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

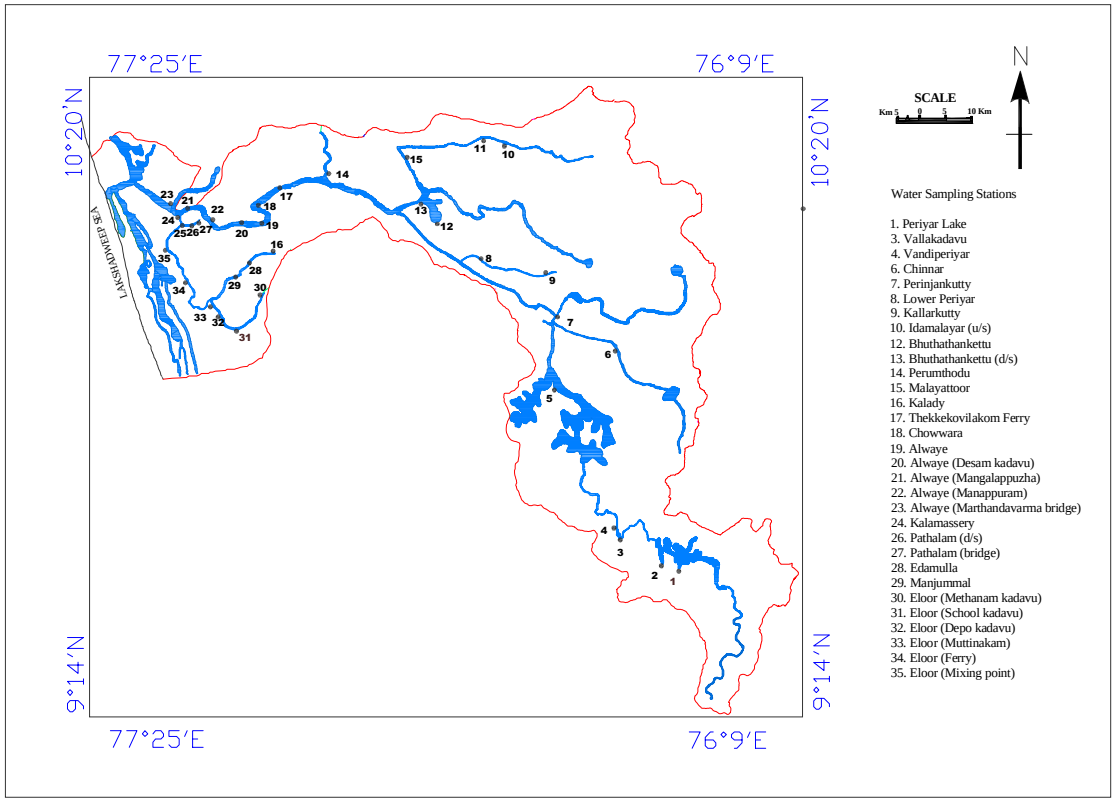


Fig. 2.1: Surface water sampling stations along Periyar river basin

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

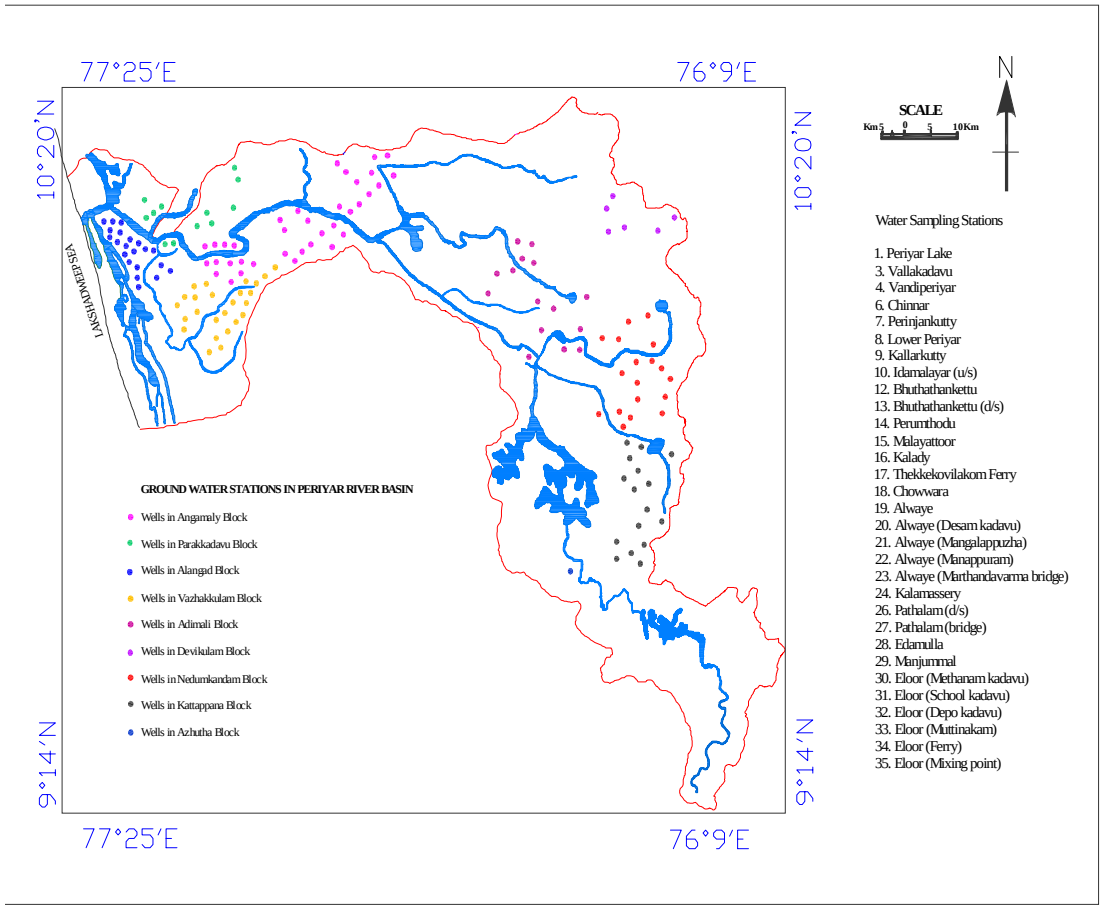


Fig. 2.2: Groundwater sampling stations along Periyar river basin

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

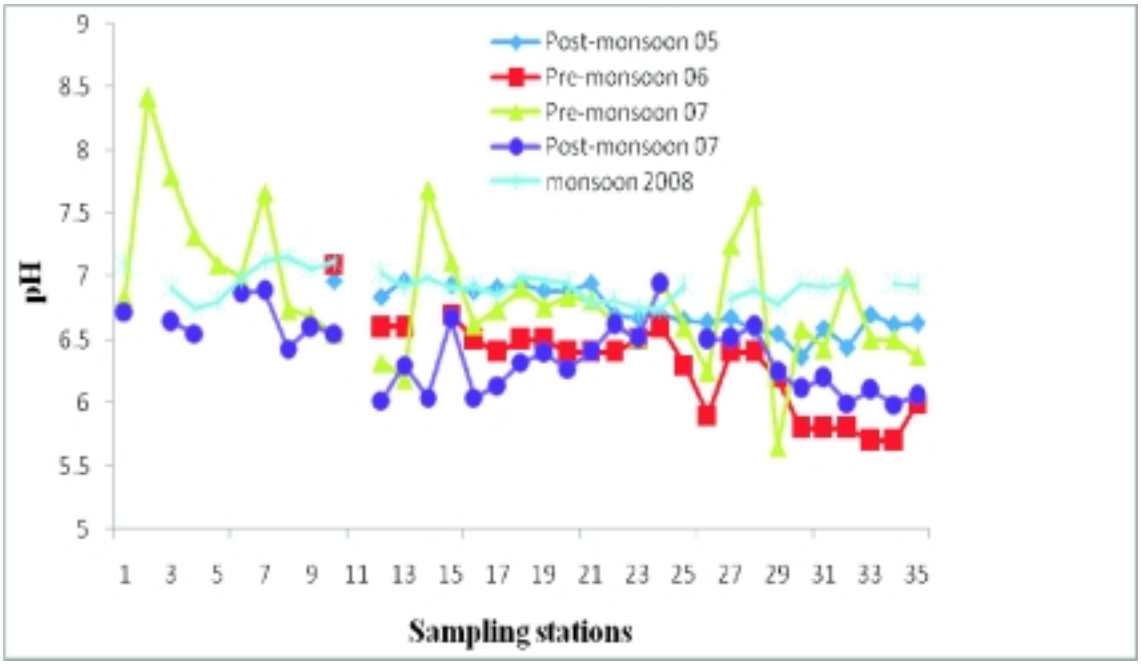


Fig 2.3: Variation in pH at various stations of Periyar river

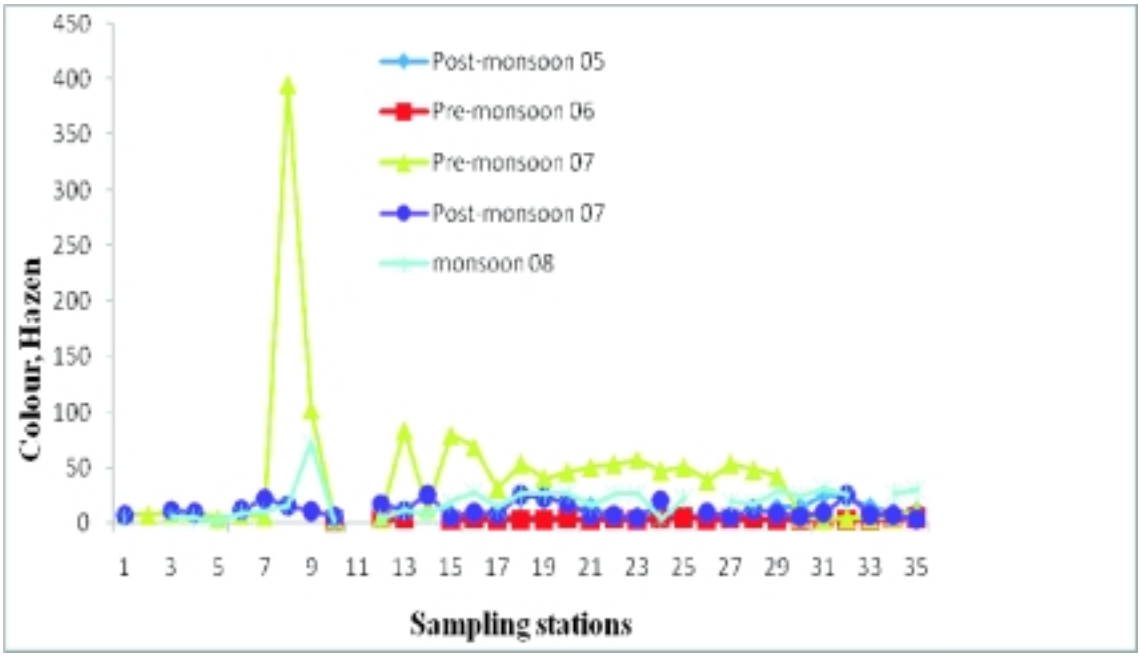


Fig 2.4: Variation of colour at various stations of Periyar river

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

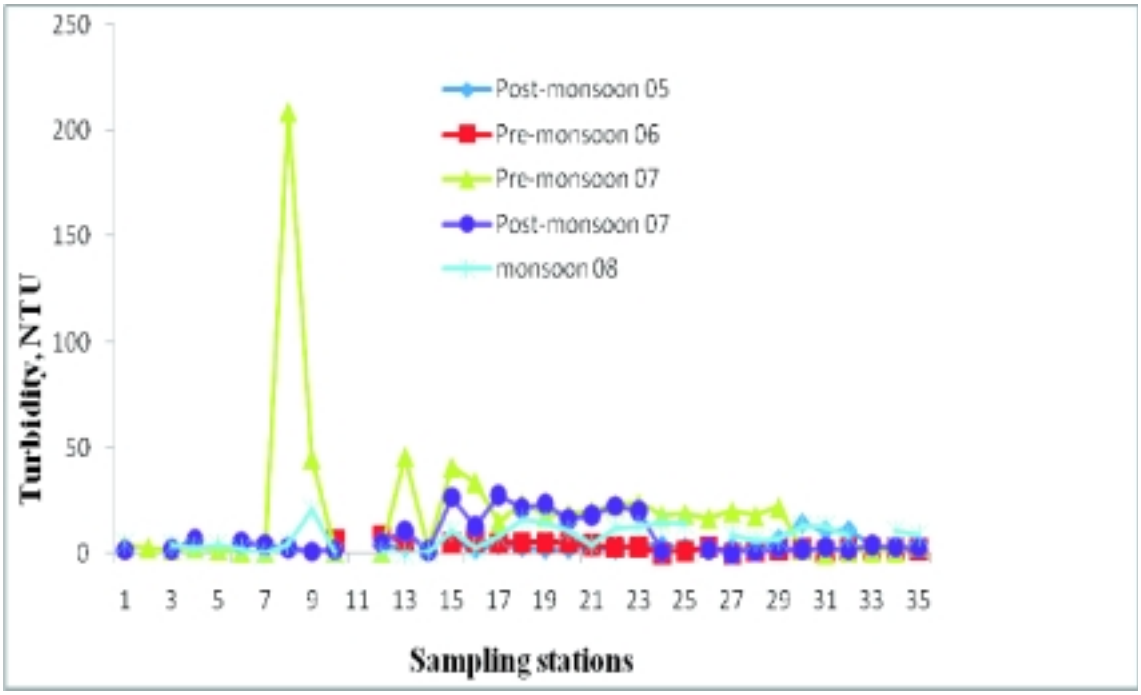
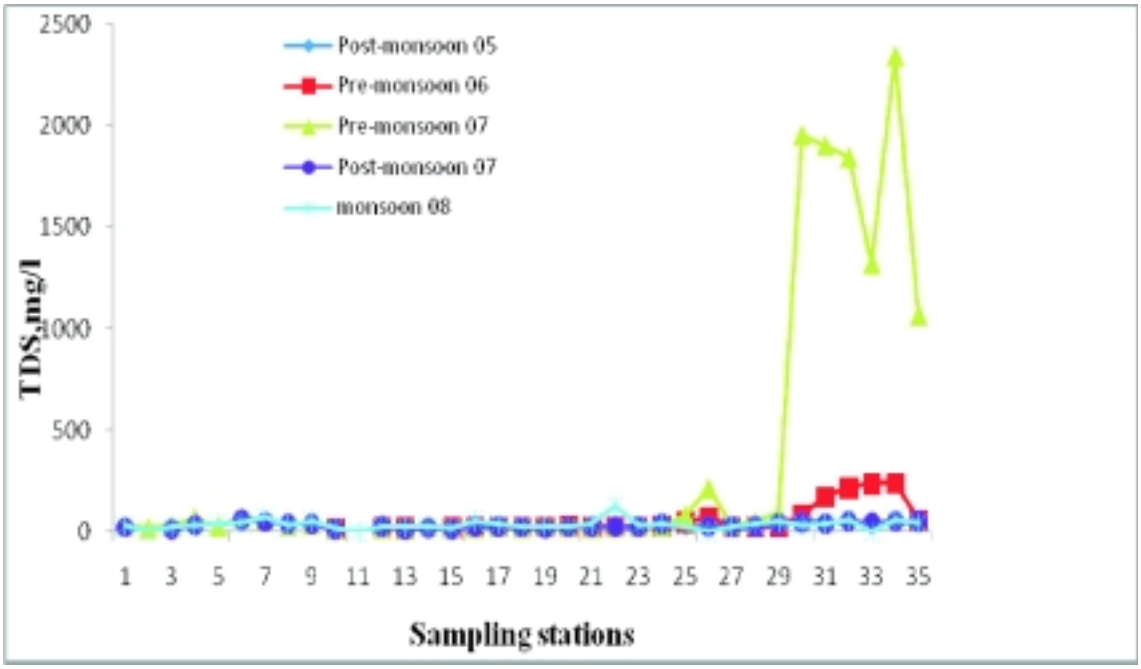


Fig 2.5: Variation of turbidity at various stations of Periyar river



2.6: Variation of TDS at various stations of Periyar river

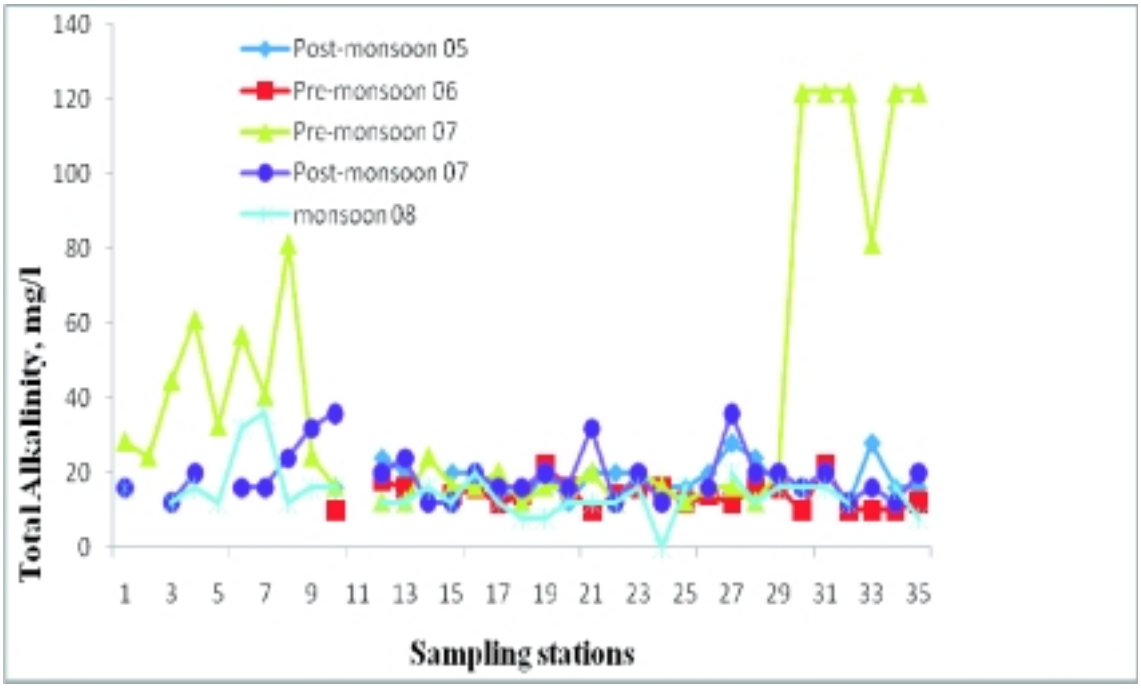


Fig 2.7: Variation of total alkalinity at various stations of Periyar river

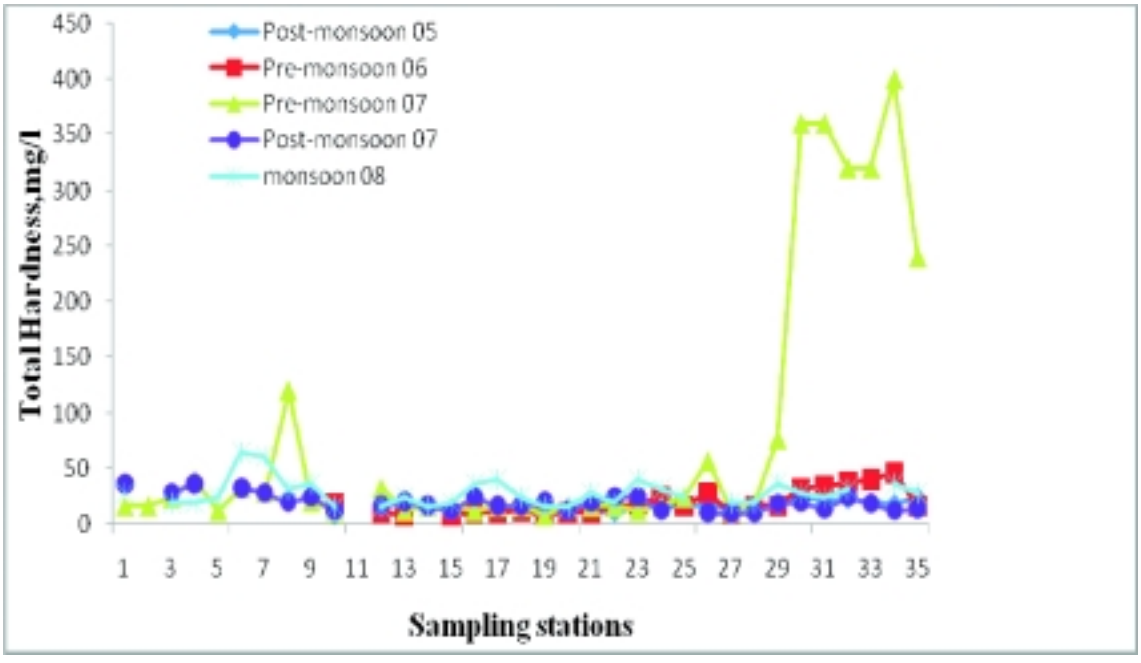


Fig 2.8: Variation of total hardness at various stations of Periyar river

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.

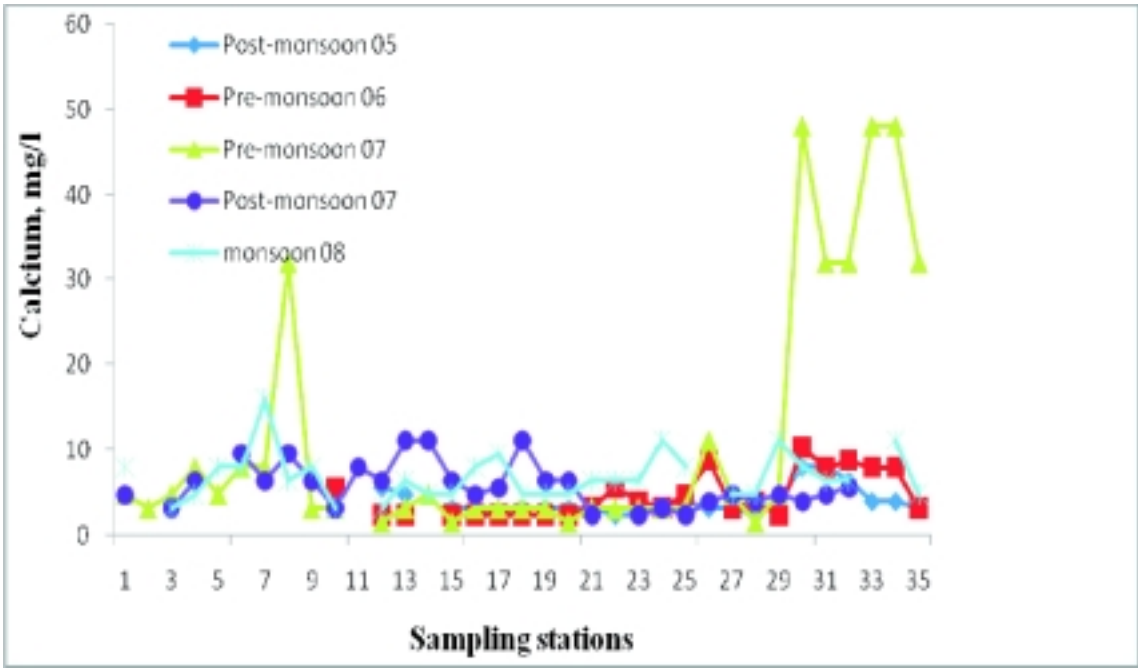


Fig 2.9: Variation of calcium at various stations of Periyar river

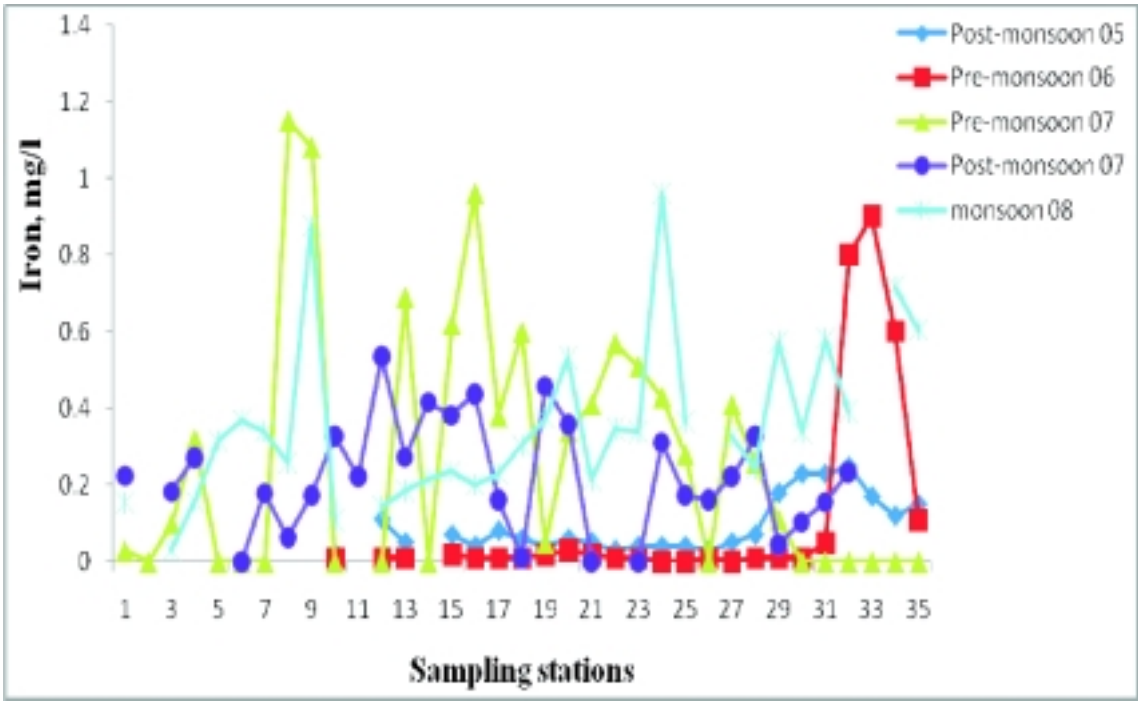


Fig 2.10: Variation of iron at various stations of Periyar river

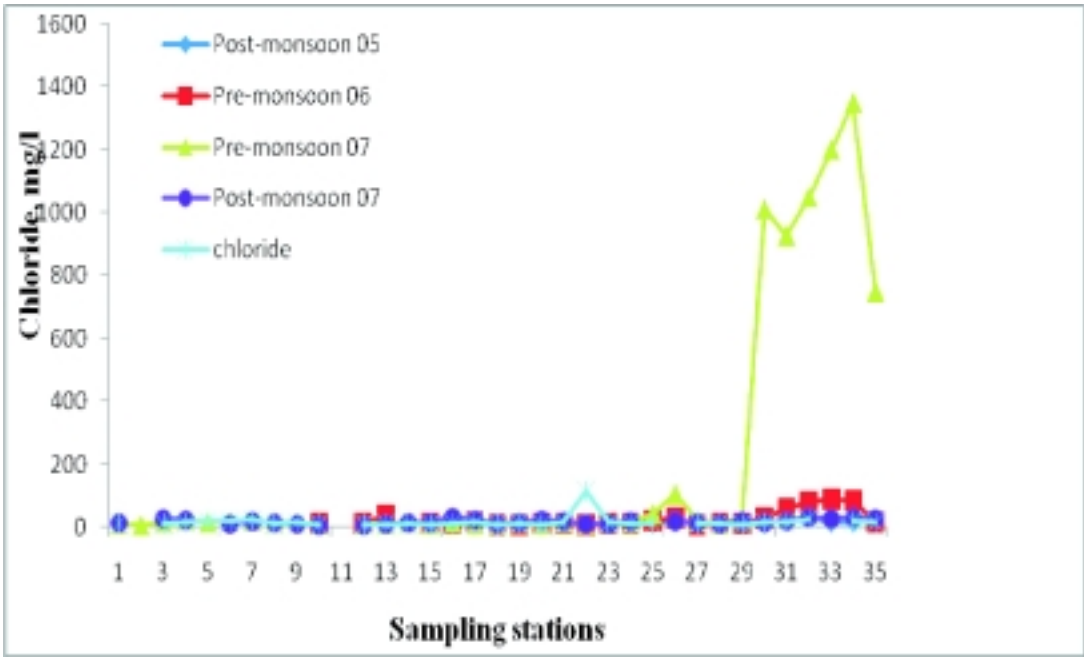


Fig 2.11: Variation of chloride at various stations of Periyar river

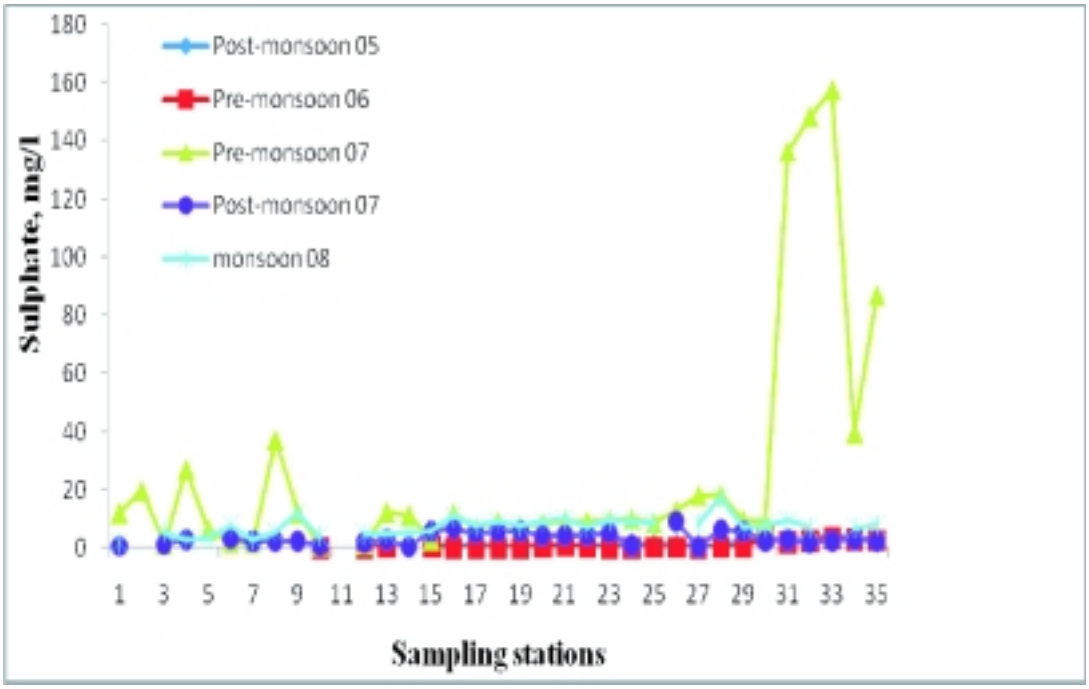


Fig 2.12: Variation of sulphate at various stations of Periyar river

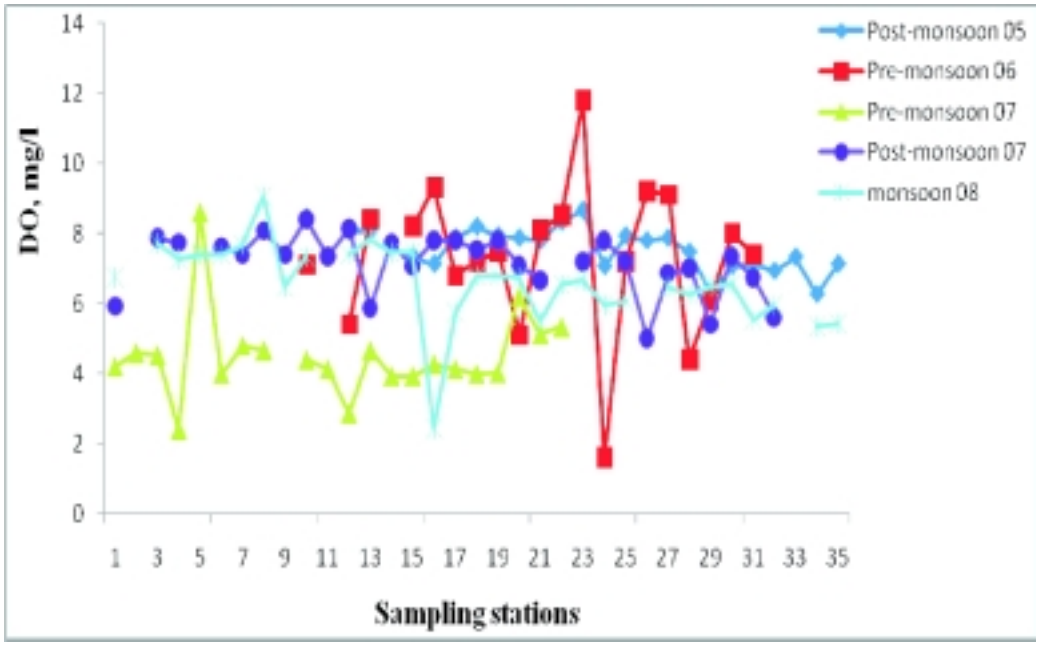


Fig 2.13: Variation of DO at various stations of Periyar river

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.

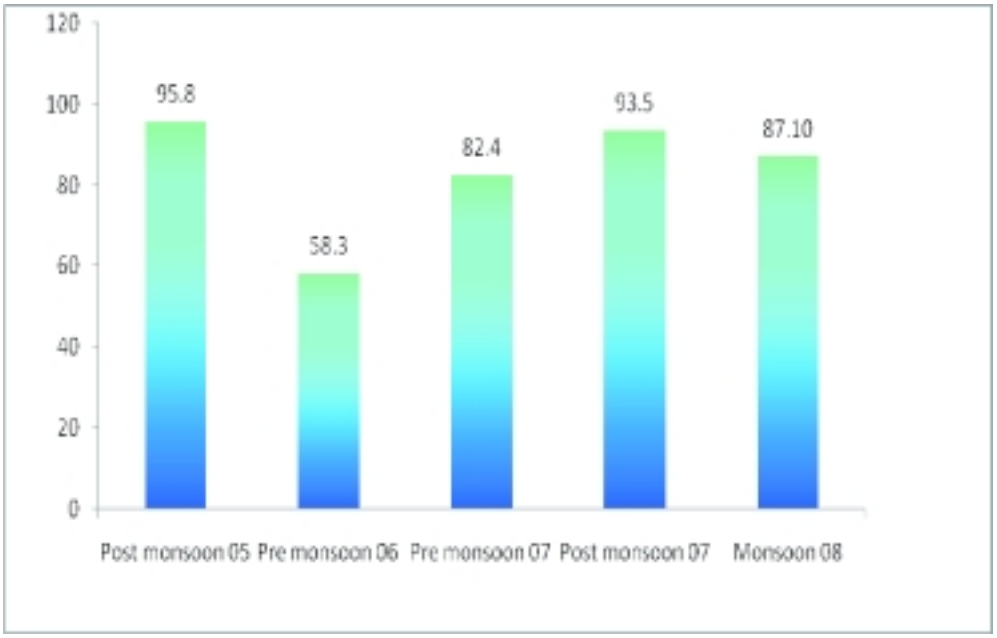


Fig 2.14: Percentage of samples tested positive for the presence of E.coli

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.

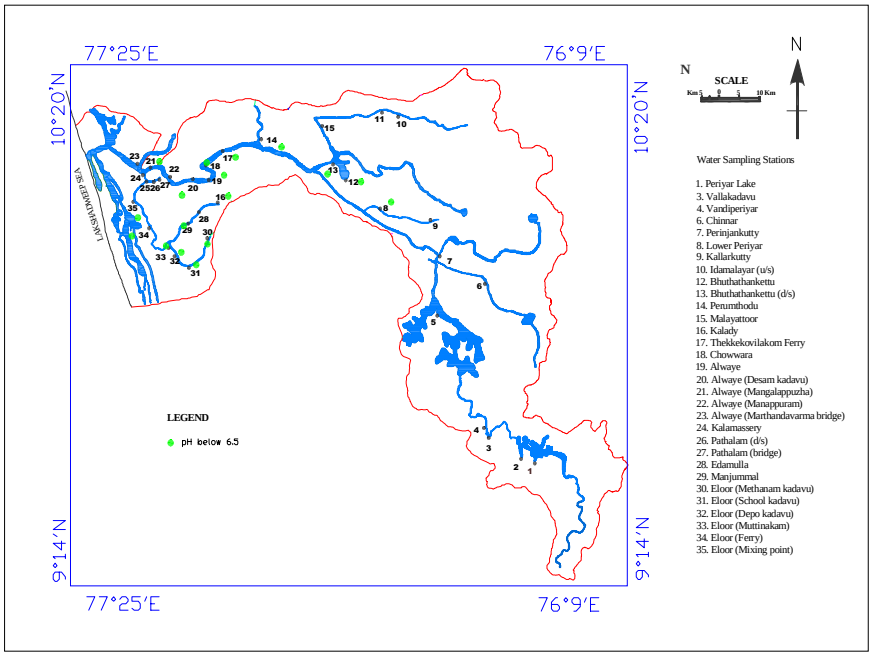


Fig 2.15: Spatial variation of pH along Periyar river (pre-monsoon 2007)

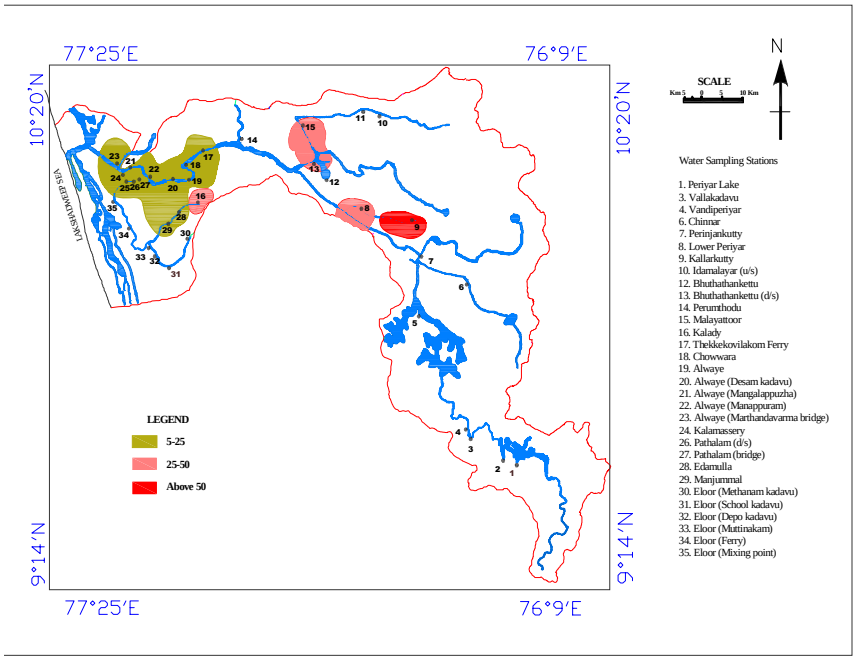


Fig 2.16: Change in colour at different stations in Periyar river during (Pre-monsoon 2007)

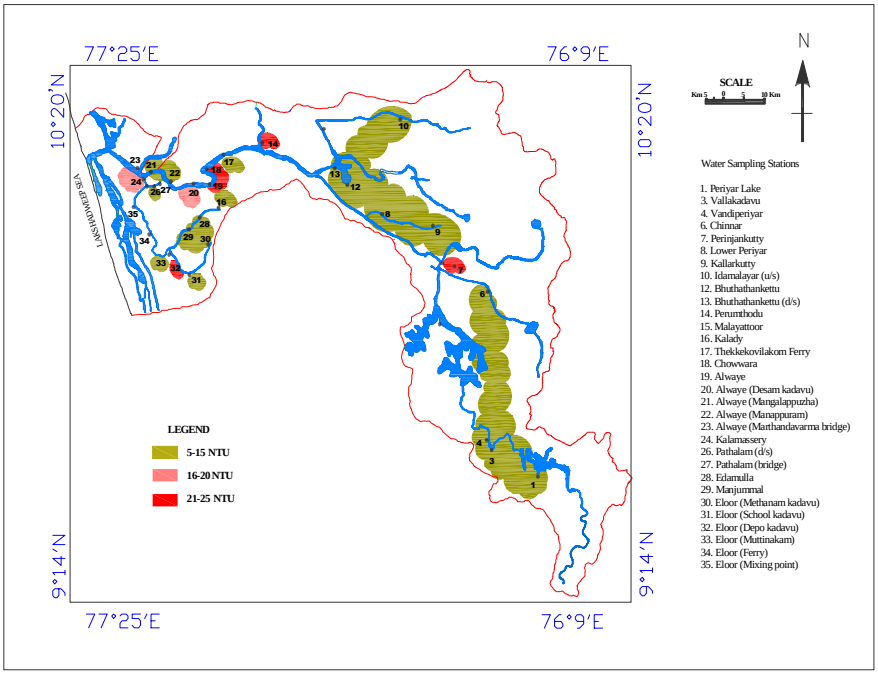


Fig. 2.17: Spatial variation of turbidity along Periyar river (pre-monsoon 2007)

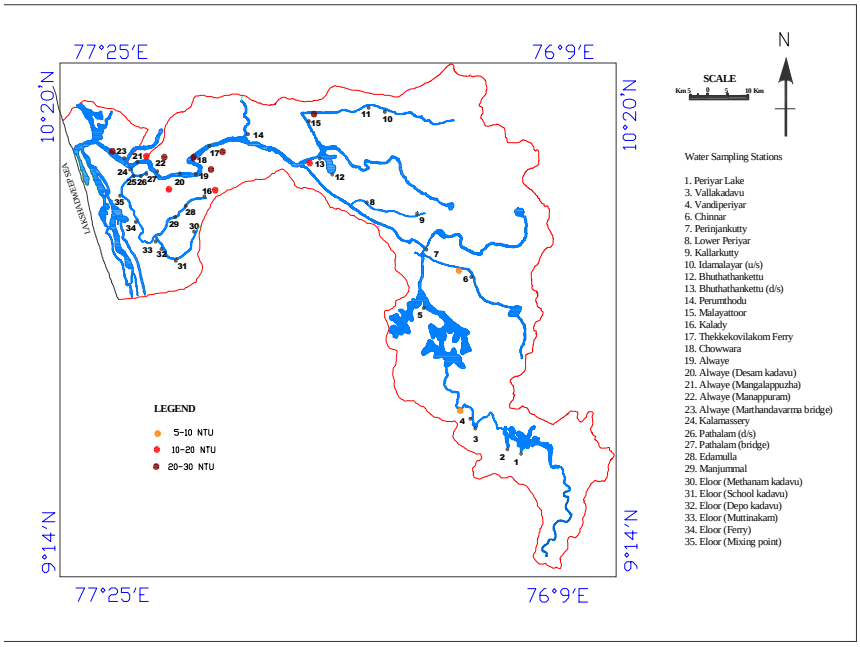


Fig. 2.18: Spatial variation of turbidity along Periyar river (post-monsoon-2007)

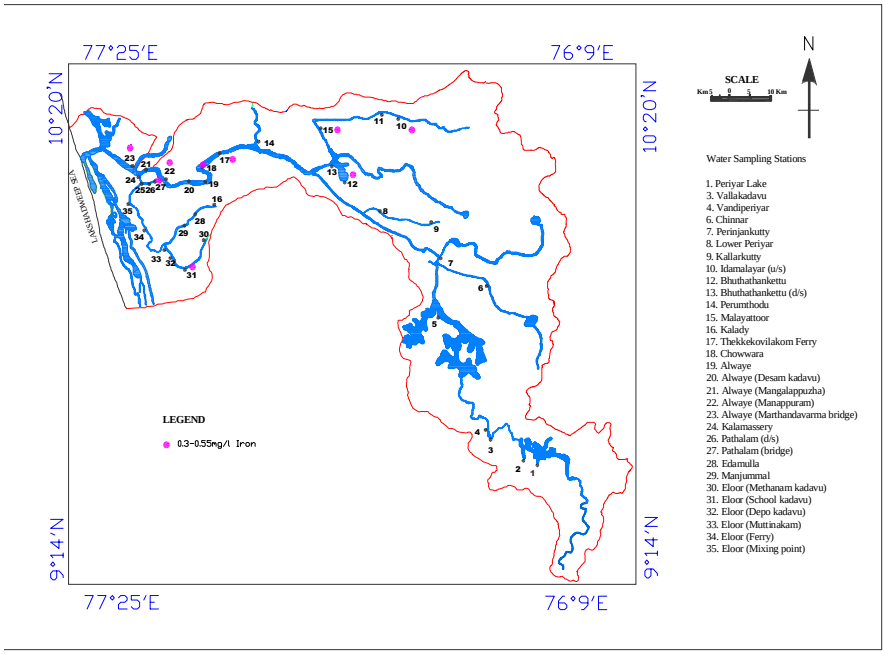


Fig. 2.19: Iron concentration at different stations in Periyar river (pre-monsoon 2007)

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

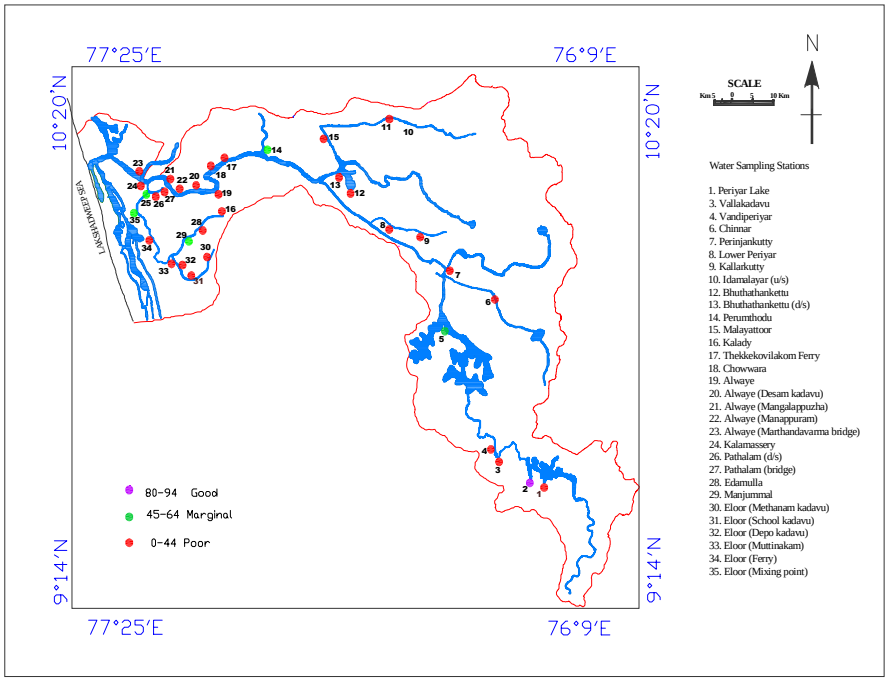


Fig 2.21: CCME WQI for Periyar river

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

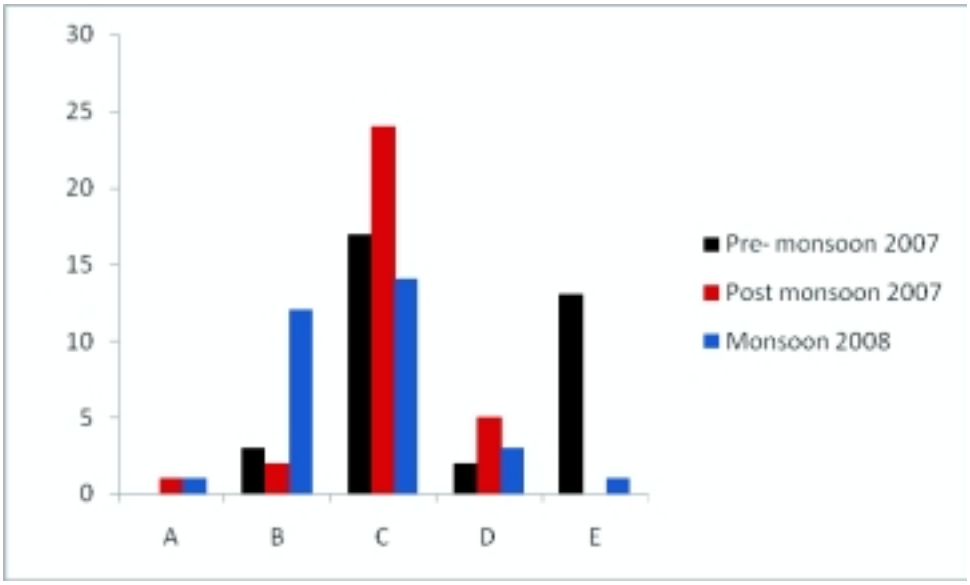


Fig 2.22: Number of samples in each class during the pre-monsoon and post-monsoon 2007 and monsoon 2008

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.

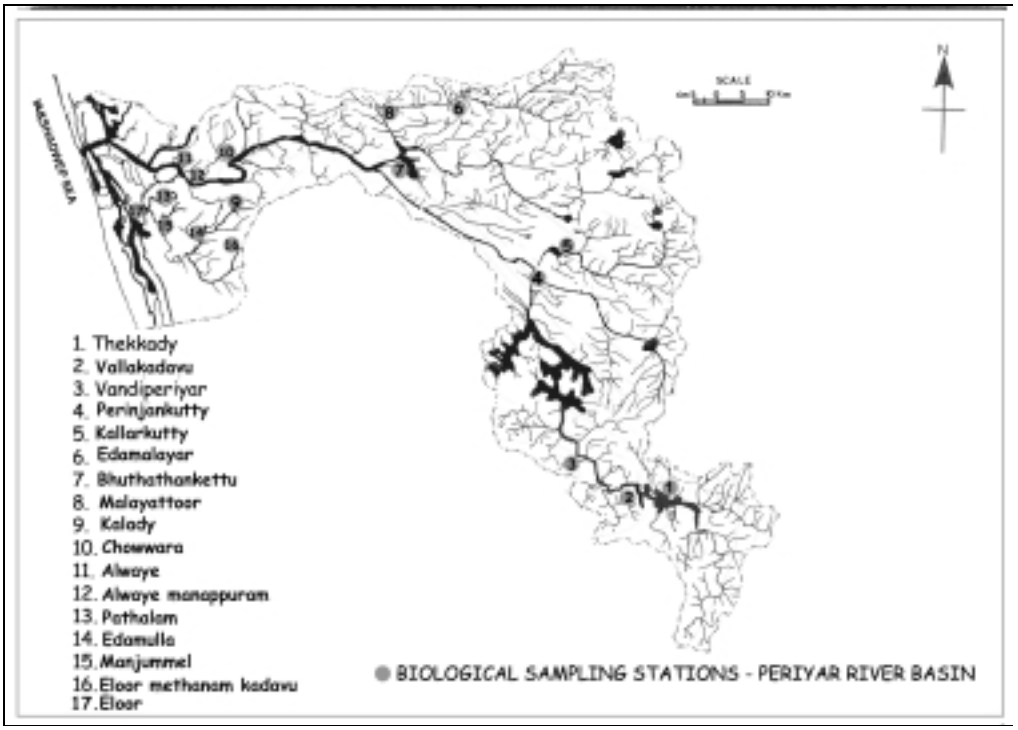


Fig 2.23: Biological sampling stations along the Periyar river

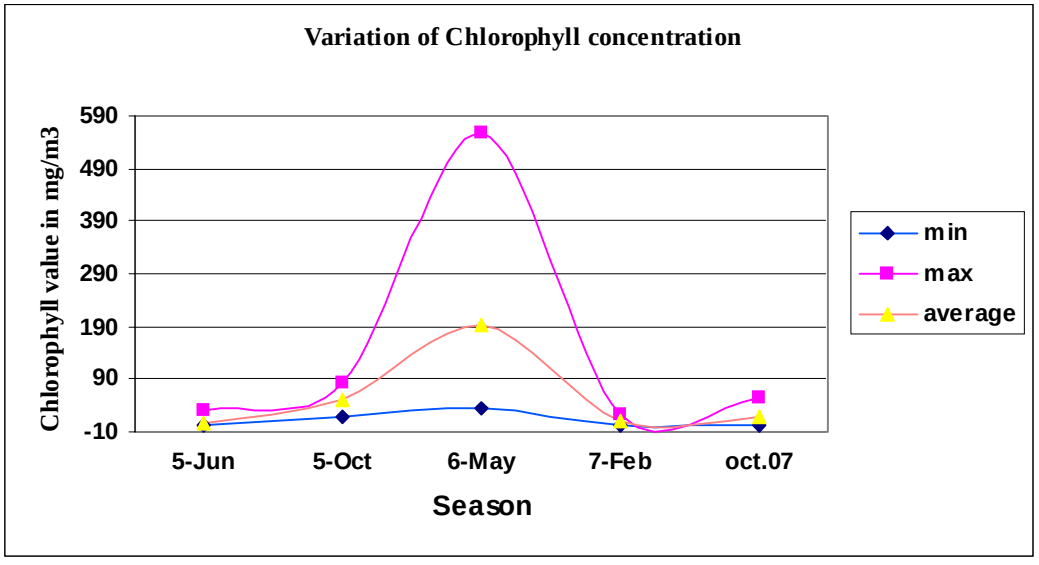


Fig 2.24: Variation of chlorophyll concentration along the Periyar river during different seasons

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

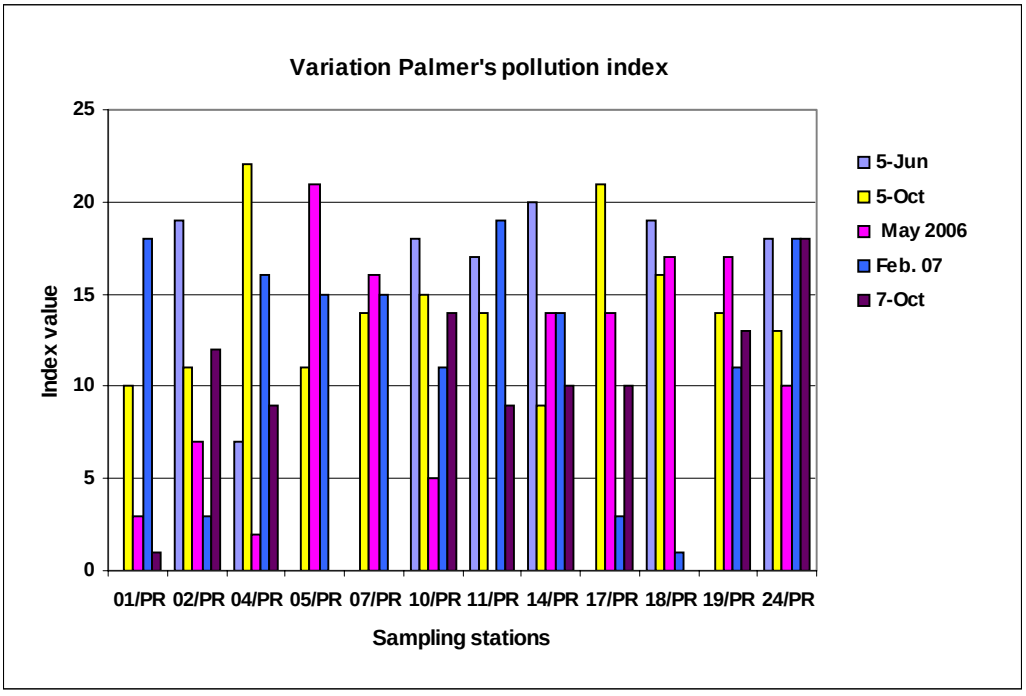


Fig 2.25: Variation of Palmer's Pollution Indices along Periyar River

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.

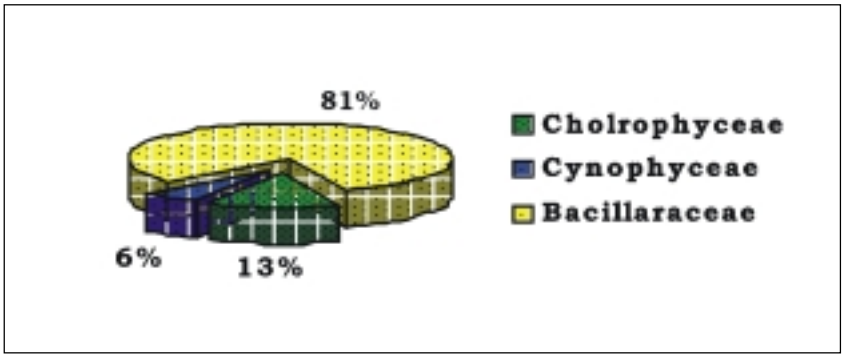


Fig 2.26: Micro-plankton density at Edamulla (May-06)

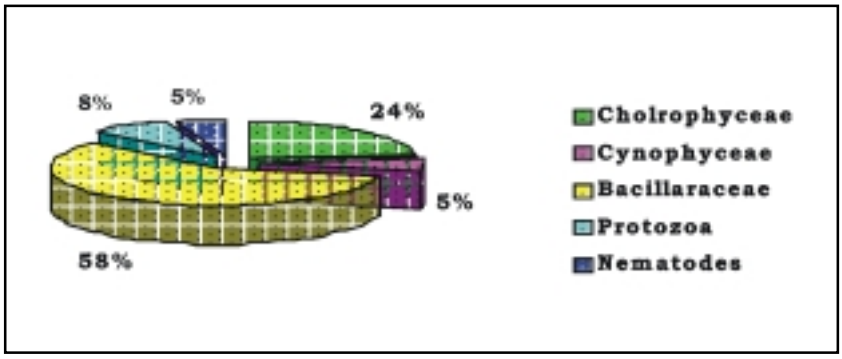


Fig 2.27: Micro-plankton density at Kalady (May 06)

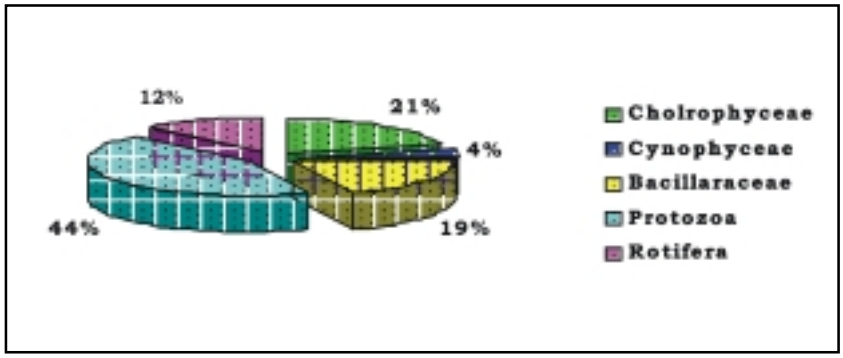


Fig 2.28: Micro-plankton density at Chowwara (May 06)

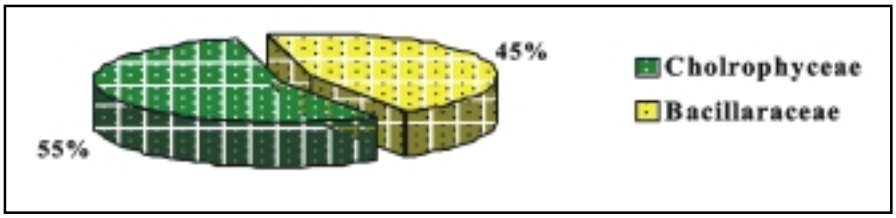


Fig 2.29: Micro-plankton density at Manjummal (May-06)

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

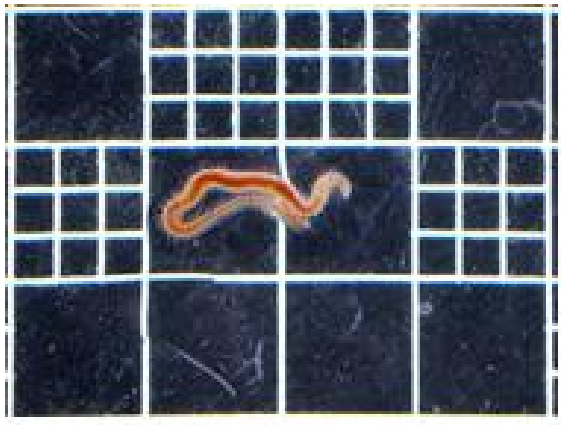
Cypris

Cyclops

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

Chironomus

Stylaria



Oligocheates

Plate 2.9: Pollution tolerant benthic species

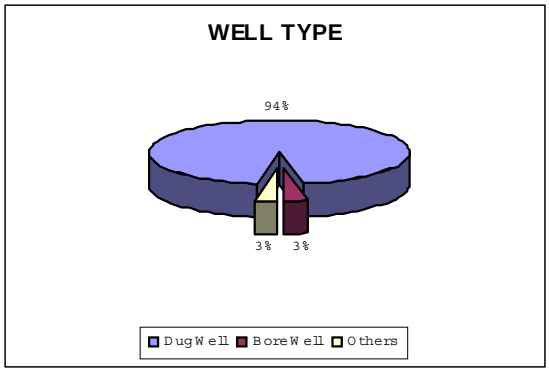


Fig 2.31: Type of sampled wells

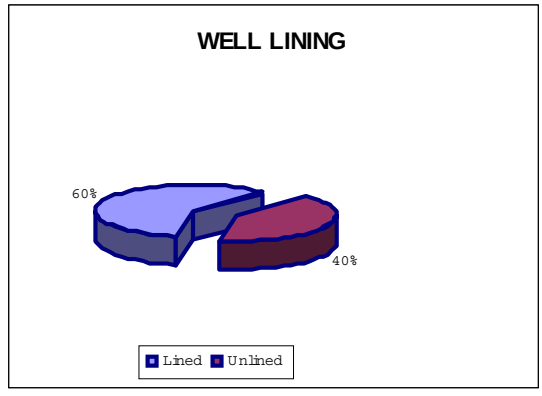


Fig 2.32: Type of well lining

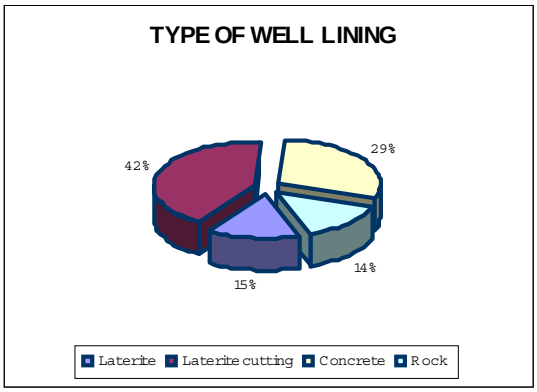


Figure 2.33: Type of well lining

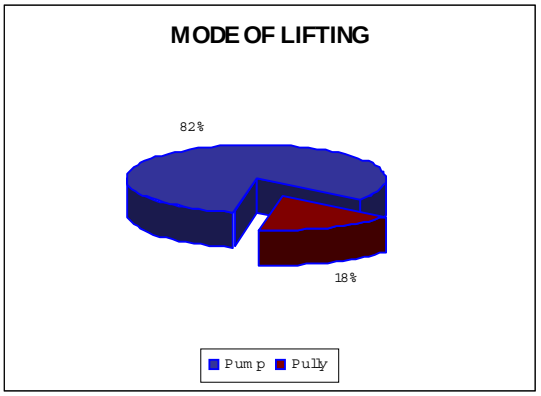


Fig 2.34: Mode of lifting

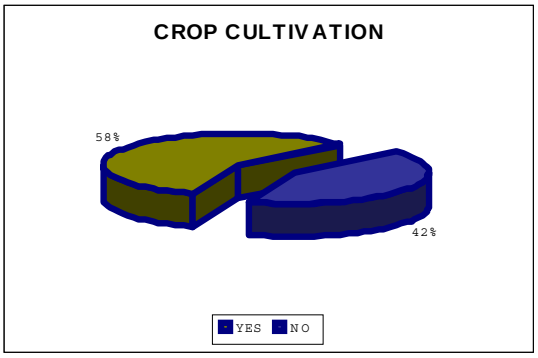


Fig 2.35: Crop cultivation in the area

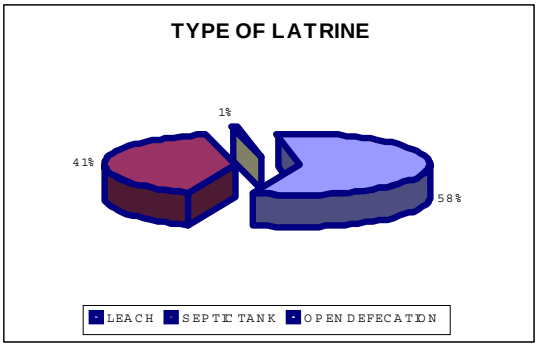


Fig 2.36: Type of latrine

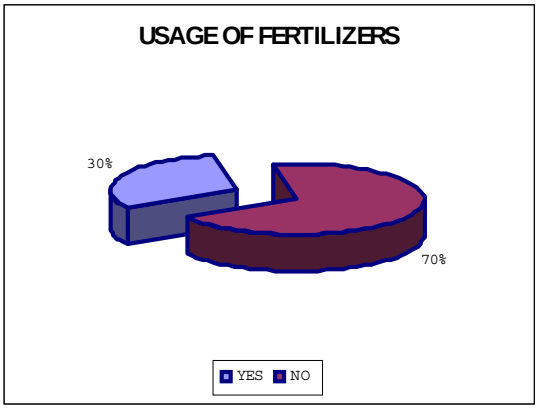


Fig 2.37: Use of fertilizers

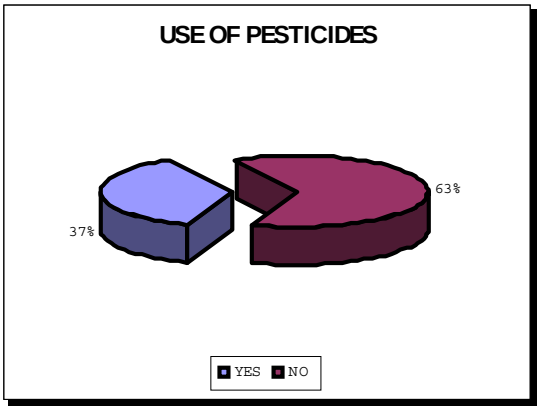


Fig 2.38: Use of pesticides

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

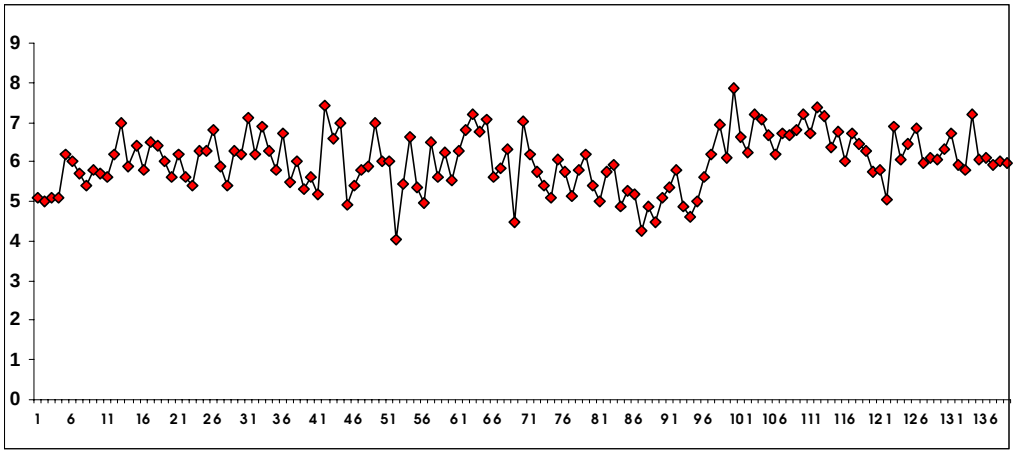


Fig 2.39: Variation in pH of groundwater

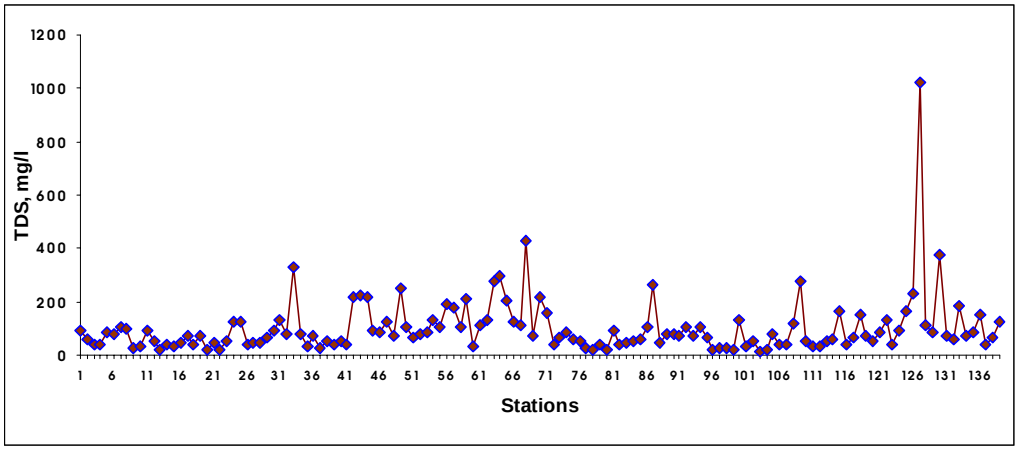


Fig 2.40: Variation in TDS of groundwater

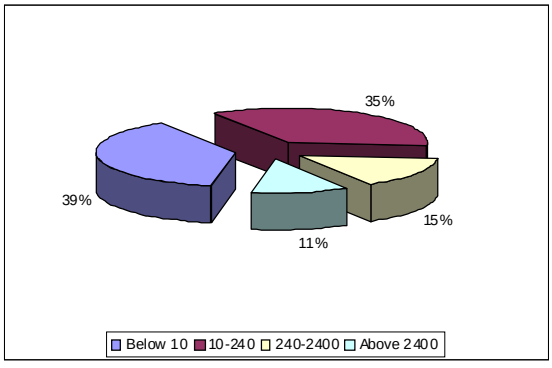


Fig 2.41: Percentage distribution of total coliform in well water

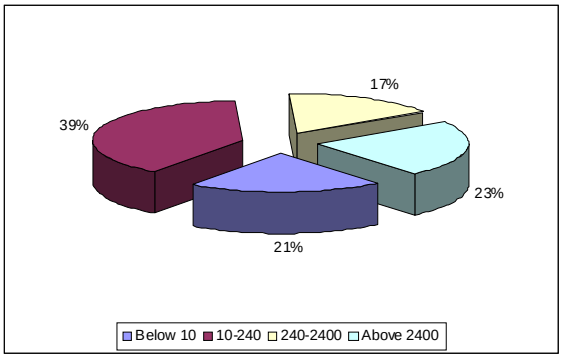


Fig 2.42: Percentage distribution of faecal coliform in well water

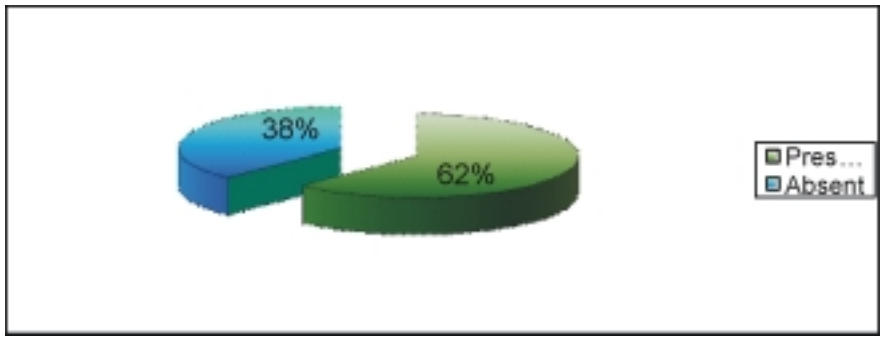


Fig 2.43: Percentage distribution of E. Coli in the Well water

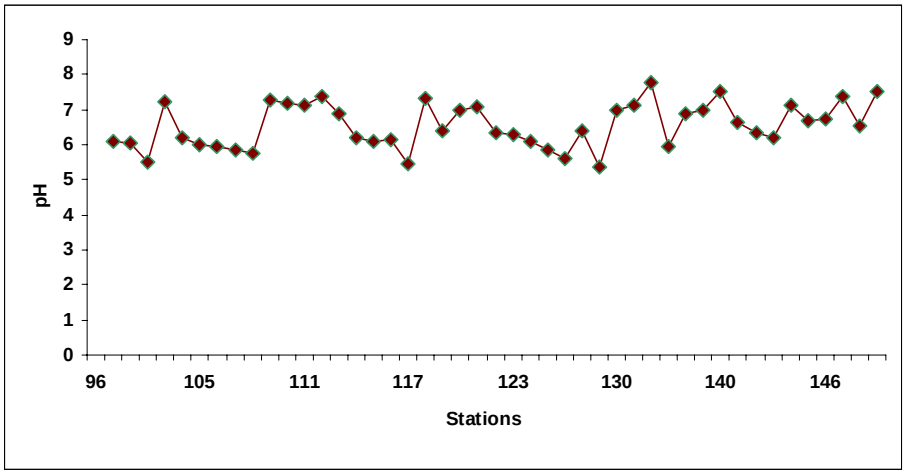


Fig 2.44: The variations of pH values in groundwater samples

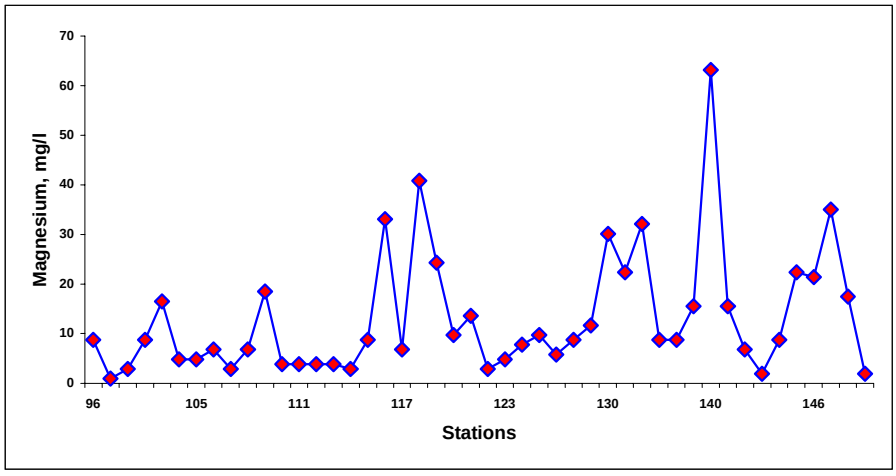


Fig 2.45: Variation of concentration of magnesium in groundwater samples

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

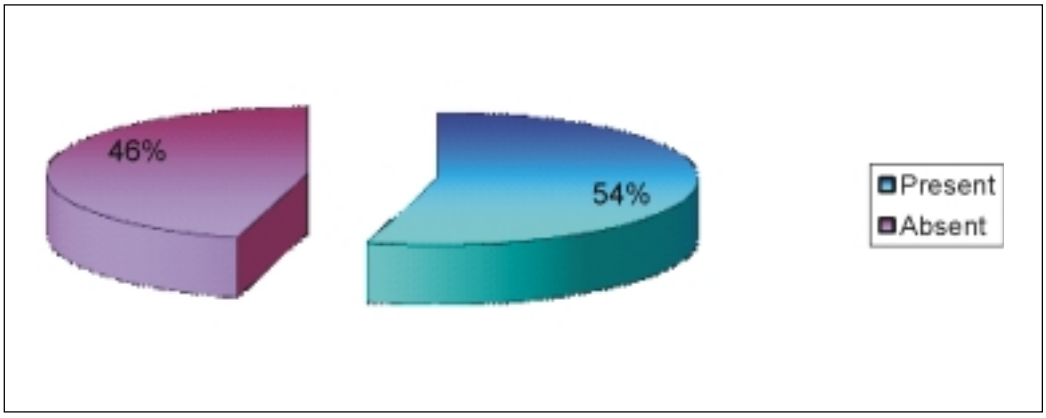


Fig 2.46: Percentage of faecal coliforms in samples collected

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

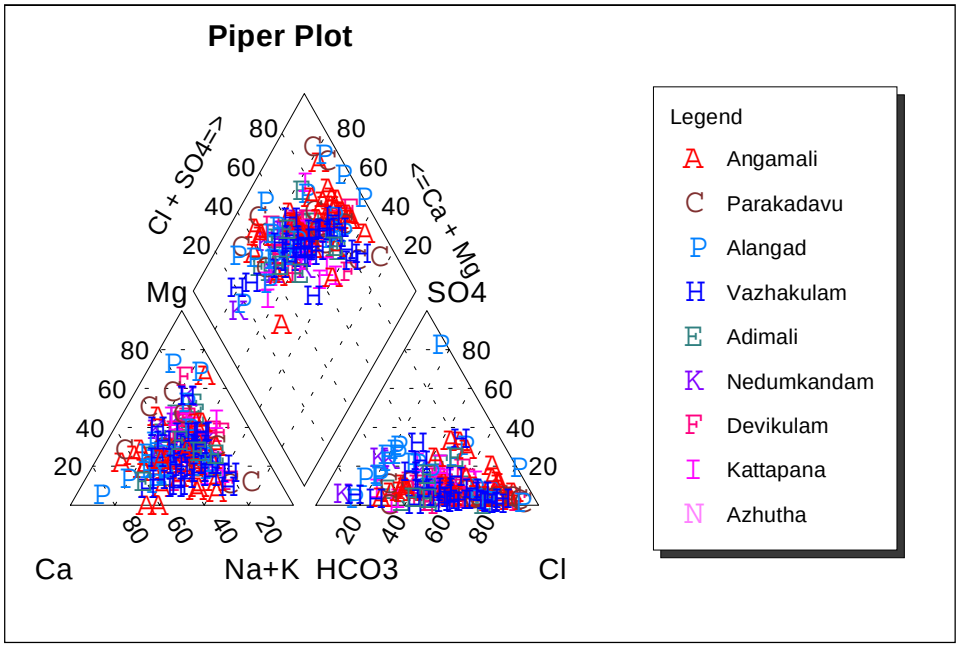


Fig 2.47: Piper diagram of groundwater (monsoon-2006)

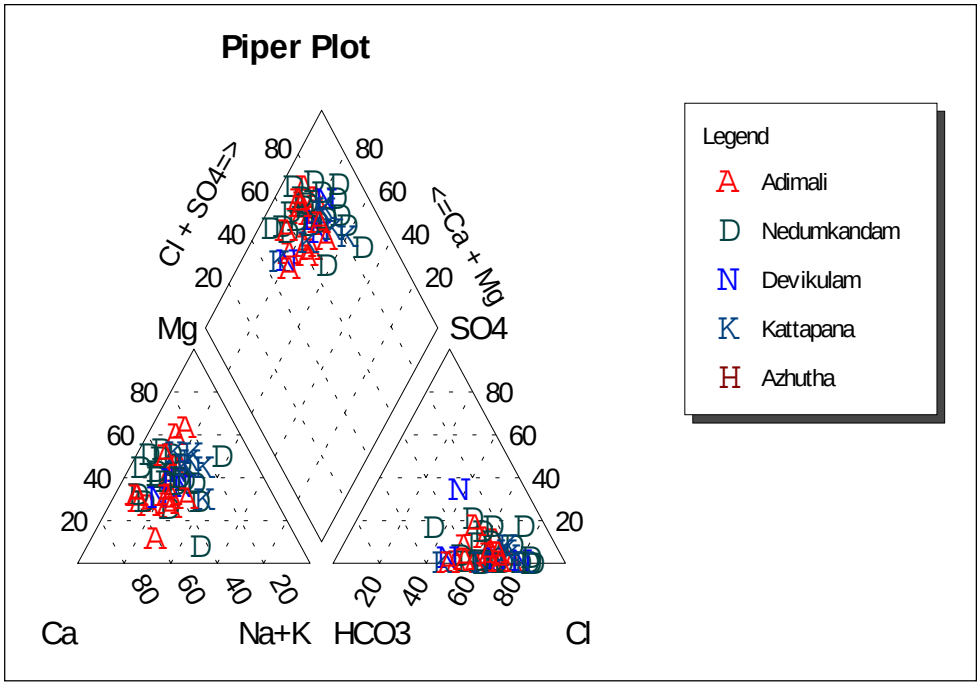


Fig 2.48: Piper plot for water type of groundwater samples (pre-monsoon 2007)

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.