

**WATER QUALITY STATUS OF  
THIRUVANATHAPURAM DISTRICT, KERALA  
(Back ground Paper-I)**

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**Research Unit, Local Self Government (RULSG)  
Centre for Development Studies  
THIRUVANANTHAPURAM  
February, 2017**

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## Executive Summary

This report is prepared as a back ground paper of the project “ River restoration of Kerala: Developing a co-evolutionary framework and river restoration action plan for Thiruvananthapuram city’ undertaken by RULSG, Centre for Development Studies. Objective of this report is to deliberate on surface and ground water quality of three river systems, the Neyyar, Karamana and Vamanapuram draining Thiruvananthapuram district. Water quality status has been assessed based on BIS, CCME and CPCB schemes.

Water samples were collected from a network of 26 stations in the Neyyar river for all three seasons- monsoon, pre-monsoon and post monsoon. Ground water samples were also collected from 15 Panchayats and one Municipality falling in the basin. Analysis of of surface water quality has shown that the downstream stations are affected due to salinity intrusion. There are some stations reporting high concentrations of iron during the pre-monsoon season. Most of the samples are bacteriologically contaminated, especially with presence of E.Coli. Faecal contamination is also an associated problem of the river. Another striking feature is the low pH observed in the river water during the post-monsoon season. Quality of ground water also varies with the seasons. Most of the groundwater samples are acidic throughout the year, which is one of the major quality problems in the Neyyar basin. About 95% of the ground water samples collected during the post-monsoon and the pre-monsoon and 98% collected during the monsoon were found to be unsuitable for drinking as per BIS standards. This is a serious issue as majority of rural population depend on well water for drinking and household purposes.

The Karamana river with two reservoirs is the main source for drinking water supply in Trivandrum city and adjoining panchayats. Twenty surface water samples have been collected from this river covering all three seasons. During monsoon, the value of pH ranged from 6.0 to 6.88 with an average value of 6.2. Out of 20 samples 15 samples were found to have pH below the lower limit of 6.5 prescribed by BIS. Colour in most of the areas of the river was found to be much high in monsoon season which is pointing towards the increased siltation and sewage input. The reduction in flow which is the trait of the water bodies during summer may be a reason for the high colour in pre monsoon season. In the downstream segment particularly near Kovalam water is almost stagnant and receives drainages from the nearby tourist areas resulting in bad aesthetic condition. Some stations reported concentration of nitrate-N which may be associated with washing and

bathing activities. The BOD of the river ranged from 1.13 to 20 mg/l. A total number of 11 samples were found to be having BOD value greater than 3 mg/l which indicates the organic load of the river. Bacteriological analysis of the samples clearly indicated microbial contamination in the river. Almost all the stations showed higher index for total coliforms and fecal coliform. In all seasons *E.coli* was present in all analysed samples. The Karamana River and its tributary the Killi Ar carry large quantities of raw sewage discharged from city drains. Ground water is acidic and is bacteriologically contaminated.

Fifteen samples were collected from the Vamanapuram river. The pH values ranged from 6.02-6.53, 6.85-7.60 and 6.90-8.07 during pre-monsoon, monsoon and post monsoon seasons respectively. The tidal impact or the salinity intrusion contributes to high TDS value in the coastal stations. At the confluence of Vamanapuram river with Anjuthengu Lake the hardness attains the maximum value of 1200 mg/l. The BOD level fluctuates between 0.07 and 10.27 mg/l throughout the period of sampling. *E.coli* contamination was found in 80% of the surface water samples during monsoon season, 67% in post-monsoon season and 60% in pre-monsoon season. Water quality index showed that 87% of water sample had marginal water quality. According to Central Pollution Control Board specification majority of the samples belongs to Class C. Seventy two per cent of the ground water samples were bacteriologically contaminated during post-monsoon season.

A separate study on Parvathy Puthanar canal which joins Karamana river at Munnattumukku near the Poonthura coastal village indicates its heavily-polluted nature.

Though the water quality in the upstream stretches of rivers of Thiruvnathapuram district are generally good and potable, the quality deteriorates as the rivers traverse through the thickly populated midland and more thickly populated lowland areas. Quality of water deteriorates downstream, which manifests impact of urbanisation, tourism, salinity intrusion and activities like coconut husk retting and use of agrochemicals. An effective water quality management should address challenges of chemical and microbiological contaminants. An integrated approach involving all key stakeholders needs to be evolved for a meaningful, effective and efficient way of providing safe water, while also guarding against environmental deterioration.

# WATER QUALITY STATUS OF THIRUVANATHAPURAM DISTRICT, KERALA

## 1.0 Introduction

Thiruvananthapuram district is situated between north latitudes 8° 17' and 8° 54' and east longitudes 76° 41' and 77° 17'. The total area of the district is 2192 sq. Km having a population of 33,07,284 (2011 census). The average population density of the district is 1509 which is 1.75 times higher than State average. Among the three rivers in the district, the Neyyar (56 km), the southernmost river of the Kerala state, has its origin in the Agasthyamala, the second-highest peak in the Western Ghats. The Karamana River (67 km) originates from Vayuvanthol (Vazhuvanthol), another mountain in Western Ghats. The Vamanapuram River has its origin from Chemunji Mottai of the Western Ghats. There are 10 major back waters in the district. The major lakes are Veli, Kadinamkulam, Anchuthengu (Anjengo), Kaappil, Akathumuri and the Edava-Nadayara. Besides these, there is a fresh-water lake at Vellayani in Thiruvananthapuram Taluk. The climate of Thiruvananthapuram district is generally hot tropical. The mean maximum temperature is 95 °F (35 °C) and the mean minimum temperature is 69 °F (20 °C). As the district stretches from north to south with the Arabian Sea in the west side, the relative humidity is generally high. It rises up to about 95% during the South-West monsoon.

Karamana River with two reservoirs at Peppara and Aruvikkara is the main surface water source for Thiruvananthapuram water supply scheme. Raw water is pumped from Karamana river at Kundamankadavu, Aruvikkara, Adimadakkayam and Trikkannapuram . Vellayani Lake also provides surface water to kayal pump house located at Thiruvallom. The city water supply scheme is one of the oldest schemes in India and there is a gap of 137 MLD of water between production and demand. The partial coverage of sewage in the city helps to cover 30-35% of the area and collection of 60-750 % of the sewage which is conveyed to sewage treatment plant at Muttathara. The remaining sewage still drains into Karamana River, Killi River, Parvathi Puthanar Canal, Enjkkal Thodu, Kannamoola Thodu etc.

Paravthi Puthnanr Canal is part of TS (Thiruvanthapuram-Shornur) canal connecting Karamana River and Veli Kayal. This canal joins Karamana River at Moonattumukku. Sewage is reaching to this canal from domestic and commercial establishment on either side

through various small drains. Another drain, Kannamoolathodu which also carries the wastewater from the urban areas discharges into Aakkulam Lake. This report is prepared as part of the background paper, commissioned for the project titled “River Restoration in Kerala: Developing a Co-Evolutionary Framework and River Restoration Action Plan for Trivandrum City” undertaken by RULSG, CDS

## **2.0 Water Quality Status of Rivers**

The water quality information systems are being developed in advanced countries to manage the water quality from a point or nonpoint source of pollution. Centre for Water Resources Development and Management (CWRDM), Kozhikode, with the support of Kerala State Council for Science Technology and Environment (KSCSTE) (2010-2015) is carrying out a project on “Environmental Monitoring Programme on Water Quality” which aims to create database on water quality and to use the derived information for practical application in the management of water resources and their effective utilization. The water quality monitoring is being done on a River basin scale. Samples are being collected for water quality analysis both from surface and groundwater sources. Groundwater sampling stations were fixed after conducting a sanitary survey in the panchayats/municipalities/corporations. The project also focuses on developing suitable water quality and biological indices for different water domains which could be utilized to identify the problem affected areas and to suggest necessary management action plans. Biological indicators exhibit the degree of imbalance that has been caused while chemical methods demonstrate the concentration of pollutants responsible. Since biota can integrate the environmental effects of water chemistry, aquatic communities like phytoplankton reflects the average ecological condition and therefore may be used as indicators of water quality. In the above context, the biological monitoring was invariably included as a part of the project on Environmental Monitoring Programme on Water Quality

Water quality monitoring is being done basically to verify whether observed quality is suitable for intended uses. Presently the monitoring is done to assess current state of water quality and its variability spatially and temporarily. Often, such assessments are appraisals of the physicochemical, biological and/or microbiological conditions in relation to reference conditions, human-health effects and/or the existing or planned uses of water

The water quality data is collected in such way that, it will yield data and information which can be used by water-use- managers. The information collected should be related to various uses such as drinking, irrigation, industrial etc and functions such as maintenance of aquatic life. This report has drawn significantly from the existing studies of CWRDM and KSCSTE (2010-2015), Harikumar and Bindhya (2012), Harikumar and Madhava Chandran (2013) and Megha et al (2015)

## **2.1 River Water Quality Index and Criteria**

The quality of river water is assessed in terms of physical, chemical and biological parameters. The main problem in water quality monitoring is the complexity associated with analyzing the large number of measured variables. The data sets contain rich information about the behaviour of the water resources.

The water quality of Rivers in this report has been ascertained mainly using Bureau of Indian Standards for drinking water specifications (IS 10500: 2012), Water Quality Index (WQI) developed by Canadian Council of Ministers of the Environment (CCME) and Central Pollution Control Board (CPCB) classification for best designated uses (CPCB, undated).

WQI is a tool widely used in different parts of the world to solve the problems of data management and to evaluate success and failures in management strategies for improving water quality. A number of indices have been developed to summarize water quality data for communication to the general public in an effective way. In general water quality indices incorporate data from multiple water quality parameters into a mathematical equation that rates the health of water body with a single number. That number is placed on a relative scale to justify the water quality in categories ranging from very bad to excellent. This number can be easily interpreted and understood by political decision makers, non-technical water managers and the general public (Table 1)

A committee of water quality experts from across Canada developed the Canadian Council of Ministers of the Environment (CCME) Water Quality Index (WQI) in the late 1990's (CCME, 2001). The index is a guideline-driven tool that allows the user to refine large amounts of water quality data from a monitoring site into a single number, or index value.

Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) provides a convenient method of summarizing complex water quality data that can be easily understood by the public, water distributors, planners, managers and policy makers.

The CCME WQI incorporates three elements:

**Scope (F1)** – The number of water quality parameters (variables) not meeting water quality objectives

**Frequency (F2)** – The number of times the objectives are not met

**Amplitude (F3)** - The extent to which the objectives are not met

The water quality index (CCME WQI) is calculated as:

$$\text{CCME WQI} = 100 - \frac{\sqrt{F1^2 + F2^2 + F3^2}}{1.732}$$

The divisor 1.732 normalizes the resultant values to a range between 0 and 100, where 0 represents the “worst” water quality and 100 represents the “best” water quality

**Table 1: Water quality scoring system**

Rank	Score	Interpretation
Excellent	95.0-100.0	Water quality meets all criteria for use as a source of drinking water
Good	80.0-94.9	Water quality rarely or narrowly violates criteria for use as a source of drinking water
Fair	65.0-79.9	Water quality sometimes violates criteria, possibly by a wide margin, for use as a source of drinking water
Marginal	45.0-64.9	Water quality often violates criteria for use as a source of drinking water by a considerable margin
Poor	0-44.9	Water quality does not meet any criteria for use as a source of drinking water

## 2.2 CPCB Classification

A well planned and well managed water quality monitoring system is required to control or predict changes or trends of changes in the quality of a particular water body, so that curative or preventive measures can be taken to restore and maintain ecological balance in the water body. Central Pollution Control Board classified the inland surface water into five i.e.; from A to E on the basis of their designated best use and desired class (Table 2). The classification has been made in such a manner that with the degradation in quality, the water quality requirement becomes progressively lower from A to E.

**Table 2 Use based classification of water of Indian rivers and coastal waters**

Designated-Best-Use	Class of water	Criteria
Drinking Water Source without conventional treatment but after disinfection	A	1. Total coli forms Organism MPN/100ml shall be 50 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 6mg/l or more 4. Biochemical Oxygen Demand 5 days 20°C 2mg/l or less
Outdoor bathing (Organized)	B	1. Total Coli forms Organism MPN/100ml shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5mg/l or more 4. Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
Drinking water source after conventional treatment and disinfection	C	1. Total Coli forms Organism MPN/100ml shall be 5000 or less 2. pH between 6 to 9 3. Dissolved Oxygen 4mg/l or more 4. Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
Propagation of Wild life and Fisheries	D	1. pH between 6.5 to 8.5 2. Dissolved Oxygen 4mg/l or more 3. Free Ammonia (as N) 1.2 mg/l or less
Irrigation, Industrial Cooling, Controlled Waste disposal	E	1. pH between 6.0 to 8.5 2. Electrical Conductivity at 25oC micro mhos/cm Max.2250 3. Sodium absorption Ratio Max. 26 4. Boron Max. 2mg/l

### 3.0 Neyyar River Basin

The Neyyar river originates from the Agasthyakudam hills, flows through Neyyattinkara taluk and joins Lakshadweep Sea near Poovar. It has a total length of 56 km. The main tributaries are Kallar and Karavaliyar. Streams like Vandichirathode, Kulathoorvaliyathode, Maruthoorthode, Athiyannoorthode, Thaliyalthode, Kottukalthode and Venganooorthode join the main stream. There is an irrigation project constructed in 1973 at Kallikadu near Katakada, which is about 29 km from Trivandrum city. Neyyar wild life sanctuary in this basin is a famous tourist place. The total area of Neyyar river basin is 128 sq.kms. It lies between 80°17' N and 80° 53' N, and 76° 40' E and 70° 17'. E. The river basin has six blocks and one municipality. A total of 41 Panchayats are there in these blocks. Water samples were collected from a network of 26 stations in the Neyyar river, during the monsoon (2006), pre-monsoon (2007) and post monsoon (2007) seasons. Among the 26 stations, nine were identified for biological analysis. Ground water samples were also collected from 15 Panchayats and one Municipality in the basin, during the monsoon 2006, pre monsoon (2007), and post monsoon (2007) seasons. In order to find out the hygienic condition depending on well characteristics, sources of pollution and soil type, a sanitary survey was also conducted in the basin. A total of 64 ground water samples were collected during each seasons.

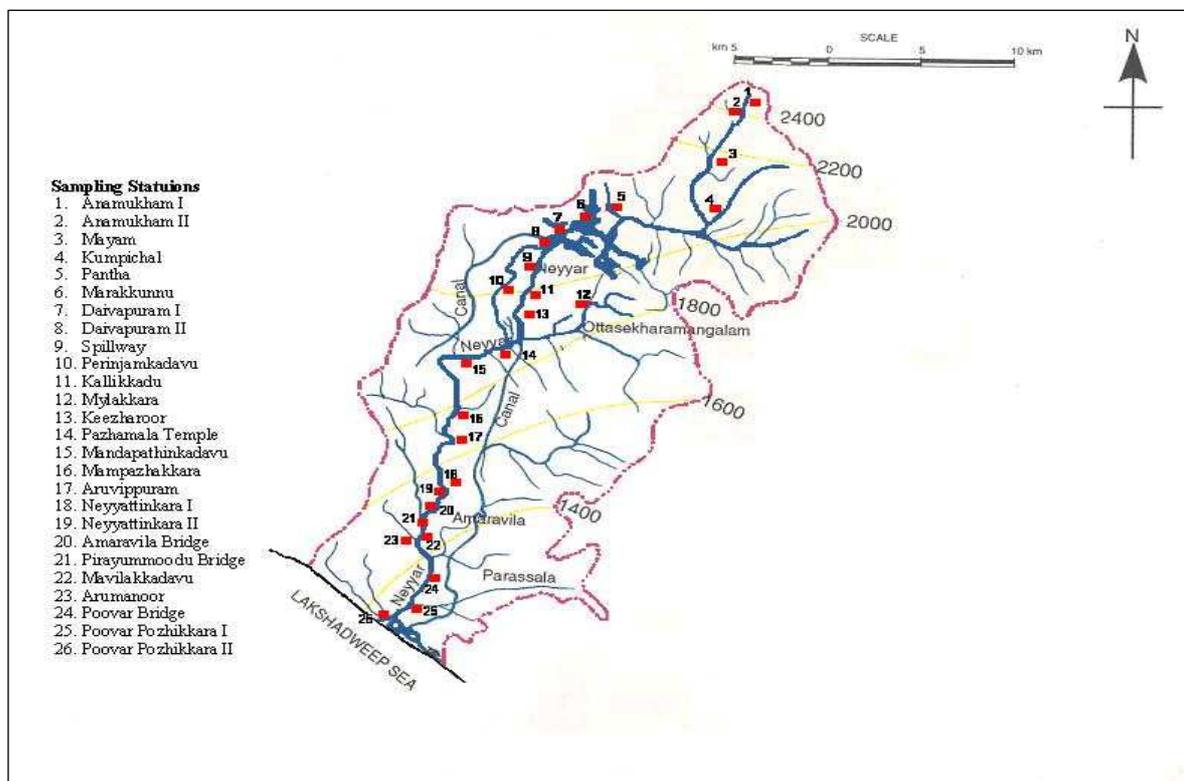


Fig: 1 Surface water sampling stations, Neyyar River

### 3.1 Surface Water Quality

The network of sampling stations in the river course areas finalized considering the localities of major drinking water abstraction points, upstream and downstream locations of discharge of industrial effluents / sewage, major fishing and recreation zones, stretches generally most prone to pollution etc. The relevant details of samples stations thus selected in the Neyyar river course are given in Appendix 1.

One ground water sample was selected from each of the wards of all the Panchayats in the Thiruvananthapuram district for estimating the water quality parameters (Fig.3). A few sediment samples were collected from the basin to determine the quality status. In addition to water quality monitoring data on important geomorphologic features, vegetation and hydrologic features such as rainfall and groundwater level fluctuations were also collected. Information on anthropogenic activities and demographic features were also collected from available sources.

The pH values during the monsoon and pre-monsoon seasons were found to be somewhat neutral, except in the samples from downstream reaches, which were slightly alkaline during the monsoon season and were slightly acidic in the pre-monsoon, but within the range prescribed, by BIS (Appendix 2). However most of the samples were found to be acidic in nature during the post-monsoon season. The pH varied between 5.93 and 7.26. Minimum value for pH was noticed at the Spillway (09/N). This site is a bathing and washing ghat and the flow is comparatively low.

The samples up to Pirayummoodu had low value for Electrical Conductivity (EC). However from Mavilakadavu onwards, an increase in the values of EC was observed and the trend continued towards the downstream reaches and attained the highest value at Poovar Pozhikara. The observation clearly indicates the impact of intrusion of saline water into the fresh water zones. In the post-monsoon, the electrical conductivity is very low compared to other seasons. An increasing trend in the concentration towards the downstream stations was noticed. The highest value of 2660  $\mu\text{s}$  was found at Poovar II, which is in an estuarine stretch. This high value is due to the salinity intrusion from the sea. The area has considerable

tourism activities, including boating. As expected Total Dissolved Solids (TDS) followed the same trend as EC in all seasons, as TDS is directly proportional to EC.

Salinity also has been gradually increasing towards the downstream reaches from Mavilakadavu. During the monsoon, salinity value was found to be the highest (19 ppt) at Poovar Pozhikkara I . This may be due to the salinity intrusion from the sea during the period of high tide. But, the concentration comes down to 4.2 ppt during the pre-monsoon due to heavy mid summer rains. But in the post-monsoon, the values were found to be very low, it ranges from 0 to 0.90 ppt, which indicates the effects of monsoon rain on the dilution of water. The overall observations indicate that during the high tide, the influence of saline water intrusion is high as expected.

In general turbidity is found to be low during the three seasons. The hardness values were beyond the limits for samples from the downstream stations like Poovar Bridge during pre-monsoon and Poovar Pozhikkara-I and II during the monsoon and pre-monsoon seasons.

The concentration of iron at Kumpichal, Pantha, Spillway, Perinjankadavu and Mylakkara exceeded the permissible limit set by BIS. Of these, iron was found to be high at Koompichal and Pantha which reported concentrations as high as 1.22 & 1.49 mg/l respectively. This may be due to the release of iron from sediments caused due to the reduction in discharge during pre monsoon seasons.

The Dissolved oxygen (DO) ranged from 4.81 to 9.28 mg/l during the pre-monsoon from 5.44 to 8.53mg/l during the monsoon and from 5.06 mg/l to 9.6 mg/l during the post-monsoon season. Biochemical Oxygen Demand (BOD), which is a measure of organic load, was low at most of the stations during both the seasons.

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

According to CCME water quality index, none of the samples have shown Excellent or Good water quality specification. Most of the samples come under “Poor” water quality. Only one station, namely Mayam has the water quality specification as “Fair”. About 61% of the sampling stations have “Poor” water quality. The presence of coliforms is the major problem

for this decline in water quality. Human and animal excreta along the banks of the river are the main reasons for the faecal contamination of the river.

Sand mining and tourism as well as salinity intrusion from the sea are some other causative factors for the deterioration of quality of water in the downstream stations.

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

Palmer has prepared a list of algae tolerant to organic pollution and derived an index to evaluate the organic pollution status of the water. Palmer's modified algal genus index is calculated herein based on the genus identified from the Neyyar. The index value shows an increasing trend towards summer. This indicates the increase in the organic content in the river due to the sewage inputs at various stretches along the course of the river. The identified spots where the aquatic flora and fauna face serious environmental stress are, Koombichal, Neyyattinkara and Poovar.

The sediments collected from the basin were subjected to heavy metal analysis. Iron content of the sediments is much high in all the stations. This is can be attributed due to geological origin. The analysis highlights that the lead content of the sediments is high and the maximum concentration of 90.80mg/kg was found at Koompichalkadavu. Manganese is reported to be high at all the stations. Heavy metals like nickel and cadmium were also detected in high concentration at all the stations. The maximum value of copper detected was 32 mg/kg at Neyyattinkara. The high concentration of heavy metals might have occurred due to dumping of municipal waste to the River.

### **3.2 Groundwater Quality**

The total dissolved solids of eight sites (two samples from Neyyattinkara Municipality, one from Chenkal, two from Poovar, one from Kallikkadu, one from Kattakkada and one from

Athiyannur) during the post-monsoon, six samples (Neyyattinkara Mnpty, Poovar and Kattakkada), during the pre-monsoon and six samples (Neyyattinkara Mnpty, Poovar, Kattakkada, Kallikkadu and Ottasekharamangalam) during monsoon seasons had TDS >500mg/l, which is above the permissible limit prescribed by BIS for drinking water. A maximum value of salinity (0.8 ppt) was reported for a pre-monsoon sample collected from Poovar. Being a coastal area, salinity intrusion may be a possible reason for the high salinity. Maximum value of Turbidity was reported during the post-monsoon and the pre-monsoon seasons at Athiyannur. The same well reported high concentration of iron.

From the study based on groundwater samples, it is revealed that, the quality of most of the samples is very poor. The quality varies with the season. The acidity shown by most of the groundwater samples is one of the major quality problems seen in the Neyyar basin. The acidic nature of the water remains as such throughout the year. Considering the other physico-chemical parameters, the areas which reported groundwater quality problems were: Neyyattinkara Municipality, Chenkal, Kulathoor, Poovar, Thirupuram, Amboori, Kallikkadu, Otasekharamangalam, Kattakkada, Poovachal and Athiyannoor. Of these, well from Neyyattinkara Municipality is the most contaminated during the post-monsoon. The quality of well from Poovar also reported to be worst during the pre-monsoon and monsoon seasons. Out of the 64 samples, only three samples had all the parameters within the prescribed limit of BIS during the post-monsoon and the pre-monsoon seasons. But, during the monsoon season, only one sample had all the parameters within the limit, ie, from the bore well located at Perunkadavila. Even though most of the samples were found to be good in its physico-chemical characteristics, these were considerably contaminated with coliforms. About 95% of the ground water samples collected during the post-monsoon and the pre-monsoon and 98% collected during the monsoon were found to be unsuitable for drinking as per BIS standards. Both surface and ground water quality of the Neyyar river basin are affected. There is a spatial trend, which is largely linked to the nature of anthropogenic activities.

#### **4.0 Karamana River**

The Karamana River has its origin in the Chemmunji mottai and Agasthya malai of the Nedumangad hills at an altitude of about 1860 m. It flows in southern direction through Thiruvananthapuram Corporation and joins the Arabian Sea near Pachallur. The major

tributaries of the river are Kavi Aar, Attai Aar, Vaiyapadi Aar and Thodai Aar. The Killi Aar which joins the Karamana river near Nadakara is its main tributary.

Karamana River has a length of 68 kms and basin area of 702 Km<sup>2</sup>. The entire catchment lies within Kerala State. Thiruvananthapuram city, the capital city of Kerala lies in this basin. The basin lies between latitude 08° 21' 49" and 08° 40' 55" N and longitude 76° 49' 46" and 77° 14' 35" E. the important towns in the basin are Nedumangad and Thiruvananthapuram. The whole catchment lies within Thiruvananthapuram district.

The best-known tributary of the Karamana River is Killiyar, has its origins in the village of Panavoor, in Nedumangad Taluk. Killiyar runs parallel to the TS Road for most of the Nedumangad-Trivandrum route. The Karamana River, joins the Killi River at Pallathukadavu (upstream of Thiruvallam) and wraps around the Edayar island on its way to the Poonthura estuary. Both the rivers carry large quantities of raw sewage discharged from city drains. The heavily-polluted Parvathy Puthanar canal joins the river at Munnattumukku near the Poonthura coastal village.

The Karamana River (Fig 2) has the distinction of having two dams on it despite its relatively short length. These are the Peppara Dam meant for irrigation on the upper reach of the river, and the Aruvikkara Dam, meant for irrigation as well as drinking water supply to the city of Trivandrum. The flow of water on the western side of the island is blocked due to heavy silting at Munnattumukku and accretion of sea sand at Kunnumanal. During high tide, seawater from the estuary surges up to Thiruvallam through the eastern side of Edayar. When the tide ebbs, the dirty water from the Parvathy Puthanar rushes in, covering the upstream portions up to Thiruvallam and beyond. Twenty samples have been collected for water quality analysis (Appendix 3).

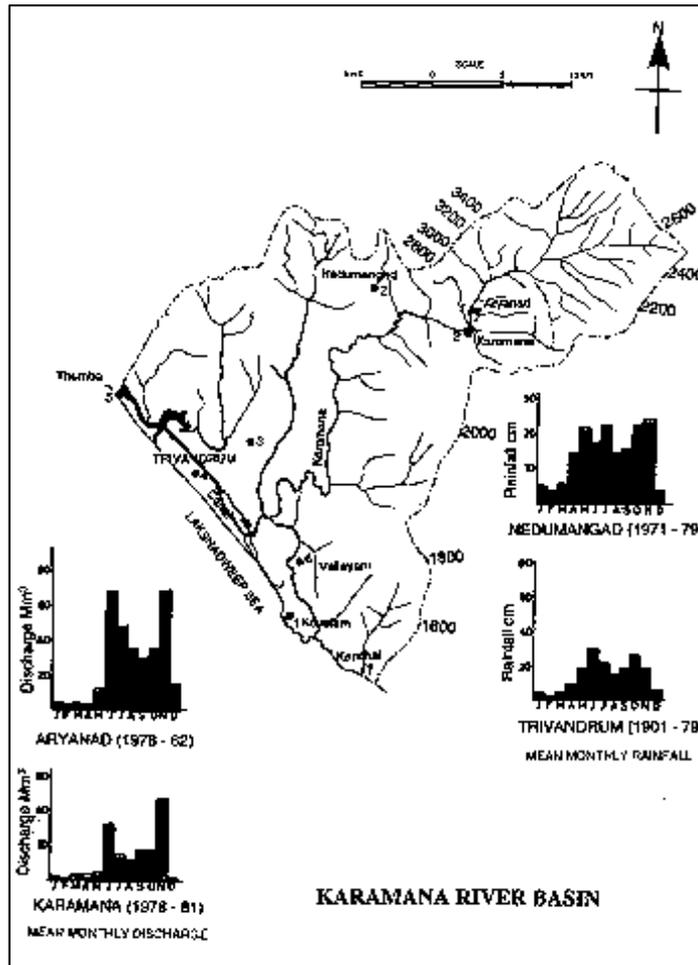


Fig. 2 Karamana River basin

#### 4.1 Surface water quality

During monsoon, the value of pH ranged from 6.0 to 6.88 with an average value of 6.2 (Appendix 4) Out of 20 samples 15 samples were found to have pH below the lower limit of 6.5 prescribed by BIS. The minimum value was recorded for the sample 2 (Thekkinkala). The pH of the samples ranged from 6 to 7.72 during pre monsoon.

Electrical Conductivity of downstream stations was found to be very high. In monsoon the maximum value of 23400 $\mu$ S/cm was found at the station Pachalloor which is an estuarine area and centre of urbanization and agglomerated settlement. The high values might be due to the tidal impact as the sampling was carried out during the period of high tide. Colour in most of the areas of the river was found to be much high in monsoon season which is pointing towards the increased siltation and sufficient sewage input which is apparent. At Aryanad maximum colour of 72 Hazen was found. This site is characterized by urbanization. High

colour could be because of surface run-off from the adjoining areas. Vellayani Kayal also reported high colour (41 Hazen unit) was found. The reduction in flow which is the trait of the water bodies during summer may be a reason for the high colour in pre monsoon season. During post monsoon high colour was observed for the sample collected from Kovalam which is a small stagnant strip of the river, retting and tourism activities were seen in that area and also infested with weeds especially water hyacinth.

Turbidity value of 15 NTU was reported at Thrikkandapuram during monsoon. The maximum value was found at Kovalam. This is a tourist place and retting area. The drainages from the nearby tourist areas are discharging in to the river. The aesthetic condition of the river here is bad and the water is stagnant especially during pre-monsoon.

In post-monsoon season, nitrate-N varied from non detected values to 4.8 mg/l. Maximum value was observed for the sample collected from Aryanad which is a site where people are engaged in washing and bathing activities. In pre-monsoon season, highest value was observed for the sample collected from the site where Parvathi Puthanar joins with the river which carried sewage and domestic waste. The concentration of nitrate-N varied from 0.88 to 6.5 mg/l. In monsoon season, highest concentration of nitrate-N was observed for the sample collected from Pachalloor where tourism activities were prevailing.

In monsoon dissolved oxygen was found to be high at Vellikadavu and was not detected in Parvathy puthanar. This could be because of the high organic load as is confirmed by the Biological oxygen demand of 39.11mg/l at this site. It is a canal joins Karamana River which carries wastes from sewage and domestic effluents. The BOD of the river ranged from 1.13 to 20 mg/l. A total number of 11 samples were found to be having BOD value greater than 3 mg/l which indicates the organic load of the river.

Bacteriological analysis of the samples clearly indicated microbial contamination in the river. Almost all the stations showed higher index for total coliforms and fecal coliform. In all seasons E.coli was present in all analysed samples.

The analysis of the water samples from the River Karamana indicated that the River is susceptible to pollution due to inputs of domestic sewage (Meenampilly Thodu, Parvathi puthanar etc).

CCME Water Quality Index of the River indicated that, samples are either marginal or poor which indicate that they are either frequently threatened or always impaired.

From the water quality analysis of Karamana River basin, during post monsoon season only two samples fall under class B, 13 samples fall under group C, two samples class D and two samples fall under class E.

Based on the genera identified, Palmer's algal pollution index of organic pollution is calculated. It clearly shows that the nutrient content of the stream gradually increases towards the downstream. At Trikanapuram, the highest index value is obtained indicating the high organic pollution. Station Pachallur also shows high organic load as some potent tolerant species like *Phacus*, *Trachelomonas*, *Nitzschia* and Cyanophycean members were noted. At Thiruvallam, the most diverse benthic fauna is obtained. Aquatic earthworm and *Rhabdolaimus* has shown the maximum incidence followed by *Chironomus* and Oligochaetan worms. In Pachallur, *Chironomus* and *Stylaria* are reported and these two are potent pollution tolerant species. The influx of nutrients is evident at Pachallur and Thiruvallam which is probably brought by the Parvathiputhanar joining at Thiruvallam. This canal is imparting a eutrophic nature to the main stream.

The concentration of iron is much high in all the sediment samples. The maximum value was found in the sample collected from Pappanamkode. One of the drains is discharging at this station. The value of iron ranged from 10576.00 to 36538.50 mg/kg. The maximum value of manganese was found at the station Pappanamkode (267.25 mg/kg). The station also reported high values of other metals such as copper and nickel. The analysis indicated that, the sediment collected from the station Pappanamkode is highly contaminated with heavy metals.

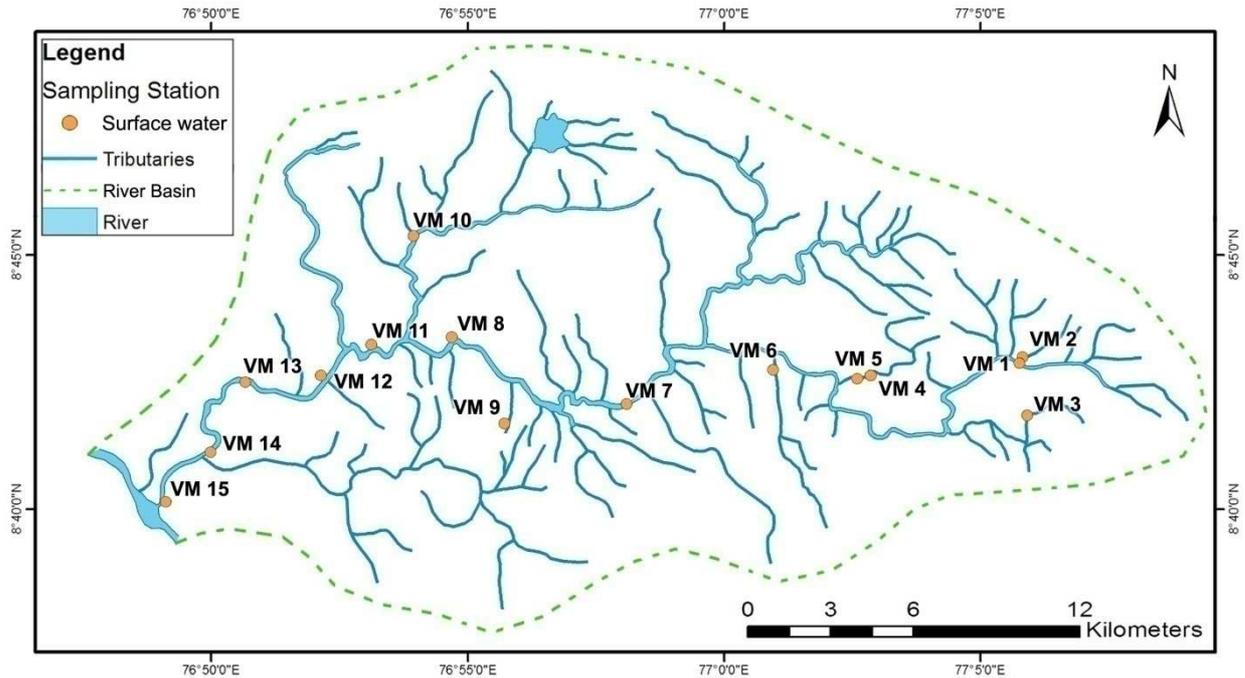
#### **4.2 Groundwater Quality**

In post-monsoon all the samples were found to be highly acidic in nature. pH value was reported less than 6.5 in 95% of the samples are below the limit prescribed by BIS. Microbial contamination is another major problem observed; most of the groundwater

samples were bacteriologically contaminated in all the seasons especially during monsoon season.

## **5.0 Vamanapuram River Basin**

The Vamanapuram river basin with a catchment area of 787 sq. km. is located mainly in Thiruvananthapuram district and a small part falls in Kollam district of Kerala state. Vamanapuram River Basin is bounded by latitudes of 8° 35' 24'' N and 8° 49' 13'' N and longitudes of 76° 44' 24'' E and 77° 12' 45'' E. The River Basin is bounded by Nedumangad Taluk of Thiruvananthapuram district in the South, Kottarakkara Taluk of Kollam districts in the North, Tamil Nadu in the East and Arabian Sea in the West. The area forms part of the midland terrain of the state, characterized by lateritic up lands with undulating topography and intermittent valleys. The river Vamanapuram is a major river in South Kerala with its network of tributaries. The trunk stream originates from the foothills of the Ponmudi hills (1074 m above msl) and the tributaries from the surrounding hills like Kallar. The river then flows onwards through Vamanapuram town and two-branch stream join at Attaramoodu where the main stream is called Kilimanur River. From there the master stream flows onward and joins the Kadinamkulam backwater at the northern most extremity. It debouches into the Arabian Sea at Mudalapallipozhi near Perumathura, 25 km north of Thiruvananthapuram city. The two tributaries of this river are the Upper Chittar & Manjaprayar streams. The major portion of the Vamanapuram River flows through midland terrain and the remaining through highlands and lowlands areas. The details of sampling stations of Vamanapuram River basin are shown in fig 3 and Appendix 5.



**Fig. 3** Locations of surface water sampling stations, Vamanapuram River

### 5.1 Surface Water Quality

The pH values were ranged from 6.02-6.53, 6.85-7.60 and 6.90-8.07 during pre-monsoon, monsoon and post monsoon seasons respectively (Appendix 6). Higher pH value was found at Aattungal Bridge which is a washing and bathing place. Total Dissolved Solids of two samples at Pulimootukadavu and Aanathalavattam in pre-monsoon, post-monsoon and monsoon seasons reported values higher than 500 mg/l prescribed by BIS limit. TDS value was found to be 6714.00 mg/L in pre-monsoon season in Aanathalavattam which is the mixing point with Anjuthengu Lake. The tidal impact or the salinity intrusion can contribute to high TDS value. The hardness was found to be in the range of 8.0 – 1200mg/l. A maximum value of 1200 mg/l hardness was observed at Aanathalavattam during pre-monsoon season. This is the site which is the mixing point of Vamanapuram river with Anjuthengu Lake. The BOD level in Vamanapuram River fluctuated between 0.07 and 10.27 mg/l throughout the period of sampling. Very high BOD (10.27 mg/l) was noticed near Palode Bridge.

The results indicated that *E.coli* contamination was found in 80% of the surface water samples during monsoon season, 67% in post-monsoon season and 60% in pre-monsoon season. A total number of 15 parameters were used for the calculation of water quality index

of 15 water samples from Vamanapuram river basin, which showed that 87% water sample had marginal water quality and 13% water samples showed poor quality.

Classification of the river based on best designated use prescribed by Central Pollution Control Board specifies that, majority of the samples belongs to Class C. The results showed that 87% of samples belonged to class C, 13% of samples belonged to class B during monsoon season.

## **5.2 Groundwater Quality**

Chloride value above the BIS limit was reported at Kadakkavur panchayath during pre-monsoon season and post-monsoon seasons. The results of bacteriological analysis indicate that 72% of the samples were bacteriologically contaminated during post-monsoon season. During monsoon and pre-monsoon, it was 59% and 25% respectively.

## **6.0 Pollution Problems of Parvathy Puthanar Canal and Adjoining Areas**

The Parvathy Puthanar is an artificial canal of 16.50 km length, stretching from Akkulam-Veli in the north to Kovalam in the south. The canal takes off from the Akkulam-Veli inlet and before ending up at Kovalam comes across a few openings to the sea, one of the important openings being Poonthurapozhi. On its path from Akkulam-Veli to Kovalam, the Parvathy Puthanar canal is joined by the Karamana River. Before it reaches this opening, the Karamana River joins this waterway. The Akkulam-Veli system is the boundary of the Project Area on the north, and from this system, the Parvathy Puthanar canal takes off. The Akkulam-Veli system does not have a perennial river draining into it. The water from a small catchment of about 10 sq km joins the Akkulam wetland on its eastern side. Along with this, considerable wastewater is brought by the Ulloor canal. The mouth of Veli opens up by the natural processes for a short period, when the fresh water flow into the wetland is high during the monsoon. During this period, it behaves like a typical coastal estuary; mudflats get exposed at Akkulam during low tide.

The salinity levels in the upstream reaches of the Akkulam-Veli system were less during the monsoon season. In order to maintain the water level in the Akkulam-Veli water body and

also to ensure flushing, the mouth at Veli is cut open from time to time in the non-monsoon season by the Water Resources Department.

The area further south of Poonthurapozhi is utilized for coconut husk processing and coir retting activities. The inflow of fresh water to the waterway is limited and confined to the monsoon season. This brings about stagnation of flow, and subsequently there is practically no flushing as such during the non-monsoon months. The area as such is not fit for navigation. People themselves are involved in blocking the waterway to suit their purposes. There are a few small islands within the water body in this stretch.

The Ulloor canal which drains into the Akkulam wetland brings in considerable wastewater from its urban catchment of about 10 sq km. During the summer season, the Ulloor canal carries only sewage flow. At the confluence of the Ulloor canal with the wetland, the DO values are very low and the total nitrogen values are high (**Fig 4**). Fresh water weeds have infested the upper reaches of the Akkulam wetland. Due to the deposition of nutrient-rich sediments in this area, weed growth is very high and the wetland is in a state of eutrophication. Large scale settlements are found on both the sides of the Parvathy Puthanar canal. The encroachers often occupied the very edge of the canal bank in certain stretches, especially in its middle reaches. Since the sanitation facilities in most of these households are very poor, it adversely affected the quality of water in the canal. Moreover, several sewage channels are joining the canal at different points, adding to the pollution load of the canal and the adjoining water bodies, and finally leading to the increase in nutrient loads, weed growth and decrease in D O.

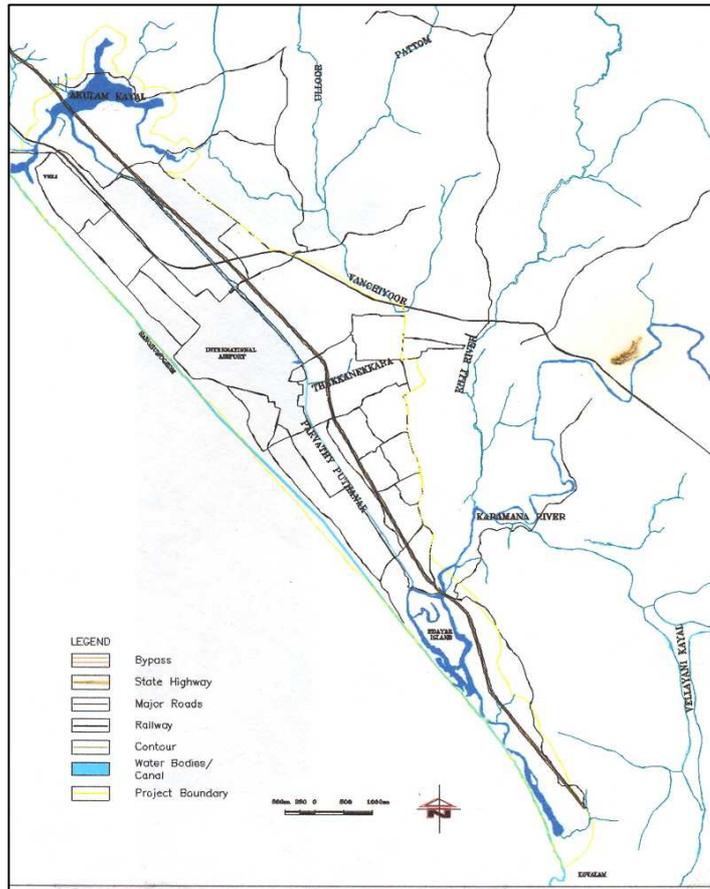


Fig. 4 Watercourses in parts of Trivandrum city

At Poonthurapozhi, in general the colour, turbidity and TDS were higher than the specification as per CPCB standards for Inland Surface Water. This is mainly due to stagnation of the water body. There was no freshwater flow from the Karamana river to the water body during the season under observation. The mouth at Poonthurapozhi is totally closed by the sand bar. Local people have been taking bath in the water near Edayar Island. Considerable weed growth was found in the water body near the island so much so that it was very difficult to navigate by boat through the water body. The chemical analysis of the water samples from Akkulam-Veli water body showed higher values of colour, turbidity, TDS, Nitrate, Phosphate and low values of DO at the station on the upstream end of Akkulam. All these indicate stagnation of water and subsequent impact on the water body.

The studies bring to light that there is a stagnation of water bodies due to the closing of the mouth at Veli and Poonthurapozhi. It also shows that the increase in the values of colour, turbidity, nutrients and weed growth are due to the lack of flushing and stagnation. The DO

values near the discharge points of municipal waste could have been brought down by flushing. There is a general trend towards eutrophication of these water bodies. In this light, it is suggested to keep the mouth at the Veli and Poonthurapozhi permanently open by constructing appropriate breakwaters and maintaining required draft.

Augmenting the flushing processes along with the preventive measures like effective sewage treatment, wherever possible through stand-alone waste water treatment plants, better sanitation, and awareness programmes, would go a long way in making the water body to serve its functions without creating any problems to the health and hygiene of the people residing in the area. The canal and associated ecosystem could be considerably restored by enhancing the flushing process with the fresh water input to the system from various sources, especially from the major single source, namely the Karamana river. The dispersion of pollutants would depend on the dynamic processes.

## **7.0 Conclusion**

Though the water quality in the upstream stretches of rivers of Thiruvnathapuram district are generally good and potable, the quality deteriorates as the rivers traverse through the thickly populated midland and more thickly populated lowland areas. Some of the streams in the highland region however are found to be contaminated due to the application of agro-chemicals. Contamination is often found in the stretches in the midland, especially near bathing ghats, pilgrimage areas and locations used for washing clothes.

The water quality of downstream reaches of rivers are obviously getting deteriorated due to several reasons, such as discharge of waste water from thickly populated areas, dumping of solid wastes, effluent discharge from industries non-point pollution due to unscientific application of agro-chemicals for crops , and also due to the other anthropogenic activities like coconut husk processing and sand mining.

An effective water quality management should address challenges of chemical and microbiological contaminants. An integrated approach involving all key stakeholders needs to be evolved for a meaningful, effective and efficient way of providing safe water, while also guarding against environmental deterioration. The data collecting agencies may be separated from users of data - to avoid compromises in monitoring and enforcement.

Enforceable rules to have desirable water quality standards are necessary for effective water quality management.

The general public can only participate in decision making on environmental health issues if it has access to information. The development of a relevant public participation policy may be ensured. It is proper to establish a dialogue to understand what the public wants from the professionals and vice versa. This can be done through information, education, communication development and capacity building. The water quality monitoring responsibility may be decentralized and in due course of time may be entrusted with panchayats. The panchayats or local bodies should be equipped with basic laboratories to carry out basic water quality monitoring, provide low cost training, analytical services and supporting low cost mitigation options.

We put forward an approach to water quality management based on Water Safety Plans (as recommended by WHO, 2014). Water safety plans identify ( i) all the potential hazards and associated risks of contamination (from source to consumer), (ii) the control measures proposed to control risks and ensure that health based targets are met, and (iii) independent mechanisms of surveillance that lead to corrective measures. A critical aspect of the programme would be to identify water quality hazards and control measures for different types of schemes, as well as the institutional roles and responsibilities to underpin the new approach to water safety planning. It is also suggested to develop Integrated Water Resources Management (IWRM) Plan for the river basins of Kerala. For ensuring safe water use, scientifically-based assessment of water supply vulnerability, addressing key factors such as hydrogeology, land use patterns and well characteristics, is urgently needed

## 9.0 References

- Central pollution Control Board, Water Quality Criteria,  
[http://www.cpcb.nic.in/Water\\_Quality\\_Criteria.php](http://www.cpcb.nic.in/Water_Quality_Criteria.php)
- CWRDM, and KSCSTE (2010-2015): Environmental Monitoring Programme on Water Quality (2010-15)
- Harikumar P S and Madhava Chandran (2013): Bacteriological Contamination of Groundwater due to Onsite Sanitation Problems in Kerala State: A case study, International Journal of Life Science Biotechnology and Plasma Research, 2 (3): 190-202.
- Harikumar P.S, Bindhya Mol.K (2012): A synoptic study on the preparation of a liquid waste management plan for Kerala state, India, Environment and Natural Resources Research..2 (2): 74-83.
- Indian Standard Drinking Water – Specification IS 10500:2012, Bureau of Indian
- Manjusha C M, Megha P U and Harikumar P S (2014). Isolation and Characterisation of Total Streptococci and Faecal Streptococci from Kuppam river basin in South west coast of India, Int.J.Curr.Microbiol.App.Sci, 3(3): 164-175
- Megha P. U., Kavya P. Murugan S and. Harikumar P. S (2015), Sanitation Mapping of Groundwater Contamination in a Rural Village of India Journal of Environmental Protection, 6 (1): 34-44 <http://dx.doi.org/10.4236/jep.2015.61005>
- Musthafa Odayooth Mavukkandy, Subhankar Karmakar & Harikumar PS (2014): Assessment and rationalization of water quality monitoring network: a multivariate statistical approach to the Kabbini River (India), Environ Science and Pollution Research, DOI 10.1007/s11356-014-3000-y,
- Sreejith K.P. , Rajeesh Kumar M.P., Kamalakshan Kokkal and Harikumar P.S.(2008) Comparison of water quality status of east and west flowing river basins of Kerala employing plankton and benthic analysis, Indian Journal of Environment and Eco planning, 15(3),463-470
- Trivandrum Corporation (2012): Trivandrum Master Plan 2012  
<http://www.corporationoftrivandrum.in/sites/default/files/tvm-corp-masterplan-draft-201304.pdf>
- World Health Organization (2014): Water safety plan: a field guide to improving drinking-water safety in small communities. New Delhi.

## Appendix 1: Water Sampling Stations in the Neyyar River Basin

Code No:	Station	Location		Description
01/N	Anamukham-I:	N 8° 30' 0.2''	E 77° 12' 7.7''	Rocky bed ; narrow channel; Mixed vegetation ;rubber plantation
02/N	Anamukham-II	N 8° 29' 59.7''	E 77° 12' 09.1''	Narrow channel with organic bed; rubber plantation
03/N	Mayam	N 8° 31' 44.1''	E 77° 10' 16.8''	Relatively undisturbed organic bed.
04/N	Koompichalkadavu	N 8° 30' 49.9''	E 77° 11' 22.7''	Ferry, small drainage joins stream; organic bed; rubber; coconut
05/N	Pantha	N 8° 31' 28.1''	E 77° 09' 59.0''	Small drainage joins the river; a bridge across; rubber
06/N	Marakkunnu	N 8° 32' 29.9''	E 77° 08' 29''	Side of the reservoir ; residential buildings on the banks ; domestic waste water discharge
07/N	Daivapram I	N 8° 31' 56.9''	E 77° 08' 57'	Margin of the reservoir, Rubber
08/N	Daivapuram II	N 8° 31' 43.3''	E 77° 09' 14.4''	Margin of the reservoir, Rubber
09/N	Spillway	N 8° 31' 55.8''	E 77° 08' 44.5''	Water (reservoir )tourism, bed with small to large pebbles, washing and bathing ghat, shallow stream, comparatively less flow
10/N	Perinjankadav	N 8° 32' 0.5''	E 77° 08' 6.8''	Steep channel with rock bed, a natural weir , small at site scale excavation of sand, faecal contamination , Mixed vegetation with settlement
11/N	Kallikkad	N 8° 31' 46.6''	E 77° 07' 38.9''	Faecal contamination , bathing and washing ghat; hollow brick manufacturing unit; Mixed vegetation with settlement.
12/N	Mylakkara	N 8° 31' 38.6''	E 77° 07' 36''	Cattle grazing; faecal contamination , a small bund ; washing and bathing ghat, pump house near by; mixed vegetation.
13/N	Keezharoor	N 8° 28' 0.5''	E 77° 05' 22.4''	Rocky bed; temple site; washing and bathing ghat; pump house nearby; Mixed vegetation with settlement.
14/N	Pazhamala Temple	N 8° 26' 57.3''	E 77° 06' 05''	Temple near by, pump house ; washing and bathing ghat; mixed vegetation.
15/N	Mandapathinkadavu	N 8° 29' 33.3''	E 77° 07' 26.5''	Pump house nearby; a small weir nearby; mixed vegetation especially banana
16/N	Mampazhakkara	N 8° 26' 27''	E 77° 05' 58.1''	Pump house nearby; Mixed vegetation with settlement.
17/N	Aruvippuram	N 8° 25' 37.0''	E 77° 05' 28.0''	Pump house nearby; faecal contamination; Mixed vegetation with settlement; Coconut dominated.
18/N	Neyyattinkara I	N 8° 24.0' 21.6''	E 77° 05' 32.0''	Domestic waste dumped; banks unstable; washing and bathing ghat, mixed vegetation with settlement.
19/N	Neyyattinkara II	N 8° 23' 52.2''	E 77° 05' 40.9''	Faecal contamination; washing and

				bathing ghat; dense riparian vegetation; Mixed vegetation with settlement.
20/N	Amaravila Bridge	N 8° 23' 24.8''	E 77° 05' 54.0''	Rocky bed, washing and bathing ghat; Mixed vegetation with settlement
21/N	Pirayummood Bridge	N 8° 22.0' 50.4''	E 77° 05' 14.0 ''	Shallow stream; washing and bathing ghat; faecal contamination; Mixed vegetation with settlement
22/N	Mavilakadavu	N 8° 20.1' 29.6''	E 77° 05' 22.1''	Bathing ghat; faecal contamination; Mixed vegetation with settlement
23/N	Arumanoor	N 8° 19.0' 53.7''	E 77° 04' 54.9''	Ferry; banks unstable; Mixed vegetation with settlement; Coconut dominated.
24/N	Poovar Bridge	N 8° 19' 9.7''	E 77° 04' 35.2''	A small rivulet joining the main stream; faecal contamination; sand mining; Urban/ agglomerated settlement; Coconut dominated.
25/N	Poovar Pozhikkara I	N 8° 18.0' 40.5''	E 77° 04' 26.1''	Just above the estuary; washing and bathing ghat; channel with mixed riparian vegetables; Urban/ agglomerated settlement.
26/N	Poovar Pozhikkara II	N 8° 18.0' 33.4''	E 77° 04' 40.7''	Estuary; tourist resort nearby; boating and tourism activities; severely eroding coast; Urban/ agglomerated settlement; Coconut dominated.

## Appendix 2: Water Quality Characteristics of the Neyyar River Basin

Sample Code	Water Quality Parameters								
	pH			TDS, mg/l			Total Hardness,mg/l		
	Post mon	Pre mon	Mon	Post mon	Pre mon	Mon	Post mon	Pre mon	Mon
01/N	7.02	7.09	7.8	34.01	103.616	30.59	20	12	12
02/N	6.49	7.2	7.8	29.96	105.792	21.63	8	20	12
03/N	6.98	7.17	8	20.13	45.18	20.42	12	12	8
04/N	6.83	7.13	8	22.57	59.392	19.58	12	20	8
05/N	6.08	6.82	7.6	21.48	35.456	23.17	16	16	12
06/N	7.06	7.22	8.4	19.1	43.712	17.92	12	12	4
07/N	6.68	7.51	8.3	16.08	44.864	18.3	12	12	16
08/N	6.05	7.87	8	21.35	44.8	17.34	12	8	12
09/N	5.93	7.27	8.3	27.46	81.152	18.69	16	20	8
10/N	5.98	7.13	7.8	24.18	68.608	22.784	16	16	8
11/N	6.46	7.24	8	25.01	67.456	20.992	12	12	8
12/N	6.82	7.23	8.2	24.31	68.288	20.8	16	20	8
13/N	7.22	7.72	7.9	27.2	86.06	31.04	20	16	12
14/N	6.71	7.23	8	32.77	85.89	32.77	16	12	8
15/N	7.26	7.05	8.2	25.92	82.3	25.92	16	16	8
16/N	6.57	7.68	7.8	33.79	95.36	33.79	16	16	12
17/N	6.43	7.31	7.7	29.44	83.71	29.44	16	16	8
18/N	6.14	7.03	7.8	31.17	108.74	31.17	20	20	12
19/N	7.1	6.93	7.6	32.9	89.22	32.9	20	16	12
20/N	6.54	6.94	7.8	33.34	90.56	33.34	32	20	8
21/N	6.16	6.92	8.2	33.37	94.66	34.37	24	16	12
22/N	6.06	6.79	8.2	158.08	635.52	158.08	28	56	32
23/N	6.58	6.73	8	674.56	3334.4	674.56	28	200	92
24/N	6.29	7.16	8.4	449.28	5785.6	449.28	60	356	64
25/N	6.21	6.6	8.2	5785.6	14400	5785.6	200	840	832
26/N	6.33	6.72	8.4	2496	18624	24960	236	880	4400

**Appendix 2: Water Quality Characteristics of the Neyyar River Basin (Contd.)**

Sample Code	Water Quality Parameters											
	DO, mg/l			BOD, mg/l			Total coliform, MPN/100 ml			E Coli		
	Post mon	Pre mon	Mon	Post mon	Pre mon	Mon	Post mon	Pre mon	Mon	Post mon	Pre mon	Mon
01/N	6.50	7.21	8.0	0.2	0.80	1.0	39	1100	≥2400	P	P	P
02/N	8.60	7.74	8.53	5.2	1.87	1.6	43	1100	≥2400	P	P	P
03/N	7.30	9.28	7.53	1.8	2.60	0.93	23	23	460	P	A	A
04/N	7.80	8.28	7.53	2.48	1.34	0.93	150	1100	23	P	P	A
05/N	7.20	7.74	8.13	3.33	2.40	3.07	≥2400	1100	460	P	P	P
06/N	7.30	6.94	7.93	2.06	1.87	1.33	1100	≥2400	≥2400	P	P	P
07/N	8.20	8.01	8.47	1.4	1.07	0.40	21	240	1100	A	A	P
08/N	7.50	7.74	7.40	2.33	2.13	1.33	23	43	460	P	A	P
09/N	8.60	9.08	7.80	2.37	2.94	1.53	3	460	460	A	P	P
10/N	6.70	8.01	7.60	0.49	2.41	1.20	1100	24	1100	P	A	P
11/N	8.20	8.01	7.40	2.2	2.67	0.67	210	210	1100	P	P	P
12/N	8.30	8.54	8.13	5.33	3.20	1.0	15	≥2400	460	P	A	P
13/N	7.50	7.21	7.93	1.93	2.67	2.73	43	240	460	P	P	P
14/N	8.0	8.28	7.73	2.87	0.27	1.33	460	460	1100	P	P	A
15/N	7.80	8.28	7.73	1.07	2.67	1.60	1100	240	150	P	P	P
16/N	7.80	8.28	8.07	5.93	2.67	2.47	460	460	≥2400	P	P	P
17/N	7.60	7.48	7.73	2.4	2.41	1.27	1100	1100	460	A	P	A
18/N	6.20	7.48	7.27	0.73	3.21	2.13	≥2400	210	460	P	P	P
19/N	7.07	8.01	8.27	2.74	4.54	1.53	39	≥2400	1100	P	P	P
20/N	7.07	7.48	7.27	4.87	1.07	1.93	240	≥2400	1100	P	P	A
21/N	5.06	7.21	6.80	1.24	3.47	1.93	1100	210	≥2400	P	P	P
22/N	6.73	9.08	7.60	3.66	1.07	2.47	210	460	≥2400	P	P	P
23/N	5.27	6.41	7.33	0.60	1.07	2.67	460	≥2400	240	P	P	P
24/N	7.53	6.94	8.07	2.20	3.74	2.33	≥2400	≥2400	1100	P	P	P
25/N	6.27	4.81	5.44	2.34	3.47	1.28	≥2400	≥2400	≥2400	P	P	P
26/N	9.6	7.21	8.32	1.0	2.40	1.28	≥2400	≥2400	43	P	P	P

P-Present A-Absent

### Appendix 3: Water sampling stations in the Karamana river basin

Sample Code	Sampling Point	Latitude	Longitude	Description
01/K	Peppara Dam	N 08°37' 26.9''	E77° 08'14.0''	Protected forest, Peppara wild life sanctuary, reservoir, (biological sampling)
02/K	Thekkinkala	N 08°35' 52.4''	E77° 05'52.5''	Mixed vegetation with settlement, bathing and washing centre, thick riparian vegetation, and two small rivulets join just before this site.
03/K	Aryanadu	N 08°34' 45.4''	E77° 05'08.5''	Urban and agglomerated settlement, washing and bathing centre, thick riparian vegetation.
04/K	Aruvikkara Dam	N 08°34' 24.3''	E77° 01'16.4''	Mixed vegetation with settlement, reservoir, Dam tourism, biological station
05/K	Irumba Junction	N 08°33' 53.4''	E77° 00'12.5''	Mixed vegetation with settlement, bathing and washing area, thick riparian vegetation and flow is reduced.
06/K	Melekkadavu	N 08°32' 21.6''	E77° 00'23.5''	Mixed vegetation with settlement, an orphanage and a temple present nearby, thick riparian vegetation, cobbles present, washing and bathing area, a stream Meenampallithodu which carries wastes from a waste treatment plant situated in Vilappilsala discharges just before this site, the flow rate is comparatively high .
07/K	Vellekkadavu	N 08°31' 57.8''	E77° 06'42.1''	Mixed vegetation with settlement, daily market place, washing and bathing area, one streamlet Vettiymthod joins here, vegetation dominated by coconut palms, (biological sampling).
08/K	Kundamankadavu	N 08°30' 30.1''	E77° 00'12.3''	Mixed vegetation with settlement, washing and bathing area.
09/K	Mangattukadavu	N 08°29' 55.6'' E77° 00'15.5''		Mixed vegetation with settlement, temple nearby, KWA intake point, washing and bathing centre, vegetation dominated by coconut palms, thick riparian vegetation.
10/K	Thrikkannapuram	N 08°28' 27.7''	E77° 00'06.4''	Mixed vegetation with settlement, sandmining prevailed, vegetation dominated by coconut palms, (biological sampling).
11/K	Mudavanmugal	N 08°29' 03.3''	E76° 59'09.7''	Urban and agglomerated settlement, Drainage containing domestic effluents nearby, washing and bathing area, ferry

12/K	Pappanamkode	N 08°28' 19.8''	E76° 58'59.8''	Urban and agglomerated settlement, industrial estate, small discharge from KSRTC service centre nearby, oily appearance in the water, flow is reduced, washing and bathing centre, contamination visible.
13/K	Karamana	N 08°28' 43.4''	E77° 58'12.3''	Urban and agglomerated settlement, temple site, washing and bathing area, mixed vegetation, school nearby.
14/K	Vellayani Kayal	N 08°27' 05.9'' ''	E77° 58'02.4	Urban and agglomerated settlement, regulator cum bridge across, thick riparian vegetation, narrow channel
15/K	Pallathukadavu	N 08°27' 14.4''	E77° 57'37.0''	Urban and agglomerated settlement, mixing point of the two streams viz, Vellayani kayal, Killiyar, ferry, mixed vegetation, bathing and washing area, biological station.
16/K	Killiyar	N 08°27' 58.9''	E76° 57'36.4''	Urban and agglomerated settlement, main tributary of Karamana river, bathing and washing area, rocky bed, high flow
17/K	Thiruvallam	N08°27'59.0''	E76° 57'36.5''	Urban and agglomerated settlement, site just before Parvathi puthanar joins the river, a small drainage joins the river, the famous Parasurama temple nearby, the site is locally known as Balikadavu as here some holy activities like forfeit of animals taking place, temple wastes are visible in the water, faecal contamination is also visible in the banks. (biological station).
18/K	Parvathi Puthanaar	N 08°26' 28.2''	E76° 57'09.5''	Urban and agglomerated settlement, a canal which joins the river, contaminated with domestic effluents, drainage and sewage. Blackish in colour, oily appearance, and offensive smell is noted, infested with water hyacinth and floating weeds.
19/K	Pachalloor	N 08°25' 31.5''	E76° 57'35.1''	Urban and agglomerated settlement, estuary, boat jetty, vegetation dominated by coconut palms, tourism activities prevailed, resorts nearby.
20/K	Kovalam	N 08°24' 24.1''	E76° 58'40.2''	Urban and agglomerated settlement, a portion of the river resides adjacent to the sea, a small stagnant strip of the river, flow is much reduced, retting area, tourism activities prevailed, resorts nearby, infested with weeds and water hyacinth.

#### Appendix 4. Water Quality Characteristics in the Karamana River Basin

Sample Code	Water Quality Parameters								
	pH			TDS, mg/l			Total Hardness,mg/l		
	Post mon	Pre mon	Mon	Post mon	Pre mon	Mon	Post mon	Pre mon	Mon
01/K	6.78	6.64	5.97	14.34	15.37	17.75	8	16	12
02/K	6.56	6	5.67	15.17	15.5	18.26	8	16	12
03/K	6.88	6.11	5.78	16.7	19.68	24.95	8	12	16
04/K	6.4	6.41	5.93	17.66	24.11	24.18	8	12	16
05/K	6.22	6.08	5.63	20.35	33.76	27.07	8	16	20
06/K	6.36	6.2	4.39	21.82	49.38	28.16	8	20	12
07/K	6.35	6.82	5.69	23.62	51.95	29.64	8	20	24
08/K	6.35	6.51	6.37	25.09	57.55	48.1	8	24	20
09/K	6.25	6.83	6.34	23.36	59.41	57.42	12	28	24
10/K	6.36	6.65	6.43	26.88	61.28	58.32	12	20	28
11/K	6.31	6.64	6.29	28.61	62.11	62.63	12	28	24
12/K	6.08	6.43	6.5	35.58	59.03	66.61	8	20	28
13/K	6.05	6.52	6.14	27.14	195.47	625.64	8	44	92
14/K	6.07	6.31	6.61	44.22	90.86	106.87	24	28	32
15/K	6.24	6.68	6.47	35.52	1149.04	3272.87	16	172	440
16/K	6.43	6.38	7.11	81.54	151.11	244.98	28	52	56
17/K	6.4	6.68	6.49	73.54	2051.17	2617.01	24	284	0
18/K	6.43	6.7	6.39	746.88	3806.56	2867.78	140	240	404
19/K	6.4	6.84	6.65	318.08	2494.84	15046.2	64	332	3600
20/K	6.57	7.72	6.47	216.96	552.98	2784.19	64	152	1200

**Appendix 4. Water Quality Characteristics in the Karamana River Basin (Contd.)**

Sample Code	Water Quality Parameters											
	DO, mg/l			BOD, mg/l			Total coliform, MPN/100 ml			E Coli		
	Post mon	Pre mon	Mon	Post mon	Pre mon	Mon	Post mon	Pre mon	Mon	Post mon	Pre mon	Mon
01/K	8.53	8.67	7.20	2.13	2.74	0.73	≥2400	≥2400	≥2400	P	P	P
02/K	8.67	8.20	8.07	1.94	2.93	1.07	1100	≥2400	≥2400	P	P	P
03/K	8.67	7.50	8.00	1.80	1.43	1.33	≥2400	≥2400	≥2400	P	P	P
04/K	8.53	5.93	6.00	0.66	1.33	2.27	≥2400	≥2400	≥2400	P	P	P
05/K	7.20	6.73	7.13	0.67	3.53	1.00	240	≥2400	≥2400	P	P	P
06/K	7.93	8.20	8.20	0.53	1.33	1.93	≥2400	460	≥2400	P	A	P
07/K	8.33	11.53	9.80	1.33	6.73	3.73	≥2400	210	≥2400	P	P	P
08/K	8.13	7.67	6.93	1.60	2.80	2.47	≥2400	≥2400	≥2400	P	A	P
09/K	7.73	7.87	6.67	0.06	7.67	1.93	1100	≥2400	≥2400	P	P	P
10/K	8.07	7.40	6.60	1.34	1.13	2.33	460	210	≥2400	P	P	P
11/K	8.13	8.13	6.07	2.73	2.80	1.60	≥2400	≥2400	≥2400	P	P	P
12/K	7.53	7.73	5.33	1.46	2.13	1.13	≥2400	≥2400	≥2400	P	P	P
13/K	7.40	6.60	5.33	1.00	10.67	1.47	≥2400	≥2400	≥2400	P	A	P
14/K	2.40	3.33	3.73	2.20	11.33	32.89	≥2400	≥2400	≥2400	P	A	P
15/K	7.53	5.13	3.53	2.33	3.06	1.07	≥2400	≥2400	≥2400	P	P	P
16/K	6.60	4.00	3.47	2.93	3.80	30.89	≥2400	≥2400	1100	P	P	P
17/K	6.07	6.13	0.00	3.87	7.33	0.00	≥2400	≥2400	NT	P	P	NT
18/K	2.47	0.00	0.00	1.94	20.00	39.11	≥2400	≥2400	≥2400	P	P	P
19/K	2.53	0.93	3.67	2.26	8.00	34.89	93	≥2400	≥2400	P	P	P
20/K	9.20	3.73	4.00	8.33	4.67	28.67	≥2400	210	≥2400	P	P	P

NT-Not Taken; P-Present; A- Absent

**Appendix 5: Water Sampling Stations in the Vamanapuram River Basin**

<b>Sampling code</b>	<b>Sampling station</b>	<b>Latitude(N)</b>	<b>Longitude(E)</b>
VM 1	Kallar Bridge	8 <sup>0</sup> 42' 35.0424''	77 <sup>0</sup> 7' 44.1984''
VM2	Annappara	8 <sup>0</sup> 42' 36.4068''	77 <sup>0</sup> 7' 45.966''
VM 3	Chettachal bridge	8 <sup>0</sup> 41' 34.9224''	77 <sup>0</sup> 7' 44.1984''
VM 4	Manjappara Bridge	8 <sup>0</sup> 42' 35.0424''	77 <sup>0</sup> 4' 10.2846''
VM 5	Palode Bridge	8 <sup>0</sup> 42' 29.9484''	77 <sup>0</sup> 3' 50.1912''
VM 6	Chelanchi	8 <sup>0</sup> 42' 44.2188''	77 <sup>0</sup> 1' 36.0228''
VM 7	Aruvipuram Bridge	8 <sup>0</sup> 42' 17.3016''	77 <sup>0</sup> 7' 58.6848''
VM 8	Vellumanadi Bridge	8 <sup>0</sup> 43' 36.8436''	76 <sup>0</sup> 53' 53.734''
VM 9	Vamanapuram Bridge	8 <sup>0</sup> 41' 28.888''	76 <sup>0</sup> 54' 26.1576''
VM 10	Ayillam	8 <sup>0</sup> 46' 7.7448''	76 <sup>0</sup> 52' 58.5588''
VM 11	Nellimood	8 <sup>0</sup> 43' 27.012''	76 <sup>0</sup> 51' 54.6084''
VM 12	Aatingal bridge	8 <sup>0</sup> 42' 41.3712''	76 <sup>0</sup> 50' 40.3872''
VM 13	Kollampuzha Bridge	8 <sup>0</sup> 42' 32.8572''	76 <sup>0</sup> 48' 48.7692''
VM 14	Pulimootukadavu	8 <sup>0</sup> 40' 48.99''	76 <sup>0</sup> 47' 56.7492''
VM 15	Anathalavattam	8 <sup>0</sup> 39' 36.1584''	76 <sup>0</sup> 46' 49.9296''

**Appendix 6: Water Quality Characteristics in the Vamanapuram River Basin**

Sample Code	Water Quality Parameters								
	pH			TDS, mg/l			Hardness, mg/l		
	Pre mon	Mon	Post mon	Pre mon	Mon	Post mon	Pre mon	Mon	Post mon
VM 1	6.47	7.42	7.59	172	20.4	57.51	24	28	12
VM2	6.47	7.38	7.41	192	21.3	56.8	24	12	8
VM 3	6	7.39	7.32	226	26.4	77.39	16	8	12
VM 4	6.44	6.85	7.12	222	26	70.29	16	28	20
VM 5	6.45	7.06	7.01	268	28.9	69.58	36	12	12
VM 6	6.52	7.6	7.2	224	29.7	58.93	12	12	12
VM 7	6.51	7.3	7.14	261	53.8	45.44	24	12	12
VM 8	6.41	7.15	6.9	271	38.4	90.17	20	16	16
VM 9	6.53	7.5	7.09	275	32.2	83.07	20	12	16
VM 10	6.42	7.38	7.01	123	35.1	70.29	28	16	12
VM 11	6.52	7.34	7.21	174	37.5	73.13	20	20	20
VM 12	6.51	7.09	7.92	407	39.1	74.55	16	16	20
VM 13	6.5	7.02	8.07	349	48.5	69.58	24	24	16
VM 14	6.5	6.98	8.01	1400	229	99.4	124	20	20
VM 15	6.02	6.97	7.52	6714	3820	3009.69	1200	380	284

**Appendix 6: Water Quality Characteristics in the Vamanapuram River Basin (Contd.)**

Sample Code	Water Quality Parameters											
	DO, mg/l			BOD, mg/l			Total coliform, MPN/100 ml			E Coli		
	Pre mon	Mon	Post mon	Pre mon	Mon	Post mon	Pre mon	Mon	Post mon	Pre mon	Mon	Post mon
VM 1	9.93	4.87	8.8	3.67	0.33	1.13	≥2400	240	≥2400	P	A	A
VM2	8.27	5.07	8.53	1.2	1.07	0.07	≥2400	460	≥2400	A	A	P
VM 3	8.73	4.93	7.27	2.33	0.6	0.6	75	≥2400	≥2400	A	P	P
VM 4	8.33	9.67	8.47	2.33	6.2	3.67	≥2400	1100	75	P	A	P
VM 5	7.87	13.67	8.47	2.87	10.27	0.47	23	≥2400	≥2400	A	P	A
VM 6	9.8	4.93	8.67	2.73	1.47	1.4	9	≥2400	≥2400	A	P	A
VM 7	7.13	4.67	8.53	1.07	0.4	2.13	≥2400	≥2400	≥2400	P	P	P
VM 8	7.33	4.27	7.4	1.27	1.73	4.27	≥2400	460	≥2400	P	P	P
VM 9	8.13	5	8.33	2.4	0.6	1.8	≥2400	≥2400	460	P	P	A
VM 10	6.73	4.13	7	3.73	0.13	0.67	≥2400	≥2400	≥2400	P	P	P
VM 11	6.67	4.53	7.6	1.13	0.4	1.13	1100	≥2400	≥2400	A	P	P
VM 12	2.27	4.2	7.73	0.93	0.53	1.07	≥2400	≥2400	93	P	P	P
VM 13	7.07	5.53	7.33	1.47	0.93	1.13	≥2400	≥2400	11	P	P	A
VM 14	6.13	5.87	8.2	2.27	2.27	2.13	≥2400	≥2400	≥2400	P	P	P
VM 15	6.87	3.33	4.07	3.67	0.47	0.27	≥2400	≥2400	210	P	P	P