, mg/kg	1535792.50	102615.00
Manganese, mg/kg	244.00	12.00
Copper, mg/kg	32.00	1.00
Lead, mg/kg	90.80	1.50
Nickel, mg/kg	42.00	1.00
Cadmium, mg/kg	2.90	0.10

The percentage of total organic matter is high at Poovar Pozhikkara-II (N/26) and it is 10.86 mg/kg. This may be due to the decomposition of the plants nearby. Organic carbon also follows the same trend.

The parameters like sodium and potassium have somewhat low values in most of the samples. Sediment collected from Poovar Pozhikara II (N/26) has the highest value of sodium, namely 448 mg/kg. This is, of course, due to the nearness to the coast.

The sediments collected from the basin were also subjected to heavy metal analysis. Iron content of the sediments is much high in all the stations. This may be due to the geology of the area. The analysis highlights that the lead content of the sediments is somewhat high and the maximum concentration of 90.80mg/kg was found at Koompichalkadavu (N/04). Manganese is reported to be high at all the stations. Mn is found to be positively correlated with the concentration of iron. The high concentration of lead may be due to the dumping of used batteries by the local people. Heavy metals like nickel and cadmium were also detected in high concentration at all the stations. The maximum value of copper detected was 32 mg/kg at Neyyatinkara I (N/18) which is an urban area.

3.8: ASSESSMENT OF GROUNDWATER QUALITY OF NEYYAR BASIN

3.8.1: Survey to Ascertain Sanitation Facilities

The evaluation of the quality of ground water resources is also important in a river basin approach. A sanitary survey was conducted to understand the causative factors for contamination.

In the present study, samples were collected from 63 dug wells and 1 bore well; 83% of the wells have sufficient water throughout the year to meet the requirements. From the survey, it was found that about 75% of the wells are situated in agricultural lands. Mixed vegetation is practised around most of the wells. Rubber is a major agricultural crop present in most of the areas. Pesticides are used in 14% of these crops. Eighty per cent of the stations are situated near the Neyyar river or very close to some streams or other. Red and black soils are the major soil types present. Septic tanks are not in common use. Fifty seven per cent of the leach pits are situated within the prescribed safe distance from the well. But, 18% of the sampled wells are very close to the latrine. Most of them were chlorinated in the immediate past. It has been noted that 30% of the wells were not satisfying the hygienic conditions. Some of the wells are not used for drinking purpose. These are the people who depend on municipal water supply for drinking water which is drawn from the Neyyar basin. A few villagers use well water even though some aesthetic problems are reported. These areas do not have municipal water supply. The results of survey are presented in Fig 3.15 to 3.25.

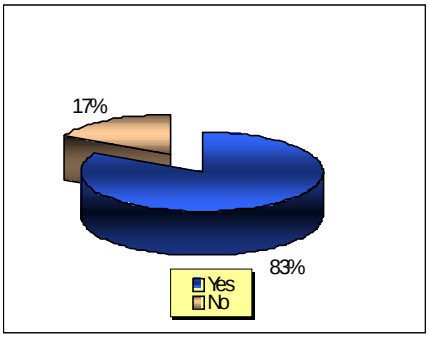


Fig. 3.15: Presence of water throughout the year

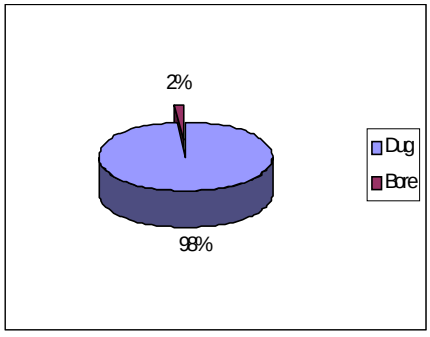


Fig. 3.16: Type of well

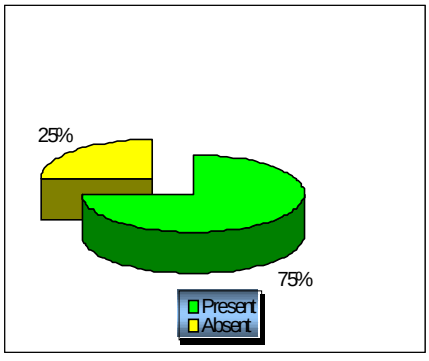


Fig. 3.17: Presence of agricultural crops

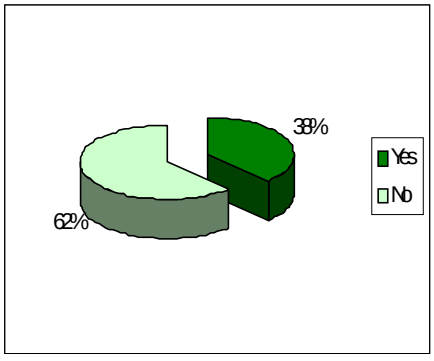


Fig. 3.18: Use of fertilizers

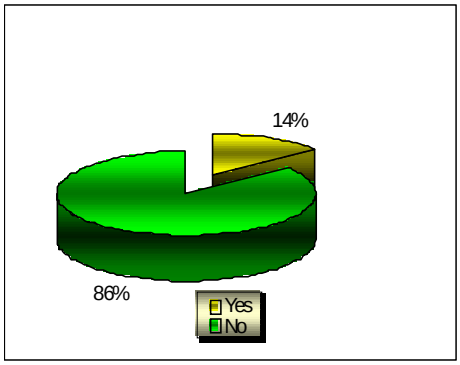


Fig. 3.19: Use of pesticides

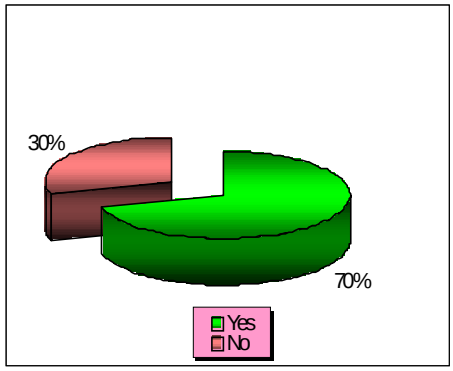


Fig. 3. 20: Cleanliness around the wells

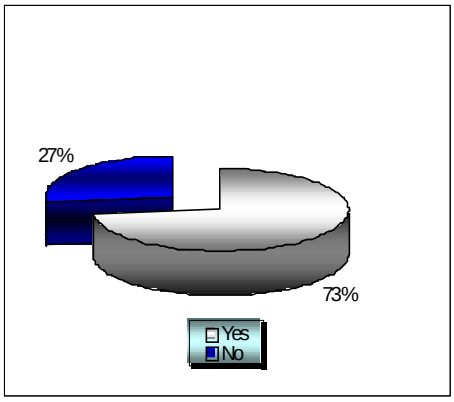


Fig. 3. 21: Disinfection practices

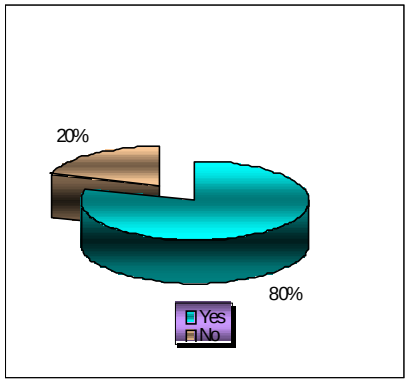


Fig. 3. 22: Presence of stream near the well

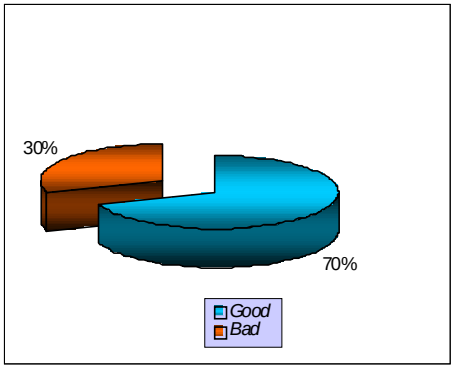


Fig. 3. 23: Aesthetic quality of water

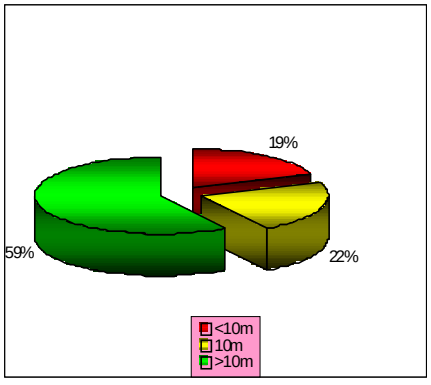


Fig. 3. 24: Distance of the latrine from the well

The details of the sampling stations which are selected for ground water monitoring are shown in the Table 3. 13. The locations are given in Fig 3.3.

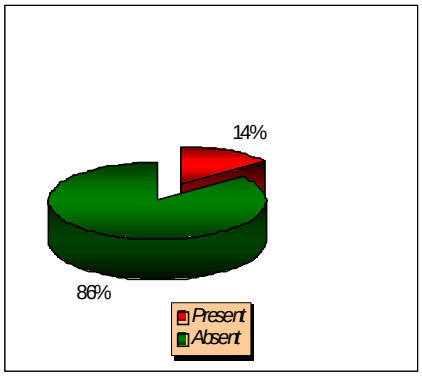


Fig. 3. 25: Presence of industry near the well

Table 3.13: Details of groundwater sampling locations, samples numbers and codes

Location Code	Panchayath / Municipality	Number of Samples Collected	Sample Code
NRG01	Neyyattinkara (Municipality)	8	01-07 & 49
NRG02	Chenkal	4	11-Aug
NRG03	Kulathoor	4	15-Dec
NRG04	Poovar	5	16-19 & 24
NRG05	Thirupuram	4	20-23
NRG06	Amboori	4	25-28
NRG07	Vellarada	4	29-32
NRG08	Kallikkadu	4	33-36
NRG09	Ottasekharamangalam	4	37-40
NRG10	Aryancodu	4	41-44
NRG11	Perumkadavila	4	45-48
NRG12	Maranalloor	4	50-53
NRG13	Kaattakkada	4	54-57
NRG14	Poovachal	4	58-61
NRG15	Athiyannur	3	62-64

3.8.2 Physico-chemical and Bacteriological Analysis

The maximum and minimum concentration of different parameters for the groundwater samples collected in pre-monsoon, monsoon and post-monsoon are given in tables 3.14 to 3.16.

Table 3.14: Maximum and minimum values of ground water samples (Pre-monsoon 2007)

Parameters	Maximum	Minimum
pH	6.76	3.96
EC,µs/cm	2420	47.7
Salinity,(ppt)	0.8	0.1
Colour ,Hazen	71	1
Turbidity, NTU	59.06767	ND
TDS, mg/L	1548.8	30.528
Alkalinity, mg/L	302	6
Total Hardness, mg/L	538	6
Calcium Hardness, mg/L	322	4
Calcium ,mg/L	128.8	1.6
Magnesium, mg/L	52.488	ND
Sodium, mg/L	282	6.6
Potassium, mg/L	62	0.2
Iron, mg/L	0.319	ND
Chloride, mg/L	504	16
sulfate, mg/L	98	0.08
Nitrate, mg/L	13.8	0.01
Phosphate, µg/L	80	ND

The hydrogen ion concentration is one of the most important parameters for ascertaining the quality of water. The present study indicates that most of the samples were acidic in nature, 54 samples during the post-monsoon, 59 samples during the pre-monsoon and 61 samples during the monsoon had pH values below 6.5 (Fig 3.26). The high acidic nature of ground water indicates the high degree of inorganic contamination.

The total dissolved solids of eight sites (two samples from Neyyattinkara Municipality, one from Chenkal, two from Poovar, one from Kallikkadu, one from Kaattakkada and one from Athiyannur) during the post-monsoon, six samples (Neyyattinkara Muncipality, Poovar and Kaattakada), during the pre-monsoon and six samples (Neyyattinkara Municipality, Poovar,

Table 3.15: Maximum and minimum values of ground water samples (Monsoon - 2007)

Parameters	Maximum	Minimum
pH	6.89	4.14
EC,microsiemen	1981	37.6
Salinity,(ppt)	0.7	0.1
Colour ,Hazen	42	ND
Turbidity,NTU	36	ND
TDS,mg/L	1267.84	24.064
Alkalinity,mg/L	324	8
Total Hardness,mg/L	368	8
Calcium Hardness,mg/L	224	4
Calcium ,mg/L	89.6	1.6
Magnesium,mg/L	34.992	0
Sodium,mg/L	284	4.8
Potassium,mg/L	82	0.3
Iron,mg/L	0.909	ND
Chloride,mg/L	312	12
sulfate, Mg/L	108.4	0.12
Nitrate,mg/L	30	0.16
Phosphate,mg/L	355	ND

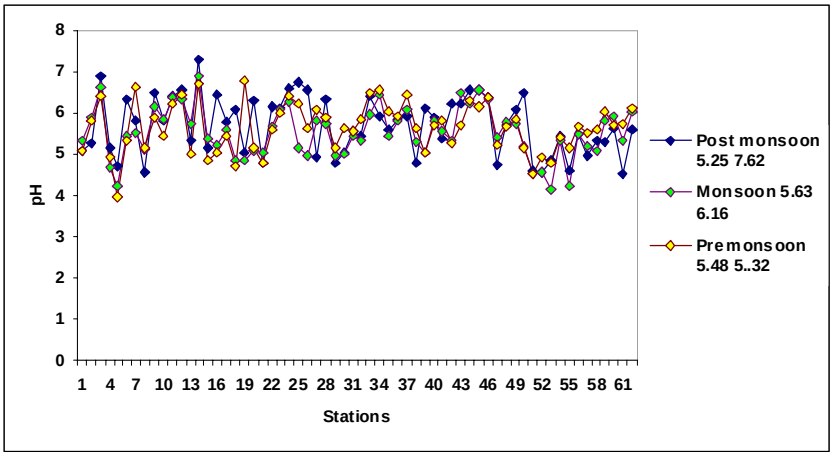


Fig. 3. 26: pH of different wells

Table 3.16: Maximum and minimum values of ground water samples (Post-monsoon 2007)

Parameters	maximum	minimum
pH	7.62	4.53
EC,microsiemen	1393	37
Salinity,(ppt)	0.6	ND
Colour ,Hazen	190	ND
Turbidity,NTU	79	ND
TDS,mg/L	891.52	23.68
Alkalinity,mg/L	216	16
Total Hardness,mg/L	252	16
Calcium Hardness,mg/L	180	4
Calcium ,mg/L	72	1.6
Magnesium,mg/L	26.244	1.944
Sodium,mg/L	208	4.4
Potassium,mg/L	130	0.4
Iron,mg/L	0.58	0.01
Chloride,mg/L	422.35	27.54
sulfate, Mg/L	180	0.12
Nitrate,mg/L	36	ND
Phosphate,mg/L	0.99	ND

Kaattakkada, Kallikkadu and Ottasekharamangalam) during monsoon seasons had TDS >500mg/l. The electrical conductivity of the same samples was also very high. The TDS values of the wells are depicted in Fig 3.27.

A maximum value of salinity (0.8 ppt) was reported for a pre-monsoon sample collected from Poovar. Being a coastal area, salinity intrusion may be a possible reason for the high salinity.

Sample from Athiyannur (No.64) had the highest value for colour during the post-monsoon and pre-monsoon. The high colour may be due to the geological conditions of the area. But, in the monsoon season, sample collected from Amboori (No.26) had maximum value of 42 Hazen.

Turbidity follows the same trend as colour. Maximum value was reported during the post-monsoon and the pre-monsoon seasons for Athiyannur (No.64). But, during the monsoon season, Amboori (No.26) showed the highest value.

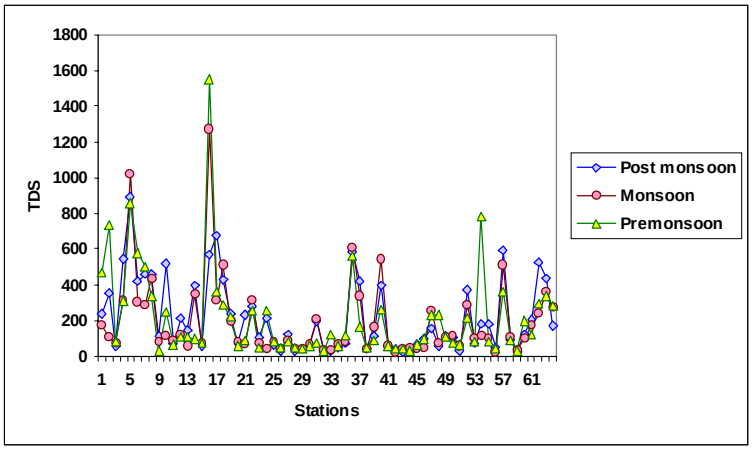


Fig. 3. 27: TDS of different wells

The maximum alkalinity value was reported for sample No: 16 (324 mg/l) during the monsoon season. The possible reason may be salinity intrusion. This sample also reported the maximum concentration during the pre-monsoon (302mg/l). Total alkalinity has an average concentration of 51.81mg/l during the post -monsoon, 30.22 mg/l during the pre-monsoon and 34.56 mg/l during the monsoon. The values reported for various samples are presented in Fig 3.28.

The average concentration of total hardness is 54.06 mg/l during the post-monsoon, 40.40 mg/l for the pre-monsoon and 43.38 mg/l for the monsoon. The maximum concentration was observed for sample No: 16 during the pre-monsoon (538 mg/l). It indicates the presence of high concentration of Ca and Mg ions in this aquifer. The hardness of all other samples during the post-monsoon is within the permissible limit. But, during the pre-monsoon and monsoon seasons, only one sample, sample No: 16 exceeded the permissible limit (Fig 3.29).

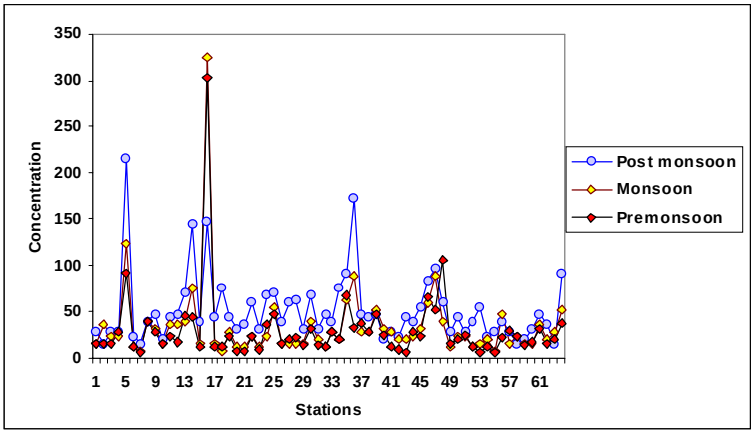


Fig. 3.28: Alkalinity of different wells

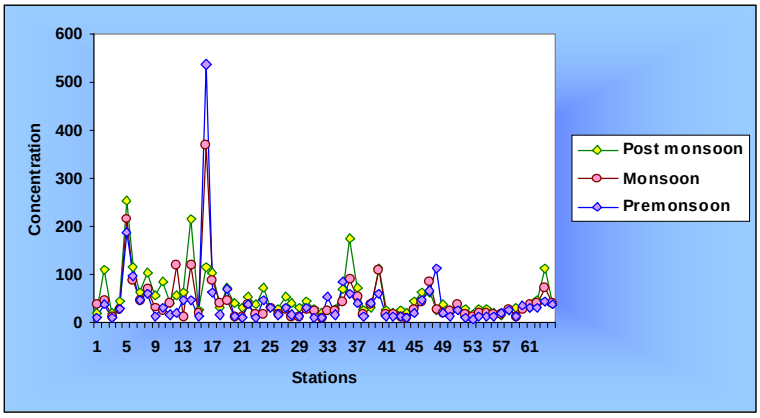


Fig. 3.29: Total Hardness of various wells

The concentration of ions like Ca and Mg were relatively high. The concentration was within the limit during the post-monsoon. The concentration was found to be beyond the limit during the monsoon and the pre-monsoon seasons for sample No: 16.

Sodium concentration has an average value of 48.41mg/l during the post-monsoon, 38.51mg/l during the pre-monsoon and 43.36mg/l during the monsoon. During the monsoon season, the maximum value was reported for the sample collected from the station No. 16 (284mg/l). Two stations viz, No.5 (Neyyattinkara Municipality) and No. 16 (Poovar) had the concentration above 200mg/l during this season. But, during the pre-monsoon sample, only No. 16 reported high concentration (282mg/l).

In the case of potassium, during the post-monsoon season, a few samples reported the concentration above 100mg/l, ie, sample No. 5 (Neyyattinkara-105mg/l), and No: 36 (Kallikkadu-136mg/l). It ranged from 0.4mg/l to 136mg/l.

The maximum concentration of iron (0.99mg/l) was reported for sample No. 64 (Athiyannur) during the monsoon season. This may be due to the characteristic property of the soil. During the pre-monsoon, the concentration was within the limit for all the samples. In the post-monsoon season, one sample reported iron content above the limit; 0.58mg/l sample No: 64.

Chloride concentration is relatively high during the three seasons. The maximum concentration was observed during the pre-monsoon, 504 mg/l in sample No. 16 (Athiyannur). Concentration of Cl^- in all other samples during the pre-monsoon was within the permissible limit. During monsoon season also the sample No. 16 had the concentration above the limit, 312mg/l. During the post-monsoon, the average concentration was found to be 0.09mg/l. The maximum concentration was reported for sample No. 17 (Poovar), 422.35mg/l. The chloride concentration in sample No. 62 (Athiyannur) was also beyond the limit, 367.26 mg/l. The concentration ranges from 27.54 mg/l to 422.35 mg/l Perumkadavila. The seawater intrusion may be the reason for the high concentration of chloride. Domestic effluent can also contribute to high chloride concentration.

The concentration of sulphate during all the seasons was found to be within the permissible limit prescribed by BIS. It has a maximum value of average concentration of 14.55 mg/l during the post-monsoon season.

Nitrate-N was not detected in some of the samples during the post-monsoon season. But, six samples showed nitrate beyond the limit, sample No. 23 Thirupuram-26mg/l, No. 36 Kallikkadu-10.5, Nos. 37 and 40 Ottasekharamangalam-36 mg/l, Nos. 62 and 63 -Athiyannoor-11mg/l and 25 mg/l. The high concentration may be due to the leaching from the drainage or due to the cesspool or improper sanitation. Sample No. 40 had reported the highest concentration of Nitrate-N. This may be due to the leaching from the drainage just 2 m away from the well. In the case of sample No.36, the well is surrounded by 3 leache pit latrines, which are at a distance of 6m, 8m and 4m. With regard to sample No. 23, a leach pit is present 6m away from the well. At the same time, only in two samples the concentration was observed beyond the limit during the pre-monsoon. This may be due to the heavy mid-summer rain which might have caused the dilution of the ion content in the wells. During the monsoon season, 4 samples, ie, samples from Neyyatinkara Municipality (sample No. 2- 10.3mg/l, sample No. 4-12.6mg/l and sample No. 49-12.6mg/l) and Athiyannur Panchayath (sample No.63-15.2) have the concentration beyond the limit. The distribution of nitrate in various wells is shown in Fig 3.30.

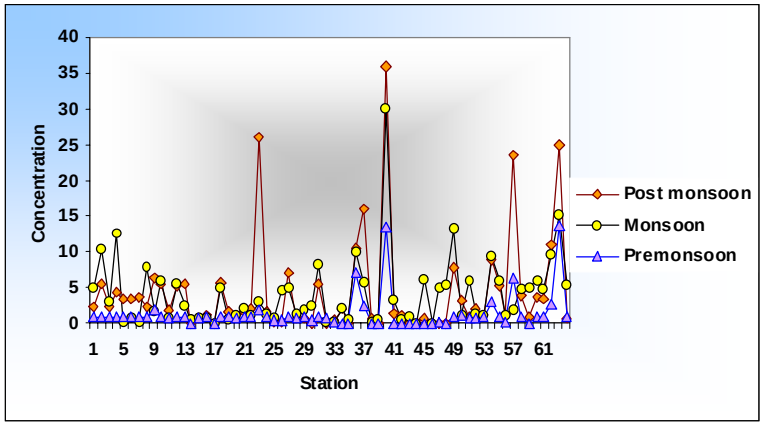


Fig. 3.30: NO3 - N Concentration in various wells

Phosphate concentration of all the samples during the post-monsoon was very less except in sample No. 27(Amboori). This sample had shown 0.99mg/l phosphate. This may be due to the leaching from the cow dung pit of a farm present near the well. The maximum concentration during the pre-monsoon is 0.08 mg/l (Athiyannur). The average value of phosphate during monsoon was 0.043mg/l.

3.8.3 Bacteriological Analysis

Coliform group of bacteria is an indicator species of pollution in water bodies. From the results of the bacteriological analysis of the present study, it is clear that most of the samples were contaminated with the presence of E.coli.

3.8.4 Correlation Matrix

The relationship between the various physicochemical characteristics of water samples have been analyzed statistically by using Correlation Matrix during the three seasons.

3.8.4.1 Post-monsoon (2006)

The pairs of parameters which showed positive correlation are : alkalinity-pH; salinity-EC; total hardness-EC; calcium-EC; Mg-EC; Na-EC; K-EC; chloride-EC; sulphate-EC; TDS- salinity; Na- salinity; Cl^- salinity; color-turbidity; color-Fe; turbidity-Fe; hardness-TDS; Mg-TDS; Na-TDS; Cl^- TDS; total hardness -Ca hardness; total hardness- Mg; Na- Cl^-; total hardness-SO_4^{2-}; Ca-Mg; total coliform- faecal coliform.

The pair of parameters which showed negative correlation is pH-NO_3.The pares which showed moderate positive correlation are : pH-Ca; EC-NO_3; salinity- alkalinity; salinity-K; TDS-SO_4^{2-}; TDS-NO_3^-; TDS-Ca; TDS-K; alkalinity-SO_4^{2-}; alkalinity-K; alkalinity- Mg; total hardness-Na; total hardness-Cl^-; Na-K; Mg-SO_4^{2-}; Na- SO_4^{2-} ; Cl^-- SO_4^{2-}.

3.8.4.2 Pre-monsoon-2007

During the pre-monsoon season, the ions which can be positively correlated with each other are: Na with Cl^- ; TDS with Ec. Likewise Ec can be correlated with Cl^- and Na. Ca can be correlated with Na. Mg can be correlated with Cl^-; Na with TDS,EC with Ca. Cl^- can be correlated with Na, TDS, Ec, Ca and Mg. Finally, the parameter SO_4^{2-} can be positively correlated with Cl^-, Na, TDS, Ec, Ca, Cl^- and Mg.

3.8.4.3 Monsoon- 2007

During the monsoon-07, the pairs which can be positively correlated with each other are : Na- Cl ; Na-TDS ; Na- EC ; Na-K ; TDS-EC ; EC- Cl ; K –TDS ; K-EC ; Ca-Cl ; Ca-Na ; Ca-TDS ; Ca-EC ; Ca-K ; Mg-Na ; Mg-Cl ; Mg-TDS ; Mg-EC ; Mg-Ca ; Mg-Cl ; SO_4-Cl ;SO_4-Na ; SO_4-TDS ; SO_4-EC ; SO_4-K ; SO_4-Na ; SO_4-Ca and SO_4-Mg

3.8.5 Groundwater Types

The groundwater can be classified into various types based on the dominant cations and anions present. This classification can be plotted in a trilinear or piper diagram. On this diagram, the relative concentrations of major ions in percent meq /l are plotted on cation and anion triangles, and then the locations.

The groundwater samples collected from the Neyyar river basin were classified into various water types using the Aquachem Software. The piper diagram showing the water types is presented in the Fig. 3.31 and 3.32.

According to this classification the dominating ions in the groundwater samples of Neyyar basin are Na and Cl. Thus, about 38% of the groundwater during post- monsoon, 40% during the pre-monsoon and 30% during the monsoon comes under Na-Cl water type.

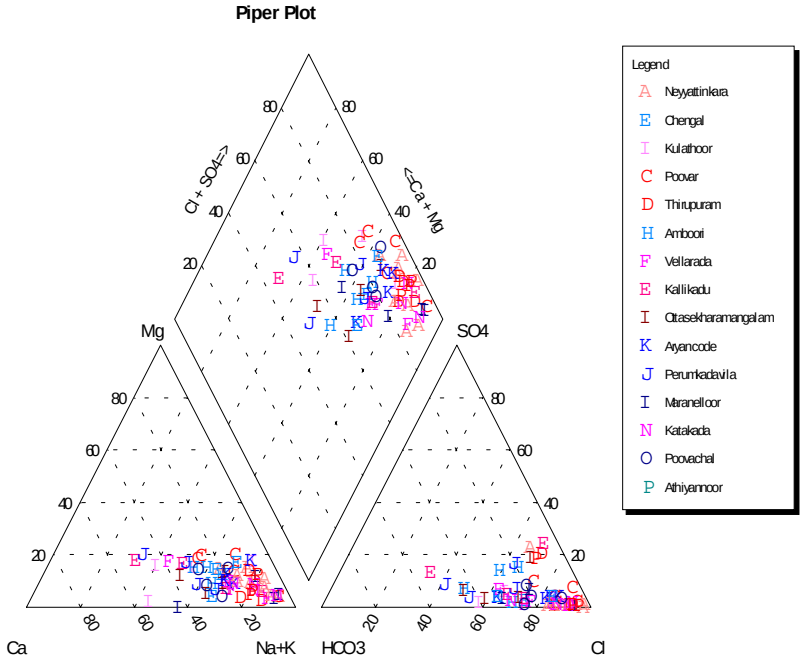


Fig. 3.31 : Piper diagram showing water types (Pre-monsoon- 07)

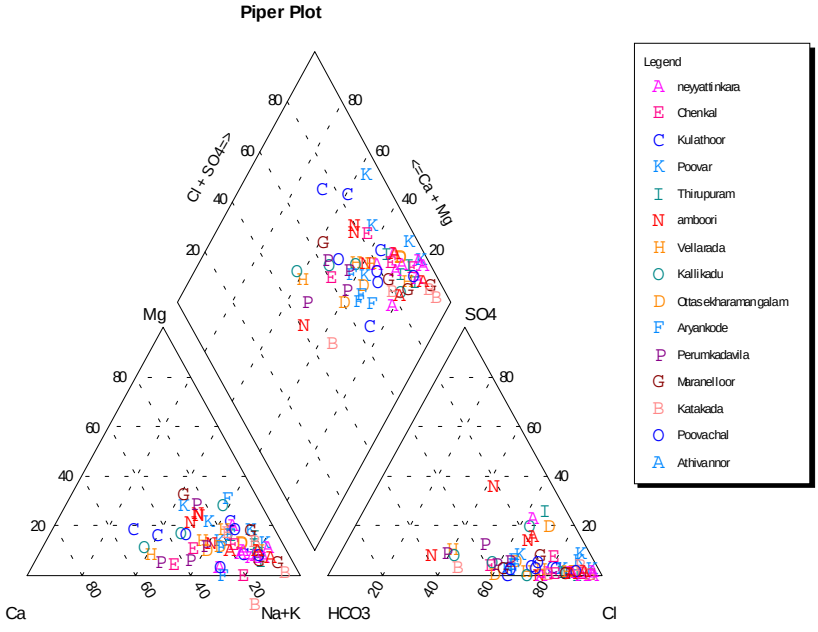


Fig. 3.32: Piper diagram showing water types (monsoon- 07)

3.9. CONCLUSION

The study of surface water quality in the Neyyar river based on water samples collected from the river course has shown that the downstream stations are affected by the problem of salinity intrusion. Also, the stations at Koompichal, Pantha, Spillway, Perinjamkadavu and Mylakkara are contaminated with high concentrations of iron during the pre-monsoon. Most of the samples are microbially contaminated, especially with the presence of E.Coli. Faecal contamination is also an associated problem of the river. Another striking point is the acidity in the river water during the post-monsoon season.

From the study based on groundwater samples, it is revealed that, the quality of most of the samples is very poor. The quality varies with the season. The acidity shown by most of the groundwater samples is one of the major quality problems seen in the Neyyar basin. The acidic nature of the water remains as such throughout the year. Considering the other physico-chemical parameters, the areas groundwater quality problems are: Neyyattinkara Municipality, Chenkal, Kulathoor, Poovar, Thirupuram, Amboori, Kallikkadu, Ottasekharamangalam, Kaattakkada, Poovachal and Athiyannur. Of these, Well No.5 from Neyyattinkara Municipality is the most contaminated during the post-monsoon. Well No. 16, Poovar has worst water quality during the pre-monsoon and monsoon seasons. Out of the 64 samples, only three samples had all the parameters within the prescribed limit of BIS during the post-monsoon and the pre-monsoon seasons. But, during the monsoon season, only one sample had all the parameters within the limit, i.e. from the bore well located at Perunkadavila. Even though most of the samples were found to be good in its physico-chemical characteristics, these were considerably contaminated with coliforms. About 95% of the ground water samples collected during the post-monsoon and the pre-monsoon and 98% collected during the monsoon were found to be unsuitable for drinking as per BIS standards. Considering together the physico-chemical and bacteriological features, none of the samples were found to be fit for drinking purpose without treatment.

The classification of groundwater using Aquachem Software reveals that Na-Cl water type is dominating in the Neyyar basin. The geology of the area can contribute to the presence of ions like Na and Cl in the groundwater.

The study reveals that the quality of the surface and groundwater resources of the Neyyar river basin is going down mainly due to anthropogenic activities, improper sanitation, and physiological factors like salinity intrusion.

Based on the biological monitoring, it can be concluded that the Neyyar river has considerable threat from sewage and other domestic wastes. The organic load in the river bed is high, several canals and streams carry the sewage into the river. Some potent pollution indicators like *Chironomus*, *Tubifex* and other Oligochaetan worms are reported in the river bed near Neyyatinkara Township and also at Poovar where the river enters the Lakshadweep Sea. The abundant presence of diatom species like *Melosira*, *Cyclotella* and *Synedra* indicates that the water is devoid of any chemical pollutants like those from untreated industrial effluents. However, presence of species like *Nitzschia* and *Navicula* indicates deterioration in water quality due to organic contamination. The identified spots where the aquatic flora and fauna face serious environmental stress are, Koombichal, Neyyatinkara and Poovar.