*Draft Final Report*

# Carrying Capacity Based Developmental Planning for Greater Kochi region

*(Volume II)*

Sponsor :
Ministry of Environment & Forests,
New Delhi

National Environmental Engineering Research Institute (NEERI),
Nehru Marg, Nagpur - 440 020

November 2001

# *Chapter III*

# Existing Scenario Environmental Quality

# 3.0 EXISTING SCENARIO: ENVIRONMENTAL QUALITY

## 3.1 Air Environment

### 3.1.1 Ambient Air Quality Status: Analysis of Secondary Data

#### 3.1.1.1 NAAQM Reports: 1990-1998

Under National Ambient Air Quality Monitoring (NAAQM) program, air quality in the city of Kochi is being monitored regularly by NEERI, for the past two decades with respect to major primary pollutants viz., SPM, $SO_2$, $NO_2$ and $NH_3$. Season-wise summary of ambient air quality status is presented in **Table 3.1.1.1** along with the details of sampling locations. The annual air quality trends for the period 1990 to 1998 in different types of zones with respect to SPM, $SO_2$, $NO_2$ and $NH_3$ in Kochi city are presented in **Figs. 3.1.1.1 through 3.1.1.4.** Additional parameters, like Hydrogen Sulfide ($H_2S$), and PM-10 are also being monitored since 1991.

Air pollution profile in Kochi indicates that annual average SPM concentration exceeds the CPCB standard of 140 $\mu g/m^3$ on some occasions. The concentrations of $SO_2$ and $NO_2$ are well below CPCB standard for mixed-use areas. Ambient ammonia levels show that industrial areas recorded higher concentrations followed by commercial and residential areas. Maximum values of ammonia ranged from 326 to 991 $\mu g/m^3$ with the maximum value observed as 950 $\mu g/m^3$ at FACT site.

The rainwater analysis of the Kochi urban centre indicates that pH of the first rain event after summer is always lower than that of the subsequent rains. Minimum pH of 4.8 was observed at Kochi during the first rain event while the average pH of all precipitation events ranged from 5.2 to 6.4. Presence of high water-soluble ions as indicated by conductivity was also recorded in first rain event (415 $\mu$S/cm).

The anionic analysis of rainwater confirmed the presence of high sulphate contents 125 mg/L $SO_4$ (max value) and chloride 35 mg/L (max value). The presence of sulphate in rain water can be attributed to conversion of anthropogenically originated $SO_2$ to $SO_4$ due to climatic influence of Kochi region while high chloride content can be primarily attributed to nearness of sea. Nitrate content in rainwater was, however, found to be low, (0.07 to 2.6 $\mu$g/L).

RSPM to SPM ratio in Kochi is 0.5. The 98$^{th}$ percentile values of RSPM ranged from 148 to 390 $\mu g/m^3$. The 8 hourly maximum RSPM concentration of 623 $\mu g/m^3$ was recorded at a commercial site (1991-98). The RSPM levels were found to exceed the CPCB standard for mixed use areas **(Fig. 3.1.1.5)**.

#### 3.1.1.2 Studies Carried out by NEERI from Aug 1989 to Dec 1990

Air pollution studies were carried out in Kochi city by NEERI continuously for a period of 17 months from Aug 1989 to Dec. 1990 under the directives of Hon'ble High Court of Kerala. In total 20 sampling locations were selected in the Kochi city representing residential (3), commercial (5), industrial (8) and mixed area (4) categories. Four pollutants SPM, $SO_2$, $NO_2$, and $NH_3$ were monitored at all the sites as per the CPCB standard procedures. At each site, sampling was done at least for 4 days in a month. SPM was monitored on 24 hrly basis, whereas gaseous pollutants were monitored on 8 hrly basis (10 - 18 hrs, 18 - 02 hrs and 02 - 10 hrs). A fixed schedule for AAQM program was followed and in total 80 SPM samples, and 240 gaseous samples for each gaseous pollutant was collected every month.

The details of sampling locations are given in **Table 3.1.1.2**. Season-wise status of ambient air quality with respect to SPM, $SO_2$, $NO_2$, and $NH_3$ in Kochi city is presented in **Figs. 3.1.1.6 through 3.1.1.9** respectively for different activity zones. The collected data is summarized and represented season wise (Monsoon, Winter and Summer) AAQ status and compared with stipulated CPCB Standards.

The average ambient SPM levels as recorded during the entire period of 17 months in Kochi city comprising over 1400 samples from all the 20 sampling locations in Cochin region indicated lower concentration. The average SPM concentration recorded at 20 stations (taken together) was around 112 $\mu g/m^3$. The data was analyzed to assess the status during five seasons; namely two monsoons, (1988 & 1989), one summer (1989) and two winters (1988 & 1989). The average SPM concentration in monsoon season was observed to be 87 $\mu g/m^3$ while during summer it was 116 $\mu g/m^3$, and in winter, it was observed to be 135 $\mu g/m^3$. In general, the average SPM levels at most of the sites did not exceed concentration level of 200 $\mu g/m^3$, the limit promulgated by CPCB. Different sampling locations were categorised under four different groups depending on the influence of residential, commercial, industrial, and mixed activities.

Among all the sampling stations, Udyogmandal industrial area showed relatively high levels in comparison to other stations. The average SPM concentrations were recorded to be 139, 209, and 233 $\mu g/m^3$ in monsoon, summer and winter seasons respectively **(Fig. 3.1.1.6)**. A maximum value to the tune of about 470 $\mu g/m^3$ was recorded on one occasion at Udyogmandal industrial area.

During the entire period of study, the maximum average $SO_2$ concentration was observed to be 44 $\mu g/m^3$. Out of the 20 sampling stations studied, at eleven sampling locations not even a single (maximum) value of $SO_2$ exceeded 80 $\mu g/m^3$, the limit set up by CPCB, indicating that the $SO_2$ pollution levels does not pose significant problem in most of the areas in Kochi city. However, higher levels of $SO_2$ were observed in Udyogmandal and Binanipuram industrial zones. Except at these two, at most of the other stations, even the 5% of the values recorded did not exceed the value of 80 $\mu g/m^3$ **(Fig. 3.1.1.7)**.

The concentrations of $NO_2$ at all the sampling sites for the entire study period were low, except at Udyogmandal, where a single maximum value of 375 $\mu g/m^3$ was observed. Such a high value could only be attributed to the local activities within the vicinity of sampling site. It is observed that at none of the sampling sites the $NO_2$ concentration exceeded the value of 80 $\mu g/m^3$, indicating that $NO_2$ levels do not pose any problem to the region **(Fig. 3.1.1.8)**.

Significant levels of ammonia were recorded at almost all the sampling sites. A perusal of **Fig 3.1.1.9** shows that the average ammonia concentration at all the sampling sites during monsoon season was 36 μg/$m^3$ (maximum 900 μg/$m^3$), while in winter and summer the ammonia concentrations were 42 μg/$m^3$ (max. 850 μg/$m^3$) and 54 μg/$m^3$ (maximum 886 μg/$m^3$) respectively. The average ammonia concentration at stations influenced by industrial activity was 68 μg/$m^3$ as against 44 μg/$m^3$ recorded at commercial zone while in other areas; residential and mixed category zones it was around 30 μg/$m^3$. Even though the average $NH_3$ concentration has not reached alarming proportions but a close look at the data definitely shows that frequency of occurrence of ammonia at concentrations of 100 μg/$m^3$ and above is high.

During summer, at almost all stations except a few ammonia values exceeded 100 μg/$m^3$, the standard proposed by KSPCB. In addition the values recorded during winter and monsoon seasons at a number of sampling stations indicate that the value of 100 μg/$m^3$ has been exceeded. The average $NH_3$ concentration at Udyogmandal during the entire period of study was 180 μg/$m^3$ and its level exceeded 100 μg/$m^3$ for 50% of the time period. Single maximum values of 907, 850 and 641μg/$m^3$ were recorded in monsoon, winter and summer seasons respectively. Udyogmandal area, therefore, appears to be the major polluted region with respect to $NH_3$.

### 3.1.1.3 EIA Study for Cochin Refineries Limited (CRL), Kochi

Further, studies were carried out by NEERI in Kochi in 1990 and 1991 during which AAQ monitoring was done at 16 locations representing 9 residential, 2 industrial and 5 rural areas within 10 Km radial area around Cochin Refinery. The details of sampling locations with respect to Cochin Refinery are shown in **Table 3.1.1.3.** Major air pollutants, viz., SPM, $SO_2$, $H_2S$, $NO_2$ and $NH_3$ and mercaptans were monitored.

The samples were collected round the clock during the study period. Gaseous pollutant samples, viz. $SO_2$, $NO_2$ and $NH_3$ were collected on 8 hrly basis by drawing air at a flow rate of 0.5 lpm through the absorbing media. SPM samples were collected on 24 hrly basis by drawing air at a flow rate of 1-1.5 $m^3$/min through glass fiber filter paper as stipulated in the standard methods. The summary of results is presented in **Table 3.1.1.4.**

The mean SPM concentration measured at all the 16 AAQMS studied in this study and additional stations covered during the previous study period in 1989 ranged widely from 84 to 249 μg/$m^3$. The variation in SPM concentrations as recorded at different stations is primarily governed by the local phenomena, viz; traffic or local village or agricultural activities leading to reentrainment of settled dust. Increase in humidity near coastal area and the higher density of surrounding vegetation resulted in low ambient dust levels. Ambient monitoring at Thripunithura showed occasional high SPM concentration to the tune of 352 μg/$m^3$ with an average of 191 μg/$m^3$.

The maximum $SO_2$ concentration of 59 μg/$m^3$ at Thripunithura residential area was within the limits. The average $SO_2$ concentration at all the monitoring sites ranged from 6 to 20 μg/$m^3$. In general, the monitoring stations located within 1-4 Km radius of the refinery occasionally recorded high concentrations depending upon the wind direction whereas, distant stations located in down wind direction (area within 10 Km), recorded high levels but with low occurrence frequency. The maximum concentration of $NO_2$ was found to be within the preferred limit at all the sites and the average concentrations were in the range of 6-13 μg/$m^3$.

The average $NH_3$ concentration recorded at Thrikkakara exceeded 100 μg/$m^3$, which is the standard recommended by KSPCB. The maximum concentration of ammonia ranged from 71 to 337 μg/$m^3$, whereas the average concentration varied from 17 to 102 μg/$m^3$. Higher concentrations of ammonia in ambient air may be attributed to the presence of other surrounding industries in the region, as there is no major source of $NH_3$ within the refinery complex.

The concentration of $H_2S$ was found to be below detection limit at most of the sampling stations except at few locations where the maximum values found to vary between 14 and 50 μg/$m^3$ and averages vary between 3 and 24 μg/$m^3$. Concentrations of mercaptans (RSH) in ambient air were found to be below 3 μg/$m^3$, the detectable limit of the method used at all the sampling sites.

The diurnal variation in ambient air quality status with respect to SPM, $SO_2$, $NO_2$ and $NH_3$ is presented in **Table 3.1.1.5** for the year 1990 and 1991, which indicate that all the average values are well within the standards.

### 3.1.1.4 AAQ Data for Ernakulam and Kottayam during 1993-1999

Ambient air quality for Ernakulam and Kottayam cities is being regularly monitored by Kerala State Pollution Control Board (KSPCB) since 1993 under the NAAQM programme monitoring for major critical pollutants, viz. SPM, $SO_2$ and $NO_2$ was carried out twice a week at three sites representing industrial, commercial and residential areas throughout the year. SPM is monitored on 8 hrly basis whereas $SO_2$ and $NO_2$ are monitored on 4 hrly basis. The data so generated has been analyzed for different seasons and as summarized in **Table 3.1.1.6** for the year 1993-1999. In winter season, average concentration of SPM in residential / commercial area of Ernakulam, Iruparan, Kottayam, Chingavanam was 138, 421, 236 and 170 μg/$m^3$ respectively, whereas in summer these were 245, 428, 215 and 205 μg/$m^3$. The SPM concentrations were occasionally found exceeding the CPCB standards of 200 μg/$m^3$.

Maximum average $SO_2$ concentration was observed to be 43 μg/$m^3$ in winter season and Eloor industrial area whereas in residential areas, it was 26 μg/$m^3$. Average $NO_2$ concentrations were found in the range of 18 to 101μg /$m^3$ at all the sampling locations and found to exceed the allowable level of 80 μg/$m^3$.

### 3.1.1.5 Ambient Air Quality Status : Analysis of Primary Data

Primary data on AAQ was collected at 58 locations representing industrial, commercial residential and sensitive areas (IA, CA, RA, SA) spread over the whole study area during 1999 – 2000. Monitoring network consisted of sampling

The air quality indices for different seasons in different activity zones are summarized in **Table 3.1.1.9,** which indicate, in general, that the air quality in Kochi falls under the category of good.

Further, AQI values for three sites in Ernakulam and two sites in Kottayam are estimated for different seasons making use of the data collected between the years 1993 and 1999. In general the air quality indices status in Ernakulam and Kottayam district is found to vary between fair and dangerous categories, as summarized in **Table 3.1.1.10**. Air quality indices estimated based on the primary data collected at industrial, residential/commercial and sensitive areas in all the districts of GKR are presented in **Table 3.1.1.11**, which indicates that in general, the air quality status lies between fair to excellent categories. However, there may be a few localized pockets, where the AAQ may be poor or bad.

## 3.1.2 Emission Inventory

The emission inventory data for the whole GKR was categorized into three main sources types as point (industrial), area (domestic), and line (vehicular) sources. Data required for emission inventory and emission loads with respect to different pollutants are presented here for each source category.

### 3.1.2.1 Point Sources

In the present context, industrial stacks are referred to as point sources. Details about these stack emissions collected by KSPCB show that point sources in GKR are located mainly near towns and urban areas. Industries are present in pockets outside the towns like Kalamassery, Udyogmandal, Aluva, Cherthala, Kottayam etc. Details of major air polluting industries are given in **Table 3.1.2.1** for each district, along with products, production capacity and type of industrial sector as well.

Kochi-Ernakulam region carries majority of the industrial population as compared to other districts in GKR, like; Alappuzha and Kottayam. Because Ernakulam has better infrastructure, road network and port facilities, large-scale industries (LSI) are mostly concentrated near Ernakulam, accommodating in total, 72 LSI and 64 MSI units. The region has refineries, chemical and fertilizer industries. Other Medium scale industries include textile, dye making, rubber, food processing etc. Stack heights of these industries vary from 20 to 45 m with diameter varying from 0.3 to 2.0 m. The exit gas volumetric flow rate varies from 300 to 12,000 $m^3$/hr.

Alappuzha district has around 36 LSIs, which include food processing (marine fisheries), steel fabricating, textile, glass manufacturing industries etc. Stack height in these industries varies from 3 to 30 m with an average flow rate of about 2000 $m^3$/hr. The next largest industrialized district is Kottayam district, having 6 LSIs, which includes a tyre manufacturing, two paper, a cement and an electrochemical industry. Stack heights in these industries vary from 5 to 70 m with diameter ranging 0.2 to 3.5 m. Volumetric discharge rate varies from 600 to 30,000 $m^3$/hr.

at Alappuzha (6), Ernakulam (34), Kottayam (5), Pathanamthitta (4), Thrissur (4) and Idukki (5) districts. The details of sampling stations are given in **Table 3.1.1.7** along with area classification and distance from Jos junction (Ernakulam) for each site. Five major primary pollutants viz., SPM, RSPM, $SO_2$, and $NH_3$, were monitored on 8 hrly basis following the standard procedure suggested by CPCB. Sampling was carried out at each station for 6-7 days continuously, thus yielding 18-21 values for each pollutant. The data so collected was statistically analysed for maximum, minimum, average and standard deviations values as summarized in **Table 3.1.1.8** for all the sampling locations in GKR.

In Alappuzha District average concentration of different pollutants; SPM, RSPM, $SO_2$, $NO_2$, $NH_3$, was found to be in the range of 24-85 $\mu g/m^3$, 45-154 $\mu g/m^3$, 4-18 $\mu g/m^3$, 7-24 $\mu g/m^3$ and 3-31 $\mu g/m^3$, respectively at all the 6 sampling locations.

In Ernakulam district, average concentration of SPM, RSPM, $SO_2$, $NO_2$, and $NH_3$, was in the range of 10-140 $\mu g/m^3$, 5-424 $\mu g/m^3$, 3-9 $\mu g/m^3$, 12-52 $\mu g/m^3$ and 7-37 $\mu g/m^3$ respectively. The level of different pollutants was recorded in the similar range in other districts. In general, the concentration of various pollutants measured in GKR was found to be within the CPCB prescribed levels. Average ambient air quality status in each district for different pollutants is presented in **Fig. 3.1.1.10**.

### 3.1.1.6 Air Quality Index

Air quality indices have been estimated using air quality data from all the studies (as described earlier) carried out by NEERI in Kochi region during the period extending from 1988 to 1998. Oak Ridge air quality index (ORAQI) is computed by using the following equation :

$$AQI = \left[ 39.02 \sum_{i=1}^{3} (X_i/X_s) \right]^{0.967}$$

Where,

$X_i$ = Concentration of individual pollutant (SPM, $SO_2$, and $NO_2$)

$X_s$ = CPCB Standards for 24 hrs annual average for the corresponding pollutant

The descriptor categories for AQI are :

| | | |
|---|---|---|
| AQI | : < 20 | Excellent |
| AQI | : 20-39 | Good |
| AQI | : 40-59 | Fair |
| AQI | : 60-79 | Poor |
| AQI | : 80-99 | Bad |
| AQI | : >100 | Dangerous |

### 3.1.3.1 Surface Meteorological Parameters

*3.1.3.1.1 Air Temperature*

The three hourly air temperature values for all months based on the analysis of secondary data of Kochi are shown in **Table 3.1.3.3.** Highest temperatures are recorded during the months of March and April. May shows large variations in the temperature values, which is attributed to the frequent pre monsoon thundershowers occurring in this month.

The monthly mean values of the daily maximum, minimum, and the average temperatures are given in **Table 3.1.3.4**. The highest maximum temperature (≈33.0°C) occurs in April and the lowest minimum temperature (≈22.5°C) occurs in January. The diurnal range decreases from January to June and increases from August to December. In July, the month of maximum rainfall, the temperature range shows higher magnitude than that of other months. The mean temperature shows a gradual increase from January to April, then decreases during monsoon months till August and thereafter increases gradually. The mean temperature value during the peak southwest monsoon period is more or less same as that of winter months.

The diurnal variation of temperature at the five stations based on the primary data collected during the study period is shown for the four different seasons in **Fig. 3.1.3.2**. Monthly variations of mean maximum and minimum temperature for five stations are given in **Fig. 3.1.3.3**. It is observed that except Kulamavu, all other stations show almost similar pattern of temperature variation. At kulamavu, the mean temperature is always less by a minimum of about 5°C for most of the months.

Analysis of time series data on temperature measured at the five different stations shows that there is a gradual decrease in temperature from the beginning of winter season till the end of the season in all stations except Kottayam. In the case of Kottayam, infact, a small increase in temperature has been observed from November. From March onwards, there is a gradual increase in temperature as summer season professes in most of the stations. However, this increase is not much prominent in the case of Kottayam and Kulamavu since both are inland stations in comparison to the other stations. Temperature at all stations shows a decreasing trend from middle of May onwards due to the arrival of pre-monsoon showers and the subsequent monsoon. It has been noticed that minimum temperature had gone below by 15° C only in the case of Kulamavu during winter and all other stations recorded temperature above this value.

*3.1.3.1.2 Relative Humidity*

Since GKR study region falls in coastal region, humidity measured is comparatively higher. It goes below 50% only during the hot hours of winter season. Month-wise three hourly values of relative humidity for Kochi, are given in **Table 3.1.3.5**. It can be seen that RH is maximum around 0530 hrs, which is the time of minimum temperature epoch. The RH decreases till it reaches to a minimum around 1430 hrs in the afternoon, which is the time of maximum temperature epoch. June, the month of onset of southwest monsoon, has higher

RH during all the three hourly observations. RH values are high during monsoon months and low during winter months. The diurnal variation of RH over Kochi shows a steep decrease in RH between 0630 hrs and 1130 hrs and an increase between 1800 hrs to 2000 hrs.

Monthly mean values of the daily maximum, minimum, range and average humidity values are shown in **Table 3.1.3.6**. It shows that range is maximum during winter months when RH is minimum and least during monsoon months when RH is maximum. The diurnal variation in RH at the five stations based on the primary data collected during is shown for the four different seasons in **Fig. 3.1.3.4**. Due to some instrumental error, the data could not be recorded at all the stations except at Kottayam in monsoon season and at Kodanadu and Kulamavu in post monsoon season.

#### *3.1.3.1.3 Wind Speed & Wind Direction*

Analysis of secondary data of Kochi shows that the station mostly experiences westerlies wind during daytime and northeasterlies of very low velocities during night time due to the effect of land and sea breeze. Relatively more calm conditions or light winds prevail during night hours and strong winds during daytime. The diurnal variation of wind velocity is minimum in July because the winds are equally strong during night hours also. During southwest monsoon, winds are more from west and northwest directions in daytime.

Buildup of pollutants is likely to occur during nighttime because of very high calm conditions prevailing. Three hourly wind roses for the different seasons; winter, summer, monsoon and post-monsoon are shown in **Figs. 3.1.3.5 to 3.1.3.8** respectively. January is considered as the representative month of winter season, April for summer, July for southwest monsoon and October for northeast monsoon season.

The calm frequency is very high in January starting from 2100 hrs with 68.3% to 12 hrs with 41.6%. Maximum calm conditions are observed at 0000 hrs, the value being 84.4% followed by 0300 hrs with 69.4%, 0600 hrs with 64.5% and 09 hrs with 64.0%. At 1800 hrs, the predominance of winds from southwest sector continued, though less vigorously and the winds are less strong. The reversal of wind direction from night time to daytime is very much evident with the transition-taking place after 0900 hrs and after 1200 hrs.

The situation in April, the representative month for summer, is slightly different. The winds from west and northwest are still of considerable frequency at 2100 hrs. The calm frequency is maximum at 0600 hrs reaching a minimum at 1500 hrs and increasing up to 0600 hrs.

Irrespective of the time, the wind appeared to be stronger in July in comparison to those in the previous months. The wind is distributed in almost all the directions during night time.

In October, the winds are less strong when compared with those in September. The westerly winds have the maximum frequency during daytime.

During night time the winds have same considerable frequency from east but are weak. The calm frequency is more than 50% from 2100 hrs to 0900 hrs and considerably less during the rest of the period.

**Table 3.1.3.7** shows the climatological mean values of wind speed in Km/h for the twelve months. The diurnal variation in mean wind speed based on the primary data collected at 5 stations in different seasons is shown in **Fig. 3.1.3.9**. The wind data collected from five different stations show that the wind velocity follows more or less same pattern except at Kulamavu, which is a high land station. At all other stations, the wind velocity is minimum during night hours and strengthens during daytime to reach the highest value in the afternoon hours. Wind velocity is very small or continues to be calm during night hours. In Kalamassery, which is an industrial area and Kodanadu, which is a comparatively interior area, calm conditions continue during most of the night hours. Prolonged calm conditions in the industrial area are highly unfavorable for better dilution or transport of air borne pollutants. Therefore, if the same rate of stack emissions as that of day time continue, the same can cause build up of pollutants in the area and can cause formation of smog or fog especially in the early morning hours of winter days.

At Kulamavu, the wind velocity is higher when compared to the other four stations during winter and monsoon months. Here, winds are equally strong both during night and day time hours in these two seasons. Being a high land region, the effect of valley winds are felt during both day and night and this is responsible for the increased wind velocity there. Windroses for all the five met stations in different seasons; winter, summer, monsoon and post-monsoon are presented in **Figs. 3.1.3.10 to 3.1.3.13** respectively.

In general, during the daytime winds are comparatively stronger and are from west, northwest and southwest direction. But during night time the winds are weak or calm conditions prevail for most of the period. The general tendency during daytime is to carry the air borne pollutants mostly towards east or northeast. On the other hand, the weak easterly or northeasterly winds especially during the night hours of the winter season cause gradual transport of polluted air from the sources situated at the north or northeast region of Kochi towards the central or southwestern parts of the city. The polluted air reaching this part of the city gets accumulated because of the low mixing height prevailing over the region due to the effect of coast. This results in the formation of fog or smog in the morning hours of winter season in the coastal city region. It has been observed that the formation of such fog or smog is not uncommon in winter in the recent past even though the frequency of occurrence is low.

*3.1.3.1.4 Precipitation (Rainfall)*

The region experiences rainfall for nearly 10 months in a year. South West monsoon months constitute the principal rainy season while the northeast monsoon months constitute the secondary rainfall season. The western slopes of the hills and mountains at the eastern border of the region receive copious rainfall during the monsoon months. One of the two pockets of heavy rainfall in the whole state comprises the Kanjirappalli area of Kottayam district and the adjoining

Pirumed area of Idukki district. Idukki district, being in the high ranges, gets an annual rainfall of 338 cm.

The rainfall statistics (Secondary data for the period 1901-1970) of the four other districts in the study region are given in the **Table 3.1.3.8** and season-wise primary data for the five stations is given in **Table 3.1.3.9**.

*3.1.3.1.5 Solar Radiation and Sunshine Duration*

Season-wise primary data on solar radiation and sunshine duration is presented respectively in **Figs. 3.1.3.14** and **3.1.3.15**, for all the five stations. In winter and summer, both parameters show higher values, whereas in monsoon it is lowest, due to the presence of large amount of clouds. Comparatively inland stations like Kottayam and Kodanadu are getting more solar radiation and sunshine than the high land or coastal stations. Increase in amount of clouds normally seen near the coastal region and at high altitude region can reduce the solar radiation reaching the ground level.

### 3.1.3.2 Upper Air Meteorological Parameters

*3.1.3.2.1 Mixing Height*

The Mixing Height (MH) values from 9 locations in and around the Kochi city are computed for every hour and a representative mean MH is estimated for each hour. The diurnal variation of such spatially averaged MH is represented for all the months in **Fig. 3.1.3.16** along with its standard deviation.

In general, MH values are minimum around 6 am and maximum in the afternoon hours in all the months. The maximum MH values recorded are around 1500 m in the winter months. The MH values are lower during monsoon months. The average air temperature also follows a similar pattern, which may be the reason for such a variation. A comparatively steep vertical temperature gradient observed during winter months causes the surface air parcels to rise more and thus an increased MH during the winter months.

The monthly variation in MH at 0000, 0600, 1200 and 1800 hours is depicted in **Fig. 3.1.3.17**. The variation is almost negligible at 0000 and 0600 hrs. though there are few variations in the values. At 1200 hrs and 1800 hrs the variation is found to be considerable. The values are decreasing from January to July and increasing from July onwards. At 1800 hrs there is a sudden fall from January to February followed by more or less same value till April and a steep fall thereafter till June. It increased slightly from June to July and decreased slightly till August followed by a rise till November with a steep rise thereafter. The lower temperatures in the monsoon season must be responsible for the low values in that season. The large variation at 1200 and 1800 hrs may be due to the complete overcast condition in the monsoon season, which remarkably reduces the surface temperature during daytime and increases the surface temperature during nighttime.

The diurnal and monthly variations in MH are well marked. In general, the monsoon months have shown the lowest MH's. Mixing heights are also very low near the water bodies during night hours especially in monsoon and winter months. The low MH values near the water bodies in the central part of the city during winter mornings and monsoon morning periods influence the build up of all pollutants in the air. The feeble land breeze blowing continuously from north or northeast during the night hours further intensifies the level of pollution in the city and eventually results in formation of the fog.

Mixing height observations were recorded at the stations where surface meteorological parameters were recorded during winter season using radiosound technique. Maximum MH recoded at Kalamassery, Kodanadu, Idukki, Kottayam and Alappuzha were around 1300 m, 1800 m, 2200 m 1800 m and 2000 m respectively, which were recorded during non-afternoon hours (11 am-2 pm).

*3 1 3 2 2 Atmospheric Stability*

The diurnal variation in the climatology of atmospheric stability during different seasons for Kochi is presented in **Fig. 3.1.3.18**. The stability classes explained here are as that proposed by Pasquill; in six categories as A (very unstable), B (moderately unstable), C (slightly unstable), D (neutral), E (slightly stable) and F (moderately stable or very stable).

In winter months, during night hours (9 pm to till 6 am) stability class F alone is found to occur. Between 0600 hrs to 0700 hrs during the season, class E is observed almost all the time. Between 1000 hrs and 1300 hrs, the stability class A is prominent followed by class B and class C. Between 1300 hrs and 1800 hrs class C is prominent followed by B and D.

In summer, during night hours and early morning hours, the prominent stability is class F followed by a small percentage of D & E. Both D and E are present in the afternoon hours also. A combination of A, B & C classes are found during mid noon hours in the early summer. Combination of C & D is found during afternoon hours.

During the night hours of southwest monsoon season, the stability class D continues for a minimum duration of 50% and the rest of the period is characterized by presence of class F and class E. During daytime, the percentage of D continues to be nearly 50%. 'A' class is in very low percentage and percentage of occurrence of 'B' has come down considerably excepting between 1100 and 1300 hrs.

The main stability classes during the night hours of post monsoon season are F or D. The percentage of D has, however, come down compared to the southwest monsoon months. In the later half of the season, the stability class A and B has increased in percentage during daytime hours. Between 1400 hours and 1800 hrs the percentage of D is more or less same as in the southwest monsoon period.

A systematic increase of D from January to August with consequent decrease of A and systematic decrease from September onwards with a consequent increase of A are the prominent features. The domination of F during night has decreased from January to July and increased from August to December. In general, stability class D provided from 1300hrs to 800hrs in all the months. The strongest winds obtained during these hours are responsible for the neutral conditions between 1300 and 1800 hrs. The dominance of class D from June to September is mainly due to overcast conditions, which also make the atmosphere neutral.

With respect to the assessment of pollutant dispersal with stability alone as the criteria, it has to be stated that the night time emissions are of considerable concern because absence of vertical mixing and light winds would result in the stagnation of the pollutants and the consequent accumulation that may eventually be brought down to the ground level immediately after the stable conditions cease to exist, i.e., in the late morning hours.

### 3.1.3.3 Other Meteorological Aspects

*3.1.3.3.1 Assimilative Characteristics: Ventilation Coefficient (VC)*

The diurnal variation in ventilation coefficient values in all the 12 months are shown in **Fig. 3.1.3.19** with the daily mean values and the standard deviations. For computing the VC, the surface wind velocities are used. Hence the values presented here may underestimate VC. However, the wind speeds are not very high enough to obtain high values.

The diurnal variation follows the same pattern as that of surface temperature or mixing height values. In all the months, the maximum values occurred from 1400 to 1600 hrs. The diurnal variation is well marked with the coefficient of variation exceeding 100% in most of the cases, which represent the pronounced diurnal variation in wind speed also. The high values from January to May are attributed to large MH and strong winds. From June to September, covering of the monsoon season, the ventilation coefficients are considerably lower mostly because of very low mixing in this season, despite equally strong winds in comparison to those observed in March and April. The values of ventilation coefficient never exceeded 6000 $m^2/s$. a minimum value suggested by EPA, to ensure a fairly good dispersal of pollutants.

Further, VC for the 5 selected zones under GKR where surface and upper air meteorological data was collected is estimated for each hour up the day as shown in the **Fig. 3.1.3.20.** VC values are found to be more during day time, peak value being around 1100-1300 hrs.

*3.1.3.3.2 Inversions Occurrence*

The frequency of occurrence of surface and elevated inversions and the isothermal conditions over Kochi as revealed by the 10 years of radiosonde data of Kochi are given in the **Table 3.1.3.10**. Most of the ground based inversions (GI) and isothermals (IS) reach beyond 100 m and their intensities are designated as

The results of the chemical analysis of the water samples from the different localities are given in **Table 3.1.3.12** in terms of maximum and minimum values. The pH values of six stations showed the variation from 6.3 in the commercial area (Ernakulam south) to 7 in the island area (Vypeen). In the case of Vypeen, the samples collected on different days show pH values ranging between 6.06 and 7.95 with a mean value of 6.98. Kalamassery, representing industrial area shows variation from 5.07 to 7.05 on different days with a mean value of 6.6. Eloor, which also represents industrial area, shows lesser variation from 6.2 to 6.6 with a mean value of 6.42. Ernakulam South, commercial area, showed variation from 6 to 6.6 with a mean value of 6.32. Palluruthy shows variations from 6.32 to 7.23 with a mean value of 6.9. Pachalam, a residential area, showed variations from 6.3 to 6.9 with a mean value of 6.49. The observed mean pH values indicated the presence of soluble atmospheric gases like $CO_2$ and $SO_2$.

Conductivity serves as a measure of total concentration of ions present. It is showing very high values for rainfall less than 1 mm in certain cases. The mean values of the stations show variations from 20 micromhos (Kalamassery) to 93 micromhos (Palluruthy). Vypeen, the coastal station shows less concentration of ions. The mean value of conductivity over the region was 55.13 micromhos. The weighted mean value was less than the average value for most of the stations, which shows the inverse relationship between rainfall and conductivity.

The values of $SO_4$ varied from 0.09 to 0.6 mg/L. The mean value for each station doesn't vary much except for Vypeen. The average value for Kochi is 0.15 mg/L. The weighted mean concentration was less than the mean concentration for most of the stations, which indicate that the concentration is inversely proportional to rainfall amount. The concentration of sulphate is much lesser when compared to that of chloride. A close examination of concentration and rainfall shows a scattered distribution of concentration for lower rainfall amounts. The lowest concentration for Eloor, the industrial area, indicates that contribution of $SO_4$ coming down through washout near industrial area need not be high. The concentration of chloride ion for rainfall amounts less than 1 mm shows much higher values while for large amount of rainfall the values are scattered. Mean value for each station shows variation from 5.77 (Ernakulam South) to 10.93 (Palluruthy). The average value of chloride (Cl) for Kochi was 7.48 mg/L.

The chemical data obtained so far from the analysis of rainwater reveals that the observed pH values are only in the expected range for tropical regions The concentration doesn't show much difference between showers, which indicates washout doesn't have much influence. It is also to be mentioned here that, in addition to the successive showers some other factors such as wind velocity, intensity of rainfall, topography of the area are also contributing factors affecting the total mineralisation of rain water of a particular area.

temperature difference between ground and 100 m level. Inversions and isothermals whose base does not start from ground level but extend well above 100 m are considered as elevated inversions (EI) and they are observed from a height of 100m. The intensity of inversions is in 3 classes, namely 0-2$^0$C, 2-4$^0$C and 4-6$^0$C.

Kochi, being coastal station, both GI and EI are negligible. If isothermals are combined with inversion frequency, then the occurrence of inversion can be seen in considerable frequencies. Mostly, the intensity of inversion is 2$^0$C. GI is maximum in January and less than 1% in May, August and October. Frequency of occurrence of IS is higher. IS frequency minimum is 16.9% and the maximum is 31.3%. Irrespective of the season, IS are present in considerable frequency, maximum in July and minimum in February. However, the observed frequency of inversions is not very serious as far as pollution dispersion is concerned.

*3.1.3.3.3 Urban Heat Island*

In order to know the effect of urbanization on air temperature, a heat island study was carried out in the urban area of the study region. Hourly air temperature measurements were made from various points at the outskirts of the city region throughout day and night for a few days in the winter 1998. Temperature measurements were also made within the city on the same days, through a mobile survey, which started from midnight till 8 am on the following day. The locations of temperature observations are presented in **Table 3.1.3.11**. The difference in temperatures at each mobile observation site and the corresponding temperature values recorded at IMD's Kochi station are noted and the same is made use of to study the spatial temperature variations in the city. The study has revealed that there exists a pocket of urban heat island with intensity of 2 to 3 °C, covering most of the central region of the city. The result is compared with an earlier similar study conducted for the region and it is found that the heat island area has now considerably spread to a larger area of the city.

*3.1.3.3.4 Rainwater Analysis*

Rainwater samples were collected from six different locations in and around Kochi using identical glass bottles fitted with large glass funnels. The locations were; Vypeen, (representing island), Kalamassery and Eloor (representing industrial areas), Ernakulam south (representing commercial area), Palluruthy and Pachalam (representing residential areas).

Samples were collected from rainfalls occurred before and after the onset of southwest monsoon. On an average, 10 samples were collected from each station. Precipitation collected from each place was kept in dark and cool place. pH was measured with the help of a standard pH meter as soon as possible. Each sample was analyzed for sulphate, chloride and electrical conductivity. The mean values and the weighted mean values of ions obtained from the total samples collected are calculated and presented. The weighted mean concentration was obtained by multiplying concentration of ion by the amount of rainfall collected and dividing by the total rainfall of the day.

**Table 3.1.1.1**

**Summary of Ambient Air Quality Status in Kochi : 1990-1998**

**Units : $\mu g/m^3$**

| Pollutants | Winter | | | Summer | | | Monsoon | | | Post Monsoon | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max | Min | Avg | Max | Min | Avg | Max | Min | Avg | Max | Min | Avg |
| **SPM** | | | | | | | | | | | | |
| Residential | 358 | 80 | 143 | 169 | 37 | 92 | 193 | 15 | 71 | 185 | 39 | 83 |
| Commercial | 339 | 55 | 176 | 194 | 43 | 97 | 166 | 32 | 88 | 245 | 23 | 116 |
| Industrial | 262 | 15 | 107 | 186 | 43 | 84 | 213 | 0 | 66 | 279 | 0 | 85 |
| **$SO_2$** | | | | | | | | | | | | |
| Residential | 11 | 6 | 7 | 21 | 6 | 9 | 38 | 6 | 9 | 9 | 6 | 7 |
| Commercial | 24 | 6 | 11 | 52 | 6 | 12 | 28 | 6 | 9 | 24 | 6 | 13 |
| Industrial | 23 | 6 | 8 | 30 | 6 | 11 | 35 | 6 | 12 | 21 | 6 | 11 |
| **$NO_2$** | | | | | | | | | | | | |
| Residential | 39 | 4 | 10 | 20 | 3 | 8 | 28 | 3 | 9 | 35 | 3 | 12 |
| Commercial | 35 | 5 | 18 | 31 | 6 | 14 | 25 | 3 | 11 | 32 | 6 | 17 |
| Industrial | 44 | 3 | 10 | 20 | 3 | 8 | 23 | 3 | 8 | 13 | 4 | 7 |
| **$NH_3$** | | | | | | | | | | | | |
| Residential | 152 | 5 | 37 | 144 | 5 | 39 | 108 | 11 | 36 | 73 | 8 | 30 |
| Commercial | 199 | 7 | 72 | 256 | 6 | 75 | 122 | 1 | 41 | 134 | 0 | 57 |
| Industrial | 223 | 12 | 84 | 261 | 33 | 86 | 245 | 9 | 118 | 203 | 25 | 77 |

Residential : Panchalam (1990-1992) ; PHED (1993-1995); Kalmassery (1996 onwards)
Commercial : Cochin Port Trust; Industrial : Cochin Refineries Ltd.
**Source :** NAQMN Reports, 1990 to 1998 by NEERI

**Table 3.1.1.2**

**Details of Air Quality Monitoring Stations in Kochi**

| Sr. No. | Sampling Locations | Distance from Centre (km) | Station Height (m) | Representative Area |
|---|---|---|---|---|
| A. | **Residential Area** | | | |
| 1 | PHED | 2 | 5 | Kochi Corporation |
| 2 | NEERI | 4 | 9 | Kochi Corporation Palarivattam |
| 3 | Kalmassery | 8 | 10 | Kalmassery Panchayat |
| B. | **Commercial Area** | | | |
| 4 | S.P. Station | 0.8 | 2 | Kochi Corporation |
| 5 | GCDA | 1.5 | 9 | Kochi Corporation Kadavantra |
| 6 | Alwaye | 12 | 12 | Alwaye Municipality |
| 7 | Will. Island | 1.5 | 4.5 | Will. Island |
| 8 | Mattenchery | 3 | 4.5 | Mattenchery |
| C. | **Industrial Area** | | | |
| 9 | Karimugal | 9.5 | 4 | Vadavucpde-Puthencruz Panchayat |
| 10 | Ambalmugal | 8.8 | 5 | Vadavucpde-Puthencruz Panchayat |
| 11 | Thiruvaniyar | 8.8 | 4 | Thiruvaniyar Panchayat |
| 12 | FACT Eloor | 8.8 | 4.5 | Eloor Panchayat |
| 13 | Binanipuram | 10 | 4.5 | Kadungaloor Panchayat |
| 14 | Eloor | 10.8 | 4.1 | Eloor |
| 15 | Mulavukad | 4 | 4.5 | Mulavukad Panchayat |
| 16 | Elakunnapuzha | 5.5 | 4.5 | Elakunnapuzha Panchayat |
| D. | **Mixed Area** | | | |
| 17 | Thripunithura | 6 | 10 | Thripunithura Municipality |
| 18 | Thiruvankkulam | 7 | 9 | Thiruvankkulam Panchayat |
| 19 | Thrikkakara | 6 | 4 | Thrikkakara Municipalty |
| 20 | Cheranellor | 5 | 10 | Cheranellor Panchayat |

**Source** : Secondary data collected by NEERI : Air Pollution studies for Cochin Region : Directives from Hon'ble High court of Kerala, July 1990

Table 3.1.1.3

**Details of Air Quality Monitoring Stations in Kochi**

| Sr. No. | Sampling Location | Direction with respect to CRL | Distance from CRL (km) | Sampling Height (m) |
|---|---|---|---|---|
| **A** | **Residential Area** | | | |
| 1 | Vytilla | W | 7.5 | 02 |
| 2 | CRL Guest house | N | 0.5 | 12 |
| 3 | Thiruvamkulam | SSW | 2.5 | 12 |
| 4 | Thrikkakara | NW | 7.0 | 12 |
| 5 | Chottanikkara | SSE | 6.5 | 05 |
| 6 | Thiruvaniyur | SE | 9.0 | 12 |
| 7 | Thripunithura | SW | 4.0 | 12 |
| 8 | Thiruvaniyur (B) | SSE | 8.5 | 05 |
| 9 | Irimpanam | WNW | 4.4 | 12 |
| **B** | **Industrial Area** | | | |
| 10 | Ambalamugal | NE | 1.5 | 05 |
| 11 | Karimugal | NE | 3.0 | 05 |
| **C** | **Rural Area** | | | |
| 12 | Peringala | W | 7.5 | 05 |
| 13 | Puthencruz | E | 6.0 | 12 |
| 14 | Mulanthuruthy | SSE | 10. | 05 |
| 15 | Brahmapuram | NNE | 3.5 | 05 |
| 16 | Kadaviruppu | ENE | 10. | 05 |

**Source :** Secondary data collected by NEERI : CRL-EIA Reports (Sep 1990 and Nov 1991)

**Table 3.1.1.4**

**Summary of Ambient Air Quality Status in Kochi : 1990-1991**

| Sampling Locations | Concentration of Pollutants ($\mu g/m^3$) | | | | | |
|---|---|---|---|---|---|---|
| | 1990 | | | 1991 | | |
| | Max | Min | Avg | Max | Min | Avg |
| **SPM** | | | | | | |
| Residential | 352 | 11 | 125 | 255 | 75 | 135 |
| Rural | 245 | 61 | 191 | 611 | 87 | 208 |
| Industrial | 326 | 101 | 191 | 166 | 66 | 143 |
| **$SO_2$** | | | | | | |
| Residential | 59 | 6 | 10 | 23 | 6 | 7 |
| Rural | 19 | 6 | 15 | 16 | 6 | 6 |
| Industrial | 42 | 6 | 9 | 103 | 6 | 14 |
| **$NO_2$** | | | | | | |
| Residential | 29 | 6 | 8 | 39 | 3 | 6 |
| Rural | 18 | 6 | 7 | 31 | 3 | 6 |
| Industrial | 12 | 6 | 7 | 9 | 3 | 4 |
| **$NH_3$** | | | | | | |
| Residential | 337 | 1 | 53 | 353 | 5 | 39 |
| Rural | 272 | 1 | 47 | 111 | 5 | 25 |
| Industrial | 103 | 1 | 44 | 170 | 5 | 30 |

**Source** : Secondary data collected by NEERI : CRL-EIA Report (1990-1991)

Table 3.1.1.5

## Summary of Diurnal Variation in Ambient Air Quality Status in Kochi

| Sampling Location | Average Concentration of Pollutants ($\mu g/m^3$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SPM (24 hrs) | | | $SO_2$ | | | $NO_2$ | | | $NH_3$ | | |
| | **Max** | **Min** | **Avg.** | 10:18 | 18: 02 | 02:10 | 10:18 | 18: 02 | 02:10 | 10:18 | 18: 02 | 02:10 |
| **1990** | | | | | | | | | | | | |
| Residential (9) | 352 | 11 | 125 | 8 | 11 | 14 | 7 | 9 | 12 | 60 | 52 | 54 |
| Rural (5) | 326 | 101 | 191 | 8 | 18 | 19 | 7 | 8 | 9 | 52 | 63 | 30 |
| Industrial (2) | 245 | 61 | 127 | 9 | 7 | 8 | 6 | 8 | 10 | 46 | 32 | 52 |
| **1991** | | | | | | | | | | | | |
| Residential (9) | 255 | 75 | 136 | 8 | 7 | 7 | 4 | 9 | 9 | 56 | 33 | 29 |
| Rural (5) | 166 | 66 | 143 | 14 | 21 | 7 | 4 | 5 | 5 | 45 | 33 | 22 |
| Industrial (2) | 611 | 87 | 208 | 7 | 6 | 6 | 4 | 7 | 9 | 20 | 32 | 42 |

**Source :** Secondary data collected by NEERI : CRL-EIA Report(Sep-1990 & Nov-1991)

Table 3.1.1.6

## Season-wise Ambient Air Quality Status in Ernakulam and Kottayam : 1993-1999

| Season | Average Pollutant Concentration ($\mu g/m^3$) | | |
|---|---|---|---|
| | SPM | $SO_2$ | $NO_2$ |
| **Ernakulam (Residential/Commercial)** | | | |
| Summer | 245 | 23 | 50 |
| Monsoon | 134 | 10 | 19 |
| Post-monsoon | 128 | 13 | 20 |
| Winter | 138 | 21 | 68 |
| **Irumpanam (Residential/Commercial)** | | | |
| Summer | 428 | 16 | 70 |
| Monsoon | 278 | 15 | 29 |
| Post-monsoon | 778 | 26 | 37 |
| Winter | 421 | 10 | 31 |
| **Eloor (Industrial)** | | | |
| Summer | 113 | 13 | 37 |
| Monsoon | 141 | 22 | 19 |
| Post-monsoon | 392 | 29 | 28 |
| Winter | 142 | 43 | 18 |
| **Kottayam (Residential/Commercial)** | | | |
| Summer | 215 | 2 | 28 |
| Monsoon | 149 | 2 | 25 |
| Post-monsoon | 216 | 2 | 47 |
| Winter | 236 | 2 | 24 |
| **Chingavanam (Residential/Commercial)** | | | |
| Summer | 205 | 2 | 89 |
| Monsoon | 160 | 2 | 53 |
| Post-monsoon | 181 | 2 | 101 |
| Winter | 170 | 2 | 42 |

**Source :** Secondary Data Collected By KSPCB

Table 3.1.1.7

Location and Bearing of AAQ Monitoring Stations

| Station Code | Station Name | Area/Class | Distance from Jos Jn. (Km) |
|---|---|---|---|
| **Alappuzha District** | | | |
| A1 | Cherthala | IA | 28.0 |
| A2 | K.S.R.T.C | CA | 51.5 |
| A3 | Kuttand | SA | 61.1 |
| A4 | Town-Alappuzha | CA | 56.8 |
| A7 | Pallatharuthy | SA | 58.0 |
| A8 | Mayithara | SA | 33.5 |
| **Ernakulam District** | | | |
| E1 | Parampally Nagar | RA | 1.6 |
| E2 | Gandhi Nagar | RA | 1.0 |
| E3 | AIMS-Edappally | SA | 10.1 |
| E4 | Hill place Tripunithura | SA | 14.6 |
| E5 | Bolgatly | SA | 4.5 |
| E6 | North over bridge | CA | 3.5 |
| E7 | Broad way Market | CA | 0.5 |
| E8 | South over bridge | CA | 0.5 |
| E9 | Valanjambalam Jn | CA | 0.25 |
| E10 | Valanjambalam N | CA | 0.25 |
| E11 | Market – Aluva | CA | 15.15 |
| E12 | G.C.D.A Colony Aluva | RA | 19.2 |
| E13 | N. Paravoor | CA | 27.2 |
| E14 | Angmaly | CA | 27.2 |
| E15 | MVPA-Town | CA | 32.32 |
| E16 | MVPA-Vaghakkulam | IA | 28.0 |
| E17 | Ayavane Market | RA | 28.2 |
| E18 | Perumbavoor Ind-Es | IA | 20.7 |
| E19 | Kodanad | SA | 34.3 |
| E20 | Market – Kothamangals | CA | 40.4 |
| E21 | D.F.O. Quarters | RA | 42.9 |
| E22 | Nadukni Kirampara | SA | 51.5 |
| E23 | Eloor-Binani Zine | IA | 8.0 |
| E24 | Eloor-Temple Jn. | IA | 8.0 |

Contd...

Table 3.1.1.7 contd...

| Station Code | Station Name | Area/Class | Distance from Jos Jn. (Km) |
|---|---|---|---|
| E25 | Eloor-Srisakthi | IA | 9.0 |
| E26 | Eloor-Pandhayath-off. | IA | 8.0 |
| E27 | Eloor-Pallipuram | IA | 8.5 |
| E28 | Eloor-K.S.E.B. | IA | 8.0 |
| E29 | Eloor-E.S.I. | IA | 8.5 |
| E30 | Eloor-Pathalam | IA | 8.5 |
| E31 | Eloor T.C.C. Colony | IA | 7.0 |
| E32 | Eloor-PCB Office | IA | 7.5 |
| E33 | Eloor-Cochin Poly. | IA | 8.5 |
| E34 | Eloor-Manjummel | IA | 6.5 |
| **Idukki District** | | | |
| ID1 | P.W.D. R.H. Town-F | CA | 52.5 |
| ID2 | Painaver | SA | 79.2 |
| ID3 | I.E. Olamattom-F | IA | 49.5 |
| ID4 | Thekkady-Reservoir | SA | 103.5 |
| ID6 | Vandanmedu | SA | 82.0 |
| **Kottayam District** | | | |
| K1 | H.N.L-F | IA | 24.7 |
| K2 | Municipal-Charry-S | CA | 61.9 |
| K3 | M.C.H. Ktm-S | SA | 44.4 |
| K4 | M.R.M. Palai-F | RA | 55.8 |
| K13 | Cochin C. | IA | 24.5 |
| **Pathanamthitta District** | | | |
| P1 | Gen. Hospital-F | SA | 91.9 |
| P2 | Pamba-S | SA | 110.6 |
| P3 | Kakki Dam-F | SA | 85.0 |
| P7 | Mooyhiyar | SA | 85.0 |
| **Thrissur District** | | | |
| T1 | Chest Hospital | SA | 58.0 |
| T2 | District Office PCB | RA | 53.0 |
| T3 | Round | CA | 50.0 |
| T4 | Yamuna | IA | 58.0 |

IA - Industrial Area; SA - Sensitive Area; CA - Commercial Area
RA - Residential Area

## Table 3.1.1.8

## Ambient Air Quality Status in GKR

8 hrly Avg. unit : µg/m³

| Location | SPM | | | | RSPM | | | | $SO_2$ | | | | $NO_2$ | | | | $NH_3$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max | Min | Avg | SD | Max | Min | Avg | SD | Max | Min | Avg | SD | Max | Min | Avg | SD | Max | Min | Avg | SD |
| Alappuzha District | | | | | | | | | | | | | | | | | | | | |
| A1 | 141 | 33 | 85 | 32.4 | 63 | 31 | 45 | 11.6 | 44 | 3 | 18 | 11 | 57 | 3 | 16 | 14 | 45 | 10 | 28 | 25 |
| A2 | 155 | 5 | 57 | 41 | 135 | 10 | 59 | 26.0 | 19 | 3 | 10 | 5 | 30 | 3 | 11 | 7 | 8 | - | - | - |
| A3 | 322 | 18 | 49 | 65.5 | 161 | 50 | 94 | 31.6 | 8 | 3 | 5 | 2 | 10 | 3 | 6 | 2 | 49 | 21 | 31 | 12 |
| A4 | 130 | 40 | 70 | 23.4 | 324 | 68 | 154 | 72.8 | 19 | 3 | 7 | 5 | 75 | 4 | 24 | 25 | 6 | 1 | 3 | 1 |
| A7 | 40 | 15 | 24 | 6.6 | 213 | 36 | 69 | 39.9 | 13 | 3 | 4 | 3 | 33 | 3 | 7 | 7 | 65 | 1 | 6 | 14 |
| A8 | 135 | 16 | 64 | 33.1 | 78 | 9 | 46 | 21.6 | 18 | 3 | 5 | 4 | 90 | 3 | 24 | 28 | 10 | 1 | 3 | 2 |
| Ernakulam District | | | | | | | | | | | | | | | | | | | | |
| E1 | 32 | 9 | 19 | 6.9 | 66 | 3 | 35 | 16.7 | 26 | 3 | 5 | 5 | 71 | 7 | 25 | 15 | 68 | 9 | 30 | 20 |
| E2 | 60 | 13 | 33 | 13.2 | 190 | 44 | 98 | 41.4 | 6 | 3 | 4 | 1 | 58 | 3 | 19 | 14 | 64 | 10 | 31 | 17 |
| E3 | 79 | 31 | 49 | 15.9 | 80 | 24 | 51 | 20.6 | 6 | 3 | 4 | 1 | 32 | 5 | 17 | 8 | 6 | 3 | 4 | 1 |
| E4 | 62 | 31 | 40 | 9.6 | 99 | 23 | 57 | 25.7 | 16 | 4 | 9 | 4 | 48 | 22 | 35 | 11 | 17 | 8 | 11 | 4 |
| E5 | 286 | 6 | 47 | 75.8 | 11 | 3 | 8 | 2.1 | 4 | 3 | 3 | 0 | 24 | 3 | 12 | 7 | 27 | 3 | 15 | 8 |
| E6 | 121 | 57 | 79 | 15.5 | 289 | 10 | 147 | 92.9 | 19 | 3 | 6 | 4 | 161 | 15 | 57 | 36 | 37 | 3 | 17 | 10 |
| E7 | 133 | 16 | 73 | 31.1 | 72 | 6 | 34 | 18.1 | 16 | 3 | 4 | 3 | 142 | 8 | 34 | 32 | 90 | 3 | 23 | 24 |
| E8 | 111 | 35 | 73 | 27.7 | 161 | 38 | 91 | 37.1 | 9 | 3 | 4 | 2 | 125 | 9 | 38 | 32 | 82 | 4 | 23 | 19 |
| E9 | 563 | 61 | 140 | 122.9 | 1108 | 52 | 424 | 297.1 | 37 | 3 | 7 | 8 | 122 | 18 | 52 | 34 | 90 | 3 | 28 | 24 |
| E10 | 133 | 101 | 119 | 16.5 | 198 | 165 | 186 | 18.0 | - | - | - | - | 59 | 23 | 36 | 20 | 34 | 21 | 28 | 7 |
| E11 | 53 | 9 | 16 | 9.9 | 47 | 1 | 27 | 13.6 | 13 | 3 | 6 | 3 | 58 | 7 | 26 | 16 | 25 | 3 | 10 | 7 |
| E12 | 63 | 7 | 43 | 18.3 | 96 | 52 | 69 | 13.8 | 10 | 3 | 6 | 2 | 33 | 9 | 21 | 8 | 17 | 3 | 10 | 5 |
| E13 | 54 | 25 | 47 | 9.4 | 183 | 31 | 100 | 55.1 | 13 | 3 | 6 | 4 | 73 | 22 | 43 | 19 | 23 | 8 | 15 | 7 |
| E14 | 32 | 8 | 14 | 6.2 | 37 | 5 | 27 | 9.0 | 14 | 3 | 5 | 3 | 415 | 6 | 46 | 97 | 21 | 4 | 11 | 6 |
| E15 | 100 | 18 | 58 | 23 | 195 | 33 | 76 | 37.8 | 16 | 3 | 6 | 4 | 114 | 15 | 43 | 28 | 18 | 3 | 8 | 5 |
| E16 | 17 | 3 | 10 | 3.6 | 57 | 3 | 28 | 16.0 | 18 | 3 | 7 | 4 | 73 | 10 | 38 | 17 | 30 | 3 | 13 | 7 |
| E17 | 71 | 18 | 40 | 18.3 | 71 | 10 | 39 | 19.5 | 13 | 3 | 6 | 4 | 72 | 7 | 22 | 16 | 11 | 3 | 7 | 3 |
| E18 | 32 | 7 | 17 | 8.8 | 56 | 3 | 26 | 18.2 | - | - | - | - | - | - | - | - | 58 | 17 | 37 | 14 |
| E19 | 4 | 1 | 3 | 1.2 | 11 | 1 | 5 | 3.3 | - | - | - | - | - | - | - | - | 32 | 12 | 25 | 7 |
| E20 | 78 | 0 | 24 | 16.3 | 31 | 1 | 15 | 8.0 | 14 | 3 | 6 | 3 | 53 | 7 | 26 | 13 | 40 | 3 | 12 | 11 |
| E21 | 56 | 4 | 20 | 14.8 | 103 | 21 | 50 | 20.6 | 13 | 3 | 6 | 3 | 67 | 5 | 20 | 15 | 19 | 3 | 8 | 5 |

Contd...

Table 3.1.1.8 Contd...

| Location | SPM | | | | RSPM | | | | $SO_2$ | | | | $NO_2$ | | | | $NH_3$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max | Min | Avg | SD | Max | Min | Avg | SD | Max | Min | Avg | SD | Max | Min | Avg | SD | Max | Min | Avg | SD |
| Ernakulam District | | | | | | | | | | | | | | | | | | | | |
| E22 | 81 | 0 | 31 | 23.6 | 39 | 4 | 17 | 11.4 | 8 | 3 | 5 | 2 | 50 | 11 | 34 | 14 | 14 | 3 | 7 | 4 |
| E23 | 83 | 43 | 62 | 11.6 | 243 | 91 | 163 | 51.4 | 147 | 3 | 48 | 47 | 38 | 10 | 22 | 7 | 76 | 3 | 35 | 25 |
| E24 | 100 | 15 | 61 | 24.8 | 121 | 49 | 78 | 22.4 | 90 | 24 | 52 | 21 | 120 | 10 | 38 | 33 | 110 | 26 | 55 | 28 |
| E25 | 101 | 40 | 65 | 20.3 | 241 | 36 | 141 | 53.3 | 165 | 3 | 58 | 40 | 265 | 27 | 82 | 59 | 130 | 1 | 47 | 41 |
| E26 | 100 | 8 | 49 | 20.7 | 285 | 62 | 142 | 64.3 | 172 | 22 | 58 | 40 | 114 | 7 | 41 | 33 | 196 | 23 | 75 | 54 |
| E27 | 65 | 19 | 47 | 12.4 | 133 | 45 | 71 | 23.8 | 106 | 24 | 57 | 24 | 108 | 3 | 38 | 29 | 84 | 1 | 40 | 25 |
| E28 | 62 | 24 | 42 | 10.9 | 210 | 44 | 92 | 44.1 | 151 | 13 | 63 | 41 | 139 | 6 | 37 | 32 | 289 | 17 | 60 | 69 |
| E29 | 30 | 3 | 21 | 6.1 | 50 | 13 | 34 | 13.0 | 79 | 3 | 35 | 20 | 24 | 8 | 16 | 4 | 139 | 1 | 31 | 35 |
| E30 | 26 | 10 | 17 | 5.6 | 42 | 7 | 26 | 8.5 | 73 | 3 | 42 | 18 | 77 | 13 | 37 | 17 | 105 | 8 | 44 | 26 |
| E31 | 40 | 8 | 18 | 9.3 | 100 | 19 | 39 | 22.2 | 131 | 6 | 58 | 35 | 112 | 21 | 53 | 26 | 71 | 1 | 35 | 22 |
| E32 | 100 | 20 | 47 | 24 | 126 | 27 | 85 | 28.7 | 152 | 3 | 48 | 40 | 143 | 3 | 52 | 52 | 424 | 1 | 86 | 107 |
| E33 | 71 | 10 | 41 | 15.9 | 128 | 10 | 35 | 30.4 | 262 | 27 | 61 | 57 | 266 | 12 | 56 | 67 | 100 | 1 | 37 | 29 |
| Idukki District | | | | | | | | | | | | | | | | | | | | |
| ID1 | 194 | 8 | 66 | 58.6 | 200 | 15 | 59 | 47.7 | 72 | 3 | 16 | 17 | 203 | 6 | 42 | 40 | 66 | 1 | 21 | 7 |
| ID2 | 670 | 5 | 19 | 19.4 | 157 | 10 | 55 | 39.7 | 81 | 3 | 27 | 27 | 32 | 3 | 14 | 9 | 67 | 45 | 55 | 8 |
| ID3 | 113 | 18 | 52 | 27.3 | 138 | 24 | 88 | 37.0 | 74 | 3 | 24 | 27 | 63 | 22 | 38 | 12 | 99 | 47 | 65 | 18 |
| ID4 | 419 | 40 | 166 | 133 | 69 | 9 | 37 | 21.3 | 113 | 3 | 43 | 44 | 21 | 3 | 6 | 6 | 68 | 26 | 50 | 17 |
| ID6 | - | - | - | - | 17 | 2 | 8 | 4.9 | - | - | - | - | 14 | 3 | 5 | 4 | 3 | 1 | 1 | 1 |
| Kottayam District | | | | | | | | | | | | | | | | | | | | |
| K1 | 83 | 14 | 38 | 13.6 | 357 | 45 | 108 | 67.7 | 64 | 3 | 26 | 17 | 46 | 3 | 24 | 12 | 40 | 1 | 15 | 13 |
| K2 | 162 | 20 | 72 | 28.9 | 226 | 45 | 141 | 55.2 | 60 | 3 | 12 | 16 | 257 | 3 | 80 | 76 | 6 | 1 | 2 | 2 |
| K3 | 48 | 2 | 18 | 12.5 | 128 | 4 | 48 | 35.1 | 16 | 3 | 7 | 4 | 75 | 3 | 28 | 20 | 51 | 1 | 6 | 14 |
| K4 | 100 | 7 | 60 | 26.3 | 122 | 31 | 75 | 25.8 | 16 | 3 | 8 | 4 | 44 | 7 | 22 | 13 | 86 | 31 | 49 | 19 |
| K13 | 100 | 72 | 83 | 15.1 | 110 | 80 | 97 | 15.3 | 30 | 3 | 11 | 8 | 125 | 11 | 34 | 23 | 115 | 1 | 17 | 30 |
| | | | | | | | | | | | | | | | | | | | | |
| Pathanamthitta District | | | | | | | | | | | | | | | | | | | | |
| P1 | 60 | 3 | 14 | 9 | 190 | 3 | 45 | 43.0 | 51 | 1 | 10 | 13 | 877 | 21 | 119 | 167.7 | 464 | 27 | 152 | 138.5 |
| P2 | 57 | 3 | 12 | 6 | 69 | 3 | 29 | 13.0 | 4 | 1 | 2 | 1 | 101 | 9 | 48 | 19.6 | 186 | 2 | 71 | 40.5 |
| P3 | 13 | 3 | 7 | 4 | 9 | 5 | 7 | 2.0 | 10 | 4 | 7 | 2 | 80 | 23 | 46 | 18 | 79 | 12 | 52 | 22.5 |

Contd...

Table 3.1.1.8 Contd...

| Location | SPM | | | | RSPM | | | | $SO_2$ | | | | $NO_2$ | | | | $NH_3$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max | Min | Avg | SD | Max | Min | Avg | SD | Max | Min | Avg | SD | Max | Min | Avg | SD | Max | Min | Avg | SD |
| P7 | 7 | 3 | 3 | 1 | 13 | 3 | 5 | 3.0 | 3 | 1 | 2 | 1 | 57 | 16 | 35 | 11.5 | 60 | 4 | 31 | 27.5 |
| Thrissur District | | | | | | | | | | | | | | | | | | | | |
| T1 | 57 | 3 | 14 | 14 | 25 | 3 | 7 | 5.0 | 17 | 2 | 6 | 5 | 92 | 9 | 46 | 23.3 | 85 | 17 | 53 | 19.8 |
| T2 | 55 | 3 | 24 | 23 | 313 | 12 | 59 | 82.0 | 36 | 1 | 8 | 9 | 53 | 7 | 22 | 15.3 | 82 | 12 | 49 | 20.2 |
| T3 | 58 | 3 | 19 | 16 | 57 | 4 | 20 | 14.0 | 17 | 1 | 8 | 5 | 100 | 12 | 47 | 26.9 | 745 | 24 | 110 | 153 |
| T4 | 40 | 3 | 13 | 11 | 22 | 3 | 8 | 6.0 | 25 | 1 | 8 | 7 | 110 | 7 | 52 | 33.1 | 201 | 3 | 83 | 55.2 |

**Source** : Primary data Collected by KSPCB during 1999 - 2000

Table 3.1.1.9

**AQI for different Seasons in Ernakulam District (1990-1998)**

| Area/Season | AQI Range | Category |
|---|---|---|
| **Residential** | | |
| Winter | 26 - 45 | Good - Fair |
| Summer | 27 - 33 | Good |
| Monsoon | 21 - 28 | Good |
| Postmonsoon | 32 | Good |
| **Commercial** | | |
| Winter | 26 - 59 | Good - Fair |
| Summer | 29 - 39 | Good |
| Monsoon | 21 - 33 | Good |
| Postmonsoon | 46 | Fair |
| **Industrial** | | |
| Winter | 15 - 18 | Excellent |
| Summer | 15 - 17 | Excellent |
| Monsoon | 10 - 15 | Excellent |
| Postmonsoon | 16 | Excellent |
| **Mixed** | | |
| Winter | 13 - 21 | Excellent - Good |
| Summer | 13 | Excellent |
| Monsoon | 10 - 12 | Excellent |
| Post Monsoon | | |

**Source :** Secondary data collected by NEERI, NAAQM Reports - 1990-98

Table 3.1.1.10

## Season-wise Air Quality Indices in Ernakulam and Kottayam Districts : 1993-1999

| Station | AQI | Category |
|---|---|---|
| **Ernakulam (Residential/Commercial)** | | |
| Summer | 99 | Bad |
| Monsoon | 49 | Fair |
| Post-monsoon | 50 | Fair |
| Winter | 83 | Bad |
| **Irumpanam (Residential/Commercial)** | | |
| Summer | 148 | Dangerous |
| Monsoon | 91 | Bad |
| Post-monsoon | 215 | Dangerous |
| Winter | 122 | Dangerous |
| **Eloor (Industrial)** | | |
| Summer | 33 | Good |
| Monsoon | 31 | Good |
| Post-monsoon | 61 | Poor |
| Winter | 40 | Fair |
| **Kottayam (Residential/Commercial)** | | |
| Summer | 69 | Poor |
| Monsoon | 52 | Fair |
| Post-monsoon | 79 | Poor |
| Winter | 71 | Poor |
| **Chingavanam (Residential/Commercial)** | | |
| Summer | 99 | Bad |
| Monsoon | 70 | Poor |
| Post-monsoon | 100 | Dangerous |
| Winter | 60 | Poor |

**Source :** Secondary Data Collected By KSPCB

Table 3.1.1.11

Air Quality Indices in different Districts of GKR (1999 - 2000)

| Area/Season | AQI Range | Category |
|---|---|---|
| **Alappuzha District** | | |
| Industrial Area | 16 | Excellent |
| Residential / Commercial Area | 19 - 26 | Excellent - Good |
| Sensitive Area | 21 - 55 | Excellent |
| **Ernakulam District** | | |
| Industrial Area | 14 - 44 | Excellent - Fair |
| Residential / Commercial Area | 15 - 49 | Excellent - Fair |
| Sensitive Area | 34 - 63 | Good - Fair |
| **Iduuki Districts** | | |
| Industrial Area | 21 | Good |
| Residential / Commercial Area | 36 | Good |
| Sensitive Area | 53 - 109 | Fair |
| **Kottayam District** | | |
| Industrial Area | 17 - 19 | Excellent - Good |
| Residential / Commercial Area | 24 - 51 | Excellent |
| Sensitive Area | 46 | Excellent |
| **Pathanamthitta District** | | |
| Industrial Area | -- | -- |
| Residential / Commercial Area | -- | -- |
| Sensitive Area | 22 - 105 | Good - Fair |
| **Thrissur District** | | |
| Industrial Area | 10 | Excellent |
| Residential / Commercial Area | 25 - 39 | Good |
| Sensitive Area | 22 | Excellent |

Source : Primary data collected by KSPCB

Table 3.1.2.1

List of Major Air Polluting Industries in GKR

| Sr. No. | Name of Industry | Location |
|---|---|---|
| | **Ernakulam District** | |
| 1. | ABN Granites Ltd. | Parur |
| 2. | AMA Food Products Pvt. Ltd. | Aluva |
| 3. | Ananth Oil Extractions Ltd. | Kunnathunadu |
| 4. | Auric Brown Crumb Rubbers Pvt. Ltd. | Aluva |
| 5. | AVT MC Cormik Ingredients (P) Ltd. | Kakkanad |
| 6. | Binani Zinc Ltd. | Aluva |
| 7. | BSES Kerala Power Ltd., | Ernakulam |
| 8. | Carbon and Chemicals India Ltd. | Vaduvacode |
| 9. | Carborandum universal Ltd. | Ernakulam |
| 10. | Cochin Kagaz Pvt. Ltd. | Aluva |
| 11. | Cochin Minerals & Rutile ltd. | Parur |
| 12. | Cochin refineries Ltd. | Kunnathunadu |
| 13. | Cochin Refineries-Balmer Lawrie Ltd. | Kunnathunadu |
| 14. | Cochin Roller Flour Mills | Kanayannur |
| 15. | Cochin Shipyard Ltd. | Kochi |
| 16. | Cochin Spices Ltd. | Kanayannur |
| 17. | Coramandel Condiments Ltd. | Kanayannoor |
| 18. | Covema Filaments Ltd. | Kanayannoor |
| 19. | Crescent Crumbs pvt. Ltd. | Aluva |
| 20. | Eastern treads Ltd. | Ernakulam |
| 21. | Edathala polymers (P) Ltd. | Aluva |
| 22. | Forest Industries (Travancore) Ltd. | Alwaye |
| 23. | G.T.N. Textiles Ltd. | Aluva |
| 24. | Gramox Paper & Boards Ltd. | Muvathuppuzha |
| 25. | Green valley Specified Rubber Pvt. Ltd. | Aluva |
| 26. | Hindustan Insecticides Ltd. | Parur |
| 27. | Hindustan Organic Chemicals Ltd. | Kanayannur |
| 28. | HMT Ltd. | Kanayannur |
| 29. | Indian Aluminium Co. Ltd. | Kanayannur |
| 30. | Indian Aluminium Company Ltd. | Kalamassery |
| 31. | Indian rare Earths Ltd. | Ernakulam |
| 32. | Indo German Carbons Ltd. | Parur |
| 33. | Kalamassery Division | Kanayannur |

Contd...

Table 3.1.2.1 Contd...

| Sr. No. | Name of Industry | Location |
|---|---|---|
| 34. | Kancoar Flavours and Extracts Ltd. (Formerly, Bombay Oil Industries Ltd.) | Aluva |
| 35. | Kerala Acid & Chemicals Ltd. | |
| 36. | Kerala Agro-Machinery Corporation Ltd. | |
| 37. | Kerala Flour Mills | Kunnathunadu |
| 38. | Kitex Ltd. | Aluva |
| 39. | Kothaldarana Roller Flour Mills Pvt. Ltd. | Aluva |
| 40. | Modern Food Industries (India) Ltd. | Kanayannur |
| 41. | Nenmeni Agro Mills Pvt. Ltd. | Aluva |
| 42. | Nilma Edapally Division | Kanayannur |
| 43. | Pensem Drugs & Pharmaceutical (P) Ltd. | |
| 44. | Periyar Chemicals Ltd. | Parur |
| 45. | Permier Ferro Alloys Ltd. | Aluva |
| 46. | Philips Carbon Black Ltd., Carbon & Chemicals India Ltd. | Kanayannur |
| 47. | Pigments India Ltd. | Aluva |
| 48. | Rado Tyres Pvt. Ltd. | Ernakulam |
| 49. | Rare earths Division | Parur |
| 50. | Rice take Agro Mills Pvt. Ltd. | Aluva |
| 51. | Sree Rahul Mills Pvt. Ltd. | Aluva |
| 52. | Sree Sakthi Paper Mills Ltd. | Parur |
| 53. | Sri Srinivas Roller Flour Mills Pvt. Ltd. | Aluva |
| 54. | Sterlix (India) Pvt. Ltd. | Kochi |
| 55. | Synthite Industrial Chemicals Ltd. | Kolencherry |
| 56. | Tamilnadu Ammonia Pvt. Ltd | Aluva |
| 57. | The Cochin Division | Kunnathunadu |
| 58. | The Fertilizers and Chemicals travancore Ltd. | |
| 59. | The Udyogamandal Division | Aluva |
| 60. | Toja Tyre and Treads Pvt. Ltd. | Aluva |
| 61. | Tolin Rubbers Pvt. Ltd. | Alwaye |
| 62. | Travancore Cochin Chemials Ltd. | Parur |
| 63. | Travancore Rayons Ltd. | Kunnathunadu |
| 64. | Travencore Chemical Manufacturing | Kalamassery |
| 65. | Union Catalyst India Ltd. | Parur |
| | **Kottayam District** | |
| 66. | Cochin Cements | |
| 67. | Hindustan Newsprint Ltd. (Subsidiary of Hindustan paper Corporation Ltd.) | Vaikom |

Contd...

Table 3.1.2.1 Contd...

| Sr. No. | Name of Industry | Location |
|---|---|---|
| 68. | Indian crumb Rubber factory (A unit of Palai Marketing Co-operative Society Ltd.) | Meenachil |
| 69. | Kanjirapalli Crumb Rubber factory | Kanjirapalli |
| 70. | Kohinoor Roller Flour Mills | Kottayam |
| 71. | Koldy Solvent Extraction Ltd. | Meenachil |
| 72. | Kollamkulam Rubbers Pvt. Ltd. | Kanjirapally |
| 73. | Kottayam Textiles | Meenachil |
| 74. | MRF Ltd. | Kottayam |
| 75. | Periyar Ferro Alloys | |
| 76. | Premiere Rubber Products (The erstwhile Ruby Rubber Works Ltd.) | Changanassery |
| 77. | TECIL Chemicals And Hydropower Ltd. (Travel Core Electrochemical Industries Ltd.) | Kottayam |
| 78. | Travancore Cements Ltd. | Kottayam |
| | **Thrissur District** | |
| 79. | Alagappa textiles (Cochin) Mills | Thrissur |
| 80. | Apollo Tyres Ltd. | Mukundapuram |
| 81. | Coats India (A Division of Madura coats Ltd.) | Mukunapuram |
| 82. | Pigments India Ltd. | Mukundapuram |
| 83. | Premiere Latex Pvt. Ltd. | Mukundapuram |
| 84. | Trinity Pharmaceutical Pvt. Ltd. | Poothotel |
| | **Alappuzha District** | |
| 85. | Excel Glass Ltd. | Kalavur |
| 86. | McDowells and Company Ltd. | Cherthala |
| 87. | Alappuzha Dairy | |
| 88. | Kuttanand Agricultural Corporation Ltd. | |
| 89. | Matha Modern Mills | Thekkakara |
| 90. | Phosphorous and Chemicals Travencore Ltd. | Ezhupunna |

Sources : Data collected by NEERI/KSPCB

## Table 3.1.2.2

## Total Number of Small Scale Industries in GKR

| Sector / Product Type | ALP | ERM | IDK | KOT | PTA | Total |
|---|---|---|---|---|---|---|
| Iron and Steel/Aluminium Fabrication | 33 | 125 | 11 | 98 | 35 | 302 |
| Coir/Coir Products | 4227 | 26 | - | 28 | - | 4281 |
| Bricks/Tiles/Cement-bricks /Clay/building Materials | 432 | 412 | 54 | 280 | 94 | 1272 |
| Granites/Mosaic/Marble/ Quarrying/Sand Mining | 4 | 284 | 17 | 63 | 81 | 449 |
| Lime Based | 36 | 13 | 1 | 6 | - | 56 |
| Sugar Mill | 5 | - | - | - | 17 | 22 |
| Drugs / Ayurvedic Medicines | 22 | 29 | 3 | 15 | 10 | 79 |
| Gas Based | - | 7 | - | - | - | 7 |
| Paper Based | 6 | 26 | - | 10 | 7 | 49 |
| Sericulture | 1 | - | - | - | - | 1 |
| Cotton Based | 58 | 66 | 4 | 52 | 9 | 189 |
| Rubber Based | 24 | 259 | 24 | 356 | 69 | 732 |
| Leather Based | 33 | 63 | 1 | 2 | 2 | 101 |
| Chemicals/Detergents/ Soaps | 7 | 216 | 3 | 24 | 5 | 255 |
| Battery Production | - | - | 2 | - | 1 | 3 |
| Bamboo/Cane Based | - | - | - | 10 | 10 | 20 |
| Paints | 8 | 14 | - | 10 | - | 32 |
| Glass/Glass Products | 2 | 9 | - | - | 9 | 20 |
| Flour Mills/Rice Mills/ Cattle Feed/Spices | 328 | 645 | 90 | 312 | 193 | 1568 |
| Vegetable Oil/Edible Oil/ Oil Extraction/Coconut Based | 260 | 179 | 37 | 124 | 74 | 674 |
| Food and Catering/Curry Powder/Pappad | 119 | 869 | 41 | 202 | 70 | 1301 |
| Cashew | 3 | 2 | - | - | - | 5 |
| Meat/Fish/Poultry/Cattle | 409 | 98 | - | - | 3 | 510 |
| Bakery Items | 43 | 94 | 16 | 70 | 35 | 258 |
| Soda Water/Soft Drinks | 52 | 67 | 21 | 31 | 78 | 249 |

Contd...

Table 3.1.2.2 Contd...

| Sector / Product Type | ALP | ERM | IDK | KOT | PTA | Total |
|---|---|---|---|---|---|---|
| Cold Storage/Ice Factory | 119 | 54 | 2 | 1 | 1 | 177 |
| Coffee | 2 | - | 44 | 2 | 4 | 52 |
| Beedi Making | 12 | - | - | - | 2 | 14 |
| Salt | - | - | - | 1 | - | 1 |
| Automobile/Cycle Workshop/boat Building | 56 | 235 | 174 | 86 | 101 | 652 |
| Agarbathy | - | 2 | - | - | - | 2 |
| Wood/forest industries/ Photo Framing | 145 | 640 | 21 | 354 | 130 | 1290 |
| Electroplating/Bangle cutting | 14 | 17 | - | 2 | 43 | 76 |
| Electronics/Electrical | 39 | 392 | - | 37 | 9 | 477 |
| Readymade/ Textiles | 121 | 827 | 38 | 121 | 37 | 1144 |
| Plastic / Upholstery/ Lamination/ PVC pipes | 17 | 119 | 15 | 32 | 25 | 208 |
| Printing/Photography/ DTP | 79 | 154 | 40 | 79 | 128 | 480 |
| Candles/Matches/ Fire Crackers | 122 | 53 | 9 | 53 | 8 | 245 |
| Mechanical/General Engg. | 92 | 1687 | 25 | 327 | 55 | 2186 |
| Repair/Servicing | 4 | 1673 | - | 2 | - | 1679 |
| Furniture | 126 | 312 | 17 | 143 | 43 | 641 |
| Welding | 13 | 4 | 3 | 12 | 34 | 66 |
| Factory | 6 | - | - | - | - | 6 |
| Handicraft | - | 18 | 1 | 11 | 1 | 31 |
| Arecanut processing | - | 2 | - | - | - | 2 |
| Fertilizer | - | - | 2 | 3 | - | 5 |
| Service Station / Misc. | - | - | 77 | - | 17 | 94 |
| Dry Cleaning | - | - | 2 | - | 1 | 3 |
| Poultry | - | - | 4 | - | - | 4 |
| Gum Solvent | - | - | - | 34 | - | 34 |
| Creep Mill | - | - | - | 2 | - | 2 |
| Rexin | - | - | - | 2 | - | 2 |
| Farm Product | - | - | - | 196 | - | 196 |
| **Total** | **7079** | **9692** | **797** | **3196** | **1440** | **22204** |
| **% in each District** | **31.88** | **43.65** | **3.59** | **14.39** | **6.49** | **-** |

**Source** : Secondary data collected by NEERI/KSSP

Table 3.1.2.3

**Block wise Fuel Consumption and Emission Loads from Area Sources**

| Sr. No. | Block Name | Population | Total Block Fuel Consumption | | | |
|---|---|---|---|---|---|---|
| | | | Wood (kgpd) | LPG (kgpd) | Kerosene (klpd) | Others (kgpd) |
| 1 | Amballapuzha | 111656 | 56945 | 2382 | 447 | 0 |
| 2 | Aryad | 97593 | 85166 | 423 | 586 | 0 |
| 3 | Chambakkulam | 133741 | 93084 | 1337 | 1071 | 4948 |
| 4 | Chengannur | 169482 | 128185 | 3051 | 3108 | 0 |
| 5 | Harippad | 164539 | 159603 | 4662 | 1153 | 0 |
| 6 | Kanjikuzhi | 140356 | 125010 | 2526 | 5616 | 0 |
| 7 | Mavelikkara | 123031 | 87680 | 2748 | 2668 | 6316 |
| 8 | Pattanakkad | 172045 | 236275 | 2409 | 3330 | 229 |
| 9 | Thykattussery | 87623 | 70244 | 584 | 527 | 0 |
| 10 | Veliyanad | 319014 | 232774 | 4998 | 1601 | 0 |
| 11 | Alangad | 132065 | 144919 | 3962 | 2775 | 484 |
| 12 | Angamali | 166016 | 172657 | 3818 | 2547 | 0 |
| 13 | Edappally | 88500 | 85402 | 3629 | 35961 | 0 |
| 14 | Koovappady | 125432 | 131913 | 3512 | 1756 | 0 |
| 15 | Kothamangalam | 130721 | 183402 | 1394 | 1308 | 0 |
| 16 | Mulanthuruthy | 114886 | 89956 | 1072 | 39 | 0 |
| 17 | Moovatupuzha | 121283 | 133533 | 2547 | 1900 | 0 |
| 18 | Palluruthy | 51484 | 47846 | 927 | 1 | 1493 |
| 19 | Pambakuda | 130338 | 66950 | 2129 | 436 | 0 |
| 20 | Parakadav | 117784 | 131565 | 3494 | 1807 | 0 |
| 21 | Paravoor | 122202 | 183955 | 448 | 1102 | 0 |
| 22 | Vadavukode | 138721 | 72089 | 2913 | 0 | 0 |
| 23 | Vazahakkulum | 167068 | 104696 | 4065 | 1897 | 0 |
| 24 | Vypin | 177016 | 154535 | 6668 | 533 | 0 |
| 25 | Vytila | 56340 | 28884 | 3042 | 1 | 0 |
| 26 | Adimali | 112241 | 164770 | 0 | 2544 | 75 |
| 27 | Azhutha | 161160 | 352726 | 2149 | 1504 | 0 |
| 28 | Elamdesam | 114291 | 68346 | 1981 | 1182 | 0 |
| 29 | Idukki | 113273 | 114217 | 906 | 604 | 0 |
| 30 | Kattappana | 153731 | 282455 | 4099 | 615 | 1998 |

Contd...

Table 3.1.2.3 Contd...

| Sr. No. | Block Name | Population | Total Block Fuel Consumption | | | |
|---|---|---|---|---|---|---|
| | | | Wood (kgpd) | LPG (kgpd) | Kerosene (klpd) | Others (kgpd) |
| 31 | Nedumkandam | 138407 | 249225 | 1661 | 1892 | 415 |
| 32 | Thodupuzha | 56087 | 39915 | 692 | 243 | 0 |
| 33 | Erattupetta | 101433 | 143967 | 2502 | 541 | 34 |
| 34 | Ettumanur | 182526 | 58652 | 7788 | 608 | 0 |
| 35 | Kaduthuruthy | 150286 | 127743 | 1653 | 1805 | 0 |
| 36 | Kanjirappally | 168774 | 251586 | 3544 | 2138 | 0 |
| 37 | Lalam | 91279 | 165002 | 3012 | 1188 | 0 |
| 38 | Madappally | 189594 | 207037 | 2718 | 4805 | 0 |
| 39 | Pallam | 232523 | 261356 | 7131 | 1552 | 0 |
| 40 | Pambady | 108795 | 190681 | 834 | 1559 | 0 |
| 41 | Uzhavur | 142220 | 253246 | 2987 | 1991 | 379 |
| 42 | Vazhur | 98181 | 79592 | 1996 | 1312 | 0 |
| 43 | Vaikom | 114709 | 40186 | 2715 | 1262 | 0 |
| 44 | Ilanthur | 111339 | 95009 | 2746 | 742 | 0 |
| 45 | Konny | 152477 | 200558 | 3609 | 3101 | 0 |
| 46 | Koipram | 114447 | 32274 | 2060 | 765 | 0 |
| 47 | Kulanada | 71879 | 96989 | 2827 | 1294 | 0 |
| 48 | Mallappally | 119519 | 55019 | 2510 | 678 | 0 |
| 49 | Pulikkeezhu | 82407 | 36781 | 3461 | 220 | 0 |
| 50 | Ranni | 186933 | 492070 | 3427 | 2932 | 0 |
| 51 | Chalakkudy | 74442 | 86675 | 4888 | 1440 | 0 |

**Source** : Data estimated by NEERI

Table 3.1.2.4

Grid wise Area Sources Emissions in GKR

| Grid No. | Population | Grid wise Emissions (Kg/day) | | | | |
|---|---|---|---|---|---|---|
| | | SPM | $SO_2$ | $NO_2$ | CO | HC |
| A1 | 167334 | 8534 | 5873 | 3246 | 122756 | 10124 |
| A2 | 295554 | 15073 | 10374 | 5734 | 216818 | 17881 |
| A3 | 142118 | 7248 | 4988 | 2757 | 104258 | 8598 |
| A4 | 140188 | 7150 | 4921 | 2720 | 102842 | 8481 |
| A5 | 84859 | 4328 | 2979 | 1646 | 62253 | 5134 |
| A6 | 15925 | 812 | 559 | 309 | 11683 | 964 |
| A7 | NA | NA | NA | NA | NA | NA |
| A8 | NA | NA | NA | NA | NA | NA |
| A9 | NA | NA | NA | NA | NA | NA |
| A10 | NA | NA | NA | NA | NA | NA |
| A11 | NA | NA | NA | NA | NA | NA |
| A12 | NA | NA | NA | NA | NA | NA |
| A13 | NA | NA | NA | NA | NA | NA |
| A14 | NA | NA | NA | NA | NA | NA |
| A15 | NA | NA | NA | NA | NA | NA |
| | | | | | | |
| B1 | 81260 | 4143 | 2851 | 1576 | 59612 | 4917 |
| B2 | 128816 | 6617 | 4557 | 2510 | 95300 | 7564 |
| B3 | 93426 | 4782 | 3292 | 1816 | 68850 | 5563 |
| B4 | 59907 | 3137 | 2166 | 1181 | 45205 | 3257 |
| B5 | 35083 | 1789 | 1231 | 680 | 25737 | 2123 |
| B6 | 26362 | 1344 | 924 | 511 | 19339 | 1596 |
| B7 | 15369 | 783 | 539 | 298 | 11274 | 931 |
| B8 | 9846 | 502 | 345 | 191 | 7223 | 596 |
| B9 | 2642 | 135 | 93 | 51 | 1938 | 160 |
| B10 | NA | NA | NA | NA | NA | NA |
| B11 | NA | NA | NA | NA | NA | NA |
| B12 | 540 | 26 | 18 | 10 | 377 | 46 |
| B13 | 4050 | 198 | 134 | 76 | 2827 | 344 |
| B14 | NA | NA | NA | NA | NA | NA |
| B15 | NA | NA | NA | NA | NA | NA |
| | | | | | | |
| C1 | 10568 | 539 | 370 | 205 | 7753 | 640 |
| C2 | 164830 | 8478 | 5839 | 3214 | 122120 | 9627 |

Contd...

NA – Not Applicable (does not come under study area / lies in the ocean)

Table 3.1.2.4 Contd...

| Grid No. | Population | Grid wise Emissions (Kg/day) | | | | |
|---|---|---|---|---|---|---|
| | | SPM | $SO_2$ | $NO_2$ | CO | HC |
| C3 | 104639 | 5384 | 3708 | 2041 | 77548 | 6105 |
| C4 | 64221 | 3060 | 2109 | 1151 | 44092 | 3352 |
| C5 | 54751 | 2268 | 1553 | 860 | 32579 | 3011 |
| C6 | 31814 | 1284 | 877 | 489 | 18428 | 1778 |
| C7 | 28532 | 1223 | 837 | 466 | 17573 | 1631 |
| C8 | 19051 | 1012 | 696 | 384 | 14569 | 1227 |
| C9 | 12279 | 680 | 467 | 257 | 9779 | 839 |
| C10 | 2121 | 118 | 81 | 45 | 1704 | 147 |
| C11 | 2106 | 116 | 79 | 44 | 1659 | 169 |
| C12 | 11609 | 568 | 384 | 217 | 8105 | 986 |
| C13 | 12149 | 594 | 402 | 227 | 8482 | 1032 |
| C14 | 945 | 46 | 31 | 18 | 660 | 80 |
| C15 | NA | NA | NA | NA | NA | NA |
| D1 | NA | NA | NA | NA | NA | NA |
| D2 | 144318 | 5761 | 3912 | 2214 | 82463 | 9039 |
| D3 | 141688 | 6110 | 4167 | 2331 | 87620 | 8865 |
| D4 | 123444 | 5556 | 3821 | 2090 | 79980 | 6433 |
| D5 | 66567 | 2663 | 1822 | 1009 | 38236 | 3608 |
| D6 | 41386 | 1560 | 1063 | 595 | 22362 | 2302 |
| D7 | 28865 | 1049 | 708 | 403 | 14972 | 1875 |
| D8 | 11607 | 695 | 477 | 261 | 9998 | 886 |
| D9 | 11607 | 695 | 477 | 261 | 9998 | 886 |
| D10 | 12137 | 685 | 468 | 258 | 9837 | 959 |
| D11 | 12836 | 672 | 457 | 255 | 9625 | 1055 |
| D12 | 13461 | 661 | 447 | 253 | 9436 | 1141 |
| D13 | 13498 | 660 | 446 | 252 | 9425 | 1147 |
| D14 | 4724 | 231 | 156 | 88 | 3299 | 401 |
| D15 | NA | NA | NA | NA | NA | NA |
| | | | | | | |
| E1 | NA | NA | NA | NA | NA | NA |
| E2 | 112510 | 1649 | 1061 | 680 | 23054 | 5150 |
| E3 | 174722 | 7303 | 4978 | 2777 | 104711 | 10636 |
| E4 | 129330 | 4616 | 3182 | 1735 | 66517 | 5024 |
| E5 | 114812 | 3844 | 2656 | 1440 | 55450 | 3888 |
| E6 | 40540 | 1291 | 872 | 497 | 18436 | 2264 |
| E7 | 56083 | 2256 | 1537 | 853 | 32334 | 3214 |
| E8 | 31472 | 1008 | 668 | 393 | 14273 | 2310 |

Contd...

Table 3.1.2.4 Contd...

| Grid No. | Population | Grid wise Emissions (Kg/day) | | | | |
|---|---|---|---|---|---|---|
| | | SPM | $SO_2$ | $NO_2$ | CO | HC |
| E9 | 12524 | 710 | 486 | 267 | 10195 | 952 |
| E10 | 12364 | 681 | 465 | 257 | 9768 | 990 |
| E11 | 13026 | 669 | 454 | 254 | 9568 | 1082 |
| E12 | 13385 | 662 | 448 | 253 | 9459 | 1131 |
| E13 | 8774 | 429 | 290 | 164 | 6126 | 745 |
| E14 | 270 | 13 | 9 | 5 | 188 | 23 |
| E15 | NA | NA | NA | NA | NA | NA |
| | | | | | | |
| F1 | NA | NA | NA | NA | NA | NA |
| F2 | 2766 | 26 | 15 | 11 | 348 | 126 |
| F3 | 587422 | 28935 | 20095 | 10688 | 418284 | 22571 |
| F4 | 116332 | 1697 | 1111 | 685 | 23910 | 4452 |
| F5 | 75700 | 115 | 37 | 78 | 1264 | 2052 |
| F6 | 77824 | 3180 | 2187 | 1193 | 45771 | 3626 |
| F7 | 54957 | 2128 | 1446 | 811 | 30463 | 3306 |
| F8 | 42676 | 1303 | 872 | 505 | 18531 | 2632 |
| F9 | 27281 | 802 | 548 | 304 | 11511 | 1104 |
| F10 | 16486 | 718 | 493 | 269 | 10329 | 885 |
| F11 | 11607 | 695 | 477 | 261 | 9998 | 886 |
| F12 | 27098 | 1139 | 759 | 442 | 16163 | 2449 |
| F13 | 18290 | 815 | 546 | 314 | 11592 | 1616 |
| F14 | 2565 | 125 | 85 | 48 | 1791 | 218 |
| F15 | NA | NA | NA | NA | NA | NA |
| G1 | NA | NA | NA | NA | NA | NA |
| G2 | NA | NA | NA | NA | NA | NA |
| G3 | 165490 | 5343 | 3655 | 2016 | 76718 | 6590 |
| G4 | 116953 | 1700 | 1114 | 679 | 23955 | 4368 |
| G5 | 66216 | 395 | 235 | 175 | 5348 | 2109 |
| G6 | 57464 | 851 | 567 | 334 | 12081 | 1830 |
| G7 | 47444 | 1163 | 785 | 448 | 16610 | 2049 |
| G8 | 66337 | 2675 | 1850 | 994 | 38598 | 2479 |
| G9 | 28461 | 769 | 530 | 290 | 11082 | 887 |
| G10 | 28431 | 773 | 533 | 291 | 11139 | 884 |
| G11 | 26794 | 602 | 397 | 237 | 8513 | 1484 |
| G12 | 30189 | 1110 | 734 | 434 | 15701 | 2613 |
| G13 | 33583 | 1293 | 854 | 507 | 18279 | 3128 |
| G14 | 135 | 7 | 4 | 3 | 94 | 11 |

Contd...

Table 3.1.2.4 Contd...

| Grid No. | Population | Grid wise Emissions (Kg/day) | | | | |
|---|---|---|---|---|---|---|
| | | SPM | $SO_2$ | $NO_2$ | CO | HC |
| G15 | NA | NA | NA | NA | NA | NA |
| | | | | | | |
| H1 | NA | NA | NA | NA | NA | NA |
| H2 | NA | NA | NA | NA | NA | NA |
| H3 | 89875 | 3891 | 2643 | 1480 | 55697 | 6079 |
| H4 | 108009 | 2341 | 1584 | 898 | 33448 | 3955 |
| H5 | 84799 | 1996 | 1356 | 762 | 28581 | 3130 |
| H6 | 68899 | 1754 | 1178 | 679 | 24983 | 3386 |
| H7 | 61753 | 2202 | 1454 | 867 | 31137 | 5329 |
| H8 | 41558 | 1055 | 688 | 423 | 14832 | 2962 |
| H9 | 32419 | 668 | 443 | 262 | 9466 | 1509 |
| H10 | 37511 | 901 | 603 | 349 | 12815 | 1796 |
| H11 | 32477 | 1234 | 847 | 463 | 17745 | 1459 |
| H12 | 28212 | 781 | 507 | 312 | 10961 | 2302 |
| H13 | 37963 | 1436 | 946 | 564 | 20276 | 3560 |
| H14 | 802 | 30 | 20 | 12 | 429 | 75 |
| H15 | NA | NA | NA | NA | NA | NA |
| | | | | | | |
| I1 | NA | NA | NA | NA | NA | NA |
| I2 | NA | NA | NA | NA | NA | NA |
| I3 | 62633 | 3688 | 2540 | 1381 | 53122 | 4242 |
| I4 | 144289 | 7961 | 5541 | 2939 | 115203 | 6181 |
| I5 | 85142 | 2756 | 1808 | 990 | 37858 | 3192 |
| I6 | 83149 | 2836 | 1859 | 1122 | 39969 | 7401 |
| I7 | 66386 | 2690 | 1796 | 1047 | 38214 | 5581 |
| I8 | 54235 | 1839 | 1220 | 721 | 26051 | 4132 |
| I9 | 39284 | 631 | 388 | 269 | 8652 | 2816 |
| I10 | 26084 | 1851 | 316 | 206 | 6935 | 1851 |
| I11 | 19257 | 661 | 347 | 213 | 7511 | 1552 |
| I12 | 13150 | 372 | 232 | 154 | 5141 | 1480 |
| I13 | 10037 | 315 | 201 | 128 | 4384 | 1069 |
| I14 | NA | NA | NA | NA | NA | NA |
| I15 | NA | NA | NA | NA | NA | NA |
| | | | | | | |
| J1 | NA | NA | NA | NA | NA | NA |
| J2 | NA | NA | NA | NA | NA | NA |
| J3 | 33897 | 2706 | 1898 | 991 | 39297 | 1562 |

Contd...

Table 3.1.2.4 Contd...

| Grid No. | Population | Grid wise Emissions (Kg/day) | | | | |
|---|---|---|---|---|---|---|
| | | SPM | $SO_2$ | $NO_2$ | CO | HC |
| J4 | 125768 | 9123 | 6382 | 3353 | 132330 | 6013 |
| J5 | 126223 | 3171 | 2023 | 1291 | 44182 | 10679 |
| J6 | 148639 | 5008 | 3297 | 1966 | 70722 | 12129 |
| J7 | 77451 | 2526 | 1665 | 996 | 35683 | 6270 |
| J8 | 60009 | 2213 | 1463 | 868 | 31299 | 5309 |
| J9 | 46086 | 1172 | 760 | 473 | 16439 | 3487 |
| J10 | 22248 | 3018 | 427 | 267 | 9264 | 2059 |
| J11 | 12600 | 3019 | 217 | 145 | 4808 | 1434 |
| J12 | 12600 | 3082 | 217 | 145 | 4808 | 1434 |
| J13 | 6300 | 1462 | 108 | 72 | 2404 | 717 |
| J14 | 1260 | 349 | 22 | 14 | 481 | 143 |
| J15 | 378 | 105 | 7 | 4 | 144 | 43 |
| | | | | | | |
| K1 | NA | NA | NA | NA | NA | NA |
| K2 | NA | NA | NA | NA | NA | NA |
| K3 | 51490 | 2275 | 1574 | 843 | 32835 | 2039 |
| K4 | 169567 | 5683 | 3899 | 2129 | 81708 | 6636 |
| K5 | 157548 | 2478 | 1615 | 998 | 34831 | 6958 |
| K6 | 150082 | 5836 | 3988 | 2211 | 83762 | 7963 |
| K7 | 92044 | 4675 | 3210 | 1758 | 67245 | 5832 |
| K8 | 71976 | 2533 | 1739 | 956 | 36429 | 3170 |
| K9 | 56275 | 1959 | 1306 | 763 | 27814 | 4155 |
| K10 | 30323 | 2824 | 657 | 397 | 14130 | 2616 |
| K11 | 13866 | 3443 | 248 | 163 | 5474 | 1518 |
| K12 | 12600 | 3490 | 217 | 145 | 4808 | 1434 |
| K13 | 12600 | 3490 | 217 | 145 | 4808 | 1434 |
| K14 | 12600 | 3490 | 217 | 145 | 4808 | 1434 |
| K15 | 6174 | 1710 | 106 | 71 | 2356 | 703 |
| | | | | | | |
| L1 | NA | NA | NA | NA | NA | NA |
| L2 | NA | NA | NA | NA | NA | NA |
| L3 | NA | NA | NA | NA | NA | NA |
| L4 | 163887 | 5426 | 3740 | 2023 | 78172 | 5473 |
| L5 | 198906 | 3001 | 1974 | 1190 | 42353 | 7499 |
| L6 | 181566 | 9132 | 6334 | 3388 | 131943 | 8083 |
| L7 | 97981 | 2401 | 1651 | 908 | 34554 | 2874 |
| L8 | 83658 | 1561 | 1066 | 597 | 22405 | 2197 |

Contd...

Table 3.1.2.4 Contd...

| Grid No. | Population | Grid wise Emissions (Kg/day) | | | | |
|---|---|---|---|---|---|---|
| | | SPM | $SO_2$ | $NO_2$ | CO | HC |
| L9 | 31924 | 1152 | 758 | 455 | 16268 | 2917 |
| L10 | 34204 | 1330 | 835 | 500 | 17899 | 3147 |
| L11 | 14724 | 2115 | 348 | 221 | 7585 | 1837 |
| L12 | 15344 | 1298 | 411 | 258 | 8927 | 2039 |
| L13 | 14997 | 1576 | 386 | 243 | 8406 | 1963 |
| L14 | 12669 | 3435 | 222 | 148 | 4912 | 1449 |
| L15 | 3654 | 1012 | 63 | 42 | 1394 | 416 |
| | | | | | | |
| M1 | NA | NA | NA | NA | NA | NA |
| M2 | NA | NA | NA | NA | NA | NA |
| M3 | NA | NA | NA | NA | NA | NA |
| M4 | 52178 | 705 | 467 | 279 | 9988 | 1604 |
| M5 | 121883 | 2417 | 1601 | 953 | 34222 | 5474 |
| M6 | 149623 | 5387 | 3731 | 2012 | 77784 | 5069 |
| M7 | 116502 | 3842 | 2665 | 1430 | 55509 | 3350 |
| M8 | 82114 | 1492 | 1009 | 577 | 21315 | 2523 |
| M9 | 20864 | 784 | 509 | 314 | 11004 | 2291 |
| M10 | 16073 | 716 | 462 | 288 | 10022 | 2200 |
| M11 | 16073 | 716 | 462 | 288 | 10022 | 2200 |
| M12 | 16073 | 716 | 462 | 288 | 10022 | 2200 |
| M13 | 15969 | 799 | 455 | 283 | 9866 | 2177 |
| M14 | 10023 | 2702 | 176 | 117 | 3903 | 1148 |
| M15 | 378 | 105 | 7 | 4 | 144 | 43 |
| | | | | | | |
| N1 | NA | NA | NA | NA | NA | NA |
| N2 | NA | NA | NA | NA | NA | NA |
| N3 | NA | NA | NA | NA | NA | NA |
| N4 | 11075 | 216 | 142 | 87 | 3046 | 559 |
| N5 | 89155 | 2220 | 1489 | 865 | 31602 | 4314 |
| N6 | 104342 | 4996 | 3472 | 1851 | 72245 | 4133 |
| N7 | 69199 | 2481 | 1708 | 935 | 35730 | 2930 |
| N8 | 83065 | 1583 | 1048 | 627 | 22405 | 3683 |
| N9 | 56364 | 2755 | 1904 | 1026 | 39739 | 2669 |
| N10 | 20516 | 1026 | 689 | 396 | 14607 | 1976 |
| N11 | 22182 | 1142 | 774 | 437 | 16326 | 1891 |
| N12 | 20701 | 1039 | 698 | 401 | 14798 | 1966 |
| N13 | 16073 | 716 | 462 | 288 | 10022 | 2200 |

Contd...

Table 3.1.2.4 Contd...

| Grid No. | Population | Grid wise Emissions (Kg/day) | | | | |
|---|---|---|---|---|---|---|
| | | SPM | $SO_2$ | $NO_2$ | CO | HC |
| N14 | 6912 | 308 | 199 | 124 | 4309 | 946 |
| N15 | NA | NA | NA | NA | NA | NA |
| | | | | | | |
| O1 | NA | NA | NA | NA | NA | NA |
| O2 | NA | NA | NA | NA | NA | NA |
| O3 | NA | NA | NA | NA | NA | NA |
| O4 | NA | NA | NA | NA | NA | NA |
| O5 | 31617 | 1547 | 1075 | 572 | 22368 | 1251 |
| O6 | 44799 | 1989 | 1378 | 740 | 28726 | 1842 |
| O7 | 52089 | 1343 | 908 | 519 | 19190 | 2323 |
| O8 | 115793 | 2245 | 1488 | 889 | 31787 | 5211 |
| O9 | 112234 | 2291 | 1522 | 904 | 32473 | 5132 |
| O10 | 51205 | 1498 | 1011 | 578 | 21381 | 2649 |
| O11 | 19503 | 1048 | 719 | 395 | 15072 | 1334 |
| O12 | 25328 | 1361 | 934 | 513 | 19574 | 1732 |
| O13 | 21071 | 1064 | 717 | 410 | 15180 | 1948 |
| O14 | 4111 | 185 | 120 | 74 | 2601 | 545 |
| O15 | NA | NA | NA | NA | NA | NA |
| P1 | NA | NA | NA | NA | NA | NA |
| P2 | NA | NA | NA | NA | NA | NA |
| P3 | NA | NA | NA | NA | NA | NA |
| P4 | NA | NA | NA | NA | NA | NA |
| P5 | NA | NA | NA | NA | NA | NA |
| P6 | NA | NA | NA | NA | NA | NA |
| P7 | 4260 | 78 | 52 | 31 | 1109 | 189 |
| P8 | 59642 | 1098 | 726 | 437 | 15532 | 2647 |
| P9 | 24141 | 445 | 294 | 177 | 6287 | 1071 |
| P10 | 1420 | 26 | 17 | 10 | 370 | 63 |
| P11 | NA | NA | NA | NA | NA | NA |
| P12 | 4053 | 218 | 149 | 82 | 3132 | 277 |
| P13 | 7599 | 408 | 280 | 154 | 5872 | 520 |
| P14 | NA | NA | NA | NA | NA | NA |
| P15 | NA | NA | NA | NA | NA | NA |
| **Total** | **10185583** | **416337** | **258493** | **144668** | **5439128** | **557654** |

**Source :** Data estimated by NEERI

## Table 3.1.2.5

### District wise Distribution of Roads in GKR

| Districts | Road Length (Km) | | |
|---|---|---|---|
| | Local | State Highway | National Highway |
| Alappuzha | 338 | 40 | 101 |
| Ernakulam | 435 | 83 | 138 |
| Kottayam | 527 | 187 | 0 |
| Pathanamthitta | 399 | 128 | 0 |
| Thrissur | 592 | 145 | 77 |
| Idukki | 814 | 284 | 95 |

**Source** : Data estimated by NEERI

## Table 3.1.2.6

### Average Daily Run and Emission Factors for each Category of Vehicle

| Type of Vehicle | No. of Vehicles | Avg. Run (km/d) | Emission Factors (g/km) | | | | |
|---|---|---|---|---|---|---|---|
| | | | SPM | $SO_2$ | $NO_2$ | CO | HC |
| 2W | 160892 | 10 | 0.00 | 0.013 | 0.00 | 8.30 | 5.18 |
| 3W | 19086 | 80 | 0.00 | 0.029 | 0.00 | 12.25 | 7.65 |
| 4W(P) | 39458 | 20 | 0.00 | 0.053 | 1.57 | 24.03 | 3.57 |
| 4W(D) | 6424 | 80 | 0.10 | 0.400 | 2.50 | 1.30 | 0.50 |
| LCV | 30332 | 150 | 0.10 | 0.400 | 2.50 | 1.30 | 0.50 |
| HD | 5183 | 200 | 0.29 | 1.520 | 8.76 | 4.63 | 1.79 |

**Source** : Data estimated by NEERI

## Table 3.1.2.7

## Grid wise Line Source Emissions in GKR

| Grid No. | Total Grid wise Emissions (Kg/day) | | | | |
|---|---|---|---|---|---|
| | SPM | $SO_2$ | $NO_2$ | CO | HC |
| GA1 | 36 | 173 | 1029 | 1287 | 559 |
| GA2 | 31 | 134 | 1166 | 2151 | 1143 |
| GA3 | 36 | 176 | 1046 | 2287 | 1092 |
| GA4 | 12 | 60 | 357 | 1080 | 532 |
| GA5 | 1 | 3 | 15 | 136 | 71 |
| GA6 | 0 | 0 | 0 | 0 | 0 |
| GA7 | 0 | 0 | 0 | 0 | 0 |
| GA8 | NA | NA | NA | NA | NA |
| GA9 | NA | NA | NA | NA | NA |
| GA10 | NA | NA | NA | NA | NA |
| GA11 | NA | NA | NA | NA | NA |
| GA12 | NA | NA | NA | NA | NA |
| GA13 | NA | NA | NA | NA | NA |
| GA14 | NA | NA | NA | NA | NA |
| GA15 | NA | NA | NA | NA | NA |
| | | | | | |
| GB1 | 17 | 82 | 486 | 512 | 353 |
| GB2 | 38 | 186 | 1110 | 2157 | 1020 |
| GB3 | 52 | 251 | 1495 | 2878 | 1326 |
| GB4 | 15 | 80 | 430 | 1528 | 765 |
| GB5 | 1 | 8 | 46 | 407 | 211 |
| GB6 | 1 | 3 | 21 | 182 | 95 |
| GB7 | 1 | 3 | 21 | 184 | 99 |
| GB8 | 1 | 4 | 21 | 188 | 94 |
| GB9 | 0 | 0 | 0 | 0 | 0 |
| GB10 | NA | NA | NA | NA | NA |
| GB11 | NA | NA | NA | NA | NA |
| DB12 | 0 | 0 | 0 | 0 | 0 |
| GB13 | 1.02 | 5.01 | 20.55 | 33.06 | 12.41 |
| GB14 | NA | NA | NA | NA | NA |
| GB15 | NA | NA | NA | NA | NA |
| | | | | | |
| GC1 | 4 | 20 | 117 | 121 | 50 |
| GC2 | 35 | 172 | 1026 | 1813 | 841 |
| GC3 | 27 | 134 | 797 | 2209 | 1081 |
| GC4 | 14 | 64 | 268 | 1223 | 611 |
| GC5 | 12 | 54 | 336 | 1391 | 639 |

Contd...

NA – Not Applicable (does not come under study area / lies in the ocean)

Table 3.1.2.7 Contd...

| Grid No. | Total Grid wise Emissions (Kg/day) | | | | |
|---|---|---|---|---|---|
| | SPM | $SO_2$ | $NO_2$ | CO | HC |
| GC6 | 12 | 67 | 315 | 1206 | 549 |
| GC7 | 2 | 9 | 56 | 500 | 251 |
| GC8 | 1 | 7 | 43 | 348 | 175 |
| GC9 | 1 | 5 | 34 | 241 | 111 |
| GC10 | 0 | 1 | 8 | 23 | 9 |
| GC11 | 0 | 0 | 0 | 0 | 0 |
| GC12 | 1 | 3 | 16 | 26 | 10 |
| GC13 | 1 | 6 | 35 | 56 | 21 |
| GC14 | 0 | 0 | 0 | 0 | 0 |
| GC15 | NA | NA | NA | NA | NA |
| GD1 | NA | NA | NA | NA | NA |
| GD2 | 16 | 76 | 464 | 813 | 343 |
| GD3 | 30 | 141 | 856 | 1808 | 782 |
| GD4 | 46 | 208 | 1279 | 2524 | 1062 |
| GD5 | 55 | 253 | 1567 | 4021 | 1719 |
| GD6 | 29 | 135 | 848 | 3660 | 1669 |
| GD7 | 6 | 28 | 179 | 1432 | 670 |
| GD8 | 1 | 4 | 23 | 55 | 27 |
| GD9 | 0 | 2 | 14 | 39 | 16 |
| GD10 | 1 | 3 | 16 | 45 | 18 |
| GD11 | 1 | 5 | 31 | 78 | 31 |
| GD12 | 2 | 9 | 56 | 115 | 45 |
| GD13 | 2 | 8 | 48 | 103 | 40 |
| GD14 | 0 | 1 | 6 | 15 | 6 |
| GD15 | NA | NA | NA | NA | NA |
| | | | | | |
| GE1 | NA | NA | NA | NA | NA |
| GE2 | 3 | 13 | 79 | 229 | 100 |
| GE3 | 34 | 154 | 950 | 1811 | 750 |
| GE4 | 36 | 163 | 1016 | 2347 | 1001 |
| GE5 | 27 | 123 | 768 | 2980 | 1348 |
| GE6 | 44 | 202 | 1253 | 3598 | 1587 |
| GE7 | 42 | 191 | 1188 | 2825 | 1215 |
| GE8 | 20 | 95 | 562 | 1456 | 629 |
| GE9 | 4 | 20 | 130 | 194 | 72 |
| GE10 | 4 | 18 | 102 | 148 | 29 |
| GE11 | 7 | 34 | 208 | 294 | 88 |
| GE12 | 7 | 36 | 219 | 338 | 78 |
| GE13 | 4 | 20 | 119 | 201 | 42 |
| GE14 | 0 | 0 | 0 | 0 | 0 |
| GE15 | NA | NA | NA | NA | NA |

Contd...

Table 3.1.2.7 Contd...

| Grid No. | Total Grid wise Emissions (Kg/day) | | | | |
|---|---|---|---|---|---|
| | SPM | $SO_2$ | $NO_2$ | CO | HC |
| GF1 | NA | NA | NA | NA | NA |
| GF2 | 0 | 0 | 0 | 0 | 0 |
| GF3 | 0 | 2 | 11 | 97 | 45 |
| GF4 | 59 | 269 | 1656 | 2857 | 1157 |
| GF5 | 40 | 186 | 1150 | 2901 | 1249 |
| GF6 | 49 | 225 | 1389 | 3296 | 1415 |
| GF7 | 35 | 160 | 989 | 2712 | 1186 |
| GF8 | 7 | 34 | 212 | 782 | 348 |
| GF9 | 2 | 10 | 60 | 119 | 45 |
| GF10 | 2 | 6 | 38 | 104 | 39 |
| GF11 | 4 | 18 | 110 | 202 | 75 |
| GF12 | 5 | 22 | 136 | 218 | 78 |
| GF13 | 3 | 13 | 79 | 118 | 41 |
| GF14 | 0 | 1 | 5 | 7 | 2 |
| GF15 | NA | NA | NA | NA | NA |
| GG1 | NA | NA | NA | NA | NA |
| GG2 | NA | NA | NA | NA | NA |
| GG3 | 4 | 18 | 110 | 191 | 79 |
| GG4 | 31 | 137 | 843 | 1438 | 582 |
| GG5 | 27 | 124 | 773 | 2512 | 1112 |
| GG6 | 28 | 130 | 821 | 3739 | 1678 |
| GG7 | 20 | 94 | 590 | 2284 | 1032 |
| GG8 | 2 | 12 | 73 | 179 | 73 |
| GG9 | 1 | 6 | 40 | 98 | 39 |
| GG10 | 1 | 6 | 38 | 84 | 33 |
| GG11 | 1 | 6 | 40 | 100 | 50 |
| GG12 | 2 | 12 | 73 | 144 | 54 |
| GG13 | 2 | 8 | 48 | 79 | 29 |
| GG14 | NA | NA | NA | NA | NA |
| GG15 | NA | NA | NA | NA | NA |
| | | | | | |
| GH1 | NA | NA | NA | NA | NA |
| GH2 | NA | NA | NA | NA | NA |
| GH3 | 6 | 29 | 180 | 611 | 283 |
| GH4 | 23 | 112 | 689 | 2232 | 989 |
| GH5 | 17 | 80 | 496 | 1454 | 624 |
| GH6 | 16 | 76 | 466 | 1212 | 514 |
| GH7 | 12 | 58 | 363 | 1447 | 634 |
| GH8 | 5 | 23 | 142 | 701 | 310 |
| GH9 | 2 | 9 | 58 | 217 | 94 |
| GH10 | 1 | 2 | 14 | 26 | 10 |

Contd...

Table 3.1.2.7 Contd...

| Grid No. | Total Grid wise Emissions (Kg/day) | | | | |
|---|---|---|---|---|---|
| | SPM | $SO_2$ | $NO_2$ | CO | HC |
| GH11 | 1 | 3 | 19 | 42 | 16 |
| GH12 | 2 | 10 | 61 | 138 | 54 |
| GH13 | 1 | 5 | 28 | 68 | 27 |
| GH14 | 0 | 0 | 0 | 0 | 0 |
| GH15 | NA | NA | NA | NA | NA |
| | | | | | |
| GI1 | NA | NA | NA | NA | NA |
| GI2 | NA | NA | NA | NA | NA |
| GI3 | 7 | 31 | 193 | 707 | 330 |
| GI4 | 18 | 83 | 512 | 1835 | 859 |
| GI5 | 9 | 46 | 282 | 949 | 411 |
| GI6 | 21 | 100 | 622 | 1530 | 636 |
| GI7 | 11 | 56 | 351 | 1779 | 790 |
| GI8 | 8 | 39 | 243 | 1235 | 548 |
| GI9 | 3 | 13 | 79 | 400 | 178 |
| GI10 | 2 | 7 | 53 | 145 | 109 |
| GI11 | 1 | 6 | 37 | 105 | 42 |
| GI12 | 1 | 5 | 29 | 69 | 27 |
| GI13 | 0 | 2 | 12 | 28 | 11 |
| GI14 | NA | NA | NA | NA | NA |
| GI15 | NA | NA | NA | NA | NA |
| | | | | | |
| GJ1 | NA | NA | NA | NA | NA |
| GJ2 | NA | NA | NA | NA | NA |
| GJ3 | 4 | 17 | 104 | 373 | 174 |
| GJ4 | 17 | 81 | 497 | 1752 | 815 |
| GJ5 | 5 | 24 | 153 | 774 | 344 |
| GJ6 | 23 | 111 | 676 | 1422 | 589 |
| GJ7 | 15 | 76 | 439 | 1261 | 539 |
| GJ8 | 12 | 57 | 354 | 1227 | 533 |
| GJ9 | 9 | 42 | 260 | 925 | 402 |
| GJ10 | 3 | 13 | 81 | 243 | 102 |
| GJ11 | 1 | 6 | 38 | 81 | 32 |
| GJ12 | 2 | 11 | 65 | 153 | 61 |
| GJ13 | 1 | 3 | 20 | 45 | 18 |
| GJ14 | 0 | 0 | 22 | 4 | 2 |
| GJ15 | 0 | 0 | 0 | 0 | 0 |
| | | | | | |
| GK1 | NA | NA | NA | NA | NA |
| GK2 | NA | NA | NA | NA | NA |
| GK3 | 0 | 0 | 0 | 0 | 0 |

Contd...

Table 3.1.2.7 Contd...

| Grid No. | Total Grid wise Emissions (Kg/day) | | | | |
|---|---|---|---|---|---|
| | SPM | $SO_2$ | $NO_2$ | CO | HC |
| GK4 | 23 | 109 | 666 | 1536 | 682 |
| GK5 | 0 | 0 | 0 | 0 | 0 |
| GK6 | 19 | 91 | 557 | 1270 | 531 |
| GK7 | 15 | 71 | 433 | 1043 | 439 |
| GK8 | 19 | 73 | 446 | 1204 | 512 |
| GK9 | 12 | 56 | 343 | 960 | 410 |
| GK10 | 4 | 17 | 110 | 521 | 230 |
| GK11 | 0 | 1 | 6 | 12 | 5 |
| GK12 | 1 | 3 | 18 | 50 | 20 |
| GK13 | 0 | 1 | 5 | 14 | 5 |
| GK14 | 0 | 0 | 0 | 0 | 0 |
| GK15 | 0 | 0 | 0 | 0 | 0 |
| | | | | | |
| GL1 | NA | NA | NA | NA | NA |
| GL2 | NA | NA | NA | NA | NA |
| GL3 | NA | NA | NA | NA | NA |
| GL4 | 20.11 | 93 | 566 | 984 | 419 |
| GL5 | 21 | 96 | 586 | 1258 | 562 |
| GL6 | 6 | 28 | 175 | 557 | 225 |
| GL7 | 6 | 29 | 186 | 533 | 210 |
| GL8 | 4 | 19 | 119 | 364 | 146 |
| GL9 | 3 | 15 | 94 | 333 | 137 |
| GL10 | 3 | 12 | 75 | 263 | 109 |
| GL11 | 2 | 8 | 54 | 191 | 79 |
| GL12 | 2 | 10 | 62 | 219 | 90 |
| GL13 | 1 | 4 | 23 | 81 | 33 |
| GL14 | 0 | 0 | 0 | 0 | 0 |
| GL15 | 0 | 0 | 0 | 0 | 0 |
| | | | | | |
| GM1 | NA | NA | NA | NA | NA |
| GM2 | NA | NA | NA | NA | NA |
| GM3 | NA | NA | NA | NA | NA |
| GM4 | 6 | 30 | 180 | 254 | 103 |
| GM5 | 32 | 146 | 891 | 1682 | 727 |
| GM6 | 7 | 32 | 195 | 748 | 345 |
| GM7 | 3 | 16 | 102 | 443 | 196 |
| GM8 | 6 | 28 | 176 | 536 | 215 |
| GM9 | 6 | 26 | 169 | 586 | 214 |
| GM10 | 5 | 21 | 133 | 471 | 194 |
| GM11 | 3 | 14 | 89 | 314 | 130 |
| GM12 | 2 | 11 | 68 | 241 | 99 |

Contd...

Table 3.1.2.7 Contd...

| Grid No. | Total Grid wise Emissions (Kg/day) | | | | |
|---|---|---|---|---|---|
| | SPM | $SO_2$ | $NO_2$ | CO | HC |
| GM13 | 1 | 3 | 22 | 79 | 32 |
| GM14 | 0 | 0 | 0 | 0 | 0 |
| GM15 | 0 | 0 | 0 | 0 | 0 |
| | | | | | |
| GN1 | NA | NA | NA | NA | NA |
| GN2 | NA | NA | NA | NA | NA |
| GN3 | NA | NA | NA | NA | NA |
| GN4 | 0 | 0 | 0 | 0 | 0 |
| GN5 | 12 | 56 | 342 | 1092 | 503 |
| GN6 | 8 | 43 | 271 | 1747 | 848 |
| GN7 | 4 | 19 | 120 | 901 | 432 |
| GN8 | 7 | 31 | 196 | 605 | 243 |
| GN9 | 7 | 30 | 191 | 588 | 236 |
| GN10 | 4 | 17 | 109 | 348 | 141 |
| GN11 | 2 | 11 | 68 | 237 | 98 |
| GN12 | 1 | 6 | 40 | 142 | 58 |
| GN13 | 0 | 1 | 9 | 33 | 14 |
| GN14 | 0 | 0 | 0 | 0 | 0 |
| GN15 | NA | NA | NA | NA | NA |
| | | | | | |
| GO1 | NA | NA | NA | NA | NA |
| GO2 | NA | NA | NA | NA | NA |
| GO3 | NA | NA | NA | NA | NA |
| GO4 | NA | NA | NA | NA | NA |
| GO5 | 3 | 14 | 87 | 321 | 151 |
| GO6 | 6 | 28 | 175 | 1118 | 544 |
| GO7 | 5 | 24 | 150 | 810 | 371 |
| GO8 | 6 | 28 | 175 | 551 | 222 |
| GO9 | 5 | 22 | 142 | 445 | 179 |
| GO10 | 4 | 21 | 130 | 383 | 152 |
| GO11 | 3 | 15 | 97 | 271 | 106 |
| GO12 | 2 | 7 | 45 | 119 | 46 |
| GO13 | 0 | 1 | 4 | 10 | 4 |
| GO14 | 0 | 0 | 0 | 0 | 0 |
| GO15 | NA | NA | NA | NA | NA |
| | | | | | |
| GP1 | NA | NA | NA | NA | NA |
| GP2 | NA | NA | NA | NA | NA |
| GP3 | NA | NA | NA | NA | NA |
| GP4 | NA | NA | NA | NA | NA |

Contd...

Table 3.1.2.7 Contd...

| Grid No. | Total Grid wise Emissions (Kg/day) | | | | |
|---|---|---|---|---|---|
| | SPM | $SO_2$ | $NO_2$ | CO | HC |
| GP5 | NA | NA | NA | NA | NA |
| GP6 | NA | NA | NA | NA | NA |
| GP7 | 0 | 0 | 0 | 0 | 0 |
| GP8 | 2 | 7 | 43 | 136 | 55 |
| GP9 | 0 | 1 | 4 | 14 | 6 |
| GP10 | NA | NA | NA | NA | NA |
| GP11 | NA | NA | NA | NA | NA |
| GP12 | 0 | 0 | 2 | 5 | 2 |
| GP13 | 0 | 0 | 1 | 2 | 1 |
| GP14 | NA | NA | NA | NA | NA |
| GP15 | NA | NA | NA | NA | NA |
| **Total** | **1715** | **8590** | **48020** | **135788** | **59895** |

**Source :** Data estimated by NEERI

## Table 3.1.3.1

### Details of Meteorological Stations Installed for Primary Data Collection

| Station No. | Place/Location | Latitude | Longitude | Height above MSL (feet) | Type of Land |
|---|---|---|---|---|---|
| 1 | Cherthala (S.N.College) | 9°37' | 76°02' | 15 | Coastal |
| 2 | Kalamassery (Cochin University) | 10°02' | 76°02' | 40 | Coastal |
| 3 | Kodanadu (Primary Health Centre) | 10°01' | 76°31' | 200 | Inland |
| 4 | Kottayam (Rubber Board) | 9°33' | 76°36' | 120 | Inland |
| 5 | Kulamavu (DRDO Lab) | 9°46' | 76°54' | 3000 | High land |

Date of installation: October 1998

Table 3.1.3.2

Monthly Mean Values of Surface Meteorological Parameters at 5 Stations
(November 1998 - October 1999)

| Months | Ambient Temp. (°C) | Wind Direction | Solar Radiation ($mw/cm^2$) | Wind Speed (m/s) | Rainfall (mm) | Relative Humidity (%) | Sunshine Duration (%) |
|---|---|---|---|---|---|---|---|
| **Cherthala** | | | | | | | |
| Nov | 26.9 | 199.1 | 16.6 | 0.4 | 0.1 | 91.1 | 23.1 |
| Dec | 26.8 | 176.2 | 15.1 | 0.4 | 0.1 | 90.8 | 0.0 |
| Jan | 26.2 | 173.6 | 17.9 | 0.5 | 0.0 | 84.7 | 13.5 |
| Feb | DM | DM | DM | DM | DM | DM | DM |
| Mar | 29.0 | 200.2 | 18.0 | 0.6 | 0.1 | 99.7 | 7.7 |
| Apr | 28.9 | 216.2 | 17.3 | 0.9 | 0.3 | DM | 15.2 |
| May | 26.2 | 195.0 | 12.7 | 1.0 | 1.5 | 85.8 | 0.0 |
| Jun | DM | DM | DM | DM | DM | DM | DM |
| Jul | 25.9 | 220.4 | 13.4 | 0.8 | 0.8 | 34.1 | 0.3 |
| Aug | 26.2 | 223.0 | 15.2 | 0.8 | 0.4 | 19.9 | 0.0 |
| Sep | 27.0 | 203.7 | 18.1 | 1.0 | 0.2 | 55.3 | 18.8 |
| Oct | 25.5 | 170.5 | 12.5 | 0.8 | 1.0 | 11.5 | 46.7 |
| **Kalamassery** | | | | | | | |
| Nov | DM | DM | DM | DM | DM | DM | DM |
| Dec | 26.9 | 152.9 | 9.8 | 0.5 | 0.0 | 60.8 | 40.5 |
| Jan | 26.3 | 137.9 | 11.2 | 0.5 | 0.0 | 57.9 | 43.5 |
| Feb | 27.7 | 136.7 | 15.4 | 0.6 | 0.6 | 65.4 | 44.4 |
| Mar | 28.6 | 161.8 | 10.8 | 0.8 | 0.1 | 87.9 | 45.5 |
| Apr | 27.9 | 184.9 | 9.1 | 0.9 | 0.1 | DM | 43.7 |
| May | 27.1 | 161.0 | 9.6 | 0.9 | 0.3 | DM | 42.3 |
| Jun | 31.3 | 172.4 | 7.5 | 0.8 | 0.8 | 50.3 | 28.9 |
| Jul | 29.1 | 183.3 | 4.9 | 0.6 | 1.2 | 35.1 | 7.5 |
| Aug | 26.3 | 186.9 | 7.7 | 0.5 | 4.6 | DM | 0.0 |
| Sep | 26.9 | 169.0 | 23.9 | 1.0 | 0.1 | 86.5 | 11.8 |
| Oct | 25.9 | 146.1 | 0.6 | 0.2 | 0.0 | 97.8 | 16.2 |
| **Kodanadu** | | | | | | | |
| Nov | 25.9 | 202.5 | 16.9 | 0.3 | 0.0 | 79.7 | 0.0 |
| Dec | 25.3 | 163.1 | 14.1 | 0.2 | 0.1 | 87.1 | 0.0 |
| Jan | 25.4 | 181.0 | 18.0 | 0.3 | 0.0 | 97.4 | 26.3 |
| Feb | 26.6 | 192.5 | 18.8 | 0.3 | 0.1 | 88.1 | 32.1 |
| Mar | 27.8 | 222.1 | 18.5 | 0.4 | 0.1 | 93.1 | 25.4 |
| Apr | 26.3 | 218.6 | 14.7 | 0.4 | 0.3 | 97.9 | 29.5 |

Contd...

Table 3.1.3.2. Contd...

| Months | Ambient Temp. (°C) | Wind Direction | Solar Radiation (mw/cm$^2$) | Wind Speed (m/s) | Rainfall (mm) | Relative Humidity (%) | Sunshine Duration (%) |
|---|---|---|---|---|---|---|---|
| May | 24.0 | 191.9 | 12.2 | 0.3 | 0.8 | 96.6 | 24.4 |
| Jun | 24.3 | 197.7 | 12.6 | 0.3 | 0.4 | 84.5 | 6.7 |
| Jul | 24.2 | 206.6 | 13.1 | 0.3 | 0.0 | 23.3 | 0.0 |
| Aug | 23.4 | 203.0 | 10.3 | 0.2 | 0.2 | DM | 0.0 |
| Sep | 27.6 | 228.8 | 30.7 | 0.4 | 0.1 | DM | 0.2 |
| Oct | DM | DM | DM | DM | DM | DM | DM |
| **Kottayam** | | | | | | | |
| Nov | 25.9 | 160.5 | 2.6 | 0.7 | 1.3 | 72.4 | 0.0 |
| Dec | DM | DM | DM | DM | DM | DM | DM |
| Jan | 26.3 | 419.4 | 20.8 | 1.0 | 0.0 | 61.6 | 36.3 |
| Feb | 27.4 | 329.4 | 22.5 | 1.1 | 0.1 | 57.3 | 36.8 |
| Mar | 28.3 | 233.5 | 22.1 | 1.1 | 0.0 | 56.9 | 38.4 |
| Apr | 27.2 | 253.4 | 16.6 | 1.2 | 0.2 | 75.7 | 33.9 |
| May | 28.6 | 181.8 | 16.7 | 2.0 | 0.7 | 88.8 | 33.6 |
| Jun | DM | DM | DM | DM | DM | DM | DM |
| Jul | 24.8 | 222.7 | 14.1 | 1.3 | 0.6 | 94.5 | 33.4 |
| Aug | 25.7 | 219.4 | 17.8 | 1.2 | 0.2 | 91.2 | 36.5 |
| Sep | 26.3 | 205.3 | 19.7 | 1.2 | 0.0 | 86.9 | 37.6 |
| Oct | 25.2 | 161.8 | 11.0 | 0.4 | 0.8 | 93.7 | 31.4 |
| **Kulamavu** | | | | | | | |
| Nov | 21.4 | 202.2 | 12.5 | 0.8 | 0.8 | 92.6 | 0.0 |
| Dec | DM | DM | DM | DM | DM | DM | DM |
| Jan | DM | DM | DM | DM | DM | DM | DM |
| Feb | 22.9 | 117.8 | 18.9 | 2.0 | 0.2 | 63.5 | 44.4 |
| Mar | 23.4 | 204.0 | 18.3 | 0.0 | 0.0 | 82.1 | 45.0 |
| Apr | 22.0 | 242.3 | 11.3 | 0.0 | 0.6 | 93.6 | 41.3 |
| May | 20.9 | 216.2 | 13.2 | 0.0 | 4.9 | 94.9 | 39.1 |
| Jun | DM | DM | DM | DM | DM | DM | DM |
| Jul | 20.1 | 256.8 | 0.0 | 2.1 | 2.2 | DM | 3.2 |
| Aug | 20.3 | 255.7 | 0.0 | 1.5 | 1.4 | DM | 0.4 |
| Sep | 22.5 | 209.7 | 13.6 | 0.8 | 0.2 | DM | 3.9 |
| Oct | 21.5 | 199.8 | 8.4 | 0.8 | 1.1 | DM | 1.2 |

DM – Data Missing

**Source** : Primary data collected by CUSAT

Table 3.1.3.3

Three hourly Mean Values of Air Temperature for Kochi

| Month | Temperature (°C) at | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0230 | 0530 | 0830 | 1130 | 1430 | 1730 | 2030 | 2330 |
| Jan | 24.5 | 23.2 | 24.7 | 30.0 | 31.0 | 29.3 | 27.1 | 25.8 |
| Feb | 25.5 | 24.5 | 26.1 | 30.5 | 31.2 | 29.7 | 27.8 | 26.6 |
| Mar | 26.7 | 25.9 | 27.9 | 31.4 | 31.8 | 30.5 | 28.5 | 27.5 |
| Apr | 27.5 | 26.7 | 29.2 | 32.0 | 32.4 | 31.0 | 28.9 | 28.2 |
| May | 27.2 | 26.3 | 28.4 | 31.3 | 31.9 | 30.6 | 28.7 | 27.8 |
| Jun | 25.7 | 25.2 | 26.7 | 28.7 | 29.2 | 28.0 | 26.8 | 26.4 |
| Jul | 24.8 | 24.6 | 25.7 | 27.9 | 28.5 | 27.6 | 25.9 | 25.3 |
| Aug | 24.8 | 24.4 | 25.6 | 27.7 | 28.3 | 27.2 | 25.8 | 25.2 |
| Sep | 25.2 | 24.7 | 26.3 | 28.6 | 29.1 | 27.9 | 26.5 | 25.8 |
| Oct | 25.3 | 24.7 | 26.6 | 29.4 | 29.8 | 28.2 | 26.8 | 25.9 |
| Nov | 25.0 | 24.4 | 26.6 | 29.9 | 30.4 | 28.8 | 27.4 | 25.8 |
| Dec | 24.9 | 23.8 | 25.9 | 30.5 | 31.3 | 29.4 | 27.1 | 25.8 |

**Source :** Secondary data collected from IMD, Kochi 1973-1981 and 1984-1992

Table 3.1.3.4

Monthly Maximum, Minimum, Range and Mean Values of Air Temperature (°C) for Kochi

| Month | Ambient Air Temperature (°C) | | | |
|---|---|---|---|---|
| | Maximum | Minimum | Range | Mean |
| Jan | 31.9 | 22.4 | 9.5 | 27.2 |
| Feb | 32.0 | 23.9 | 8.1 | 27.9 |
| Mar | 32.6 | 25.4 | 7.3 | 29.0 |
| Apr | 33.1 | 26.1 | 7.1 | 29.6 |
| May | 32.6 | 26.2 | 6.4 | 29.4 |
| Jun | 30.5 | 24.6 | 5.8 | 27.5 |
| Jul | 29.8 | 23.9 | 5.9 | 26.8 |
| Aug | 29.4 | 23.9 | 5.4 | 26.6 |
| Sep | 30.1 | 24.1 | 6.0 | 27.1 |
| Oct | 30.9 | 24.2 | 6.6 | 27.6 |
| Nov | 31.3 | 23.6 | 7.7 | 27.4 |
| Dec | 32.3 | 23.4 | 8.9 | 27.9 |

**Source :** Secondary data collected from IMD, Kochi

## Table 3.1.3.5

### Three Hourly Mean Values of Relative Humidity for Kochi

| Month | Relative Humidity (%) at | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0230 | 0530 | 0830 | 1130 | 1430 | 1730 | 2030 | 2330 |
| Jan | 83.96 | 85.21 | 74.24 | 55.31 | 54.42 | 60.98 | 73.17 | 79.92 |
| Feb | 84.66 | 87.75 | 77.26 | 59.08 | 57.51 | 64.7 | 74.39 | 80.93 |
| Mar | 84.96 | 87.96 | 77.58 | 63.9 | 63.68 | 68.14 | 76.84 | 80.56 |
| Apr | 84.87 | 88.2 | 77.81 | 65.94 | 65.71 | 70.86 | 78.17 | 81.41 |
| May | 87.22 | 90.65 | 83.44 | 73.7 | 72.42 | 75.47 | 81.76 | 82.89 |
| Jun | 93.62 | 94.9 | 90.56 | 82.37 | 80.18 | 84.1 | 89.9 | 92.03 |
| Jul | 93.92 | 94.53 | 90.52 | 81.03 | 78.48 | 82.54 | 89.86 | 92.38 |
| Aug | 93.82 | 94.95 | 90.82 | 81.68 | 78.41 | 82.16 | 89.87 | 92.38 |
| Sep | 92.83 | 94.35 | 87.93 | 76.75 | 78.88 | 79.45 | 86.73 | 90.33 |
| Oct | 92.17 | 92.73 | 84.88 | 73.08 | 70.87 | 77.05 | 85.12 | 89.95 |
| Nov | 89.98 | 90.47 | 79.99 | 63.36 | 62.21 | 69.49 | 81.15 | 86.04 |
| Dec | 83.3 | 84.27 | 71.96 | 52.14 | 52.07 | 60.38 | 72.84 | 79.92 |

**Source** : Secondary data collected from IMD, Kochi

## Table 3.1.3.6

### Monthly Maximum, Minimum, Range and Mean Values of Relative Humidity (%) for Kochi

| Month | Maximum | Minimum | Range | Mean |
|---|---|---|---|---|
| Jan | 85.21 | 54.42 | 30.79 | 69.82 |
| Feb | 87.75 | 57.51 | 30.24 | 72.63 |
| Mar | 87.96 | 63.68 | 24.28 | 75.82 |
| Apr | 88.2 | 65.71 | 22.49 | 76.96 |
| May | 90.65 | 72.42 | 18.23 | 81.54 |
| Jun | 94.9 | 80.18 | 14.72 | 87.54 |
| Jul | 94.53 | 78.48 | 16.05 | 86.51 |
| Aug | 94.95 | 78.41 | 16.54 | 86.68 |
| Sep | 94.35 | 73.88 | 20.47 | 84.12 |
| Oct | 92.73 | 70.87 | 21.86 | 81.8 |
| Nov | 90.47 | 62.41 | 28.26 | 76.34 |
| Dec | 84.27 | 52.07 | 32.2 | 68.17 |

**Source** : Secondary data collected from IMD, Kochi

### Table 3.1.3.7

### Monthly Maximum Values of Wind Speed of Kochi

| Month | Wind speed (Km/h) | Month | Wind speed (Km/h) |
|---|---|---|---|
| Jan | 8 | Jul | 9.6 |
| Feb | 9.3 | Aug | 9.9 |
| Mar | 10.6 | Sep | 9.1 |
| Apr | 10.7 | Oct | 7.8 |
| May | 10.9 | Nov | 6.7 |
| Jun | 9.1 | Dec | 7.1 |
| | | **Annual** | **9.1** |

### Table 3.1.3.8

### Rainfall Statistics of Four Districts in the Study Region

| District | Rainfall (mm) | | | | | |
|---|---|---|---|---|---|---|
| | Parameter | Winter | Summer | Monsoon | Post Monsoon | Annual |
| Alappuzha | Mean | 51 | 491 | 1830 | 592 | 2964 |
| | Max* | 1.7 | 16.6 | 61.7 | 20 | 100 |
| | Max | 175 | 1205 | 2751 | 1039 | 4111 |
| Ernakulam | Mean | 35 | 485 | 2194 | 574 | 3288 |
| | Max* | 1.1 | 14.8 | 66.7 | 17.4 | 100 |
| | Max | 108 | 1080 | 3937 | 940 | 4950 |
| Kottayam | Mean | 53 | 455 | 1908 | 606 | 3022 |
| | Max* | 1.8 | 15.0 | 63.1 | 20.1 | 100 |
| | Max | 167 | 1045 | 2821 | 894 | 4245 |
| Thrissur | Mean | 18 | 413 | 2185 | 485 | 3101 |
| | Max* | 0.6 | 13.3 | 70.5 | 15.6 | 100 |
| | Max | 99 | 1122 | 3778 | 906 | 4575 |

* - Seasonal rainfall as percentage of annual

**Source** : Secondary data collected by CUSAT (1901-1970,IMD)

### Table 3.1.3.9

### Total Rainfall in Different Seasons at the Five Stations

| Place | Rainfall (mm) | | | | |
|---|---|---|---|---|---|
| | Winter | Summer | Monsoon | Post Monsoon | Total |
| Cherthala | 113.5 | 728.0 | 757.1 | 907.6 | 2506.2 |
| Kalamassery | 431.0 | 412.5 | 2796.7 | 631.0 | 4271.2 |
| Kodanadu | 125.6 | 859.1 | 391.2 | 33.8 | 1409.7 |
| Kottayam | 39.1 | 678.6 | 501.1 | 623 | 1841.8 |
| Kulamavu | 181.7 | 3786.4 | 884.8 | 1008.7 | 5861.6 |
| Mean | 178.2 | 1292.9 | 1066.2 | 640.8 | 3178.1 |

**Source** : Primary data collected by CUSAT (Nov. 1998-Oct. 1999)

## Table 3.1.3.10

### Percent Frequency of Occurrence of Inversions and Isothermals Over Kochi

| Type of Inversion | Intensity (°c) | Frequency of Occurrence of Inversion | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Surface based Inversion | 0° - 2° | 7.1 | 4.1 | 2.6 | 3.7 | 0.6 | 1.3 | 1.3 | 0.3 | 1.0 | 0.3 | 2.0 | 4.0 |
| | 2° - 4° | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 4° - 6° | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Elevated Inversicn | 0° - 2° | 1.3 | 0.0 | 0.6 | 0.3 | 0.3 | 0.3 | 1.0 | 0.6 | 1.0 | 0.0 | 0.0 | 1.3 |
| | 2° - 4° | 0.3 | 0.7 | 0.0 | 0.6 | 0.0 | 0.7 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 |
| | 4° - 6° | 0.6 | 0.7 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Iso-thermal | Surface based | 28.1 | 16.9 | 21.0 | 23.5 | 21.9 | 22.0 | 31.3 | 23.9 | 19.7 | 25.2 | 29.3 | 25.2 |
| | Elevated | 1.0 | 3.1 | 4.2 | 4.2 | 4.5 | 4.0 | 4.8 | 2.6 | 2.3 | 4.2 | 4.7 | 3.2 |

**Source** : Secondary data collected by CUSAT

## Table 3.1.3.11

### Observed and Reduced Temperature at Different Places in Kochi City on 22-02-1999

| Sr. No. | Name of the Place | Observed Temperature (°C) | Reduced Temperature (°C) | | |
|---|---|---|---|---|---|
| | | | at 4 am | at 5 am | at 6 am |
| 1 | Edappally toll | 27.5 | 27.7 | 27.2 | 27.2 |
| 2 | Palarivattom | 27.5 | 27.8 | 27.3 | 27.3 |
| 3 | Kaloor | 27.5 | 27.9 | 27.4 | 27.4 |
| 4 | Lissy Jn. | 27.5 | 27.9 | 27.4 | 27.4 |
| 5 | Kacheripady | 28.0 | 28.4 | 27.9 | 27.9 |
| 6 | Shenoys Jn. | 28.0 | 28.4 | 27.9 | 27.9 |
| 7 | South Jn. | 28.0 | 28.4 | 27.9 | 27.9 |
| 8 | Vytilla | 27.5 | 28.0 | 27.5 | 27.5 |
| 9 | Ravipuram | 27.5 | 28.0 | 27.5 | 27.5 |
| 10 | Thevara | 27.0 | 27.5 | 27.0 | 27.0 |
| 11 | Naval Base | 27.0 | 27.5 | 27.0 | 27.0 |
| 12 | Fine Arts Hall | 27.0 | 27.5 | 27.0 | 27.0 |
| 13 | Menaka Jn. | 27.5 | 28.0 | 27.5 | 27.5 |
| 14 | Saritha | 27.5 | 28.0 | 27.5 | 27.5 |
| 15 | Semitherimukku | 27.0 | 27.6 | 27.1 | 27.1 |
| 16 | Varappuzha | 25.5 | 25.5 | 25.5 | 25.0 |
| 17 | Kadungalloor | 24.5 | 24.5 | 24.5 | 24.0 |
| 18 | Paravur | 25.5 | 25.5 | 25.0 | 26.0 |
| 19 | Vypin | 27.1 | 27.1 | 26.5 | 26.0 |
| 20 | Palluruthy | 27.0 | 27.0 | 26.9 | 26.2 |
| 21 | Kalamassery | 26.5 | 26.5 | 26.0 | 25.0 |
| 22 | Elamakkara | 26.2 | 26.2 | 25.9 | 24.2 |

**Source** : Primary data collected by CUSAT

## Table 3.1.3.12

### Chemical Analysis of Rain Water

| Station | Chloride Concentration (mg) | | | | Sulphate Concentration (mg) | | | |
|---|---|---|---|---|---|---|---|---|
| | Max | Min | Avg | Weighted Mean | Max | Min | Avg | Weighted Mean |
| Vypeen | 9.99 | 6.25 | 8.54 | 7.58 | 0.50 | 0.05 | 0.200 | 0.120 |
| Kalamassery | 6.25 | 4.69 | 5.99 | 6.25 | 0.15 | 0.08 | -0.116 | 0.115 |
| Eloor | 12.49 | 3.12 | 7.42 | 9.61 | 0.20 | 0.0 | 0.088 | 0.065 |
| Ernakulam (South) | 12.49 | 3.12 | 5.77 | 6.35 | 0.20 | 0.0 | 0.113 | 0.085 |
| Palluruthy | 9.37 | 6.25 | 10.93 | 6.95 | 0.25 | 0.15 | 0.242 | 0.347 |
| Pachalam | 12.49 | 3.12 | 6.25 | 7.49 | 0.25 | 0.0 | 0.136 | 0.157 |

| Station | pH | | | | Conductivity ($\mu$S/cm) | | Cl & $So_4^{2-}$ Correlation |
|---|---|---|---|---|---|---|---|
| | Max | Min | Mean | Avg | Weighted Mean | Correlation coefficient | Degree of freedom |
| Vypeen | 7.95 | 6.06 | 6.98 | 30.2 | 25.75 | 0.330 | 5 |
| Kalamasery | 7.05 | 5.07 | 6.60 | 20.5 | 22.17 | 0.260 | 6 |
| Eloor | 6.60 | 6.20 | 6.42 | 75.25 | 32.36 | 0.260 | 6 |
| Ernakulam (South) | 6.66 | 6.00 | 6.32 | 36.85 | 20.59 | 0.088 | 11 |
| Polluruthy | 7.23 | 6.32 | 6.32 | 93.25 | 78.38 | 0.250 | 5 |
| Pachalam | 6.90 | 6.30 | 6.49 | 74.75 | 34.84 | 0.088 | 5 |

**Source :** Primary data collected by CUSAT

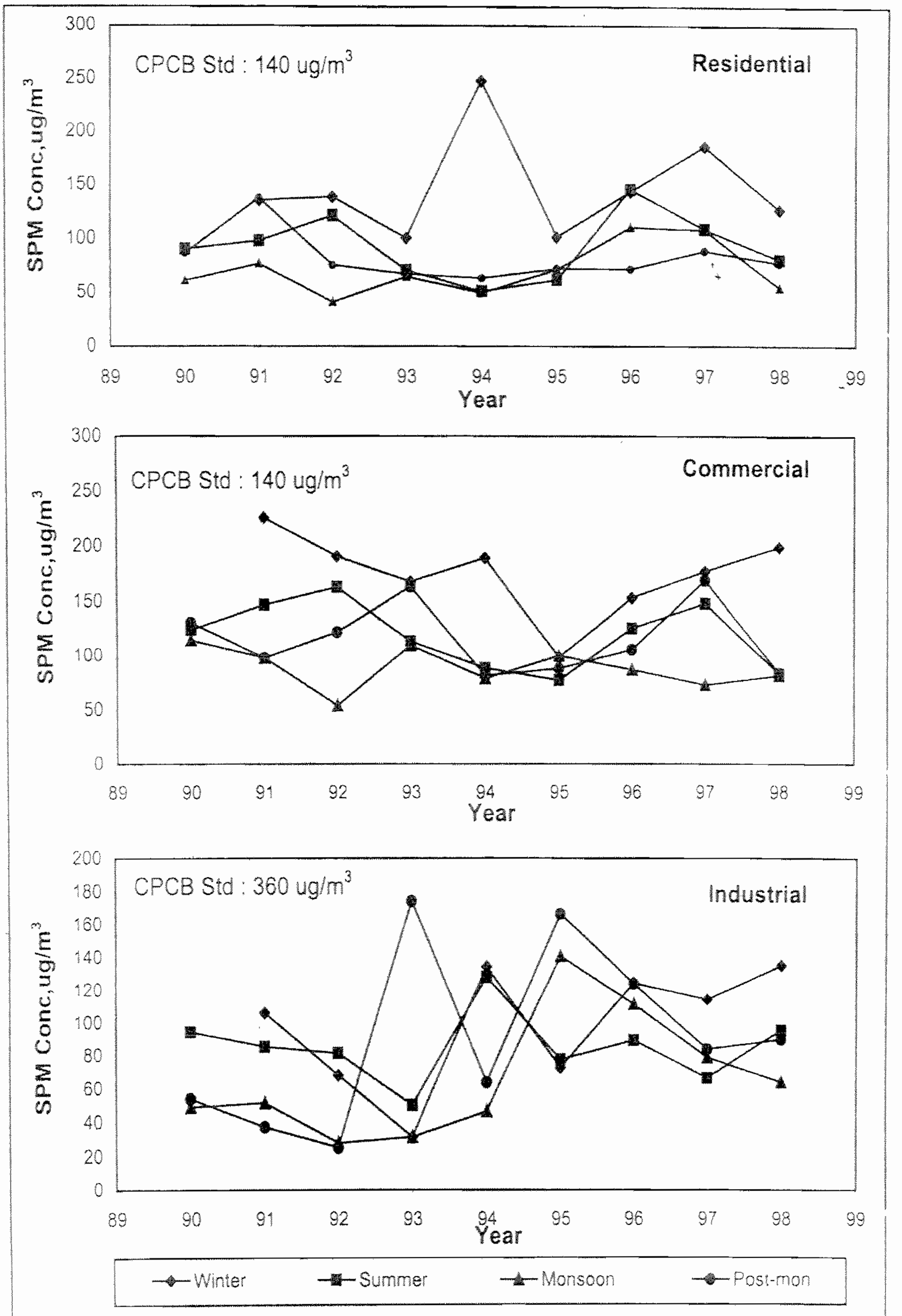



Fig 3.1.1.1 : Average Concentration of SPM in Kochi : 1990-98

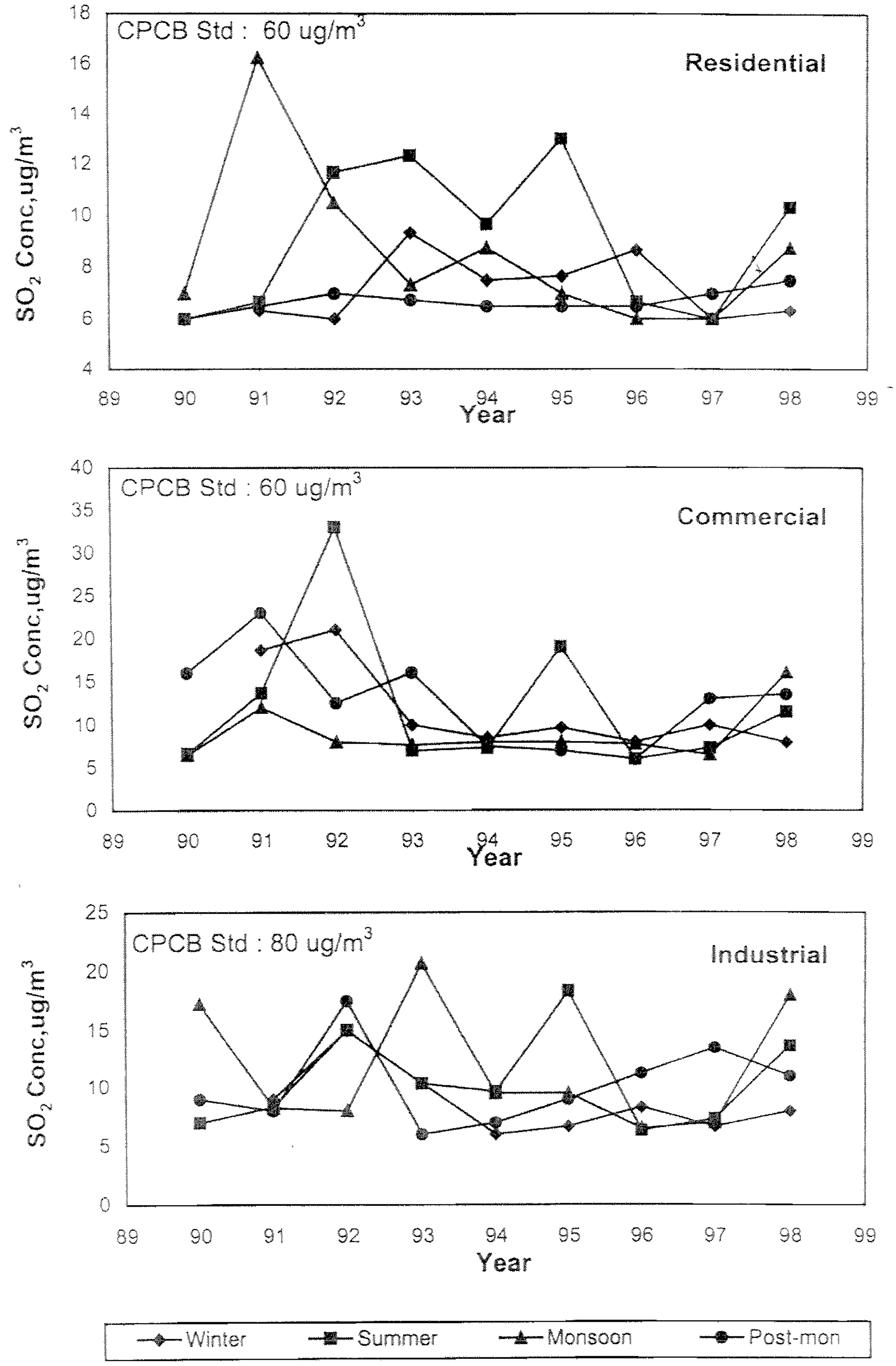



Fig 3.1.1.2 : Average Concentration of $SO_2$ in Kochi : 1990-98

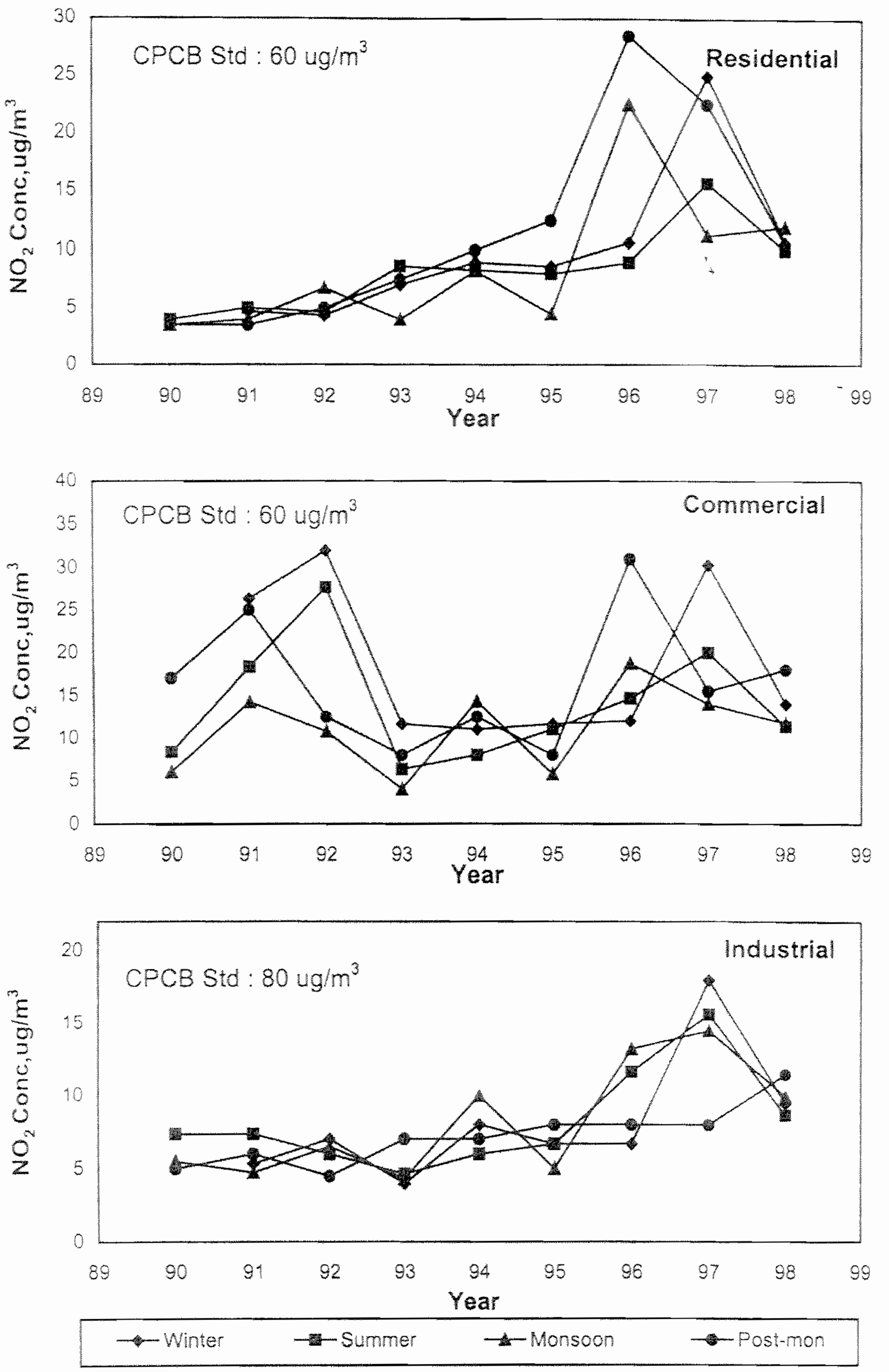



Fig 3.1.1.3 : Average Concentration of $NO_2$ in Kochi : 1990-98

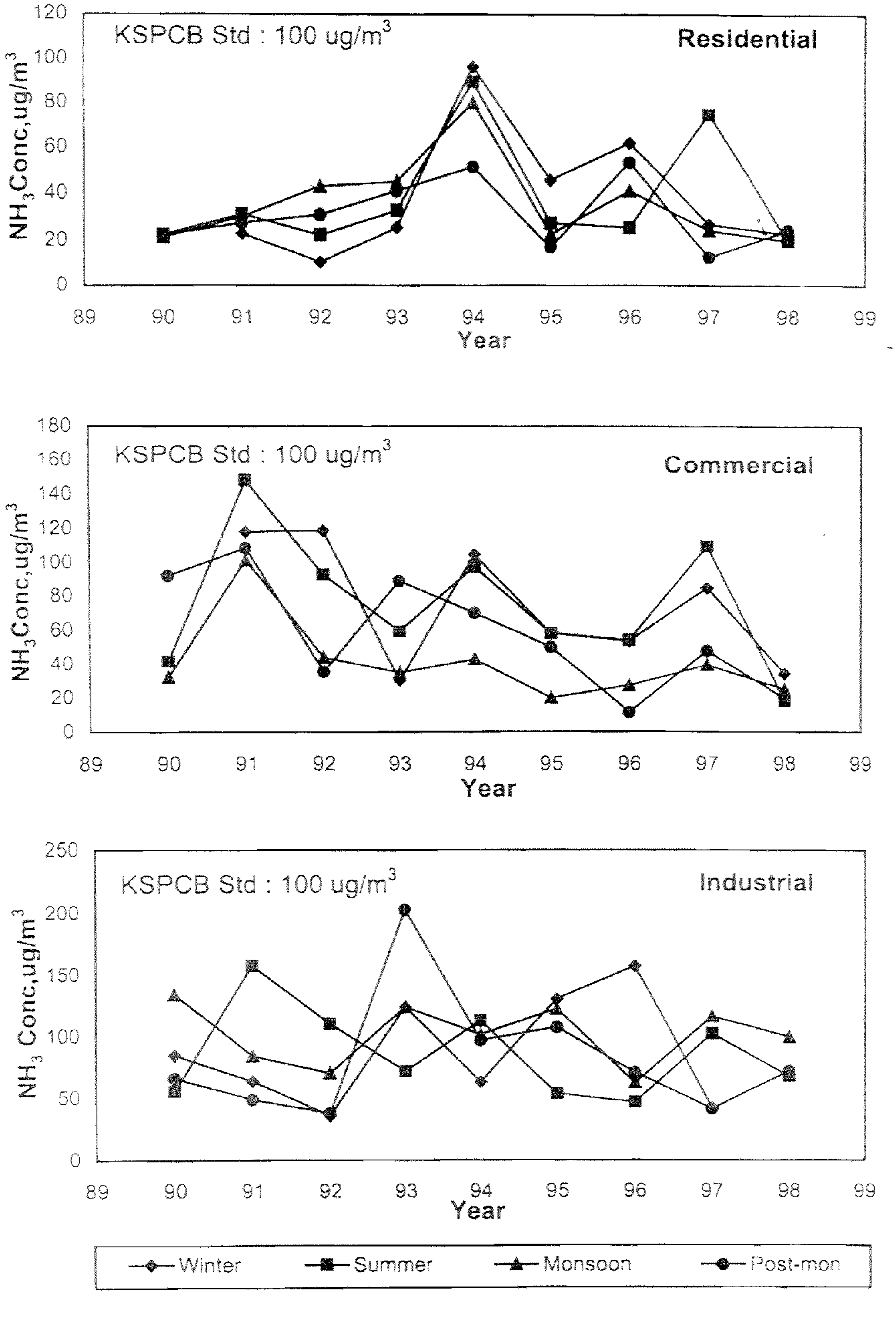



Fig 3.1.1.4 : Average Concentration of $NH_3$ in Kochi : 1990-98

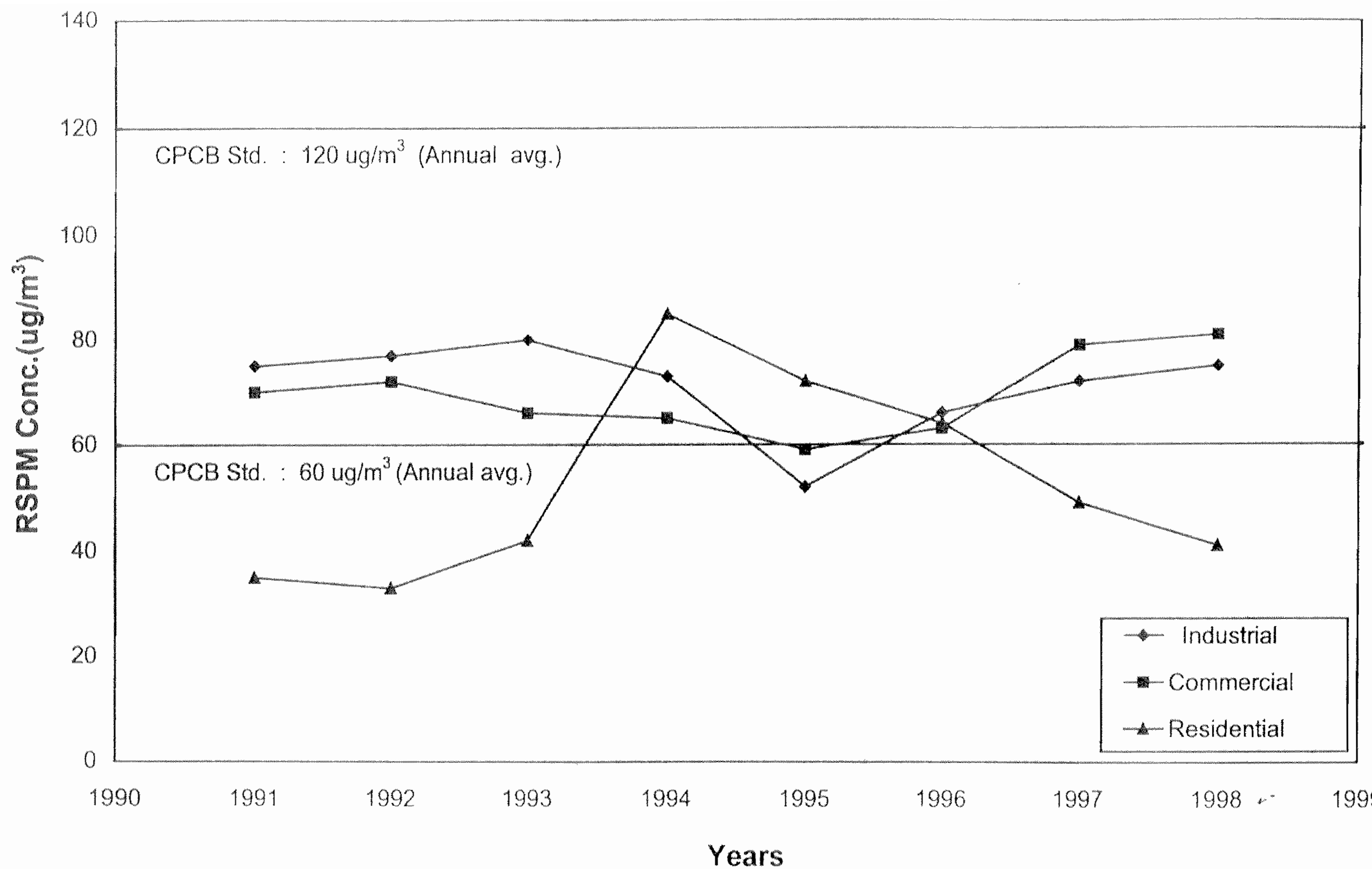
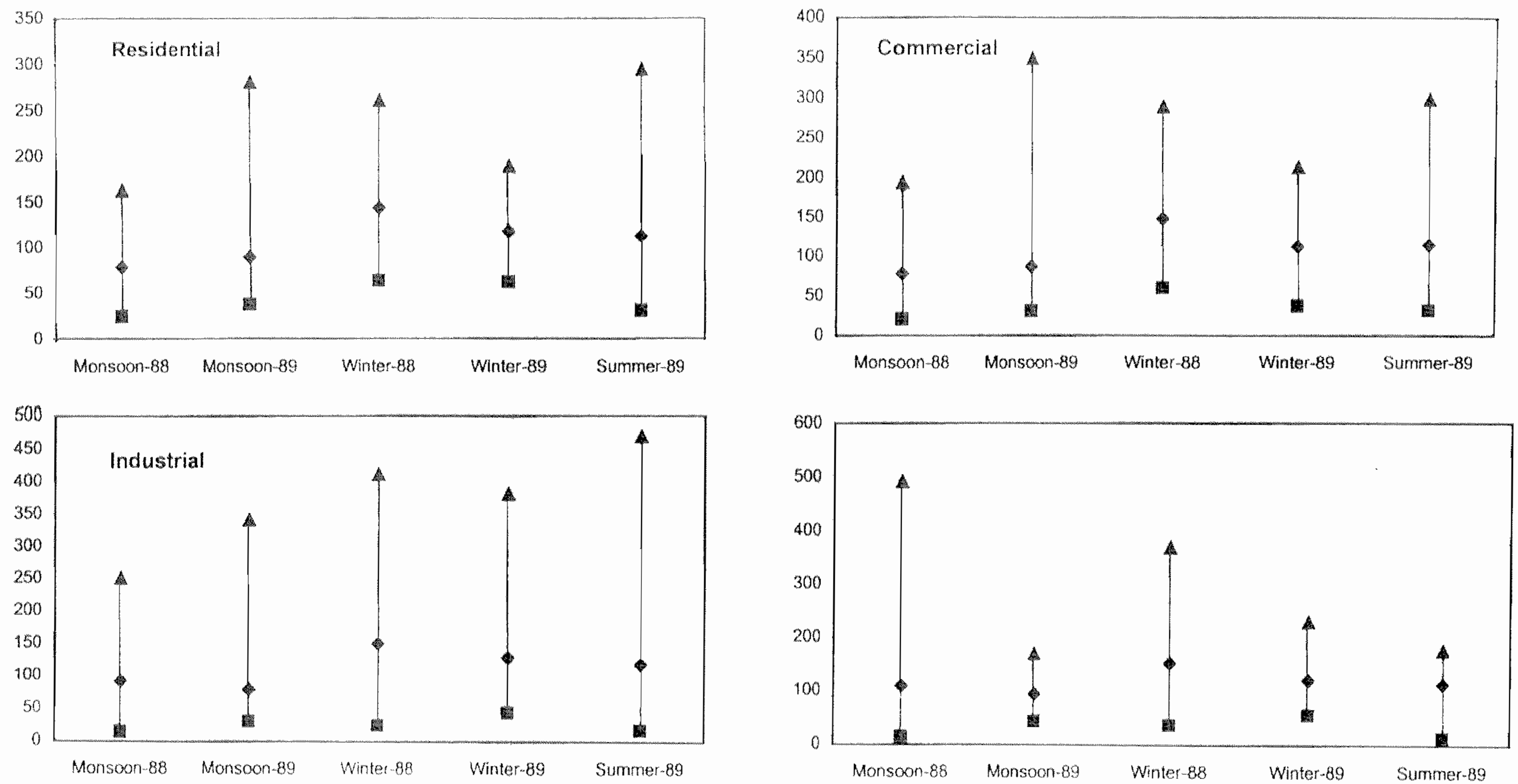
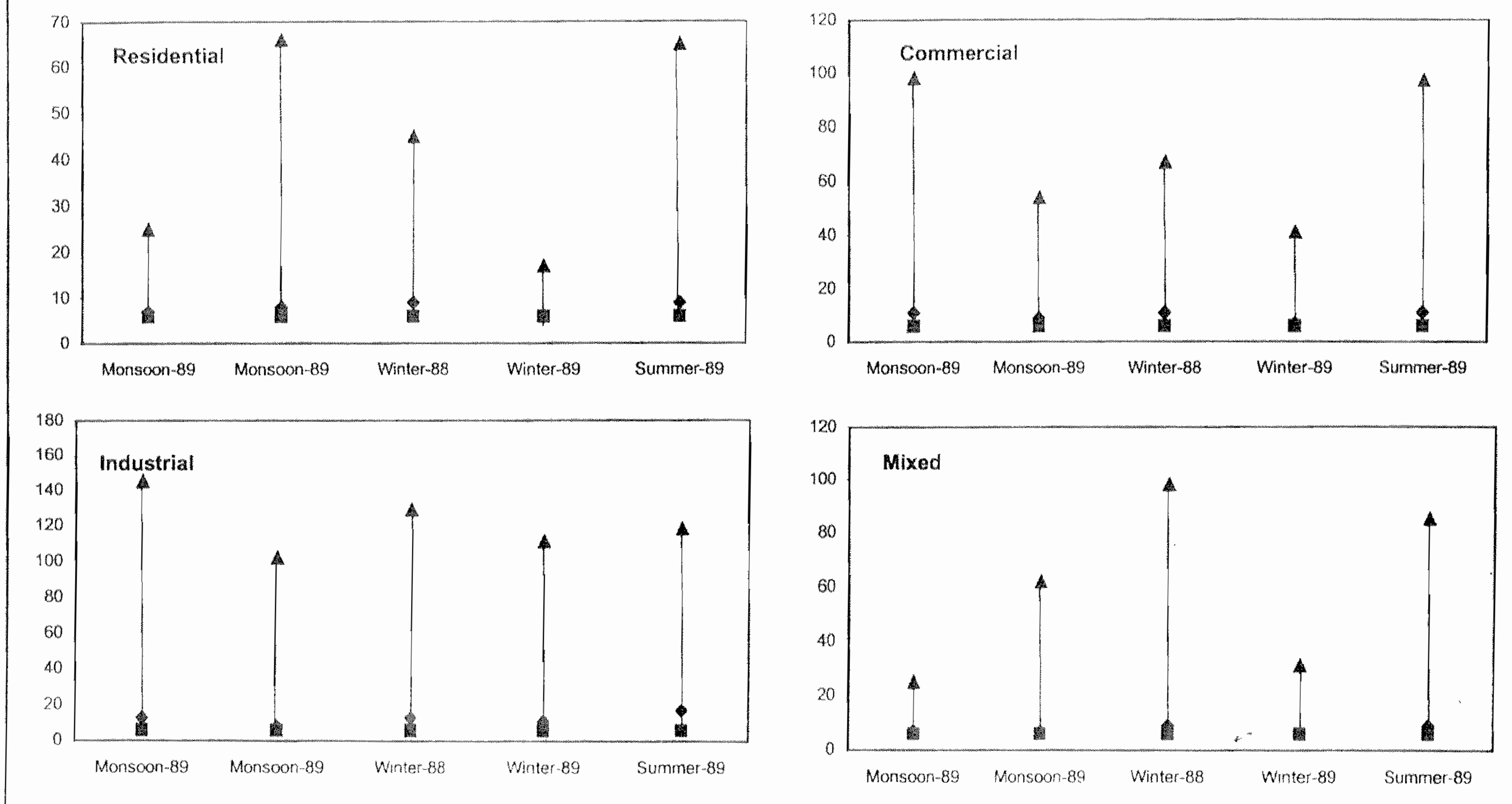



Fig 3.1.1.5 : Average Concentration of RSPM in Kochi : 1991-98



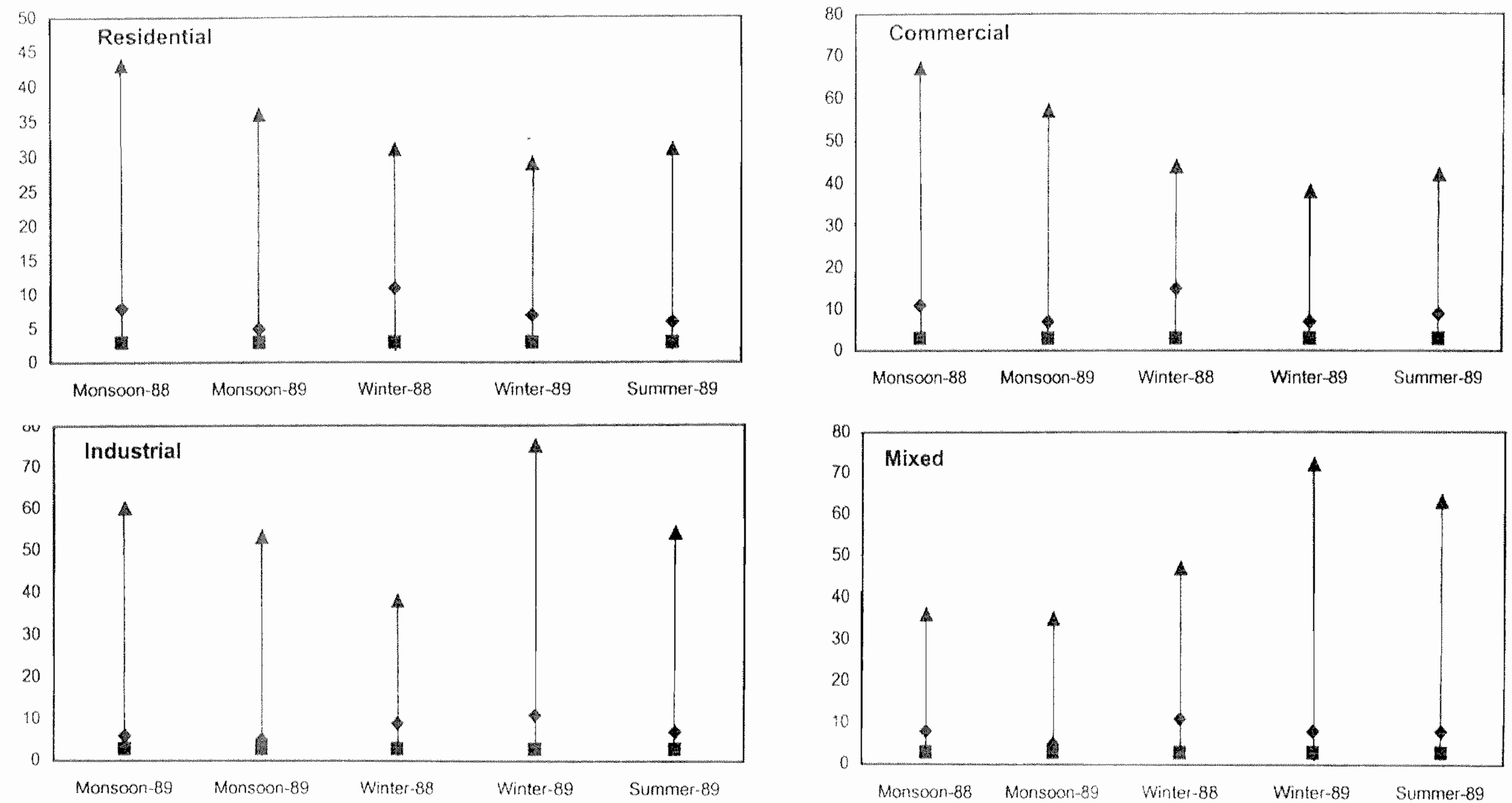

X axis : **Season** ; Y axis : **SPM** Conc. (ug/m$^3$)

Fig 3.1.1.6 : Seasonal Variation in SPM Concentration in Kochi : 1988-89



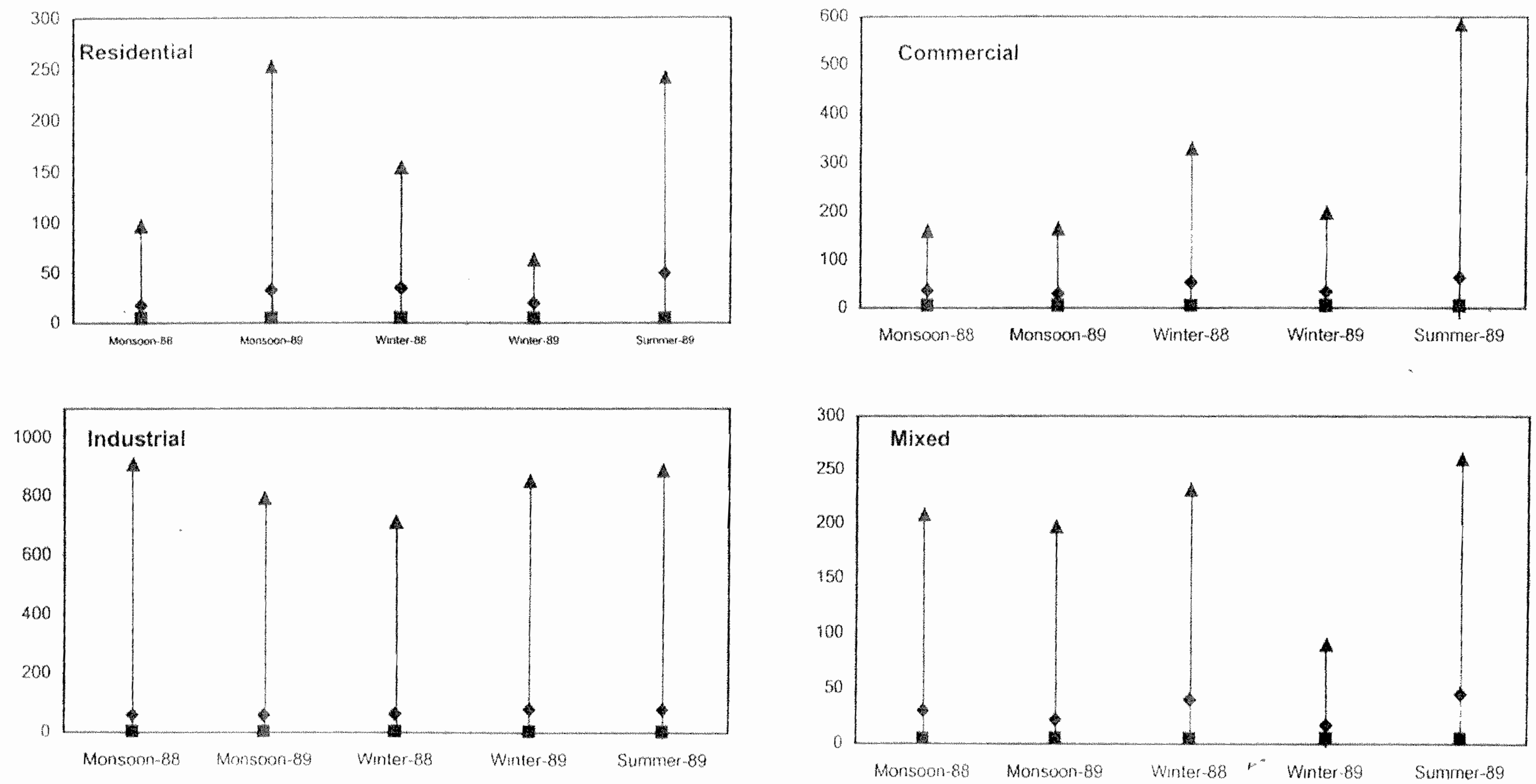

X axis : Season ; Y axis : $SO_2$ Conc. (ug/m$^3$)

Fig 3.1.1.7 : Seasonal Variation in $SO_2$ Concentration in Kochi : 1988-89




X axis : Season ; Y axis : $NO_2$ Conc.(ug/m$^3$)

Fig 3.1.1.8 : Seasonal Variation in $NO_2$ Concentration in Kochi : 1988-89




X axis : Season ; Y axis : $NH_3$ Conc(ug/m$^3$)

Fig 3.1.1.9 : Seasonal Variation in $NH_3$ Concentration in Kochi : 1988-89

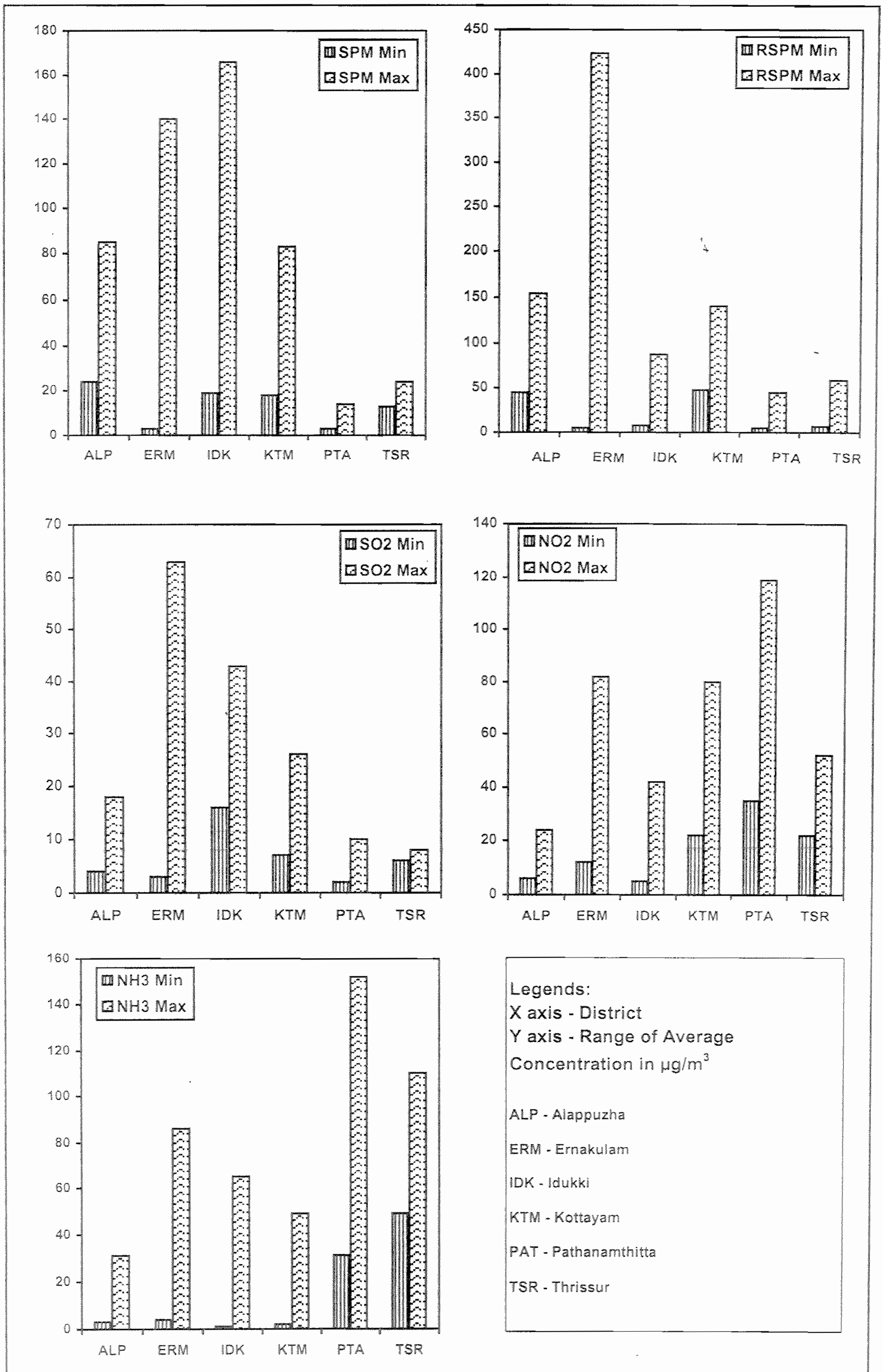



Fig. 3.1.1.10 : District-wise Range of Average Concentration of Different Pollutants: Primary Data 1999-2000

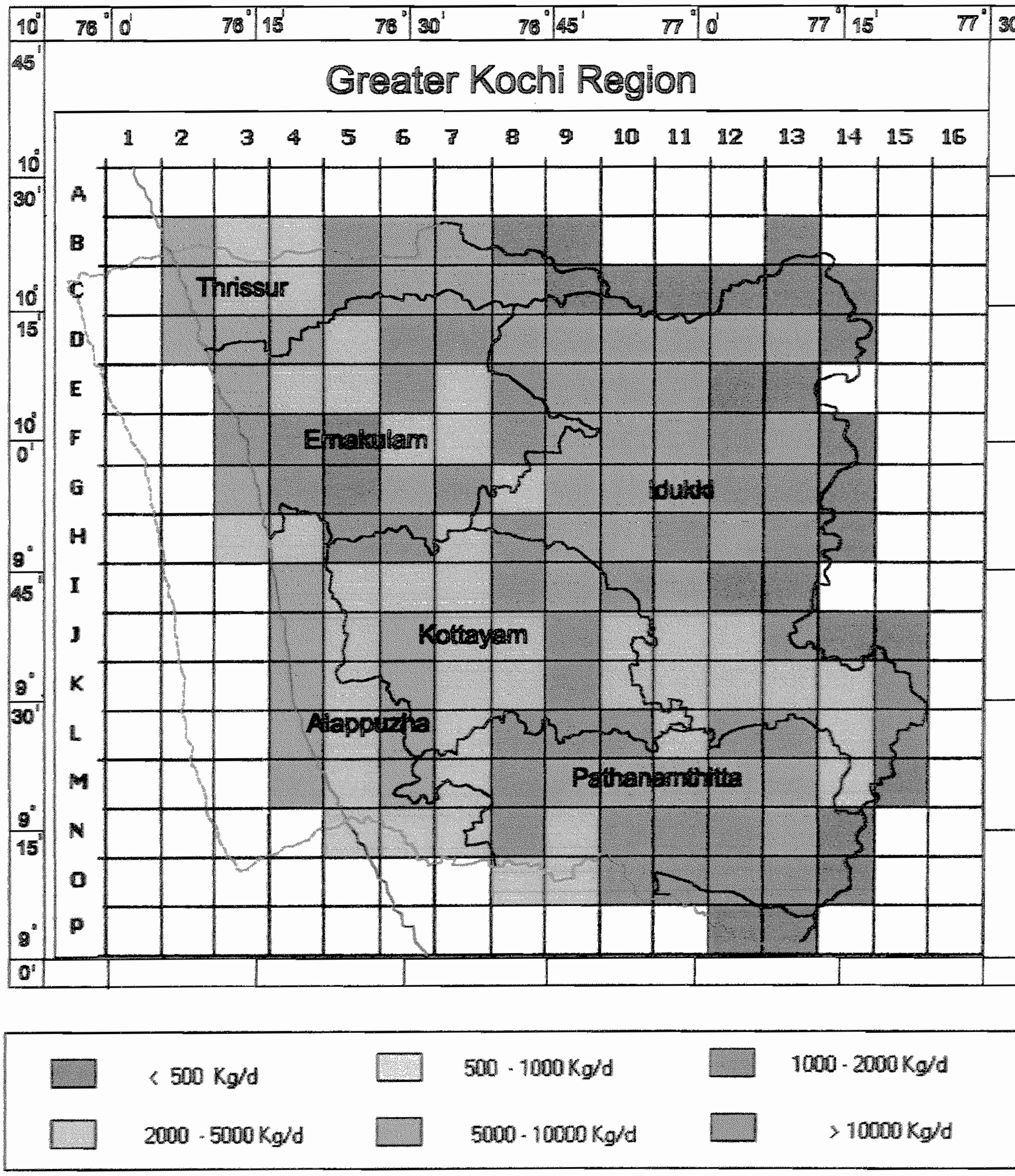



**Fig. 3.1.2.1 : Gridwise SPM Emissions from Area Sources**

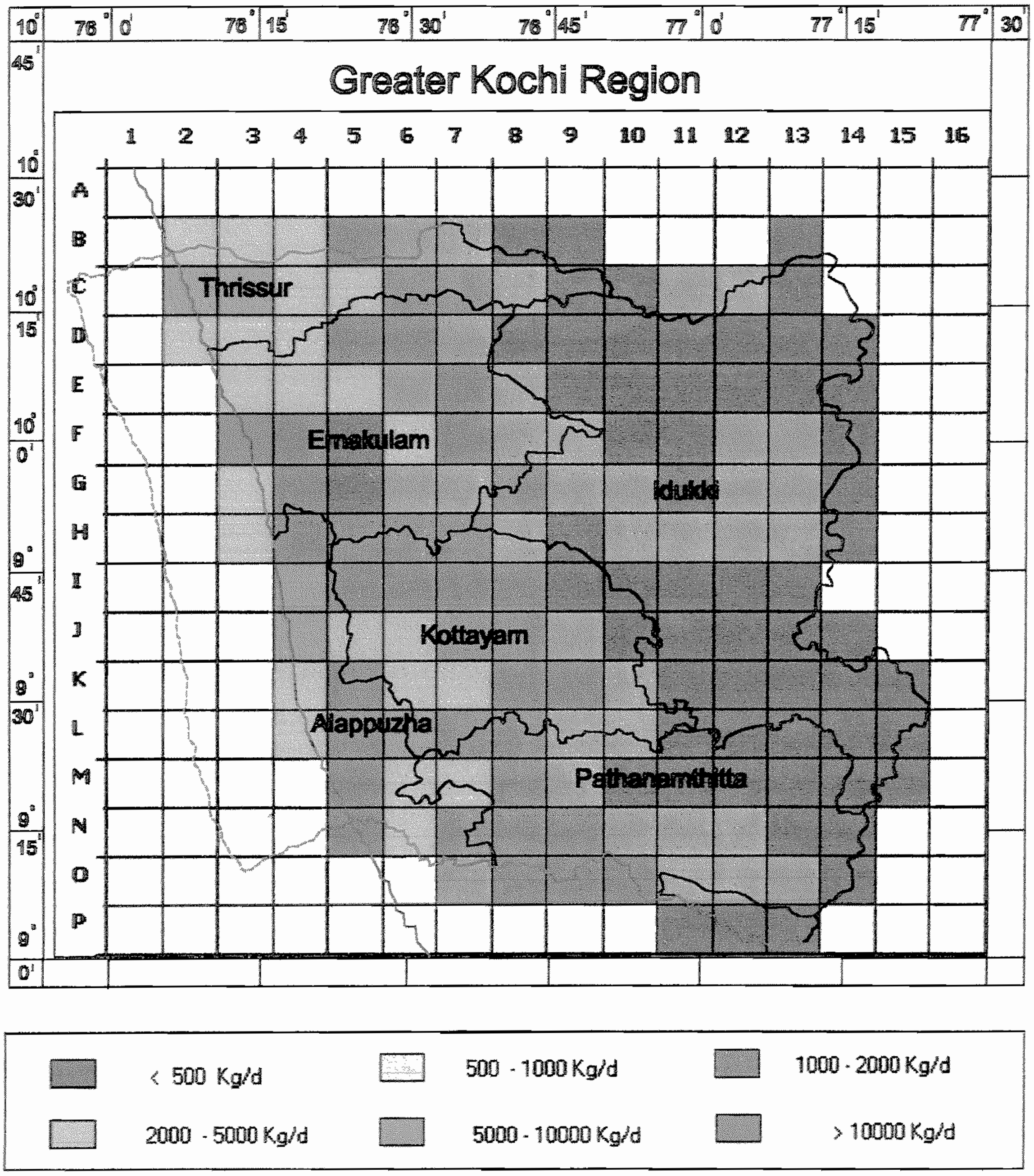



**Fig. 3.1.2.2 : Gridwise SO2 Emissions from Area Sources**

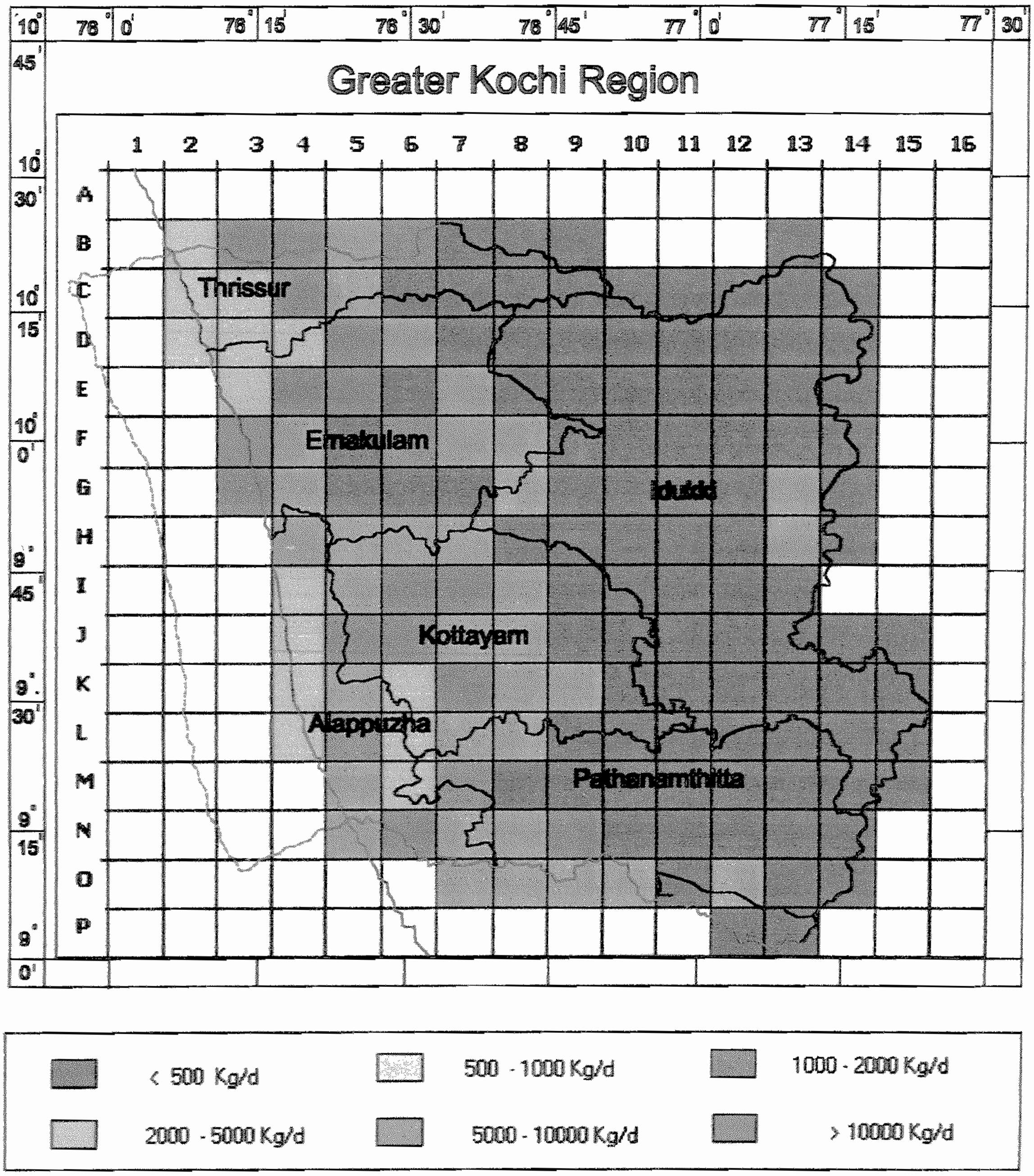



**Fig. 3.1.2.3 : Gridwise NO2 Emissions from Area Sources**

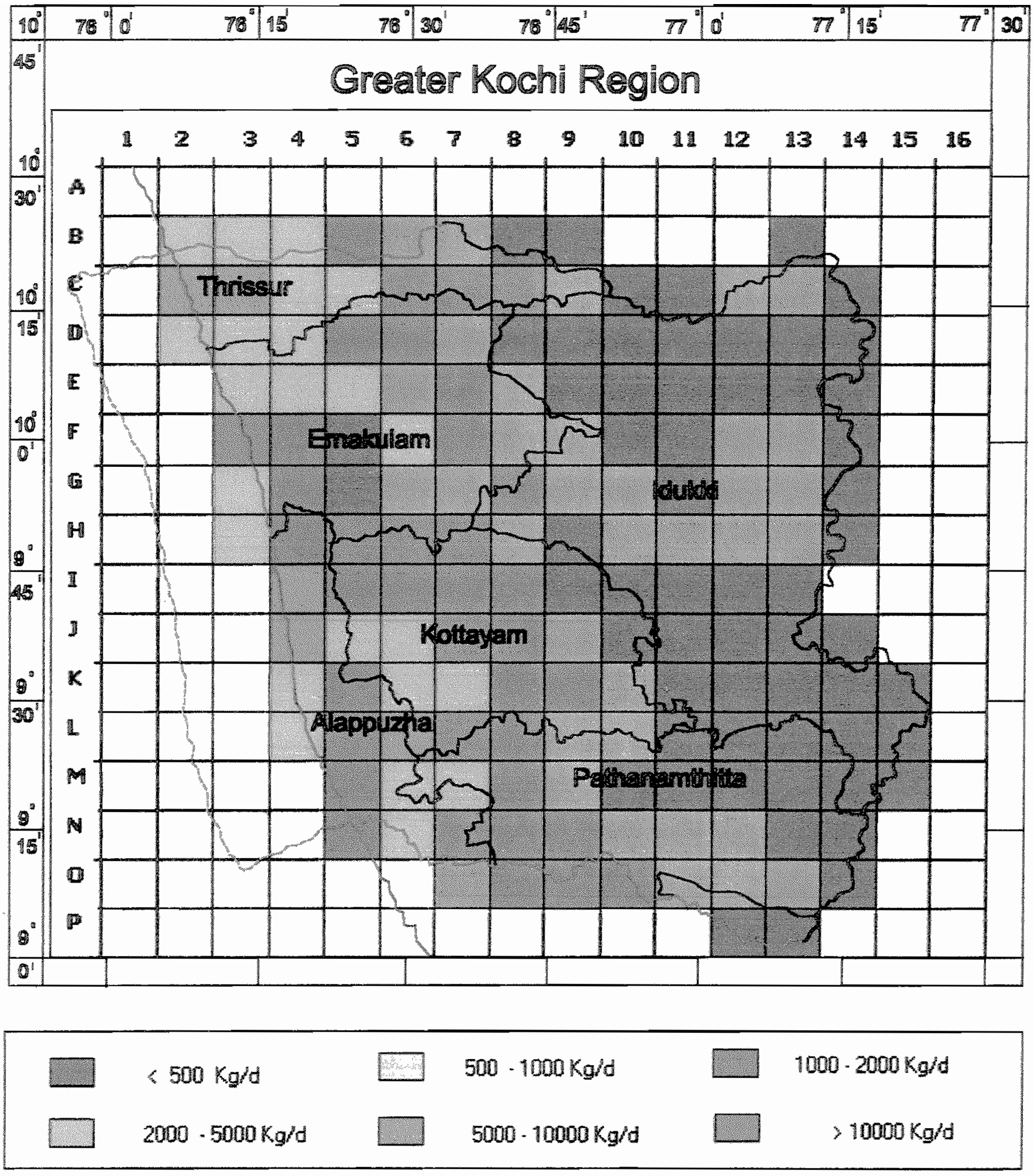



**Fig. 3.1.2.4 : Gridwise HC Emissions from Area Sources**

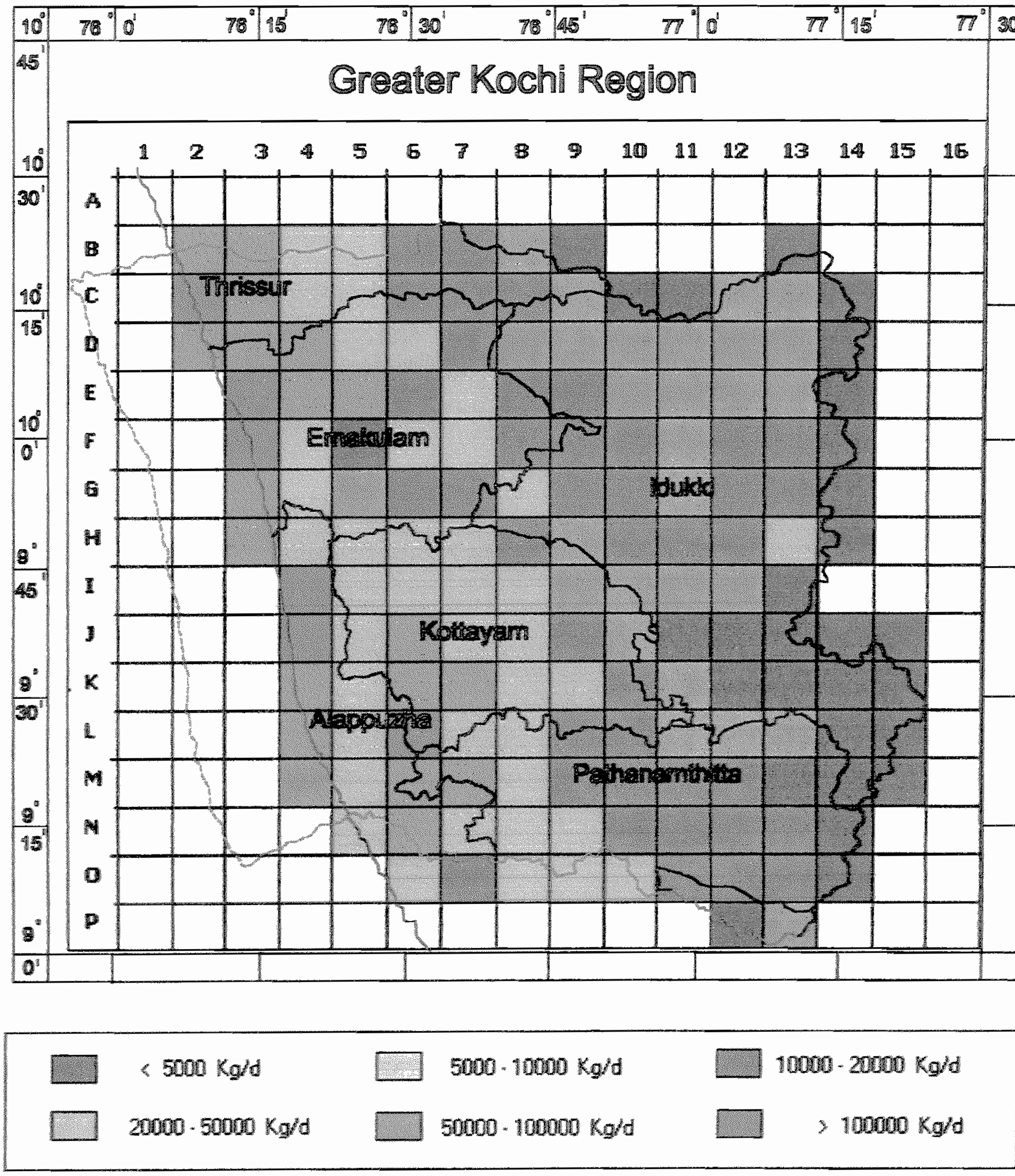



**Fig. 3.1.2.5 : Gridwise CO Emissions from Area Sources**

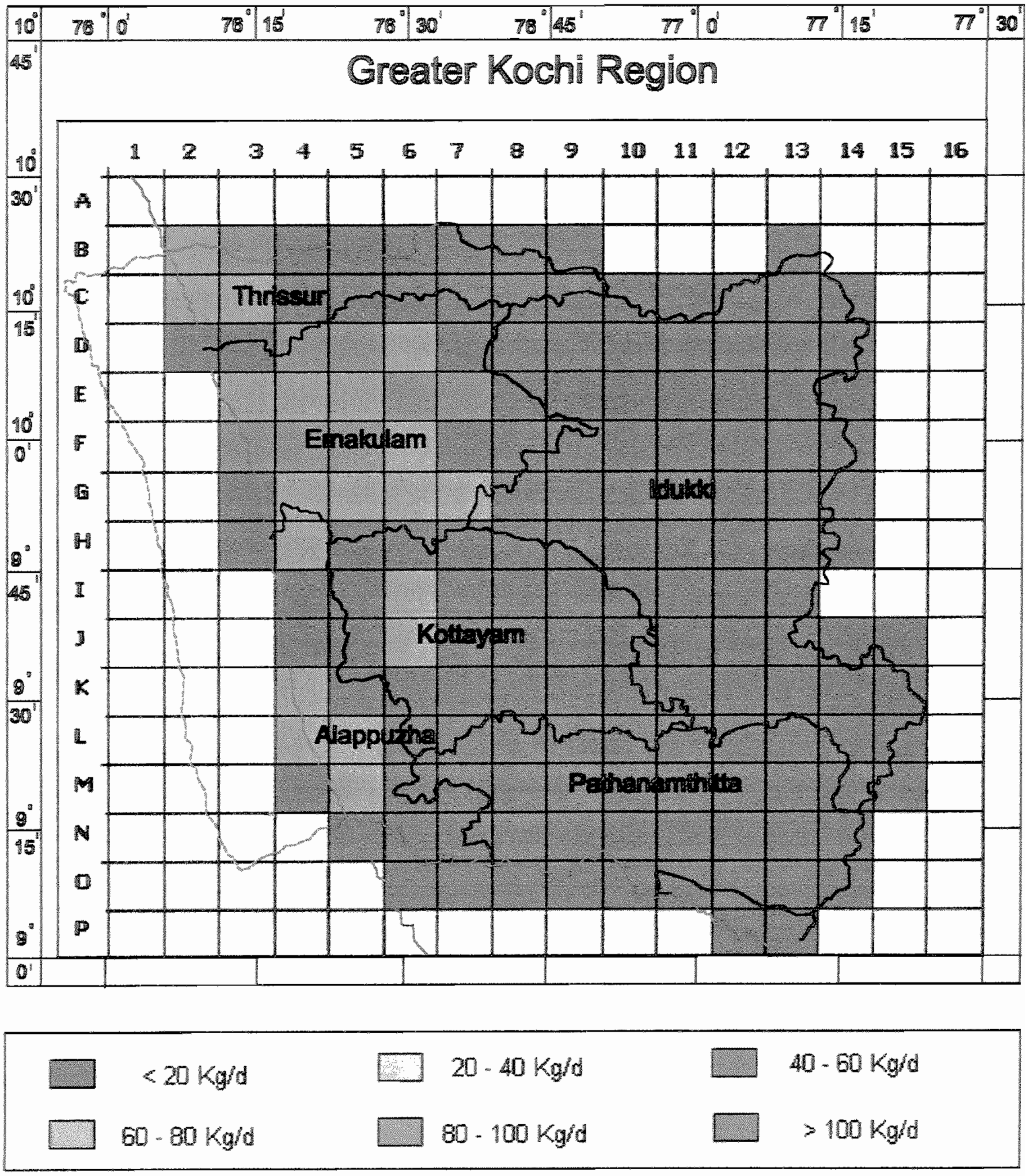



Fig. 3.1.2.6 : Gridwise SPM Emissions from Line Sources

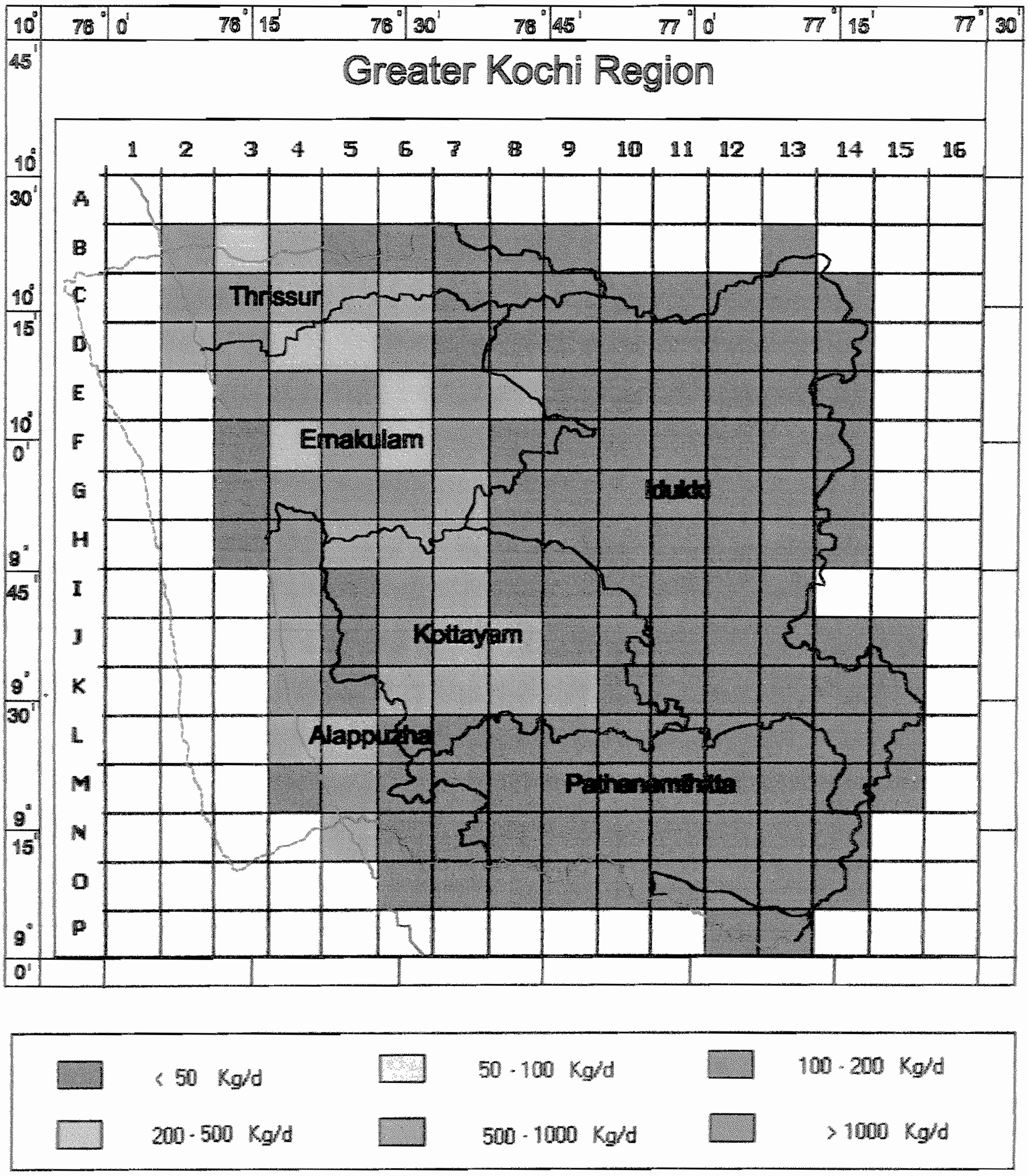



**Fig. 3.1.2.7 : Gridwise SO2 Emissions from Line Sources**

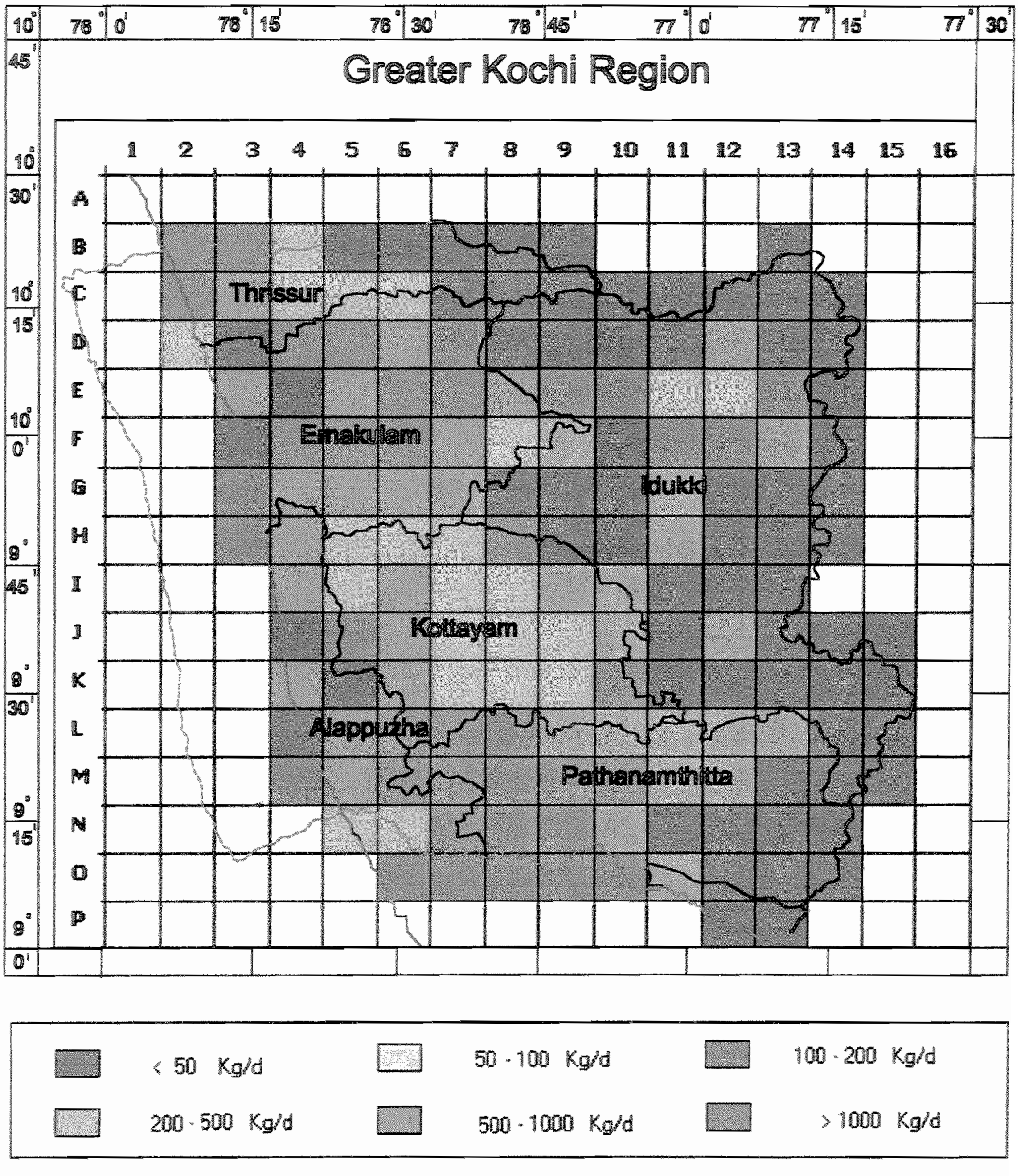



Fig. 3.1.2.8 : Gridwise NO2 Emissions from Line Sources

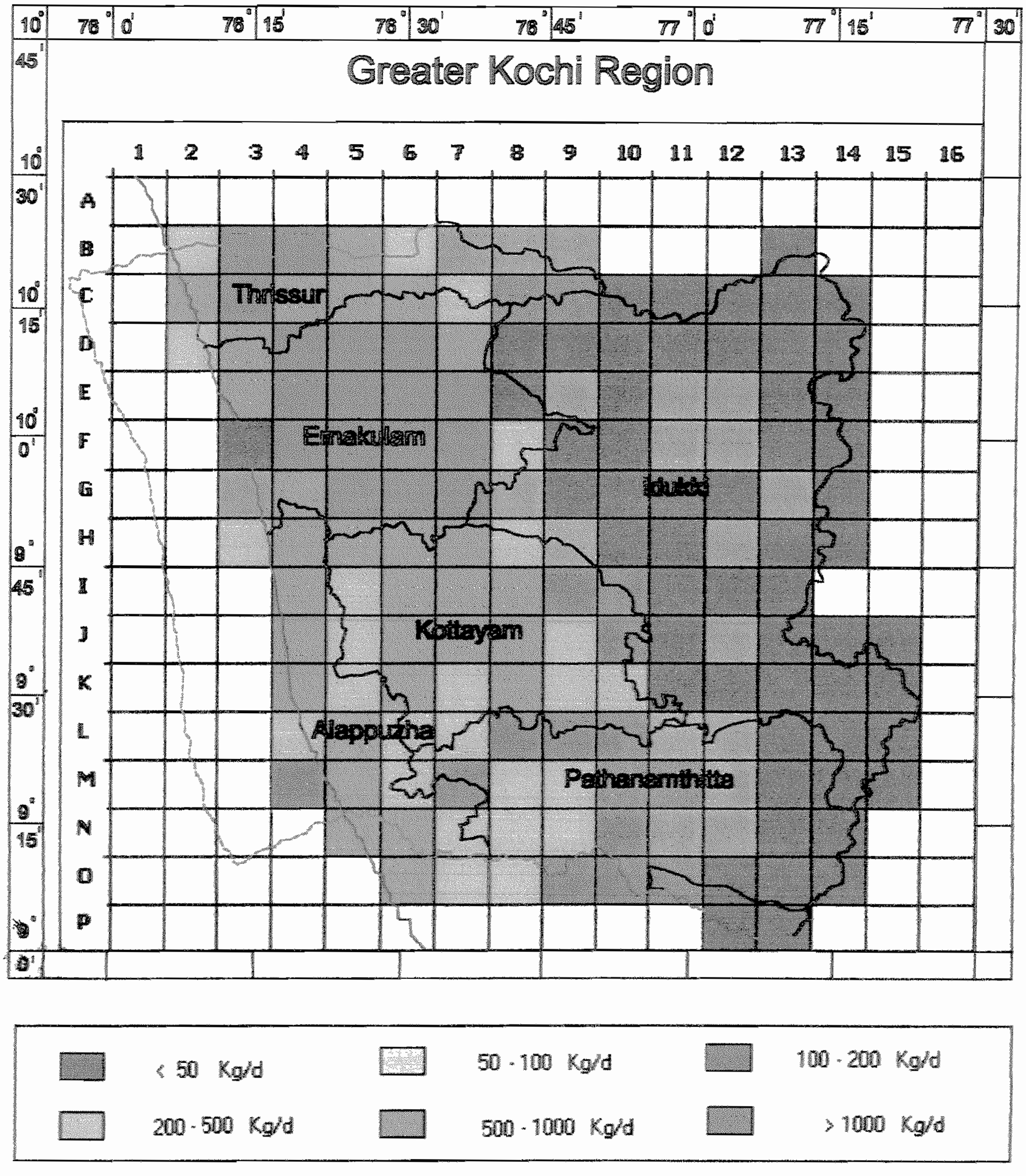



Fig. 3.1.2.9 : Gridwise HC Emissions from Line Sources

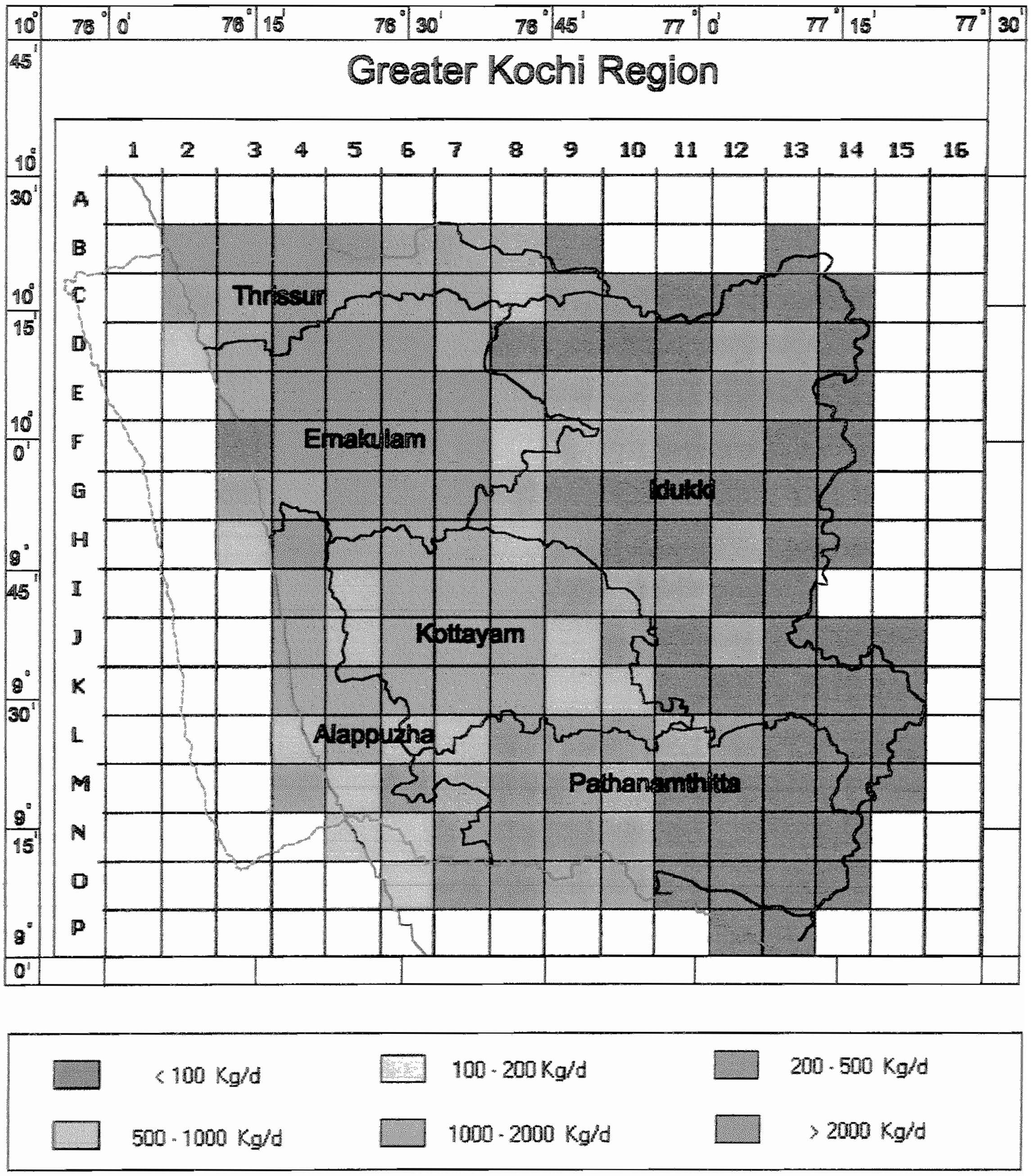



Fig. 3.1.2.10 : Gridwise CO Emissions from Line Sources

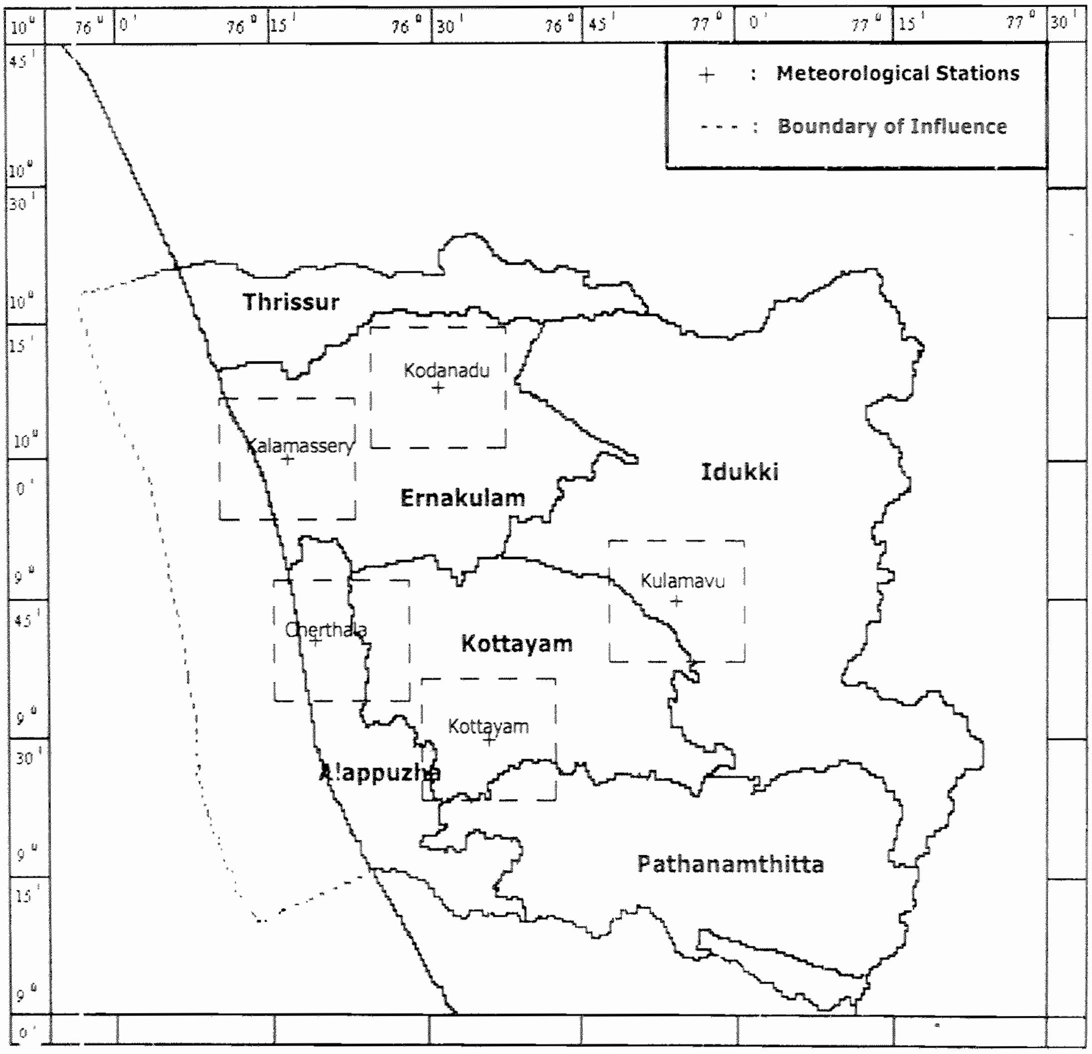



Fig. 3.1.3.1 : GKR Study Area - Meteorological Stations

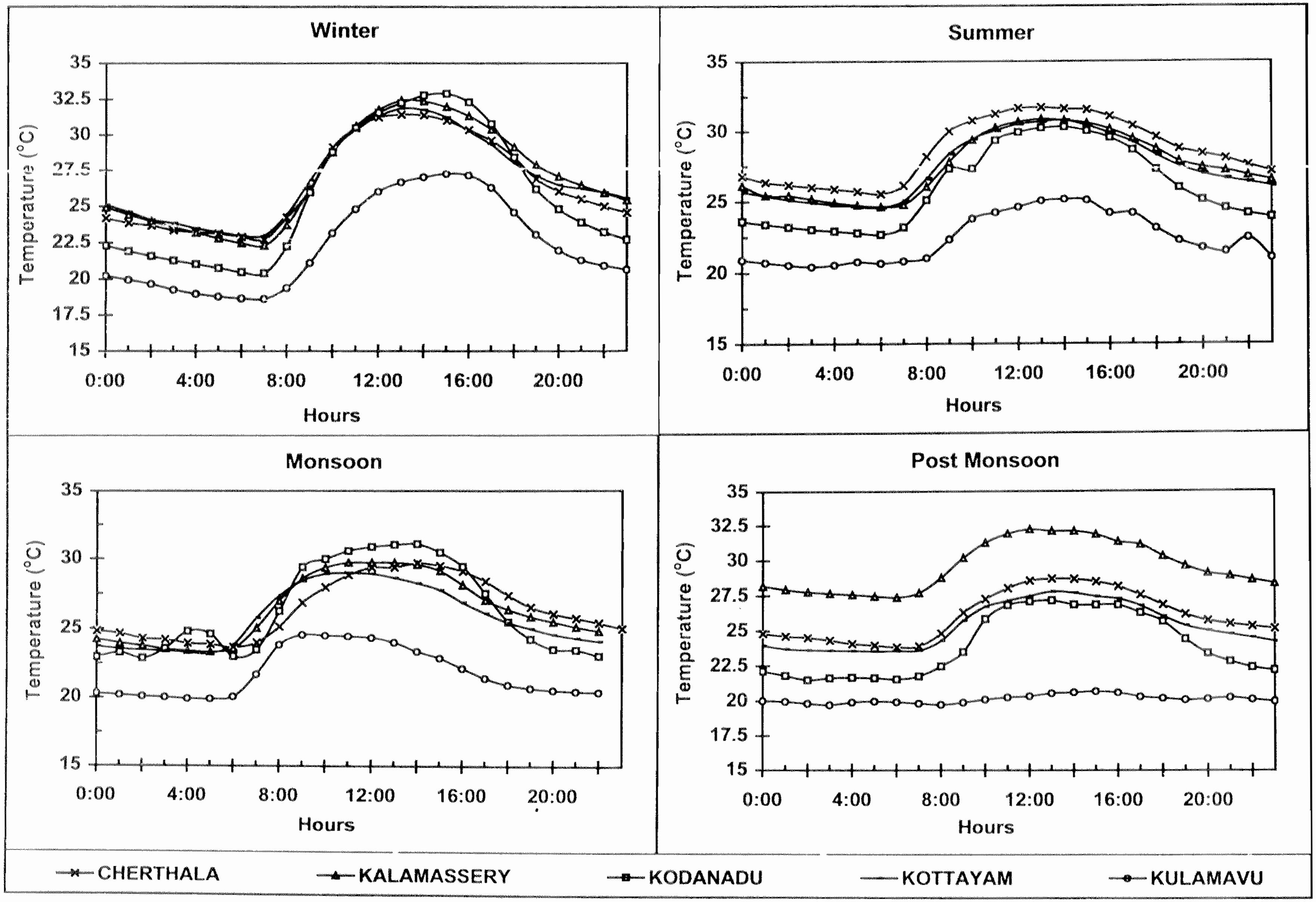



Fig. 3.1.3.2 : Diurnal Variation of Mean Temperature for Five Stations : Primary Data (Nov 98 - Oct 99)

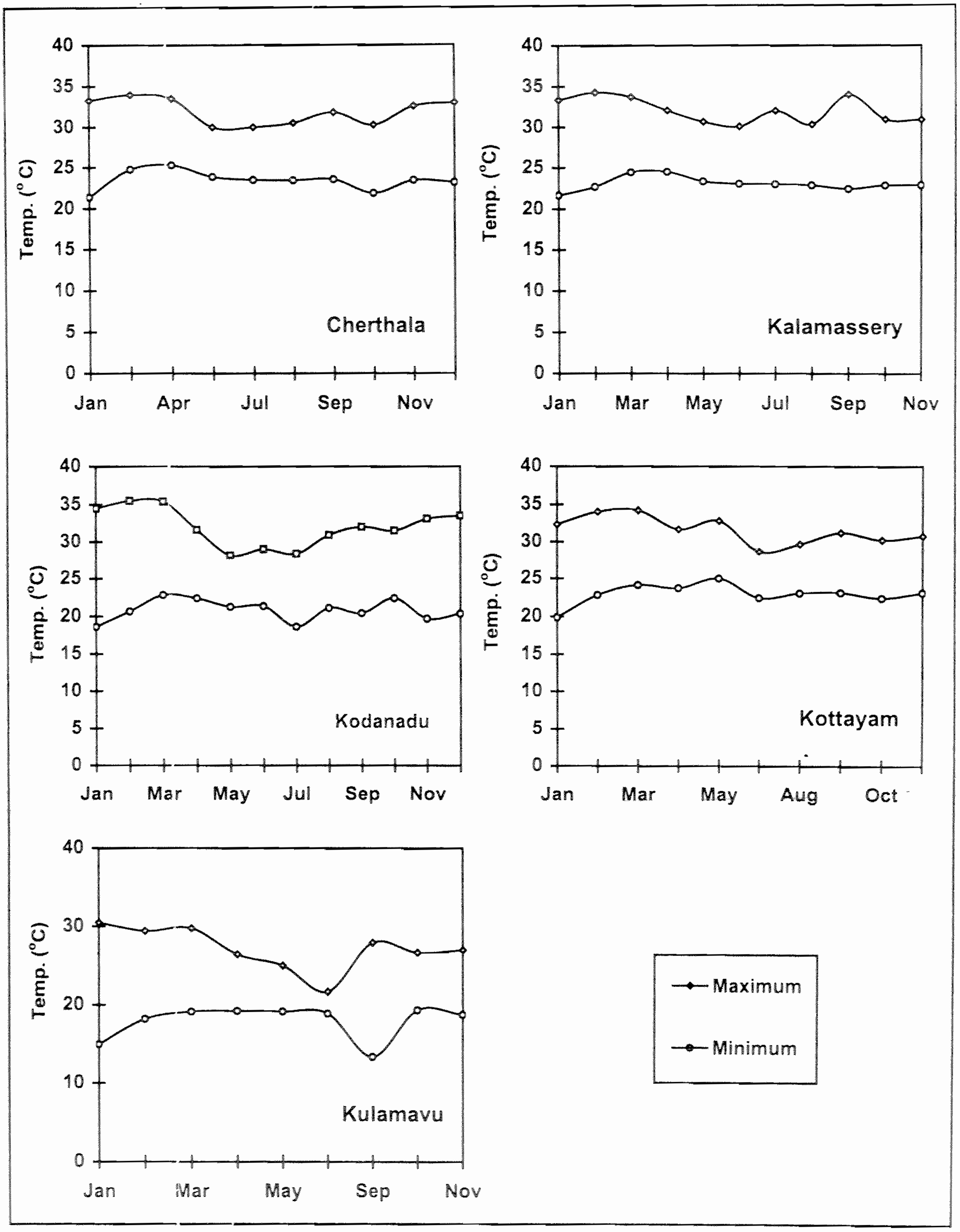



Fig. 3.1.3.3 : Monthly Variation of Mean Max. and Min. Temperature for Five Stations : Primary Data (Nov 98 - Oct 99)

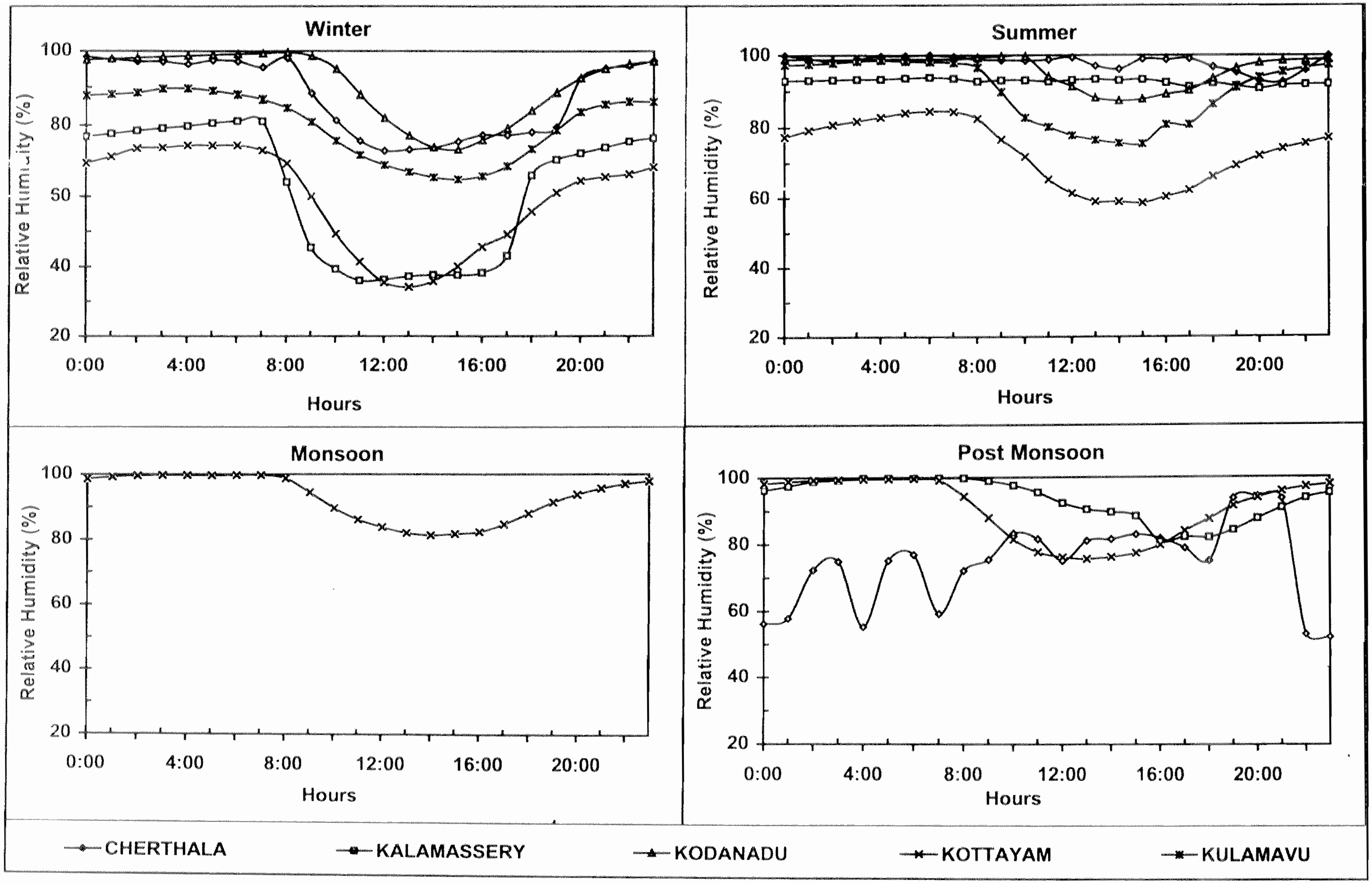



Fig. 3.1.3.4 : Diurnal Variation of Mean Relative Humidity at Five Stations : Primary Data (Nov 98 - Oct 99)

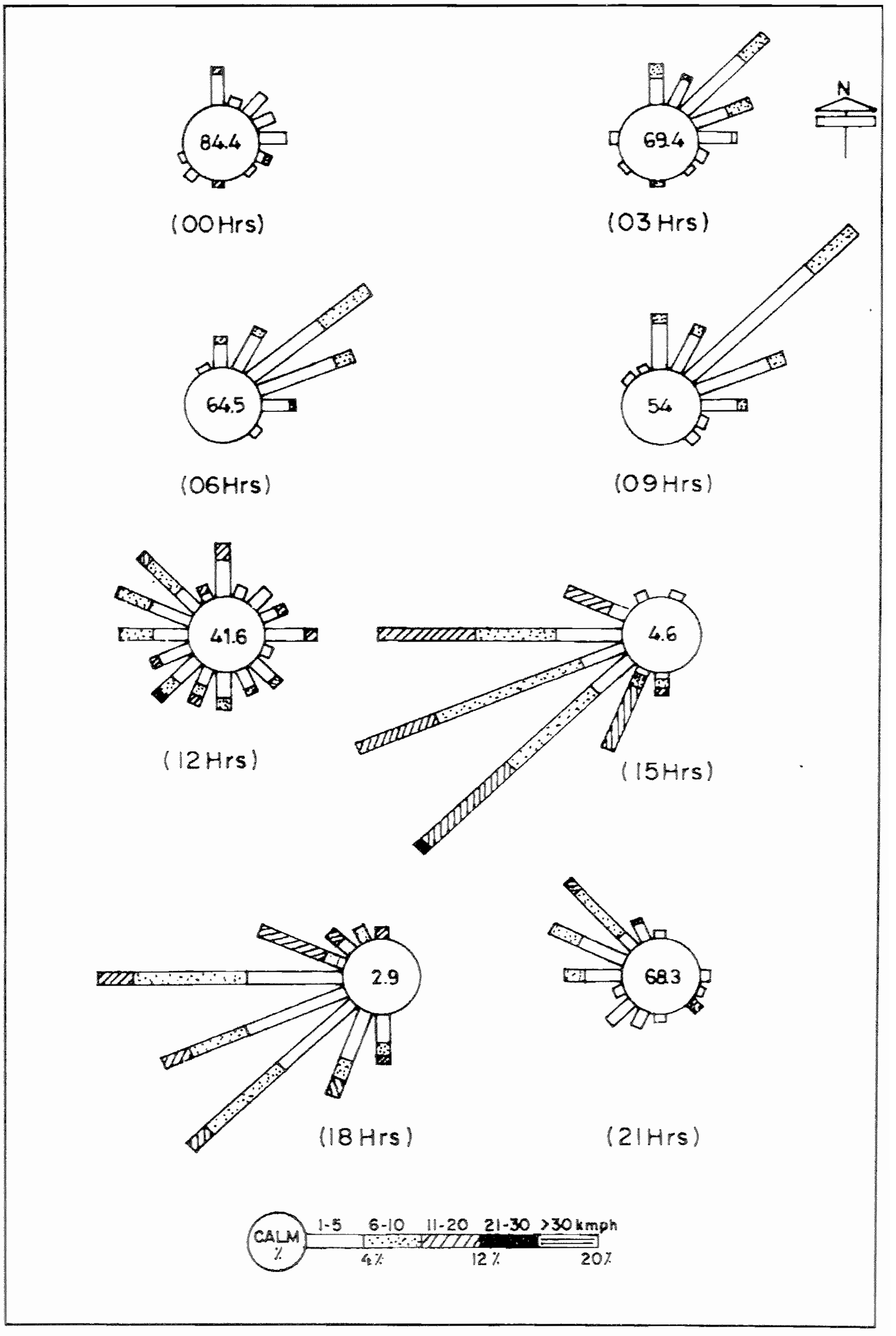



Fig. 3.1.3.5 : Diurnal Variation in Windroses for Kochi : Winter

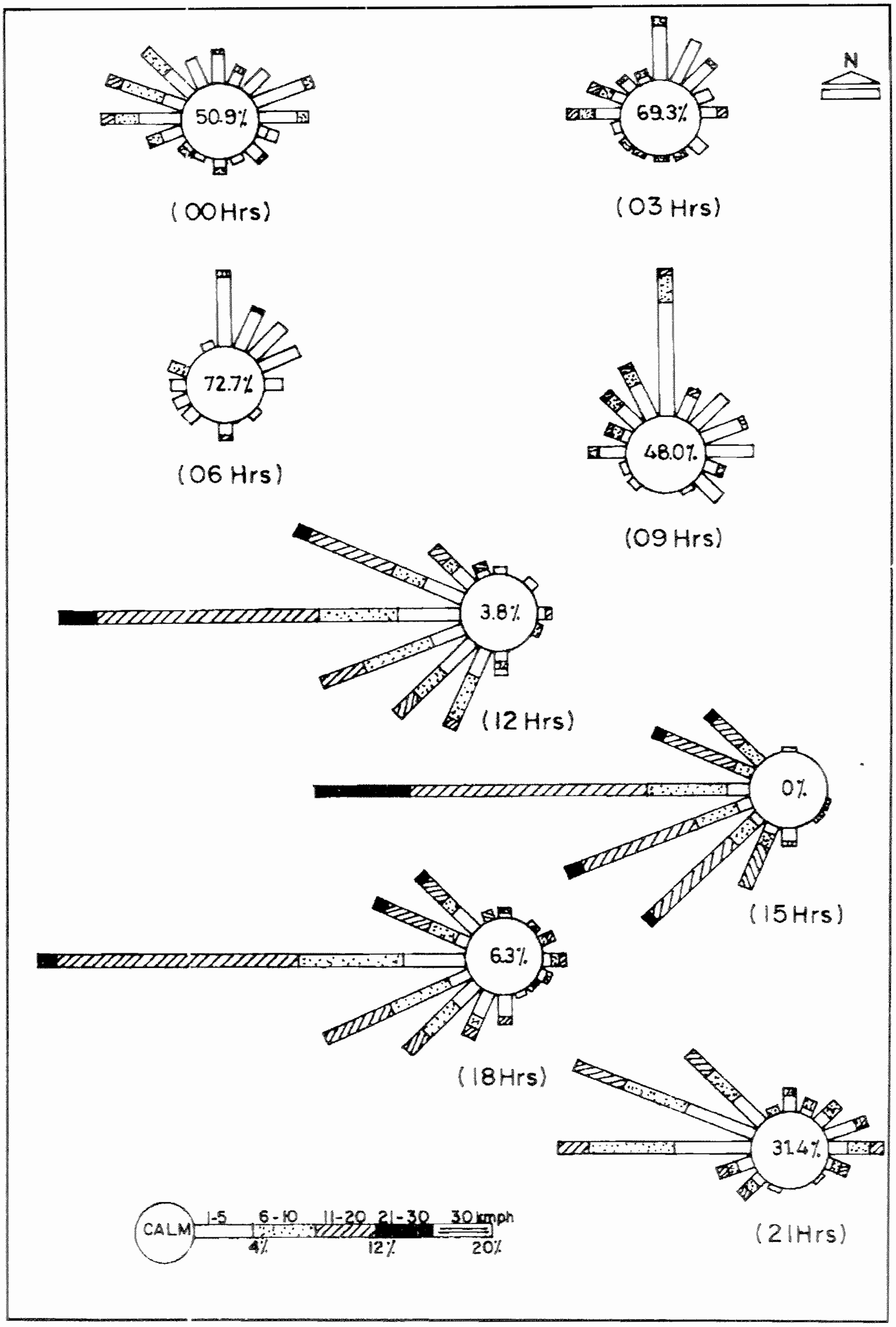



Fig. 3.1.3.6 : Diurnal Variation in Windroses for Kochi : Summer

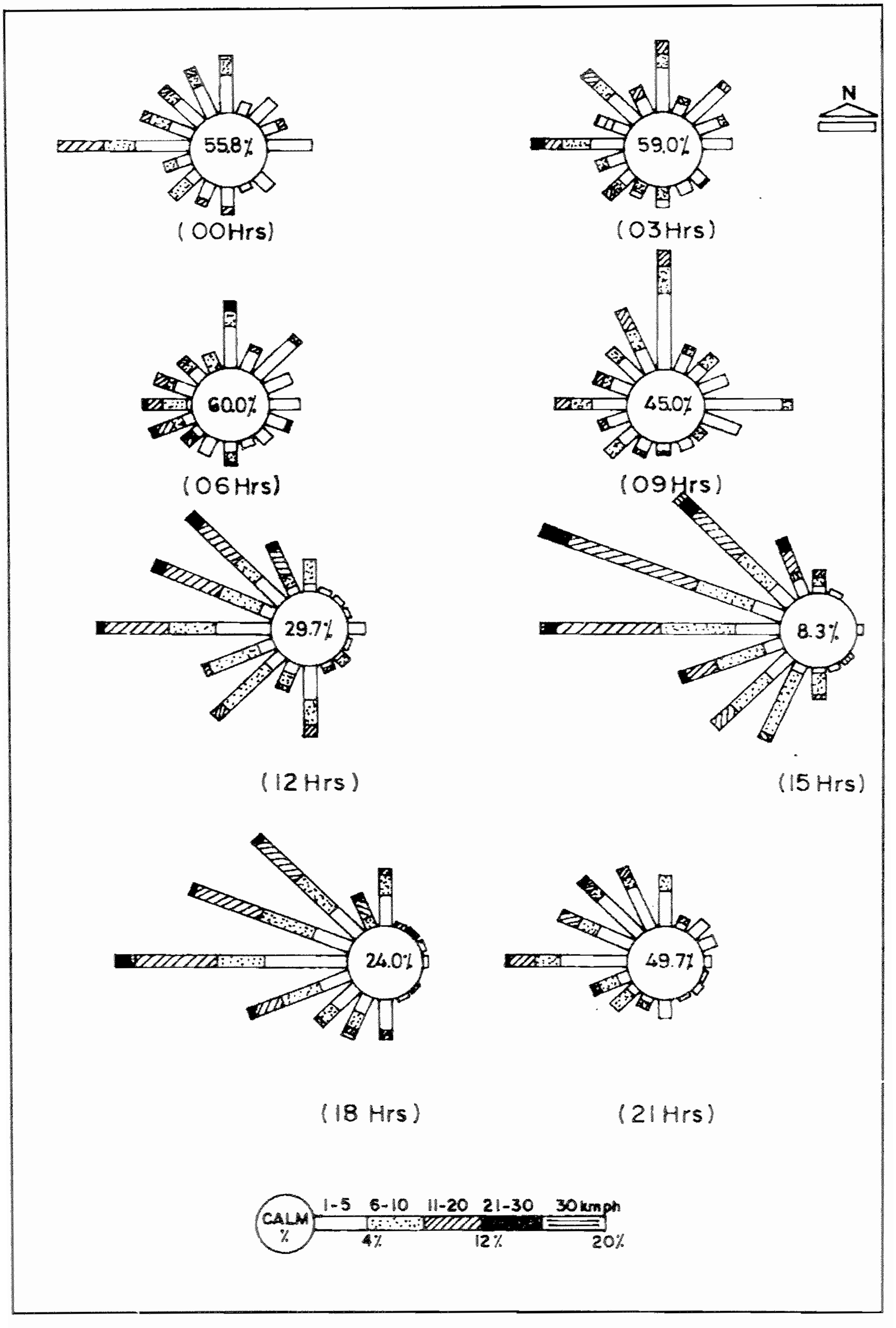



Fig. 3.1.3.7 : Diurnal Variation in Windroses for Kochi : Monsoon

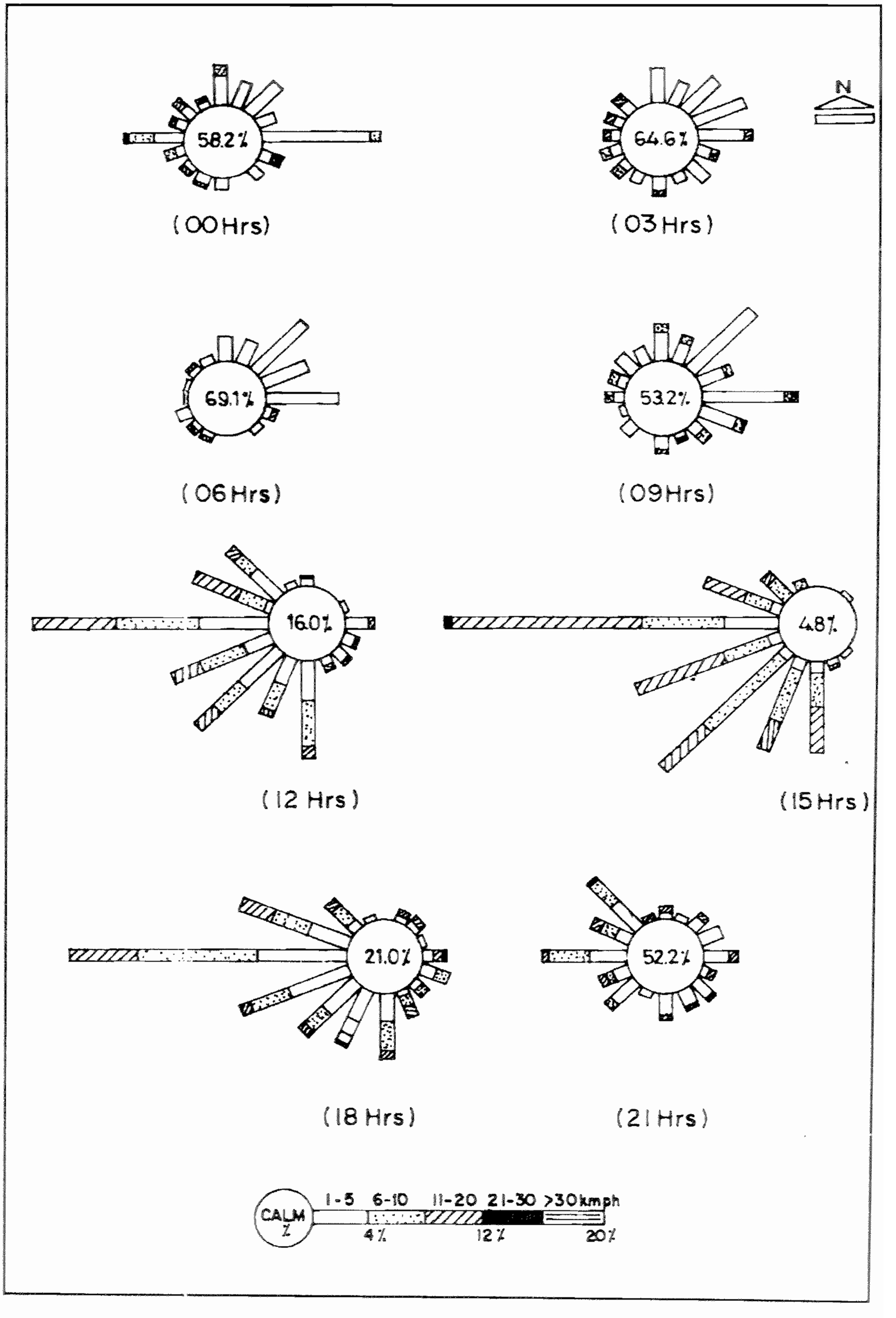



Fig. 3.1.3.8 : Diurnal Variation in Windroses for Kochi : Post monsoon

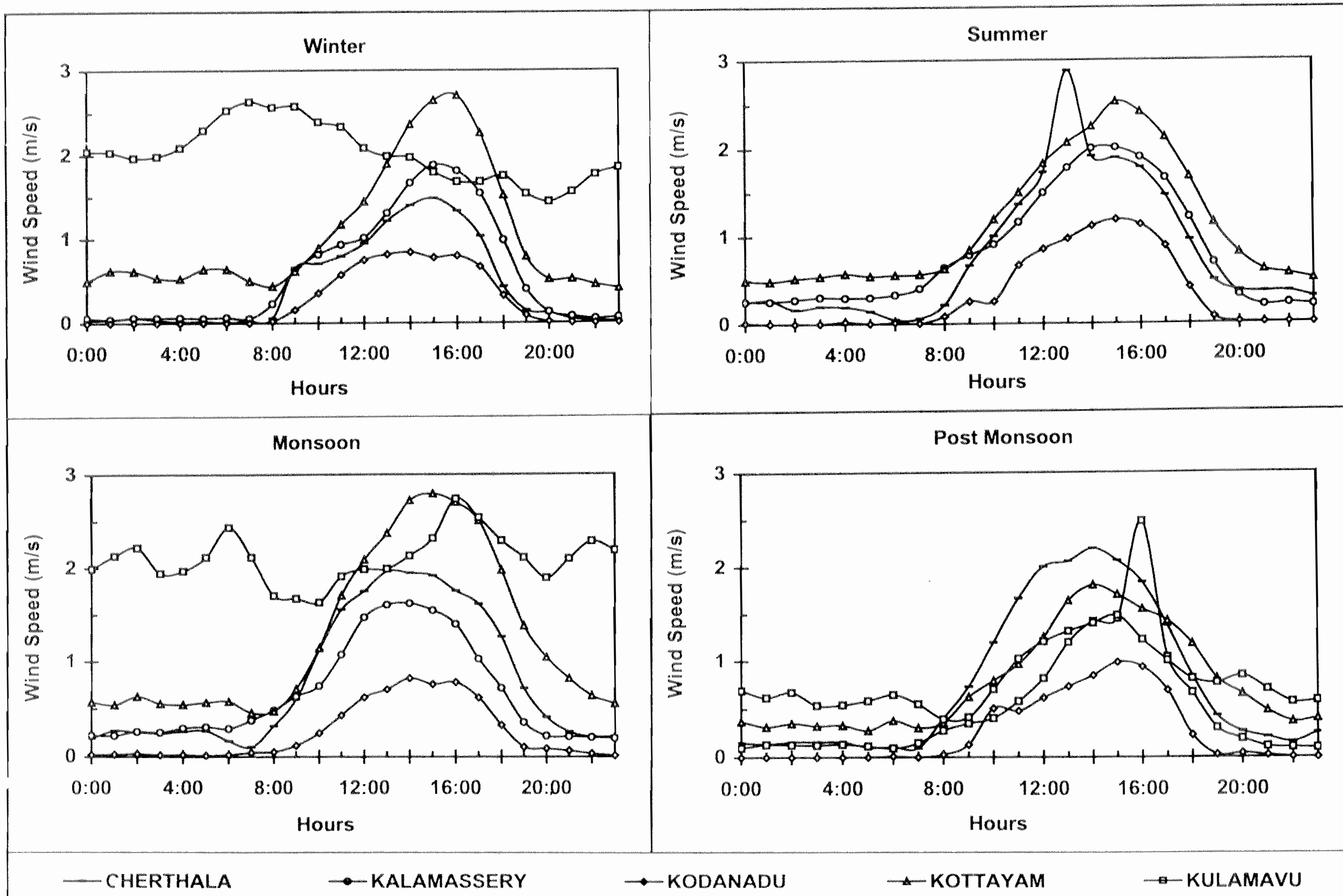



Fig. 3.1.3.9 : Diurnal Variation of Mean Wind Speed for Five Stations : Primary Data (Nov 98 - Oct 99)

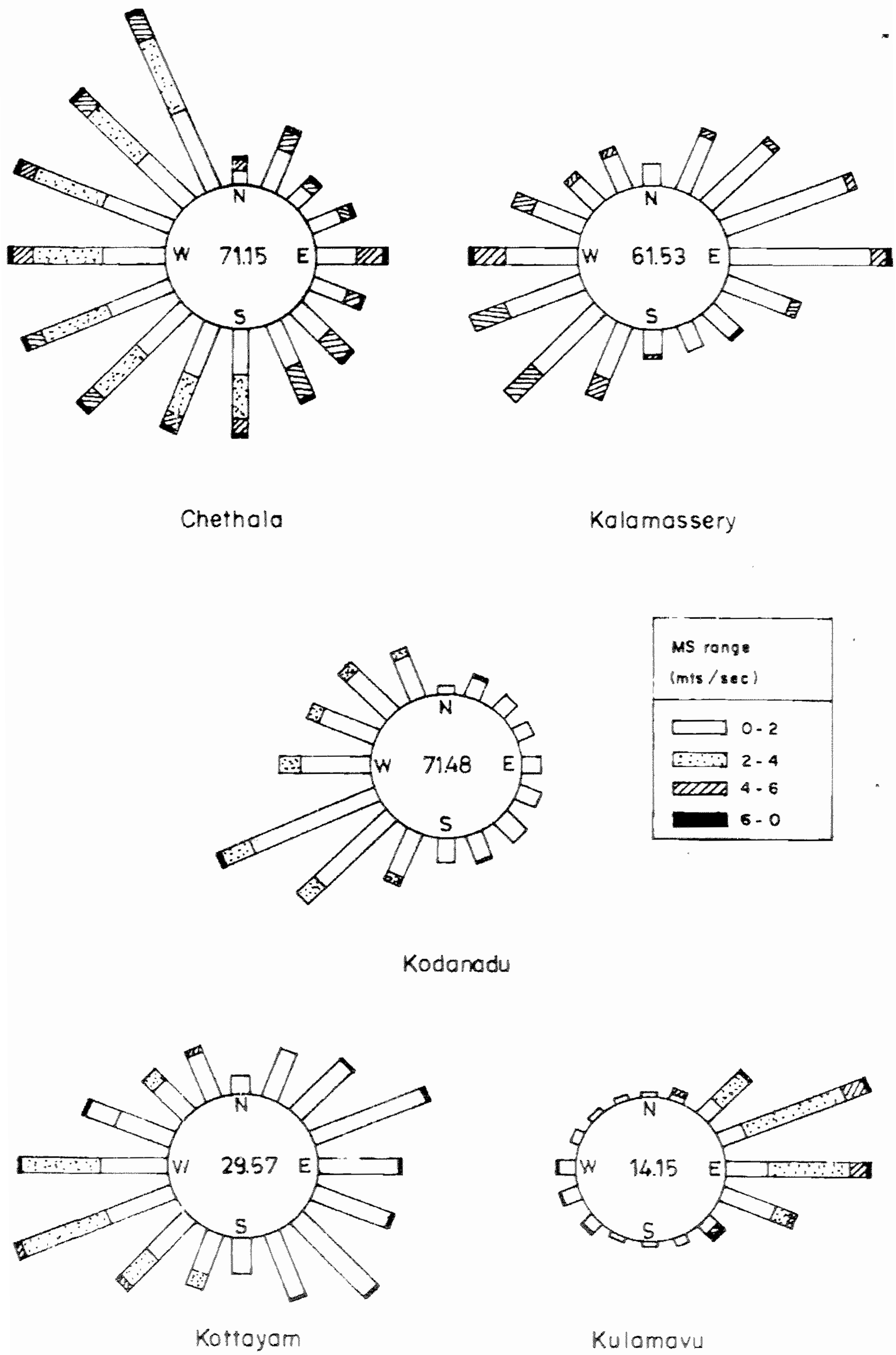



Fig. 3.1.1.10 : Windroses for Five Met Stations of GKR : Winter

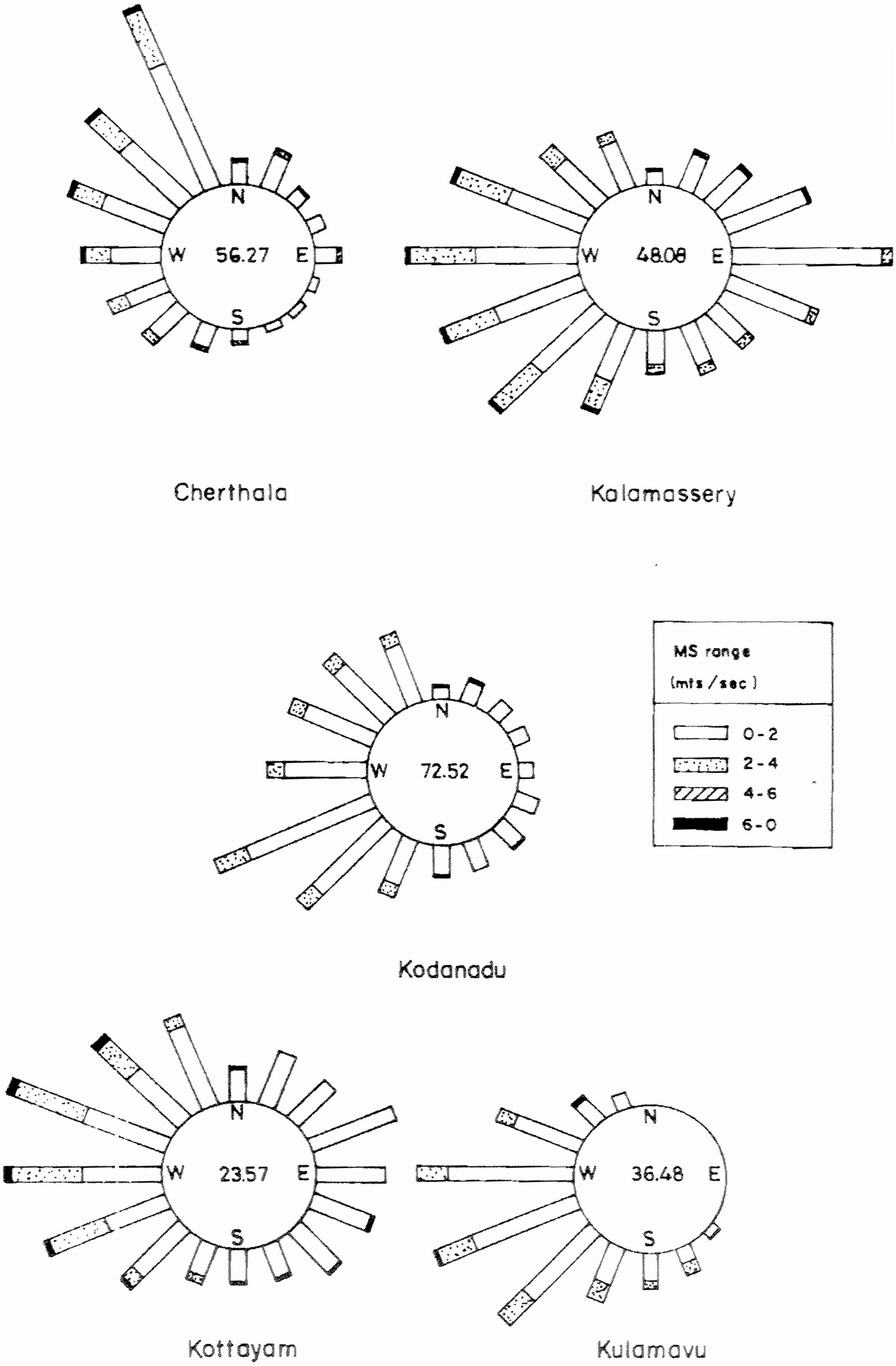



Fig. 3.1.3.11 : Windroses for Five Met Stations of GKR : Summer

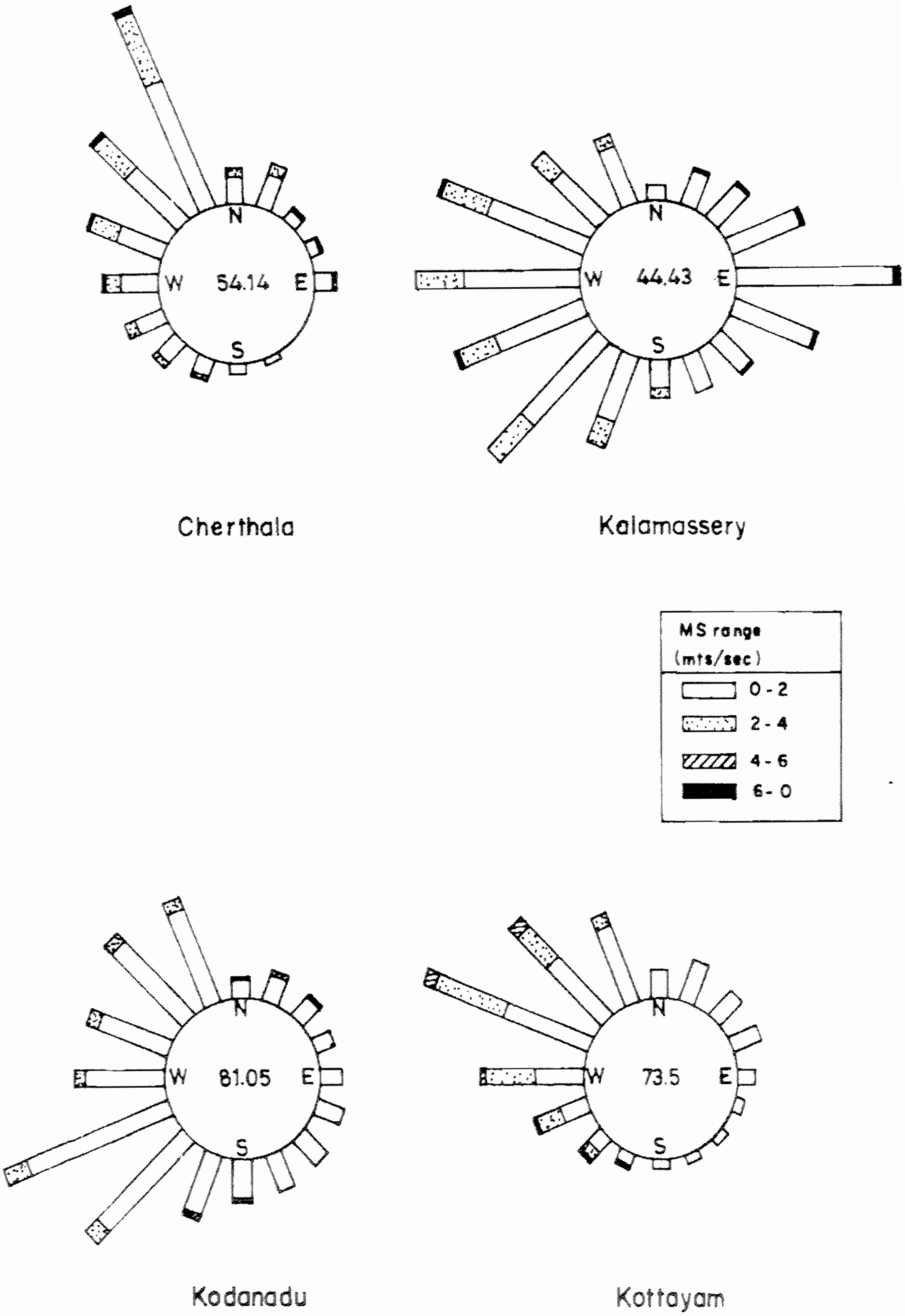



Fig. 3.1.3.12 · Windroses for Five Met Stations of GKR : Monsoon

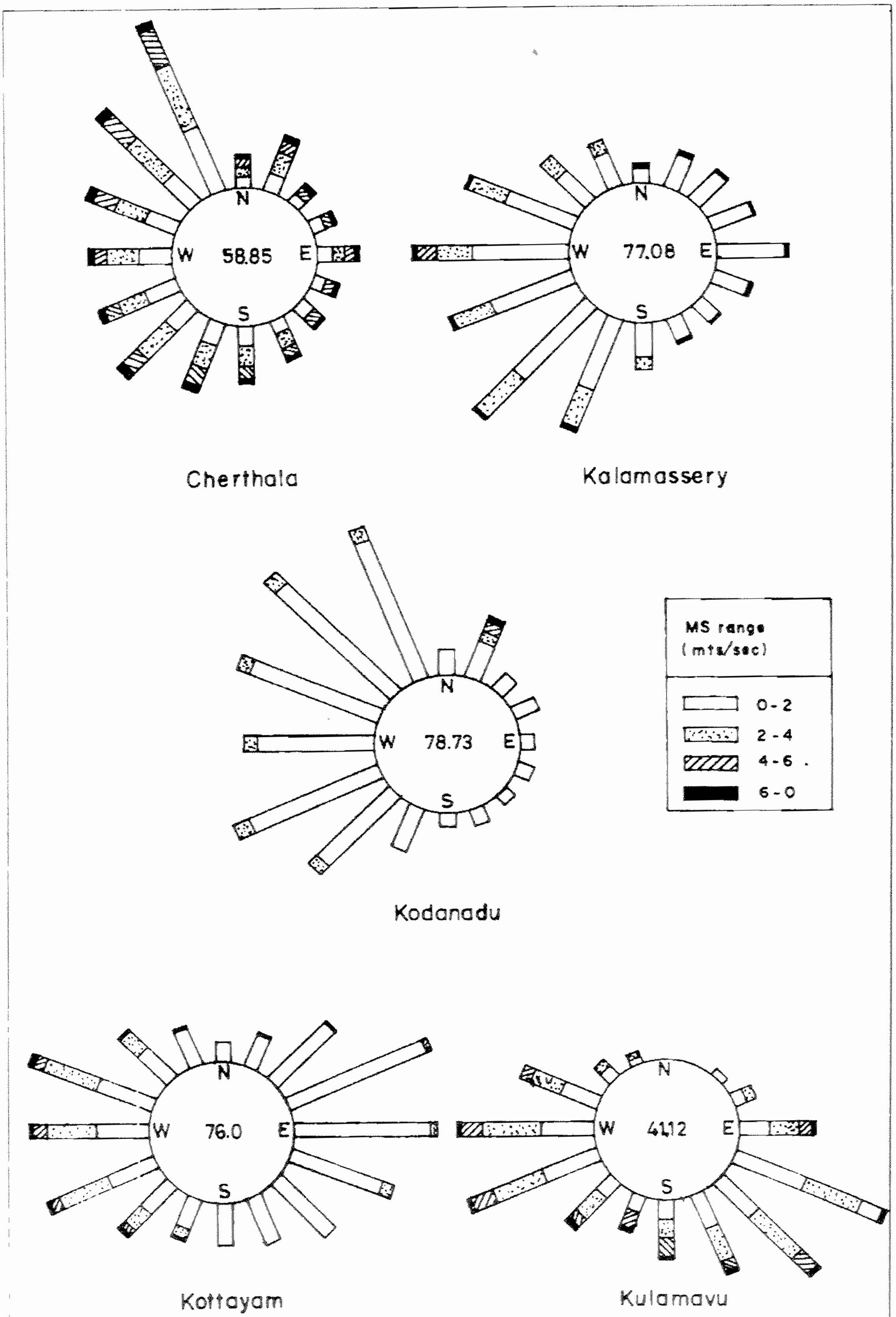



Fig. 3.1.3.13 : Windroses for Five Met Stations of GKR : Post monsoon

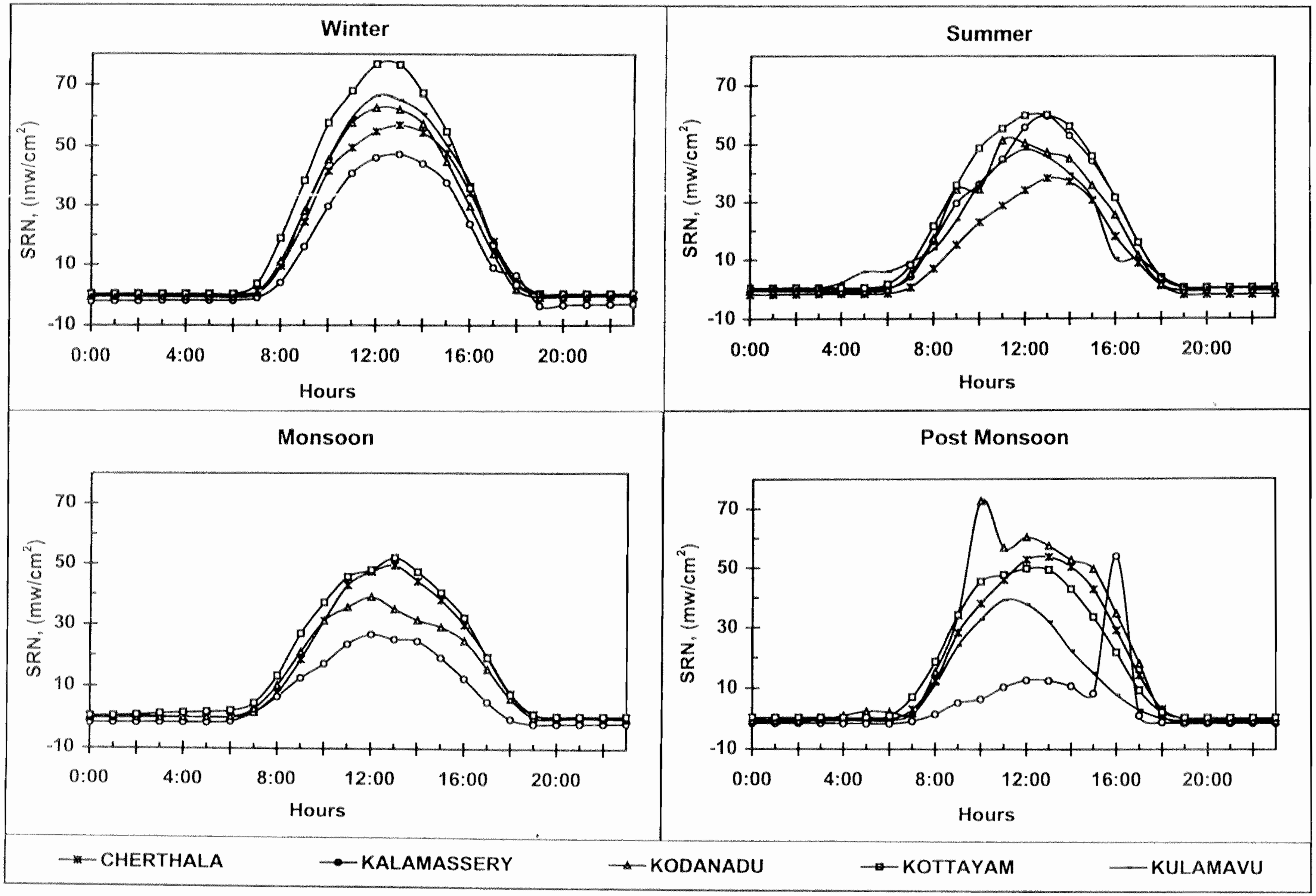



Fig. 3.1.3.14 : Diurnal Variation of Mean Solar Radiation for Five Stations : Primary Data (Nov 98 - Oct 99)

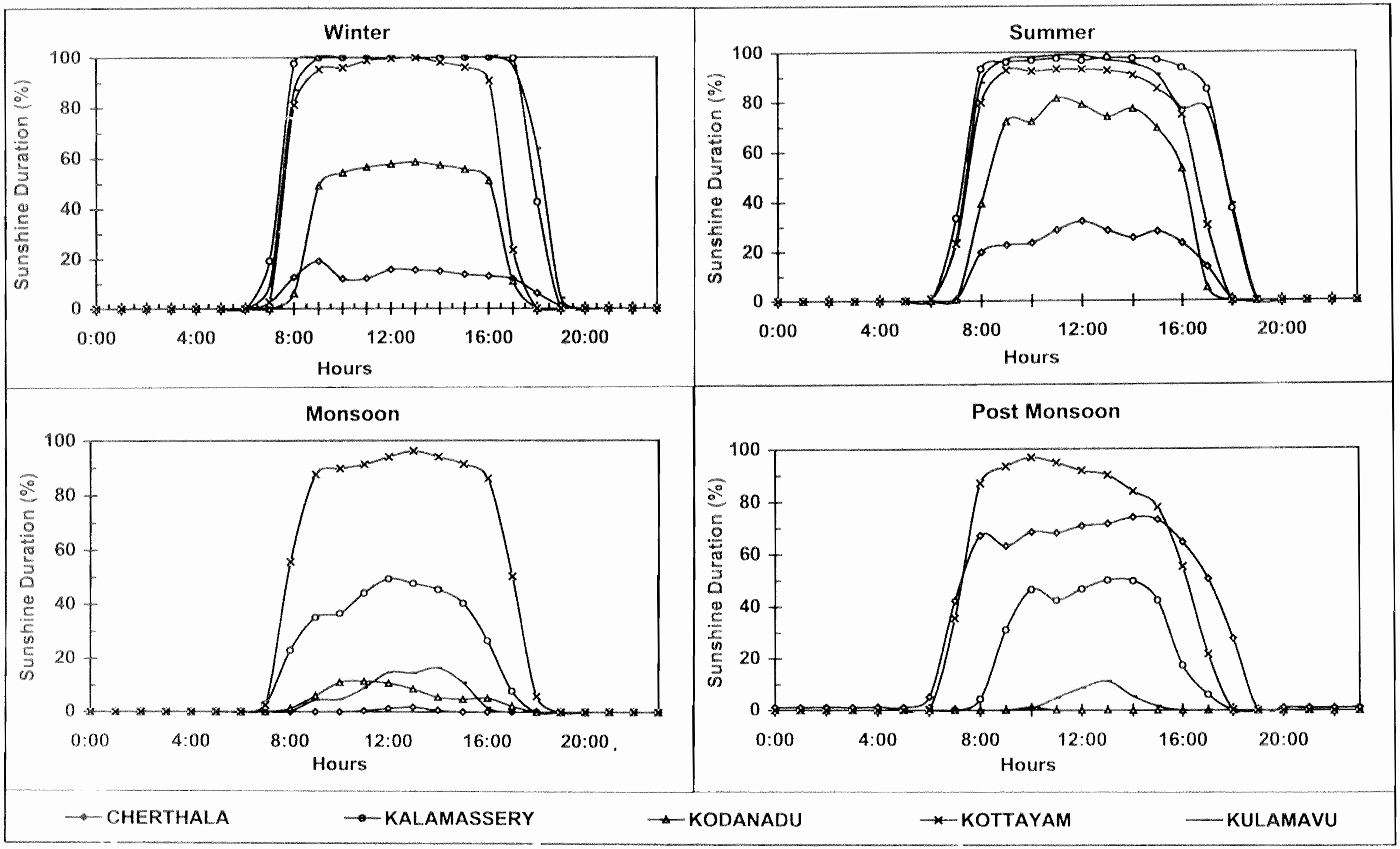
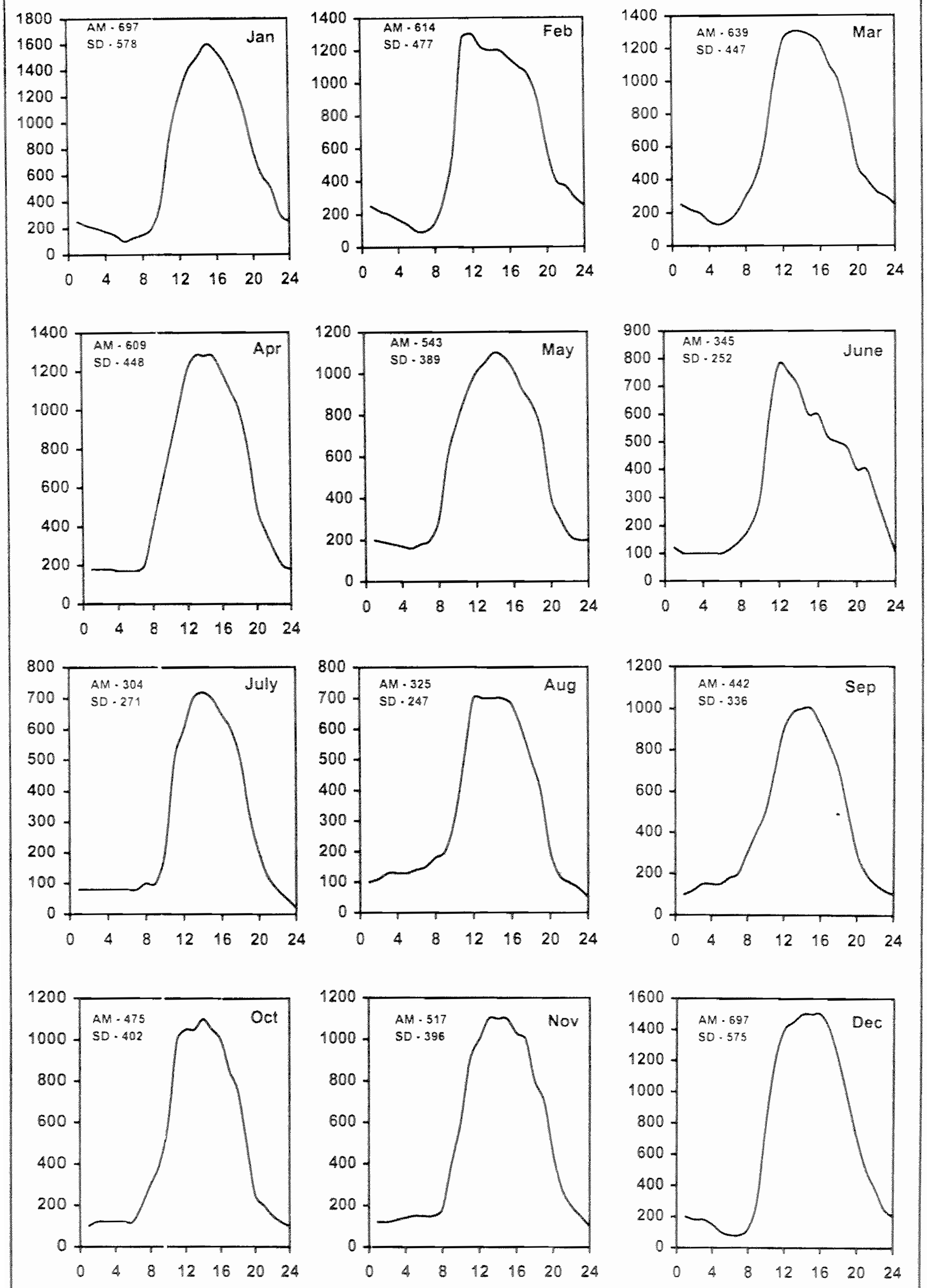



Fig. 3.1.3.15 : Diurnal Variation of Mean Sunshine Duration for Five Stations : Primary Data (Nov 98 - Oct 99)




AM - Arithmetic Mean
SD - Standard Deviation

X axis : Hourly of the Day
Y axis : Mixing Height in Meters

Fig. 3.1.3.16 : Diurnal Variation in Mean Mixing Height - Kochi Region

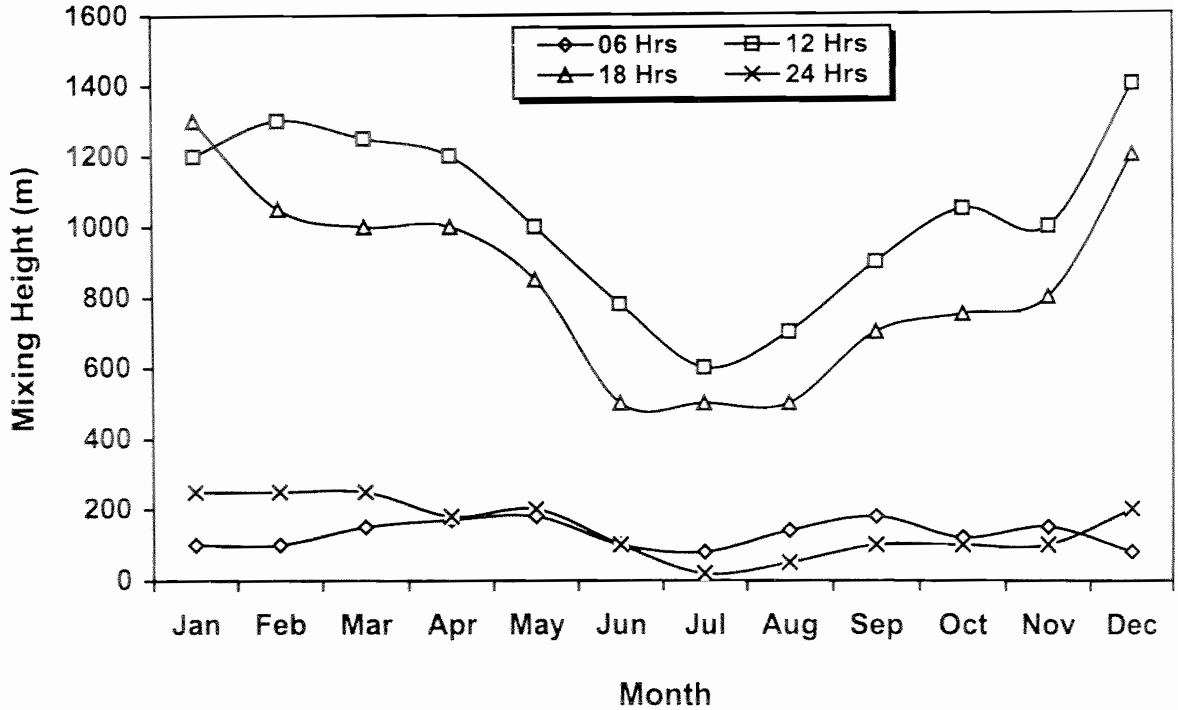



Fig. 3.1.3.17 : Variation in Mean Mixing Height in Kochi Region

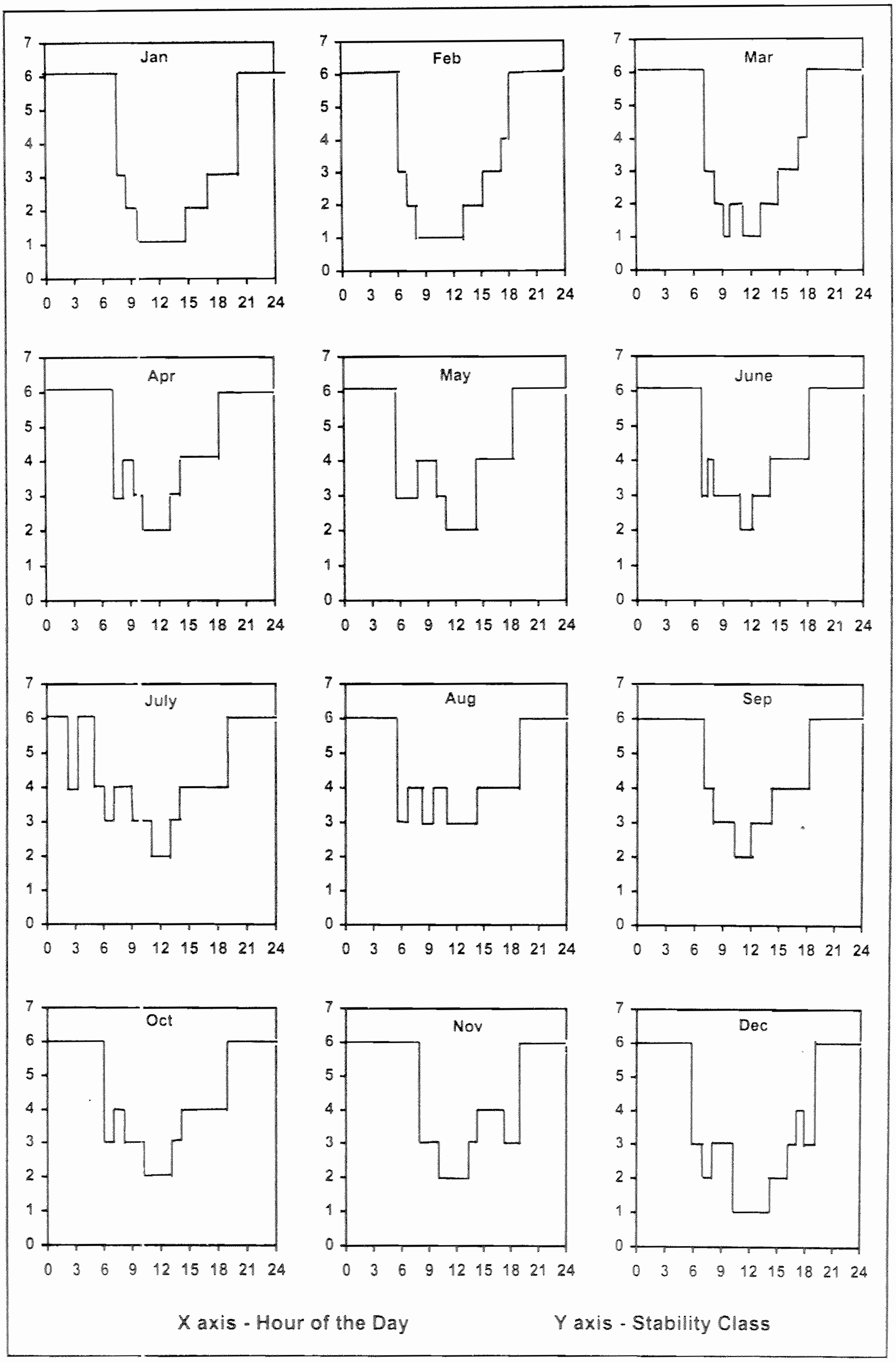



Fig. 3.1.3.18 : Diurnal Variation in Stability Class - Kochi Region

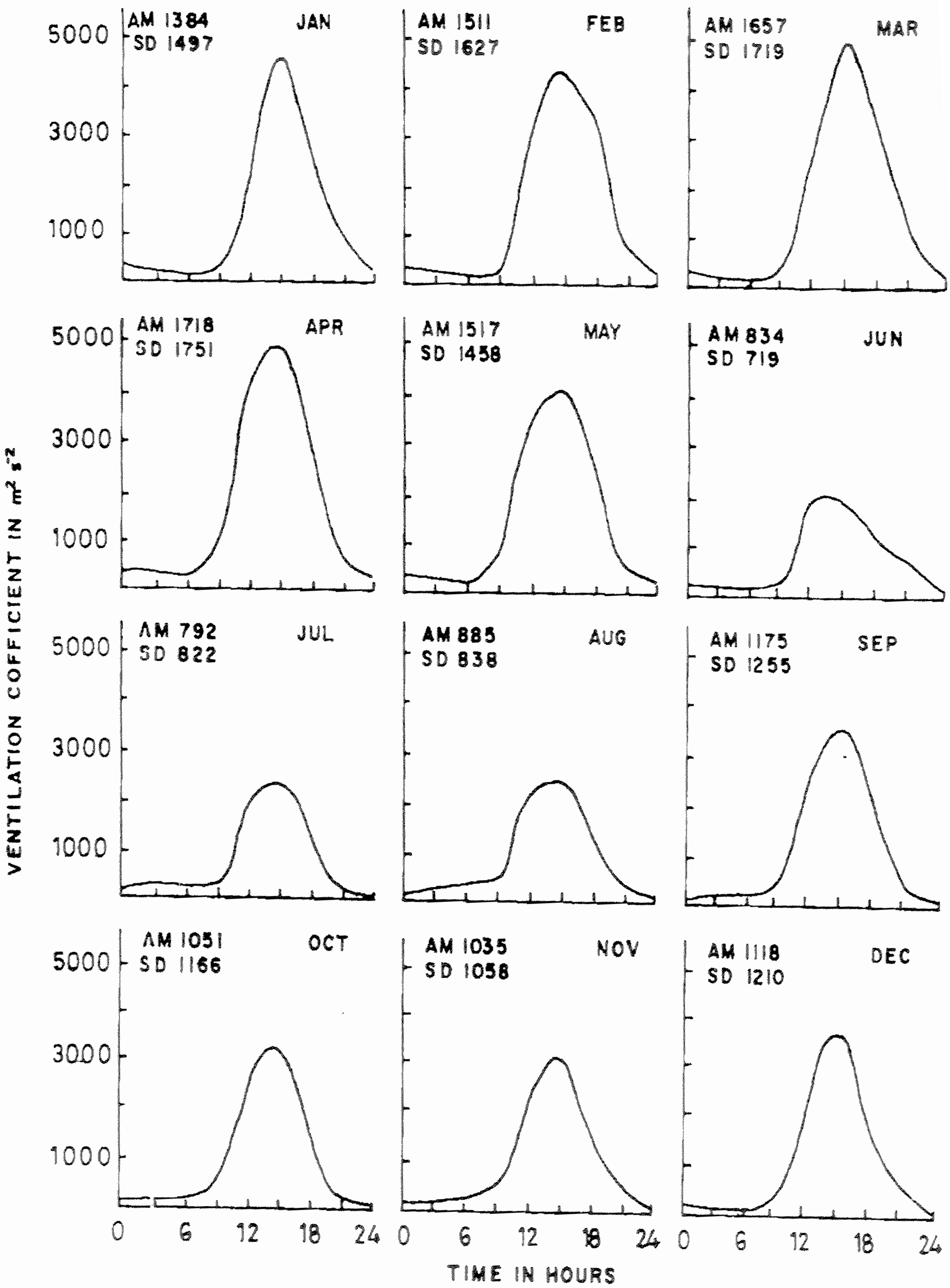



Fig. 3.1.3.19 : Diurnal Variation in Ventilation Coefficient for Kochi

## 3.2 Noise Environment

### 3.2.1 Analysis of Secondary Data

Status of ambient noise levels in Kochi city was studied in 1990 by NEERI. Noise levels monitored at 60 locations in residential and commercial zones within 10 Km radial distance of Cochin Refinery indicated that CPCB standard [noise level of 55 dB(A)] exceeded at 12% of the locations. However, in sensitive zones (schools, hospitals etc.), the noise standard of 50 dB(A) was found to exceed at 64% of the locations. The noise levels are given in **Tables 3.2.1.1 & 3.2.1.2** and summarized in **Fig. 3.2.1.1**.

### 3.2.2 Analysis of Primary Data

The noise levels (1997) in many zones of Kochi Metropolitan area and Kottayam exceeded the daytime CPCB standards of 50, 55 and 65 dB(A) in the silent, residential and commercial zones respectively. Maximum noise levels recorded even in silent zone ranged from 50 to 74 dB(A) during the day time whereas the maximum noise levels recorded at traffic junctions ranged from 72 to 80 dB(A) against the permissible level of 65 dB(A).

Further data on ambient noise levels was collected during April-May 2000 at number of locations in the study region. The details of monitoring locations and measured minimum and maximum noise levels are given in **Table 3.2.2.1.**

Table 3.2.1.1

Noise Levels in Residential and Commercial Zones of Kochi City

| Sr. No. | Monitoring Location | Direction | Aerial Distance (km) | Noise Level dB(A) |
|---|---|---|---|---|
| 1 | Tanker parking place opposite CR | S | 0.8 | 50 |
| 2 | CR Colony | NE | 0.4 | 44-56 |
| 3 | State Bank of Travancore, Ambalamugal | NE | 0.7 | 44-68 |
| 4 | Kerala Water Authority | W | 4.2 | 52-70 |
| 5 | Railway crossing (Eroor) | W | 4.6 | 50 |
| 6 | Alinchode | NW | 8.2 | 40-44 |
| 7 | Irimapanam square | SW | 2.1 | 66 |
| 8 | AQM Site, Irimpanam | NW | 2.9 | 40 – 42 |
| 9 | AQM Site. Thiruvamkulam | S | 2.5 | 50-52 |
| 10 | AQM Site, Thiruvaniyoor | SE | 8.6 | 46-48 |
| 11 | AQM Site, Kadayirippu (Aikkarnad North) | NE | 9.8 | 40-42 |
| 12 | Hoc gate | SE | 0.7 | 58-60 |
| 13 | 50 meters off the road | SE | 1.0 | 52 |
| 14 | FACT gate | NE | 1.0 | 52 |
| 15 | Kuzhikadu | E | 1.7 | 42-44 |
| 16 | Karigugal Market Square | NE | 3.2 | 42 |
| 17 | AQM Site, Brahmapuram | N | 3.3 | 42 |
| 18 | Sahuwala Wax & Chem., Brahmapuram | N | 3.4 | 42-44 |
| 19 | Carbon Chemicals (gate) | NE | 3.7 | 50 |
| 20 | AQM Site, Peringala | NE | 5.7 | 44 |
| 21 | Lammomad junction | NE | 5.7 | 50 |
| 22 | Vadayukode | E | 5.3 | 50 |
| 23 | Puthencruz Market Suqare | E | 6.0 | 52 |
| 24 | Vadaympadi | E | 7 1 | 50 |
| 25 | Pangode | NE | 7.9 | 34 |
| 26 | Pattimattom Market Square | NE | 9.5 | 52 |
| 27 | Kizhakkambalam Market area | NE | 8.8 | 44-48 |
| 28 | Parakkode | NE | 8.2 | 32 |
| 29 | Alwaye Minerals & Chem. Ltd., Pazhangadu | N | 9.3 | 48 |
| 30 | Pookattupady Market Area. | N | 9.0 | 54 |
| 31 | Kuzhiudipady | N | 8.7 | 40 |

Contd...

Table 3.2.1.1 Contd...

| Sr. No. | Monitoring Location | Direction | Aerial Distance (km) | Noise Level dB(A) |
|---|---|---|---|---|
| 32 | Maniyathramugal | NW | 7.0 | 38-44 |
| 33 | HMT gate | NW | 10.0 | 50 |
| 34 | Vazhkkala | NW | 7.7 | 50-60 |
| 35 | AIR office, Kakkand | NW | 7.7 | 48-52 |
| 36 | Shopping complex, Thrikkakara | NW | 7.0 | 50 |
| 37 | Arrak Synthetics Ltd., and CEPZ | NW | 0.6 | 48-54 |
| 38 | Petta Junction, Udamperoor road | SW | 4.4 | 50-54 |
| 39 | Thripunithura Market Railway junctions | SW | 3.6 | 60 |
| 40 | Traco Cable Company Ltd., Irimpanam | NW | 3.7 | 36 |
| 41 | Hill Palace | SW | 2.3 | 42-56 |
| 42 | Puttumanur (Ambalamugal) | E | 1.7 | 32 |
| 43 | Varikkol | E | 3.0 | 38-40 |
| 44 | Mattakuzhiambalam | E | 2.6 | 34-40 |
| 45 | Venmani | E | 2.7 | 32 |
| 46 | KEL Gate, Manimala | S | 2.3 | 42 |
| 47 | Panchayat Office Poothrikka | E | 7.7 | 47 |
| 48 | Nadukurizhu, near Thiruvanyoor | SE | 8.3 | 40 |
| 49 | OEN, Mulamthuruthy | SE | 7.1 | 50-60 |
| 50 | Market Area, Mulamthuruthy | S | 8.5 | 50-60 |
| 51 | Residential Area, Chottanikkara | S | 6.3 | 34-40 |
| 52 | Peniggapara, Mulamthuruthy | S | 8.0 | 42-44 |
| 53 | Railway crossing, Kureedadu | S | 3.8 | 40 |
| 54 | Kandanaddu | SW | 5.9 | 36-40 |
| 55 | Thamanam | W | 8.1 | 52-56 |
| 56 | Railawy crossing, Vittila | W | 8.9 | 50-54 |
| 57 | Bye-pass junction, Vyttila | W | 8.6 | 54-60 |
| 58 | Kudanoor (Nettoor) | SW | 8.5 | 50 |
| 59 | Market Area, Maradu | SW | 5.6 | 50 |
| 60 | Panangad | SW | 8.6 | 50 |

Direction and Distance are with respect to Cochin Refinery.
**Source :** Secondary Data collected by NEERI : CRL-EIA Report (1990-91)

## Table 3.2.1.2

### Noise Pollution at Sensitive Receptors around Cochin Refinery

| Sr. No. | Monitoring Location | Direction | Aerial Distance (km) | Noise Level (dBA) |
|---|---|---|---|---|
| 1 | Refinery School | - | - | 44-46 |
| 2 | Govt. High School, Ambalamugal | NE | 1.1 | 38-40 |
| 3 | Retina's College | NE | 2.1 | 46-50 |
| 4 | JBS School, Brahmapuram | NE | 3.1 | 48-50 |
| 5 | St. Joseph's School, Kizhakkambalam | N | 9.2 | 45-50 |
| 6 | Samaritan Hospital | N | 9.3 | 48 |
| 7 | Therakkal Govt. School | NW | 8.7 | 50 |
| 8 | Cochin University | NW | 9.7 | 54 |
| 9 | Ernakulam Medical Center | W | 6.7 | 50-54 |
| 10 | Rice Research Centre | W | 6.5 | 54 |
| 11 | St. Xaviers Medical Mission Hospital | SW | 4.7 | 54-60 |
| 12 | Gover's Hospital | SW | 3.7 | 60 |
| 13 | Women's Industrial School, Kolecherry | NE | 9.8 | 42 |
| 14 | Sir Dorabji Tata Trust Aided Hospital | S | 5.7 | 42-46 |

Direction and Distance are with respect to Cochin Refinery
**Source :** Secondary data collected by NEERI : CRL - EIA Report (1990-91)

## Table 3.2.2.1

## Ambient Noise Levels in GKR

| Sr. No. | Monitoring Location | Zone Classification | Noise Level dB(A) | |
|---|---|---|---|---|
| | | | Min | Max |
| | **Alappuzha** | | | |
| 1 | (YMCA) | Sensitive | 54 | 62 |
| 2 | NH-47(excell) | Commercial | 62 | 70 |
| 3 | Chertala | Sensitive | 49 | 60 |
| 4 | Kodanadu | Commercial | 46 | 63 |
| 5 | Kodanadu | Residential | 38 | 55 |
| 6 | Kodanadu | Sensitive | 36 | 68 |
| 7 | Kothamangalam | Commercial | 52 | 62 |
| 8 | Kothamangalam | Residential | 48 | 70 |
| 9 | Kothamangalam | Residential | 41 | 61 |
| | **Ernakulam** | | | |
| 1 | Naval Base | Sensitive | 44 | 52 |
| 2 | Mattanchery | Commercial | 58 | 62 |
| 3 | Fort Cochin (Beach) | Commercial | 57 | 60 |
| 4 | Fort Cochin (St. Francis Church, outside) | Sensitive | 54 | 70 |
| 5 | Fort Cochin (St. Francis Church, inside) | Sensitive | 50 | 63 |
| 6 | Thoppumpady | Commercial | 50 | 64 |
| 7 | Willington Island | Commercial | 46 | 58 |
| 8 | Padivattom | Residential | 58 | 72 |
| 9 | Chalikavattom | Residential | 50 | 65 |
| 10 | Ponnurunni | Sensitive | 48 | 63 |
| 11 | Kadavanthara | Sensitive | 50 | 58 |
| 12 | Kacherippady | Commercial | 52 | 63 |
| 13 | Kaloor | Commercial | 49 | 65 |
| 14 | Kalamassery | Commercial | 52 | 68 |
| 15 | FACT / IRE | Industrial | 48 | 56 |
| 16 | Pathalam | Sensitive | 48 | 61 |
| 17 | Mupathadam | Sensitive | 51 | 59 |
| 18 | Aluva | Sensitive | 60 | 72 |

Contd...

Table 3.2.2.1 Contd...

| Sr. No. | Station | Zone | Noise Level dB(A) | |
|---|---|---|---|---|
| | | | Min | Max |
| 19 | Aluva (Rly. Stn.) | Commercial | 62 | 77 |
| 20 | Aluva | Sensitive | 49 | 68 |
| 21 | Aluva | Commercial | 54 | 69 |
| 22 | FACT | Residential | 38 | 48 |
| 23 | Udyogamandal | Industrial | 48 | 57 |
| 24 | Poothotta | Sensitive | 48 | 57 |
| 25 | | Commercial | 52 | 62 |
| 26 | | Residential | 53 | 65 |
| 27 | Vaikkom | Sensitive | 49 | 56 |
| 28 | | Commercial | 53 | 65 |
| 29 | | Residential | 52 | 63 |
| 30 | Thalayolaprarambu | Commercial | 51 | 57 |
| 31 | Ettumanur | Sensitive | 47 | 53 |
| 32 | | Commercial | 52 | 67 |
| | **Kottayam** | | | |
| 1 | | Sensitive | 48 | 52 |
| 2 | | Sensitive | 52 | 58 |
| 3 | | Commercial | 60 | 68 |
| 4 | | Residential | 46 | 52 |
| 5 | Chingavanam | Commercial | 64 | 72 |
| 6 | Changanassery | Sensitive | 56 | 64 |
| 7 | | Commercial | 57 | 63 |
| 8 | | Residential | 48 | 57 |
| | **Pathanamthitta** | | | |
| 1 | | Sensitive | 43 | 50 |
| 2 | | Commercial | 51 | 62 |
| 3 | | Commercial | 52 | 65 |
| 4 | | Commercial | 51 | 63 |

**Source :** Primary data collected by NEERI, during April-May 2000

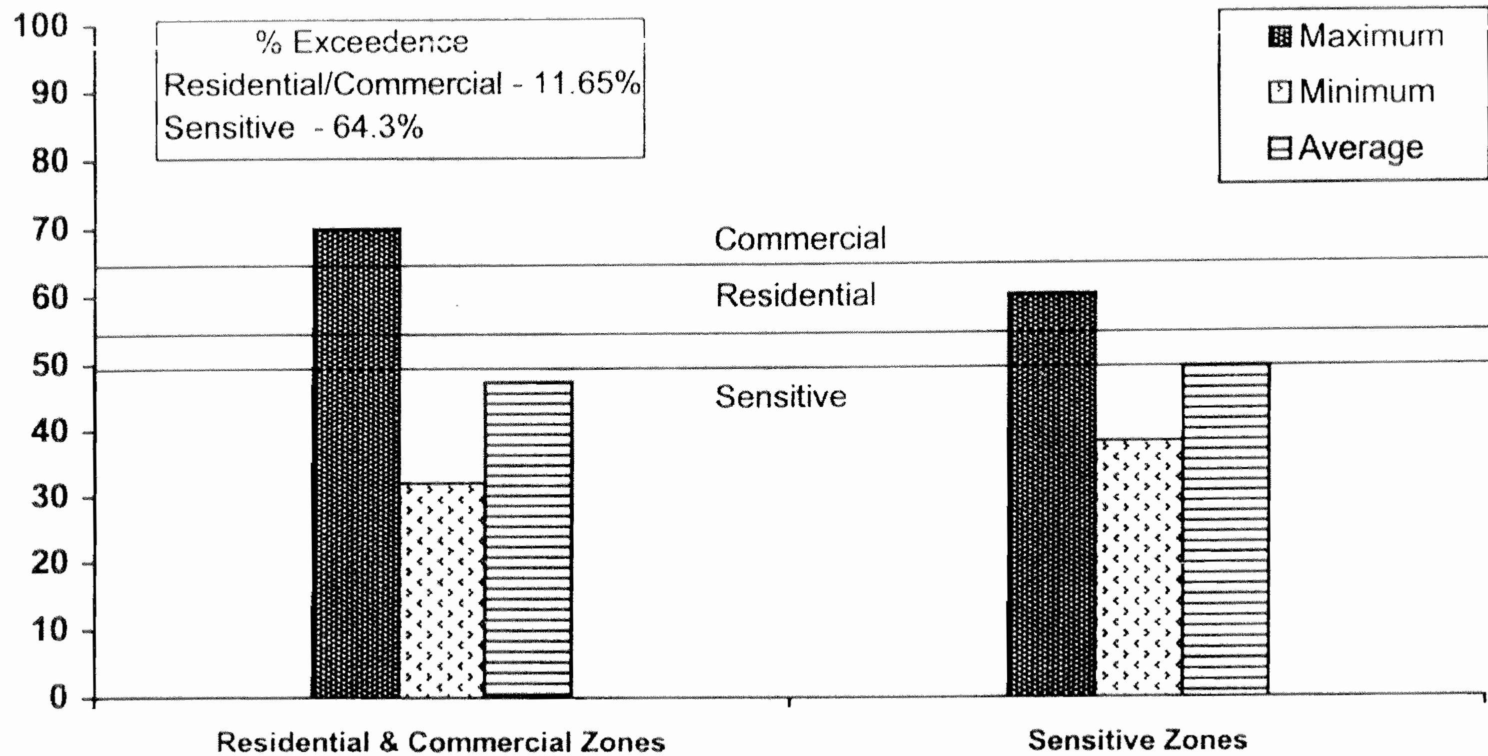



Fig 3.2.2.1 : Ambient Noise Levels in Kochi (1990)

## 3.3 Water Environment

### 3.3.1 Surface Water

Seven major rivers, namely; Chalakkudy, Periyar, Muvattupuzha, Meenachil, Manimala, Pamba and Achencoil flow through the Greater Kochi Region Kerala State Pollution Control Board (KSPCB) assessed river water quality status with respect to physico-chemical and biochemical parameters of all these rivers during 1995-1996. Further, water quality of Chithrapuzha River, a tributary of River Periyar was also assessed during 1995-1997 by CWRDM. This river receives daily about 33600 $m^3$ of effluent from various industries located in Cochin.

Water sampling locations on various rivers are shown in **Fig. 3.3.1.1**. River-wise details of sampling locations are given in **Table 3.3.1.1** whereas summary of results of analysis for major physico-chemical and biological parameters are presented in **Table 3.3.1.2** for each sampling locations in each of the 7 rivers. River wise water quality status is discussed here.

#### 3.3.1.1 Chalakkudy River

Chalakkudy River is formed by the confluence of five streams, Parambikulam, Kuriarkutty, Sholayar, Karappara and Anakkayam, all of them originate from the Anamalai hills of the Western Ghats. The river has a length of 130 km with drainage area of 1704 $km^2$. One major industry; Madurai Coats is situated in this river basin alongwith a few small-scale industries mainly based on tapioca products. Water samples were collected at different sampling locations; Athirappally, Chalakkudy, Kakkiyar, Kanjirappara, Palapuzhakkal, Peringalkuthu, Pulikkalkadavu and Vettilappara.

Even though all the waters are contaminated with coliforms, Vettilapara station is comparatively less polluted with bacterial pollution. This station recorded a minimum value of 25 MPN/100 ml during the month of January. But a maximum value of 2800 MPN/100 ml was recorded during the month of April. All other stations are contaminated with faecal coliforms. At Athirapally, the nitrate-nitrogen is estimated to be having a minimum value of 0.8 mg/L and maximum of 1.0 mg/L. At Kakkiyar, the nitrate-nitrogen concentration recorded a minimum value of 90 mg/L and maximum value of 300 mg/L.

#### 3.3.1.2 Periyar River

Periyar River is one of the longest rivers in Kerala, having a length of 244 Km. It originates from the Western Ghats. The drainage area of the basin is 5400 $km^2$. The river flows through hilly terrain for about 48 km distance before various tributaries namely Mullayar, Perunthanni Aar, Cheruthoni Aar, Chittar, Mudirapuzha, Chithrapuzha and Idamalayar join it. At Alwaye, the river breaks up into two branches; Marthandavarma and Mangalapuzha. The Mangalapuzha branch joins Chalakkudy River and drains into the Lakshadweep Sea at Munambam, while the Marthandavarma branch flows southwards, through the Udyogamandal area and joins the Cochin backwater system at Varapuzha.

The water supplied to the residents of Cochin Corporation and Alappuzha municipality is drawn through the Kerala Water Authority (KWA) intake wells located at Alwaye. Major industries like, Fertilizers And Chemicals Travancore Ltd. (FACT), Hindustan Insecticides Ltd., Travancore Cochin Chemicals Ltd and Travancore Chemical Manufacturing Company Ltd. have their water intakes in the Idamula branch of the Periyar. The Idamula branch is susceptible to the intrusion of saline water from the Vembanad backwaters in summer. Salinity does not affect the intake wells at Alwaye, being located much upstream. To protect the industrial water intakes in the Idamula branch from salinity, a series of earthen bunds are put up in various locations every year.

The river Periyar is of utmost importance due to the fact that more than 25% of the industries of Kerala and one of the largest hydroelectric projects are situated in this river basin. The industries are mostly crowded within a stretch of 5 km in the Eloor - Edayar region, which is at a distance of 10 km from the Cochin harbour. These factories depend on the river for their water requirement and disposal of effluents.

The water analysis data provided by KSPCB for the various stations, viz. Alwaye, Alwaye Minars, Bhoothathankettu, Chowara, Eloor, Kaladi, Kodanadu, Kuttikkattukara, Mangalapuzha, Marthandavarma Bridge and Neriamangalam show district spatial variations in water quality.

Further, primary data has been collected by CWRDM from the stations Alwaye (upstream of Indal Aluminium) at different points, Pathalam, near FACT, Binanipuram, Methanamjetty and Olanad Kadavu. The results of monitoring during different seasons/ periods for all the sampling locations are summarized in **Table 3.3.1.3**.

The concentration of ammonical nitrogen ranged up to 7.6 mg/L and it was high in the downstream samples, especially at Eloor. Following constituent values i.e conductivity (30.7 to 1461 µs/cm), hardness (10 to 144 mg/L), phosphate (0.01 to 0.16 mg/L), and nitrate-nitrogen (0.02 to 11.9 mg/L) were reported during sampling. Comparatively high mineral content was noticed at sampling points near the discharge point of effluents from factories such as FACT, IRE etc. A very low pH was noticed in the water samples collected from the point just before the Pathalam bund during May 2000. This bund is a temporary one constructed to prevent salinity intrusion during summer. A low pH at this point may be either due to discharge of effluents from industries upstream or because of the stagnation of water at the point of bund. Water is also found to be acidic at Olanadukadavu, downstream of Periyar River during May and high conductivity was noticed at this point, which is due to the saltwater intrusion from the Cochin backwaters. BOD values were found to be less than 5 mg/L at all the sampling locations indicating absence of organic pollution.

Bacteriologically all the samples were found contaminated. Faecal coliform count was reported (max 6693 MPN/100 ml) to be present in all the samples. The river receives stormwater drainage and municipal and domestic effluents. Fishery wastes and wastes from coconut rettings are also dumped adding to the contamination.

### 3.3.1.3 Muvattupuzha River

Muvattupuzha River formed by the confluence of three rivers; viz. Thodupuzha, Kaliyar and Kothamangalam, flows in a South Westerly direction for about 2 km, then flows in a westerly direction for about 13 km, again turns Southwest and passes through low swampy lands. At Vettikattumukku, it bifurcates into the Murinjapuzha and the Ithipuzha to join the Vembanad Lake through a series of channels. The river has a total length of 121 km with a total drainage area of 1554 $km^2$.

Samples for water quality of the Muvattupuzha River were collected from Ithipuzha, Murinjapuzha, Muvattupuzha, Palamkadavu, Piravom, Ramamangalam and Vettikkattumukku.

At Ithipuzha, chloride recorded a maximum value of 120 mg/L during the month of March. The high value may be because of the domestic effluents discharged into the river. Nitrate ranged between 0.01 & 1.16 mg/L. BOD at Ithipuzha was low except in June. It recorded a value of 1.2 mg/L, which may be because of the high load of organically decomposable wastes discharged into it. Total coliforms were found to be in excess of the prescribed limit at all the stations, recording values in the range of 200 to 6000 MPN/100 ml. At Murinjapuzha, the chloride concentration was found to be high (600 mg/L) during the Month of March. At Muvattupuzha, BOD was observed to be 2.1 mg/L during the month of May, whereas coliforms recorded a very high value of 6000 MPN/100ml. At Piravom nitrate-nitrogen was observed to be 5.5 mg/L during the month of January during which coliforms were also found to be high (5400 MPN/100ml). At Ramamangalam, coliform counts were in the range of 25 to 8000 MPN/100ml. All the stations in Muvattupuzha River were found to be contaminated with coliforms.

### 3.3.1.4 Meenachil River

This river has a length of 78 km with total drainage area of 1272 $km^2$. A few miles upstream of Kottayam town, Meenachil River bifurcates and the Neelimangalam branch flows northwards to join the Vembanad Lake through a series of criss-cross channels. The other branch after flowing in a westerlv direction for some distance turns sharply and takes a southerly course skirting the Kottayam town. This branch also drains into Vembanad Lake. The important towns of the basin are Poonjar, Palai, Ettumanoor and Kottayam.

Secondary data on water quality of the Meenachil river for the stations Chalakadavu, Cherpumkal, Erattupetta, Kadapattoor, Kidangoor, Lalam bridge, Nagambadam bridge, Neelimangalam bridge, Palai bridge, Poonjar bridge and Punnathara bridge indicated in general bacteriological pollution problem. Other physico-chemical parameters are found to be within the limits prescribed by CPCB for classification under the category "A". At Kidangoor, the total coliforms were reported to be 1600 MPN/100 ml and faecal coliforms were reported to be 500 MPN/100 ml in the month of December. All the water samples collected from Nagambadam, Nattasserry, Neelimangalam, Palai and Poonjar were found bacteriologically contaminated.

### 3.3.1.5 Manimala River

The length of the river is 90 km with a drainage area of 847 km$^2$. The river originates from Tatamala at an altitude of 1156 m above mean sea level (ms The river takes a southerly direction till Mundakayam and then it follows a wester course. It joins with the Pamba River at Neerettupuram. The river passes through the villages of Peruvanthanam, Mundakayam, Erumeli, Manimala, Kalluppara Kaviyoor and the Tiruvalla town.

In Manimala river basin the secondary data available only at the station (Thondara) did not show any water quality problem with respect to its physico-chemical characteristics. However, the river was observed to be bacteriologically contaminated with the total coliforms (max. 1600 MPN/100 ml) during the period of January.

### 3.3.1.6 Pamba River

Pamba River originates from the Western Ghats and drains into the Vembanad Lake through several distributaries. The total length of the river is 176 km and the drainage area is 4337 km$^2$.

Secondary data on water quality is available for the years 1994 and 1995 for the stations Chengannur, Edathua, Kochupamba, Kozhencherry, Maramon, Neerettupuram, Perinad, Pulikkeezhu, Pamba up, Pamba middle, Pamba down Ranni, Thakazhi and Vadasserikkara.

Further primary data has been collected from various locations at Triven, Nadappalam, Njunangar, Pamba upstream, Pamba middle and Pamba downstream. The stations for which primary data available are located near the Sabarimala Pilgrimage centre, one of the important places in the river basin. The results of analysis are summarized in **Table 3.3.1.4** for all the three sampling periods; twice during post-monsoon and once in pre-monsoon season.

At Thakazhi maximum concentration of chloride was 18.41 mg/L during the pre-monsoon period. Total nitrate and nitrite - nitrogen value of 4 712 mg/L were also observed at this station during the month of April. At Pamba down station higher concentration of nitrate-nitrite-nitrogen (max up to 813 mg L) was reported during the month of July. BOD values ranged up to 4.47 mg/L and the maximum value was observed at Pamba upstream near Sabarimala, however the values were within the permissible limits at all other stations. All the stations were found contaminated with coliforms with the values ranging from 240 to 46000 MPN/100 ml.

### 3.3.1.7 Achencoil River

Several small streams originating from the Pasukida, Mettu, Ramakkal Te and Rishi malai join together to form the Achencoil River. The river then splits into several smaller branches and the main branch flows in a northwester direction to join the Pamba River at Veeyapuram. The length of the river is 128 km with a drainage area of 1484 km$^2$.

Secondary data on water quality for the river Achencoil available for the stations at Chennithala and Thumbamon, was observed to be virgin in respect of the physico-chemical characteristics, however, biological contamination due to faecal coliforms was observed. At Chennithala a minimum value of faecal coliforms (13 MPN/100 ml) was observed during May and maximum (16000 MPN/100 ml) during January. Similarly at Thumbamon, minimum value (170 MPN/100 ml) was observed during May and maximum during (12500 MPN/100 ml) September.

**Classification and Zoning of Rivers**

Water quality objectives for freshwaters take into account several major usage to which water is put i.e. irrigation, drinking, industry, power generation, recreation and even for discharging wastewaters. All the water bodies or stretches are not necessarily required to meet all potential uses. This has led to the concept of classification and zoning of water bodies, based on which, the quality has to meet the requirement of one or more of the above potential uses termed as designated best use (DBU).

The rivers are classified depending upon the best designated usage of the water between A to E category as suggested by the CPCB. The water quality criteria of this classification for fresh waters scheme is given in **Table 3.3.1.5**.

Based on the analysis of secondary data provided by KSPCB, all the seven rivers in the study area fall under different categories of water usage at different stretches as shown in **Fig. 3.3.1.2**.

### 3.3.1.8 Water Quality of Irrigation Reservoirs in the Study Area

A study was taken up by CWRDM during 1985-87 to assess the water quality of the three irrigation reservoirs in the study area namely; Chalakkudy, Periyar Valley and Pamba. Before discussing the water quality status, the salient features of these reservoirs are discussed briefly. The basic data of each reservoir is given in **Table 3.3.1.6**.

*3.3.1.8.1 Chalakkudy Reservoir*

This scheme consists of a diversion weir across Chalakkudy River at Thumburmuzhi, to divert the water for irrigation purposes, regulators and main canals on the right and left banks with a network of distributaries and field bothics for irrigating lands in Ernakulam and Trichur district. This serves an ayacut of 11,495 ha of land. The weir site is situated nearly 16 km east of Chalakkudy town. The nearest railway station is Chalakkudy and the nearest airport is Cochin, which is 67 km away. The headworks is approachable by a good motorable road.

The weir is 185 m long and 3.66 m high. This will raise the water level in the river to divert the same into the two main canals on the right and left sides of the river. The weir is of gravity type and is constructed on rock. Several branch canals and distributaries serve the major portion of the ayacut. There are 18 branch canals from this main canal. Several distributaries are branching off from these branch canals. The total length of main canals, branches and distributaries under both stages is 313.35 km.

*3.3.1.8.2 Periyar Valley Reservoir*

An irrigation project has been proposed to afford irrigation facilities to 25167 ha of lands lying in Ernakulam District by the construction of a barrage across Periyar at Planchode and a suitable system of canals to feed the ayacut. With the implementation of Idamalayar scheme, it is possible to extend irrigation facilities to an additional ayacut of 6760 ha, thus, covering an area of 32377 ha lying on the left bank of Periyar.

The barrage is located across Periyar at Planchode about 11.25 Km from Kothamangalam town. There is good motorable approach road to this site from Kothamangalam. The barrage consists of 15 vents of which 3 nos. at centre are scouring vents each 9.15m long and others are of 12.19 m span. The nearest city is Cochin, which is 66 km away from headworks. The nearest airport is Cochin and railway station Alwaye that are 75 km and 50 km respectively from the headworks.

The main canal starts from headworks on the left bank and is 28.78 km long. The head regulator is located at 21103.12 m from the starting point. The canal system consists of the main canal with a number of branch canals. The crop pattern in the area (with the implementation of the project) will be of double crop (32377 ha) type.

*3.3.1.8.3 Pamba Reservoir*

The Pamba irrigation project aims at the utilization of the tailrace waters of the Sabarigiri Hydro-electric project for irrigation purposes in the valley. The net area benefited by the project is 19,800 ha and falls in the Pathanamthitta taluk of Pathanamthitta district and in the Chenganur, Thiruvalla, Mavelikkara and Karthikappally taluk of Alappuzha district.

The headworks of the project includes a barrage across Kakkad river, a tributary of the Pamba river at Maniar in Pathanamthitta district. The site is approachable by a road along the left bank starting from Pathanamthitta-Chittar road, 25 km from Pathanamthitta. The nearest city and airport is Trivandrum, 140 km away from the headworks. The nearest railway station is Chenganur, 48 km from the headworks.

The canal system of the project consists of a left bank main canal, taking off from the barrage site and running for 20 km length up to Kurudamannil, where it bifurcates into left bank canal and right bank canal. The RBC crosses the main river Pamba at Kurudamannil near Kozhencherry and flows for a length of 29 km and passes through Chengannur and Thiruvalla taluks of Alappuzha district. The LBC extends for a length of 46.6 km passing through Pathanamthitta and Chengannur, Mavelikkara and Karthigappally taluks.

### Water Quality Status of Reservoirs

Water quality status in pre-monsoon, monsoon, and post-monsoon periods during 1985-87 was assessed and the results are summarized in **Tables 3.3.1.7 to 3.3.1.9** respectively for Chalakkudy, Periyar and Pamba river reservoirs. Seasonal variation in water quality parameters in these reservoirs is summarized in **Fig. 3.3.1.3** and discussed below.

The constituents usually determined under irrigation water analyses are pH, electrical conductivity, total dissolved solids, sodium, sodium absorption ratio, boron content, cations like calcium, magnesium, potassium and anions like carbonate, bicarbonates, sulphates, chlorides, phosphates and nitrates. Tolerance limits of these constituents in irrigation water for use in different crops and soils are given in **Table 3.3.1.10.**

### Physico-chemical Parameters

Most crops tolerate a pH range of 4.5-8.5. Low pH may lead to toxicity by increased solubility of heavy metals. In all the seasons, the pH of the reservoir water varied between 6.2 & 7.6. The electrical conductivity was observed to be in the range of 5-43 $\mu$ mhos/cm. The carbonate/bicarbonate contents of these reservoirs are negligible. The low concentration indicates that there is no sodium hazard from the irrigation water for the crops. The chloride concentration is also very low (1.35-10.09 mg/L) in the reservoir water. The maximum concentration was observed in Chalakkudy reservoir and minimum in Periyar. Seasonal variation in phosphate and nitrate are very low. A maximum Phosphate value of 0.56 mg/L was recorded in the Periyar reservoir. The range of values observed for nitrate was 0.067-0.19 mg/L.

Low calcium/magnesium concentration was noted (below 5 mg/L) in all the reservoirs. The sodium content was observed to be in the range of 2 to 6 mg/L. In general, water from these reservoirs does not have any quality problems with respect to designated irrigation use.

Table 3.3.1.1

River-wise Details of Sampling Locations

| Rivers/Sampling Stations | Year of Sampling | Rivers/Sampling Stations | Year of Sampling |
|---|---|---|---|
| **A. Chalakkudy** | | 28. Cherpumkal | 1993 |
| 1. Athirapally | 1996 | 29. Erattupeta | 1993 |
| 2. Chalakkudy | 1996 | 30. kadapattoor | 1993 |
| 3. Kakkiyar | 1995 | 31. Kidangoor | 1993 |
| 4. Kanjirappara | 1996 | 32. Lalam Bridge | 1993 |
| 5. Palappuzhakadavu | 1996 | 33. Negambadam Bridge | 1993 |
| 6. Peringalkuthu | 1996 | 34. Neelimangalam Bridge | 1993 |
| 7. Pulikkalkadavu | 1996 | 35. Palai Bridge | 1993 |
| 8. Ventilappara | 1996 | 36. Poonjar Bridge | 1993 |
| **B. Periyar** | | 37. Punnathara Bridge | 1993 |
| 9. Alwaye | 1996 | **E. Manimala** | |
| 10. Alwaye minars | 1996 | 38. Thondara | 1992 |
| 11. Bhoothathankettu | 1996 | **F. Pamba** | |
| 12. Chowara | 1996 | 39. Chengannur | 1995 |
| 13. Eloor | 1996 | 40. Edathur | 1995 |
| 14. Kalady | 1996 | 41. Kochupamba | 1995 |
| 15. Kodanadu | 1996 | 42. Kozhencherry | 1995 |
| 16. Kuttikattukara | 1996 | 43. Maramon | 1995 |
| 17. Mangalapuzha | 1996 | 44. Neerettupuram | 1995 |
| 18. Marthandavarma Bridge | 1996 | 45. Perinadu | 1995 |
| 19. Neriyamangalam | 1996 | 46. Pulikkeezhu | 1995 |
| **C. Muvattupuzha** | | 47. Pamba Down | 1995 |
| 20. Ithipuzha | 1996 | 48. Pamba Middle | 1995 |
| 21. Murinjapuzha | 1996 | 49. Pamba Up | 1995 |
| 22. Muvattupuzha | 1996 | 50. Ranni | 1995 |
| 23. Palamkadavu | 1996 | 51. Thakazhi | 1995 |
| 24. Piravam | 1996 | 52. Vadasserikkara | 1995 |
| 25. Ramamangalam | 1996 | **G. Achencoil** | |
| 26. Vettikkattumukku | 1996 | 53. Chennithala | 1995 |
| **D. Meenachil** | | 54. Thumbamon | 1995 |
| 27. Chalakadavu | 1993 | | |

## Table 3.3.1.2

## River-wise and Station-wise Summary of River Water Quality Parameters

| River/Station | pH | Electrical Conductivity (µmol/cm) | Suspended Solids (mg/L) | DO (mg/L) | BOD (mg/L) | Chloride (mg/L) | $NO_3$-N + $NO_2$ (mg/L) | Total Coliform (MPN/100ml) |
|---|---|---|---|---|---|---|---|---|
| **A. Chalakkuddy** | | | | | | | | |
| 1. Athirapally | 7.0-7.4 | 3.2-13.3 | 3-20 | 6.8-7.9 | 0.2-0.7 | 6-24 | 0.18-1.0 | 500-2200 |
| 2. Chalakkudy | 5.9-6.9 | 3.8-7.8 | 4-35 | 6.4-8.1 | 0.2-0.8 | 6-16 | 0.061-1.26 | 450-2200 |
| 3. Kakkiyar | 6.5-7.1 | NA | 12-26 | 5.7-8.3 | 0.4-1.5 | 5-9 | 90-300 | 32-1200 |
| 4. Kanjirappara | 5.8-7.2 | 3.7-17.5 | 5-16 | 6.5-8.6 | 0.2-0.8 | 6-19 | 0.087-3.33 | 450-3200 |
| 5. Palappuzhakadavu | 6.3-7.4 | 6.4-27.2 | 4-35 | 6.1-8.0 | 0.2-0.9 | 12-59 | 0.027-2.55 | 25-2500 |
| 6. Peringalkuthu | 6.5-7.6 | 3.2-12.5 | 3-22 | 4.9-8.0 | 0.2-0.6 | 3-21 | 0.019-1.002 | 25-1700 |
| 7. Pulikkalkadavu | 6.6-7.4 | 11-206.5 | 3-32 | 6.6-8.1 | 0.3-0.8 | 13-59 | 0.29-0.995 | 550-2300 |
| 8. Ventilappara | 6.7-7.1 | 3.4-7.4 | 4-18 | 6.3-8.5 | 0.2-0.5 | 6-11 | 0.14-1.29 | 25-2800 |
| **B. Periyar** | | | | | | | | |
| 9. Alwaye | 3.8-8.9 | 62.9-1898 | NA | 4.5-8.1 | 0.3-1.0 | 12-590 | 0.66-2.30 | 110-2400 |
| 10. Alwaye minars | 6.7-7.4 | 4.8-74 | NA | 5.6-8.2 | 0.5-1.0 | 5-13 | 0.15-3.33 | 280-3000 |
| 11. Bhoothathankettu | 6.5-6.9 | 4.5-14.3 | 7-40 | 6.8-8.2 | 0.4-1.8 | 6-31 | 0.26-4.4 | 250-2500 |
| 12. Chowara | 6.5-7.8 | 2.4-13.2 | 4-48 | 6.2-8.3 | 0.2-2.0 | 7-800 | 0.21-1.44 | 50-1800 |
| 13. Eloor | 4.0-7.1 | 5.2-1340 | 4-50 | 5.2-8.2 | 0.1-2.0 | 7-800 | 0.21-1.44 | 50-1800 |
| 14. Kalady | 5.5-7.6 | 15.2-57.8 | 6-30 | 7.1-10.4 | 0.3-0.6 | 6-21 | 0.18-0.79 | 667-2200 |
| 15. Kodanadu | 6.3-7.3 | 3.0-23.5 | 3-22 | 2.4-8.1 | 0.2-0.7 | 5-22 | 0.151-5.28 | 250-1800 |
| 16. Kuttikattukara | 5.2-7.1 | 3.2-7.4 | 4-20 | 2.5-7.8 | 0.2-0.6 | 6-14 | 0.021-1.631 | 300-2000 |
| 17. Mangalapuzha | 6.5-7.3 | 2.5-11.8 | 3-38 | 6.7-8.0 | 0.2-1.0 | 6-13 | 0.13-3.12 | 500-2200 |
| 18. Marthandavarma Bridge | 5.1-7.3 | 2.9-64.7 | 6-32 | 5.4-8.1 | 0.2-0.9 | 6-70 | 0.23-2.15 | 600-2500 |
| 19. Neriyamangalam | 6.6-7.0 | 5.0-7.2 | 6-36 | 6.0-8.0 | 0.3-1.5 | 10-11 | 0.56-5.28 | 1000-1500 |
| **C. Muvattupuzha** | | | | | | | | |
| 20. Ithipuzha | 6.6-7.4 | 5.1-54.4 | 4-35 | 6.1-8.1 | 0.2-1.2 | 9-120 | 0.01-1.16 | 200-2800 |
| 21. Murinjapuzha | 6.4-7.5 | 5.1-210 | 4-20 | 6-7.9 | 0.2-0.7 | 5-600 | 0.43-2.1 | 200-2500 |
| 22. Muvattupuzha | 6.1-7.3 | 3.7-10.2 | 2-50 | 6.6-8.3 | 0.3-2.1 | 7-15 | 0.33-1.02 | 300-6000 |
| 23. Palamkadavu | 6.5-7.2 | 5.9-12.9 | 5-20 | 6.8-8.3 | 0.2-0.8 | 9-29 | 0.38-4.36 | 600-3000 |

**Contd...**

Table 3.3.1.2 Contd..

| River/Station | pH | Electric Conductivity (μmol/cm) | Suspended Solids (mg/L) | DO (mg/L) | BOD (mg/L) | Chloride (mg/L) | $NO_3$-N + $NO_2$ (mg/L) | Total Coliform (MPN/100ml) |
|---|---|---|---|---|---|---|---|---|
| 24. Piravam | 6.0-7.3 | 4.2-9.8 | 5.24 | 4.1-8.0 | 0.2-0.8 | 7-12 | 0.14-5.5 | 500-5400 |
| 25. Ramamangalam | 6.2-7.9 | 4.2-64.2 | 3-20 | 6.0-8.0 | 0.2-0.7 | 8-78 | 0.038-1.89 | 25-8000 |
| 26. Vettikkattumukku | 6.5-7.4 | 5.0-50.2 | 6-20 | 5.7-8.1 | 0.4-0.6 | 8-15 | 0.18-2.18 | 605-2200 |
| **D. Meenachil** | | | | | | | | |
| 27. Chalakadavu | 6.9-7.2 | 27 | 10-23 | 6.5-8.3 | ND-0.6 | 7-14 | 0.02-0.4 | 4-780 |
| 28. Cherpumkal | 6.9 | 34 | NA | 7.2 | ND | NA | 0.42 | 260 |
| 29. Erattupeta | 6.9-7.2 | NA | 13-20 | 6.6-7.8 | ND-0.5 | 10-12 | 0.08-0.41 | 4-440 |
| 30. kadapattoor | 7.0 | 32 | NA | 7.3 | 0 | NA | 0.45 | 80 |
| 31. Kidangoor | 5.8-7.4 | 7.4-135 | NA | 33-8.0 | 0.3-0.6 | 6-36 | 0.05-0.77 | 26-1600 |
| 32. Lalam Bridge | 6.9-7.3 | 35 | 16-23 | 6.5-8.0 | 0.4 | 8-22 | 0.12-0.38 | 120-360 |
| 33. Negambadam Bridge | 6.8-7.8 | 43 | 10-26 | 5.8-8.0 | 0.5-0.9 | 8-19 | 0.079-0.46 | 24-170 |
| 34. Neelimangalam Bridge | 6.9-7.6 | 42 | 12-27 | 5.8-7.3 | 0.4 | 9.28 | 0.10.48 | ND-130 |
| 35. Palai Bridge | 6.9-7.4 | NA | 12-25 | 66-8.2 | ND | 8-20 | 0.025-0.45 | 12-80 |
| 36. Poonjar Bridge | 6.9-7.1 | NA | 18-30 | 7.5-8.2 | 0.4-0.6 | 8-20 | 0.15-0.5 | 320-780 |
| 37. Punnathara Bridge | 6.9-7.6 | 51 | 7-25 | 5.7-7.5 | ND | 7-13 | 0.19-0.48 | 230-3200 |
| **E. Manimala** | | | | | | | | |
| 38. Thondara | 6.6-7.6 | 3.1-15.1 | NA | 5.8-8.7 | 0.3-0.8 | 6-24 | 0.13-1.4 | 50-1600 |
| **F. Pamba** | | | | | | | | |
| 39. Chengannur | 6.9-7.4 | 3.6-6.0 | 9-22 | 5-8.05 | 0.2-0.5 | 8-11 | 0.22-83.55 | 123-14250 |
| 40. Edathur | 6.7-7.8 | NA | 9-28 | NA | 0.4-0.6 | 7-13 | 125-250 | 100-1520 |
| 41. Kochupamba | 6.7-7.0 | NA | 10-25 | 5.8-8.5 | 0.3-1.5 | 6-9 | 40-250 | 8-1100 |
| 42. Kozhencherry | 6.9-7.7 | NA | 11-25 | 5.4-8.4 | 0.2-1.0 | 7-9 | 75-125 | 64-4000 |
| 43. Maramon | 6.8-7.1 | NA | 10-25 | 6.8-7.47 | 0.4-1.0 | 6-9 | 75-100 | 20-6800 |
| 44. Neerettupuram | 6.8-7.3 | NA | 8-20 | 5.5-7.6 | 0-0.6 | 7-12 | 100-250 | 64-360 |
| 45. Perinadu | 6.8-7.5 | NA | 10-25 | 4.9-8.4 | 0.4-1.5 | 6-11 | 50-187 | 50-1700 |
| 46. Pulikkeezhu | 6.8-7.3 | NA | 8-25 | 5.3-8.3 | 0.3-0.6 | 7-11 | 90-251 | 32-1400 |
| 47. Pamba Down | 6.5-7.1 | NA | 8-30 | 6.3-9 | 0.3-1.2 | 5-56 | 90-197 | 10-2400 |
| 48. Pamba Middle | 6.8-7.2 | NA | 10-25 | 5.4-8.1 | 0.3-2 | 6-10 | 40-187 | 60-6400 |

Contd...

**Table 3.3.1.2 Contd...**

| River /Station | pH | Electric Conductivity (μmol/cm) | Suspended Solids (mg/L) | DO (mg/L) | BOD (mg/L) | Chloride (mg/L) | $NO_3$-N + $NO_2$ (mg/L) | Total Coliform (MPN/100ml) |
|---|---|---|---|---|---|---|---|---|
| 49. Pamba up | 6.7-7.2 | NA | 8-32 | 4.8-8.9 | 0.3-2.5 | 6-10 | 50-200 | 10-1600 |
| 50. Ranni | 6.8-7.6 | NA | 9-18 | 6.6-8.8 | 0.2-1.2 | 6-10 | 100-375 | 124-20000 |
| 51. Thakazhi | 6.8-7.6 | 3.2-100 | 10-25 | 4.75-13.9 | 0.2-0.6 | 7-94 | 0.23-112.68 | 140-4800 |
| 52. Vadasserikkara | 6.5-7.3 | NA | 9-22 | 6.2-8.9 | 0.3-0.6 | 6-11 | 100-250 | 40-650 |
| **G. Achencoil** | | | | | | | | |
| 53. Chennithala | 6.8-7.7 | 4.0-9.0 | NA | 6.0-8.4 | 0.4-0.6 | 8-15 | 0.14-0.78 | 150-16000 |
| 54. Thumbamon | 7.0-7.8 | 3-9 | NA | 5.6-8.3 | 0.3-0.6 | 7-14 | 0.13-0.74 | 170-12500 |

**Source :** Secondary data from KSPCB/CWRDM

## Table 3.3.1.3

## Water Quality Characteristics of Periyar River

| Parameters | Monsoon (10-8-1999) | Post-Monsoon (25-11-1999) | Pre-Monsoon (3-3-2000) | Pre-Monsoon (26-5-2000) |
|---|---|---|---|---|
| Temperature | 26.5-28.0 | 28-30 | NA | 31 |
| pH | 6.6-6.9 | 6.5-7.0 | 6.6-6.8 | 3.4-5.6 |
| Electrical Conductivity | 30.7-91.1 | 36.1-95.9 | 49.6-58.2 | 147-1461 |
| DO | 6.87-7.60 | 6.47-7.6 | NA | 4.87-6.73 |
| BOD | 0.003-1.670 | 1.05-2.93 | NA | 0.87-3.53 |
| $NO_2$-N | 0.002-0.015 | 0.035-0.397 | NA | NA |
| $NO_3$-N | 0.26-2.26 | 0.01-1.41 | 0.87-5.35 | 0.2-11.9 |
| Organic Nitrogen | 0.13-1.26 | | NA | NA |
| Total Hardness | 10-18 | 12-22 | 10-14 | 26-144 |
| Sodium | 2.0-8.0 | 2-10.4 | NA | 7.6-224 |
| Potassium | 0.1-0.6 | 0.2-0.6- | NA | 3-16.5 |
| Sulphates | 0.8-3.6 | 6-16 | 3.2-6.4 | 6-64.8 |
| Total Alkalinity | 8-12 | 8-12 | NA | 4-12 |
| Copper | 0.01-0.05 | 0.01-0.08 | NA | NA |
| Manganese | 0.04- | 0.04 | NA | NA |
| Zinc | 0.05- | 0.07 | NA | NA |
| Organic Phosphate | 0.01-0.16 | | NA | NA |
| Total coliforms | <3-7500 | <3-1100 | NA | NA |
| Calcium | NA | NA | 1.6-3.2 | 6.4-19.2 |
| Magnesium | NA | NA | 0.97-1.94 | 1.46-16.53 |
| Chloride | NA | NA | 8.72-9.69 | 34-480 |
| Iron | NA | NA | 0.01-0.03 | 0-0.22 |

All parameters are in mg/L except Temperature, pH, Electrical conductivity (μS/cm) and Coliforms (MPN/100ml).
**Source** : Primary data from KSPCB/CWRDM (1999-2000)

Table 3.3.1.4

Water Quality Characteristics of Pamba River

| Parameters | Post-Monsoon (26-11-1999) | Post-Monsoon (23-12-1999) | Pre-Monsoon (14-3-2000) |
|---|---|---|---|
| Temperature | 23-25 | 21-26 | 33-35 |
| pH | 6.86-7.32 | 6.27-7.13 | 6.75-7.26 |
| Electrical Conductivity | 32.1-36.5 | 24.8-149.1 | 59.8-164.3 |
| DO | 7.53-7.93 | 2.9-8.33 | 6.07-7.33 |
| BOD | 0.13-1.73 | 0.54-4.47 | 1.93-2.8 |
| $NO_2$-N | ND | 0.004-0.114 | 0.005-0.038 |
| $NO_3$-N | 0.44-1.28 | 0.16-1.13 | 0.58-4.71 |
| $NH_4$-N | 0.004 | 0.002-0.019 | 0.002-0.014 |
| $PO_4$-P | 0.01 | ND | 0.02-0.03 |
| Chloride | 2 | 2-22 | 6.78-18.41 |
| Fluoride | ND | ND | 0.06-0.44 |
| Total Hardness | 12-16 | 8-30 | 16-24 |
| Calcium | 2.4-3.2 | 1.6-5.6 | 2.4-3.2 |
| Magnesium | 0.972-1.944 | 0.49-3.89 | 1.46-3.4 |
| Sulphate | 6-8 | ND | 0.4-2.4 |
| Total Alkalinity | 14-16 | 10-36 | 22-32 |
| Sodium | 1.2-2.4 | 0.8-12 | 0.4-14.8 |
| Potassium | 0.1 | 0.1-4.2 | 0.6-4.2 |
| Iron | 0.01-0.06 | 0.03-0.81 | 0.02-0.33 |
| Copper | 0.01-0.05 | 0.01-0.09 | 0.02-0.05 |
| Total Coliforms | 1100-46000 | 240-9300 | 240-46000 |

All parameters are in mg/L except Temp, pH, Electrical Conductivity (μS/cm) and Coliforms (MPN/100 ml)

**Source :** Primary data from KSPCB/CWRDM (1999-2000)

## Table 3.3.1.5

## Classification of Inland Surface Water (CPCB Standards)

| Sr. No. | Characteristics | Classification | | | | |
|---|---|---|---|---|---|---|
| | | A | B | C | D | E |
| 1 | Dissolved Oxygen, mg/l, min | 6 | 5 | 4 | 4 | - |
| 2 | BOD, mg/l, max | 2 | 3 | 3 | - | - |
| 3 | Total Coliforms,* MPN/100 ml, max | 50 | 500 | 5000 | - | - |
| 4 | Total Dissolved Solides, mg/l, max | 500 | - | 1500 | - | 2100 |
| 5 | Chlorides (as Cl), mg/l, max | 250 | - | 600 | - | 600 |
| 6 | Colour, Hazen units, max | 10 | 300 | 300 | - | - |
| 7 | Sodium Absorption Ratio, max | - | - | - | - | 26 |
| 8 | Boron (as B), mg/l, max | - | - | - | - | 2 |
| 9 | Sulphates (as $SO_4$), mg/l, max | 400 | - | 400 | - | 1000 |
| 10 | Nitrates (as $NO_3$), mg/l, max | 20 | - | 50 | - | - |
| 11 | Free Ammonia (as N), mg/l, max | - | - | - | - | 1.2 |
| 12 | Conductivity at $25^0$C, micromhos/cm, max | - | - | - | 1000 | 2250 |
| 13 | pH value | 6.5-8.5 | 6.5-8.5 | 6.5-8.5 | 6.5-8.5 | 6-8 |
| 14 | Arsenic (as As), mg/l, max | 0.05 | 0.2 | 0.2 | - | - |
| 15 | Iron (as Fe), mg/l, max | 0.3 | - | 50 | - | - |
| 16 | Fluorides (as F), mg/l, max | 1.5 | 1.5 | 1.5 | - | - |
| 17 | Lead (as Pb), mg/l, max | 0.1 | - | 0.1 | - | - |
| 18 | Copper (as Cu), mg/l, max | 1.5 | - | 1.5 | - | - |
| 19 | Zinc (as Zn), mg/l, max | 15.0 | - | 15.0 | - | - |

* If the coliform count is found to be more than the prescribed tolerance limits, the criteria for coliforms shall be satisfied if not more than 20 percent of samples show more than the tolerance limits specified, and not more than 5 percent of samples show values more than 4 times the tolerance limits. Further, the fecal coliform should not be more than 20 percent of the coliform

**Classification**
A - Drinking water source without conventional treatment but after disinfection
B - Outdoor bathing (organised)
C - Drinking water source with conventional treatment followed by disinfection
D - Propogation of Wildlife, Fisheries
E - Irrigation, Industrial cooling, controlled waste disposal

**Source** : Indian standard (IS :229 - 1982)

## Table 3.3.1.6

## Basic Data of Various Irrigation Reservoirs

| Particular | Chalakkudi | Periyar | Pamba (Kakkad) |
|---|---|---|---|
| Nearest City | Chalakudi | Cochin | Pathanamthitta |
| District | Thrissur | Ernakulam | Pathanamthitta |
| Longitude | $76^0$ 26' E | $76^0$ 15' E | $76^0$ 53' E |
| Latitude | $10^0$ 10' N | $10^0$ 10' N | $9^0$ 20' N |
| Type of Structure | Weir | Barrage | Barrage |
| Catchment Area | 313 $km^2$ | 3048 $km^2$ | 280 $km^2$ |
| Length of barrage/weir | 185 m | 210 m | 115 m |
| Max height of barrage/weir | 366 m | 20.73 m | 16.76 m |
| Length of distribution and field bothics | - | 427 km | 1020 km |
| Purpose | Irrigation | Irrigation | Irrigation |
| Ayacut: Net | 11495 | 32377 ha | 19800 ha |
| Gross | | 64754 ha | 46000 ha |

## Table 3.3.1.7

## Water Quality Status - Chalakkudy Reservoir

| Parameter | Pre-Monsoon | | | Monsoon | | | Post-Monsoon | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1985 | 1986 | 1987 | 1985 | 1986 | 1987 | 1985 | 1986 | 1987 |
| Temperature, ° C | 28 | 27 | 28 | 24.5 | 25 | 25 | 27 | 26 | 27 |
| Density, g/ml | 0.994 | 0.995 | 0.995 | 0.995 | 0.995 | 0.995 | 0.994 | 0.994 | 0.995 |
| pH | 7.3 | 7.5 | 7.4 | 6.9 | 6.8 | 6.9 | 7.1 | 7.2 | 7.2 |
| pHc | 8.6 | 8.4 | 8.4 | 8.2 | 7.8 | 8.0 | 8.3 | 8.1 | 8.3 |
| Electrical Conductivity, µmhos/cm | 36 | 37.1 | 36.45 | 29.7 | 24.00 | 26.45 | 31.2 | 34 | 32.73 |
| Total Dissolved Solids, mg/l | 28.4 | 27 | 31.3 | 23.0 | 21.2 | 21.9 | 24.2 | 21.9 | 24.2 |
| Chloride, mg/l | 9.92 | 9.05 | 10.09 | 5.72 | 4.95 | 5.25 | 7.99 | 8.52 | 6.89 |
| Sulphate, mg/l | 1.30 | 1.12 | 0.80 | 0.50 | 0.37 | 0.60 | 0.80 | 0.55 | 0.75 |
| Carbonate/Bicarbonate, mg/l | 8.23 | 9.89 | 11.73 | 3.47 | 5.03 | 6.30 | 6.10 | 7.65 | 9.10 |
| Phosphate-P, mg/l | 0.16 | 0.14 | 0.07 | 0.08 | 0.03 | 0.068 | 0.15 | 0.06 | 0.16 |
| Nitrate-N, mg/l | 0.14 | 0.044 | 0.13 | 0.09 | 0.057 | 0.029 | 0.33 | 0.061 | 0.05 |
| Fluoride, mg/l | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.03 | 0.03 | 0.01 | 0.01 |
| Sodium, mg/l | 3.50 | 3.57 | 4.0 | 2.50 | 1.87 | 2.18 | 3.0 | 2.35 | 3.5 |
| Potassium, mg/l | 0.90 | 0.90 | 0.85 | 0.50 | 0.45 | 0.45 | 0.90 | 0.80 | 0.70 |
| Calcium/ Magnesium, mg/l | 7.24 | 9.69 | 5.84 | 4.32 | 5.51 | 4.82 | 6.78 | 7.75 | 6.30 |
| Iron, mg/l | 0.54 | 0.19 | 0.17 | 0.29 | 0.32 | 0.17 | 0.51 | 0.14 | 0.16 |
| Manganese, mg/l | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Aluminium, mg/l | 0.005 | 0.01 | 0.095 | 0.01 | 0.01 | 0.01 | 0.01 | 0.005 | 0.01 |
| Zinc, mg/l | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |
| Copper, mg/l | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Organic matter, % | $0.4 \times 10^{-4}$ | $0.4 \times 10^{-4}$ | $0.2 \times 10^{-4}$ | $0.9 \times 10^{-4}$ | $0.5 \times 10^{-4}$ | $0.9 \times 10^{-4}$ | $0.5 \times 10^{-4}$ | $0.9 \times 10^{-4}$ | $0.2 \times 10^{-4}$ |

**Source :** Secondary data collected by CWRDM

## Table 3.3.1.8

## Water Quality Status- Periyar Reservoir

| Parameter | Pre-Monsoon | | | Monsoon | | | Post-Monsoon | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1985 | 1986 | 1987 | 1985 | 1986 | 1987 | 1985 | 1986 | 1987 |
| Temperature, ° C | 28 | 29 | 30 | 24.5 | 25.0 | 26.0 | 27 | 27 | 28 |
| Density, g/ml | 0.995 | 0.995 | 0.995 | 0.993 | 0.994 | 0.994 | 0.995 | 0.995 | 0.995 |
| pH | 7.2 | 7.0 | 7.1 | 6.6 | 6.7 | 6.7 | 6.9 | 6.9 | 6.9 |
| pHc | 8.2 | 8.1 | 8.2 | 8.3 | 8.1 | 8.2 | 7.9 | 8.2 | 8.0 |
| Electrical Conductivity, μmhos/cm | 41.7 | 41.5 | 44.0 | 32.6 | 32.4 | 28.2 | 37.6 | 36 | 34.4 |
| Total Dissolved Solids, mg/l | 35.02 | 33.28 | 31.8 | 24.5 | 23.8 | 16.0 | 31.4 | 30 | 22.3 |
| Chloride, mg/l | 2.10 | 2.14 | 1.97 | 1.41 | 1.19 | 1.09 | 1.85 | 1.77 | 1.34 |
| Sulphate, mg/l | 0.50 | 0.40 | 0.50 | 0.37 | 0.30 | 0.32 | 0.40 | 0.68 | 0.57 |
| Carbonate/Bicarbonate, mg/l | 5.39 | 3.70 | 4.01 | 3.74 | 2.21 | 2.99 | 5.65 | 44.35 | 3.40 |
| Phosphate-P, mg/l | 0.12 | 0.17 | 0.15 | 0.17 | 0.21 | 0.22 | 0.10 | 0.22 | 0.26 |
| Nitrate-N, mg/l | 0.05 | 0.06 | 0.08 | 0.22 | 0.32 | 0.19 | 0.25 | 0.10 | 0.10 |
| Fluoride, mg/l | 0.03 | 0.03 | 0.03 | 0.03 | 0.07 | 0.02 | 0.03 | 0.05 | 0.04 |
| Sodium, mg/l | 3.0 | 4.0 | 5.1 | 1.50 | 1.80 | 3.50 | 2.5 | 2.45 | 4.1 |
| Potassium, mg/l | 0.909 | 1.20 | 1.10 | 0.35 | 0.40 | 1.05 | 0.42 | 0.7 | 1.21 |
| Calcium/ Magnesium, mg/l | 6.53 | 6.90 | 5.87 | 3.10 | 2.57 | 2.08 | 4.71 | 4.88 | 3.66 |
| Iron, mg/l | 0.9 | 0.81 | 0.40 | 0.25 | 0.24 | 0.32 | 0.15 | 0.28 | 0.26 |
| Manganese, mg/l | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.005 | 0.02 | 0.01 | 0.005 |
| Aluminium, mg/l | 0.07 | 0.05 | 0.02 | 0.01 | 0.01 | 0.01 | 0.08 | 0.06 | 0.003 |
| Zinc, mg/l | 0.01 | 0.01 | 0.01 | 0.001 | 0.001 | 0.001 | 0.01 | 0.01 | 0.01 |
| Copper, mg/l | 0.001 | 0.001 | 0.001 | 0.09 | 0.08 | 0.04 | 0.001 | 0.001 | 0.001 |
| Organic matter, % | $1.1x10^{-4}$ | $1.0x10^{-4}$ | $1.0x10^{-4}$ | $1.2x10^{-4}$ | $1.4x10^{-4}$ | $1.2x10^{-4}$ | $1.3x10^{-4}$ | $1.3x10^{-4}$ | $1.3x10^{-4}$ |

**Source :** Secondary data collected by CWRDM

## Table 3.3.1.9

### Water Quality Status - Pamba Reservoir

| Parameter | Pre-Monsoon | | | Monsoon | | | Post-Monsoon | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1985 | 1986 | 1987 | 1985 | 1986 | 1987 | 1985 | 1986 | 1987 |
| Temperature, ° C | 30 | 30 | 30 | 25 | 25 | 25 | 28 | 27.5 | 28 |
| Density, g/ml | 0.996 | 0.996 | 0.995 | 0.994 | 0.995 | 0.995 | 0.995 | 0.994 | 0.994 |
| pH | 7.3 | 7.3 | 7.2 | 6.6 | 6.8 | 6.8 | 6.9 | 6.8 | 6.9 |
| pHc | 8.5 | 8.4 | 8.4 | 7.6 | 8.1 | 7.8 | 7.8 | 7.6 | 8.0 |
| Electrical Conductivity, μmhos/cm | 29.7 | 29.8 | 29.5 | 19.0 | 21.5 | 22.70 | 24.15 | 23.5 | 24.5 |
| Total Dissolved Solids, mg/l | 22 | 20 | 18.6 | 15.38 | 12.7 | 11.05 | 19.0 | 13.65 | 14.3 |
| Chloride, mg/l | 1.99 | 2.10 | 2.05 | 1.11 | 1.09 | 1.36 | 1.55 | 1.43 | 1.58 |
| Sulphate, mg/l | 1.0 | 1.05 | 1.10 | 0.47 | 0.50 | 0.50 | 0.75 | 0.80 | 0.95 |
| Carbonate/Bicarbonate, mg/l | 4.68 | 5.22 | 6.21 | 2.39 | 2.25 | 2.16 | 3.41 | 3.92 | 4.30 |
| Phosphate-P, mg/l | 0.06 | 0.05 | 0.05 | 0.05 | 0.05 | 0.035 | 0.07 | 0.06 | 0.05 |
| Nitrate-N, mg/l | 0.05 | 0.02 | 0.01 | 0.08 | 0.04 | 0.08 | 0.10 | 0.05 | 0.06 |
| Fluoride, mg/l | 0.025 | 0.015 | 0.01 | 0.02 | 0.02 | 0.015 | 0.03 | 0.02 | 0.015 |
| Sodium, mg/l | 2.00 | 2.05 | 2.0 | 1.00 | 1.00 | 1.00 | 1.25 | 1.50 | 1.25 |
| Potassium, mg/l | 0.60 | 0.80 | 0.60 | 0.400 | 0.50 | 0.35 | 0.50 | 0.70 | 0.50 |
| Calcium/ Magnesium, mg/l | 4.80 | 3.18 | 3.76 | 1.389 | 2.86 | 1.67 | 3.90 | 2.77 | 2.57 |
| Iron, mg/l | 0.75 | 0.75 | 0.64 | 0.44 | 0.62 | 0.24 | 0.75 | 0.57 | 0.37 |
| Manganese, mg/l | 0.015 | 0.005 | 0.005 | 0.01 | 0.005 | 0.002 | 0.005 | 0.003 | 0.001 |
| Aluminium, mg/l | 0.01 | 0.01 | 0.02 | 0.02 | 0.03 | 0.04 | 0.03 | 0.02 | 0.01 |
| Zinc, mg/l | 0.005 | 0.004 | 0.01 | 0.005 | 0.01 | 0.007 | 0.005 | 0.005 | 0.01 |
| Copper, mg/l | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Organic matter, % | $1.0x10^{-4}$ | $1.0x10^{-4}$ | $1.1x10^{-4}$ | $1.5x10^{-4}$ | $1.4x10^{-4}$ | $1.5x10^{-4}$ | $1.3x10^{-4}$ | $1.2x10^{-4}$ | $1.2x10^{-4}$ |

**Source** : Secondary data collected by CWRDM

## Table 3.3.1.10

### Tolerance Limits of Water Quality Parameters for Irrigation

| Sr. No. | Parameters | No Problem | Increasing Problem | Severe Problem |
|---|---|---|---|---|
| 1 | pH | 5.5 - 6.5 | 7.5 - 8 | > 8 |
| 2 | Salinity as Electrical conductivity, millimhos/cm | < 0.75 | 0.75 - 3.00 | > 3 |
| 3 | Permeability as electrical conductivity, mhos/cm | > 0.5 | 0.5 - 2 | < 0.2 |
| 4 | Sodium Absorption Ratio | | | |
| | a. Montmorrillonite | < 6.0 | 6 - 9 | > 9 |
| | b. Lallite – Vermiculite | < 8.0 | 8 - 6 | > 16 |
| | c. Kaolinite – Sesquioxide | < 16 | 16 - 24 | > 24 |
| 5 | Specific ion toxicity | | | |
| | a. Sodium as SAR | < 3 | 3 - 9 | > 9 |
| | b. Chloride meq/l | < 4 | 4 - 10 | > 10 |
| | c. Bicarbonate meq/l | < 1.5 | 1.5 - 8.5 | > 8.5 |
| | d. Boron meq/l | 0.75 | 0.75 | > 2.0 |

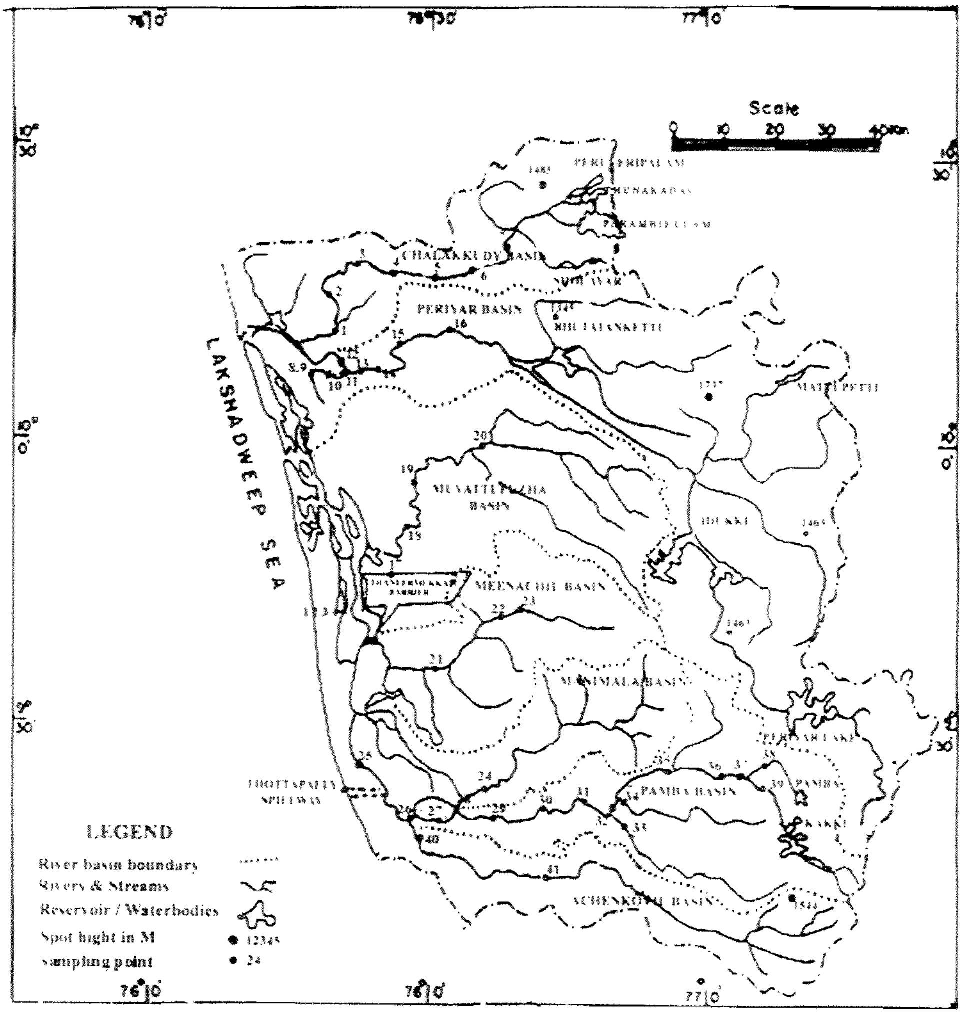



Fig. 3.3.1.1 : Surface Water Sampling Locations

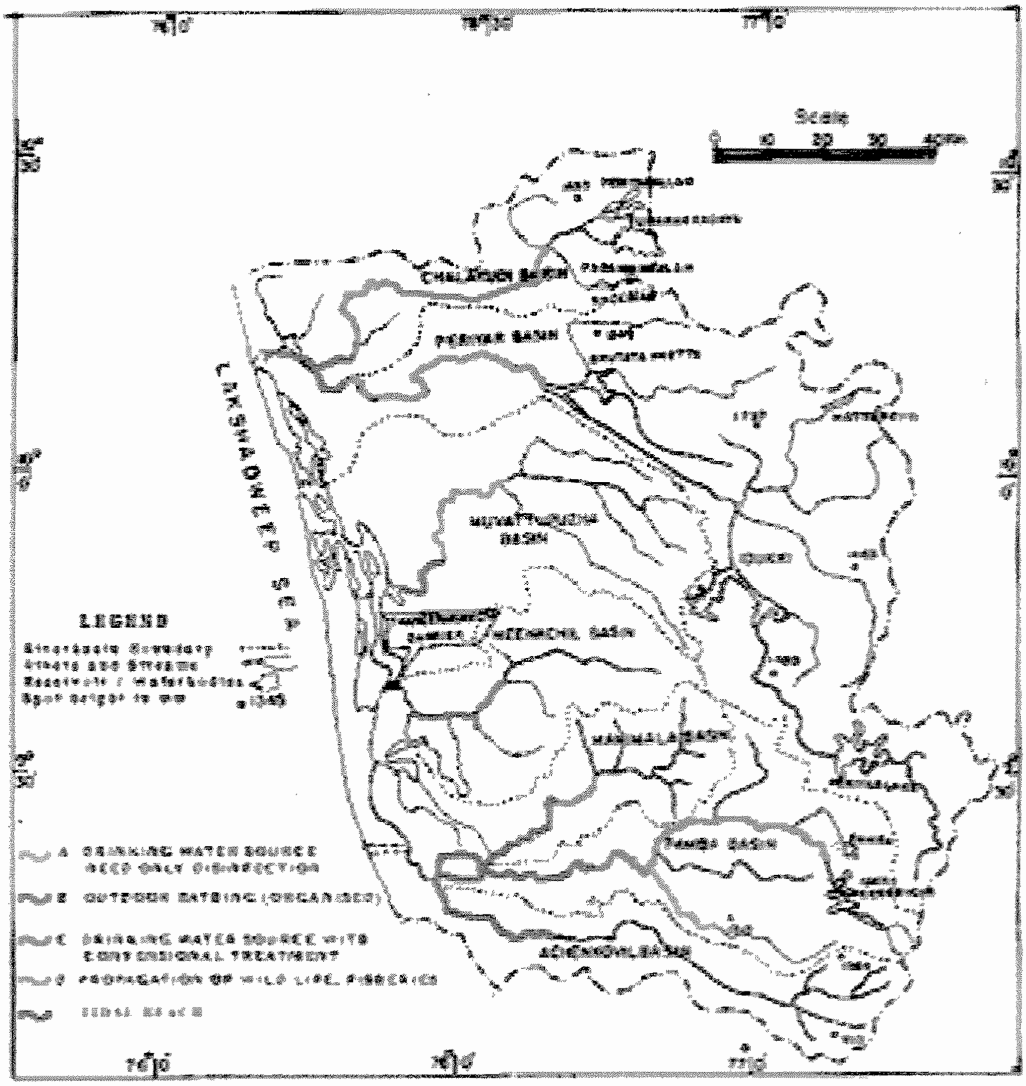



Fig. 3.3.1.2 : Classification of Water Bodies Based on Designated Use

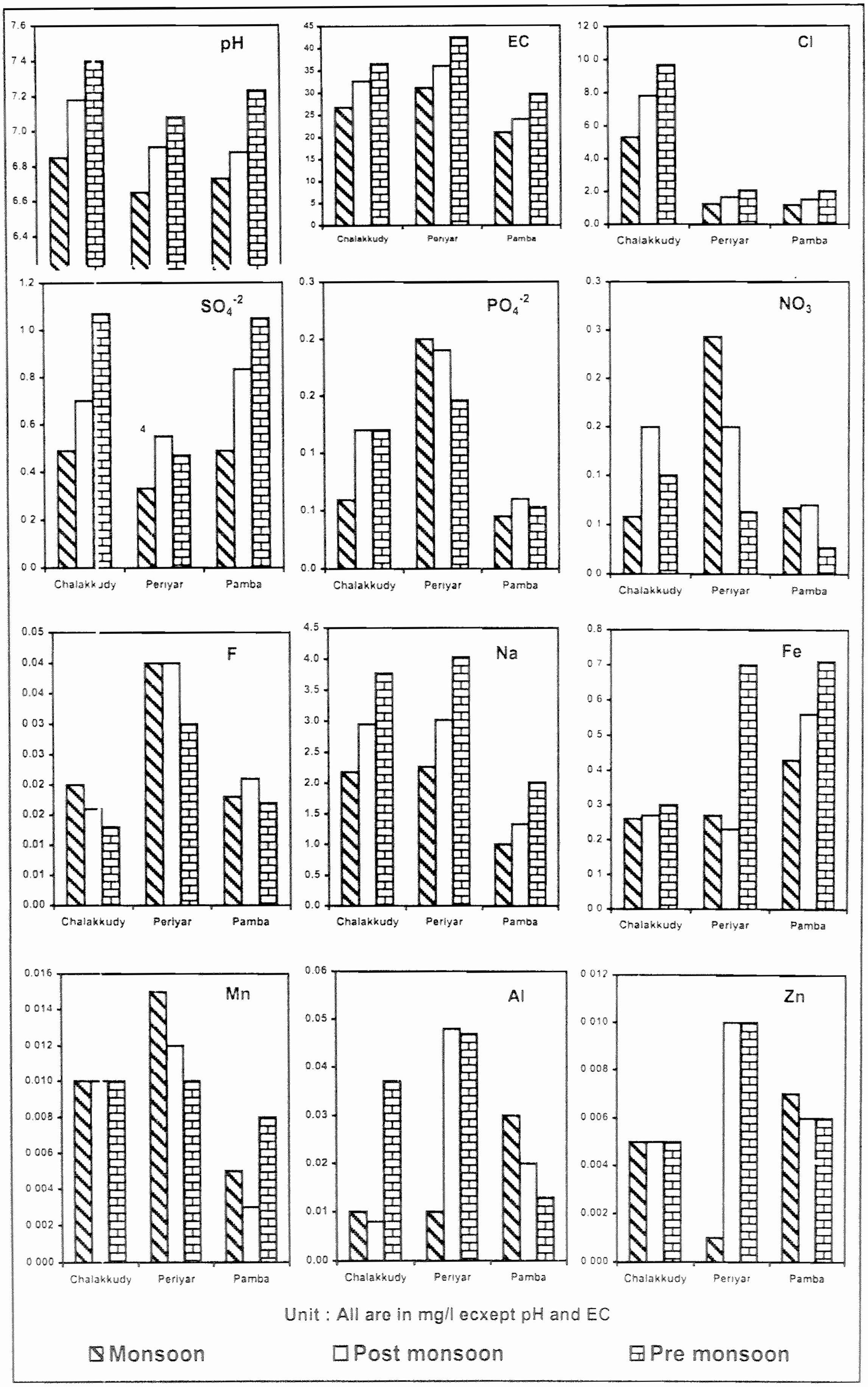



Fig. 3.3.1.3 : Seasonal Variation of Quality Parameters in Various Reservoirs

### 3.3.2 Ground Water

The groundwater quality problems in the study region are mainly associated with natural processes, which occur mainly due to the leaching of salts from the aquifer material. The other type of quality problem like bacteriological pollution, which is found in more than 90% of the open wells is due to the anthroprogenic activities. The discharge of untreated sewage and solid waste is also contributing to the pollution of groundwater.

The other water quality problems are associated with Iron, (which is of minerological origin especially in the laterite regions of the State), Chloride and low pH. The salinity problems are noticed in the shallow aquifers of the coastal wells because of he salinity intrusion. The low pH may be associated with acidic soils in the respective sampling locations.

The groundwater pollution due to industrial effluents is noticed in Alwaye, Eloor area and eastern parts of Cochin. The pollution problems were observed, especially in the laterite soil, up to a distance of about 250-300 m from the industrial area. The problems were mainly associated with fluoride, acidity and trace metals. Some of the wells, which were found to be affected in Cochin-Ambalamedu area, were found to be filled due to land reclamation processes.

Localized problem of fluoride is seen in the tube wells of Alappuzha town in the deeper aquifers tapping Warkali formations. An increasing trend of fluoride is noted from Kayamkulam to Alappuzha north (from 0.3 to 2.6 mg/L). In the Warkali formation, the aquifer changes from calcium bicarbonate type and to sodium bicarbonate type towards the north. Alappuzha town has an increasing concentration of fluoride because of the fact that alkaline waters seen in these areas are more effective in releasing fluoride. The domestic pollution of the open wells is mainly because of the fecal matter from birds and animals, kitchen waste and practice of using bucket and rope for drawing water.

Water samples were collected in three seasons-pre-monsoon-98, post-monsoon-98 and pre-monsoon-99 and were analyzed for physicochemical and bacteriological parameters. The number of samples collected in each season from different locations is given in **Table 3.3.2.1.** The locations of sampling points are shown in **Fig 3.3.2.1.** The detailed groundwater quality with respect to various physico-chemical parameters for pre-monsoon-98, post-monsoon-98 and pre-monsoon-99 are given in **Table 3.3.2.2,** whereas nutrients and trace metals are given in **Table 3.3.2.3**. The ground water quality status in different districts is discussed here.

#### 3.3.2.1 Alappuzha District

A total number of 98 water samples were collected from various parts of Alappuzha district, out of which bacteriological analysis of 59 samples was done.

**Alappuzha** : Most of the samples have high EC (310 to 887 µS/cm) and coliforms. Of the samples collected during post-monsoon-98, sample from a public tap has high alkalinity (200 to 236 mg/L) and samples from a bore well and open wells of Chandanakavu and Thiruvambadi have high Iron content in the range of 0.3 to 1.15 mg/L. Tap water samples have fluoride content up to 1.67 mg/L.

**Aroor** : Samples close to ice plants and food product factories have high EC (88 to 5140 μS/cm). Samples close to Arookutty Ferry have very high EC (up to 5140 μS/cm), high alkalinity, and high chloride content and high hardness. Sample collected from a hand pipe near Veterinary hospital has very low pH (4.47). Samples collected from bore wells have high fluoride content up to 1.45 mg/L. Samples collected from locations close to food product factories have high coliforms up to 1100 MPN/100 ml.

**Alappuzha Kerala Water Authority :** Water samples were collected during pre-monsoon-99 from Kerala Water Authority tube wells in Alappuzha town. All samples have high EC (466 to 1750 μS/cm), high fluoride content (1.25 to 1.82 mg/L) and high alkalinity (220-290 mg/L). Sample collected from Chandanakavu contains high Chlorides (330 mg/L) and one sample from Vadikad North has high Coliforms (150 MPN/100 ml).

**Kuttanad** : The water quality problem in Kuttanad is mainly because of the presence of high coliforms.

**Punnapra Milk Plant Area :** Sample collected from a bore well have high EC (75 μS/cm), fluoride (1.28 μS/cm), chloride (280 mg/L) and coliforms (681 MPN/100 ml). Sample collected from an open well has an iron content of 0.62 mg/L, EC (240 μS/cm) and coliforms (300 MPN/100 ml).

### 3.3.2.2 Ernakulam District

In total 145 samples were collected from different places in Ernakulam district, out of this bacteriological analysis was done for 68 samples.

**Alwaye** : Sample collected from a well at Keezhmadu Panchayat have high coliforms (93 MPN/100 ml).

**Industrial Area (Kalamassery/Eloor)** : The samples were collected from Aluva-Eloor area during pre-monsoon-99. The samples collected from locations very near to industries have high EC in the range of 45.8 to 2890 μS/cm. Samples collected from open wells near Cochin Crop Mill, Kalamassery have low pH (<5.0). Open well near IRE has low pH (3.78), and high EC (2890 μS/cm), chloride (1100 mg/L) fluoride content (4.2 mg/L). One of the samples collected near FACT has high hardness (366) and fluoride content (1.43 mg/L). A sample collected from a well near IRE has high chloride content (460 mg/L). One sample from Eloor east has high fluoride content (1.52 μS/cm). Samples from Eloor have high coliforms beyond 2400 MPN/100 ml.

**Ernakulam** : One sample from Ernakulam town has high pH (8.92) [Southern Investments, Cannonshed Road]. All samples in Ernakulam town area have high EC (326-1882 μS/cm).

Three samples collected during post-monsoon from Ernakulam town have high alkalinity (250-326 mg/L). The same samples also have high hardness, chloride and calcium contents. Samples collected during pre and post monsoon-98 from Vytila, Irimbanam and Ernakulam town have high coliform content ($\geq$2400 MPN/100 ml). Three open well samples collected during pre-monsoon-99 from Ernakulam town have high coliform content (up to 11,000 MPN/100 ml).

**Perumbavoor** : Three open well samples (Pulluvazhi, Palakkottuthazham & Angamali road) from Perumbavoor town have low pH (<5.0) and four samples have high Iron content in post-monsoon-98. The iron content in a bore well at Malamuri is 13.2 mg/L and an open well at Kanjirakadavu has 4.96 mg/L irons. Open wells near burial ground at Kochi have high EC and calcium and one sample has high total alkalinity. Samples from an open well and a tube well close to the Govt. Maharajas Hospital, Karivelippady, Ernakulam have high EC (1564 & 2638 $\mu$S/cm), total hardness (350, 414 mg/L), calcium content (108.8 & 125.6 mg/L), chloride content (340 & 740 mg/L) and high total alkalinity (178 & 304 mg/L) and sodium content (190 & 380 mg/L). The open well sample has high Fluoride content (1.5 mg/L).

### 3.3.2.3 Idukki District

From different panchayats of Idukki district, 123 samples were collected covering bore wells, open wells and public taps. Bacteriological analyses were carried out for 69 samples.

**Moolamattam** : Water samples collected during pre-monsoon-98 from bore well at Vazhathodi panchayat has high EC (above 300$\mu$S/cm) and sample collected from open well at Kulaman road contains high coliforms (240 MPN/100 ml).

**Thodupuzha** : Water samples collected during post-monsoon-98 from an open well near Sri Krishna Tourist Home has low pH (4.95) and samples collected from open well and tap water near Telecom Co-axial Station contain high coliforms (460, 21 MPN/100 ml). Other physicochemical parameters are within the stipulated limits.

**Udumbanchola** : Water samples collected during post-monsoon-98 from public tap and open well near Panchayat office contain high coliforms (75, 43 MPN/100 ml) and sample collected from public tap at Parathodi contained high coliforms (93 MPN/100 ml). Sample collected from open well at Nadumkandam also contains high coliforms (240 MPN/100 ml). Water samples collected during pre-monsoon-98 from open wells at Pambadumpara, Nedumkandam, Santhanpara and Munnar panchayats have high EC (305-610 $\mu$S/cm). All the other parameters are within the prescribed limit.

**Peerumedu** : Water samples collected during pre-monsoon-99 from public well near K. R. Cinema Hall, Vandiperiyar has high EC (663$\mu$S/cm). Sample collected from public well near Kalarikkal Buildings, Vandiperiyar, Kumili road contains high coliform content (2400MPN/100 ml). Other physicochemical parameters are confirming to the limits.

**Devikulam** : All the physicochemical parameters are within the prescribed limits. To find the effect of agricultured runoff water sample from an open well near Peerumedu Tea Plantation was collected. The parameters with respect to agro-chemicals like nitrate, phosphate, chloride, sulphate, etc. are found to be within the stipulated limits.

### 3.3.2.4 Kottayam District

A total number of 68 samples were collected, out of which bacteriological analysis was conducted on 35 samples.

**Changanassery** : Samples close to the market and nursing home have low pH. Two open wells have high EC in all seasons (up to 486 $\mu$S/cm) and have high Chloride content (up to 1100 mg/L). Two public wells have high fluoride content (1.43, 4.2 mg/L) and three samples have high coliforms.

**Kottayam** : Sample collected during post-monsoon-98 from an open well has high EC (347 $\mu$S/cm). Sample collected during pre-monsoon-98 from a public tap has high fluoride content (1.48 mg/L) and three samples have high coliforms up to 240 MPN/100 ml. One of the samples collected from a bore well at Kanjikuzhi has high iron content (1.43 mg/L).

**Palai** : Sample collected from a bore well near Anthinad temple has high iron content (1.427 mg/L) in pre-monsoon-98 and 2.41 mg/L in post-monsoon-98. Another bore well opposite to the fire station has high EC and high alkalinity.

### 3.3.2.5 Pathanamthitta District

A total number of 106 samples were collected, out of which bacteriological analysis was carried out on 57 samples.

**Adoor** : All the physicochemical parameters are in conformity with the prescribed limits.

**Ranni** : The open well samples have high coliforms up to 1100 MPN/100 ml. All the other parameters are within the stipulated limit.

**Pathanamthitta** : Samples collected from open wells have high coliforms up to 1100 MPN/100 ml. All the other parameters are within the stipulated limits.

### 3.3.2.6 Thrissur District

A total number of 28 samples were collected, out of which bacteriological analysis was conducted on 18 samples.

**Chalakkudy** : Samples collected from an open well at Town Masjid, Chalakkudy during post-monsoon-98 have high EC (307 $\mu$S/cm) and most of the samples have high coliform counts up to a maximum of 1100 MPN/100 ml

Table 3.3.2.1

## District wise Total Number of Ground Water Samples Collected

| Sampling Location | Pre-Monsoon 1998 | Post-Monsoon 1998 | Pre-Monsoon 1999 |
|---|---|---|---|
| **Alappuzha District** | | | |
| Alappuzha | 13 | 13 | 13 |
| Aroor | 13 | 13 | 13 |
| Alappuzha- Kerala Water Authority | - | - | 15 |
| Kuttanad | - | - | 4 |
| Punnapra Milk Plant Area | - | - | 4 |
| **Ernakulam District** | | | |
| Alwaye | 8 | 8 | 8 |
| Kalamassery/Eloor | 17 | 17 | 17 |
| Ernakulam | 15 | 15 | 15 |
| Muvattupuzha | 10 | 10 | 10 |
| Perumbavoor | 9 | 9 | 9 |
| **Idukki District** | | | |
| Moolamattam | 10 | 9 | 8 |
| Thodupuzha | 8 | 6 | 7 |
| Udumbanchola | 8 | 13 | 11 |
| Peerumedu | 5 | 10 | 9 |
| Devikolam | 3 | 8 | 6 |
| **Kottayam District** | | | |
| Changanassery | 8 | 8 | 8 |
| Kottayam | 8 | 8 | 8 |
| Palai | 7 | 7 | 7 |
| **Pathanamthitta District** | | | |
| Adoor | 11 | 11 | 11 |
| Ranni | 12 | 12 | 12 |
| Pathanamthitta | 12 | 12 | 12 |
| **Thrissur District** | | | |
| Chalakkudy | 8 | 8 | 8 |

## Table 3.3.2.2

## Physico-Chemical Characteristics of Groundwater Sources in Greater Kochi Region

| Place | pH | EC | TA | TH | Cl | $SO_4$ | $PO_4$-P | $NO_3$-N | F | Coliform |
|---|---|---|---|---|---|---|---|---|---|---|
| Alappuzha District | | | | | | | | | | |
| Alappuzha (13) | | | | | | | | | | |
| Premonsoon 98 | 6.4-7.5 | 85-887 | 20-236 | 0-132 | 12-140 | 1 2-36.4 | 0-0.59 | 0-0.92 | 0.45-1.6.0 | <3->=2400 |
| Postmonsoon 98 | 7.5-8.4 | 179-805 | 42-234 | 60-154 | 4-160 | 0.4-32.8 | 0.007-0.67 | 0.24-2.49 | 0.3-1.51 | <3->=2400 |
| Premonsoon 99 | 6.3-7 4 | 125-740 | 38-248 | 32-152 | 4-120 | 2.5-23 | 0.023-0.68 | 0.01-7.8 | 0.11-1.67 | <3-1100 |
| Aroor (13) | | | | | | | | | | |
| Premonsoon 98 | 4 5-7.7 | 172-5140 | 8-504 | 28-430 | 16-1600 | 5.6-28.8 | 0-0.81 | 0-1.37 | 0 | - |
| Postmonsoon 98 | 7 1-8.2 | 88-1653 | 20-296 | 38-294 | 2-390 | 4-35.2 | 0.003-0.53 | 0.1-0.8 | 0.009-1.45 | 9-1100 |
| Premonsoon 99 | 5.7-7.1 | 92-2520 | 30-282 | 34-380 | 12-900 | 3-72.5 | 0.003-0.3 | 0.1-2.13 | 0.02-0 25 | - |
| Alappuzha -Kerala water authority (15) | | | | | | | | | | |
| Premonsoon 99 | 6.8-7.5 | 466-1750 | 190-290 | 64-194 | 30-330 | 0.5-25 | 0.005-0.3 | 2.19-4.79 | 1.25-1.82 | 4-150 |
| Kuttanad (4) | | | | | | | | | | |
| Premonsoon 99 | 6.2-7.4 | 118-729 | 28-134 | 34-156 | 14-32 | 1-75 | 0.02-0.101 | 0.18-1.17 | 0.34 | 240->2400 |
| Punnapra Milk Plant Area (4) | | | | | | | | | | |
| Premonsoon 99 | 6.3-7.4 | 108-681 | 30-178 | 30-138 | 20-280 | 2.5-10 | 0.023-0.92 | 1.42-5.01 | 0.17-1.28 | <3-240 |
| Ernakulam District | | | | | | | | | | |
| Alwaye(8) | | | | | | | | | | |
| Premonsoon 98 | 5.2-6.8 | 51-227 | 12-80 | 12-80 | 8-32 | 0-29 | 0.03-0.10 | 0-0.89 | 0-0.34 | 0-<3 |
| Postmonsoon 98 | 5.1-6.6 | 65-219 | 10-54 | 10-54 | 4-30 | 5 2-14.8 | 0.05-0.09 | 0.34-7.4 | 0.36-0.52 | <3-93 |
| Premonsoon 99 | 5.4-6.8 | 43-298 | 2-82 | 10-102 | 8-26 | 2-31 | 0.007-0.046 | 0.31-4.1 | 0.01-0.11 | - |
| Kalamassery/Eloor (17) | | | | | | | | | | |
| Premonsoon 98 | 4 8-5.7 | 47-194.3 | 4-24 | 8-52 | 8-28 | 0-41 | 0.05-0.08 | 0.22-0.94 | 0 14-0 4 | <3- >=2400 |
| Postmonsoon 98 | 4 8-5 3 | 46-160.2 | 4-16 | 8-36 | 8-24 | 1.2-30.4 | 0.04-0.06 | 0.1-3.1 | **0.36-36** | 93->=2400 |
| Premonsoon 99 | 3 8-7.2 | 59-2890 | 8-62 | 12-366 | 10-1100 | 1.5-200 | 0.001-0.05 | 0 14-15.6 | 0.16-4.2 | - |
| Ernakulam (15) | | | | | | | | | | |
| Premonsoon 98 | 6 0-8.9 | 57-1163 | 16-200 | 16-280 | 8-180 | 0-78 | 0.06-1.11 | 0-1.64 | 0-0.69 | <3->=2400 |
| Postmonsoon 98 | 5 9-7.3 | 58-1605 | 16-326 | 20-332 | 6-380 | 2-68 | 0.05-0.85 | 0.1-17 | 0.17-0.86 | <3-1100 |
| Premonsoon 99 | 5 4-8.9 | 44-1882 | 10-300 | 16-368 | 4-420 | 0.5-41 | 0.016-0.627 | 0.27-4.59 | 0.05-0.92 | <3-11000 |

Contd ...

Table 3.3.2.2 Contd.

| Place | pH | EC | TA | TH | Cl | $SO_4$ | $PO_4$-P | $NO_3$-N | F | Coliform |
|---|---|---|---|---|---|---|---|---|---|---|
| **Muvattupuzha (10)** | | | | | | | | | | |
| Premonsoon 98 | 5.2-7.3 | 46-305 | 12-164 | 12-144 | 8-24 | 0-1.6 | 0-0.063 | 0-1.18 | 0.14-0.64 | <3 |
| Postmonsoon 98 | 6.6-8.2 | 44-321 | 1-120 | 12-92 | 6-22 | 0.5-20.5 | 0.015-0.035 | 0.07-5.55 | 0.09-0.14 | <3-93 |
| Premonsoon 99 | 5.2-7.2 | 45-295 | 10-168 | 12-146 | 10-20 | 0.5-14.5 | 0.002-0 008 | 0.32-7.80 | 0.03-0.12 | - |
| **Perumbavoor (9)** | | | | | | | | | | |
| Premonsoon 98 | 5.0-7.4 | 40-273 | 4-140 | 4-120 | 8-32 | 0.8-28 | 0-0.024 | 0-1.11 | 0.04-0.88 | - |
| Postmonsoon 98 | 4.6-8. 5 | 33-288 | 6-132 | 8-114 | 4-18 | 0.4-24.4 | - | 0.3-3.9 | 0.61-0.63 | <3-14 |
| Premonsoon 99 | 5.1-8.2 | 39-228 | 8-132 | 10-112 | 8-24 | 5.5-26.0 | 0.001-0.026 | 0.19-3.4 | 0.07-0.57 | - |
| **Idukki District** | | | | | | | | | | |
| **Moolamattam** | | | | | | | | | | |
| (10) Premonsoon 98 | 5.8-6.9 | 38-421 | 0-76 | 12-112 | 4-16 | 0-6.4 | 0-0.18 | 0-1.08 | 0-0.48 | <3-240 |
| (9) Postmonsoon 98 | 5.5-6.9 | 36-211 | 6-70 | 12-94 | 6-16 | 0.5-14 | 0.001-0.096 | 0.2-2.29 | 0.04-0.35 | <3-460 |
| (8) Premonsoon 99 | 5.2-7.0 | 33-299 | 14-164 | 14-150 | 8-18 | 0.5-13.5 | 0.01 | - | 0.02-0.13 | - |
| **Thodupuzha** | | | | | | | | | | |
| (8) Premonsoon 98 | 5.3-6.5 | 46-241 | 0-16 | 16-48 | 8-36 | 0-16.8 | 0-0.116 | 0.01-1.7 | 0-0.45 | <3-4 |
| (6) Postmonsoon 98 | 4.9-6.5 | 47-200 | 4-12 | 16-40 | 4-20 | 0.5-17 | - | 1.99-4.63 | 0.1 | <3 |
| (7) Premonsoon 99 | 5.3-6.3 | 37-245 | 10-24 | 12-54 | 10-30 | 2-10 | 0.001-0.005 | - | 0.02-0.7 | - |
| **Udumbanchola** | | | | | | | | | | |
| (8) Premonsoon 98 | 5.4-6.4 | 20-610 | 16-60 | 12-112 | 4-40 | 0-8.4 | 0.08-0.14 | 0-1.78 | 0-0.03 | - |
| (13) Postmonsoon 98 | 5.4-7.5 | 75-491 | 8-78 | 16-188 | 6-58 | 0 5-29.5 | 0.003-0.3 | 0.29-7.1 | 0.14-0.77 | <3-240 |
| (11) Premonsoon 99 | 5.2-7.2 | 54-281 | 18-98 | 16-92 | 8-44 | 0.5-26 | 0.008-0 04 | - | 0.2-0 53 | - |
| **Peerumedu** | | | | | | | | | | |
| (5) Premonsoon 98 | 5.7-6.5 | 67-287 | 12-72 | 12-60 | 4-24 | 0.8-3.2 | 0.03-0.34 | 0-0.078 | 0 | - |
| (10) Postmonsoon 98 | 5 8-8 1 | 35-773 | 2-106 | 12-124 | 4-160 | 0.5-14 | 0.005-0.55 | 0.1-22.1 | 0.13-0.97 | <3 |
| (9) Premonsoon 99 | 6.2-8.2 | 32-663 | 10-136 | 8-116 | 8-180 | 0 5-14 5 | 0.018-0.18 | - | 0.04-0.33 | <3->2400 |
| **Devikolam** | | | | | | | | | | |
| (3) Premonsoon 98 | 6 2-7 2 | 4-168 | 16-76 | 24-68 | 4-16 | 0-7.2 | 0.13-0.88 | 0.28-0.85 | 0-0.03 | - |
| (8) Postmonsoon 98 | 6.0-7.8 | 22-171 | 2-48 | 6-62 | 4-10 | 1-8.5 | 0 008-0.035 | 0.02-0 67 | 0.23-0.35 | - |
| (6) Premonsoon 99 | 7.3-8 3 | 37-161 | 8-80 | 10-64 | 6-14 | 0.5-10 | - | - | 0.01-0.1 | <3-7 |

Contd ...

Table 3.3.2.2 Contd.

| Place | pH | EC | TA | TH | Cl | $SO_4$ | $PO_4$-P | $NO_3$-N | F | Coliform |
|---|---|---|---|---|---|---|---|---|---|---|
| **Kottayam District** | | | | | | | | | | |
| Changanassery (8) | | | | | | | | | | |
| Premonsoon 98 | 4.2-6.8 | 43-468 | 0-40 | 0-80 | 8-48 | 1.2-38 | 0 | 0.22-4.95 | 0-0.95 | <3-1100 |
| Postmonsoon 98 | 4.2-8.5 | 3-450 | 6-26 | 22-106 | 8-60 | 1.2-32 | 0.003-0.015 | 0.51-24.2 | 0.09-0.68 | <3-240 |
| Premonsoon 99 | 4.8-6.1 | 138-486 | 8-26 | 22-90 | 22-90 | 2-50.5 | 0.009-0.021 | 1.07-18.9 | 0.02-0.22 | 9-4600 |
| **Kottayam (8)** | | | | | | | | | | |
| Premonsoon 98 | 5.4-6.7 | 35-440 | 8-84 | 12-124 | 8-20 | 1.2-12.4 | 0.009-0.09 | 0-0.78 | 0-1.48 | <3-240 |
| Postmonsoon 98 | 7.0-7.9 | 45-347 | 8-68 | 16-104 | 4-36 | 2-12 | 0.0001-0.001 | 0.68-2.34 | 0.05-0.8 | <3-1100 |
| Premonsoon 99 | 5.7-7.0 | 38-234 | 12-78 | 14-74 | 10-28 | 0.5-8.5 | 0.006 | - | 0.02-0.25 | - |
| Palai (7) | | | | | | | | | | |
| Premonsoon 99 | 5.5-7.5 | 61-408 | 16-148 | 20-120 | 4-28 | 1.2-20.4 | 0.018-0.057 | 0-0.6 | 0.37-0.75 | 9-23 |
| Postmonsoon 99 | 5.3-7.7 | 44-434 | 10-134 | 8-100 | 8-24 | 1-17.5 | 0.055-0.094 | 0.07-4.28 | - | - |
| Premonsoon 99 | 5.2-8.0 | 58-421 | 12-212 | 12-74 | 12-26 | 0.5-11.0 | - | 0.32-10.6 | 0.05-0.25 | - |
| **Pathanamthitta District** | | | | | | | | | | |
| Adoor (11) | | | | | | | | | | |
| Premonsoon 98 | 4.9-6.9 | 75-223 | 0-28 | 8-40 | 12-52 | 0-4.8 | 0-0.13 | 0.05-1.45 | 0-0.95 | 23->=2400 |
| Postmonsoon 98 | 5.9-7.4 | 31-138.8 | 2-22 | 6-36 | 6-54 | 0.4-8 | 0.003-0.18 | 0.27-5.12 | 0.27-0.64 | <3-1100 |
| Premonsoon 99 | 4.8-7.4 | 40-240 | 2-28 | 4-26 | 12-48 | 1.5-3.5 | 0.004-0.061 | 0.38-4.57 | 0.04-0.31 | - |
| Ranni (12) | | | | | | | | | | |
| Premonsoon 98 | 5.3-7.8 | 31-360 | 0-24 | 8-140 | 4-56 | 0-28 | 0-0.056 | 0-2.51 | 0-0.9 | <3-240 |
| Postmonsoon 98 | 5.4-8.0 | 23-291 | 4-108 | 10-194 | 4-26 | 1.2-32 | 0.001-0.058 | 0.37-5.05 | 0.08-0.4 | <3-93 |
| Premonsoon 99 | 5.3-8.1 | 26-326 | 6-164 | 6-152 | 6-32 | 1.5-14 | 0.005-0.06 | 0.26-8.2 | 0.05-0.24 | <3-1100 |
| Pathanamthitta (12) | | | | | | | | | | |
| Premonsoon 98 | 5.2-6.5 | 45-226 | 0-20 | 12-104 | 4-60 | 0-7.2 | 0-0.066 | 0-1.36 | 0-0.33 | <3-150 |
| Postmonsoon 98 | 5.4-7.8 | 55-252 | 4-90 | 10-116 | 10-40 | 0.5-9 | 0.001-0.018 | 0.41-5.15 | - | 4-1100 |
| Premonsoon 99 | 5.8-7.5 | 52-254 | 6-128 | 10-114 | 12-34 | 0.5-5.0 | 0.001-0.043 | 0.27-6.02 | 0.11-0.31 | 4-1100 |
| **Thrissur District** | | | | | | | | | | |
| Chalakkudy | | | | | | | | | | |
| (8) Premonsoon 98 | 5.1-7.5 | 36-156 | 12-16 | 12-24 | 8-28 | 0-11.6 | 0-0.073 | 0.01-1.01 | 0.02-0.56 | <3-460 |
| (8) Postmonsoon 98 | 5.1-7.2 | 42-307 | 6-26 | 10-36 | 2-54 | 0.4-25.6 | 0.01-0.05 | 0.3-1.96 | 0.29-0.41 | <3-1100 |
| (8) Premonsoon 99 | 4.9-6.3 | 44-229 | 1-12 | 8-24 | 14-38 | 0.5-33 | 0.031-0.077 | 0.18-4.05 | 0.09-0.33 | - |

All values are in mg/L except pH, EC is in µS/cm, Coliform is in MPN/100ml; TA - Total Alkalinity; TH - Total Hardness, Value in () indicates number of sampling locations. **Source** : Primary data collected by CWRDM

# Table 3.3.2.3

## Nutrients and Trace Metals in Groundwater Sources of Greater Kochi Region

| Place | Ca | Mg | Na | K | Fe | Al | As | Cu | Mn | Zn |
|---|---|---|---|---|---|---|---|---|---|---|
| Alappuzha District | | | | | | | | | | |
| **Alappuzha (13)** | | | | | | | | | | |
| Premonsoon 98 | 0-43.2 | 0-13.6 | 20-270 | 3.2-12.4 | 0-0 29 | 0.02 | - | 0.07-0.045 | 0.023-0.29 | 0.025-0.887 |
| Postmonsoon 98 | 14.4-48.8 | 0.486-19.44 | 12-220 | 4.4-12.8 | 0.034-1.147 | - | - | - | - | - |
| Premonsoon 99 | 9.6-50.4 | 1.94-18.95 | 6.4-114 | 1.6-81 | 0.03-0.04 | - | - | - | - | - |
| **Aroor (13)** | | | | | | | | | | |
| Premonsoon 98 | 6.4-56 | 2.43-81.4 | 13-950 | 1.6-44 | 0-0.33 | 0.02 | - | 0.001-0.19 | 0.033-0.076 | 0.126-0.262 |
| Postmonsoon 98 | 9.6-72.8 | 0.49-27.22 | 6-340 | 1.2-17.2 | - | - | - | - | - | - |
| Premonsoon 99 | 11.2-120 | 1.4-19.44 | 1.6-372 | 1.7-13 | - | - | - | - | - | - |
| **Alappuzha –Kerala water authority (15)** | | | | | | | | | | |
| Premonsoon 99 | 7.2-29.6 | 8.26-29.16 | 82-345 | 8.4-15.6 | 0.01-0.07 | - | - | - | - | - |
| **Kuttanad (4)** | | | | | | | | | | |
| Premonsoon 99 | 7.2-45.6 | 3.89-21.87 | 9.2-91 | 2.7-15.2 | 0.01-0.15 | - | - | - | - | - |
| **Punnapra Milk Plant Area (4)** | | | | | | | | | | |
| Premonsoon 99 | 6.4-28.8 | 3.4-18.95 | 13.6-81 | 2.4-12 | 0.01-0.62 | - | - | - | - | - |
| Ernakulam District | | | | | | | | | | |
| **Alwaye (8)** | | | | | | | | | | |
| Premonsoon 98 | 3.2-8 | 0-14.6 | 7-30 | 0.8-7.2 | - | 0.02 | - | 0.001-0.018 | 0.033-0.061 | 0.015-0.135 |
| Postmonsoon 98 | 3.2-13.6 | 0.49-4 86 | 6-47 | 0.8-10 | 0.07-0.28 | - | - | - | | - |
| Premonsoon 99 | 1.6-28 | 0.48-7.77 | 3-24 | 0.4-6.4 | 0.01-0.08 | - | - | - | - | - |
| **Kalamassery/Eloor (17)** | | | | | | | | | | |
| Premonsoon 98 | 1.6-16 | 0.97-2.9 | 10-26 | 0.8-6.8 | - | - | - | 0.003-0.007 | 0.018-0.049 | 0.01-0.247 |
| Postmonsoon 98 | 1.6-7.2 | 0.97-4.37 | 8-24 | 0.4-7.2 | 0.01-0.42 | - | - | - | | - |
| Premonsoon 99 | 1 6-74.4 | 0.97-64.64 | 6-188 | 0.8-20 | 0.002-0.58 | | | | - | - |
| **Ernakulam (15)** | | | | | | | | | | |
| Premonsoon 98 | 4.8-70.4 | 0.97-30.13 | 7-220 | 1.2-30.8 | 0-0.03 | - | - | 0.01-0.057 | 0.03-0.053 | 0.002-0.602 |
| Postmonsoon 98 | 1 6-80 | 1.94-32.08 | 5-320 | 0.8-36 | 0.43-0 72 | - | - | - | - | - |
| Premonsoon 99 | 1 6-84.8 | 1.46.37.91 | 3-206 | 0.5-30 | 0.01-0 07 | - | - | - | - | - |

Contd...

Table 3.3.2.3 Contd...

| Place | Ca | Mg | Na | K | Fe | Al | As | Cu | Mn | Zn |
|---|---|---|---|---|---|---|---|---|---|---|
| **Muvattupuzha (10)** | | | | | | | | | | |
| Premonsoon 98 | 3.2-41.96 | 0.97-12.6 | 5-26 | 0-11.2 | 0-0.35 | 0.02 | - | 0.001-0.033 | 0.032-0.094 | |
| Postmonsoon 98 | 1.6-36 | 0.49-17.01 | 1.6-17.2 | 0.6-9.6 | - | - | - | - | | 0.004-0.195 |
| Premonsoon 99 | 2.4-38.4 | 0.97-13.61 | 0.4-5.2 | 0.3-12.8 | 0.07 | - | - | - | - | |
| **Perumbavar (9)** | | | | | | | | | | |
| Premonsoon 98 | 1.6-28.8 | 0-11.66 | 6-32 | 0-27.2 | 0-0.1 | 0.01 | - | 0.01-0.04 | 0.007-0.069 | 0.004-0.835 |
| Postmonsoon 98 | 2.4-12 | 0.49-20.16 | 5-19 | 0.4-20.8 | 0.01-13.2 | - | - | - | - | - |
| Premonsoon 99 | 2.4-26.4 | 0.49-11.18 | 1.6-9.2 | 0.5-21.0 | - | - | - | - | - | - |
| **Idukki District** | | | | | | | | | | |
| **Moolamattam (10)** | | | | | | | | | | |
| Premonsoon 98 | 3.2-20.8 | 0.97-12.64 | 6-24 | 0.4-16 | 0-0.87 | - | - | 0.002-0.019 | 0.036-0.155 | 0.024 |
| Postmonsoon 98 | 1.6-15.2 | 1.46-10.21 | 3.2-10 | 0.5-4.3 | - | - | - | - | - | 0.232 |
| Premonsoon 99 | 3.2-36.8 | 1.44-14.09 | 3.6-10 | 0.6-2.8 | - | - | - | - | - | - |
| **Thodupuzha (8)** | | | | | | | | | | |
| Premonsoon 98 | 3.2-11.2 | 0.97-4.86 | 7-38 | 1.6-13.6 | 0-0.46 | - | - | 0.007-0.007 | 0.037-0.05 | 0.0132-0.083 |
| Postmonsoon 98 | 1.6-8 | 1.94-4.86 | 2.8-17.6 | 0.7-7.8 | - | - | - | - | | |
| Premonsoon 99 | 1.6-12 | 0.97-5.83 | 4-27 | 0.6-12 | - | - | - | - | | |
| **Udumbanchola (13)** | | | | | | | | | | |
| Premonsoon 98 | 3.2-19.2 | 0-15.55 | 9-31 | 1.2-4 | 0.15-2.8 | - | - | 0.002-0.024 | 0.027-0.058 | 0.018-0.191 |
| Postmonsoon 98 | 1.6-30.4 | 2.43-27.23 | 5.2-24.4 | 1-9 | - | - | - | - | - | - |
| Premonsoon 99 | 2.4-20 | 1.46-11.66 | 3.6-23.2 | 0.2-6.3 | - | - | - | - | - | - |
| **Peerumedu (10)** | | | | | | | | | | |
| Premonsoon 98 | 3.2-11.2 | 0-7.78 | 5-28 | 0.8-4 | 0-4.2 | - | - | 0.008-0.017 | 0.035-0.069 | 0.037-0.084 |
| Postmonsoon 98 | 1.6-24 | 1.46-17 | 2-87 | 1-35.6 | - | - | - | - | - | - |
| Premonsoon 99 | 1.6-23.2 | 0.97-15.07 | 0.8-76 | 0.4-39 | 0.01-0.04 | - | - | - | - | - |
| **Devikolam (8)** | | | | | | | | | | |
| Premonsoon 98 | 8-16 | 1.94-6.8 | 8-21 | 1.6-2.4 | 0.07-0.14 | - | - | 0.002-0.027 | 0.033-0.059 | 0.025-0.08 |
| Postmonsoon 98 | 2.4-19.2 | 0.97-5.35 | 0.4-10.4 | 0.4-5.8 | - | - | - | - | - | - |
| Premonsoon 99 | 2.4-15.2 | 0.97-6.32 | 1.3-15 | 0.1-2.8 | | - | - | - | - | - |
| **Kottayam District** | | | | | | | | | | |
| **Changanassery (8)** | | | | | | | | | | |
| Premonsoon 98 | 0-27.2 | 0-292 | 6-50 | 0-26 | 0-0.13 | - | - | 0.002-0.022 | 0.033-0.126 | 0.004-0.301 |
| Postmonsoon 98 | 6.4-24 | 1.46-11.67 | 3.2-37.2 | 0.7-28 | - | - | - | - | | - |
| Premonsoon 99 | 6.4-25.6 | 1.46-6.32 | 14-80 | 2.6-27.6 | - | - | - | - | - | - |

Contd...

Table 3.3.2.3 Contd...

| Place | Ca | Mg | Na | K | Fe | Al | As | Cu | Mn | Zn |
|---|---|---|---|---|---|---|---|---|---|---|
| **Kottayam (9)** | | | | | | | | | | |
| Premonsoon 98 | 1 6-20.8 | 0.97-17.5 | 7-58 | 0-15.2 | 0-0.92 | - | - | 0.003-0.054 | 0.029-0.054 | 0.011-0.264 |
| Postmonsoon 98 | 2.4-3.8 | 1.46-6.8 | 4-27.6 | 0.4-8.4 | - | - | - | - | - | - |
| Premonsoon 99 | 3.2-24.8 | 0.97-4.37 | 0.8-6.8 | 0.4-8 | 0.01-1.43 | - | - | - | - | - |
| **Palai (7)** | | | | | | | | | | |
| Premonsoon 99 | 4.8-48 | 0.97-12.64 | 7-64 | 0.8-18 | 0 | - | - | 0.007-0.027 | 0.036-0.051 | 0.049-0.345 |
| Postmonsoon 99 | 2 4-19.2 | 1.46-12.64 | 4.4-64 | 0.2-14 | - | - | - | - | - | - |
| Premonsoon 99 | 3.2-16 | 0.97-8.75 | 0.4-83 | 0.5-12.8 | 2.41 | - | - | - | - | - |
| **Pathanamthitta District** | | | | | | | | | | |
| **Adoor (11)** | | | | | | | | | | |
| Premonsoon 98 | 3.2-11.2 | 0-3.89 | 11-48 | 0.4-18 | 0-0.74 | - | - | 0.012-0.076 | 0.038-0.085 | 0.057-0.633 |
| Postmonsoon 98 | 0.8-8.8 | 0.972-4.86 | 7-54 | 0.4-16 | 0.009-0.341 | - | - | - | - | - |
| Premonsoon 99 | 0.8-7.8 | 0.49-2.92 | 3.6-16.4 | 0.1-13 | 0.01-0.05 | - | - | - | - | - |
| **Ranni (12)** | | | | | | | | | | |
| Premonsoon 98 | 3.2-25.6 | 0-14.58 | 7-57 | 0 4-18.4 | 0-0.24 | - | - | 0.005-0.048 | 0.009-0.048 | 0.003-2.93 |
| Postmonsoon 98 | 1.6-30.4 | 0.97-28.672 | 1-28 | - | - | - | - | - | - | - |
| **Pathanamthitta (12)** | | | | | | | | | | |
| Premonsoon 98 | 3.2-22.4 | 0-11.6 | 8-25 | 1.2-7.6 | 0-3.2 | - | - | 0.009-0.019 | 0.013-0.05 | 0.012-0.54 |
| Postmonsoon 98 | 1 6-5.6 | 0.49-27.2 | 7-30 | 1.2-9.6 | - | - | - | - | - | - |
| Premonsoon 99 | 1.6-24 | 0.49-13.12 | 4-27 | 1-11 | - | - | - | - | - | - |
| **Thrissur District** | | | | | | | | | | |
| **Chalakkudy (8)** | | | | | | | | | | |
| Premonsoon 98 | 0.97 2.92 | 12-24 | 0.003-0.042 | 0.033-0.061 | 0.033-0.113 | - | | - | - | - |
| Postmonsoon 98 | 0.8-9 6 | 1.94-4 37 | 4-55 | 0.9-18.8 | 0.04-0.42 | - | | - | - | - |
| Premonsoon 99 | 0.8-4.8 | 1 45-2.91 | 3-34 | 0.7-2.5 | 0.01-0.08 | - | | - | - | - |

All values are in mg/L

**Source** : Primary data collected by CWRDM

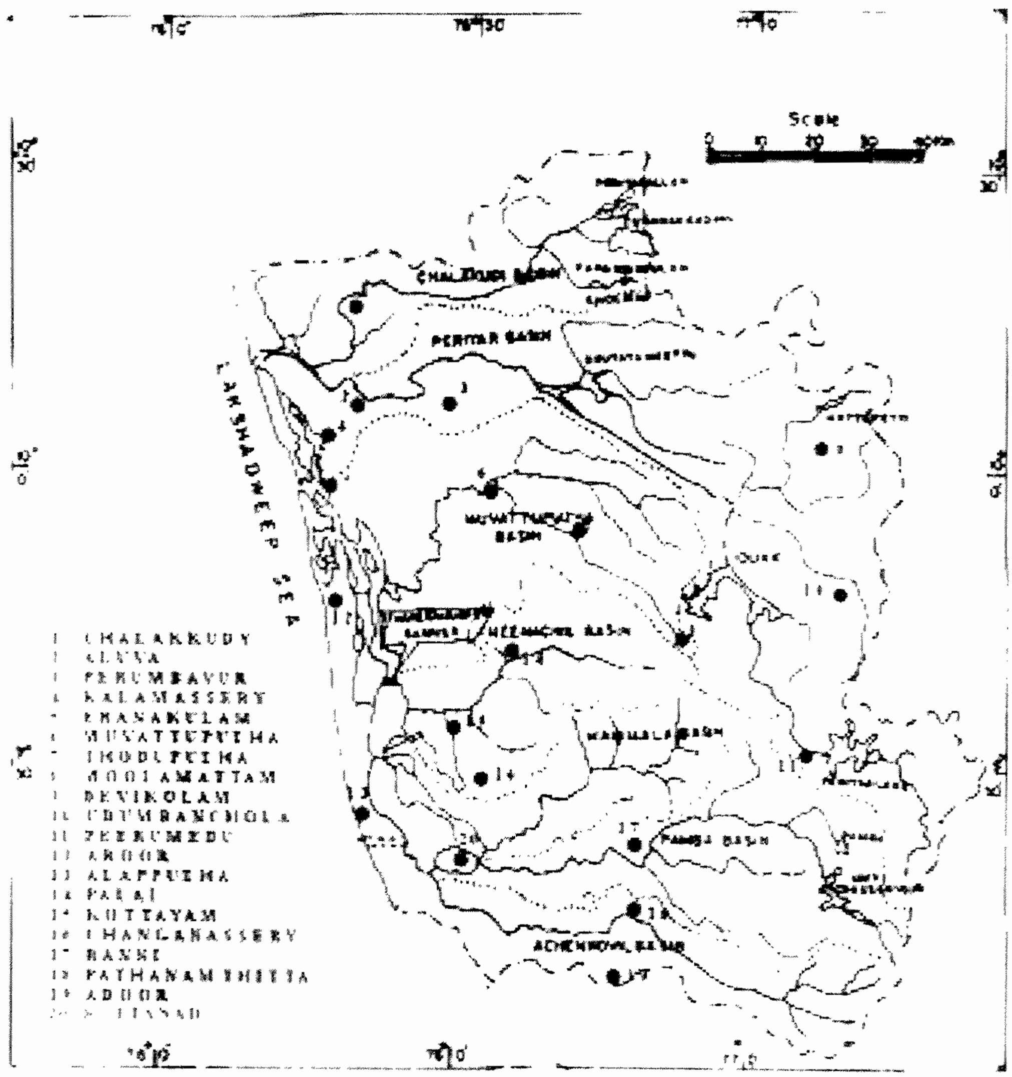


Fig. 3.3.2.1 : Ground Water Sampling Locations

### 3.3.3 Estuarine Water (Vembanand Lake)

#### 3.3.3.1 Physico-Chemical Characteristics

The Cochin estuarine system extends from Eloor in the north to Aroor in the south. Sampling for primary data collection was done from Aug 1998 to May 1999 covering three seasons; monsoon (August and September), post monsoon (January and March) and pre-monsoon (April and May). In each season, two sets of samplings were undertaken. Water samples and sediment samples were collected from 14 stations located in the estuary from Eloor to Thannirmukkom. The stations were Thannirmukkom (before bund), Thannirmukkom (after bund), Ithipuzha, Murinjapuzha, Perumbalam, Thevara, Mar.Sci.Jetty, Fisheries, Harbour, Barmouth, Bolgatty, Vaduthala, Varapuzha-Cheranelloor, Eloor and Pathalam, as shown in **Fig. 3.3.3.1** and detailed in **Table 3.3.3.1** along with the specific sampling objective. This estuary exhibits wide range of fluctuations in almost all characteristics.

The parameters identified for determination include; hydrographic parameters, nutrients and trace metals. Statistical summary of physical parameters is given in **Table 3.3.3.2** whereas chemical parameters in the surface and bottom waters are given in **Table 3.3.3.3** along with trace metals in sediments. The estuarine water quality of parameters have direct bearing on the amount of water discharges from various rivers during different months / seasons **Fig. 3.3.3.2** shows the monthly mean dishcarge rate of various rivers, viz. Periyar, Muvattupuzha, Maniman, meenachil, Pamba and Achencoil into Vembanad lake during the period 1980-1990 and 1990-1995. The figure indicates that river discharge rate in general has increased from 1980-90 to 1990-95. Further, maximum discharge rate is observed during monsoon and post-monsoon period (from June to November). The trend is almost uniform for all the rivers. Accordingly, water quality of the Vembanad lake vary seasonwise.

Sampling station wise distribution pattern of hydrographic and physico-chemical parameters in surface and bottom waters is presented through **Figs. 3.3.3.3** to **3.3.3.13** and discussed here briefly. Average current speed in surface waters was 25.2, 27.4 and 43.3 cm/s during monsoon, post monsoon and pre monsoon seasons. It was recorded 20-30% less in bottom waters. Current speed was found maximum at station number 6 (Thevara), where the sewage outfall is located (**Fig. 3.3.3.3**). No specific trend in current movement (direction) was observed, it was found to rotate almost in all the directions (**Fig. 3.3.3.4**). The distribution of **pH** in the Cochin backwaters was generally within the permissible range of 6.5 to 7.5. pH value was found to decrease in waters towards the northern end of the backwater. The acidic nature of the water at stations located towards the northern end of the backwater indicates the influence of industrial effluents discharged into this water body. A sharp decrease of pH 4.3 at surface and 5.2 at bottom was noticed at Pathalam (Station 13) during pre-monsoon sampling (**Fig. 3.3.3.5**).

The maximum and minimum **temperatures** of the backwaters observed were 31.5$^0$C and 26$^0$C respectively. The average temperature variation observed was 2.5$^0$C with a recorded maximum variation of 4$^0$C in the bottom during winter season. The temperature of water at all stations of the backwater was found to be minimum during monsoon months and it reached maximum value during post monsoon and thereafter, it decreased. The stations located away from the barmouth showed comparatively high temperature values than those of the stations located in the estuarine region except in monsoon months (**Fig. 3.3.3.6**).

Concentration of **Suspended Solids** in the surface as well as in bottom waters was maximum during pre-monsoon than in post monsoon and lowest during monsoon season. Suspended solids content in waters on either end of the estuary indicated comparatively lower concentration (2-30 mg/L), whereas locations near the estuarine barmouth exhibited values, in the range of 50-150 mg/L (**Fig. 3.3.3.7**).

High **salinity** values were recorded at all the stations located near the estuarine mouth (5-10) and comparatively low values at stations located upstream of the estuary (1-4). During the south west monsoon, fresh water discharge showed predominant influence on the salinity, and freshwater conditions nearly prevailed throughout the backwater system. During monsoon months (August and September), large quantities of freshwater enter the estuary resulting in low saline water at the surface (0.8 ppt), and more dense & saline waters at the bottom (6.8 ppt). Consequent to decrease in river discharge (**Fig. 3.3.3.2**), a gradual increase in salinity was noticed in the entire water column. Season-wise salinity distribution pattern at all the sampling locations is presented in **Fig. 3.3.3.8**.

Average **DO** level in surface water was 4.8, 3.5 and 3.3 during monsoon, post & pre-monsoon respectively. The same was slightly more (by 0.2 ml/L) in all the season. In general, lower DO levels are recorded at the sampling stations near the barmouth (**Fig. 3.3.3.9**).

**Nutrients** are of significant importance in chemical as well as biological fields of study, since they influence the primary productivity of the waters. The important nutrients are nitrate, nitrite, ammonia, phosphate and silicate. During monsoon, the fluctuations were found to be irregular at sampling sites. Concentrations of nutrients reported were found to be in the following range; nitrite : 0-6.5, nitrate : 0-6.44, phosphate : 0.2-27.8, silicate : 20.2-534.9 $\mu$mol/L.

**Silicate** levels were generally found to decrease from October to May Silicate exhibits higher concentration levels in fresh water than in seawater. The distribution pattern of nitrite, phosphate and silicates in surface and bottom waters is presented through **Figs. 3.3.3.10** to **3.3.3.12** respectively for each sampling period. No specific thrend was observed in the measured nutrient concentration levels in the lake.

**Fluoride** content in water was found to increase from October onwards at all the stations. Maximum concentration recorded during December-April around the industrial belt was > 1.5 mg/L. Minimum concentration (< 0.2mg/L) was observed in waters near barmouth and at north end of the industrial complex during Monsoon. The surface and bottom values did not show much marked difference.

The major **trace metals** detected in the estuarine water include Cu, Zn, Mn, Pb, and Cd. Higher concentrations were recorded in sediments than those in water

The maximum concentrations were observed in pre-monsoon and post-monsoon seasons. Concentration of different metals varied in the range of Cu: 1-169, Zn: 12-382, Mn: 15-508, Pb: 4.5-80, and Cd: 0-22.5 µg/mg, during different seasons (**Table 3.3.3.3**)

Station wise and season-wise variation in the trace metals concentration in sediments in projected in **Fig. 3.3.3.13**, which indicates no specific trend along the sampling locations.

### Organic Compounds

**Particulate organic matter** was reported to be in the range of 3-257 mg/L, wherein organic carbon varied between 0.2 and 8.48 mg/L. Both surface and bottom values showed marginal difference only. **Total petroleum hydrocarbons** in sediments were found to vary in the range of 249 to 570 µg/g (dry wt). The maximum concentration recorded was near the harbour area and minimum near a riverine station (Muvattupuzha river). Both maximum and minimum values were recorded during non-monsoon months (October - May). **Protein** content was found to vary between 0.1-1.8 µg/L during water quality monitoring survey conducted from stations in Periyar (around industrial complex) to Newsprint Nagar. Higher concentrations were reported at stations located downstream of industrial area to barmouth.

**Pesticides** including the hazardous pesticide DDT were found to be at higher concentrations (55-422 µg/L). The minimum concentration was observed at a riverine station located in Periyar river and maximum was found near a industrial discharge area. Pesticides are applied to the tune of 485 MT annually. It was reported that lindane concentration in samples varied from 4 to 20 µg/L in lagoon sediments, DDT up to 4 µg/L in river water, 12-22 µg/L in lake surface to 35 µg/L near the Thanneermukkom barrier. Presence of these levels of pesticides have resulted in fish mortality and reduction in plankton and benthic communities during the dry pre-monsoon season.

Eutrophication due to nitrate has led to explosive growth of pernicious weeds like, *Salvainia molesta* Mitchell *and Eichhornia crassipes* (Mart), Solms in the inland waterways and canals of the backwater. Reduction in salinity due to the Thanneermukkom barrier, constructed to prevent salinity ingress during summer months for intensive rice cultivation, has led to reduction in fish yeild and lime shell deposits. Water impoundment has increased organic pollution load in the lake resulting in increased incidence of water borne diseases such as filariasis, schistosomiasis, cholera, typhoid, jaundice, gastroenteritis and dysentery.

### 3.3.3.2 Microbiological Characteristics

Total heterotrophic bacteria (THB) counts in any aquatic environment depend on the availability of growth supporting organic matter and micronutrients. High counts of THB like those encountered at stations 12 and 13 during monsoon and at stations 11 and 12 during post-monsoon in sediment samples clearly confirm the fact that the abundant micro-nutrients and organic matter in the sediment are highly responsible.

THB count in water is high during monsoon and post-monsoon, whereas in sediment, the same is high during post monsoon. Seasonal variation in THB counts in water and sediment samples is given in **Table 3.3.3.4** at each sampling station. The turbulence caused by the monsoon as well as the land run off may be considered as the contributing factors for the high THB values in the water column during monsoon. Sediment is always characterized by high THB counts but the monsoonal washing away of the surface sediment layers result in comparatively low values during monsoon. The permissible value for total coliforms in estuaries is 1000 MPN/ 100ml and that of faecal coliforms is 200 MPN/ 100ml.

Total coliform levels were always higher than faecal coliform levels, which is not surprising since total coliforms can originate from non-faecal sources such as plants and soils. Total coliform counts has determined using Mac Conkey agar whereas faecal coliform count was estimated using MEC agar. In all the samples. the number of indicator organisms was lower for water than for sediments. Total and faecal coliforms count in water and sediment samples during pre and post-monsoon seasons are given in **Table 3.3.3.5**.

Faecal Coliforms count is a useful measure in determining the magnitude of faecal pollution. Sewage effluent discharge sites (SP-6) yielded greater faecal coliform values, which indicate that the pollution was derived from contamination by faeces. The high value may be due to the extensive use of this backwater by pleasure boats and sewage discharge. The occurrence of bacteria of faecal origin in the sediment is significant in that it may greatly affect the overall long term water quality of the estuarine system.

**Table 3.3.3.1**

**Sampling Stations in Cochin Backwater System**

| Sr. No. | Station | Depth (m) | Objective | Location |
|---|---|---|---|---|
| 1 | South of Thannermukkom Bund | 4.5 | To compare the hydrographical changes, faunal distribution and diversity in relation to changes in salinity | 9°40'11"N 76°23'40"E |
| 2 | North of Thannermukkom Bund | 3.5 | To compare the hydrographical changes, faunal distribution and diversity in relation to changes in salinity | 9°41'07"N 76°23'39"E |
| 3 | Ithipuzha R Mouth | 11.0 | To study the influence of fresh water discharge into the estuary | 9°46'57"N 76°22'7"E |
| 4 | Murinijapuzha R. Mouth | 9.0 | To study the impact of effluents from the Vellor News Print Factory on the estuarine system | 9°50'8"N 76°22'20"E |
| 5 | Kumbalam Perumbalamm | 6.0 | To study the impact of high organic content (due to husk retting, sewage on the ecology of the water body) | 9°52'29"N 76°19'33"E |
| 6 | Thevara | 7.5 | To study impact due to sewage outfall and impacts of construction of bridges | 9°55'35"N 76°17'53"E |
| 7 | Off Marine Science Jetty | 7.0 | The influence of operations at oil terminal, wastes from shipyard, berthing of boats and the peculiarity in circulation | 9°57'39"N 76°16'54"E |
| 8 | Fisheries Harbour | 3.5 | To study the impact of fishing and processing unit operations | 9°56'47"N 76°15'52"E |
| 9 | Barmouth | 13.0 | Cochin Harbour entrance to identify the influence of tidal currents in the estuarine circulation features and to study marine influence on the biota | 9°58'26"N 76°14'39"E |
| 10 | Bolghatty | 2.0 | To study the degradation in water quality due to inland navigation and other tourism operations | 9°58'52"N 76°15'50"E |
| 11 | Vaduthala | 3.0 | To study the impact of husk retting and disposal of domestic wastes | 10°21'13"N 76°15'9"E |
| 12 | Varapuzha Cheranellur | 3.0 | Industrial belt. To study the impact of effluents discharge | 10°4'30"N 76°16'48"E |
| 13 | Eloor | 3.5 | Industrial belt. To study the impact of effluents discharge | 10°5'23"N 76°17'49"E |
| 14 | Pathalam Bund | 3.5 | Freshwater zone represents relatively uncontaminated water | 10°5'23"N 76°17'49"E |

Table 3.3.3.2

Seasonal Variations in Physical Parameters in Surface and Bottom Waters

| Parameters | Monsoon | | Post-Monsoon | | Pre-Monsoon | |
|---|---|---|---|---|---|---|
| | Range | Average | Range | Average | Range | Average |
| **Current Speed (cm/s)** | | | | | | |
| Surface | 2-156 | 25.2 | 8-143 | 27.4 | 5-195 | 43.3 |
| Bottom | 2-116 | 21.4 | 5-73 | 23.9 | 4-77 | 30.3 |
| **Direction (Degree)** | | | | | | |
| Surface | 1-355 | 110.6 | 7-359 | 212.9 | 30-358 | 252.2 |
| Bottom | 1-340 | 75.8 | 2-350 | 165.3 | 22-353 | 226.5 |
| **pH** | | | | | | |
| Surface | 6.6-7.6 | 7.1 | 6.4-8.5 | 7.3 | 4.3-7.5 | 6.9 |
| Bottom | 6.6-7.9 | 7.1 | 6.2-8.5 | 7.3 | 5.2-7.4 | 7.0 |
| **Temperature ($^0$C)** | | | | | | |
| Surface | 26.0-28.9 | 27.5 | 26.8-31.5 | 27.1 | 28.1-31 | 27.6 |
| Bottom | 26.0-29.0 | 27.4 | 26.8-31.5 | 27.5 | 28.0-31.0 | 27.6 |
| **Suspended Solids (mg/L)** | | | | | | |
| Surface | 0.4-48.4 | 14.4 | 1.6-104.9 | 30.1 | 6.2-128.9 | 43.6 |
| Bottom | 1.9-273.4 | 39.7 | 4.5-179 | 52.4 | 10 7-516.7 | 124.6 |
| **Salinity (ppt)** | | | | | | |
| Surface | 0.0 – 4.0 | 0.8 | 0 - 29 | 11.2 | 0 - 22 | 8.4 |
| Bottom | 0.0 - 6.0 | 1.8 | 0 - 31 | 13.1 | 0 - 26 | 10.1 |

**Source :** Primary data collected by CUSAT, 1998-1999

## Table 3.3.3.3

### Seasonal Variations in Chemical Parameters in Surface Waters and Trace Metals in Sediments

| Parameters | Monsoon | | | Post-monsoon | | | Pre-monsoon | | |
|---|---|---|---|---|---|---|---|---|---|
| | Range | Average | SD | Range | Average | SD | Range | Average | SD |
| Dissolved Oxygen (ml/L) | | | | | | | | | |
| Surface | 4.2-5.6 | 4.8 | 1.0 | 3.0-5.2 | 3.5 | 1.3 | 2.2-5 4 | 3.3 | 1.3 |
| Bottom | 4.5-6.1 | 5.0 | 1.0 | 3.0-5.2 | 3.7 | 1.3 | 2.3-5.3 | 3.5 | 1.3 |
| Nitrite (μmol/L) | | | | | | | | | |
| Surface | 0.0-7.9 | 0.7 | 1.8 | 0.0-6.4 | 1.7 | 1.5 | 0.0-2.4 | 1.1 | 0.7 |
| Bottom | 0.0-8.0 | 0.8 | 1.8 | 0.0-6.5 | 1.8 | 1.7 | 0.0-3.7 | 1.0 | 0.9 |
| Phosphate (μmol/L) | | | | | | | | | |
| Surface | 0.9-27.8 | 6.4 | 6.5 | 0.2-5.6 | 2.2 | 1.3 | 0.3-7.0 | 2.9 | 3.2 |
| Bottom | 0.9-22.7 | 6.5 | 6.4 | 0.3-11.8 | 3.2 | 2.7 | 0.4-7.7 | 3.2 | 2.1 |
| Silicate (μmol/L) | | | | | | | | | |
| Surface | 58.7-187.3 | 110.7 | 65.7 | 20.2-160.5 | 79.3 | 51.8 | 31.0-144.0 | 64.0 | 31.0 |
| Bottom | 64.6-534.9 | 203.7 | 115.1 | 12.7-159.0 | 71.1 | 53.8 | 31.8-107.8 | 58.3 | 21.2 |
| Trace Metals in Sediments (μg/mg) | | | | | | | | | |
| Cu | 1.1-84.9 | 233.9 | 93.6 | 3.2-105.1 | 167.7 | 62.2 | 5.1-169.2 | 165.1 | 70.2 |
| Zn | 20.3-346.7 | 116.4 | 142.5 | 12.1-382.2 | 72.1 | 84.8 | 24.7-327.6 | 63.1 | 70.7 |
| Mn | 14.9-419.8 | 29.9 | 32.0 | 34.5-507.5 | 33.9 | 41.7 | 16.5-116.5 | 36.1 | 41.2 |
| Pb | 4.5-39.5 | 9.9 | 6.9 | 4.7-7.0 | 7.1 | 2.5 | 5.0-80.0 | 8.0 | 1.7 |
| Cd | 0.0-15.8 | 1.4 | 4.2 | 0.0-21.5 | 3.2 | 5.8 | 0.3-22.5 | 5.0 | 6.4 |

**Source :** Primary data collected by CUSAT, 1998-99

Table 3.3.3.4

Seasonal Variation in Total Heterotrophic Bacterical (THB) Count in Estuarine Water and Sediment Samples

| St. No. | THB in water (x $10^3$ Nos. /100 ml) | | | THB in sediment (x $10^5$ Nos./100 ml) | | |
|---|---|---|---|---|---|---|
| | Monsoon | Post Monsoon | Pre Monsoon | Monsoon | Post Monsoon | Pre Monsoon |
| 1 | 59.6 | 12.7 | 6.6 | 9.6 | 15.9 | 2.7 |
| 2 | 6.1 | 20.6 | 4.2 | 5.8 | 29 | 2.1 |
| 3 | 24.6 | 21 | 6.4 | 1.2 | 6.6 | 2.2 |
| 4 | 7.1 | 21 | 10.6 | 1 3 | 1.7 | 0.5 |
| 5 | 12.4 | 56.5 | 4.1 | 3.9 | 5.5 | 0.7 |
| 6 | 13.9 | 24.2 | 15.2 | 5.5 | 2.1 | 0.4 |
| 7 | 24.3 | 8.2 | 5 | 4.2 | 1.2 | 6.4 |
| 8 | 18.6 | 6.1 | 34.3 | 9.8 | 15.4 | 2.9 |
| 9 | 11.1 | 10.5 | 4 | 1.9 | 11.9 | 1 |
| 10 | 5.9 | 9.0 | 0.3 | 3.0 | 4.1 | 2.8 |
| 11 | 6.5 | 4.7 | 0.3 | 1.3 | 27.9 | 0.7 |
| 12 | 12 | 6.6 | 3.6 | 21.3 | 31.3 | 0.2 |
| 13 | 17.2 | 8.3 | 3.3 | 10.1 | 2.9 | 3.7 |
| 14 | 18.9 | Not sampled | Not sampled | 1.3 | Not sampled | Not sampled |

**Source :** Primary data collected by CUSAT, 1998-99

## Table 3.3.3.5

### Total and Faecal Coliform count in Water and Sediment Samples during Pre and Post Monsoon

| St. No. | Total Coliforms (x $10^3$) | | | | Faecal Coliforms (x $10^3$) | | | |
|---|---|---|---|---|---|---|---|---|
| | Pre Monsoon | | Post Monsoon | | Pre Monsoon | | Post Monsoon | |
| | Water | Sediment | Water | Sediment | Water | Sediment | Water | Sediment |
| 1 | 0.4 | 10 | 0.2 | 10 | 0.3 | 0.01 | 0.06 | 0.2 |
| 2 | 0.8 | 30 | 0.2 | 60 | 0.6 | 0.3 | 0.2 | 0.4 |
| 3 | 0.3 | 30 | 0.02 | 220 | 0.2 | 0.3 | 0.01 | 1.8 |
| 4 | 1.1 | 10 | 0.2 | 150 | 0.4 | 0.02 | 0.1 | 1 |
| 5 | 0.4 | 10 | 0.1 | 10 | 0.3 | 0.1 | 0.1 | 0 03 |
| 6 | 1.7 | 40 | 0.02 | 50 | 1.2 | 0.3 | 0.02 | 0.5 |
| 7 | 0.03 | 20 | 0.1 | 30 | 0.02 | 0.1 | 0.04 | 0.1 |
| 8 | 0.005 | 40 | 0.02 | 70 | 0.003 | 0.1 | 0.01 | 0.4 |
| 9 | 0.3 | 10 | 0.01 | 50 | 0.2 | Nil | 0.01 | 0.1 |
| 10 | 0.2 | 1 | 0.02 | 4 | 0.1 | Nil | 0.02 | Nil |
| 11 | 0.6 | 40 | 0.2 | 40 | 0.4 | 0.3 | 0.02 | 0.3 |
| 12 | 0.3 | 10 | 0.04 | 30 | 0.2 | 0.1 | 0.01 | 0.02 |
| 13 | 0.2 | 10 | 0.02 | 10 | 0.1 | Nil | Nil | 0.02 |
| 14 | Not Sampled | | Not Sampled | | Not Sampled | | Not Sampled | |

TC & FC in water : Nos/100ml; TC & FC in Sediments : Nos/g (dry wt)
**Source** : Primary data collected by CUSAT, 1998-99

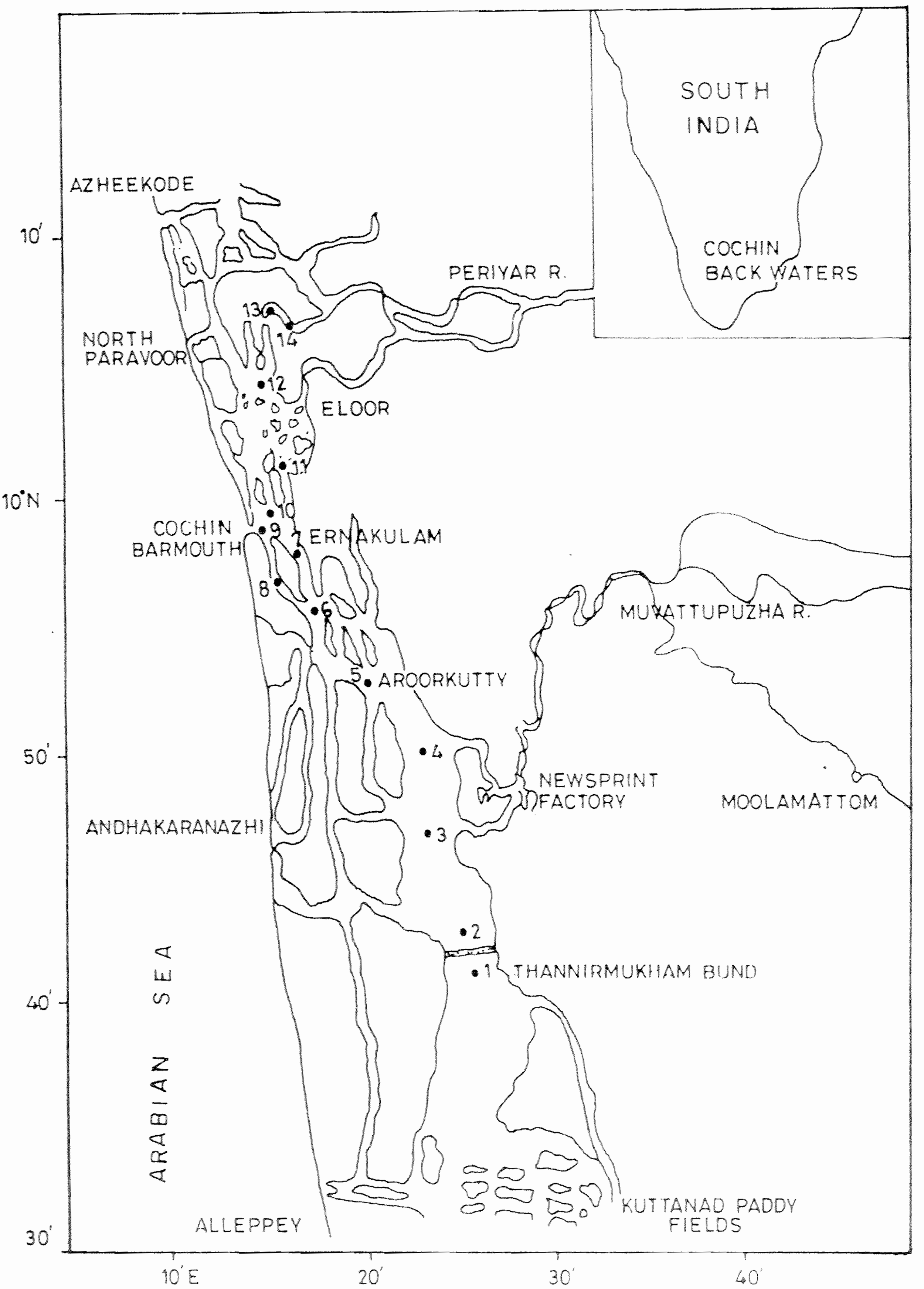



Fig. 3.3.3.1: Sampling Locations in Cochin Back Water Systems (Vembanad Lake)

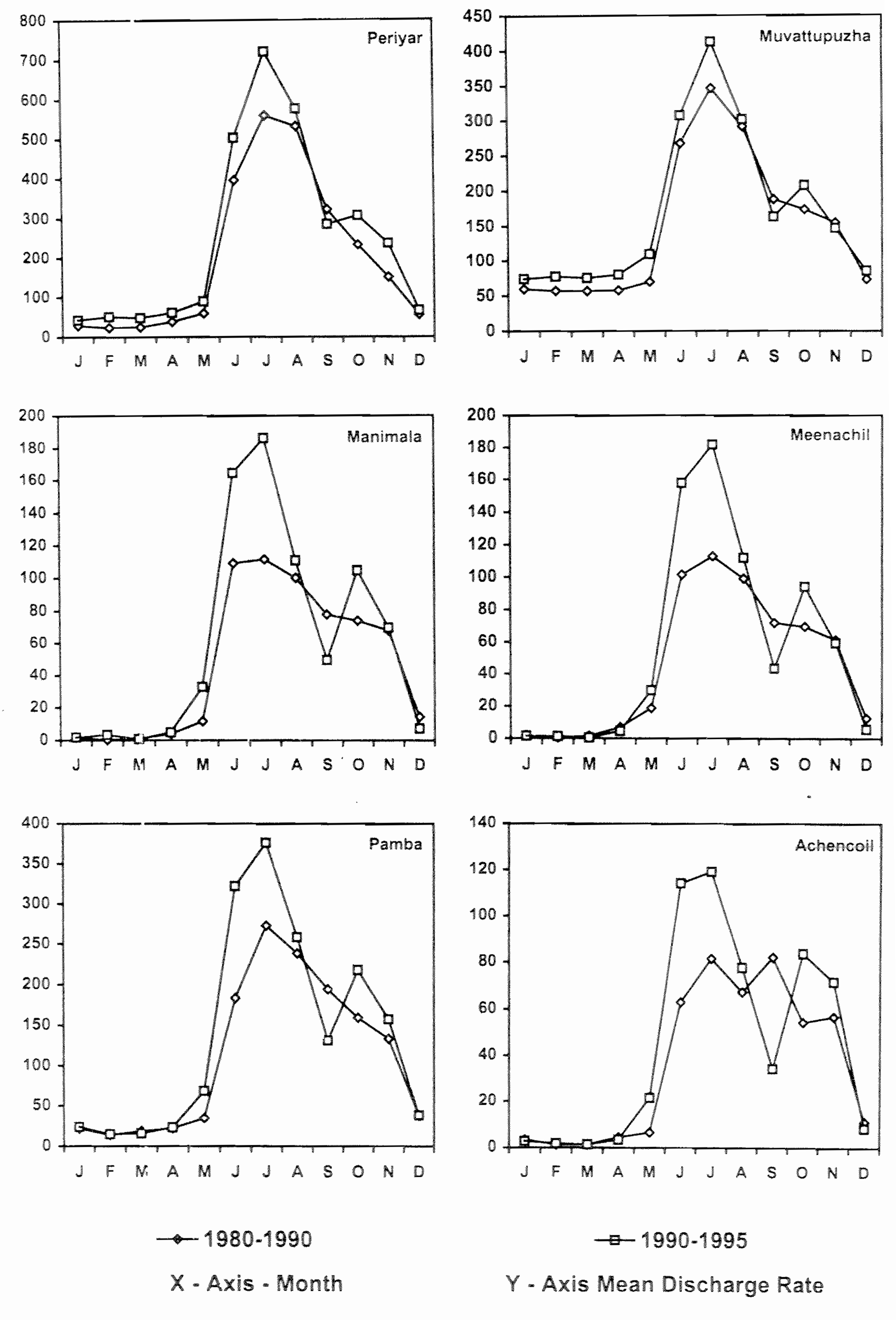



Fig. 3.3.3.2 : Monthly Mean Discharge Rate of Various Rivers into Vambanad Lake

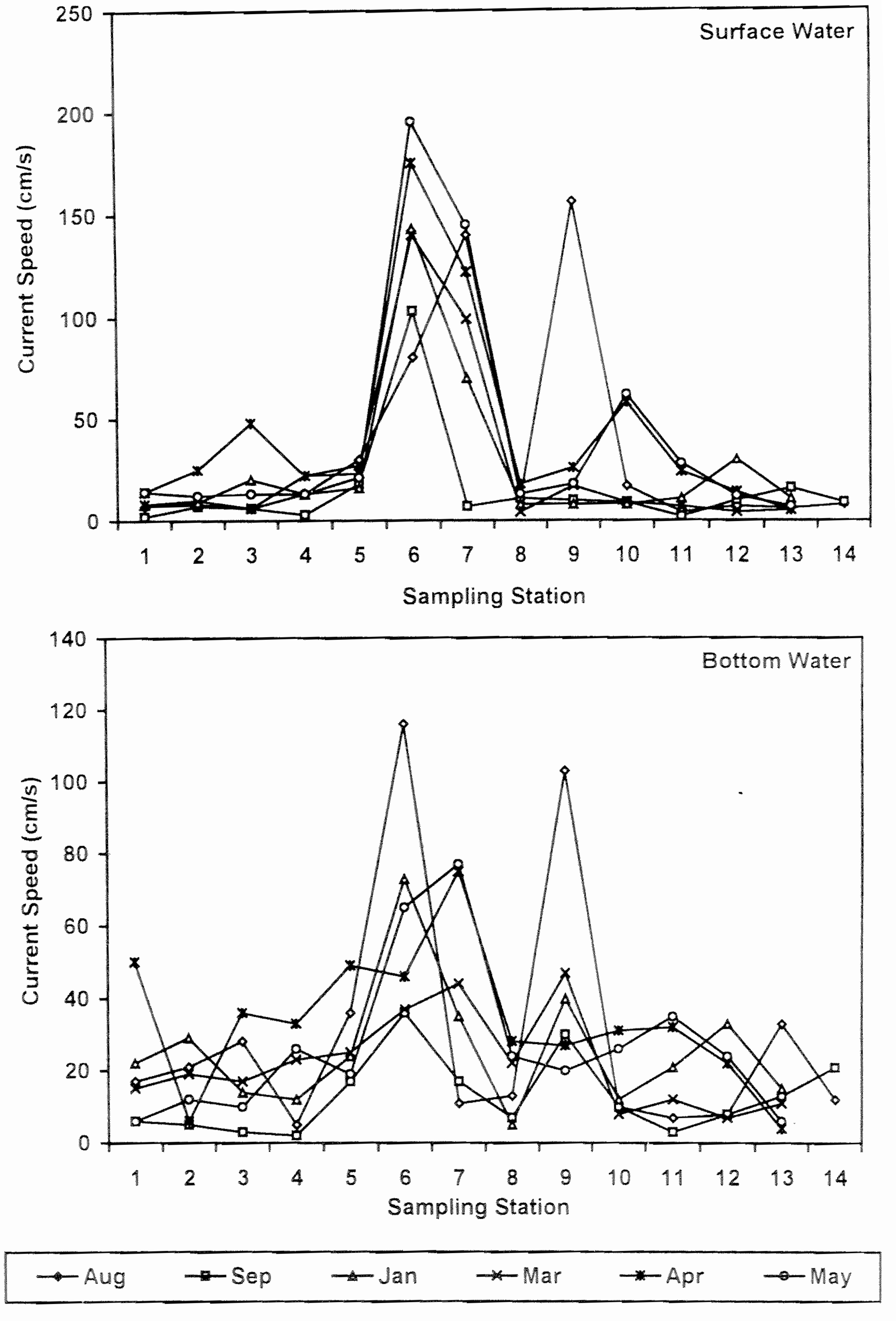



Fig. 3.3.3.3 : Season-wise Distribution of Current Speed in Surface and Bottom Waters

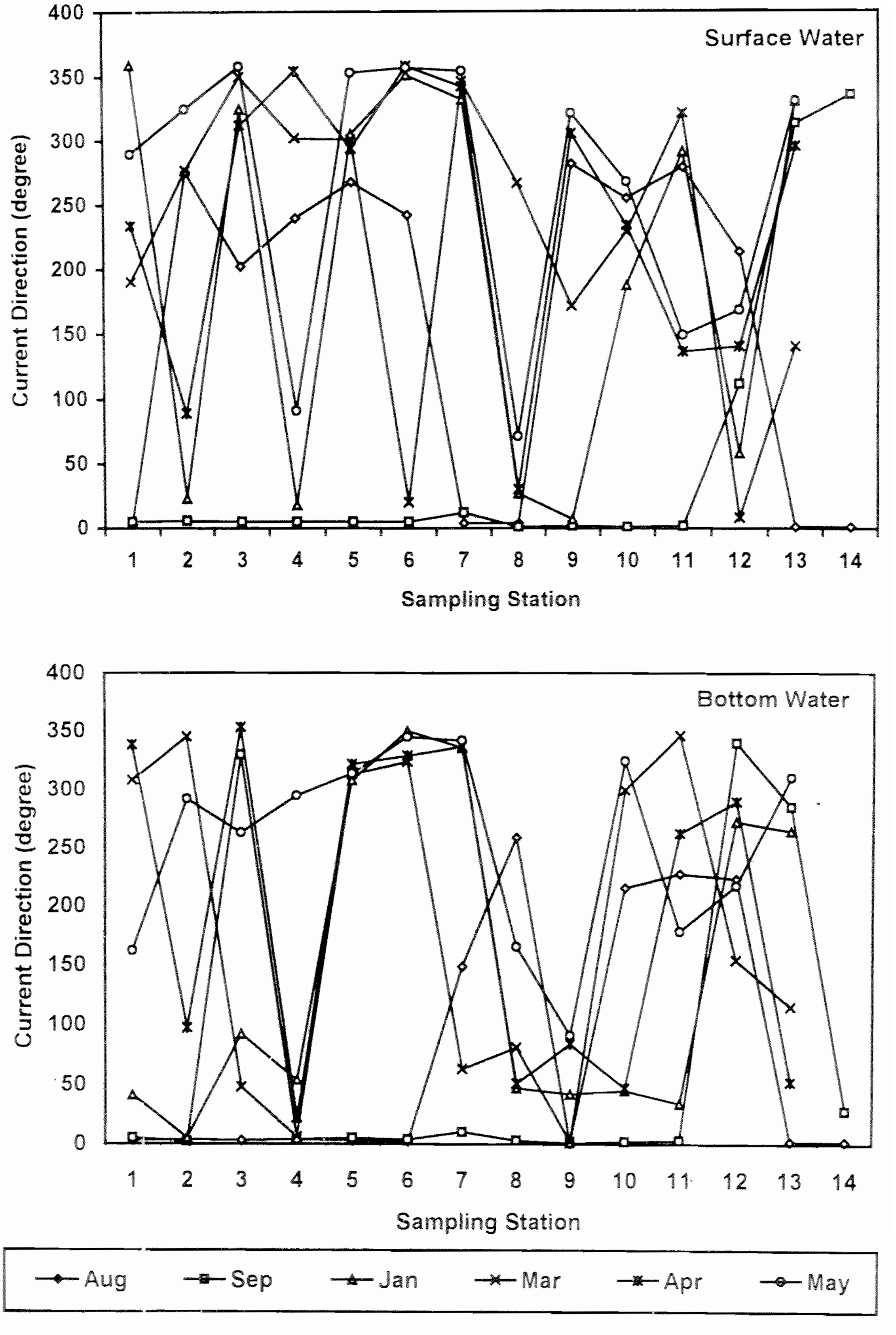



Fig. 3.3.3.4 : Season-wise Distribution of Current Direction in Surface and Bottom Waters

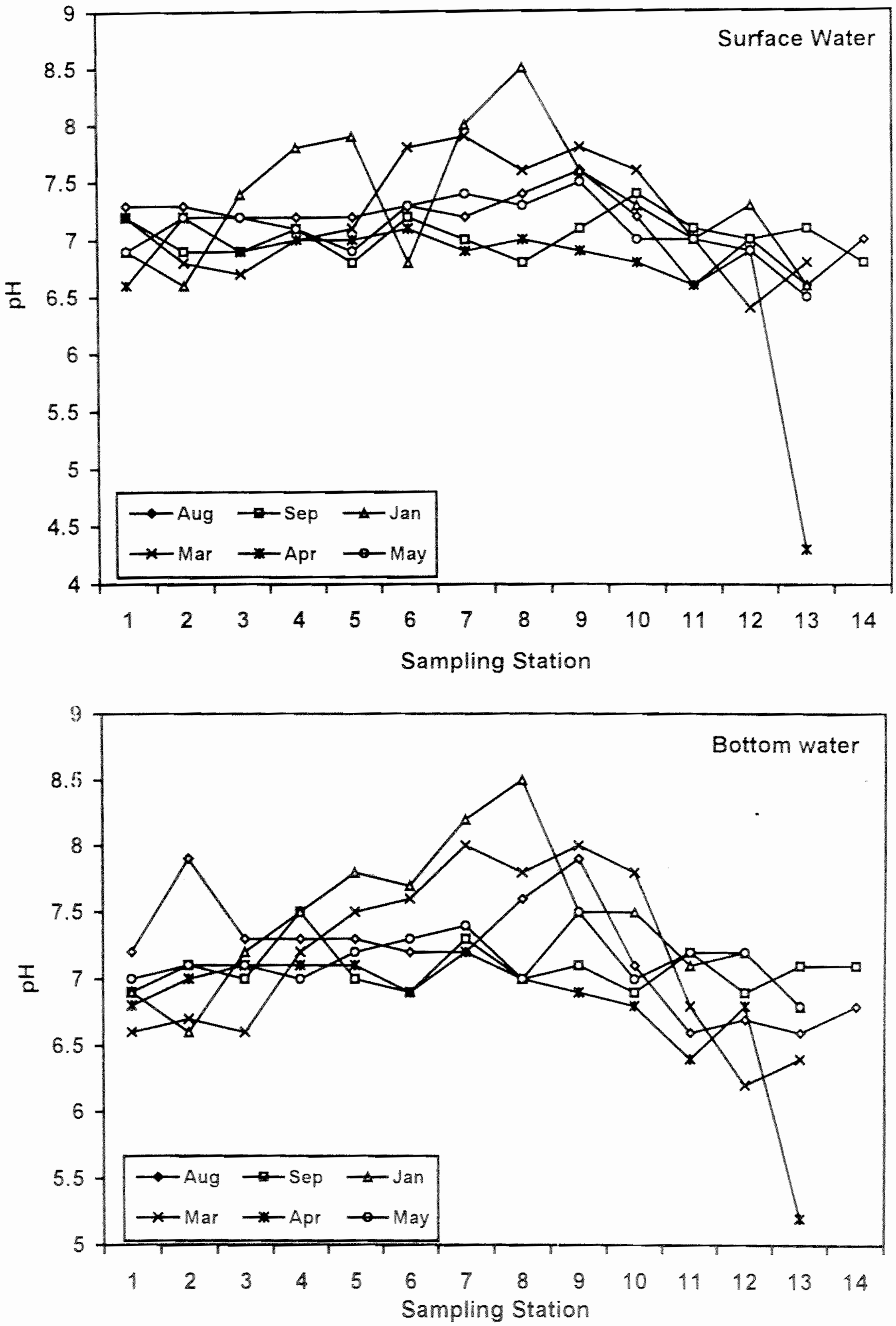



Fig. 3.3.3.5 : Season-wise Distribution of pH in Surface and Bottom Waters

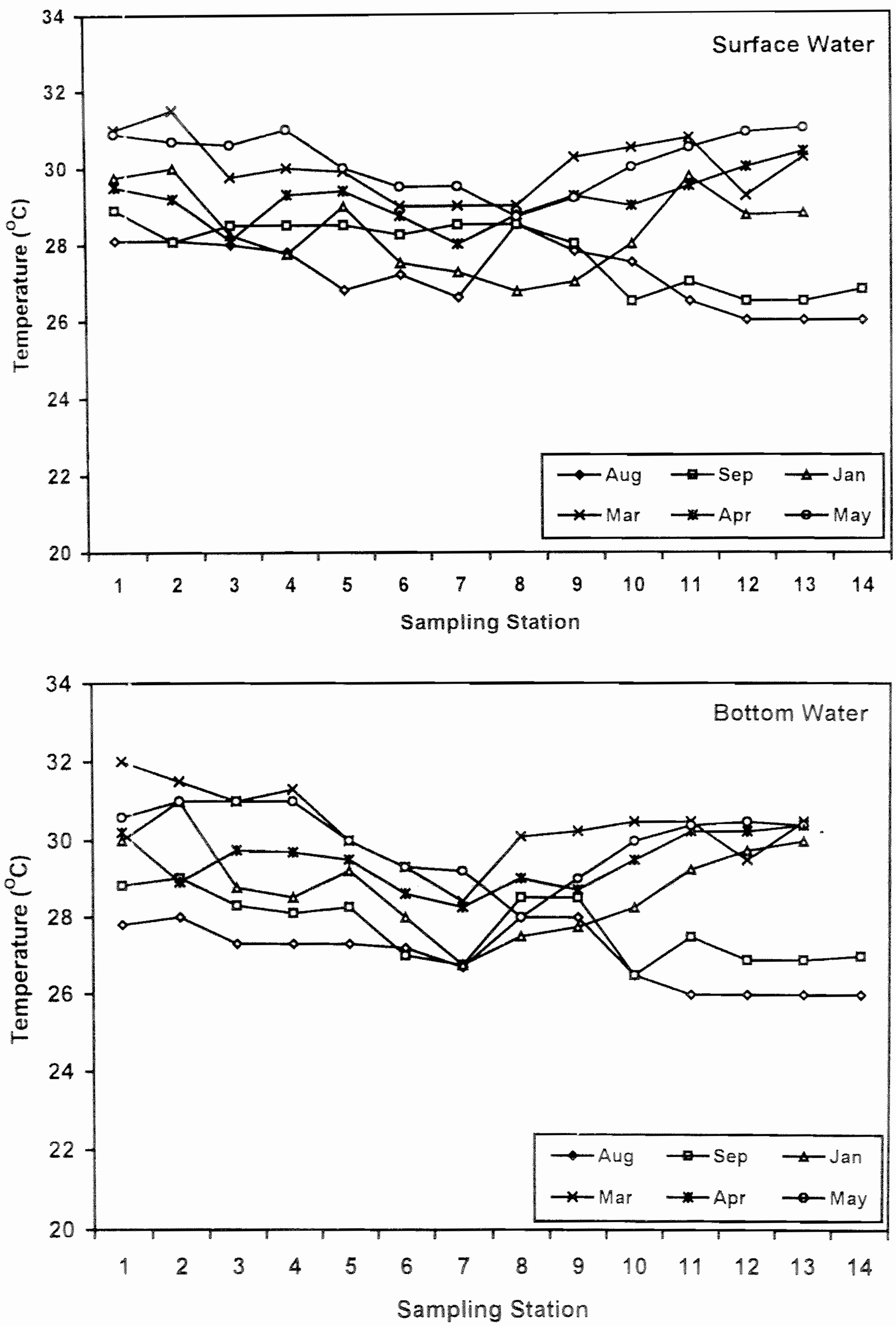
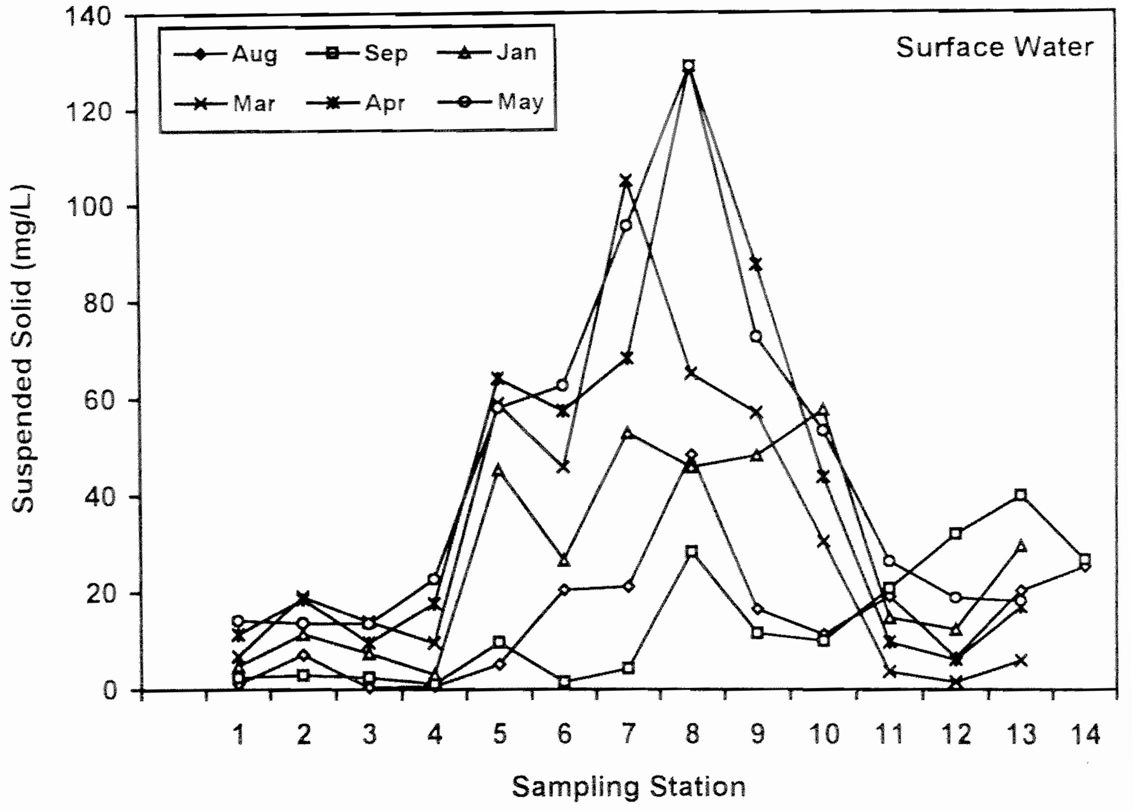



Fig. 3.3.3.6 : Season-wise Distribution of Tempurature in Surface and Bottom Waters



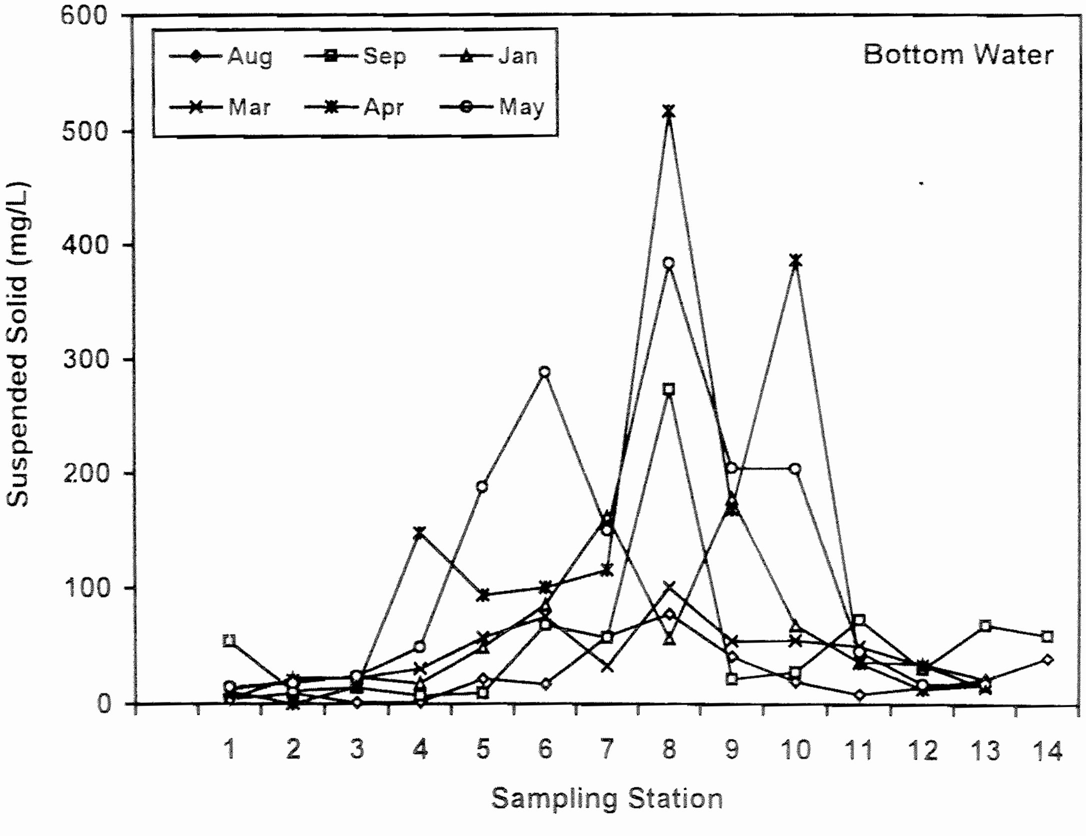
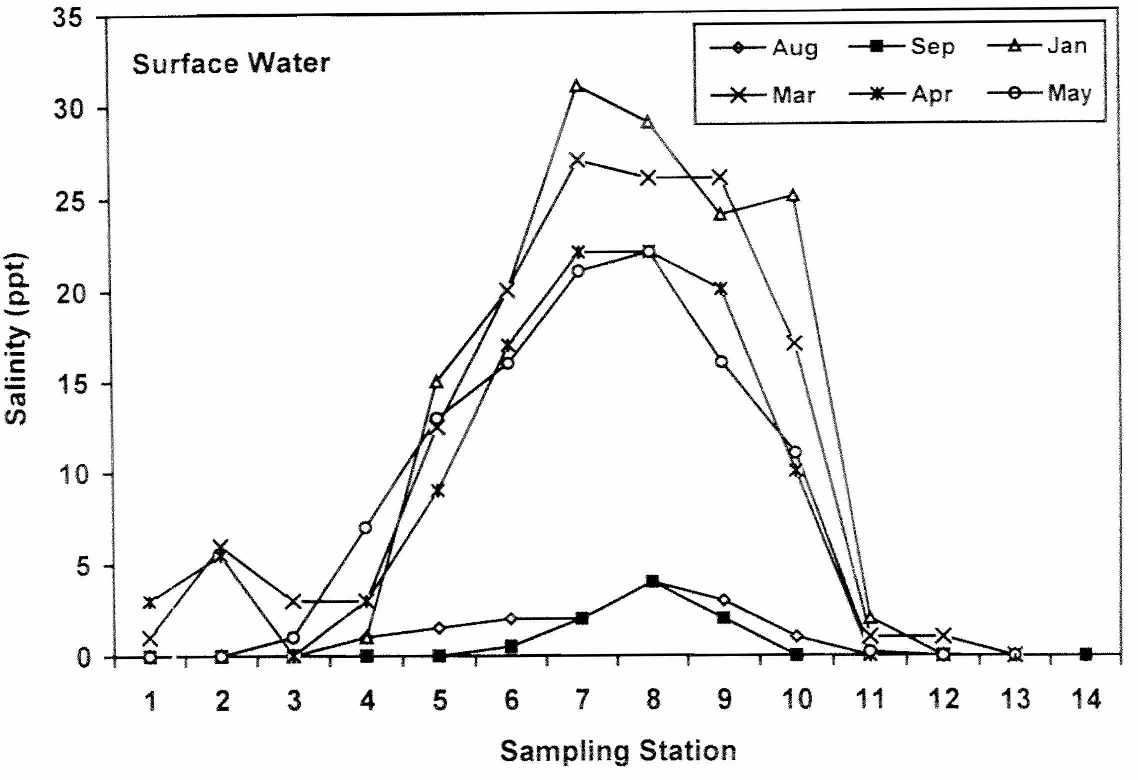




Fig. 3.3.3.7 : Season-wise Distribution of Suspended Solid in Surface and Bottom Waters



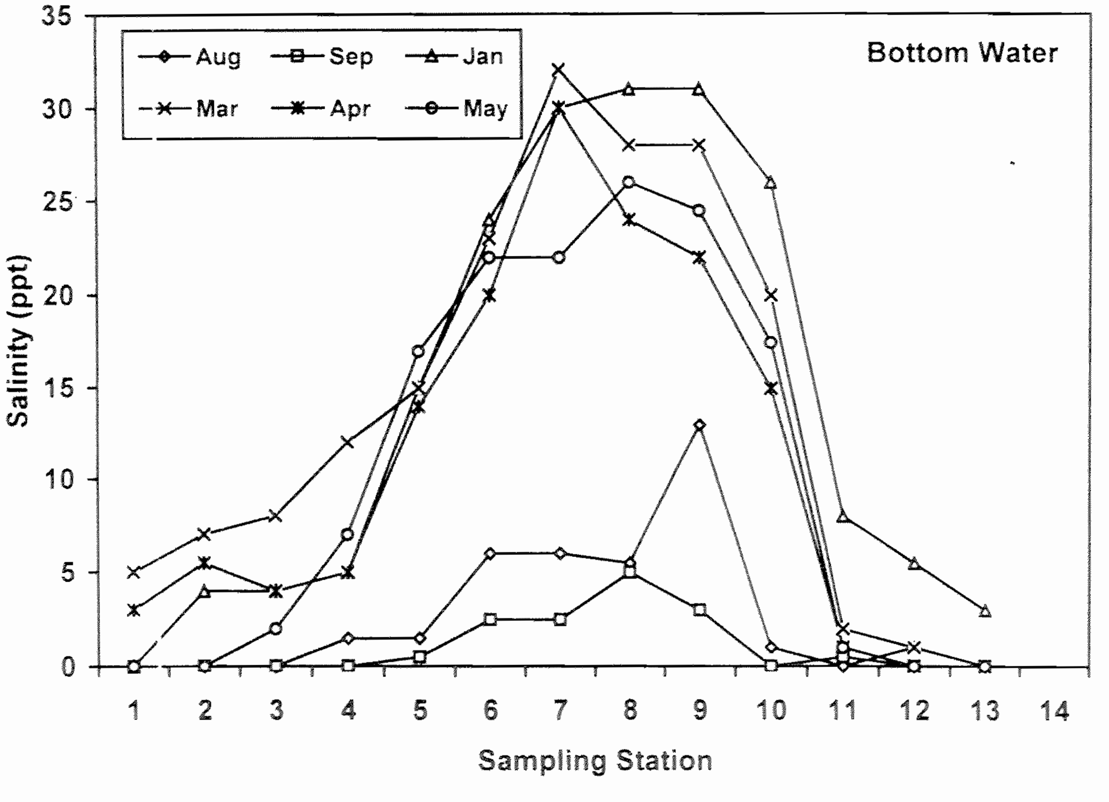




Fig. 3.3.3.8 : Season-wise Distribution of Salinity in Surface and Bottom Waters

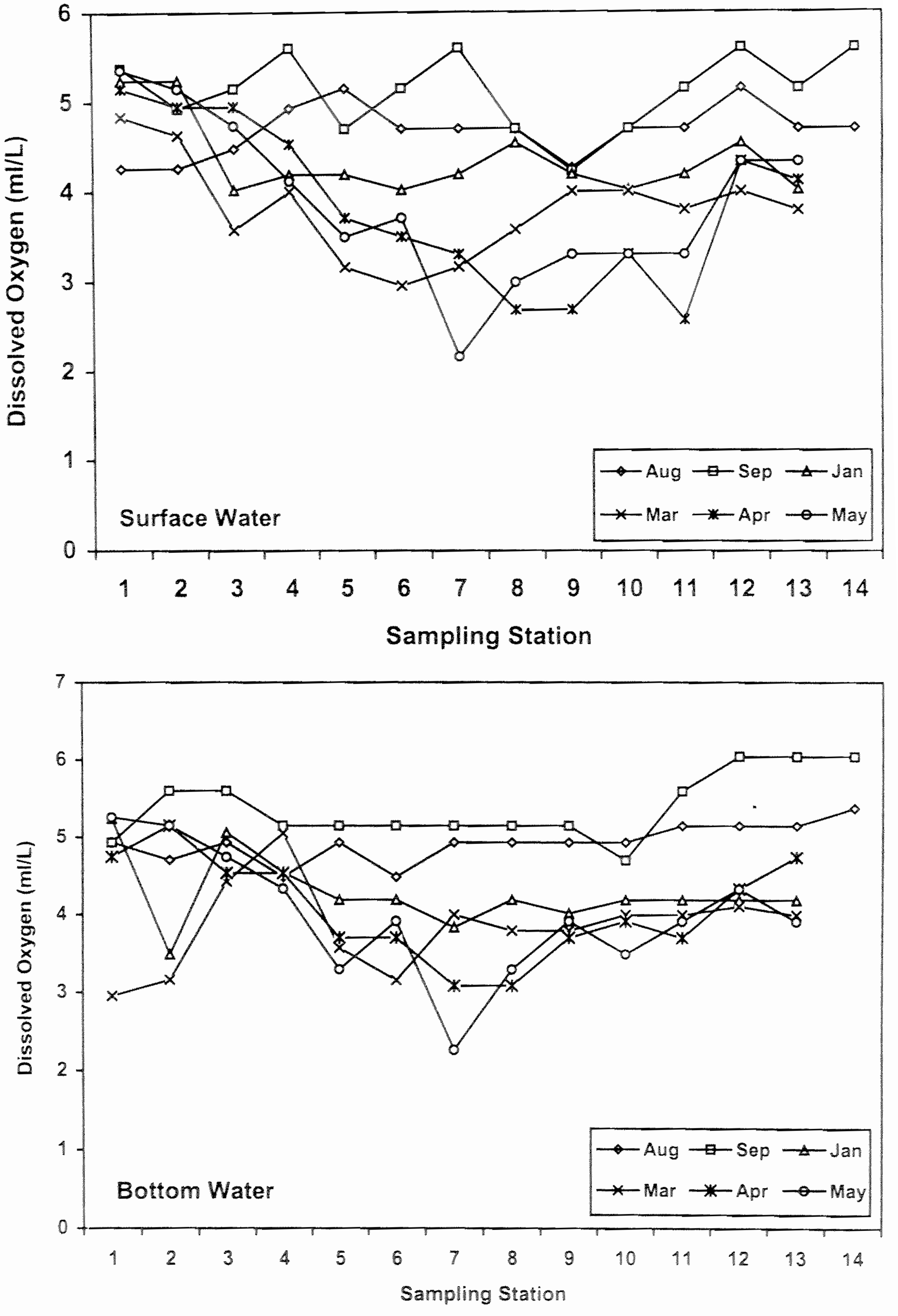



Fig. 3.3.3.9 : Season-wise Distribution of Dissolved Oxygen in Surface and Bottom Waters

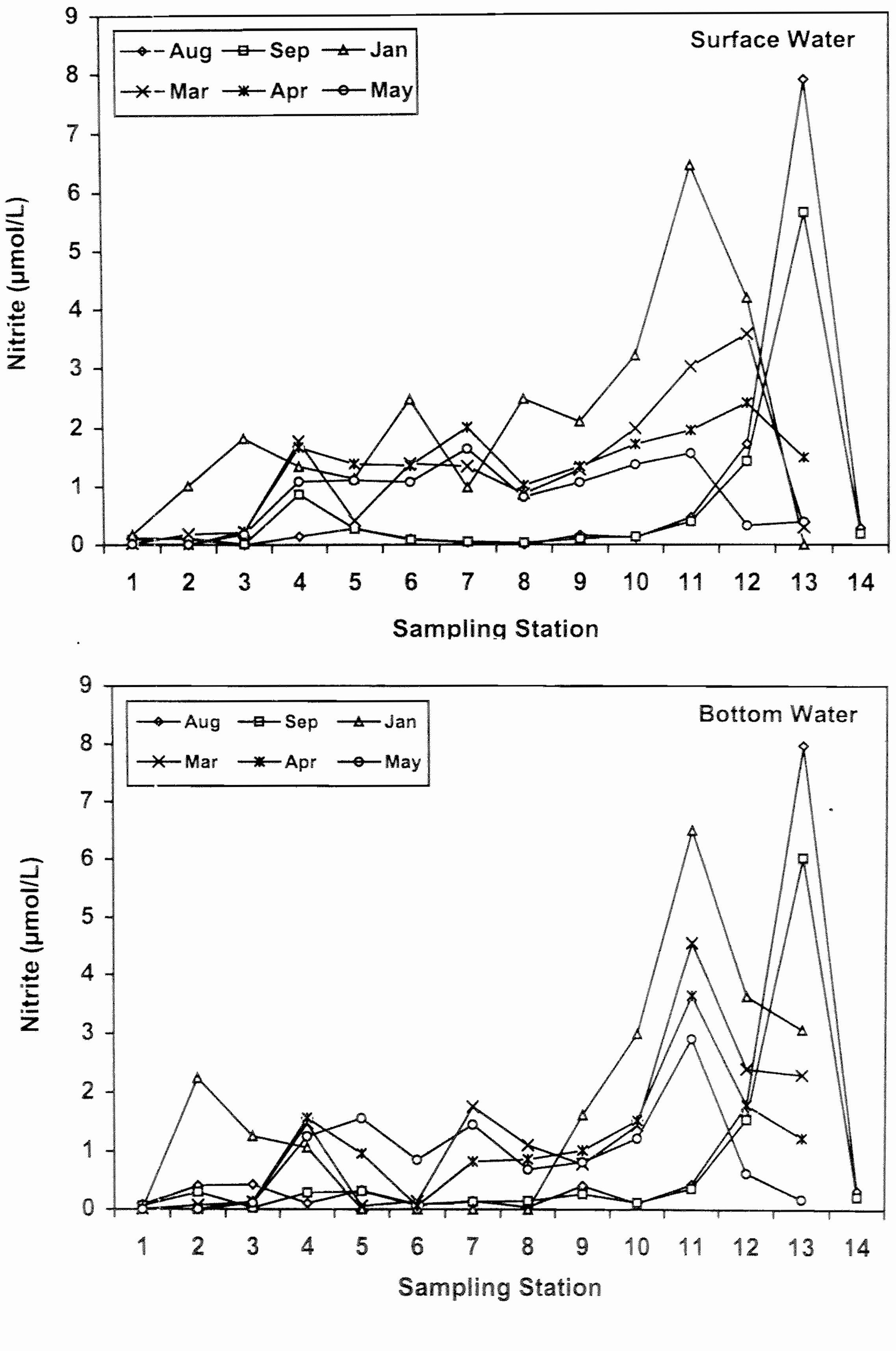



Fig. 3.3.3.10 : Season-wise Distribution of Nitrite in Surface and Bottom Waters

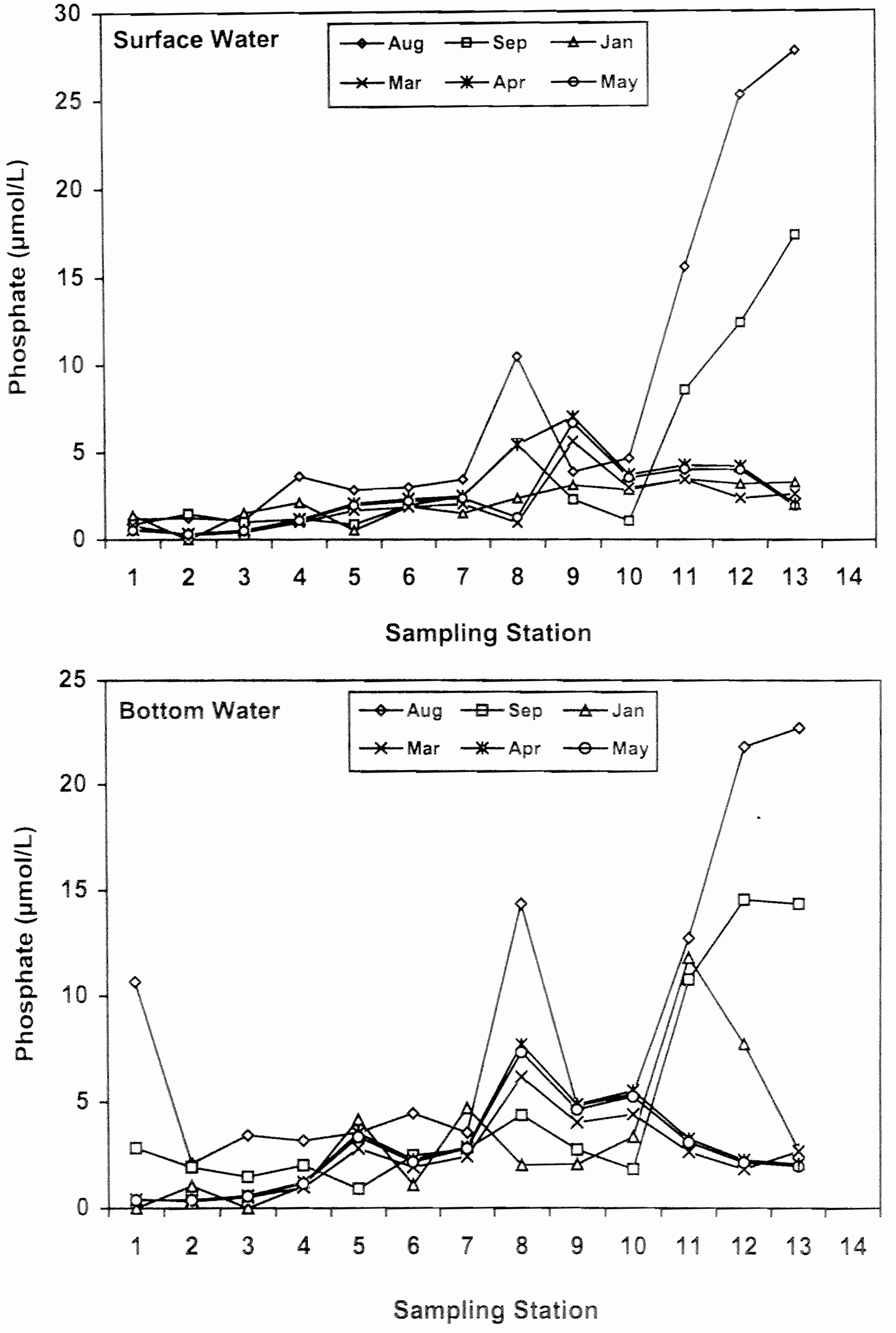
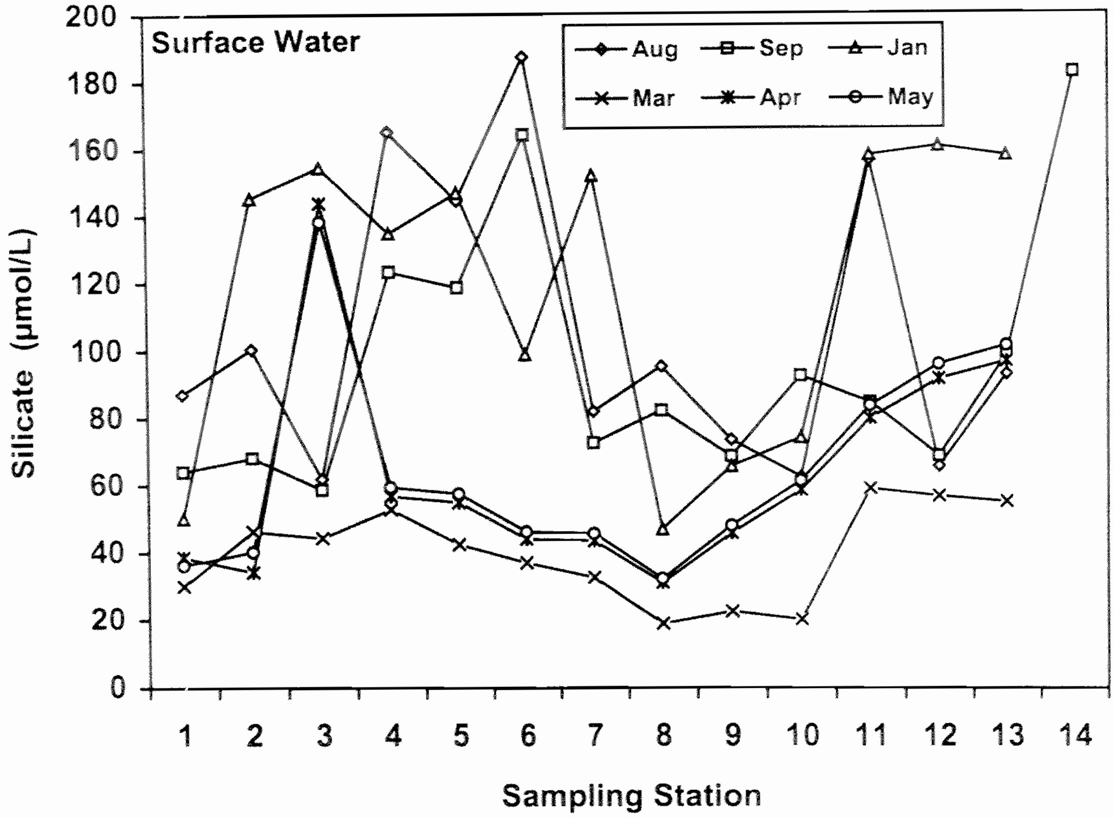



Fig. 3.3.3.11 : Season-wise Distribution of Phosphates in Surface and Bottom Waters



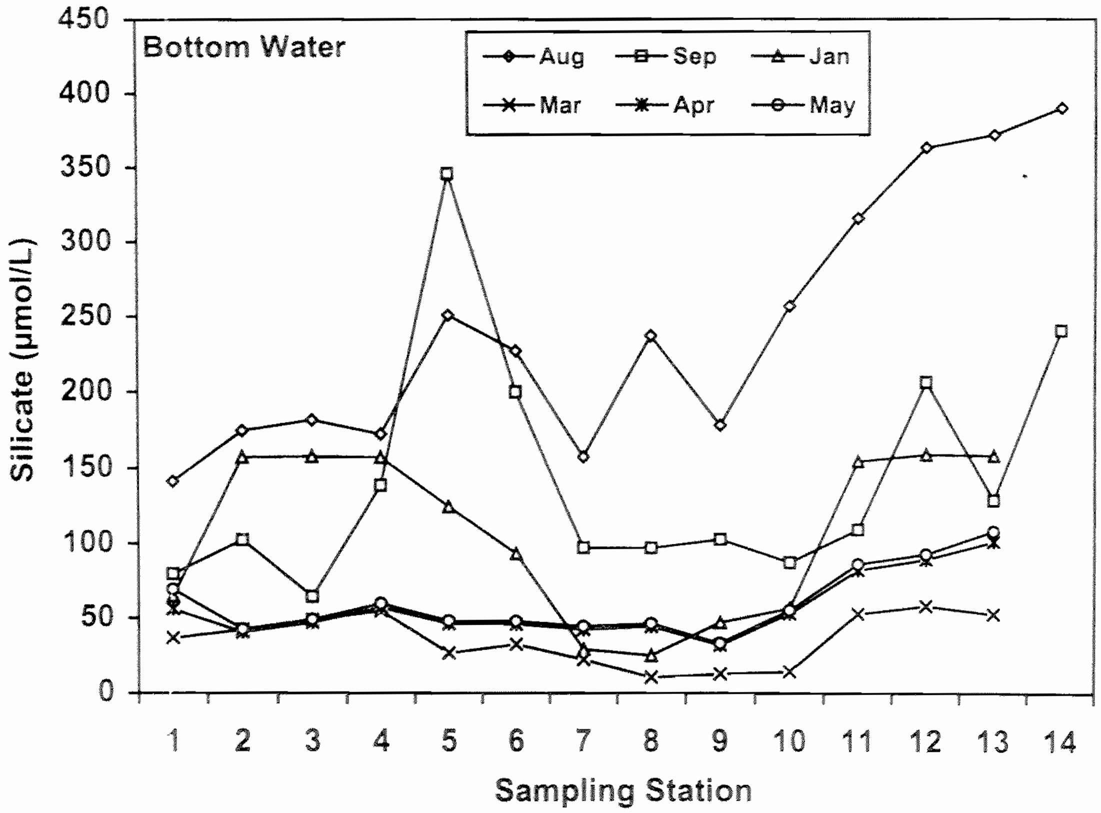




Fig. 3.3.3.12 : Season-wise Distribution of Silicates in Surface and Bottom Waters

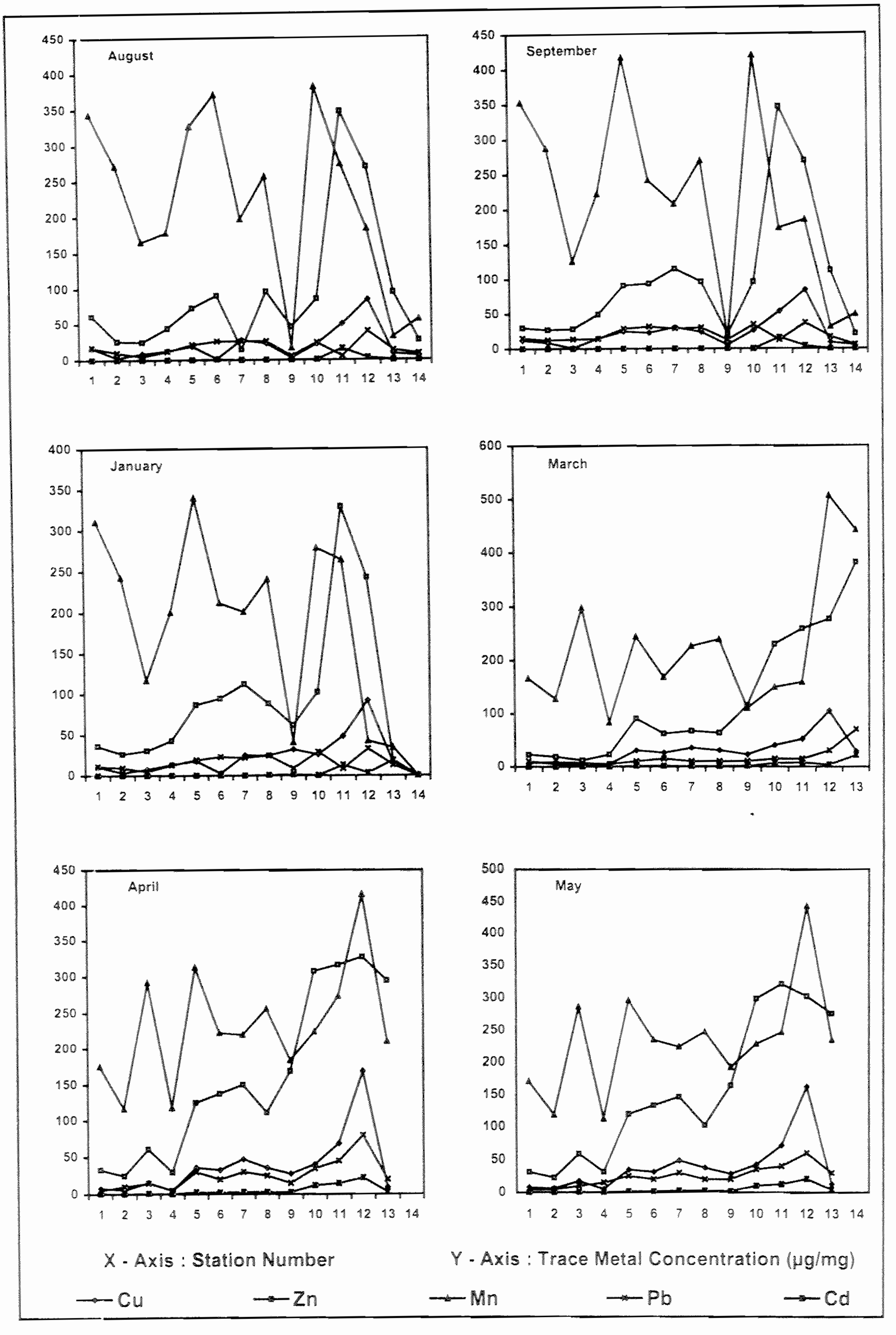



Fig. 3.3.3.13 : Season-wise Distribution of Heavy Metals in Sediments of Vembanad Lake during Different Months

### 3.3.4 Coastal Water

#### 3.3.4.1 Flow characteristics

The primary and secondary data on physical characteristics of coastal waters for the study region were collected for establishing baseline data and for modeling the water quality.

#### 3.3.4.1.1 Tides

Because of the importance of tides in estuary-coastal ocean interactions, hourly tide gauge data at Kochi for the period 1988-1993 was analyzed. Tidal predictions making use of 68 tidal harmonic constituents determined from the hourly data were done for each year. The residuals (observed minus predicted using the 68 tidal harmonic constituents) had a RMS value less than 8 cm for the individual years. The shallow water constituents have amplitude less than 10% of the total amplitude. For the six-year period, it was seen that the shallow water constituents showed considerable inter-annual variability as compared to the principal tidal constituents ($M_2$, $K_1$, $O_1$ & $S_2$ - given in the order of importance). The seasonal cycle is well displayed by the $K_1$ and $S_2$ constituents.

The tides at Kochi were found to be of a mixed, predominantly semi-diurnal type. It was observed that during May 98 and March 99 semi diurnal forcing was more whereas during December 99 diurnal forcing was more. This is mainly due to the sun's movement. Various tidal heights with reference to the Chart Datum are given below:

| | |
|---|---|
| Lower Low Water springs (near Solstices) | +0.20 |
| Mean Lower Low Water | +0.29 |
| Mean Higher Low Water | +0.56 |
| Mean Sea Level | +0.64 |
| Mean Lower High Water | +0.79 |
| Mean Higher High Water | +0.92 |
| Higher High Water Springs near Solstices | +1.05 |

*3.3.4.1.2 Currents*

Currents were measured during April-May, 1998 at three stations off Kochi at 2 km, 4.5 km and 5.5 km away from the coast, where water depths were 3 m, 6.5 m and 8 m, respectively, during March 1999 at two stations at water depth of 10 and 15 m and during December, 1999 at three stations at 5,10, and 15 m depths. Currents were predominantly in southerly direction, during March-May **(Fig. 3.3.4.1)**. During December, the current direction was predominantly towards north **(Figs. 3.3.4.2 to 3.3.4.3)** at two stations (5 and 10 m depths) whereas at offshore station (15 m depth) the surface current was towards west and the bottom current was towards southwest **(Fig. 3.3.4.4)**. Maximum and average current speed and predominant directions during March, May and December are given in **Table 3.3.4.1**. The southerly coastal currents were found to be stronger during May as compared to March. The magnitude of the coastal currents was weaker during December as compared to March and May.

Normally, coastal currents along the West Coast of India are northerly during the northeast monsoon (October-January) and southerly during the southwest monsoon (February-September).

### 3.3.4.2 Physico-Chemical Characteristics

Availability of secondary data on water quality for the study area was limited to a few stations, off Kochi and Alappuzha. Data on water quality collected at three stations (at water depths of 5, 10 and 15 m) each along two transects off Kochi and Alappuzha for a period of eight years were available. Therefore, primary data on water quality of the study area were collected during October 1997, February 1999 and November 2000, because these months represent the transitional periods from northeast monsoon to southwest monsoon and from southwest monsoon to northeast monsoon respectively. These months cover the lean period as regard to the fresh water inflow and turbulence of the sea, and, therefore, form the critical period as far as the assimilative capacity of coastal waters is concerned.

#### *3.3.4.2.1 Secondary Data*

Range of water quality parameters off Kochi and Alappuzha at 5, 10 & 15 m depths as compiled from secondary sources are presented in **Table 3.3.4.2** and discussed briefly here.

Dissolved oxygen in the surface water off Kochi barmouth did not vary during the period of 1989-1997. At 5, 10 and 15 m depth stations off Kochi DO shows an increasing trend in the surface and bottom waters. DO at the surface of 5 and 10 m depth stations off Alappuzha showed a decreasing trend during the period of 1989-1997 and the bottom values at all stations (5, 10 & 15 m) and the surface value at 15 m showed an increasing trend. The trend shows a general increase in the oxygen levels over the years. Oxygen saturation levels were always greater than 80% in the coastal waters and therefore, coastal waters appear to be well oxygenated.

Nitrite value in the surface water off Kochi at 5 m station showed an increasing trend from 1990 to 1998 and decreasing trend in the bottom waters. At 10 and 15 m stations, the surface and bottom water nitrite concentrations were found decreasing. Nitrite concentration in the surface water samples of 5 m and 10 m stations off Alappuzha showed a nearly constant value during the period 1990-1998 and in the bottom water the concentration showed a decreasing trend.

Ammonia values of Kochi barmouth showed an increasing trend in the bottom waters and a decreasing trend in the surface waters during the period 1989-1998.

Nitrate value in the surface and the bottom waters at Kochi barmouth decreased during the period 1989 to 1997. At the 5 m depth station off Kochi, the nitrate value showed an increasing trend in the surface and bottom waters, where as it showed a decreasing trend at the 15 m and 10 m stations at surface and an increasing trend in the bottom water of 10 m depth station. In Alappuzha region, all the stations (5, 10 and 15 m) showed an increasing trend in nitrate values during the period 1990-1998.

Phosphate in the surface water of Kochi barmouth showed a nearly constant value, whereas the bottom water showed an increasing trend during 1987 to 1998. Phosphate value in the surface water off Kochi at 5 m depth station showed an increasing trend whereas in the bottom water, the value showed a decreasing trend. At the 10 m and 15 m depth stations, it showed a decreasing trend at the surface and bottom waters. In Alappuzha region, phosphate concentration at 5 m depth station showed an increasing trend at the surface and a decreasing trend in the bottom for the period 1990 - 1998. At the 10 and 15 m depth stations, it showed a decreasing trend in the surface and bottom waters.

Silicate in the surface waters at the Kochi barmouth showed a decreasing trend during the period 1989 to 1997, whereas in the bottom waters almost a constant value was observed as compared to surface waters.

Some of the heavy metals (dissolved) in the water do not show any definite trend over the years. Concentration of copper varied from <0.40 to 3.0 $\mu$g/l, zinc from below detectable levels to 9 $\mu$g/l, cadmium from below detectable levels to 0.8 $\mu$g/l and lead was not detectable.

*3.3.4.2.2 Primary Data*

On scrutiny of the secondary data available on the above mentioned parameters, it has been observed that the data on environmental parameters is scanty, though time series data on water quality parameters were available for a few stations; off Kochi and Alappuzha. Therefore, primary data on water quality of the costal waters of GKR (Thottapally in the south to Azhikode in the north) were collected during October 1997 and during February 1999 and November 2000 at 45 stations each along 9 transects perpendicular to the coast (**Fig. 3.3.4.5**), covering a distance of about 120 km. The ranges of water quality parameters are shown in **Table 3.3.4.3** along with the trace metals content in surface water and sediments. Summary of range of physico-chemical characteristics of coastal waters during the month of October (1997), February (1999) and November (2000) are given in **Table 3.3.4.4**, where as the concentration levels of different trace metals are given in **Table 3.3.4.5** and discussed here.

**Coastal water quality during October 1997**

Data on water quality parameters are summarized in **Table 3.3.4.4** and presented through **Figs. 3.3.4.6** to **3.3.4.10.**

Surface water temperature varied from 28 to 31.2°C and decreased from surface to bottom. The bottom water temperature varied from 25 to 26.8°C. In the near shore water, pH showed low values compared to the open ocean and the value increased towards offshore. The pH value varied from 7.9 to 8.3. The DO concentration varied between 1.5 to 5.1 ml/L in the surface water and between 1.2 to 4.9 ml/L in the bottom water. BOD varied up to 4 mg/L, the highest value was observed at the bottom samples as compared to mid depth or surface water samples. The salinity value varied from 24.9 to 34.4 psu. The surface salinity showed wide fluctuations compared to the bottom and mid depth values.

Concentration of nitrite was generally high in the bottom as compared to surface water except in the near shore water off Kochi. At near shore stations off Kochi, the nitrite values were high in the surface waters. This may be due to the input of nitrite from the Kochi estuarine system. The concentration of nitrite in the coastal water depends on various factors such as bacterial decomposition of planktonic detritus, effluents discharged, phytoplankton excretion, oxidation of ammonia and reduction of nitrate.

Nitrate value in the study area varied between ND levels to 24.1 μmol/L. Nitrate shows high values compared to nitrite which may be due to the fact that nitrate is thermodynamically the most stable oxidation level of nitrogen in the presence of oxygen and could accumulate if left unutilized. Nitrate values in the offshore stations showed high values that may be due to oxidation of ammonia. Nitrate distribution pattern of surface and bottom water was similar in all stations off Kochi (5, 10 & 20 m depth), maximum values were observed during monsoon season of 1987. The mean values were higher in the surface waters as compared to that of bottom during monsoon.

The concentration of ammonia in the study area varied from ND level to 45.09 μmol/L and the majority of the stations showed very low values. The higher value of ammonia in the subsurface and surface water is partly due to the death and subsequent decomposition of phytoplankton and anthropogenic input. The gradual decrease of ammonia concentration from near shore to offshore stations and the corresponding increase in nitrate may be due to oxidation of ammonia to more stable forms of nitrogen.

Phosphate value in the surface and bottom waters of the study area during October decreased from near shore to the offshore stations. The concentration of phosphate in the bottom water was high as compared to that of the surface waters. In surface waters, it varied from 0.01 to 3.06 μmol/L and in the bottom waters; it varied from 0.03 to 2.10 μmol/L. The average phosphate concentration at 5, 10 & 20 m depth stations was high (0.55 μmol/L) in the surface water during monsoon 1987 and at bottom during pre-monsoon (0.62 μmol/L). The phosphate concentration showed high values in the 10 and 30 m depth stations during pre-monsoon and for 20 m during monsoon.

Silicate value was not uniform in the water column of the study area, usually the bottom water shows high values and at a few stations, the surface waters showed high values especially in the off Kochi stations. It varied between 1.02 to 18.05 μmol/L. At the surface and bottom waters, distribution of silicate was similar in all stations off Kochi; the maximum value was reported during post monsoon. Maximum value was 18.05 and 16.42 μmol/L respectively in surface and bottom waters.

Occurrence of higher concentration of nutrients along some transects indicates that the utilization of nutrients was not optimum perhaps because of sunlight limitation to photosynthesis due to high turbidity. The concentration of nutrients in the study area clearly indicates that the estuarine system introduces nutrients in to the coastal water. Higher levels of nutrients are concentrated very close to the coast within 5 km distance. In the offshore region (>10 km distance from the coast) the nutrient levels are low.

Dissolved trace metals in surface and bottom waters showed wide fluctuation in the study area **(Table 3.3.4.5).** The range of concentrations (in µg/L) observed were: Cu: 3.0 - 11.9; Cd: 0.9 - 8.8; Cr: ND - 3.5; Co: ND - 7.9; Ni: ND - 27.7; Pb: ND - 8.3; Mn: ND - 19.9; Zn: 10.4 - 42.3; and Fe: 4.0- 381.0.

**Coastal Water Quality during February 1999**

Data on water quality parameters collected at 45 stations in the coastal waters during February 1999 are presented in **Table 3.3.4.4** and through **Figs. 3.3.4.11** to **3.3.4.15.**

Water temperature varied from 28.8 to 32.5°C. In near shore water pH showed low values compared to the open ocean and the value increases towards offshore. The pH value varied from 6.6 to 8.3.

DO varied between 2.9 to 6.7 ml/L. The lowest values occur at the bottom and highest at the surface. BOD varied between 0 to 3 mg/L, the highest value was observed in the surface and the bottom waters as compared to mid depth water samples. The salinity varied from 29.9 to 32.6 psu.

Nitrite concentration in the surface and bottom waters decreased in concentration from near shore to offshore and the value varies from 0.0 level to 4.09 µmol/L. Nitrate value in the study area varied between 0.32 and 11.2 µmol/L. Phosphate value in the surface and bottom waters of the study area during decreased from near shore to the offshore stations. The concentration of ammonia in the study area varied from ND level to 7.49 µmol/L and the majority of the stations showed very low values. The silicates varied from 0.17 to 12.91µmol/L.

Dissolved trace metals showed wide fluctuation in the study area **(Table 3.3.4.5).** The ranges of concentration (in µg/L) observed were: Cu: 0.8 – 5.6; Zn: 5.9 – 174.7; Fe: 0 – 526; Pb: ND – 14.1; Cd: ND – 9.1; Ni & Co: ND.

**Coastal Water Quality during November 2000**

Data on water quality parameters collected at 45 stations (**Fig. 3.3.4.7b**) in the coastal waters during November 2000 are presented in **Table 3.3.4.4** and through **Figs. 3.3.4.16** to **3.3.4.20.**

Water temperature varied from 29°C to 31°C. The salinity values vary from 31.29 to 35.92 psu. Temperature and salinity profiles indicate vertically mixed water column with maximum of 1° gradient in temperature and 1 psu in salinity. DO values showed a variation between 2.96 to 4.98 ml/L. The lowest value at the bottom and highest at surface was observed. BOD values showed a variation between ND to 3.6 mg/L. Comparatively highest values were observed at surface and bottom as compared to mid depths.

Nitrite values vary between ND level to 2 µmol/L. The variation in the study area was from ND to 3.4 µmol/L. Ammonia showed a variation from ND to 7.0 µmol/L. Phosphates varied between 0.2 to 3.8 µmol/L. Silicates showed a variation between 0.6 & 14.6 µmol/L and the variation of PHC was between ND to 65 µg/L. The higher values were observed towards the Cochin barmouth region (65 µg/L) and a decreasing trend was observed towards the offshore region.

Only Cu, Zn and Fe were observed in dissolved phase in the samples. Dissolved metals showed wide fluctuation in the study area (**Table 3.3.4.5**). Fe was the abundant element, with concentrations ranging from 8 to 617 µg/l in the surface waters and 263 to 921 µg/L in the bottom waters along the offshore waters. At the near shore stations, dissolved Fe ranged from 173 to 617 µg/L in the surface and 327 to 921 µg/L in the bottom waters respectively. Dissolved Zn in offshore waters was in the range of ND to 10 µg/L in surface and ND to 9 µg/L in the bottom layers. Along the near shore stations, the values were in the range of ND to 17 µg/L (surface) and ND to 9 µg/L (bottom) respectively. Range of dissolved Cu in offshore waters was from ND to 3 µg/L (surface) and ND to 2 µg/L (bottom) and coastal near shore waters, it ranged from ND to 7 µg/L (surface) and ND to 2 µg/L (bottom).

### 3.3.4.3 Coastal Water Sediment Quality

The bottom sediment largely consisted of clay, followed by silt and sand. The organic carbon varied from 0.4 to 29.7 mg/g. The bottom sediment was clayey, silt dominated the substratum holding high organic carbon content ranging between 1.7 and 33.8 mg/g during February. The data are presented in **Table 3.3.4.6** and **Fig. 3.3.4.21.**

Sediment characteristic in the study area during November showed the dominance of clayey portion holding high organic carbon contents. Except for a few low values, the organic carbon ranged between 10.8 and 40.7 mg/g **Fig. 3.3.4.22**.

#### *3.3.4.3.1 Trace Metal Distribution in Sediments*

Study of the trace metal levels in seawater is very important from the point of view of their possible adverse effects on marine biota. Shellfishes by their ability to concentrate trace metals from the environment are considered to be useful indicators of metal pollution. Many of the trace metals get adsorbed on to the particulate matter and are ultimately deposited at the bottom. Hence, sediments usually provide a reliable estimate of metals pollution status. The relationship between the gross concentration of heavy metals in solution and its ability to cause toxic effects in an organism is a complex one, and is mostly decided by the speciation of metal and the condition of the organism. Whether or not a trace metal can interact with the biota depends on its bio-availability in the medium.

#### Trace Metal Distribution in Sediments during October 1997

Trace metals concentrations in the sediments of the study area during October 1997 (**Table 3.3.4.7**) were found to be high and there were no significant difference in their distribution. The ranges in metal concentrations (in μg/g) were: Cu: 1 to 34; Cd: 1 to 4; Cr: 31 to 199; Co: 5 to 40; Fe: 6 to 43; Ni: 16 to 213; Pb: 18 to 60; Mn: 118 to 773; and Zn: 23 to 155 as presented through **Figs. 3.3.4.23** & **3.3.4.24** respectively

**Trace Metal Distribution in Sediments during February 1999**

The results of the sediment analysis of the study area carried out during Feb 1999 are furnished in **Table 3.3.4.7** and **Figs. 3.3.4.25** & **3.3.4.26.** The impact of anthropogenic heavy metals in the shelf region is evident from the contours drawn in the figures. The higher metal concentrations were located along the coastline, and there was a gradient in the levels towards the mid-shelf. This gradient took place across sediment of similar texture and composition. Thus, the distribution can be attributed to the offshore diffusion of anthropogenic contamination. This trend was interrupted by a strong local anomaly in the mid-shelf, north of the river mouth and towards the inner-shelf around Ambalapuzha, where the metals tend to accumulate in the bottom.

It is evident from the figure that the most contaminated sediment accumulated southwards from the river mouth, along the inner-shelf (< 30 m), indicating that the sediment sources from the backwaters as well as from the dredge spoil dump sites were re-oriented by coastal currents prevailing in this direction. The two major sites identified for dumping the dredged materials of harbors area are located at 10-12 m depths north and south of the navigational channel. A portion of the sediment from the northern dumping zone, due to the strong barrier effect of the river mouth may drift northwards of the channel and finally get deposited in the mid-shelf region as seen in the contour maps. This distribution corroborates that the dispersion processes at the dumping sites are less effective. In the outer-shelf, heavy metal concentrations are very low and this region can be considered as an unpolluted area.

Concentration of trace metals in the Kochi area showed high values in the near shore stations compared to offshore stations, which may be due to the input from the Kochi estuarine system and dumping of dredge spoil in the near shore area.

**Trace Metal Distribution in Sediments during November 2000**

Trace metal concentrations, in general, were lower than the samples taken during October 1997 but higher than the survey carried out in February 1999. **Table 3.3.4.7** and **Figs 3.3.4.27** & **3.3.4.28** present the levels of various trace metals in the sediments samples collected during November 2000. The concentration range for the trace metals (in μg/g) were: Fe: 0 to 57; Mn: 0 to 430; Zn: 0 to 274; Cr: 0 to 205; Pb: 0 to 112; Ni: 0 to 83; Cu: 0 to 50; Co: 0 to 53; Cd: below detection limit to 3.7 (dry weight).

**3.3.4.4 Microbial Characteristics**

Secondary data on total Coliforms off Kochi are reported to be in the range of 7 to 50 Nos./ml in water and 8 to 18 Nos./mg in sediments. Off Alappuzha, the total Coliforms were reported to be less than 14 Nos./ml in water and less than 30 Nos./mg. in sediments. Bacteria count in coastal waters and sediments off Kochi and off Alappuzha is given in **Table 3.3.4.8.**

Primary data on bacteria were collected during October (1997), February (1999) and November (2000). Station wise bacterial counts are summarized in **Tables 3.3.4.9** to **3.3.4.11** respectively for the above three sampling periods.

**Data collected during October 1997**

**Heterotrophic Bacteria** were found in large numbers in sediments as compared to that in water. Among the deep stations the highest count was as 206/gm, from the sediments of Pallippuram (Parur), and among the shallow stations, the highest count was 328/gm, from the sediments off Kochi.

**Coliforms** were isolated from all the stations. Their highest count among the deep stations was 28/ml, from the water at Kanda Kadavu and among the shallow stations; the highest count was 34/ml, from the water sample collected at Parur region.

**E. coli** (*Escherichia coli)* was isolated in meagre numbers from a few stations. Their highest count was 2/ml from Kandakadavu region. **Faecal Streptococci** were isolated in lesser numbers. But from their higher counts were noted in sediments of stations near Kandakadavu (48/gm). Parur (48/gm), south Kuzhippilly (38/gm) etc. **Pseudomonas Aeruginosa** was isolated in small numbers, throughout the period of study. The highest count recorded was 6/gm, from the sediments of S. Mundamveli. Human pathogens like ***Salmonella, Shigella, Proteus*** etc. were isolated in small numbers throughout the period of study. Presence of *salmonella* was positive only in the water collected from Azhikkal, while occurrence of *shigella* was noted in the sediments collected from S. Kuzhippilli region. The presence of *proteus* sp. was common in almost all stations but only in meager numbers. The highest count obtained was 20/gm, from the sediments of Azhikkal region.

**Vibrio Parahaemolyticus** was found in lesser numbers in most of the stations. The highest count obtained was 28/gm, from the sediments off Fort Kochi region. The occurrence of **Vibrio Cholerae (Non-01)** was found to be much less, except from Kandakadavu region. The highest count 49/g was obtained in the sediments from Kandakadavu region (**Table 3.3.4.9**).

The higher incidence of heterotrophs indicates the higher nutritional status of the ecosystem, i.e., the higher inflow of the nutrients into the ecosystem. The results of analysis have shown that the Kochi region is having the higher heterotrophs counts. The indicator group of bacteria i.e. coliforms, *E. Coli, faecal streptococci* indicate the organic pollution prevailing at Azhikkal, Kandakadavu, S. Mundamveli region.

Human pathogens like *salmonella, shigella*, and *proteus* were isolated in lesser numbers. *Salmonella* was isolated from Azhikkal region, while presence of *shigella* was recorded at Azhikkal, S. Kuzhippilli and Kandakadavu.

*V. Parahaemolyticus* and *V. Cholerae non-01* are also pathogenic organisms. Higher counts of these organisms may cause diarrhea to human beings. Higher counts of *V. Cholerae non-01* were noted in Kandakadavu region. This denotes the organic pollution prevailing in the ecosystem.

**Data collected during February 1999**

**Heterotrophic Bacteria:** The general incidence of heterotrophs in water and sediments was very high in all the 45 stations along the area of study. Higher incidence of these organisms in the sediments of the stations was a notable phenomenon. Near shore stations were having lesser representation of these organisms while deep stations higher. The highest count registered was 374/ml from the surface water of shore station near Kannamali.

The occurrence of **Coliforms** varied significantly from south to north. The highest incidence was seen near Anthakaranazhi and Kannamali region. Bottom water of this study area generally yielded lesser numbers of coliforms while sediments higher. The highest count registered was 68/gm from the sediment of a shore station at Cherai (Parur). Distribution of **Faecal Coliforms** in the surface and bottom waters at various stations is presented in **Fig. 3.3.4.29**. Faecal coliforms were totally absent in stations at Thottapally, Ambalapuzha and Alappuzha. In the region from Alappuzha to Kodungallur, these organisms occurred rarely in lesser quantities in surface and bottom water and sediment. The highest count registered was 12/ml in a near shore station at kodungallur.

The incidence of **Faecal Streptococci** was much high when compared to the faecal coliforms in all the stations. These organisms were isolated from near shore stations as well as from deep stations in both from water and sediment. High incidence was recovered from the surface water excepting from Cherai to Kodungallur area. The highest count recorded was 22/ml from a near shore station between Alappuzha and Andhakaranazhi. ***Salmonella* sp.** was totally absent in the area of study during the observation. **Vibrio Cholerae Non-01** though in rare numbers, were recorded from surface and bottom water and sediments. Alappuzha, Andhakaranazhi and Kochi were the regions from where these organisms were isolated. The highest count registered was 6/ml from a near shore station at Alappuzha. The incidence of ***Pseudomonas* sp.** was found to be very meager in the study area. These organisms were present in lesser numbers in station near Alappuzha, Kochi and Cherai. The highest count recorded was 9/gm from a shore station at Cherai.

In general, stations off Alappuzha, Kochi and Cherai were having comparatively higher degree of bacterial contamination. The total absence of s*almonella* and the meager occurrence of *faecal coliforms* during the period of study are notable features. Occurrence of *faecal streptococci* in comparatively higher numbers could be attributed to the faecal pollution caused by non-human sources in this area. The occurrence of *vibrio cholerae* non01 and *pseudomonas* sp. in surface and bottom waters and sediments indicate that the coastal water region is not free from organic pollution. The very high incidence of heterotrophs in water and sediment denotes that this vast stretch of coastal water region is rich in nutrient flows (**Table 3.3.4.10**).

**Data collected during November 2000**

**Heterotrophic bacteria** Heterotrophic bacterial population was comparatively lesser in incidence than that of pre-monsoon. Stations off Andhakaranazhi, Azhikode, and Edavanakad were having lesser representation of these bacteria than that during post-monsoon. The highest count recorded was 536/gm from the sediment of the nearshore station off Edavanakad. The heterotrophic bacterial population maintained the general trend of the coastal water ecosystem (more incidences in sediment than that of water).

**Coliforms** incidence in the coastal water was high generally. Isolation of Coliforms was positive and high in deep stations especially in sediments. The highest count registered was 68/gm from the sediment of the deep station off Kannamaly. **Faecal coliforms** incidence was significantly high in coastal water between Ambalapuzha and Andhakaranazhi. These organisms were found in comparatively high numbers in the sediments of this region. Faecal coliforms were present off Kochi and Edavanakad. The highest count recorded was 8/ml from the surface water of the near shore station off Kochi. Distribution of heterotrophs, coliforms and faecal coliforms in surface and bottom waters is given in **Fig. 3.3.4.30**.

**Salmonella** were isolated from the surface water in the shore stations off Kochi and Azhikode. The presence of the pathogen from these coastal waters is very significant since their presence indicates the highly polluted nature of the ecosystem at large. **Vibrio cholerae** occurrence was also very high when compared to that of pre-monsoon. High counts of these organisms from the surface water indicate the influence of municipal waste discharge and also of land discharge to a great extent. The highest count recorded was 6/ml from surface water of the shallow station off Kochi. These organisms were frequent in the stretch of the coastal water between Thottapally and Kochi.

To summarize, it may be stated that the stretch of coast water region between Thottapally and Kochi is subjected to a continuous influence of land drainage. The high counts of faecal coliforms, Vibrio cholerae and the presence of Salmonella though at two stations indicate that the coastal water stretch between Thottapally and Azhikode is not free from organic pollution. The counts of heterotrophs were generally less through out, however the fair counts of these organisms from the sediments indicate that the region is benefited by the inflow of nutrients by mixing (**Table 3.3.4.11**).

Table 3.3.4.1

Maximum and Average Current Speed and Predominant Direction off Kochi

| Station Depth (m) | Depth of Measurement (m) | Maximum Speed (m/s) | Average Speed (m/s) | Predominant Direction (deg. North) |
|---|---|---|---|---|
| **May 1998** | | | | |
| 3.0 | 1.5 | 0.24 | 0.10 | 180° |
| 6.5 | 1.0 | 0.90 | 0.20 | 170 - 350° |
| 6.5 | 4.0 | 0.74 | 0.08 | 170 - 330° |
| 8.0 | 1.0 | 0.39 | 0.18 | 170 - 220° |
| | 6.0 | 0.28 | 0.10 | 180° |
| **March 1999** | | | | |
| 10.0 | 0.5 | 0.70 | 0.19 | 240 - 330° |
| 15.0 | 0.5 | 0.24 | 0.10 | 120 - 210° |
| **December 1999** | | | | |
| 5.0 | 4.5 | 0.25 | 0.13 | 330 - 030° |
| 10.0 | 0.5 | 0.50 | 0.17 | 270 - 360° |
| 10.0 | 9.5 | 0.30 | 0.10 | 330 - 360° |
| 15.0 | 0.5 | 0.26 | 0.11 | 270 - 330° |
| 15.0 | 9.5 | 0.07 | 0.03 | 210 - 270° |

**Source :** Primary data collected by NIO

## Table 3.3.4.2

### Summary of Range of Coastal Water Quality Parameters off Kochi and Alappuzha (1989 - 1998)

| Depth | | Temp ($^0C$) | Salinity (PSU) | pH | DO (ml/L) | $BOD_5$ (ml/L) | $NO_2$-N (µmol/L) | $NO_3$-N (µmol/L) | $NH_4$-N (µmol/L) | TN (µmol/L) | $PO_4$-P (µmol/L) | TP (mg/L) | $SiO_4$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Off Kochi** | | | | | | | | | | | | | |
| 5 m | S | 27.5-32.0 | 27.4-34.7 | 7.9-8.6 | 2.0-5.6 | 0.0-3.6 | 0.1-2.5 | 0.0-15.7 | 0.0-5.2 | 0.9-34.1 | 0.2-1.4 | 0.4-5.2 | 1.8-18.8 |
| | M | - | - | - | - | - | - | - | - | - | - | - | - |
| | B | 27.0-31.5 | 38.1-35.6 | 8.0-8.7 | 2.0-5.3 | 0.0-4.7 | 0.2-2.5 | 0.1-38.8 | 0.0-12.9 | 0.6-18.9 | 0.2-2.6 | 0.4-2.3 | 2.1-22.5 |
| 10 m | S | 28.0-32.0 | 27.7-34.8 | 8.0-8.3 | 3.1-5.2 | --- | 0.1-1.2 | 0.0-34.6 | 0.0-14.9 | 1.4-25.2 | 0.3-1.5 | 0.5-2.5 | 1.7-14.6 |
| | M | 26.0-32.0 | 28.1-34.9 | 8.0-8.8 | 3.1-5.1 | --- | 0.0-1.5 | 0.0-24.6 | 0.0-5.2 | 1.6-19.1 | 0.2-0.1 | 0.5-1.5 | 2.4-15.4 |
| | B | 27.5-31.5 | 28.1-35.2 | 8.0-8.8 | 2.1-4.9 | --- | 0.2-1.9 | 0.9-6.7 | 0.0-3.7 | 1.8-12.8 | 0.4-1.5 | 0.5-4.3 | 1.1-11.6 |
| 15 m | S | 26.6-31.5 | 28.8-31.5 | 8.0-8.8 | 3.2-5.2 | 0.0-3.1 | 0.0-1.5 | 0.0-8.8 | 0.0-8.4 | 0.3-21.2 | 0.2-1.5 | 0.2-11.9 | 0.4-12.4 |
| | M | 26.5-31.0 | 28.1-31.0 | 8.1-8.8 | 2.8-5.8 | --- | 0.0-1.2 | 0.0-4.1 | 0.0-6.6 | 0.2-18.3 | 0.2-2.0 | 0.4-4.3 | 0.5-10.8 |
| | B | 26.4-31.0 | 26.4-31.0 | 8.1-8.8 | 1.4-6.6 | 0.5-3.9 | 0.1-1.0 | 0.1-10.1 | 0.0-11.5 | 1.2-17.5 | 0.3-4.5 | 0.1-5.2 | 1.2-9.9 |
| **Off Alappuzha** | | | | | | | | | | | | | |
| 5 m | S | 28.0-32.5 | 31.6-35.2 | 8.0-8.3 | 3.7-5.7 | 0.5-3.7 | 0.1-0.9 | 0.0-16.4 | 0.0-5.1 | 1.1-20.9 | 0.1-0.9 | 0.7-2.2 | 0.4-20.2 |
| | M | - | - | - | - | - | - | - | - | - | - | - | - |
| | B | 28.0-32.0 | 32.0-35.7 | 8.0-8.3 | 2.5-4.9 | 0.2-2.2 | 0.1-2.0 | 0.5-9.3 | 0.0-6.8 | 1.0-21.4 | 0.2-1.6 | 0.5-1.8 | 0.8-22.5 |

Contd...

Table 3.3.4.2 contd..

| Depth | | Temp ($^0C$) | Salinity (PSU) | pH | DO (ml/L) | $BOD_5$ (ml/L) | $NO_2$-N (µmol/L) | $NO_3$-N (µmol/L) | $NH_4$-N (µmol/L) | TN (µmol/L) | $PO_4$-P (µmol/L) | TP (mg/L) | $SiO_4$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 m | S | 26.4-31.8 | 32.3-35.1 | 8.0-8.3 | 2.8-5.3 | - | 0.03-0.63 | 0.02-27.90 | 0.00-6.86 | 0.00-35.10 | 0.07-0.74 | 0.16-2.67 | 0.60-19.53 |
| | M | 28.0-31.8 | 32.3-35.2 | 8.0-8.3 | 3.5-4.9 | - | 0.00-0.22 | 0.21-4.64 | 0.00-7.60 | 0.00-42.17 | 0.08-1.00 | 0.54-2.00 | 0.36-17.53 |
| | B | 28.0-31.0 | 32.9-36.3 | 8.0-8.2 | 2.2-5.0 | - | 0.10-3.11 | 0.05-5.78 | 0.00-13.03 | 0.48-14.59 | 0.48-1.56 | 0.53-3.50 | 1.07-14.90 |
| 15 m | S | 26.4-32.0 | 32.1-35.3 | 8.1-8.4 | 3.0-5.4 | 0.8-3.5 | 0.00-1.22 | 0.09-13.73 | 0.00-12.50 | 0.23-28.90 | 0.21-0.93 | 0.00-1.34 | 0.85-23.68 |
| | M | 27.4-30.8 | 32.8-35.2 | 8.1-8.2 | 3.0-5.6 | - | 0.00-1.79 | 0.00-10.23 | 0.00-4.22 | 0.51-17.29 | 0.20-0.93 | 0.02-1.52 | 1.53-11.76 |
| | B | 26.2-30.5 | 33.0-36.3 | 8.1-8.2 | 2.4-5.2 | 0.0-3.4 | 0.00-3.14 | 0.13-14.79 | 0.00-7.12 | 0.53-39.75 | 0.22-1.49 | 0.05-1.84 | 0.84-19.99 |

S – Surface; M – Mid Depth; B – Bottom; TN – Total Nitrogen; TP – Total Phosphate

**Source** : Secondary and Primary data collected by NIO 1989-1998

Table 3.3.4.3

Summary of Range of Coastal Water Quality Parameters

| Parameters | October 1997 | February 1999 | November 2000 |
|---|---|---|---|
| **Physico-Chemical Parameters** | | | |
| Temperature (°C) | 25.0 - 31.2 | 28.8 - 32.5 | 29.0 - 31.0 |
| pH | 7.9 - 8.4 | 6.6 - 8.3 | 7.8 - 8.4 |
| Salinity (psu) | 24.9 - 34.8 | 29.9 - 32.6 | 31.3 - 35.9 |
| Dissolved Oxygen (ml/L) | 2.2 - 5.1 | 2.9 - 6.8 | 2.8 - 4.9 |
| BOD (mg/L) | ND - 4.7 | 0.1 - 2.9 | 0.2 - 3.6 |
| $NO_2$-N (μmol/L) | ND - 1.7 | ND - 2.0 | ND - 2.0 |
| $NO_3$-N (μmol/L) | ND - 24.1 | 0.3 - 11.2 | ND - 3.4 |
| $NH_4$-N (μmol/L) | ND - 45.1 | ND - 7.5 | ND - 7.0 |
| $PO_4$-P (μmol/L) | 0.1 - 4.8 | 0.1 - 3.2 | 0.2 - 3.8 |
| $SiO_4$-Si (μmol/L) | ND - 16.8 | 0.2 - 12.9 | 0.5 -14.6 |
| PHC (μg/L) | - | - | ND - 65.0 |
| **Trace Metals in Water (μg/L)** | | | |
| Cu | ND - 23.0 | ND - 5.6 | ND - 1.0 |
| Cd | 0.8 - 8.9 | ND - 9.1 | ND |
| Cr | ND - 3.4 | ND | ND |
| Co | ND - 2.5 | ND | ND |
| Ni | ND - 5.2 | ND | ND |
| Pb | ND - 11.5 | ND - 14.1 | ND |
| Mn | 1.6 - 11.0 | ND | ND |
| Zn | 6.9 - 30.1 | 5.9 - 174.7 | ND - 17.0 |
| Fe | 18.0 - 213.8 | ND - 526.0 | 8.0 - 921.0 |
| **Trace Metals in Sediment (dry weight) (μg/g)** | | | |
| Cu | 1.39 - 32.5 | 1.5 - 42.0 | 0.0 - 50.4 |
| Cd | 0.5 - 4.1 | ND - 7.34 | ND - 3.7 |
| Cr | 30.9 - 199.3 | 9.56 - 146.4 | 0.1 - 205.1 |
| Co | 5.1 - 39.8 | ND - 18.8 | ND - 52.5 |
| Ni | 15.6 - 212.8 | ND - 39.8 | ND - 83.3 |
| Pb | 18.0 – 60.2 | ND - 71.3 | 0.1 - 112.0 |
| Mn | 124.1 - 445.3 | 37.9 - 260.5 | 0.2 - 403.3 |
| Zn | 23.5 - 155.5 | 8.7 - 106.2 | 0.1 - 274.0 |
| Fe (mg/g) | 6.4 - 43.2 | 0.2 - 55.6 | 0.0 - 57.4 |

ND - Not Detectable

**Source :** Primary data collected by NIO

## Table 3.3.4.4

## Summary of Range of Coastal Water Quality Parameters : Primary Data (1997- 2000)

| Transect (Station) | Depth (m) | Temp ($^0$C) | pH | Salinity (PSU) | DO (ml/L) | $BOD_5$ (mg/L) | $NO_2$-N (µmol/L) | $NO_3$-N (µmol/L) | $NH_4$-N (µmol/L) | $PO_4$-P (µmol/L) | TN (µmol/L) | TP (µmol/L) | $SiO_4$ (µmol/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **October 1997** | | | | | | | | | | | | | |
| I (1-24) | S | 28.5-31.2 | 7.9-8.3 | 30.7-34.4 | 2.0-5.1 | 0-3 | 0.0-1.5 | 0.0-9.5 | 0.3-45.1 | 0.0-1.4 | 1.2-13.8 | 0.1-2.0 | 1.0-14.1 |
| | 5 | 28.7-30.1 | 8.0-8.3 | 33.4-34.6 | 2.4-3.4 | 1-1 | 0.0-0.5 | 1.6-3.8 | ND | 0.7-2.4 | - | - | 4.6-10.4 |
| | 10 | 27.4-29.5 | 8.0-8.3 | 32.8-34.6 | 2.0-5.1 | 0-3 | 0.0-0.6 | 0.1-3.7 | 0.2-2.6 | 0.0-0.9 | 7.2-16.4 | 0.6-2.4 | 1.1-14.9 |
| | 20 | 27.0-28.5 | 8.0-8.3 | 33.0-34.5 | 1.7-4.0 | 0-3 | 0.0-0.6 | 0.7-4.6 | 0.4-2.6 | 0.0-0.4 | | 1.3-2.4 | 0.0-8.9 |
| | 30 | 26.0-26.8 | 8.0-8.3 | 34.4-34.5 | 1.2-4.8 | 0-2 | 1.0-1.3 | 0.1-11.8 | 1.8 | 0.0-0.8 | 18.5-23.2 | 1.0-3.9 | 1.8-7.6 |
| II (25-56) | S | 28.0-31.0 | 7.9-8.3 | 24.9-31.1 | 1.5-4.5 | 0-3 | 0.0-1.5 | 0.1-5.2 | 0.0-33.4 | 0.1-3.1 | 2.9-28.7 | 0.6-4.8 | 1.3-18.1 |
| | 5 | 29.0-30.0 | 8.0-8.3 | 32.1-34.5 | 1.9-3.2 | - | 0.2-0.6 | 0.0-0.9 | 27.8 | 0.9-3.9 | - | - | 1.1-10.6 |
| | 10 | 27.0-28.7 | 7.9-8.3 | 33.0-34.7 | 1.7-3.7 | 0-3 | 0.0-2.0 | 0.0-3.6 | 2.9-21.1 | 0.1-4.8 | 1.9-18.3 | 1.3-3.7 | 1.8-13.9 |
| | 20 | 26.0-29.5 | 7.9-8.3 | 34.2-34.9 | 1.3-5.1 | 0-3 | 0.0-0.6 | 0.3-5.5 | 0.6-2.8 | 0.1-1.8 | 10.2-18.3 | 1.4-4.1 | 2.1-11.2 |
| | 30 | 25.0-26.7 | 7.9-8.3 | 34.3-34.6 | 3.7-4.9 | 2-4 | 0.1-1.3 | 4.0-6.8 | ND | 0.0-2.1 | 11.9-18.0 | 0.6-4.1 | 5.4-16.4 |
| **February 1999** | | | | | | | | | | | | | |
| I (1-5) | S | 29.8-30.3 | 7.5-8.1 | 31.4-31.5 | 4.1-6.6 | 1-3 | 0.2-0.3 | 1.5-2.8 | 0.4-5.6 | 0.6-1.4 | - | - | 3.8-10.8 |
| | 5 | 29.2-29.8 | 7.9-8.0 | 31.4-31.5 | 4.5-4.9 | 3 | 0.4-0.5 | 2.2-4.3 | 2.5 | 0.6-0.8 | - | - | 5.1-6.5 |
| | 10 | 29.3-30.2 | 8.1-8.1 | 31.5-31.5 | 5.0-5.9 | - | 0.2-0.3 | 2.2-3.4 | 0.3-0.5 | 0.3-0.4 | - | - | 4.9-5.6 |
| | 20 | 29.2-29.3 | 8.1-8.2 | 31.5-31.5 | 5.6-6.7 | - | 0.1-0.2 | 2.1-4.8 | 0.6-0.9 | 0.2-0.5 | - | - | 3.9-7.6 |
| II (6-10 | 30 | 29.2 | 8.1 | 31.5 | 5.0 | - | 0.2 | 3.5 | ND | 0.4 | - | - | 2.8 |
| | S | 29.2-29.8 | 8.0-8.1 | 31.3-31.3 | 4.3-4.7 | 2 | 0.1-0.6 | 2.7-6.1 | 1.0-1.8 | 0.3-0.8 | | - | 1.6-4.1 |
| | 5 | 29.1-29.3 | 8.1-8.2 | 31.4-31.5 | 3.6-4.3 | 1 | 0.4-0.6 | 2.0-4.7 | 0.3-2.1 | 0.5-0.9 | - | - | 2.8-3.1 |
| | 10 | 29.0-29.2 | 8.1-8.2 | 31.2-31.5 | 4.3-4.7 | - | 0.1-0.5 | 2.0-3.6 | 1.3 | 0.4-0.5 | - | - | 3.3-5.9 |
| | 20 | 28.8-28.9 | 8.1-8.2 | 31.4-31.5 | 4.5-5.9 | 1 | 0.1-0.2 | 3.4-6.3 | 0.1-4.6 | 0.1-0.5 | - | - | 2.8-4.9 |

**Contd...**

Table 3.3.4.4 Contd....

| Transect (Station) | Depth (m) | Temp ($^0$C) | pH | Salinity (PSU) | DO (ml/L) | $BOD_5$ (mg/L) | $NO_2$-N (µmol/L) | $NO_3$-N (µmol/L) | $NH_4$-N (µmol/L) | $PO_4$-P (µmol/L) | TN (µmol/L) | TP (µmol/L) | $SiO_4$ (µmol/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 | 28.8 | 8.2 | 31.6 | 5.2 | 1 | 0.1 | 1.90 | ND | 0.3 | - | - | 2.0 |
| III (11-15) | S | 30.0-32.5 | 8.1-8.2 | 31.3-31.6 | 3.4-5.2 | - | 0.2-0.7 | 6.5-10.4 | 0.0 | 0.2-0.4 | - | - | 7.2-12.9 |
| | 5 | 32.2-32.4 | 8.2-8.1 | 31.3-31.6 | 3.8-4.7 | - | 0.4-0.6 | 7.1-7.7 | 0.5 | 0.4-1.0 | - | - | 6.0-7.7 |
| | 10 | 29.5-32.4 | 8.2 | 31.3-31.5 | 5.2 | - | 0.1-0.4 | 8.5-11.2 | 0.7-2.1 | 0.2-0.4 | - | - | 7.4-10.0 |
| | 20 | 29.4-29.6 | 8.2 | 31.5-31.7 | 5.0-5.9 | - | 0.1-0.2 | 8.0-10.0 | 1.3 | 0.2-0.5 | - | - | 4.2-7.8 |
| | 30 | 29.40 | 8.2 | 32.0 | 2.9 | 1 | 0.5 | 6.2 | ND | 0.2 | - | - | 6.6 |
| IV (16-20) | S | 29.8-30.6 | 6.6-8.2 | 31.2-31.5 | 3.8-5.0 | 0-2 | 0.0-0.3 | 0.4-1.7 | 3.2-7.0 | 0.3-0.4 | - | - | 2.4-5.5 |
| | 5 | 29.5-30.2 | 7.6-8.2 | 31.3-31.4 | 4.3-4.7 | - | 0.0-0.3 | 1.5-2.4 | 2.4-3.9 | 0.3-0.7 | - | - | 3.4-6.1 |
| | 10 | 29.2-28.8 | 8.2-8.2 | 31.4-31.7 | 4.3-5.2 | - | 0.0-0.6 | 0.4-2.0 | 2.6-7.5 | 0.2-1.0 | - | - | 3.5-7.7 |
| | 20 | 29.2-29.5 | 8.2-8.3 | 31.4-31.7 | 4.5-4.7 | - | 0.0-0.1 | 0.3-1.6 | 3.0-3.4 | 0.3-0.5 | - | - | 2.6-4.8 |
| | 30 | 29.30 | 8.2 | 31.9 | 4.5 | 2 | 0.3 | 2.4 | 3.8 | 0.4 | - | - | 3.1 |
| V (21-25) | S | 29.9-30.3 | 8.2-8.2 | 31.1-31.6 | 5.1-5.3 | 1 | 0.1-0.3 | 1.0-3.0 | 0.0-0.5 | 0.4-0.7 | - | - | 2.7-6.2 |
| | 5 | 29.8-30.6 | 8.2-8.2 | 31.3-31.3 | 4.5-6.1 | 1 | 0.2-0.5 | 2.8-2.9 | ND | 0.6-0.8 | - | - | 5.1-7.7 |
| | 10 | 29.3-29.9 | 8.2-8.2 | 31.6-31.8 | 3.7-5.1 | - | 0.1-0.9 | 1.0-2.9 | ND | 0.4-0.6 | - | - | 3.7-5.1 |
| | 20 | 29.7-29.9 | 8.2-8.2 | 31.8-31.8 | 4.8-5.2 | - | 0.3-0.4 | 1.2-1.3 | ND | 0.5-0.6 | - | - | 3.2-4.1 |
| | 30 | 29.6 | 8.2 | 31.9 | 4.8 | 1 | 0.13 | 3.01 | ND | 0.4 | - | - | 2.4 |
| VI (26-30) | S | 29.9-30.3 | 8.0-8.1 | 31.2-31.7 | 4.5-6.2 | 0-2 | 0.0-4.1 | 0.7-2.4 | 0.1-0.5 | 0.3-0.7 | - | - | 3.0-7.0 |
| | 5 | 29.8-29.9 | 7.9-8.1 | 31.5-31.5 | 4.5-5.8 | 1 | 0.6-0.8 | 0.8-2.9 | 0.1-0.2 | 0.6-0.8 | - | - | 5.9-7.0 |
| | 10 | - | - | - | - | - | - | - | - | - | - | - | - |
| | 20 | - | - | - | - | - | - | - | - | - | - | - | - |
| | 30 | 29.5 | 8.12 | 32.0 | 4.5 | 0.2 | 0.2 | 4.0 | ND | 0.5 | - | - | 3.8 |

Contd...

Table 3.3.4.4 Contd....

| Transect (Station) | Depth (m) | Temp ($^0C$) | pH | Salinity (PSU) | DO (ml/L) | $BOD_5$ (mg/L) | $NO_2$-N (μmol/L) | $NO_3$-N (μmol/L) | $NH_4$-N (μmol/L) | $PO_4$-P (μmol/L) | TN (μmol/L) | TP (μmol/L) | $SiO_4$ (μmol/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VII (31-35) | S | 29.3-30.0 | 8.1-8.2 | 30.7-31.7 | 4.4-5.1 | 0-2 | 0.1-0.3 | 1.1-4.1 | 0.2-1.2 | 0.3-1.1 | - | - | 2.1-4.6 |
| | 5 | 29.2-29.9 | 8.1-8.2 | 31.3-31.7 | 4.8-5.3 | 0 | 0.1-0.2 | 2.0-4.1 | 0.3 | 0.4-0.8 | - | - | 1.9-4.2 |
| | 10 | 29.3-29.9 | 8.2 | 31.6-31.9 | 3.9-5.1 | 1 | 0.2-0.5 | 2.0-2.4 | - | 0.4-0.8 | - | - | 2.6-3.4 |
| | 20 | 29.3 | 8.17 | 32.1 | 5.0 | - | 0.5 | 2.2 | 0.7 | 0.6 | - | - | 3.7 |
| | 30 | 29.8 | 8.17 | 32.1 | 4.9 | 1 | 0.4 | 3.5 | - | 0.6 | - | - | 2.1 |
| VIII (36-40) | S | 30.0-30.8 | 7.0-8.2 | 29.9-31.8 | 3.5-5.5 | - | 0.0-0.2 | 0.5-3.3 | 0.5-1.8 | 0.3-0.7 | - | - | 0.2-3.3 |
| | 5 | 29.9-30.3 | 8.0-8.2 | 30.9-31.2 | 4.7-5.0 | 1 | 0.1-0.1 | 1.2-1.6 | - | 0.6-0.7 | - | - | 1.1-3.1 |
| | 10 | 29.8-30.2 | 8.20 | 31.8-32.0 | 4.6-5.0 | - | 0.3-2.5 | 2.7-3.5 | 0.6 | 0.4-0.9 | - | - | 2.6-5.9 |
| | 20 | 30 | 8.2 | 32.4 | 3.9 | - | 0.8 | 3.7 | 1.7 | 0.5 | - | - | 2.9 |
| | 30 | 29.8-30.0 | 8.2 | 32.3-32.6 | 4.4-4.7 | 1 | 0.4-1.2 | 2.5-5.9 | 1.0 | 0.7-1.4 | - | - | 1.4-3.4 |
| IX (41-45) | S | 30.8-31.3 | 8.0-8.2 | 31.1-31.9 | 3.4-6.0 | 1-2 | 0.0-0.2 | 1.5-3.1 | 0.2-5.7 | 0.4-0.8 | | | 1.6-3.7 |
| | 5 | 30.5-31.0 | 7.9-8.1 | 31.2-31.6 | 3.6-4.9 | 2 | 0.0-0.1 | 1.3-3.9 | 0.4-0.7 | 0.4-0.6 | | | 0.7-5.6 |
| | 10 | 30.0-30.5 | 8.1-8.2 | 31.9-32.2 | 4.8-5.9 | - | 0.1-2.0 | 2.4-4.7 | 0.4-1.8 | 0.4-0.7 | | | 1.3-6.3 |
| | 20 | 30.0 | 8.2 | 32.2 | 6.0 | - | 0.5 | 5.1 | 0.4 | 0.5 | | | 0.9 |
| | 30 | 30.0 | 8.2 | 32.4 | 4.8 | - | 0.2 | 7.5 | - | 0.6 | | | 5.3 |
| **November 2000** | | | | | | | | | | | | | |
| I (1-5) | S | 29.8-30.3 | 7.8-8.1 | 34.1-34.9 | 3.8-4.9 | 1.0-2.1 | 0.1-0.5 | 0.6-1.6 | 0.0-2.0 | 0.4-1.4 | | | 5.0-10.6 |
| | 5 | 29.8-30.3 | 7.9-8.0 | 34.4-34.5 | 3.9-4.9 | - | 0.2-0.5 | 1.0-1.3 | 0.4-0.9 | 0.6-1.4 | | | 5.2-11.0 |
| | 10 | 29.7-29.8 | 8.0-8.0 | 34.5-35.0 | 4.6-5.0 | - | 0.2-0.2 | 0.6-0.6 | 0.1-0.4 | 0.4-0.8 | | | 4.6-5.3 |
| | 20 | 29.6-29.7 | 8.0-8.0 | 34.8-34.9 | 3.9-5.0 | 0.8-0.9 | 0.3-0.7 | 1.1-1.6 | 0.1-1.0 | 0.5-0.8 | | | 4.2-7.2 |
| | 30 | 29.6-29.8 | 7.9-8.0 | 34.3-34.6 | 3.6-3.8 | - | 1.9-2.0 | 1.6-2.6 | 0.4-0.8 | 0.8-1.0 | | | 7.8-8.2 |

Contd...

Table 3.3.4.4 Contd....

| Transect (Station) | Depth (m) | Temp ($^0C$) | pH | Salinity (PSU) | DO (ml/L) | $BOD_5$ (mg/L) | $NO_2$-N' (µmol/L) | $NO_3$-N (µmol/L) | $NH_4$-N (µmol/L) | $PO_4$-P (µmol/L) | TN (µmol/L) | TP (µmol/L) | $SiO_4$ (µmol/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| II (6-10) | S | 29.0-29.3 | 7.8-8.1 | 31.3-34.9 | 3.8-4.5 | 1.2-2.2 | 0.1-0.8 | 1.0-3.3 | 0.4-2.9 | 0.6-2.0 | | | 5.5-14.6 |
| | 5 | 29.3-29.8 | 7.8-8.0 | 34.7-34.7 | 3.7-4.3 | ND-0.9 | 0.7-0.8 | 2.2-3.0 | 0.9-1.9 | 1.5-2.1 | | | 10.4-14.1 |
| | 10 | 29.2-29.3 | 8.0-8.1 | 34.7-34.9 | 3.3-4.4 | - | 0.4-1.3 | 0.6-3.0 | 0.2-1.0 | 0.6-2.8 | | | 5.4-13.0 |
| | 20 | 29.2-29.4 | 8.1-8.1 | 34.9-35.1 | 3.4-4.4 | - | 0.2-1.3 | 0.6-2.6 | 0.0-0.7 | 0.7-1.4 | | | 5.8-8.4 |
| | 30 | 29.2-29.5 | 8.0-8.1 | 35.1-35.3 | 3.4-3.6 | ND-1.0 | 1.3-1.4 | 1.7-2.6 | 0.0-0.8 | 1.4-1.4 | | | 7.9-8.4 |
| III (11-15) | S | 29.2-29.9 | 7.9-8.2 | 34.7-34.9 | 3.8-4.3 | 0.3-1.0 | 0.1-0.6 | 0.8-1.9 | 1.1-2.4 | 0.3-1.6 | | | 1.1-8.0 |
| | 5 | 29.2-29.3 | 8.0-8.0 | 34.7-34.9 | 3.1-3.8 | ND-0.5 | 0.56-0.8 | 1.2-2.1 | 0.0-4.6 | 1.5-2.0 | | | 4.6-9.0 |
| | 10 | 29.2-29.6 | 8.1-8.2 | 34.1-34.8 | 4.3-4.4 | - | 0.2-0.7 | 0.4-1.8 | 0.0-7.0 | 0.4-1.4 | | | 3.9-5.6 |
| | 20 | 29.6-29.9 | 8.1-8.1 | 34.8-35.0 | 3.6-3.8 | - | 0.5-0.8 | 1.0-1.2 | 0.0-2.6 | 0.9-1.0 | | | 1.5-2.4 |
| | 30 | 3.00 | 8.1 | 35.1 | 3.4 | - | 0.7 | 2.3 | 0.0 | 0.9 | | | 2.4 |
| IV (15-20) | S | 29.2-30.0 | 7.8-8.0 | 34.8-35.0 | 3.2-4.3 | ND-1.9 | 0.0-0.7 | 0.0-1.0 | 0.0-0.9 | 0.2-1.8 | | | 4.9-10.4 |
| | 5 | 29.2-29.5 | 7.9-8.0 | 34.7-35.0 | 3.3-3.9 | ND-1.4 | 0.4-0.8 | 0.4-1.0 | 0.5-1.1 | 1.0-2.3 | | | 6.9-9.5 |
| | 10 | 29.4-30.0 | 8.0-8.0 | 34.3-35.0 | 3.8-4.3 | ND | 0.0-0.4 | 0.0-1.0 | 0.2-0.9 | 0.3-1.1 | | | 5.2-7.9 |
| | 20 | 29.8-29.9 | 8.0-8.0 | 35.0-35.0 | 3.4-4.2 | ND | 0.2-0.8 | 0.2-1.7 | 0.0-0.6 | 0.4-1.3 | | | 6.2-9.5 |
| | 30 | 29.9 | 8.0 | 35.1 | 3.8 | 0.2 | 0.7 | 1.0 | 0.4 | 0.6 | | | 8.0 |
| V (21-25) | S | 30.0-31.0 | 8.1-8.4 | 34.2-34.9 | 4.2-4.4 | 1.0-2.0 | 0.0-0.3 | 0.1-0.8 | 0.4-2.2 | 0.2-0.4 | | | 0.8-4.3 |
| | 5 | 29.9-30.2 | 8.2-8.2 | 34.7-34.8 | 3.7-4.4 | ND-2.4 | 0.1-0.6 | 0.5-0.7 | 0.6-1.8 | 0.3-0.9 | | | 1.8-4.7 |
| | 10 | 29.8-29.9 | 8.3-8.4 | 34.5-34.7 | 4.3-4.4 | ND | 0.0 | 0.2-0.4 | 0.0-0.5 | 0.1-0.2 | | | 0.8-1.1 |
| | 20 | 29.7-29.8 | 8.3-8.4 | 34.5-34.7 | 3.1-4.4 | ND-0.7 | 0.0-1.0 | 0.2-1.8 | 0.1-0.5 | 0.1-1.2 | | | 0.9-3.4 |
| | 30 | 29.8-30.0 | 8.3-8.4 | 34.7-34.8 | 3.9-4.2 | ND-0.5 | 0.12-0.4 | 0.1-0.5 | 0.2-0.8 | 0.4-0.5 | | | 1.7-2.2 |

Contd...

Table 3.3.4.4 Contd...

| Transect (Station) | Depth (m) | Temp ($^0$C) | pH | Salinity (PSU) | DO (ml/L) | $BOD_5$ (mg/L) | $NO_2$-N (µmol/L) | $NO_3$-N (µmol/L) | $NH_4$-N (µmol/L) | $PO_4$-P (µmol/L) | TN (µmol/L) | TP (µmol/L) | $SiO_4$ (µmol/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VI (25-30) | S | 30.0-30.2 | 8.0-8.1 | 33.7-35.3 | 3.7-4.7 | ND-3.7 | 0.09-0.7 | 0.3-3.4 | 0.0-4.2 | 0.3-0.9 | | | 2.4-5.6 |
| | 5 | 30.0-30.0 | 7.9-8.0 | 35.0-35.1 | 3.1-4.2 | ND | 0.2-1.0 | 0.0-1.8 | 0.5-1.2 | 0.3-2.2 | | | 3.7-6.2 |
| | 10 | 30.0-30.0 | 8.1-8.1 | 35.2-35.2 | 4.3-4.5 | ND | 0.2-0.2 | 0.1-0.4 | 0.0-0.3 | 0.3-0.4 | | | 2.2-3.3 |
| | 20 | 29.8-30.1 | 8.0-8.1 | 34.4-35.2 | 3.7-4.5 | 1.0-ND | 0.1-1.2 | 0.1-ND | 0.2-2.0 | 0.4-1.6 | | | 3.5-9.3 |
| | 30 | 30.0-30.0 | 8.0-8.0 | 35.4-35.6 | 3.0-3.4 | ND-0.9 | 1.0-1.1 | 0.9-1.2 | 1.3-1.9 | 1.4-1.4 | | | 4.5-6.9 |
| VII (31-35) | S | 29.8-30.6 | 8.0-8.2 | 33.0-35.3 | 3.8-4.4 | ND-0.6 | 0.0-0.4 | 0.3-1.0 | 0.3-1.6 | 0.3-1.1 | | | 1.4-7.0 |
| | 5 | 29.8-29.8 | 8.0-8.1 | 34.1-35.4 | 3.3-3.7 | ND-1.0 | 0.9-1.0 | 0.8-1.2 | 1.3-1.4 | 3.0-3.8 | | | 8.0-8.6 |
| | 10 | 29.9-29.9 | 8.2-8.2 | 35.1-35.3 | 4.2-4.7 | ND | 0.0 | 0.2-0.2 | 0.0-0.2 | 0.2-0.3 | | | 1.4-3.2 |
| | 20 | 29.8-29.8 | 8.1-8.2 | 35.5-35.6 | 3.2-3.4 | ND | 0.6-0.8 | 0.6-1.4 | 0.8-0.8 | 2.2-2.4 | | | 7.9-8.0 |
| | 30 | 29.6 | 8.2 | 35.9 | 3.3 | ND | 0.7 | 1.3 | 0.5 | 1.0 | | | 7.3 |
| VIII (36-40) | S | 30.0-30.5 | 7.9-8.1 | 34.4-35.4 | 3.7-4.3 | ND-1.9 | 0.1-0.3 | 0.4-2.6 | 0.0-0.7 | 0.3-0.6 | | | 0.5-1.8 |
| | 5 | 30.6 | 8.0 | 35.2 | 4.0 | ND | 0.2 | 0.4 | 0.0 | 0.4 | | | 1.2 |
| | 10 | 30.2-30.5 | 7.9-8.0 | 35.0-35.4 | 3.3-3.7 | ND-1.2 | 0.3-0.6 | 0.6-1.4 | 0.0-3.0 | 0.5-1.2 | | | 1.8-2.7 |
| | 20 | 30.2-30.5 | 8.1-8.1 | 35.5-35.6 | 3.7-4.4 | ND-0.7 | 0.1-0.4 | 0.0-0.9 | 0.0-0.4 | 0.2-0.9 | | | 0.2-1.1 |
| | 30 | 30.2-30.2 | 8.1-8.1 | 35.8-35.8 | 3.4-3.8 | ND | 0.6-1.0 | 1.0-1.3 | 0.0 | 0.5-0.8 | | | 0.5-1.3 |
| IX (41-45) | S | 30.0-31.0 | 7.8-8.1 | 34.6-35.6 | 3.6-3.9 | 0.7-2.2 | 0.3-0.6 | 0.6-1.4 | 0.0-2.6 | 0.5-1.2 | | | 4.9-8.9 |
| | 5 | 30.0-30.5 | 7.9-8.1 | 35.2-35.4 | 3.0-4.0 | 0.5-ND | 0.4-1.3 | 0.4-1.1 | 0.0-2.8 | 0.7-3.2 | | | 5.9-9.1 |
| | 10 | 30.0-30.3 | 8.1-8.1 | 35.4-35.6 | 3.7-3.7 | ND | 0.4-0.4 | 0.5-0.7 | 0.5-2.0 | 0.6-0.7 | | | 4.7-6.2 |
| | 20 | 30.2-30.2 | 8.1-8.1 | 34.9-35.8 | 3.2-3.3 | ND | 0.5-0.7 | 0.6-2.8 | 0.5-2.6 | 1.0-1.3 | | | 5.4-8.8 |

**Transects :**

I - off Pallana; II - off Pazhayangadi; III - off Alappuzha; IV - off Chettri beach; V - off Andhakaranazhi

VI - off Kannamali; VII - off Fort Kochi; VIII - off Edavanakkudu; IX - off Azhikode

**Source** : Primary data collected by NIO

## Table 3.3.4.5

**Summary of Range of Dissolved Trace Metals in Coastal Waters during October 1997, February 1999 and November 2000**

| Station No. | Concentration of Dissolved Trace Metals (µg/L) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cu | | Zn | | Mn | | Cd | | Fe | | Pb | | Ni | | Co | | Cr | |
| | S | B | S | B | S | B | S | B | S | B | S | B | S | B | S | B | S | B |
| **October 1997** | | | | | | | | | | | | | | | | | | |
| I (4-24) | 3.0-11.9 | 4.5-8.2 | 15.7-33.6 | 14.4-42.3 | ND-19.9 | ND-2.7 | 2.1-8.8 | 2.0-8.7 | 15.4-265.9 | 143.9 - 381.0 | ND | ND-8.3 | ND-21.2 | 3.7-27.7 | 3.4-6.9 | 1.8-7.9 | ND | ND-1.7 |
| II (25-56) | 4.5-9.3 | 4.1-7.8 | 10.4-22.8 | 11.5-31.9 | 2.0-4.0 | ND-9.9 | 1.0-8.4 | 0.9-5.8 | 4.0-162.2 | 51.1-119.3 | ND-8.3 | ND | ND-1.9 | ND-17.5 | ND-1.8 | ND-1.7 | ND-3.5 | ND-1.6 |
| **February 1999** | | | | | | | | | | | | | | | | | | |
| I &II (1-10) | 1.6-3.2 | 0.8-1.6 | 35.1-174.7 | 51.4-85.7 | - | - | ND | 0.9 | 0-303.0 | 2.1-526.0 | 9.4-14.1 | 9.4 | - | - | - | - | - | - |
| III & IV (11-20) | 1.6-1.6 | 0.8-3.2 | 9.7-40.7 | 14.3-45.0 | - | - | 0.64 | 0.6 | 0-6 | 14.7-134.7 | 9.4 | ND | - | - | - | - | - | - |
| V & VI (21-30) | 0.8-3.2 | 2.4-5.6 | 5.9-28.1 | 7.6-35 | - | - | 1.52-9.1 | 0.9-1.3 | 2.1-295.6 | 5.3-460.9 | 14-14.1 | ND | - | - | - | - | - | - |
| VII (31-35) | 0.8-1.6 | 0.8-2.4 | 9.7-20.7 | 8.1-14.7 | - | - | ND | ND | 6.2-54.7 | 11.6-22.0 | ND | ND | - | - | - | - | - | - |
| VIII & IX (36-45) | 0.8-1.6 | 0.8-1.6 | 9-21.7 | 6.7-21.7 | - | - | 0.4-0.6 | 0.4-0.6 | 23.1-136.8 | 8.4-258.8 | 14.1 | ND | - | - | - | - | - | - |

Contd...

Table 3.4.4.5 Contd....

| Station No. | Concentration of Dissolved Trace Metals (µg/L) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cu | | Zn | | Mn | | Cd | | Fe | | Pb | | Ni | | Co | | Cr | |
| November 2000 | | | | | | | | | | | | | | | | | | |
| I & II (1-10) | 0.8-2.0 | 0.0-2.0 | 0.0-9.0 | 0.0-9.0 | - | - | - | - | 15.0-442.0 | 58.0-808.0 | - | - | - | - | - | - | - | - |
| III & IV (11-20) | 0.0-2.0 | 0.0-0.8 | 0.0-6.0 | 2.0-6.0 | - | - | - | - | 8.0-617.0 | 263.0-640.0 | - | - | - | - | - | - | - | - |
| V & VI (21-30) | 0.0-3.0 | 0.0-0.8 | 2.0-9.0 | 0.0-7.0 | - | - | - | - | 32.0-403.0 | 289.0-588.0 | - | - | - | - | - | - | - | - |
| | S | B | S | B | S | B | S | B | S | B | S | B | S | B | S | B | S | B |
| VII (31-35) | 3.0-7.0 | 0.8-2.0 | 8.0-14.0 | 6.0-8.0 | - | - | - | - | 45.0-329.0 | 296.0-921.0 | - | - | - | - | - | - | - | - |
| VIII & IX (36-45) | 0.8-7.0 | 0.0-2.0 | 0.0-17.0 | 4.0-9.0 | - | - | - | - | 16.0-324.0 | 44.0-518.0 | - | - | - | - | - | - | - | - |

**Transects :**

I - off Pallana　II - off Pazhayangadi　III - off Alappuzha　IV - off Chettri beach　V - off Andhakaranazhi
VI - off Kannamali　VII - off Fort Kochi　VIII - off Edavanakkudu　IX - off Azhikode

S-Surface, B-Bottom, ND-Non Detectable, In each Transect, data is collected at 3 sampling points

**Source :** Primary data collected by NIO

## Table 3.3.4.6

## Sediment Characteristics of Coastal Waters during February 1999

| Transects (Station No.) | Sand (%) | | | | Clay (%) | | | | Silt (%) | | | | Organic Carbon (mg/g) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Avg | SD | Min | Max | Avg | SD | Min | Max | Avg | SD | Min | Max | Avg | SD |
| **During October 1997** | | | | | | | | | | | | | | | | |
| I (1-24) | 0.0 | 72.0 | 13.6 | 23.5 | 27.9 | 98.8 | 64.5 | 19.1 | 0.2 | 40.7 | 21.9 | 11.9 | 0.4 | 26.6 | 20.9 | 5.7 |
| II (25-56) | 0.0 | 85.3 | 20.6 | 27.9 | 2.6 | 85.0 | 50.1 | 20.5 | 0.1 | 57.3 | 27.0 | 19.7 | 0.4 | 29.7 | 15.8 | 10.0 |
| **During February 1999** | | | | | | | | | | | | | | | | |
| I & II (1-10) | 4.5 | 48.8 | 24.3 | 15.8 | 18.8 | 79.9 | 47.2 | 22.2 | 6.2 | 63.4 | 28.8 | 15.3 | 1.7 | 32.43 | 16.1 | 9.0 |
| III & IV (11-20) | 2.6 | 80.4 | 31.2 | 28.6 | 17.2 | 77.0 | 42.5 | 22.3 | 0.2 | 68.6 | 28.2 | 27.8 | 7.9 | 31.4 | 20.1 | 8.0 |
| V & VI (21-30) | 2.0 | 95.1 | 47.8 | 41.7 | 0.8 | 82.9 | 32.7 | 30.2 | 0.7 | 82.9 | 21.1 | 26.9 | 2.1 | 33.8 | 21.7 | 10.9 |
| VII (31-35) | 0.1 | 82.3 | 27.5 | 38.5 | 13.6 | 87.8 | 50.2 | 36.2 | 0.2 | 85.8 | 22.3 | 36.0 | 3.1 | 32.4 | 20.6 | 14.2 |
| VIII & IX (36-45) | 0.1 | 74.6 | 25.1 | 26.4 | 18.7 | 83.7 | 58.0 | 23.3 | 1.3 | 42.8 | 16.3 | 13.0 | 2.8 | 32.1 | 20.7 | 11.2 |
| **During November 2000** | | | | | | | | | | | | | | | | |
| I & II (1-10) | 0.3 | 78.0 | 14.3 | 22.5 | 20.0 | 85.7 | 51.3 | 19.1 | 2.0 | 53.3 | 34.4 | 16.2 | 0.4 | 34.4 | 24.6 | 9.8 |
| III & IV (11-20) | 0.4 | 47.0 | 21.5 | 19.2 | 30.0 | 80.0 | 47.0 | 17.1 | 9.0 | 43.7 | 31.4 | 11.9 | 2.4 | 40.4 | 21.2 | 13.1 |
| V & VI (21-30) | 1.0 | 55.0 | 11.4 | 16.3 | 36.5 | 78.6 | 58.2 | 13.8 | 0.7 | 61.5 | 30.1 | 18.4 | 12.9 | 40.7 | 25.8 | 7.6 |
| VII (31-35) | 0.1 | 42.0 | 10.6 | 15.9 | 40.8 | 90.6 | 68.1 | 16.3 | 9.3 | 28.7 | 21.3 | 7.3 | 10.8 | 27.5 | 21.4 | 6.0 |
| VIII & IX (36-45) | 0.1 | 88.8 | 14.4 | 25.4 | 10.2 | 95.0 | 64.6 | 21.4 | 1.0 | 38.5 | 21.0 | 12.4 | 0.4 | 35.8 | 27.4 | 12.0 |

## Table 3.3.4.7

## Trace Metals Distribution in Sediments of Coastal Waters: Primary Data (1997-2000)

| Transects (Station No.) | Concentration of Dissolved Trace Metals ( μg/g ) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pb | | Ni | | Co | | Cr | | Fe | | Cu | | Zn | | Mn | | Cd | |
| | Range | Avg | Range | Avg | Range | Avg | Range | Avg | Range | Avg | Range | Avg | Range | Avg | Range | Avg | Range | Avg |
| **During October 1997** | | | | | | | | | | | | | | | | | | |
| I (1-24) | 18.4-60.0 | 45.9 | 23.7-212.8 | 127.1 | 12.2-37.7 | 32.1 | 30.9-190.2 | 152.0 | 6.6-43.2 | 35.2 | 1.4-32.8 | 23.2 | 28.9-127.9 | 80.0 | 117.6-445.3 | 20.9 | 0.6-3.9 | 1.8 |
| II (25-56) | 18.0-60.2 | 18.0 | 15.6-193.6 | 117.0 | 5.1-39.9 | 28.0 | 36.9-199.3 | 137.0 | 6.4-41.6 | 32.0 | 1.4-33.7 | 22.2 | 23.3-155.4 | 83.8 | 124.1-773.3 | 273.0 | 0.7-4.1 | 1.7 |
| **During February 1999** | | | | | | | | | | | | | | | | | | |
| I & II (1-10) | 6.6-26.4 | 20.7 | 5.6-39.3 | 25.8 | 2.8-16.9 | 12.3 | 12.7-124.7 | 84.7 | 0.2-46.3 | 33.9 | 1.5-25.8 | 17.0 | 8.7-65.4 | 48.7 | 37.9-260.5 | 157.2 | 0.4-2.6 | 2.0 |
| III & IV (11-20) | 0-57.1 | 29.3 | 0.0-38.2 | 10.6 | 2.8-15.0 | 11.1 | 60.6-146.4 | 78.5 | 6.4-55.6 | 34.5 | 1.5-40.0 | 22.6 | 9.7-106.2 | 61.3 | 55.8-175.6 | 143.8 | 0.4-4.4 | 2.4 |
| V & VI (21-30) | 0-42.8 | 23.0 | 0.0-31.3 | 8.4 | 0- 18.8 | 9.8 | 15.7-100.8 | 44.3 | 7.5-46.4 | 28.0 | 2.2-35.9 | 17.0 | 10.7-71.6 | 37.0 | 66.6-227.7 | 157.2 | 0.0-7.3 | 2.4 |
| VII (31-35) | 6.6-71.3 | 33.3 | 0.0-39.8 | 15.5 | 1.4-15.4 | 9.9 | 9.6-133.1 | 88.5 | 8.0-49.4 | 34.2 | 2.3-30.8 | 16.6 | 12.9-99.3 | 56.0 | 110.2-255.0 | 180.4 | 0.0-2.9 | 1.6 |
| VIII & IX (36-45) | 6.6-57.1 | 24.4 | 0.0-32.8 | 11.1 | 1.4-14.2 | 9.3 | 15.9-102.4 | 54.9 | 5.9-42.2 | 27.8 | 4.5-42.0 | 20.6 | 9.9-82.4 | 48.9 | 92.0-216.6 | 165.2 | 0.0-2.2 | 1.2 |
| **During November 2000** | | | | | | | | | | | | | | | | | | |
| I & II (1-10) | 25 5-53.1 | 36 8 | 29.8-77.7 | 55 2 | 10.5-29.6 | 19.1 | 74.9-184.8 | 132 9 | 15.8-37.0 | 29.6 | 9.8-26.9 | 21.6 | 29.5-153.4 | 78.8 | 137.3-277.0 | 181.9 | 1.5-3.0 | 2.3 |
| III & IV (11-20) | 0.0-112.0 | 31.4 | 0.1-80.3 | 35.0 | 0.0-52.5 | 14.9 | 0.1-187.8 | 91 9 | 0.0-57.4 | 20.1 | 0.0-50.4 | 16.4 | 0.1-274.0 | 65.9 | 0.2-430.3 | 139.5 | 0.0-3.7 | 1.4 |
| V & V (21-30) | 19.7-39.5 | 28.4 | 8.2-66.9 | 48 6 | 3.0-21.6 | 16.2 | 32.2-181.2 | 116.4 | 6.3-34.2 | 25.2 | 3.9-27.6 | 19.4 | 14.0-83.4 | 56.8 | 67.6-232.8 | 154.3 | 0.0-3.3 | 2.0 |
| VII (31-35) | 30.1-38 2 | 28.8 | 54.9-71.9 | 64 6 | 15.4-21.6 | 18.43 | 150.6-186.3 | 173.1 | 27.5-32.7 | 29.2 | 21.9-32.6 | 27.36 | 79.8-132.4 | 97.8 | 164.7-178.7 | 169.8 | 1.5-2.1 | 1.7 |
| VIII & IX (36-45) | 12.9-26 4 | 19.1 | 0.0-83.3 | 52 3 | 3 1-26.1 | 18.2 | 35.1-205.0 | 150.3 | 3.4-36.8 | 21.5 | 3.0-36.4 | 24.3 | 7.3-85.5 | 59.6 | 39.4-278.6 | 160.1 | 0 0-2.6 | 1 7 |

Table 3.3.4.8

Bacterial Count in Coastal Waters and Sediments off Kochi and Alappuzha

| Type of Bacteria | Depth | Bacterial Count in Water (No./ml) | | Bacterial Count in Sediments (No./mg) | |
|---|---|---|---|---|---|
| | | Dec. 96 | Feb. 97 | Dec. 96 | Feb. 97 |
| **Off Kochi** | | | | | |
| TC | 5 S | 7 | 12 | - | - |
| | 5 B | 21 | - | 18 | 15 |
| | 10 S | 50 | - | - | - |
| | 10 B | 24 | - | 8 | - |
| | 15 S | 28 | 3 | - | - |
| | 15 B | - | - | - | 2 |
| | 20 S | 26 | - | - | - |
| | 20 B | 15 | - | 10 | - |
| ECLO | 5 S | 0 | 0 | - | - |
| | 5 B | 2 | - | 0 | 0 |
| | 10 S | 25 | - | - | - |
| | 10 B | 6 | - | 0 | - |
| | 15 S | 7 | 0 | - | - |
| | 15 B | - | - | - | 0 |
| | 20 S | 0 | - | - | - |
| | 20 B | 5 | - | 5 | - |
| **Off Alappuzha** | | | | | |
| TC | 5 S | 12 | 14 | | |
| | 5 B | - | - | 21 | 8 |
| | 10 S | 11 | - | - | - |
| | 10 B | - | - | 30 | - |
| | 15 S | - | 8 | - | |
| | 15 B | - | - | - | 5 |
| | 20 S | - | - | - | - |
| | 20 B | - | - | 8 | - |
| ECLO | 5 S | 0 | 0 | - | - |
| | 5 B | - | - | 0 | 0 |
| | 10 S | 0 | - | - | - |
| | 10 B | - | - | 15 | - |
| | 15 S | - | 0 | - | - |
| | 15 B | - | - | - | 2 |
| | 20 S | - | - | - | - |
| | 20 B | - | - | 0 | - |

**Source :** Secondary data collected by NIO

## Table 3.3.4.9

## Bacterial Count in Coastal Waters during October 1997

| St. No. | Heterotrophs | | | Coliforms | | | F.strepto-cocci | Proteus | | | V.cholerae | | | V.parashaemolyticus | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SW | BW | SED | SW | BW | SED | SED | SW | BW | SED | SW | BW | SED | SW | BW | SED |
| 1 | 150 | 130 | 140 | 6 | 4 | 16 | 0 | 5 | 2 | 7 | 1 | 0 | 1 | 6 | 10 | 8 |
| 3 | 114 | 162 | 128 | 9 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 9 | 3 | 0 |
| 14 | 86 | 75 | 84 | 4 | 6 | 12 | 0 | 1 | 8 | 11 | 0 | 0 | 0 | 1 | 10 | 0 |
| 15 | 69 | 90 | 60 | 12 | 17 | 2 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 6 | 2 |
| 17 | 98 | 102 | 112 | 2 | 3 | 8 | 1 | 6 | 12 | 5 | 1 | 12 | 0 | 8 | 3 | 2 |
| 20 | 80 | 160 | 60 | 1 | 6 | 4 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 8 |
| 29 | 248 | 152 | 208 | 6 | 6 | 8 | 0 | 2 | 2 | 5 | 1 | 0 | 0 | 2 | 4 | 1 |
| 32 | 146 | 100 | 150 | 3 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| 33 | 224 | 268 | 328 | 34 | 12 | 16 | 0 | 6 | 8 | 4 | 0 | 2 | 0 | 6 | 8 | 12 |
| 36 | 164 | 158 | 286 | 15 | 24 | 28 | 1 | 2 | 16 | 12 | 2 | 2 | 6 | 0 | 10 | 2 |
| 45 | 218 | 116 | 128 | 4 | 6 | 4 | 1 | 4 | 4 | 20 | 0 | 0 | 2 | 1 | 2 | 2 |
| 48 | 264 | 98 | 308 | 12 | 18 | 21 | 0 | 16 | 2 | 6 | 0 | 3 | 0 | 2 | 8 | 2 |
| 49 | 294 | 268 | 288 | 6 | 3 | 6 | 0 | 0 | 5 | 6 | 0 | 4 | 2 | 0 | 1 | 3 |
| 52 | 158 | 152 | 184 | 12 | 6 | 8 | 1 | 8 | 2 | 8 | 0 | 4 | 0 | 10 | 2 | 6 |
| 4 | 82 | 78 | 124 | 6 | 28 | 12 | 0 | 2 | 3 | 5 | 12 | 0 | 46 | 1 | 5 | 1 |
| 8 | 104 | 92 | 168 | 12 | 18 | 6 | 48 | 1 | 6 | 6 | 1 | 0 | 49 | 6 | 18 | 0 |
| 9 | 128 | 154 | 162 | 6 | 18 | 8 | 3 | 12 | 6 | 2 | 0 | 1 | 0 | 10 | 10 | 16 |
| 13 | 142 | 88 | 186 | 10 | 6 | 10 | 1 | 4 | 2 | 4 | 0 | 2 | 2 | 10 | 10 | 6 |
| 21 | 176 | 162 | 281 | 12 | 18 | 26 | 28 | 6 | 8 | 12 | 0 | 2 | 6 | 2 | 2 | 28 |

Contd....

**Table 3.3.4.9 Contd...**

| St. No. | Heterotrophs | | | Coliforms | | | F.strepto-cocci | Proteus | | | V.cholerae | | | V.parashaemolyticus | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SW | BW | SED | SW | BW | SED | SED | SW | BW | SED | SW | BW | SED | SW | BW | SED |
| 24 | 114 | 96 | 128 | 14 | 12 | 2 | 0 | 2 | 3 | 2 | 0 | 1 | 0 | 2 | 10 | 14 |
| 25 | 124 | 152 | 130 | 18 | 16 | 24 | 11 | 6 | 5 | 6 | 0 | 2 | 4 | 6 | 14 | 6 |
| 37 | 74 | 98 | 124 | 3 | 18 | 12 | 18 | 2 | 5 | 0 | 10 | 0 | 0 | 2 | 4 | 8 |
| 40 | 136 | 182 | 198 | 6 | 4 | 1 | 28 | 6 | 8 | 2 | 2 | 4 | 4 | 10 | 0 | 0 |
| 41 | 94 | 108 | 162 | 6 | 8 | 19 | 1 | 0 | 3 | 8 | 0 | 0 | 0 | 10 | 0 | 10 |
| 44 | 54 | 137 | 164 | 3 | 1 | 1 | 38 | 6 | 13 | 2 | 2 | 0 | 0 | 1 | 1 | 2 |
| 53 | 64 | 48 | 154 | 14 | 2 | 6 | 0 | 0 | 4 | 2 | 0 | 0 | 0 | 1 | 2 | 1 |
| 56 | 162 | 93 | 206 | 6 | 2 | 2 | 48 | 1 | 8 | 2 | 8 | 0 | 26 | 2 | 16 | 12 |

Unit – All parameters are in Numbers/ml, SW = Surface water, BW = Bottom water, SED = Sediment, E.coli, F.streptococci, P.aeruginosa, Salmonella, and Shigella are negligible at all stations except at stations 9,13,44 and 53.

**Source :** Primary data collected by NIO

## Table 3.3.4.10

### Bacterial Count in Coastal Waters during February 1999

| Stn. No. | Coliforms | | | Heterotrophs | | | Faecal coliforms | | | Faecal streptococci | | | Vibrio cholerae | | | Pseudomonas | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SW | BW | SED | SW | BW | SED | SW | BW | SED | SW | BW | SED | SW | BW | SED | SW | BW | SED |
| 1 | 52 | 198 | 304 | 8 | 12 | 8 | - | - | - | 5 | 2 | 6 | - | 4 | - | - | - | - |
| 2 | 14 | 16 | 22 | 6 | 12 | 8 | - | - | - | - | 2 | 2 | - | - | - | - | - | - |
| 3 | 284 | 58 | 52 | 8 | 4 | 6 | - | - | - | - | - | 4 | 1 | - | - | - | - | - |
| 4 | 298 | 182 | 102 | 18 | 6 | 12 | - | - | - | 6 | 2 | - | - | - | - | - | - | - |
| 5 | 12 | 16 | 28 | 10 | 12 | 8 | - | - | - | - | - | 4 | - | 2 | - | - | - | - |
| 6 | 64 | 184 | 142 | 12 | - | 6 | - | - | - | 5 | - | - | - | - | - | - | - | - |
| 7 | 282 | 308 | 314 | 2 | 12 | 6 | - | - | - | - | - | 2 | 4 | - | - | - | - | - |
| 8 | 42 | 28 | 38 | 12 | 6 | 22 | - | - | - | - | 4 | 2 | - | - | - | - | - | - |
| 9 | 84 | 62 | 98 | 12 | 8 | 2 | - | - | - | - | - | 1 | - | - | - | - | - | - |
| 10 | 128 | 82 | 112 | 18 | 2 | 16 | - | - | - | 8 | 4 | - | - | - | - | - | - | - |
| 11 | 318 | 142 | 298 | 20 | 12 | 12 | - | - | - | 8 | - | 6 | 2 | - | - | - | 1 | 4 |
| 12 | 288 | 52 | 192 | 12 | 2 | 24 | - | - | - | 22 | 4 | 6 | 6 | - | - | - | - | 2 |
| 13 | 248 | 98 | 138 | 22 | 12 | 8 | - | - | - | 2 | - | - | - | 1 | - | - | - | - |
| 14 | 272 | 148 | 324 | 16 | 12 | 48 | - | - | - | 12 | 10 | 14 | - | - | - | - | - | 2 |
| 15 | 72 | 48 | 282 | 12 | 2 | 20 | - | - | - | 8 | 2 | 6 | - | - | - | - | - | 1 |
| 16 | 128 | 198 | 288 | 12 | - | 18 | - | - | - | - | 1 | 4 | - | - | - | - | - | - |
| 17 | 62 | 98 | 162 | 16 | 18 | 12 | - | 4 | - | - | 2 | 8 | - | - | 1 | - | - | - |
| 18 | 192 | 124 | 92 | 4 | 6 | 12 | - | - | - | - | 2 | - | 2 | - | 1 | - | - | - |
| 19 | 228 | 112 | 183 | 20 | 26 | 28 | - | - | 2 | 9 | - | - | - | 2 | - | - | - | 6 |
| 20 | 142 | 208 | 168 | 16 | 12 | 22 | 2 | - | - | 4 | - | - | 2 | - | 1 | - | - | 2 |

Contd...

Table 3.3.4.10 Contd...

| Stn. No. | Coliforms | | | Heterotrophs | | | Faecal coliforms | | | Faecal streptococci | | | Vibrio cholerae | | | Pseudomonas | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SW | BW | SED | SW | BW | SED | SW | BW | SED | SW. | BW | SED | SW | BW | SED | SW | BW | SED |
| 21 | 302 | 298 | 362 | 40 | 32 | 22 | - | - | 3 | - | - | - | - | - | - | - | - | - |
| 22 | 224 | 262 | 294 | 26 | 31 | 38 | - | 1 | 4 | 4 | 2 | - | 2 | 1 | - | - | - | 7 |
| 23 | 52 | 292 | 354 | 12 | 28 | 10 | - | 1 | - | - | - | - | - | 1 | - | - | - | - |
| 24 | 238 | 276 | 288 | 28 | 42 | 21 | 8 | 1 | - | - | - | 1 | - | - | - | - | - | - |
| 25 | 274 | 32 | 358 | 38 | 21 | 6 | - | 2 | - | - | - | - | - | - | 2 | - | - | - |
| 26 | 158 | 132 | 178 | 28 | 3 | 8 | - | 1 | - | - | 2 | - | - | - | - | - | - | - |
| 27 | 368 | 290 | 198 | 46 | 32 | 2 | - | 2 | - | 2 | - | - | - | - | - | - | 1 | - |
| 28 | 208 | 154 | 286 | 6 | 10 | 42 | - | - | - | - | 12 | 6 | - | - | - | 4 | - | - |
| 29 | 374 | 246 | 298 | 13 | 16 | - | - | 4 | - | - | - | 12 | - | - | - | - | - | - |
| 30 | 228 | 236 | 302 | 31 | 26 | 16 | 5 | 3 | - | 5 | 4 | - | - | 1 | - | 1 | 6 | - |
| 31 | 325 | 202 | 258 | 2 | 2 | 4 | - | - | - | - | - | - | - | 1 | - | - | - | - |
| 32 | 108 | 112 | 282 | 2 | 1 | 3 | - | - | - | - | - | - | - | 1 | - | - | - | - |
| 33 | 196 | 72 | 192 | 21 | 27 | 2 | - | - | - | - | - | - | - | - | - | - | - | - |
| 34 | 212 | 286 | 198 | 10 | 17 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 35 | 78 | 62 | 158 | 7 | 9 | 2 | - | - | - | - | 1 | - | - | - | - | - | - | - |
| 36 | 108 | 94 | 196 | 36 | 16 | 22 | 8 | - | 6 | - | - | 4 | - | - | 3 | 4 | - | 6 |
| 37 | 88 | 126 | 112 | 8 | 12 | 16 | - | 2 | 2 | - | 1 | - | - | - | - | - | 2 | - |
| 38 | 242 | 266 | 186 | 10 | 21 | 18 | - | - | 1 | - | - | - | - | - | - | - | 6 | - |
| 39 | 228 | 306 | 256 | 26 | 48 | 42 | 6 | 6 | 2 | 8 | 2 | 10 | - | - | - | 1 | 1 | - |
| 40 | 264 | 282 | 208 | 22 | 28 | 68 | - | - | 4 | 1 | 2 | 12 | - | 2 | - | 8 | 6 | 9 |
| 41 | 36 | 58 | 186 | 2 | 2 | 6 | - | - | - | - | 2 | 6 | - | - | - | 2 | - | - |
| 42 | 362 | 286 | 192 | 24 | 10 | 38 | 12 | - | 6 | 2 | 2 | 6 | - | - | - | 2 | - | - |
| 43 | 32 | 58 | 198 | 9 | 8 | 12 | - | - | - | - | - | 3 | - | - | - | - | - | - |
| 44 | 42 | 64 | 98 | 10 | 7 | 11 | - | - | - | - | - | 8 | - | - | - | - | - | - |
| 45 | 38 | 148 | 92 | 16 | 18 | 2 | - | - | - | - | - | 1 | - | - | - | - | - | - |

SW - Surface water, BW - Bottom water, SED – Sediment, **Source** : Primary data collected by NIO

## Table 3.3.4.11

### Bacterial Count in Coastal Waters during November 2000

| Station No. | Heterotrophs | | | Coliforms | | | Faecal Coliforms | | | Salmonella | | | Vibrio Cholerae | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SW | BW | SED | SW | BW | SED | SW | BW | SED | SW | BW | SED | SW | BW | SED |
| 1 | 176 | 28 | 137 | 27 | 12 | 11 | 3 | 1 | 0 | 0 | 0 | 0 | 4 | 0 | 0 |
| 5 | 87 | 70 | 147 | 2 | 2 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 |
| 6 | 72 | 26 | 113 | 11 | 5 | 40 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 92 | 90 | 110 | 13 | 12 | 7 | 1 | 2 | 3 | 0 | 0 | 0 | 1 | 0 | 0 |
| 11 | 139 | 68 | 79 | 10 | 21 | 17 | 0 | 7 | 5 | 0 | 0 | 0 | 1 | 1 | 0 |
| 15 | 98 | 28 | 110 | 36 | 11 | 48 | 0 | 3 | 5 | 0 | 0 | 0 | 3 | 0 | 0 |
| 16 | 30 | 25 | 26 | 12 | 14 | 10 | 1 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | 112 | 73 | 196 | 12 | 13 | 29 | 2 | 0 | 4 | 0 | 0 | 0 | 2 | 1 | 0 |
| 21 | 120 | 110 | 145 | 22 | 10 | 16 | 4 | 1 | 6 | 0 | 0 | 0 | 5 | 2 | 0 |
| 25 | 35 | 14 | 55 | 10 | 5 | 17 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | 112 | 50 | 121 | 11 | 10 | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 | 98 | 59 | 58 | 32 | 10 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 2 |
| 31 | 122 | 124 | 82 | 14 | 16 | 10 | 8 | 2 | 2 | 2 | 0 | 0 | 6 | 2 | 1 |
| 35 | 78 | 248 | 240 | 15 | 20 | 17 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 1 | 1 |
| 36 | 144 | 96 | 130 | 16 | 7 | 26 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 | 56 | 416 | 536 | 14 | 27 | 33 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 41 | 63 | 40 | 134 | 13 | 17 | 11 | 2 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 45 | 62 | 69 | 140 | 14 | 12 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

SW - Surface water, BW - Bottom water, SED – Sediment; **Source :** Primary data collected by NIO

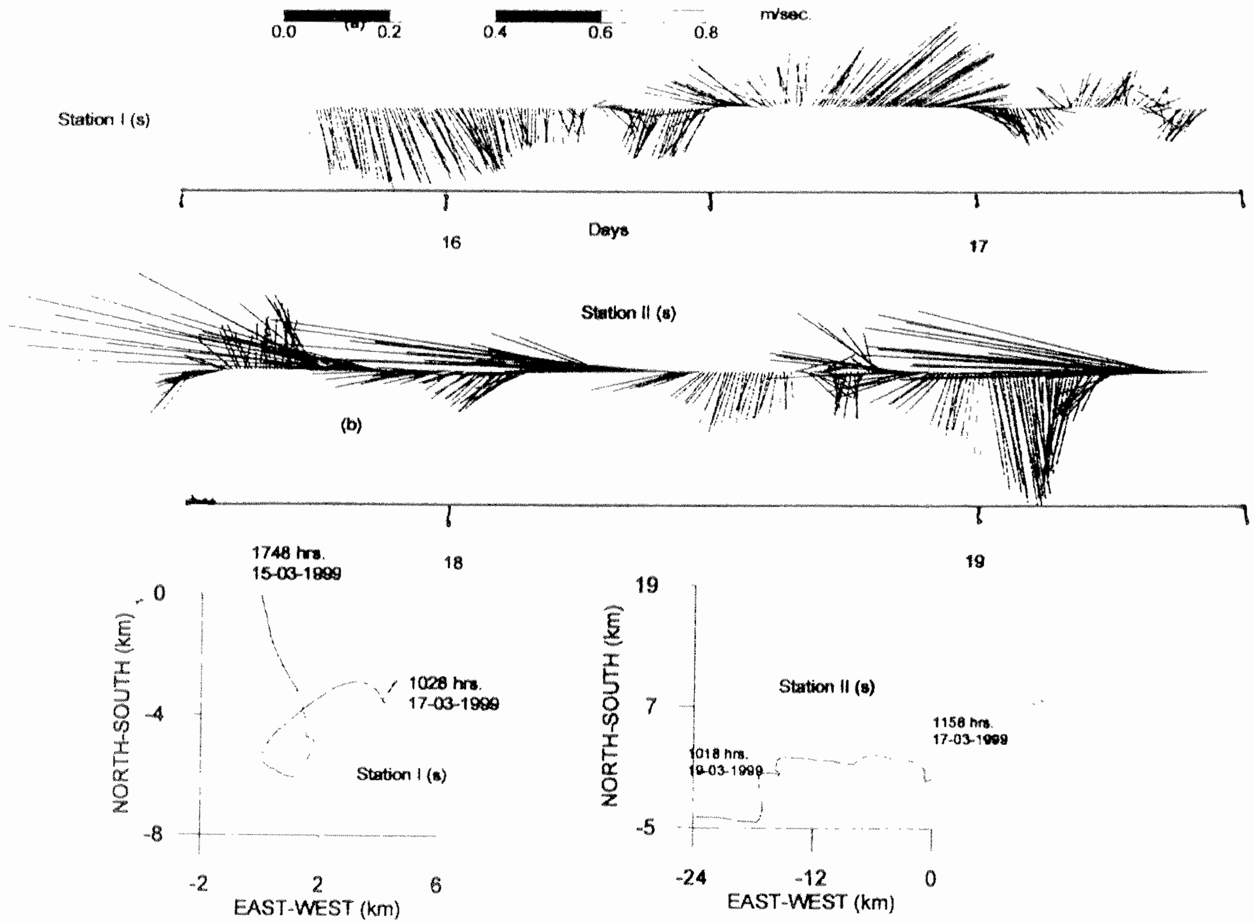



Fig. 3.3.4.1 : Stick Plots and Progressive Vector Diagrams of Currents at the Surface (s) of Station I (15m) and II (10m) during March

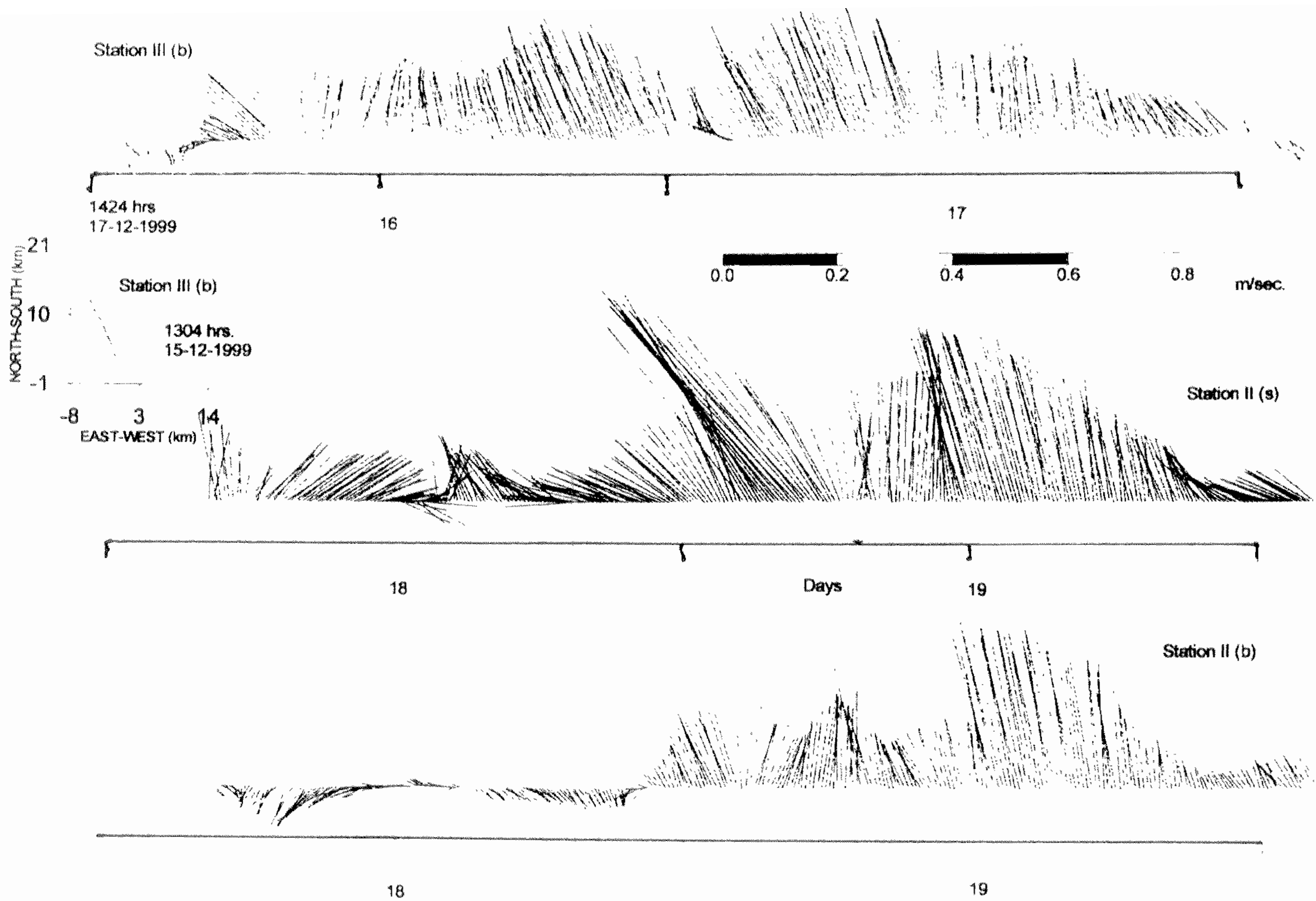



Fig. 3.3.4.2 : Stick Plot and Progressive Vector Diagram of Currents at the Bottom of Stations III (5m depth) and Stick Plots at the Surface and Bottom II (10m depth) during December

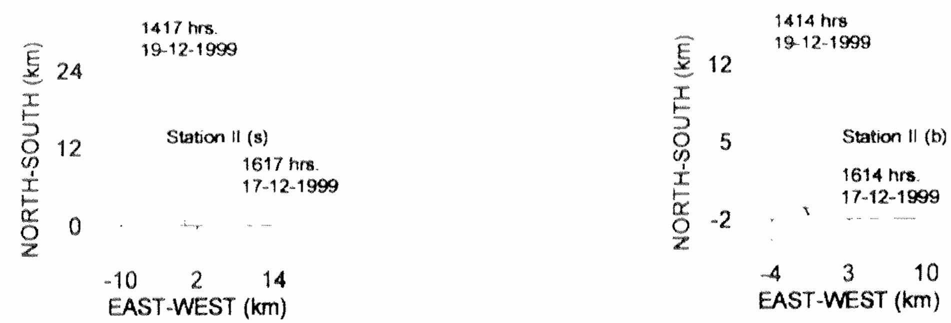



Fig. 3.3.4.3 : Progressive Vector Diagram for Surface and Bottom Currents at Station II (10m depth) during December

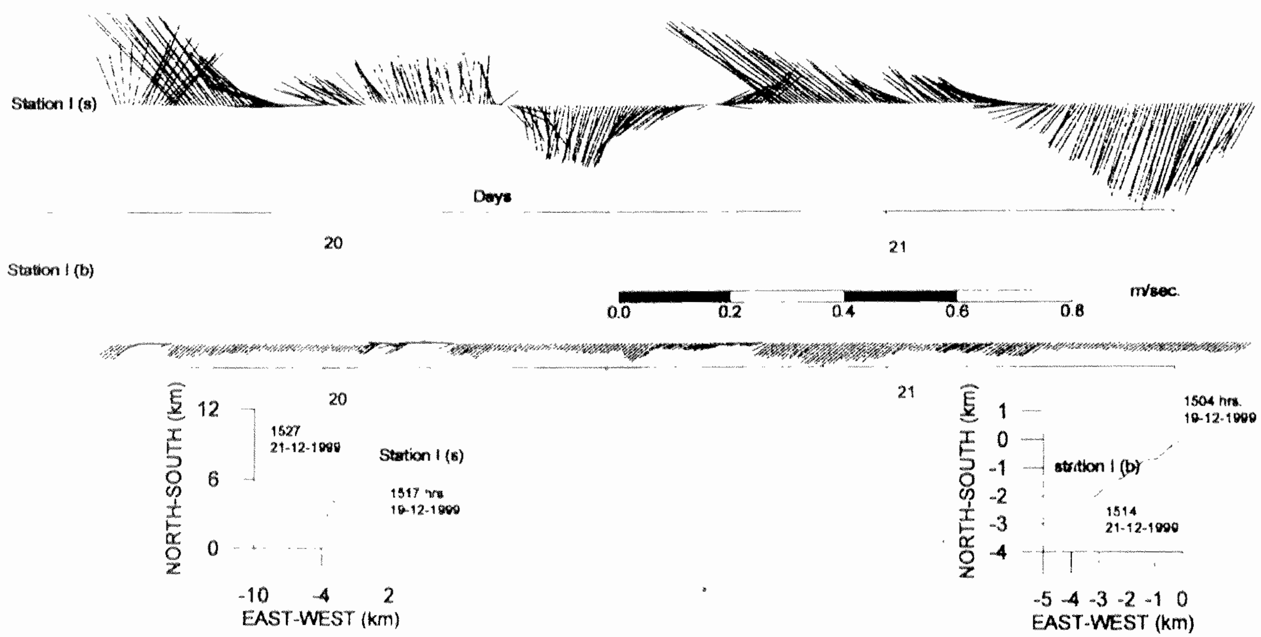
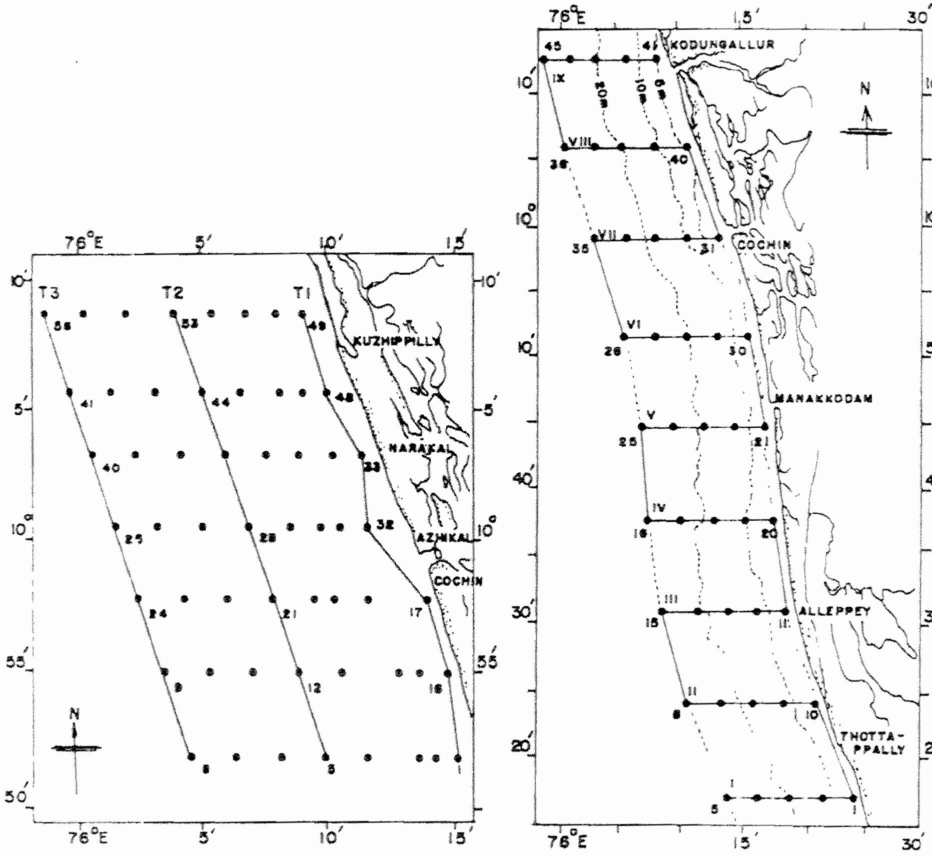



Fig. 3.3.4.4: Stick Plot and Progressive Vector diagram of Currents at Station I (15m depth) during December




a) October, 1997 b) February, 1999 and November, 2000

**Fig. 3.3.4.5 : Sampling Locations of Primary Data Collection during October 1997, February 1999 and November 2000**

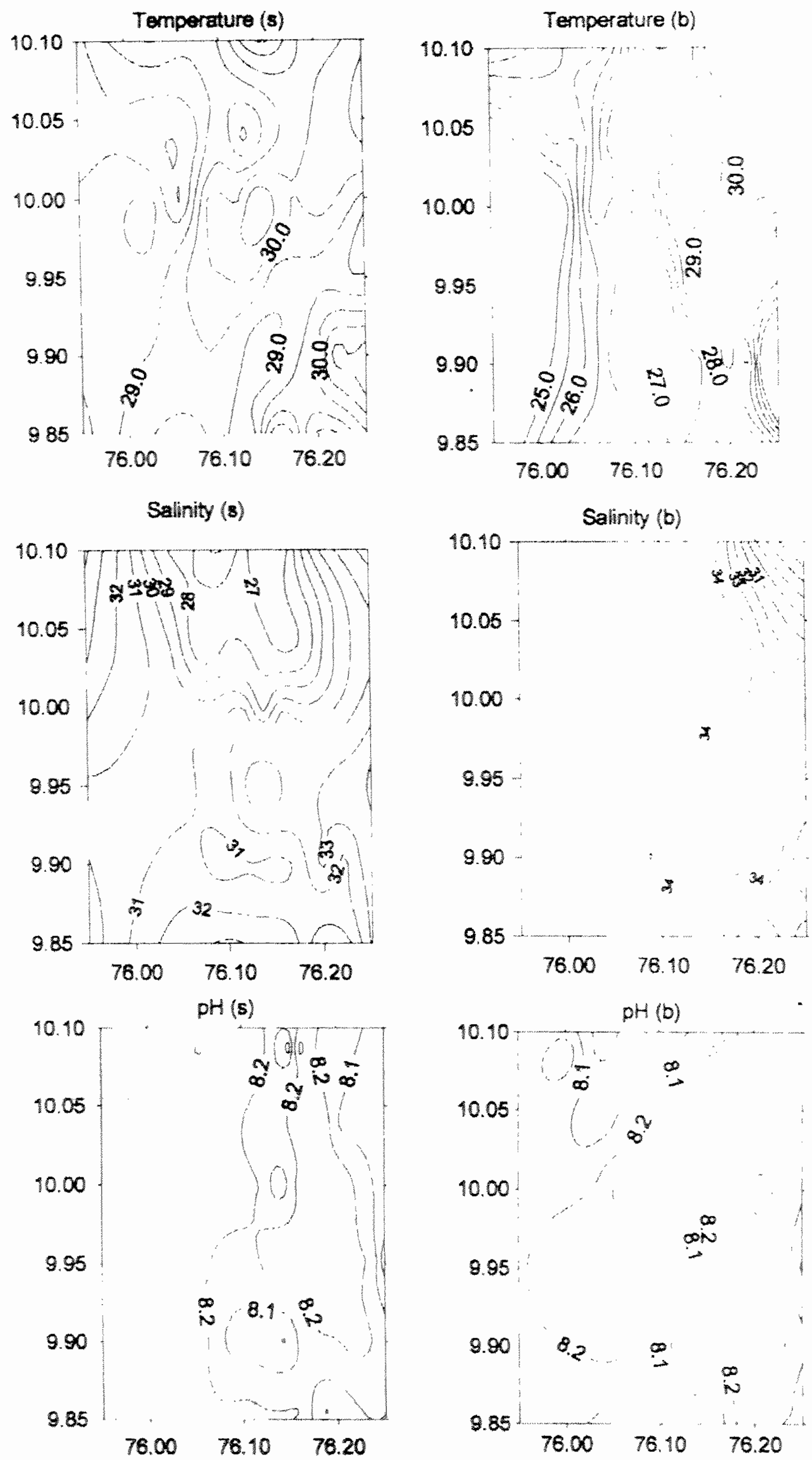



Fig. 3.3.4.6 : Horizontal Distribution of Temperature ($^0$C), Salinity (psu), and pH at the Surface (s) and Bottom (b) Waters during October

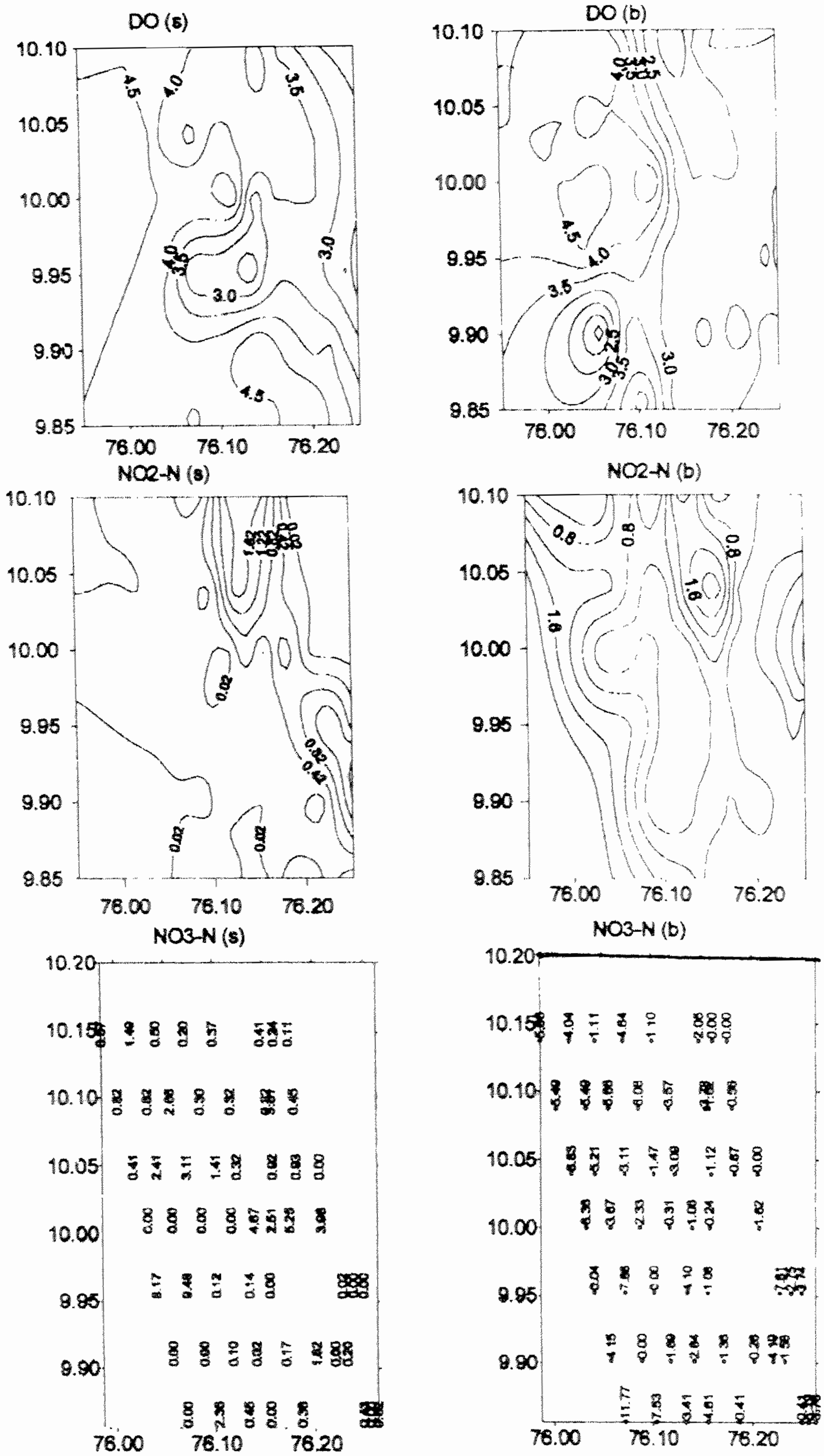



Fig. 3.3.4.7 : Horizontal Distribution of DO (ml/L), $NO_2$-N (μmol/L) and $NO_3$-N (μmol/L) at the Surface (s) and Bottom (b) Waters during October

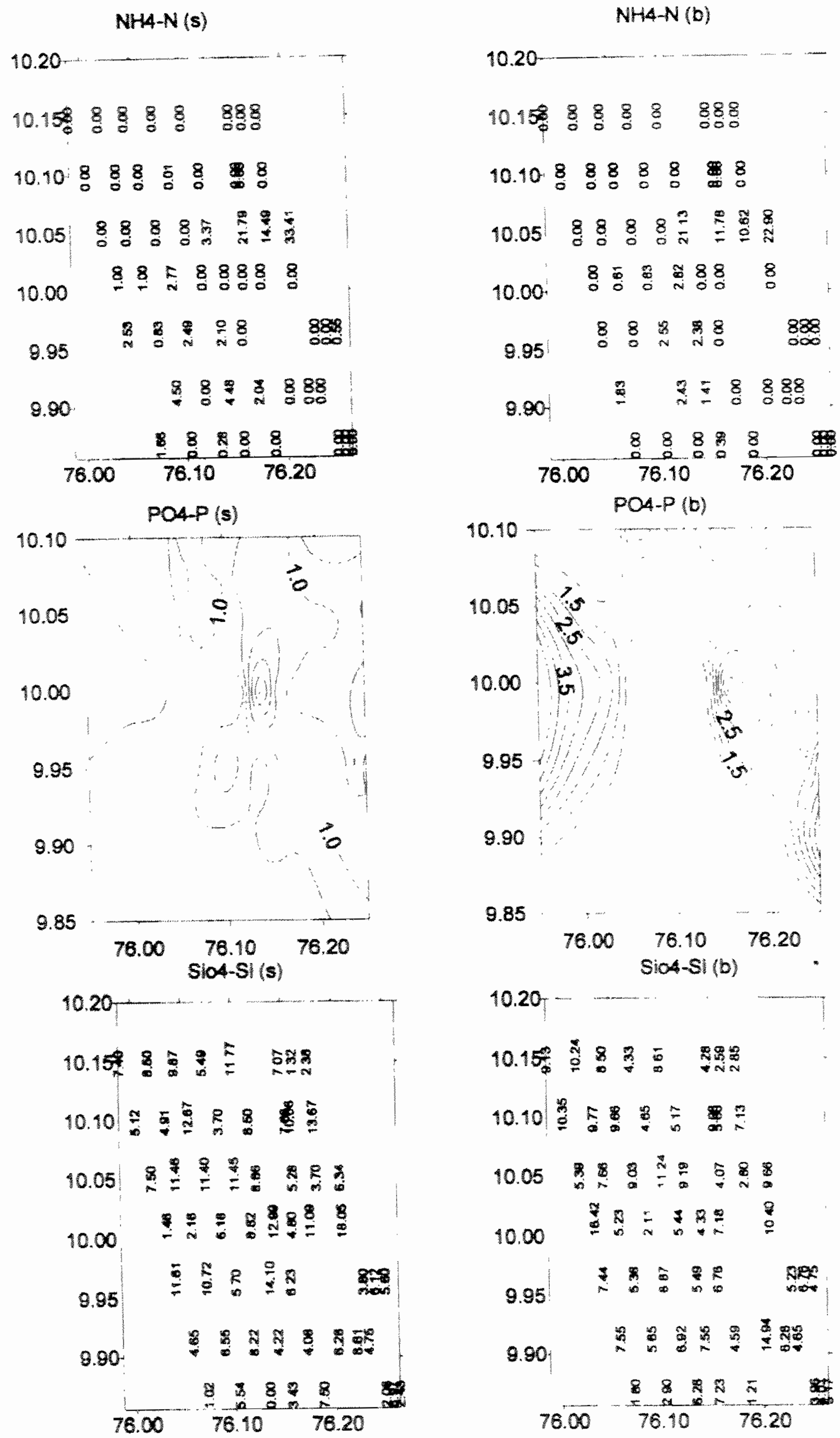



Fig. 3.3.4.8 : Horizontal Distribution of $NH_4$-N (μmol/L), $PO_4$-P and $SiO_4$-Si (μmol/L) at the Surface (s) and Bottom (b) Waters during October

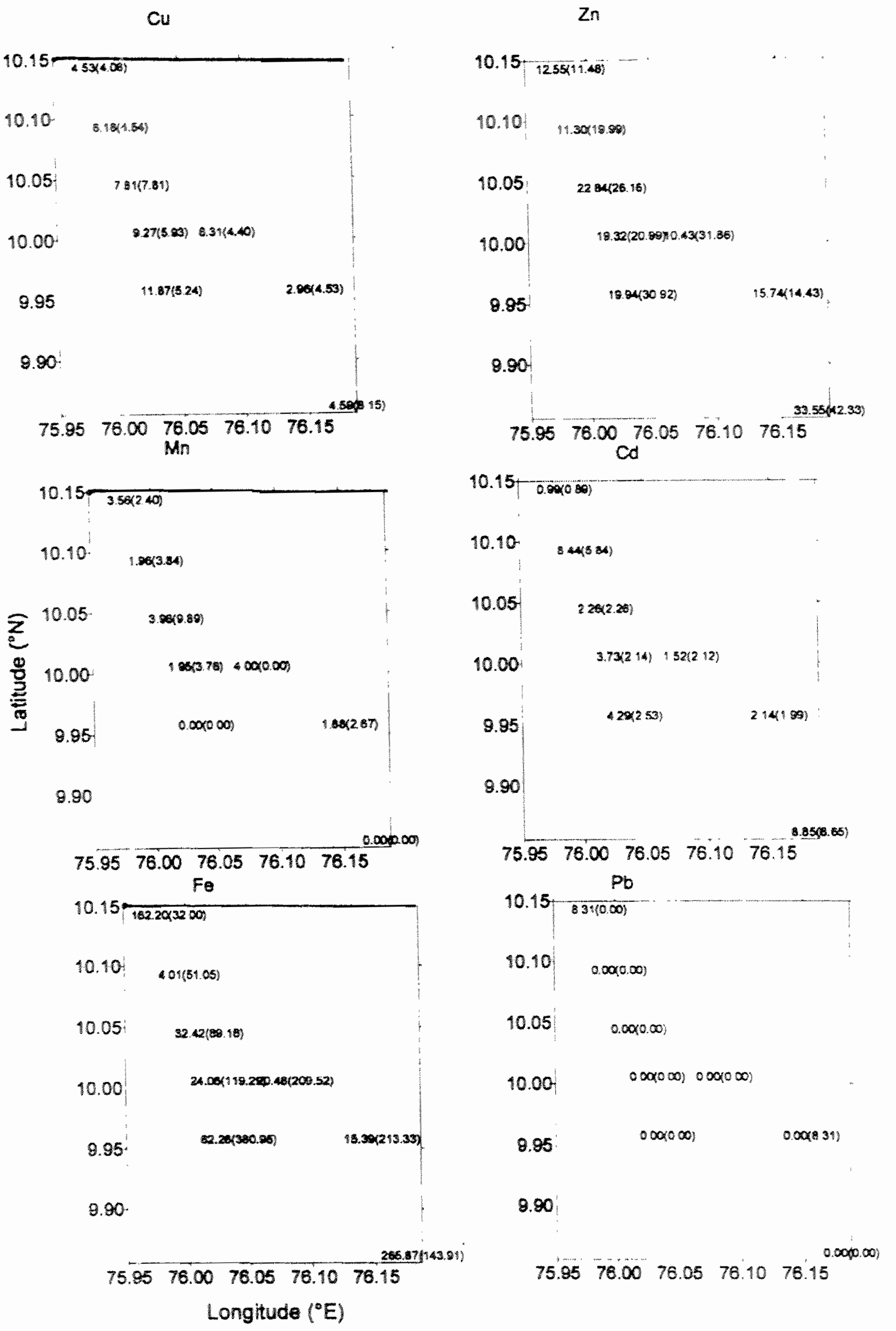



Fig. 3.3.4.9 : Horizontal Distribution of Cu, Mn, Cd, Fe and Pb (all in µmol/L) at the Surface (s) and Bottom (b) Waters during October

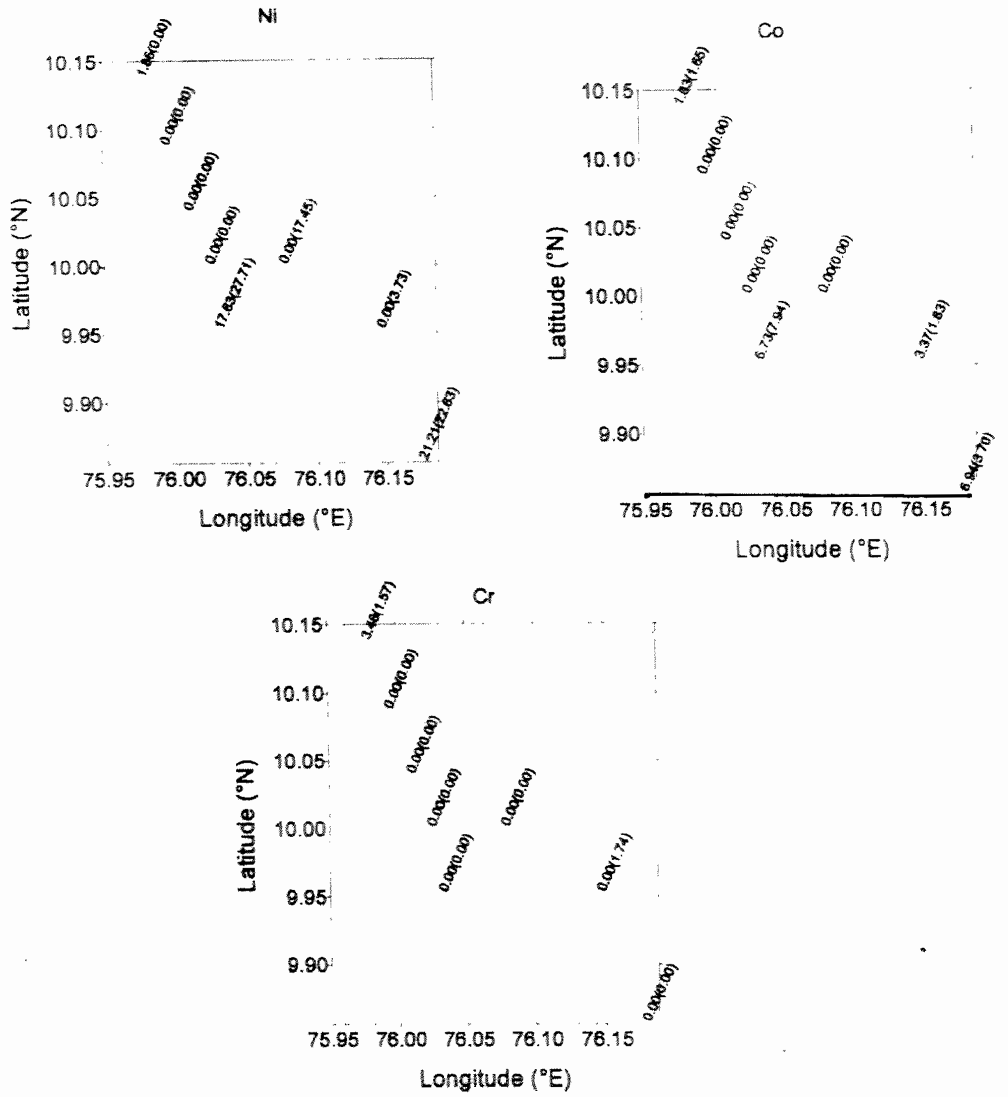



**Fig. 3.3.4.10 : Horizontal Distribution of Ni, Co and Cr (µmol/L) at the Surface (s) and Bottom (b) Waters during October**

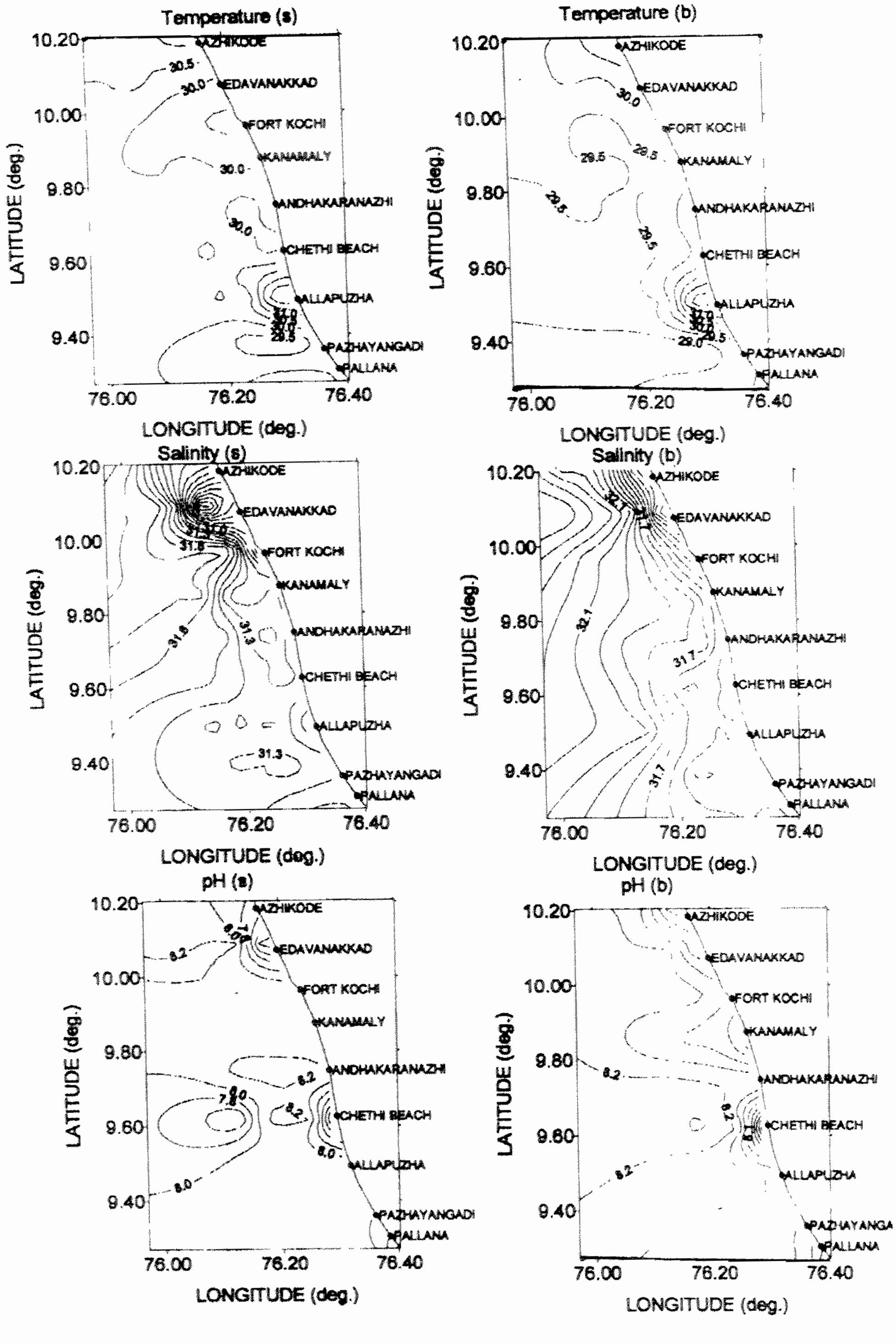



Fig. 3.3.4.11: Horizontal Distribution of Temperature ($^0$C), Salinity (psu), and pH at the Surface (s) and Bottom (b) Waters during February 1999

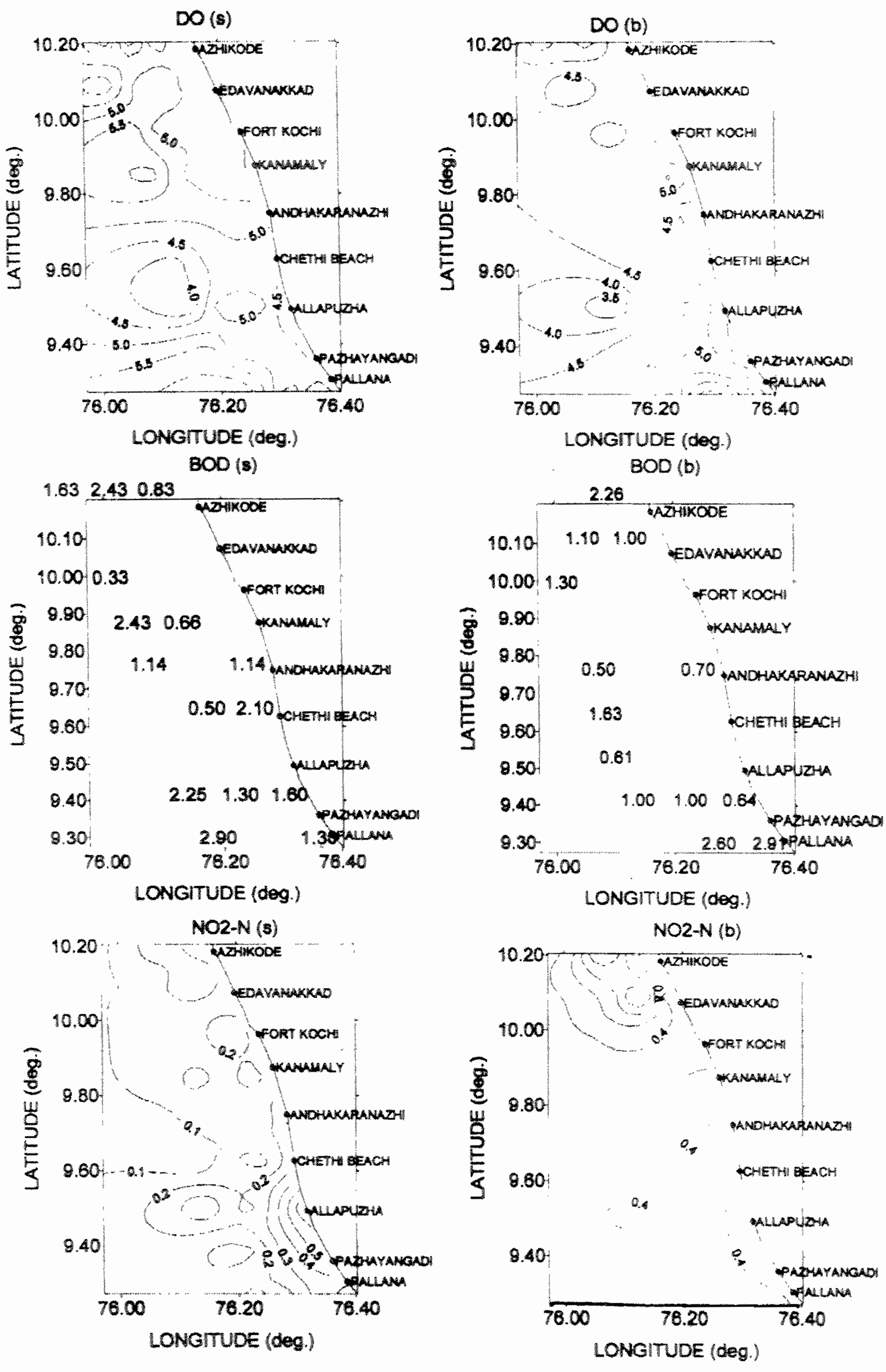



Fig. 3.3.4.12 : Horizontal Distribution of DO (ml/L), $NO_2$-N (μmol/L) and $NO_3$-N (μmol/L) at the Surface (s) and Bottom (b) Waters during February 1999

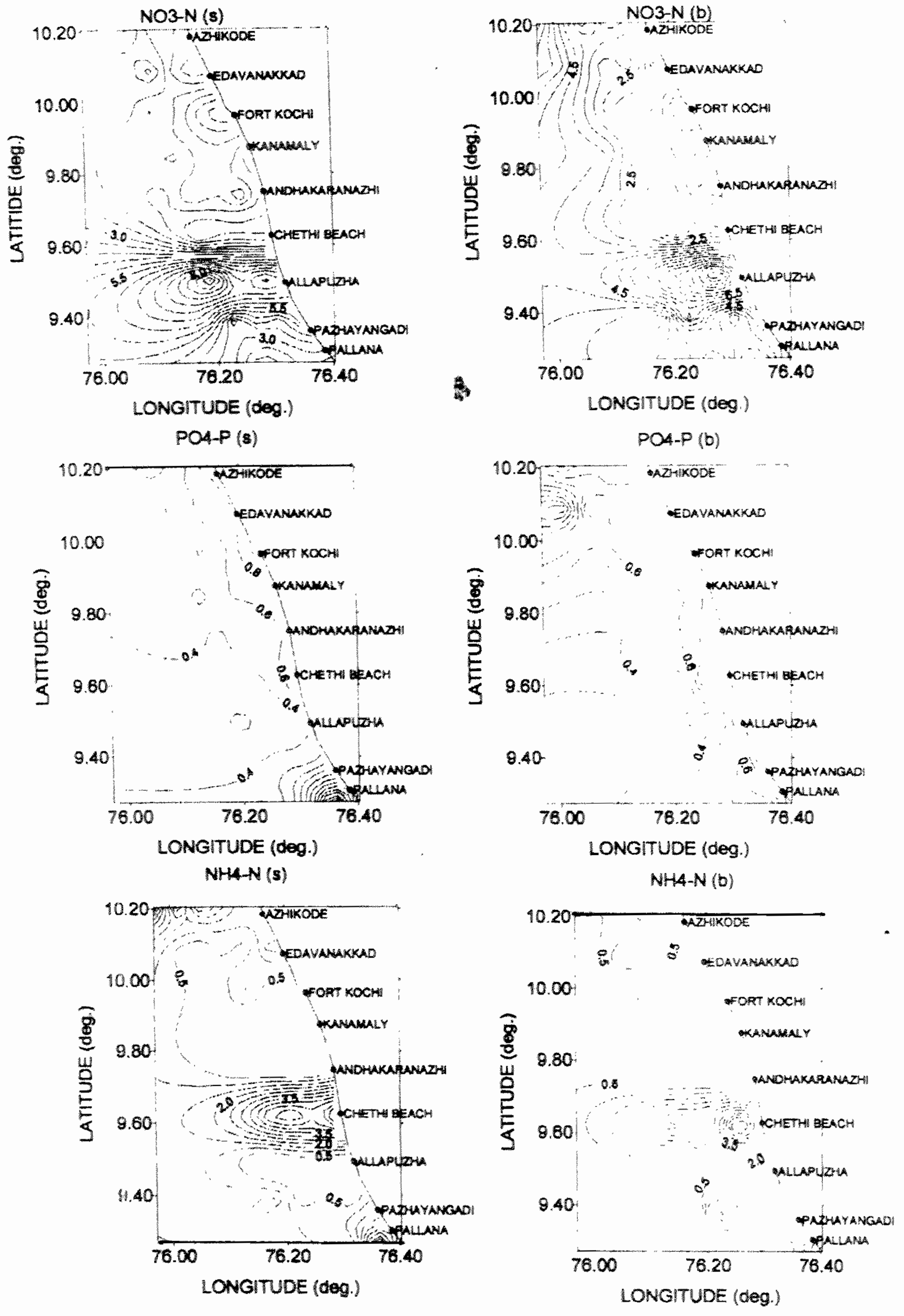



Fig. 3.3.4.13 : Horizontal Distribution of $NH_4$-N (µmol/L), $PO_4$-P and $NH_4$-N (µmol/L) at the Surface (s) and Bottom (b) Waters during February 1999

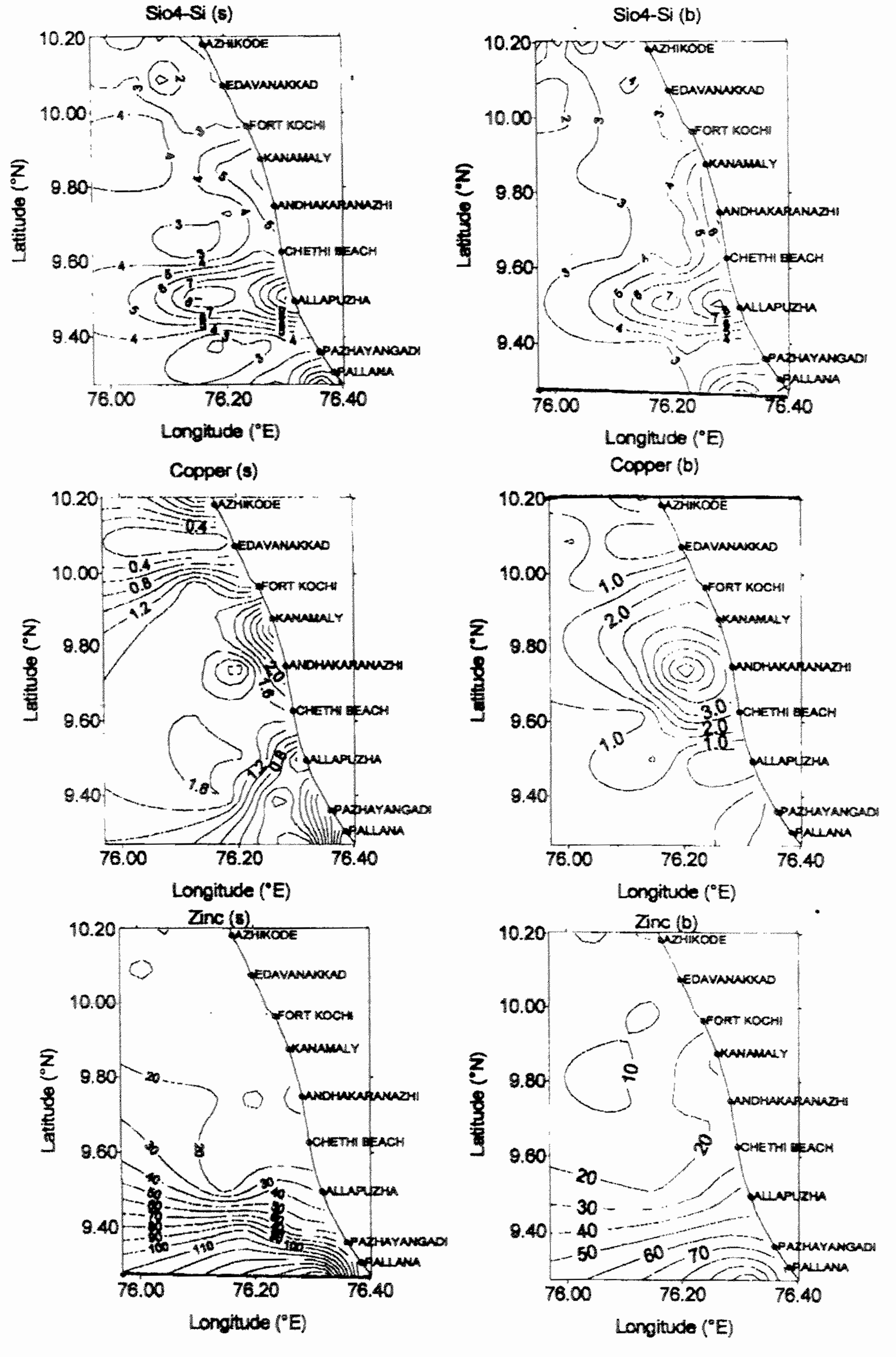



Fig. 3.3.4.14 : Horizontal Distribution of $SiO_4$-Si, Cu, and Zn (all in µmol/L) at the Surface (s) and Bottom (b) Waters during February 1999

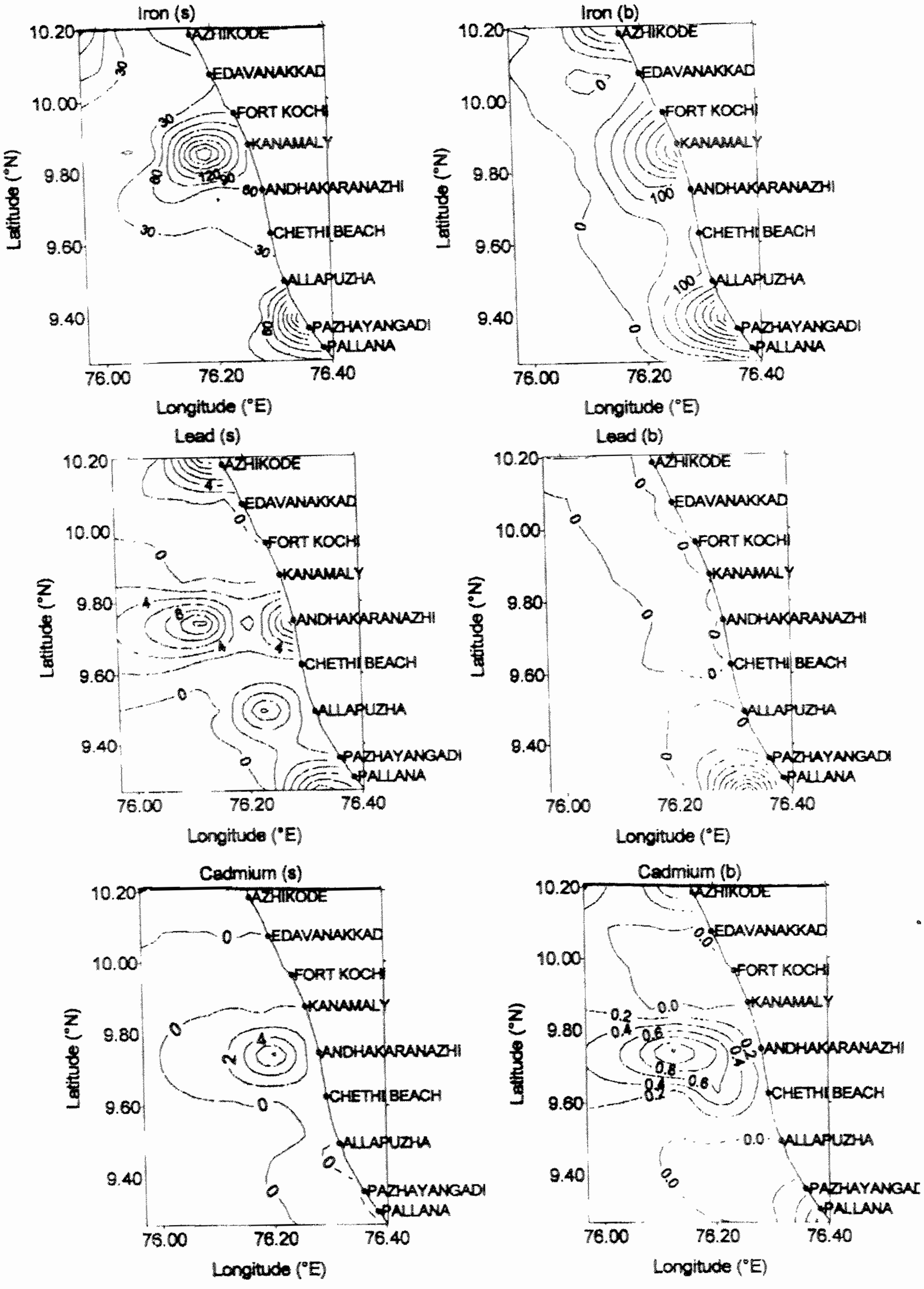



Fig. 3.3.4.15 : Horizontal Distribution of Fe, Pb and Cd (all in µmol/L) at the Surface (s) and Bottom (b) Waters during February 1999

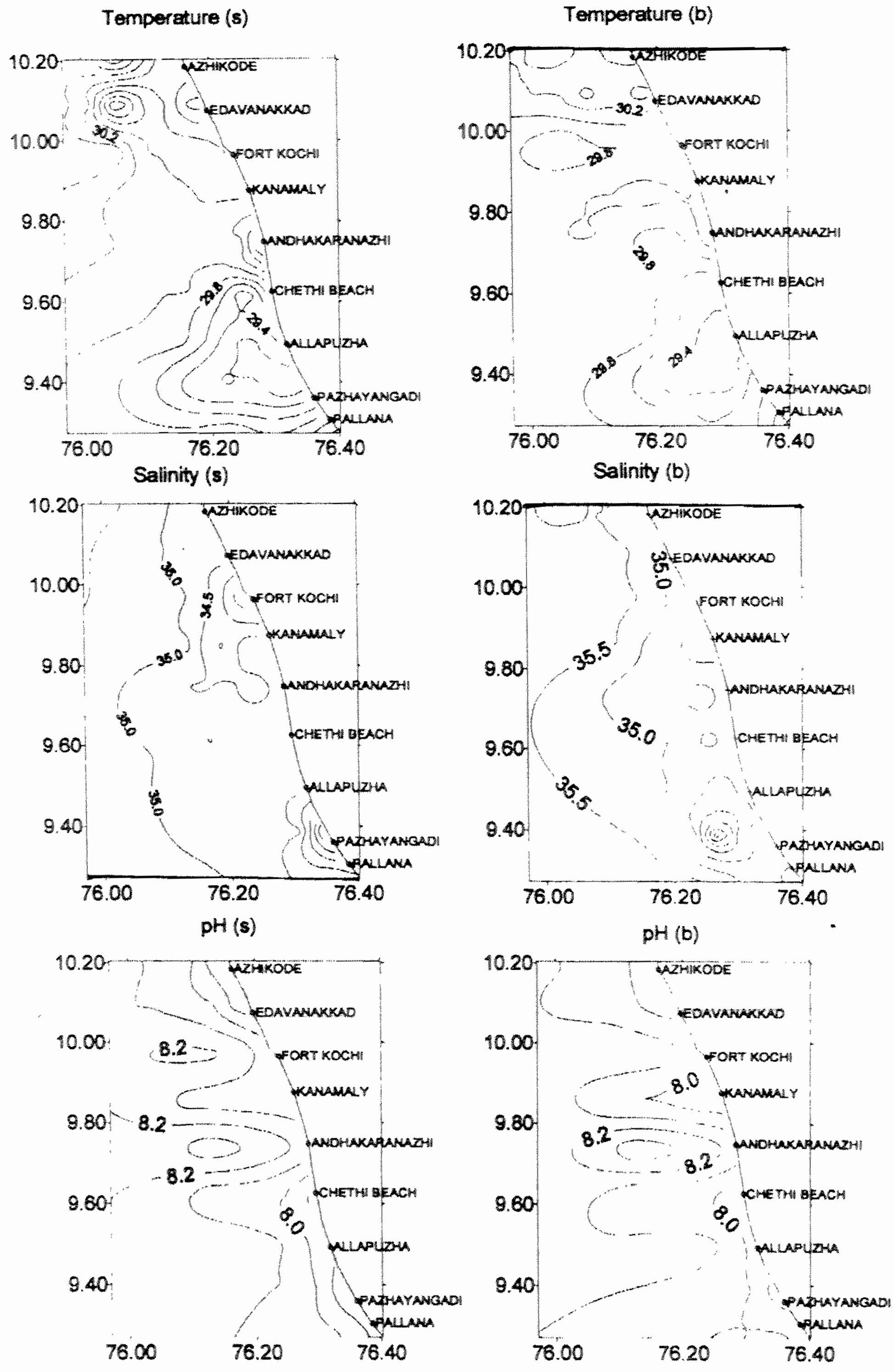



Fig. 3.3.4.16 : Horizontal Distribution of Temperature ($^0$C), Salinity (psu) and pH at the Surface (s) and Bottom (b) Waters during November 2000

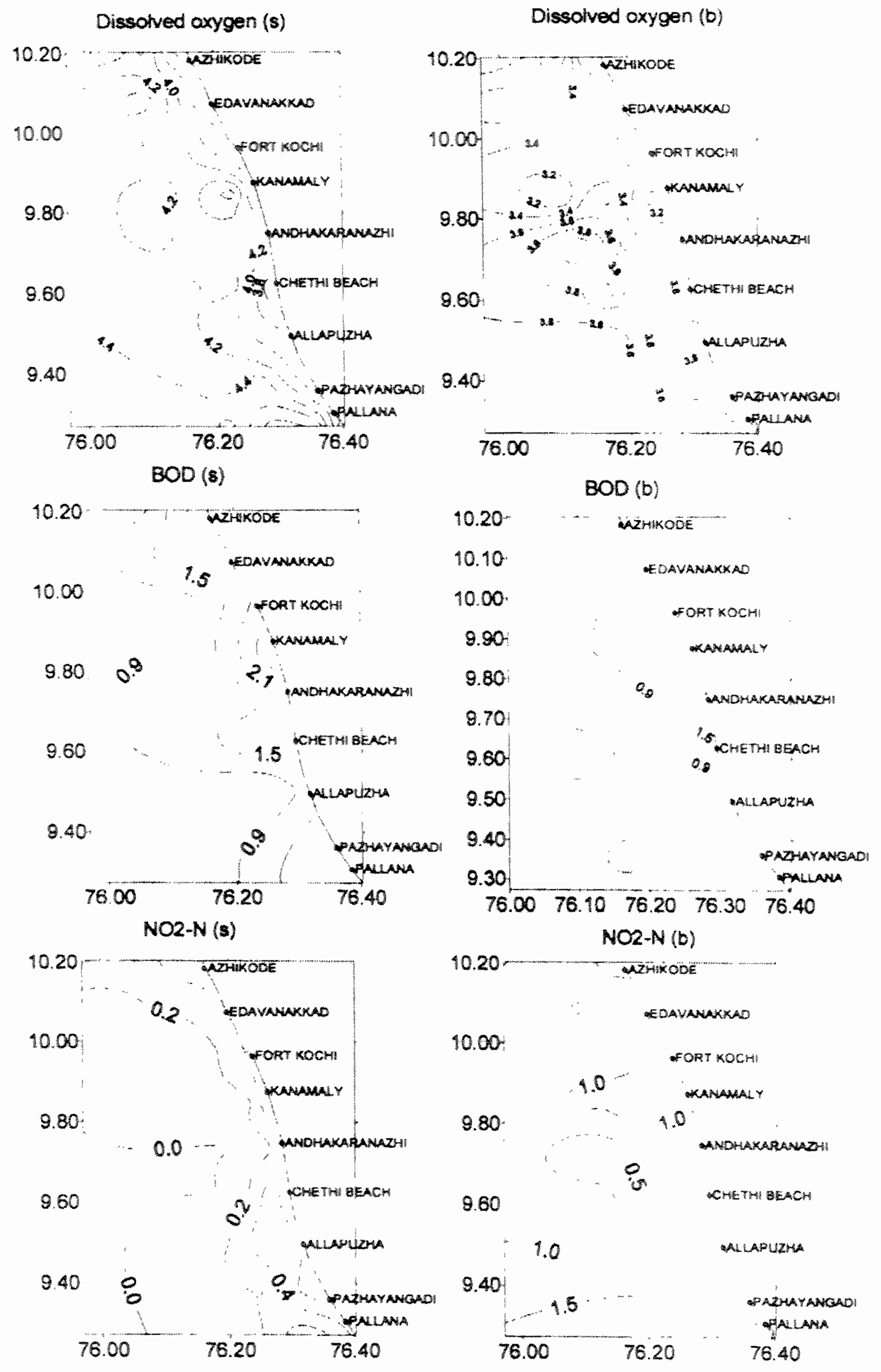



Fig. 3.3.4.17 : Horizontal Distribution of DO (ml/L), BOD (mg/L), and $NO_2$-N ($\mu$mol/L) at the Surface (s) and Bottom (b) Waters during November 2000

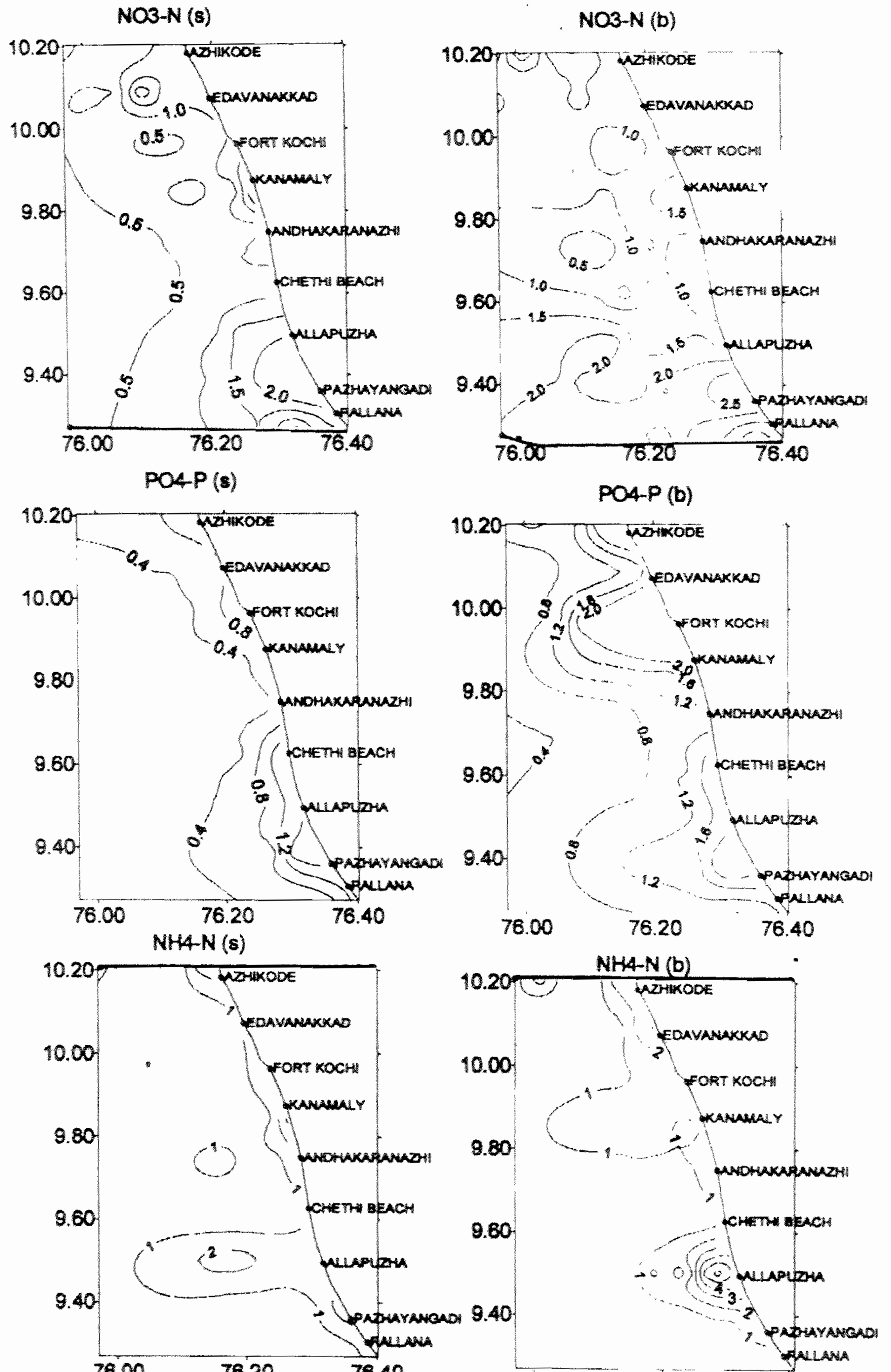



Fig. 3.3.4.18 : Horizontal Distribution of $NO_3$-N (μmol/L), $PO_4$-P and $NH_4$-N (μmol/L) at the Surface (s) and Bottom (b) Waters during November 2000

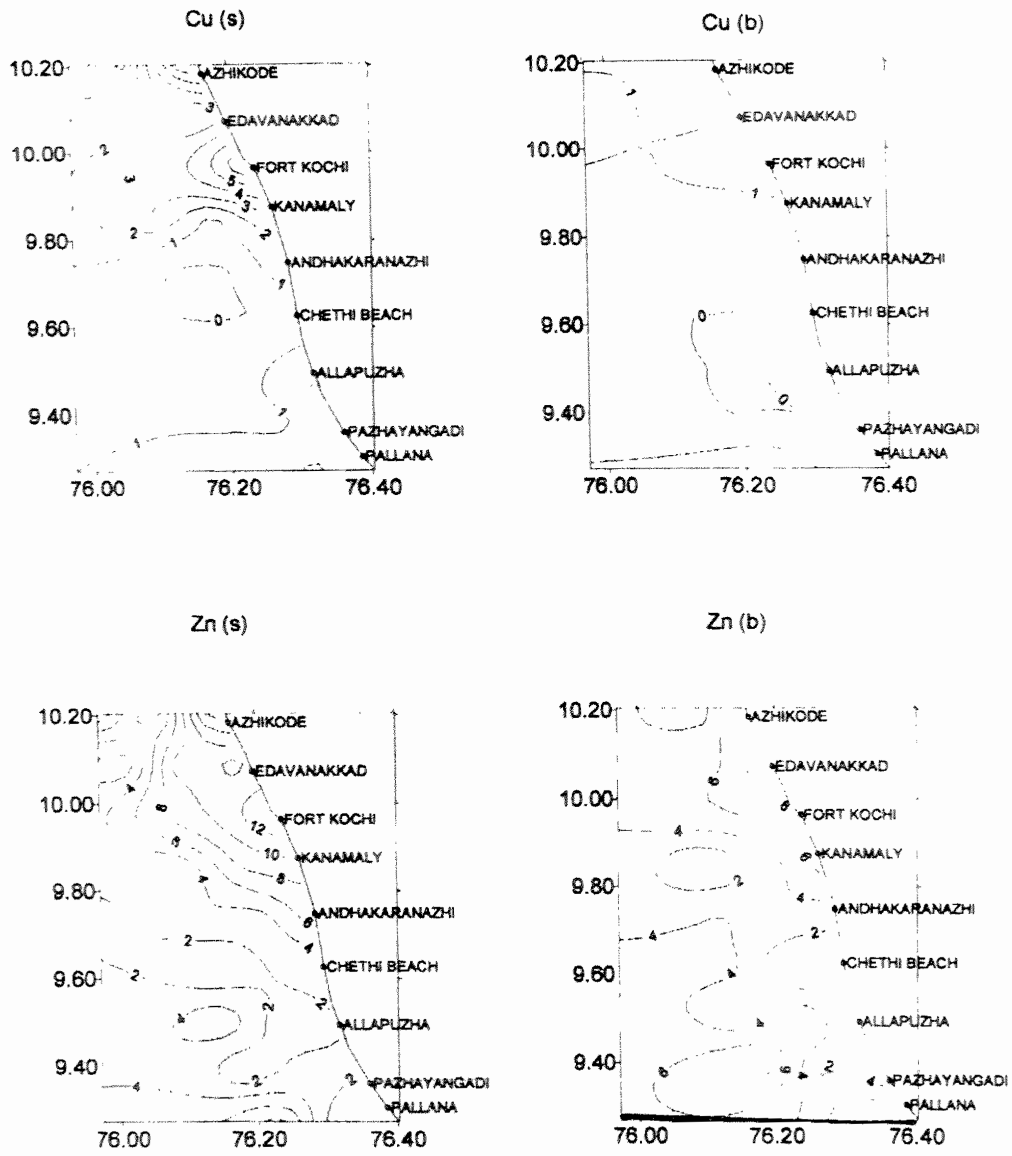
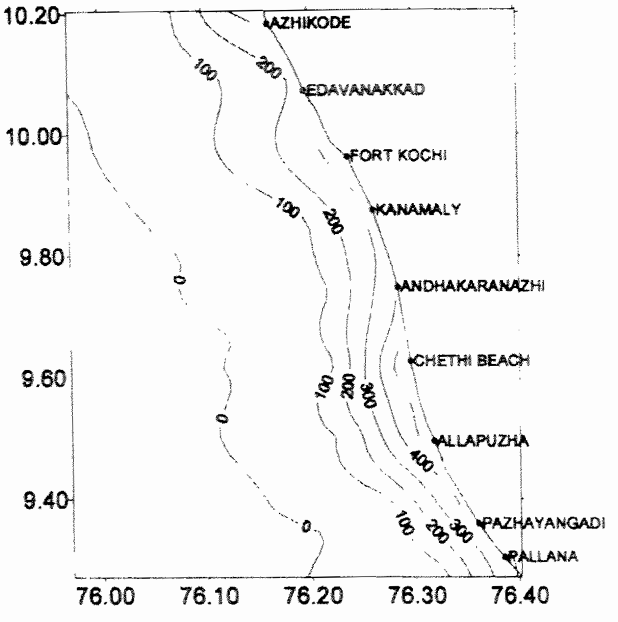



**Fig. 3.3.4.19 : Horizontal Distribution of Cu and Zn (all in µmol/L) at the Surface (s) and Bottom (b) Waters during November 2000**

Fe (s)




Fe (b)

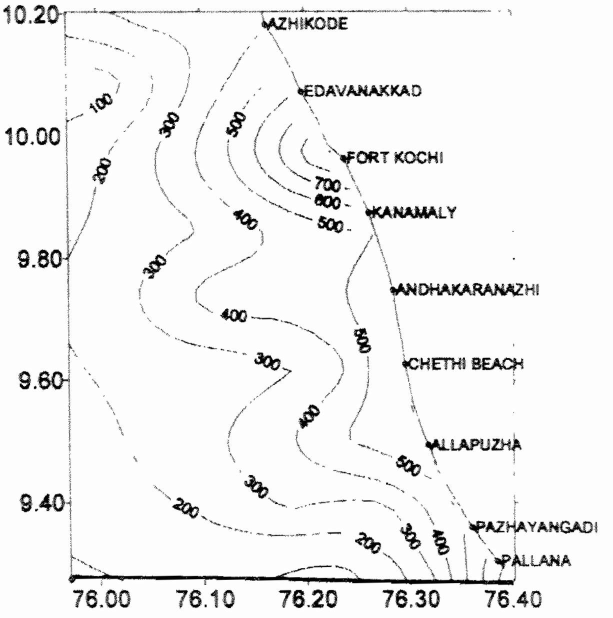



Fig. 3.3.4.20 : Horizontal Distribution of Fe (µmol/L) at the Surface (s) and Bottom (b) Waters during December 2000

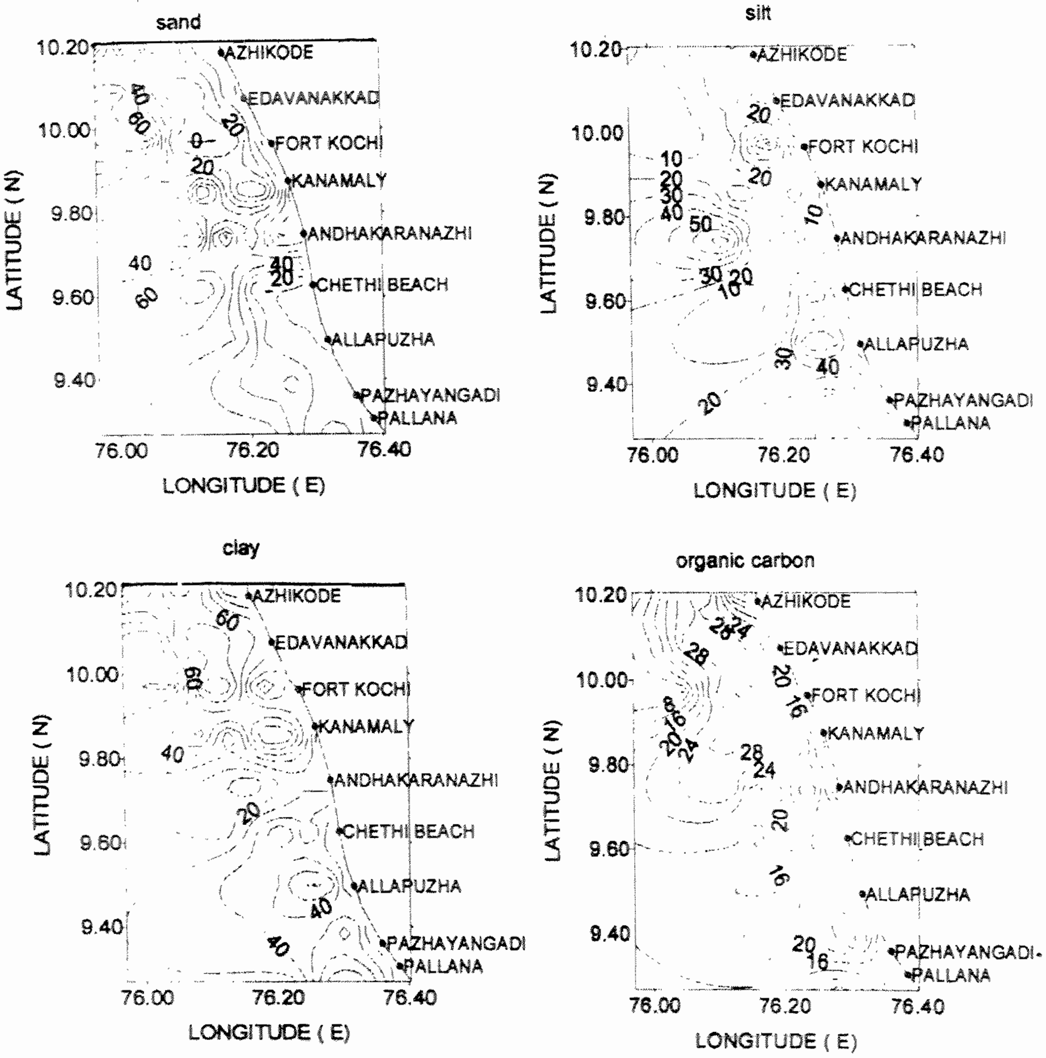



Fig. 3.3.4.21 : Horizontal Distribution of Sand (%), Silt (%), Clay (%) and Organic Carbon (mg/g) at the Bottom Sediments during November 2000

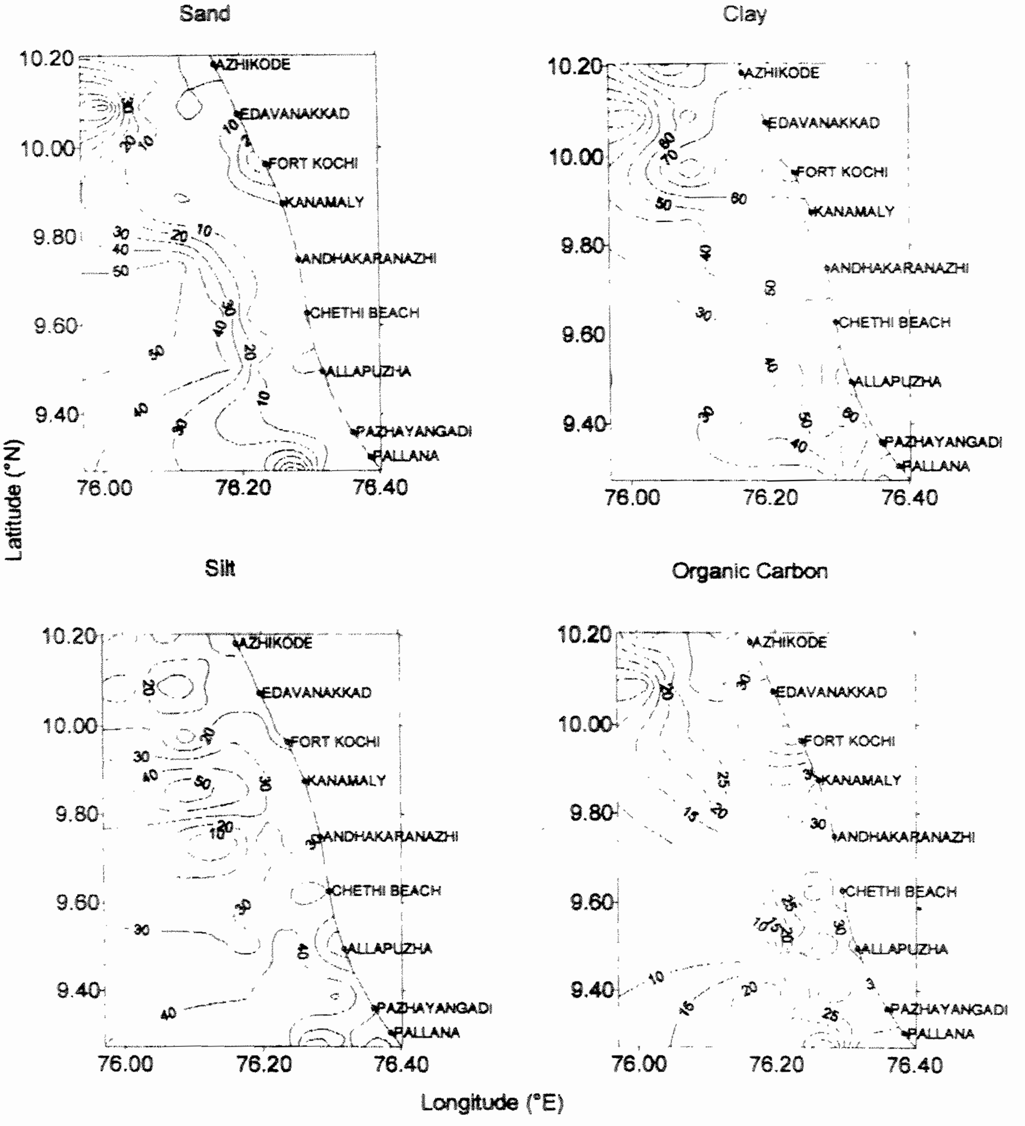



**Fig. 3.3.4.22: Distribution of Sand (%), Clay (%), Silt (%) and Organic Carbon (mg/g) during November 2000**

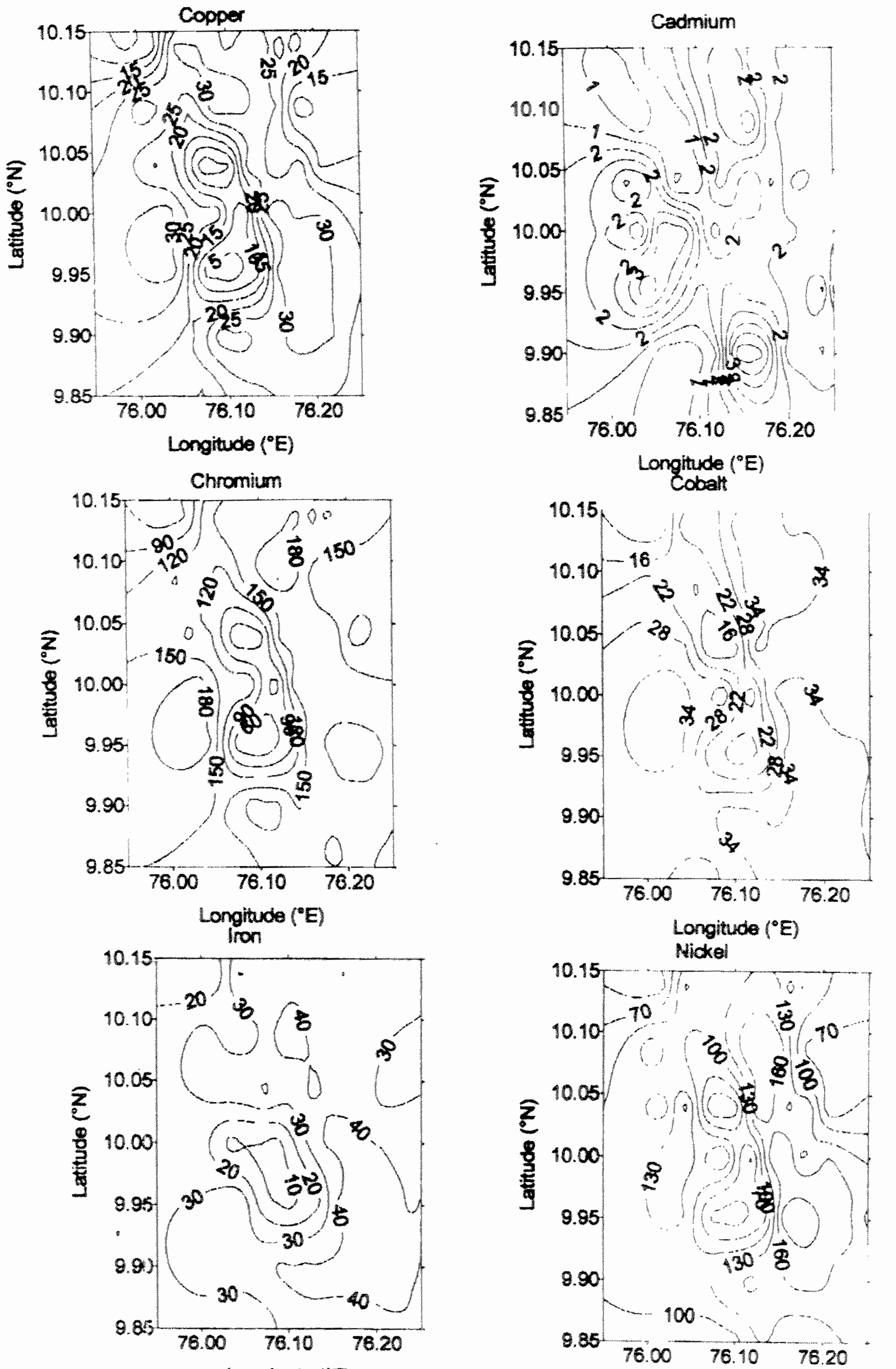



Fig. 3.3.4.23 : Horizontal Distribution of Cu, Cd, Cr, Co, Fe and Ni (all in µg/g excepting for Fe which is in mg/g) in the Bottom Sediments during October

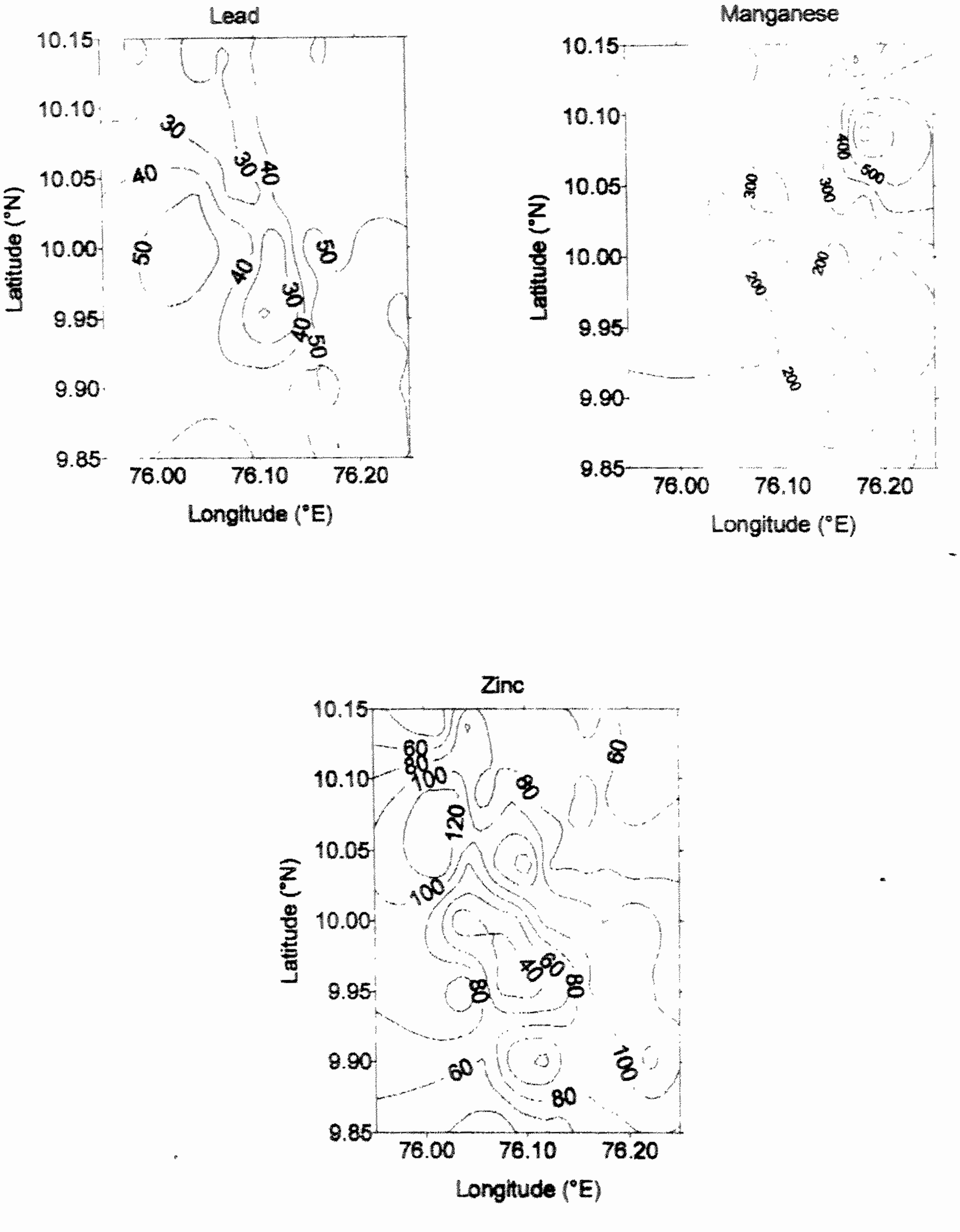



Fig. 3.3.4.24 : Horizontal Distribution of Pb, Mn and Zn (all in µg/g) in the Bottom Sediments during October

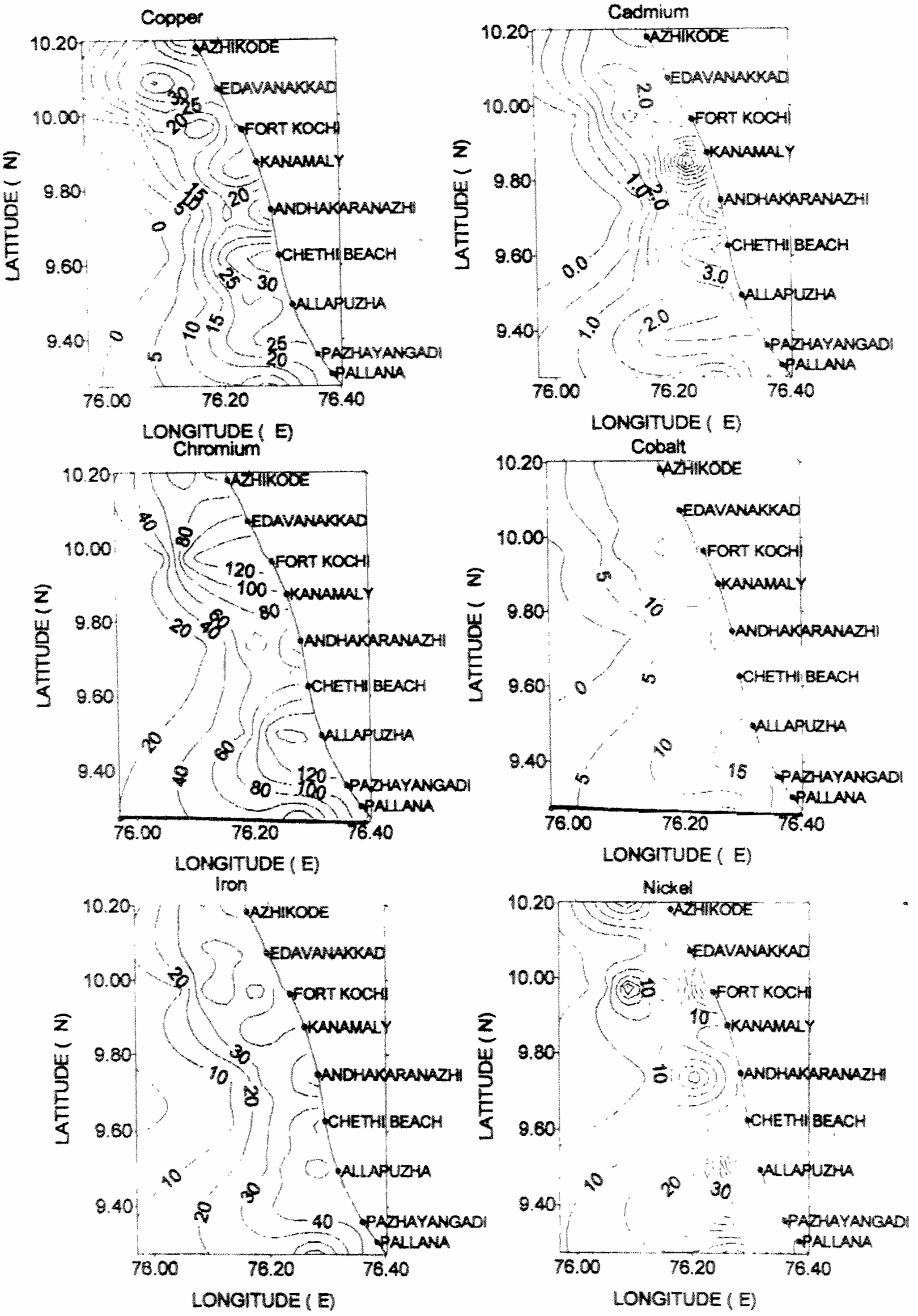



Fig. 3.3.4.25 : Horizontal Distribution of Cu, Cd, Cr, Co, Fe and Ni (all in µg/g excepting for Fe which is in mg/g) in the Bottom Sediments during February 1999

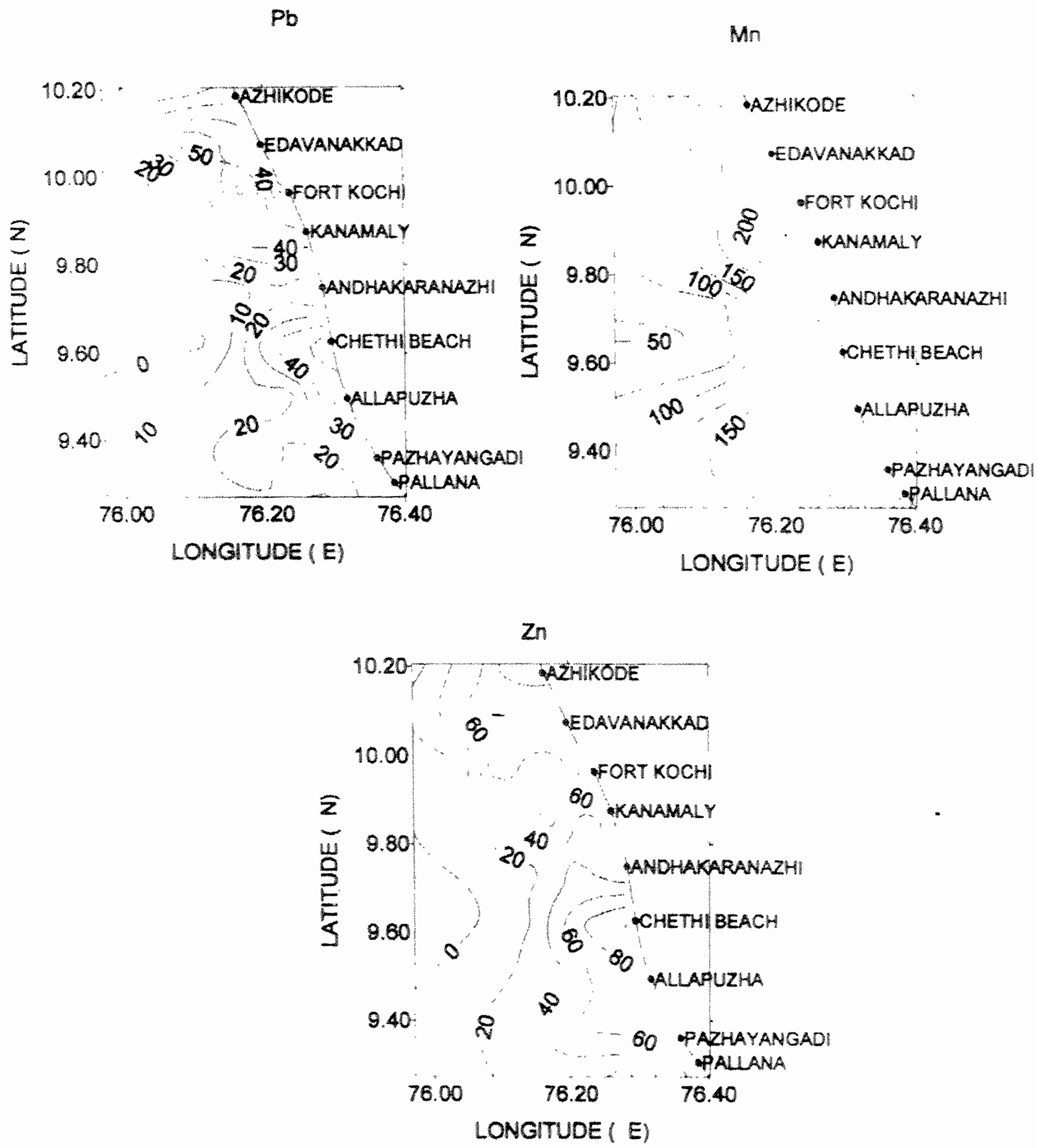



**Fig. 3.3.4.26 : Horizontal Distribution of Pb, Mn and Zn (all in μg/g) in the Bottom Sediments during February 1999**

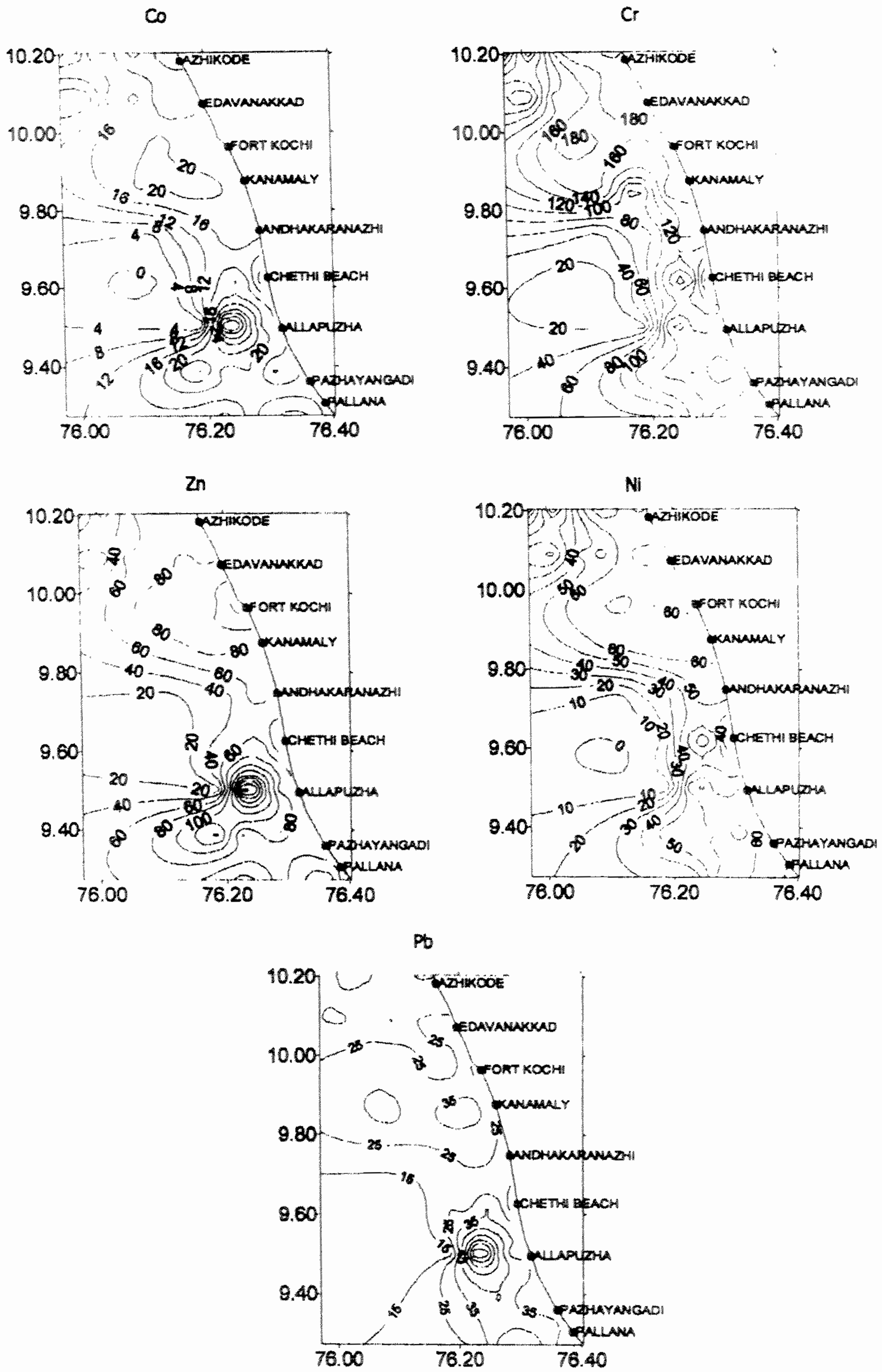



Fig. 3.3.4.27 : Horizontal Distribution of Cr, Co, Zn, Ni and Pb (all in µg/g) in the Bottom Sediments during November 2000

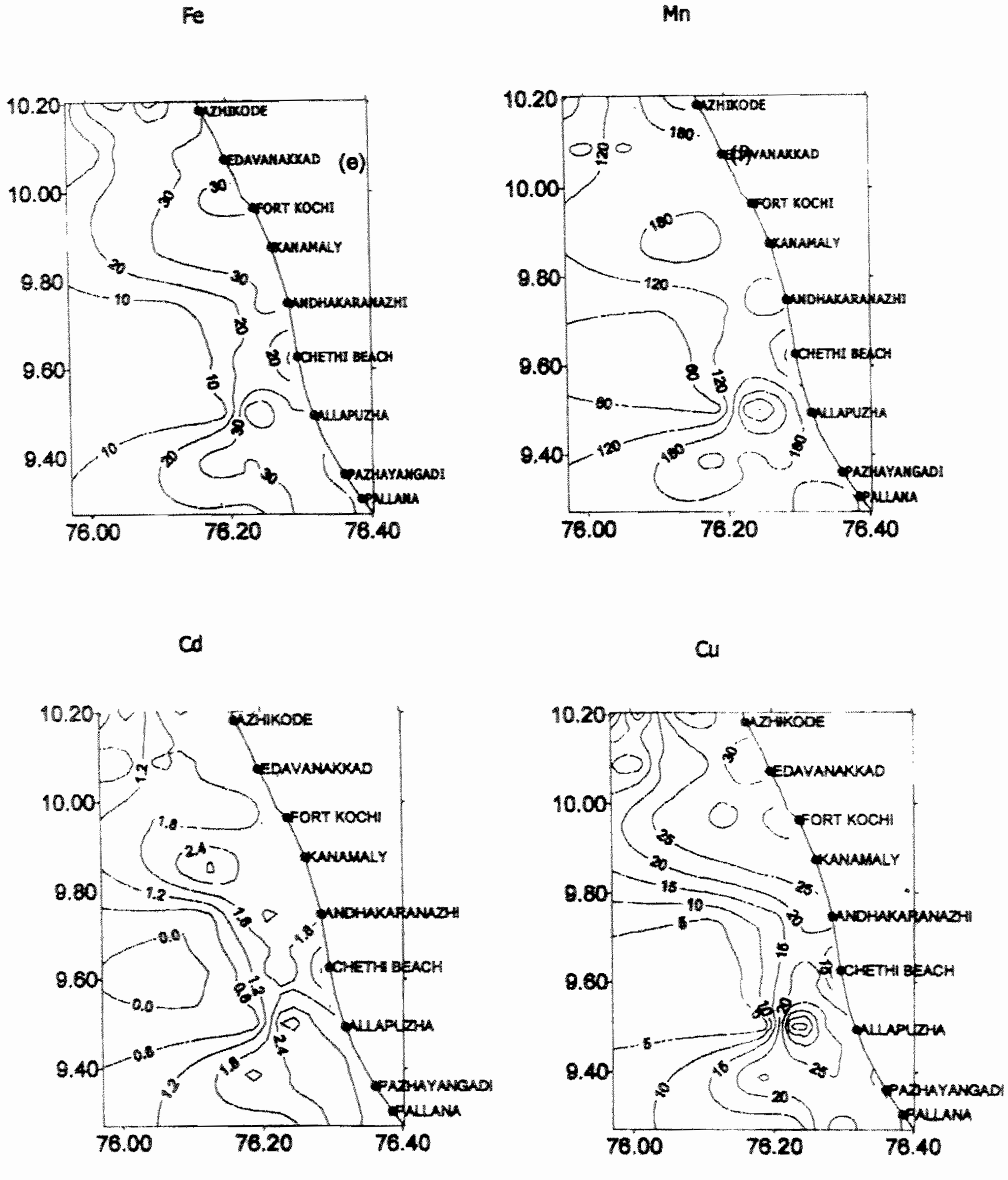



Fig. 3.3.4.28 : Fe, Mn, Cd, and Cu (µg/g, excepting for Fe, which is in mg/g) in the Sediments during November, 2000

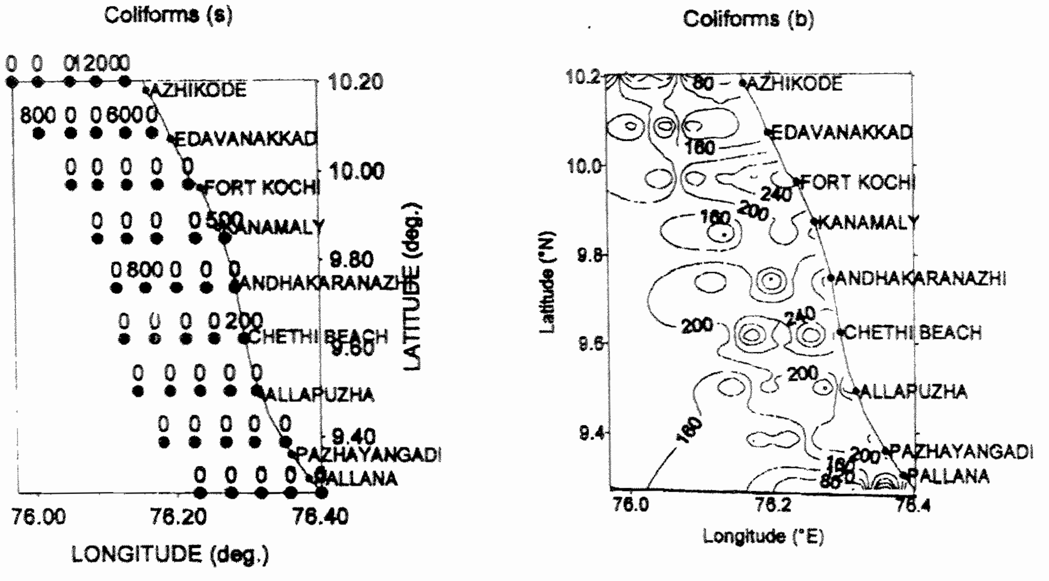



Fig. 3.3.4.29 Distribution of Faecal Coliforms (No./100 ml) in Surface (s) and Bottom (b) Waters during February 1999

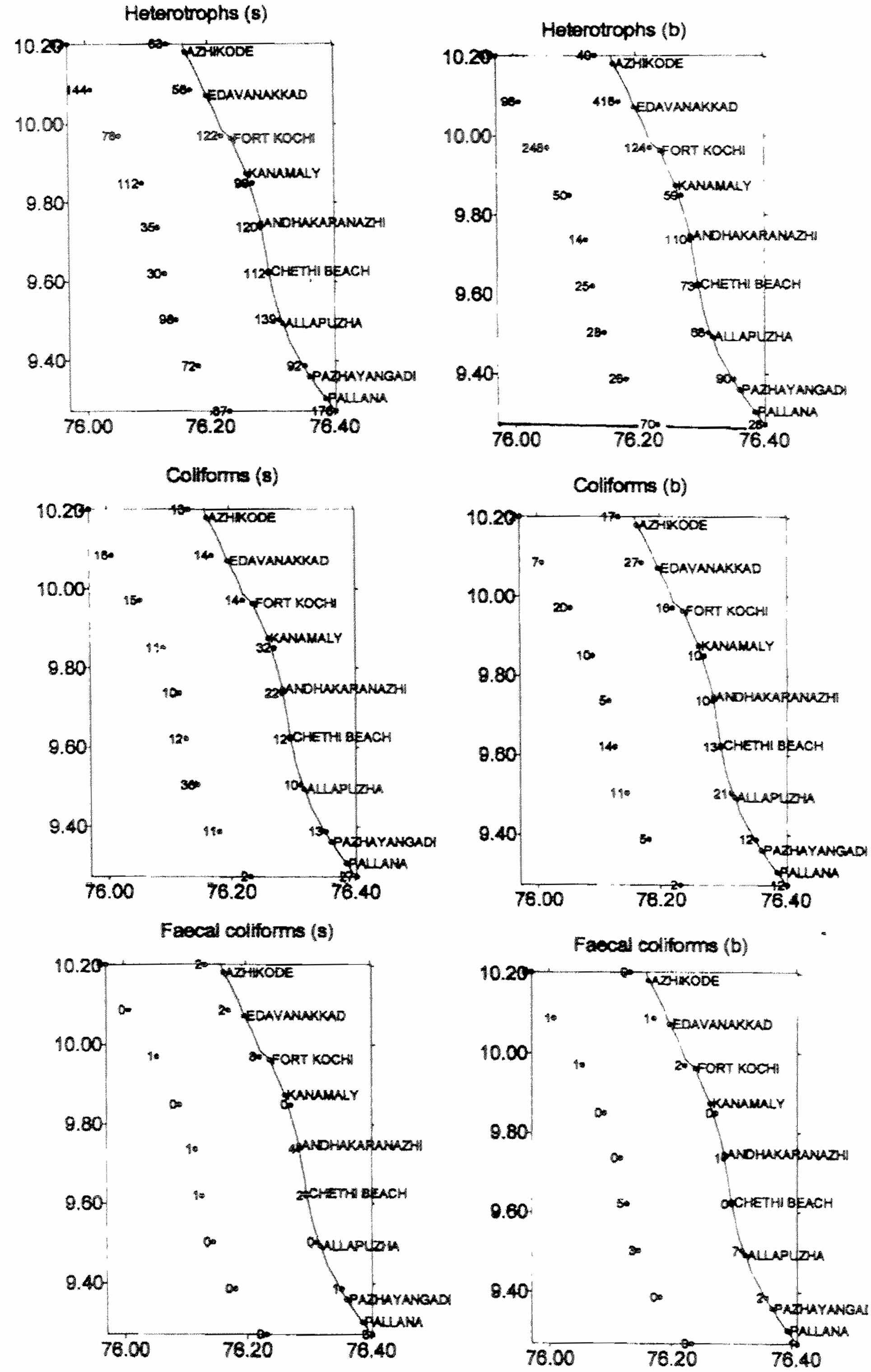



Fig. 3.3.4.30 : Distribution of Heterotrophs, Coliforms and Fecal Coliforms (numbers per ml.) in the Surface (s) and Bottom (b) Waters during November 2000

## 3.4 Land Environment

### 3.4.1 Landmass Problems

#### 3.4.1.1 Change in Land use Pattern

Historical trend in land use pattern for a period from 1968-72 to 1999 suggests that among natural ecosystems, forests suffered relatively more in GKR. The area under forests got reduced from 4870.6 km$^2$ in 1968-72 to 4415.6 km$^2$ in 1999, registering a reduction of 455 km$^2$. The percentage of area under forest in 1999 was 29.6%, which is below the national recommended level of 33%. The forests of Kerala, also include forest plantations, therefore, the actual forest coverage will be less than that is reported herein. Besides, the mangroves that grew in profusion along the backwaters of Kerala got almost wiped out during the recent past, which, considering the productivity of backwaters is an irreparable loss.

The grasslands cover an area of 537.1 km$^2$, which is more than 111.5 km$^2$ of that, was in 1968-72. The increase is also due to the regeneration of the previously occupied forest area, which needs to be conserved.

Wetlands of GKR, especially the backwaters and paddy fields are fastly disappearing on account of its conversion into various activities such as construction of settlements and other land use practices. This is a subject of great environmental concern and shrinking of Vembanad Lake is an instant example. About 6450 ha area of the lake has been reclaimed for paddy cultivation in order to meet the deficit of this all important food grain for the State.

The built- up area has increased considerably, from 1968-72, to 1999, in Ernakulam district on account of industrialization and urbanization. Unfortunately, this in its wake has brought in environmental quality deterioration such as blockage of drainage, destruction of wetland vegetation and destruction of wetlands themselves. This, in turn, has been causing flash floods, creation of stagnant water bodies, which are breeding grounds of mosquitoes etc.

#### 3.4.1.2 Landslides

In the area, forming part of the Western Ghats of Kerala, several types of mass movements and landslides have been recorded. This includes rock falls, rock slips, debris flows and, in a few cases, rotational types of slides. The rock falls are generally confined to very steep slopes with practically vertical rock cliff faces. Rock slips and in many cases rock falls occur in areas where artificial cuts are made in rock slopes during some construction activity. However, the most prevalent, recurring and disastrous type of mass movements is the debris flows. In local vernacular, the event is called "Urul Pottal". Every year, with the onset of monsoon, reports pour in about the land disturbances in the form of debris flows, causing considerable damage to life and property. The characteristic pattern of this phenomenon is the swift and sudden down slope movement of highly water saturated overburden, overlying the hard rock, containing a varied assemblage of debris material, ranging in size from soil particles to huge boulders, destroying and carrying with it every thing that lies on its path. The volume of material transported range from a few cubic metres in smaller slides to several thousands of cubic metres in massive slides.

This leads to severe land degradation with consequent heavy economic losses to community and Government. Several governmental agencies in Kerala have carried out investigations and considerable work has been brought out mainly as reports covering various aspects of the phenomenon, chiefly, aiming at providing localized urgent relief measures and mitigatory works.

A detailed investigation on the landslides and landslide mitigation measures has been carried out by Thampi et al. (1998) in the districts of Idukki and Kottayam of the study area. The investigation covered an area of 750 $m^2$, resulting in a landslide zonation as well as the evolution of a broad, rapid approach for landslide hazard zonation in Western Ghats. It is now possible to zone the vulnerable areas prone to landslides, if not predict location specific landslide.

The methodology evolved included preparation of thematic maps, such as, administrative, landform, drainage, slope, landuse, overburden and its thickness, landslide population, etc. on 1:25,000 scale. Interpretative maps on relative relief, drainage density and pattern of shear resistance etc. were also prepared. Rainfall intensity and variation were also recorded continuously for one year besides analyzing the secondary data for a period of 30 years and its integration. Assessment of the role of factors influencing slope stability by devising and applying a numerical system was also employed. Other methodologies like computer assisted statistical analysis of factors combined with automated plotting of grid cells to build up a map of hazard zonation, etc. were also tried.

### Hazard Zonation

Based on the methodologies described, a landslide hazard zonation has been worked out, as given in **Fig. 3.4.1.1**. The panchayats coming under the hazard zone are also cited in map. They are: Thannithodu, Chittar and Seethathodu of Pathanamthitta district, Kumily, Peruvanthanam, Peermade, Kokkayar, Arakkulam, Vazhathope, Erattayar, Narayanapuram, Nedumkandam, Udumbannur, Vathikudi, Konnathady, Rajakkad, Vellathuval, Bisonvalley, Pallivasal, Mannamkandam, Kuttampuzha, Munnar, Vattavada, Kanthallur and Marayur of Idukki district and Parathode, Poonjar, Teekoy and Thalanad of Kottayam district. Idukki district has maximum number of panchayats, prone to landslides; therefore, Idukki district should have maximum importance to landslide hazard management programme.

### 3.4.1.3 Seismic Activity

Moderate tremors have been reported from different parts of Kerala from historic past; the earliest one dating back to 1341 AD, a tremor felt in Malabar. As a consequence severe earthquake in 1904, Vypin Island of Kochi was raised above the sea level.

Seismicity of Kerala and that of the west coast of India has been studied by several investigations over the past three decades, which in general, suggested that the tremors in the west coast are the result of adjustments on preexisting faults in the region. Till recently, the largest instrumentally recorded earthquake in Kerala (magnitude 4.5) occurred at Nedumkandam in 1988, about 25 km west of Idukki dam During the last decade (1984-94), there have been isolated occurrences of earthquakes in different parts of the state. However, recently, an earthquake of moderate magnitude 5.0 on the Ritcher Scale occurred at Painavu, in Idukki, on Dec. 12, 2000. Although the tremors were felt over a wide region in the state, from Calicut to Thiruvananthapuram, the maximum intensity was felt in Idukki and Kottayam districts of GKR. Since Kerala falls in Zone III of the seismic zone map, earthquake intensities up to VII can be expected.

The locations of seismic occurrences, which include historic and recent tremors including the one recorded as Reservoir Induced Seismicity (RIS) at Nedumgandam in Idukki district, in 1988, are also shown in **Fig. 3.4.1.1**.

The largest regional earthquake (magnitude 6.0) that occurred in the area within 100 km radius was at Coimbatore on February 8,, 1900. This was also the largest earthquake to have occurred in this part of south India, during the historic past. Another earthquake of M 5 intensity occurred near Coimbatore on July 29, 1972. However, as such, higher magnitude earthquakes are not generally expected in the region.

### 3.4.1.4 Floods

Although Kerala, with its incised rivers does not experience floods as severe as in the Indo-Gangetic plains or the Godavari, the flooding in the State is becoming more frequent and severe. In the 1961 flood, nearly 100 persons lost their lives. 5000 houses were damaged and 5000 ha of agricultural land was seriously affected. In October-November, 1992 floods in South Kerala caused at least 75 deaths and about 7500 houses were washed away, resulting a total loss of about Rs. 1000 crores. Such an estimate for GKR alone is not compiled. However a map (**Fig. 3.4.1.2**) derived based on area under identified flood plains of coastal plane Panchayat, where floods have been reported in the past and areas lying below 10 m height above mean sea level (MSL) exhibit the flood prone areas in the GKR.

### 3.4.1.5 Shoreline Erosion

Several short term (few years) and long term (couple of decades) studies pertaining to erosion /accretion of Kerala's coastline have been reported. Various agencies, like Centre For Earth Science Studies, Kerala Engineering Research Institute & Public Works Department of Government of Kerala, have been engaged in the collection of data and field studies related to coastal erosion along the Kerala coast.

Costal erosion at a rate of 2-5 m per year is reported for nearly 300 km of Kerala coast. Active erosion is also reported in 60-65% of the total length of the shoreline of Kerala causing damage to property and loss of valuable land. Based on systematic beach profile observations for the entire Kerala coast at 5 km interval during pre and post monsoon periods, seasonal erosion of 1276 $m^3/m$ and accretion of 626 $m^3/m$ for the entire Kerala coast are reported. This suggested that there has been loss of 650 $m^3/m$ of beach material during the monsoon period for the Kerala coast.

Studies reported on long term erosional / accretional trend using satellite imagery, aerial photographs/and SOI toposheets for the period 1968-1992 have classified the beaches into high, moderate and low erosion/accretion areas. The shoreline sectors with change up to 100 m have been taken as low; between 100 m and 200 m considered as moderate and above 200 m as high erosion/accretion zone. The study revealed that about 148 km of the Kerala coast is getting eroded, while about 304 km is getting accreted.

#### 3.4.1.6 Mud-banks

Mud banks along the southwest coast of India have been defined as patches of calm, turbid waters with a high load of suspended sediment, appearing close to the shore with a clay substrate during the rough monsoon season. In GKR, they appear around Alappuzha and Kochi almost every year. On an average, these mud banks have dimensions of 2-5 km along shore and 1.5-4.0 km offshore. During monsoon season, there are strong waves, which cause at places, severe erosion. However, because of the presence of mud banks, the beach behind the mud bank gets protected, though the beach on the down drift side of littoral drift may get eroded on account of starvation of sediments.

#### 3.4.1.7 Sediments

Based on the reservoir sedimentation surveys carried out in seven reservoirs in the river basins draining into the wetland, an average of 26 t/ha/yr sediment yield is observed. The total annual sediment yield from all the river basins draining into the Vembanad Lake is estimated to be 32 million tonnes. Sediment distribution pattern in Vembanad wetland is as follows :

**Coarse Sand** : about 10 - 20% occurs north of Ithipuzha river mouth and 5 to 20% between Alappuzha and Vaikom

**Medium Sand** : this mainly occurs in abundance in the river mouth of Muvattupuzha and Ithipuzha rivers (30 - 50%); 10 - 70% medium sand is confined to the western margin of the lake and below 10% in the rest of the area

**Fine Sand** : Percentage distribution of fine sand in the sediments of Muvattupuzha and Ithipuzha rivers is low; in the southern half of the lake, 30 - 50% occurs all along the western margin of the lake and 20 - 30% occurs as a narrow band along the western margin of the lake up to a little south of Thanneermukkom and up to Vaikom

**Very Fine Sand** : this occurs in the range of 10 - 30% and is characteristic of the southern half of the lake except at its southern end; in the northern half of the lake 30 - 50% occurs east of Perumbalam island and east of Wellingdon island

**Silt** : Around 30 - 80% is confined to the eastern half while up to 20% is confined to the western margin of the lake; 50 - 70% is confined to the channels around Wellingdon island and 30 - 50% east of Perumbalam island

**Clay** : In the southern half, 30 - 50% occurs as a small patch at the southern end surrounded on either side by 20 - 30%, 10 - 20% in the northern half, 30 - 70% are confined to the channels on either side of Wellingdon island.

#### 3.4.1.8 Salinization

A very large tract of the coastal plain of GKR is affected by the presence of acid saline and alkaline soils. These areas include the Kuttanad region, which is a unique agricultural area. The acidity and alkalinity are also present along the distributory areas of the rivers-Pamba, Manaimala, Meenachil and Muvattupuzha. The prawn filtration ponds adjoining the Vembanad estuary are affected by acid sulphate soil because of lack of drainage. These problems make the land unsuitable for drawing its full potential of agriculture.

### 3.4.2 Municipal Solid Waste Generation and Disposal

#### 3.4.2.1 Quality of Municipal Solid Waste

GKR hosts 23 municipal towns and the Kochi Corporation, located in 6 districts; viz - Pathanamthitta, Alappuzha, Kottayam, Idukki, Ernakulam and Trichur. Location of various municipalities and Kochi Corporation in GKR is shown in **Fig. 3.4.2.1**. The class category and population are given in **Table 3.4.2.1**. The per capita solid waste generation and other details are given in **Table 3.4.2.2** for the entire municipalities/ corporation under GKR.

**Alappuzha district**

Kayamkulam, Mavelikkara, Alappuzha, Chengannur and Cherthala municipalities fall within the administrative boundary of Alappuzha district. Of these, Alappuzha municipality falls under Class I, Kayamkulam in Class II and the remaining in Class III. These municipalities together contribute about 45 MT of solid wastes per day, a greater portion (about 55%) of which comes from Alappuzha municipality. The per capita solid waste production varies from 104 g/day (Kayamkulam municipality) to 193 g/day (Chengannur municipality). Out of the five municipalities, Alappuzha and Kayamkulam municipalities have designated waste disposal sites and dispose the wastes as open dumps. The other municipalities dispose the wastes in landfills in private lands. **Table 3.4.2.3** gives information about the infrastructural facilities as well as details about the waste disposal sites.

**Ernakulam district**

Eight municipalities and the Kochi Corporation fall within the administrative boundaries of Ernakulam district, which together generate an amount of 300 MT of solid wastes per day. Kochi Corporation (area 94.88 km$^2$ ) with a total population of 564589 falls under Class I category; Thripunithura and Kalamassery municipalities in Class II and Kothamangalam, Muvattupuzha, Perumbavur, Aluva,

### 3.4.2.2 Sources of Municipal Solid Wastes

Huge amount of solidwastes is generated in GKR. The major sources of municipal solid wastes are domestic, fruit and vegetable markets, hotel and restaurants, fish/meat shops or markets, street sweepings, hospitals, office/institutions etc. Of these, the former three categories together contribute nearly 70% of the total wastes. Streets contribute about 10% and hospitals about 5%, while offices, educational institutions, etc contribute the remaining 15%. The percentage contribution of solid wastes generated in various municipalities/ corporation area of GKR is illustrated in **Fig. 3.4.2.2**.

### 3.4.2.3 Composition of Solid Wastes

Physical separation of solid waste samples collected from waste generating centres of various municipalities of GKR showed that, on an average, over 50% (by weight) of the total solid waste was of vegetative matter. Paper, plastic, metal, glass and textile were 9.62%, 0.4%, 0.76%, 0.86% and 2.7%, respectively. The municipality wise details of some of the major towns of GKR are presented in **Fig. 3.4.2.3**. **Table 3.4.2.5** gives the composition (wt %) of paper, metal, glass, textile, etc. in the municipal wastes of GKR, in general and Kochi Corporation, in particular, in relation to major metropolitan cities of India.

### 3.4.2.4 Physical and Chemical Characteristics

The physical and chemical characteristics of solid waste samples from a few selected municipal towns and the Kochi corporation determined/estimated are furnished in **Table 3.4.2.6**. The density of samples varied from 420 to 688 $kg/m^3$ and moisture content from 45.08 to 61.61%. The combustible fraction estimated after drying the sample at constant weight varied between 64.96 and 76.52%. The calorific values of the MSW of GKR are comparatively lower and varied between 923 and 2664 (avg. 1622) KCal/kg.

The pH of the samples varied between 6.6 and 8.3. The samples exhibited high organic matter (26.57 - 52.43%) and carbon (13.76 - 30.41) content. The average concentrations of nitrogen, phosphorous and potassium were 0.49%, 0.4% and 0.48%, respectively. **Table 3.4.2.7** shows the comparison of the C, N, P, K values of the MSW of GKR with the published results of some of the major cities in India. The samples accounted for 1.38% of Fe, 187.38 ppm of Mn, 24.63 ppm of Ni, 2.3 ppm of Cd, 156.75 ppm of Pb, 72.38 ppm of Cr, 103.88 ppm of Cu and 186.63 ppm of Zn (**Table 3.4.2.8**). The heavy metal values are compared with the reported quantities for NCR (**Table 3.4.2.9**). The substantially high concentration of these toxic metals in organic matter samples of GKR warrants for a prudent leachate treatment unit in the solid waste management design.

## 3.4.3 Industrial Solid Waste Generation and Disposal

### 3.4.3.1 Quality of Industrial Solid Waste

In all there are 26 large, 16 medium and 21 small scale industries generating hazardous solid wastes in GKR. District wise distribution of the hazardous waste generating industries is given in **Table 3.4.3.1**. Ernakulam

Paravur, and Angamali in Class III categories. The per capita municipal solid waste production varied from 92 g/day (Kalamasseri municipality) to 484 g/day (Aluva municipality). The solid waste production of Kochi Corporation is 443 g/day. A comparative evaluation of the per capita solid waste generation of the various municipalities/corporation of GKR with that of the other major metropolitan cities of India revealed that the per capita solid waste generation of Aluva municipality and Kochi corporation is very close to that of Calcutta (500 g/day) and Bangalore (550 g/day) (**Table 3.4.2.4**). Except Perumbavur, Angamali and Thripunithura municipalities, all the other municipal towns have designated waste disposal sites (**Table 3.4.2.3**), which, in many cases, are either insufficient or not properly selected based on scientific scrutiny.

**Idukki district**

Thodupuzha municipality comes in Idukki district, which generates an amount of 4.5 MT of solid wastes per day. The per capita solid waste generation is about 111 g/day. The municipality has a designated waste disposal site of about 1.75 acres in the Porathusseri panchayat. The wastes are disposed off as open dumps. Three major townships, namely, Munnar, Nedumkantom and Kattappana together contribute 3 to 4 MT of solid wastes per day.

**Kottayam district**

Four municipalities, namely Changanasseri, Kottayam, Pala and Vaikom fall within the Kottayam district. The first two fall within Class II and the remaining in Class III categories, as per 1991 Census. They together generate an amount of 35 MT of wastes per day. The per capita solid waste production recorded the lowest value of 138 g/day for Vaikom and the highest of 249 g/day for Kottayam. Municipality - wise break up of the solid waste production is given earlier in **Table 3.4.2.2** along with other details. All the four municipalities of the Kottayam district have designated waste disposal sites. In Vaikom and Kottayam, solid wastes are disposed off as landfills and in Pala and Changanasseri as open dumps.

**Pathanamthitta district**

Two municipal towns- Pathanamthitta and Thiruvalla - fall in Pathanamthitta district. They together generate about 11 MT of solid wastes per day. The per capita solid waste generation is about 139 g/day for Pathanamthitta (Class III municipality) and 110 g/day for Thiruvalla (Class II municipality). These two municipal towns do not have any designated waste disposal sites. The collection, transportation and disposal systems of wastes are very poor. At present, these two municipalities dispose their wastes as landfill in low-lying private lands.

**Thrissur district**

Three municipalities of the Thrissur district namely, Irinjalakkuda, Kodungallur and Chalakudy, come within the GKR jurisdiction. They together generate about 15 MT of wastes per day. All of them have designated waste disposal sites as land fills. The per capita solid waste generation is about 133 g/day for Chalakkudy, 146 g/day for Irinjalakkuda and 160 g/day for Kodungallur.

district has maximum number of hazardous waste industries, whereas Idukki and Pathanamathitta district do not have such industries. District wise details on the type and quantity of waste generated from large, medium and small industries are summarized in **Table 3.4.3.2**. Industry-wise details on chemical characteristics, waste type, quantity of solid waste generated are given in **Table 3.4.3.3** along with the present management practice followed for its disposal.

Table 3.4.2.1

**Categorization of Towns in Terms of Total Population (as per 1991 Census)**

| Sr. No. | Category | Population | Municipality / Corporation |
|---|---|---|---|
| 1 | Class I | 1,00,000 & above | Kochi, Alappuzha |
| 2 | Class II | 50,000 - 99,999 | Kottayam, Thiruvalla, Changanasseri, Kalamassery, Thripunithura, Kayamkulam |
| 3 | Class III | 20,000 - 49,999 | Muvattupuzha, Pala, Chalakkudy, Angamali, Perumbavur, Kothamangalam, Thodupuzha, Chengannur, Cherthala, Vaikom, Irinjalakkuda, Piravam, Aluva, Kodungallur, Mavelikkara, Pathanamthitta |

Table 3.4.2.2

**Details of Municipal Solid Waste Producing Centres of the GKR**

| Sr. No. | Municipality / Corporation | Area ($km^2$) | Population (1991 census) | Solidwaste (kg/day) | Per Capita Solid Waste Production (g) |
|---|---|---|---|---|---|
| | **Midland** | | | | |
| 1 | Muvattupuzha (M) | 13.18 | 27595 | 6000 | 217 |
| 2 | Pala (M) | 15.93 | 21890 | 5500 | 251 |
| 3 | Kottayam (M) | 15.55 | 63155 | 15750 | 249 |
| 4 | Kothamangalam (M) | 40.04 | 35553 | 3750 | 105 |
| 5 | Chalakkudi (M) | 25.23 | 45069 | 6000 | 133 |
| 6 | Angamaly (M) | 24.05 | 30391 | 5000 | 165 |
| 7 | Perumbavur (M) | 13.59 | 24667 | 7000 | 284 |
| 8 | Pathanamthitta (M) | 23.50 | 35882 | 5000 | 139 |
| 9 | Thodupuzha (M) | 35.43 | 40656 | 4500 | 111 |
| | **Low Land** | | | | |
| 10 | Thiruvalla (M) | 27.94 | 54780 | 6000 | 110 |
| 11 | Chengannur (M) | 13.00 | 25872 | 5000 | 193 |
| 12 | Sherthala (M) | 16.18 | 43326 | 5300 | 122 |
| 13 | Vaikom (M) | 8.73 | 21788 | 3000 | 138 |
| 14 | Alappuzha (M) | 46.77 | 174666 | 25000 | 143 |
| 15 | Changanasseri (M) | 13.50 | 52445 | 10000 | 191 |
| 16 | Kochi (C) | 94.88 | 564589 | 250000 | 443 |
| 17 | Irinjalakkuda (M) | 11.24 | 27491 | 4000 | 146 |
| 18 | Paravur (M) | 9.02 | 27906 | 4000 | 143 |
| 19 | Kalamasseri (M) | 27 | 54342 | 5000 | 92 |
| 20 | Thrippunithura (M) | 18.69 | 51078 | 7000 | 137 |
| 21 | Aluva (M) | 7.18 | 24774 | 12000 | 484 |
| 22 | Kodungallur (M) | 17.3 | 31249 | 5000 | 160 |
| 23 | Kayamkulam (M) | 21.79 | 67151 | 7000 | 104 |
| 24 | Mavelikkara (M) | 12.65 | 28299 | 3000 | 106 |

M = Municipality C = Corporation

**Source** : Secondary data collected by CESS

Table 3.4.2.3

Collection and transportation facilities and other Relevant Details of Various Municipal / Corporation Areas of GKR

| Sr. No. | Municipality / Corporation | Area ($km^2$) | Density of Population (1991 Census) | Number of Transport Vehicles and Type | Number of Sweepers | Quantity of Solid Waste (MT/day) | Ownership of Waste Disposal Site | Area & Soil Characteristic of Waste Disposal Site |
|---|---|---|---|---|---|---|---|---|
| I | **Alappuzha District** | | | | | | | |
| 1 | Kayamkulam | 21.79 | 3082 | 1 Lorry (DCM) | 32 | 7 | Municipal Land, Pullikkanakku (Near Mulikkummood) | 1.5 Acres; sandy soil |
| 2 | Mavelikkara | 12.65 | 2237 | 1 Tractor | 30 | 3 | Private Land | - |
| 3 | Chengannur | 13.00 | 1990 | 1 Mini Lorry | 21 | 5 | Private Land | - |
| 4 | Cherthala | 16.18 | 2678 | 1 Lorry (DCM) | 20 | 5.3 | Private Land | - |
| 5 | Alappuzha | 46.77 | 3735 | 3 Lorries (Benz), 1 Tractor | 170 | 25 | Municipal Land, Survodayapuram | 12.5 Acres; Sandy soil |
| II | **Ernakulam District** | | | | | | | |
| 1 | Kothamangalam | 40.04 | 887 | 2 Lorries (Benz) | 32 | 3.75 | Municipal Land Kumblathumuri (Near Nadukani Road) | 1.41 Acres; Rocky terrain |
| 2 | Muvattupuzha | 13.18 | 2094 | 1 Lorry (Benz), 2 Tractors | 62 | 6 | Municipal Land Payipra | 0.6 Acres; Lateritic & Partially paddy field |
| 3 | Perumbavoor | 13.59 | 1815 | 1 Lorry (Benz), 1 Tractor; 1 Triller | 46 | 7 | Private Land | - |
| 4 | Aluva | 7.18 | 3450 | 2 Lorries (Benz), 1 Tractor; 1 Triller | 102 | 12 | Municipal Land Kizhmad Panchayat | 4.5 Acres; Laterite soil |
| 5 | Kalamassery | 27 00 | 2013 | 1 Tempo | 35 | 5 | Municipal Land (Near HMT Compound) (Ward 13) | 5 Acres; Laterite soil |

Contd...

**Table 3.4.2.3 Contd...**

| Sr. No. | Municipality / Corporation | Area ($km^2$) | Density of Population (1991 Census) | Number of Transport Vehicles and Type | Number of Sweepers | Quantity of Solid Waste (MT/day) | Ownership of Waste Disposal Site | Area & Soil Characteristic of Waste Disposal Site |
|---|---|---|---|---|---|---|---|---|
| 6 | Paravur | 9.02 | 3094 | 1 Lorry (Benz), 1 Tractor, 1 Triller | 30 | 4 | Municipal Land; Vedimara (Ward 11) | 3 Acres; Sandy soil |
| 7 | Angamaly | 24.05 | 1264 | 2 Lorries (DCM) | 19 | 5 | Private Land | - |
| 8 | Trippunithura | 18.69 | 2733 | 1 Lorry (DCM) 1 Tractor, 1 Triller | 39 | 7 | Private Land | - |
| 9 | Cochi Corporation | 94.88 | 5951 | 12 Lorries (Hired Benz) 3 Lorries (DCM) 1 Container Lorry 7 Tractors, 1 Triller | 994 | 250 | Municipal Land; Karimugal | 13 Acres; Lateritic soil |
| III | **Idukki District** | | | | | | | |
| 1 | Thodupuzha | 35.43 | 1148 | 1 Lorry (Benz) | 27 | 45 | Municipal Land Parakkadavu | 1.75 Acres; Rocky Terrain |
| IV | **Kottayam District** | | | | | | | |
| 1 | Changanacherry | 13.50 | 3885 | 4 Lorries (DCM) 1 Triller; 1 Tempo | 97 | 10 | Municipal Land Fathimapuram | 10 Acres; Laterite soil |
| 2 | Vaikom | 8.73 | 2496 | 1 Lorry (DCM) 1 Triller | 18 | 3 | Municipal Land Vallakom (Near KSEB Substation) | 1.7 Acres; Sandy soil |
| 3 | Kottayam | 15.55 | 4061 | 3 Lorries (DCM) 2 Tractors | 139 | 15.75 | Municipal Land Vadavathoor (Vijayapuram Panchayat) | 3.4 Acres; Laterite soil |

**Contd...**

Table 3.4.2.3 Contd...

| Sr. No. | Municipality / Corporation | Area ($km^2$) | Density of Population (1991 Census) | Number of Transport Vehicles and Type | Number of Sweepers | Quantity of Solid Waste (MT/day) | Ownership of Waste Disposal Site | Area & Soil Characteristic of Waste Disposal Site |
|---|---|---|---|---|---|---|---|---|
| 4 | Palai | 15.93 | 1374 | 1 Lorry (Benz)<br>1 Tripper | 4 | 5.5 | Municipal Land Kanattupara | 2.5 Acres; Rocky terrain |
| V | **Pathanamthitta District** | | | | | | | |
| 1 | Pathanamthitta | 23.50 | 1527 | 1 Lorry (Benz); 1 Tractor | 34 | 5 | Private Land | - |
| 2 | Thiruvalla | 27.94 | 1961 | 2 Lorries (DCM) | 35 | 6 | Private Land | - |
| VI | **Thrissur District** | | | | | | | |
| 1 | Irinjalakuda | 11.24 | 2446 | 1 Lorry (Benz);<br>1 Tripper | 47 | 4 | Municipal Land (Manjadikkunnu) (Porathisseri - P) | 5.6 Acres; Laterite Hillocks |
| 2 | Kodungallur | 17.30 | 1806 | 2 Lorries (Benz) | 18 | 5 | Municipal Land Chappara (Near Pullut) | 2 Acres; Clayey soil - paddy |
| 3 | Chalakkudy | 25.23 | 1786 | 1 Lorry (DCM);<br>1 Tractor | 30 | 6 | Municipal Land Panappalli (Near College) | 2 Acres; Sandy soil |

Source : **Primary & Secondary data collected by CESS**

## Table 3.4.2.4

### Comparision of Municipal Solid Waste Generation in GKR with Other Metropolitan Cities

| Sr. No. | City / Region | Solid Waste Generation ($x10^5$kg/day) | Computed per capita Solid Waste Contribution (g/day) |
|---|---|---|---|
| 1 | Greater Kochi Region (GKR) | 4.05 | 183 |
| 2 | Kochi Corporation | 2.5 | 443 |
| 3 | Aluva municipality | 0.12 | 484 |
| 4 | Municipalities other than Aluva | 1.47 | 156 |
| 5 | Delhi * | 16-18 | 300 |
| 6 | Calcutta * | 16-18 | 500 |
| 7 | Bangalore * | 10-11 | 550 |

* **Source** : Planning Commission Report (1994)

## Table 3.4.2.5

### Comparison of Various Components of Municipal Solid Wastes with Other Metropolitan Cities

| City / Region | Composition of Municipal Solid Wastes (%) | | | | |
|---|---|---|---|---|---|
| | Paper | Metals | Glass | Textile | Misc. |
| Greater Kochi Region (GKR) | 9.62 | 0.76 | 0.86 | 2.68 | 5.41 |
| Kochi Corporation | 7.78 | 0.78 | 0.82 | 3.96 | 5.17 |
| Delhi * | 5.58 | 0.59 | 0.31 | 3.56 | 1.46 |
| Calcutta * | 0.14 | 0.66 | 0.24 | 0.28 | 1.54 |
| Lucknow * | 1.66 | 0.20 | 0.66 | 2.91 | 4.20 |
| Chennai * | 5.90 | 0.70 | -- | 7.07 | -- |
| Bangalore * | 1.50 | 0.10 | 0.20 | 3.10 | 0.90 |

Misc. = Plastic + Leather + Rubber etc.
**Source** : Planning Commission Report (1994)

**Table 3.4.2.6**

**Physico-Chemical Characteristics of the Municipal Solid Waste Samples of the Study Area**

| Sr. No. | Sampling Location/area | Density ($Kg/m^3$) | Moisture Content (%) | Calorific Value (K.Cal/kg) | pH | Organic Matter (%) | C (%) | N (%) | C/N | P (as $P_2O_5$ %) | K ($K_2O$) (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Changanasseri | 613 | 51.04 | 1331 | 8.3 | 31.95 | 18.53 | 0.55 | 33.51 | 0.49 | 0.54 |
| 2 | Chengannur | 688 | 60.58 | 1670 | 7.7 | 26.57 | 15.41 | 0.50 | 30.58 | 0.20 | 0.61 |
| 3 | Muvattupuzha | 538 | 45.08 | 923 | 8.1 | 30.67 | 17.79 | 0.37 | 47.95 | 0.37 | 0.54 |
| 4 | Pala | 420 | 56.76 | 1198 | 6.6 | 23.73 | 13.76 | 0.50 | 27.69 | 0.30 | 0.37 |
| 5 | Kottayam | 510 | 58.98 | 1408 | 7.4 | 32.27 | 18.72 | 0.33 | 56.89 | 0.52 | 0.46 |
| 6 | Alappuzha | 570 | 61.61 | 2393 | 7.0 | 31.00 | 17.98 | 0.53 | 34.25 | 0.72 | 0.44 |
| 7 | Mundanveli (Kochi) | 618 | 50.18 | 1927 | 7.3 | 47.13 | 27.34 | 0.44 | 62.13 | 0.31 | 0.42 |
| 8 | Cheranallur (Kochi) | 568 | 51.44 | 1181 | 7.1 | 32.63 | 18.93 | 0.43 | 44.33 | 0.42 | 0.38 |
| 9 | Kothamangalam | 472 | 58.12 | 2664 | 6.8 | 52.43 | 30.41 | 0.76 | 39.86 | 0.47 | 0.54 |
| 10 | Aluva | 522 | 53.74 | 1523 | 6.6 | 41.76 | 24.22 | 0.53 | 46.13 | 0.24 | 0.51 |
| | **Study Area (avg.)** | **551.90** | **54.75** | **1621.80** | **7.3** | **35.01** | **20.31** | **0.49** | **42.33** | **0.40** | **0.48** |
| | **Kochi (avg.)** | **593.00** | **50.81** | **1554.00** | **7.2** | **39.88** | **23.13** | **0.43** | **53.23** | **0.37** | **0.40** |

Table 3.4.2.7

**Comparison of Physico-Chemical Characteristics of Municipal Solid Waste Samples of the Study Area with other Major Cities of India**

| Location /Area | Moisture (%) | N (%) | P (as $P_2O_5$) (%) | K (as $K_2O$) (%) | Organic Matter (%) | C (%) | C/N | Calorific Value (K.Cal / Kg) |
|---|---|---|---|---|---|---|---|---|
| Present study (GKR) | 45.08-61.61 | 0.33-0.76 | 0.20-0.72 | 0.37-0.61 | 23.73-52.43 | 13.76-30.41 | 27.69-62.13 | 923-2664 |
| Kochi Corporation | 50.18-51.44 | 0.44-0.43 | 0.31-0.42 | 0.38-0.42 | 32.63-47.13 | 18.93-27.34 | 44.33-62.33 | 1181-1927 |
| Thiruvananthapuram | 21.99-31.82 | 0.8-0.83 | 0.48-0.50 | 0.33-0.65 | 24.45-28.53 | 13.50-15.85 | 21.78-26.88 | 1968-2047 |
| Delhi | 14.25-16.00 | 0.6-0.66 | 0.65-0.68 | 0.31-0.64 | 31.90-42.35 | 18.50-24.56 | 21.92-34.00 | 2400-3000 |
| Culcutta | 40.00-51.35 | 0.43-0.68 | 0.42-0.62 | 0.31-0.68 | 31.00-40.14 | 17.5-22.30 | 31.00-50.80 | 2000-2500 |

Table 3.4.2.8

Heavy Metal Contents in the Municipal Solid Waste Samples of GKR

| Sr. No. | Sampling Location / Area | Heavy metals (Fe in % and others in μg/g) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Fe | Mn | Ni | Cd | Pb | Cr | Cu | Zn |
| 1 | Changanasseri | 1.51 | 176 | 24 | 2.00 | 68 | 69 | 119 | 223 |
| 2 | Chengannur | 1.68 | 229 | 37 | 1.78 | 265 | 96 | 172 | 207 |
| 3 | Muvattupuzha | 1.18 | 141 | 21 | 1.46 | 295 | 82 | 115 | 127 |
| 4 | Pala | 1.00 | 122 | 17 | 1.55 | 90 | 58 | 48 | 97 |
| 5 | Kottayam | 1.61 | 229 | 26 | 2.53 | 84 | 77 | 167 | 267 |
| 6 | Alappuzha | 1.52 | 247 | 21 | 2.08 | 308 | 56 | 68 | 224 |
| 7 | Mundanveli (Kochi) | 0.84 | 168 | 20 | 2.22 | 44 | 46 | 52 | 161 |
| 8 | Cheranallur (Kochi) | 1.66 | 187 | 31 | 4.79 | 100 | 95 | 90 | 187 |
| **Study Area (avg)** | | **1.38** | **187** | **24** | **2.30** | **156** | **72** | **103** | **186** |
| **Kochi (avg)** | | **1.25** | **177** | **25** | **3.51** | **72** | **70** | **71** | **174** |

Table 3.4.2.9

Comparison of Average Heavy Metal Contents in Municipal Solid Waste Samples of GKR with other Cities

| Location / Area | Mn | Ni | Cd | Pb | Cr | Cu | Zn |
|---|---|---|---|---|---|---|---|
| GKR | 187 | 25 | 2.30 | 157 | 72 | 104 | 186.63 |
| Kochi Corporation | 178 | 26 | 3.51 | 72 | 70 | 71 | 174.00 |
| Meerut (1) | 489 | 88 | 1.27 | 63 | 85 | 688 | 692 |
| Alwar (1) | 334 | 20 | 0.28 | 12 | 96 | 226 | 440 |
| Nizamuddin (1), (Delhi) | 380 | 36 | 0.24 | 28 | 13 | 84 | 795 |

All values are in ppm
**Source** : Carrying Capacity Studies of NCR, NEERI, Nagpur.

## Table 3.4.3.1

### District Wise Distribution of Hazardous Waste Generating Industries

| District | Drugs & Pharmaceutical | | | | Organics & Petrochemical | | | | Insecticides | | | | Paints & Dyes | | | | Asbestos | | | | Inorganic Chemicals | | | | Others | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L | M | S | O | L | M | S | O | L | M | S | O | L | M | S | O | L | M | S | O | L | M | S | O | L | M | S | O |
| **Alappuzha** | 1 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | 1 | 2 | 2 | 5 |
| **Ernakulam** | - | - | - | - | 7 | - | - | 7 | 1 | - | - | 1 | 1 | - | - | 1 | - | - | - | - | 3 | 3 | - | 6 | 9 | 6 | 12 | 27 |
| **Idukki** | No industries are identified as generators of Hazardous wastes | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Kottayam** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | 2 | 4 |
| **Pathanam-thitta** | No industries are identified as generators of Hazardous wastes | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Thrissur** | - | 2 | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | 5 | 8 |
| **Total** | **1** | **2** | - | **3** | **7** | - | - | **7** | **1** | - | - | **1** | **1** | - | - | **1** | - | - | - | - | **4** | **3** | - | **7** | **12** | **11** | **12** | **44** |

L : Large Scale Industries; M : Medium Scale Industries; S : Small Scale Industries; O : Other Industries

**Source** : Secondary data collected by KSPCB

Table 3.4.3.2

District wise Type and Quantity Of Waste Generated from Large, Medium and Small Scale Industries

| District | Quantiy of Solid Waste Generated (MTPA) | | | | |
|---|---|---|---|---|---|
| | Solids | Semi Solids | Solvents | ETP Sludge | Total |
| **Alappuzha** | | | | | |
| Large | 9603 | 23 | 1 | 6 | 9633 |
| Medium | - | - | - | - | - |
| Small | 108 | - | - | - | 108 |
| **Total** | **9711** | **23** | **1** | **6** | **9741** |
| **Ernakulam** | | | | | |
| Large | 1265 | 598399 | 300 | 3035 | 542799 |
| Medium | 15 | 341 | - | 6 | 362 |
| Small | 0.2 | - | - | - | 0.2 |
| **Total** | **1280** | **5387** | **300** | **3041** | **543361** |
| **Idukki** | | | | | |
| Large | - | - | - | - | - |
| Medium | - | - | - | - | - |
| Small | - | - | - | - | - |
| **Total** | - | - | - | - | - |
| **Kottayam** | | | | | |
| Large | 1200 | 10890 | - | 69500 | 81590 |
| Medium | - | 156 | - | 75 | 230 |
| Small | - | - | - | - | - |
| **Total** | **1200** | **11045** | - | **69575** | **81820** |
| **Pathanamthitta** | | | | | |
| Large | - | - | - | - | - |
| Medium | - | - | - | - | - |
| Small | - | - | - | - | - |
| **Total** | - | - | - | - | - |
| **Thrissur** | | | | | |
| Large | - | - | - | - | - |
| Medium | - | 550 | - | 24 | 574 |
| Small | 60000 | 2920 | - | - | 62920 |
| **Total** | **60000** | **3470** | - | **24** | **63494** |

**Source** : Secondary data collected by KSPCB

## Table 3.4.3.3

## Industrial Solid Waste : Quantity, Chemical Characteristics & Management Practices

| Sr. No. | Name of the Industry | Type | Chemical Characteristics | Waste Type | Waste Quantity (tpa) | Management Practices |
|---|---|---|---|---|---|---|
| **Alappuzha District** | | | | | | |
| 1 | Kerala State Drugs and Pharmaceuticals, (Kalavur) | LSI | pH-5.4, Methyl & Vinyl ketone-0.24%,<br>1. Acidity : a) Methyl orange acidity-Nil b) Phenolphthalien –85.5 mg/l<br>2. Alkalinity : a) Phenolphthalein-Nil, b) Methyl orange-72.8 mg/l<br>3. Moisture –48.5%<br>4. Volatile matter-59.8%<br>5. Iron, Aluminium oxide % by pass-1.75%<br>6. Silica and acid solubles % bypass-13.5%<br>7. Calcium sulphate-26.4 mg/l | Semi Solid<br>Semi Solid<br>Solvent | 19<br>6<br>1<br>0.6 | Stored in drums, disposed in concrete pits<br>Stored in drums, disposed in concrete pits<br>Stored in open land<br>Stored in drums |
| 2 | Anizham Products (Valvanad) | SSI | | | 3.6 | |
| 3 | Mahesh Enterprises (Vadakkal) | SSI | | | 108 | |
| 4 | Phosphorus and Chemicals (Ezhupunna) | LSI | Pb-ND, Cu-ND, Zn-ND, Cr-ND, Ni-ND, Se-ND, Ba-ND, Sb-ND, Hg-ND, As-ND, Cd-ND | Solid<br>Solid | 9600<br>3 | Land filled<br>Land filled |
| | | | Methyl Vinyl Ketone-2.1%<br>Methyl Vinyl Ketone-2.3%<br>Polymers of M.V.K. | Residues<br>Residues<br>Residue | | |
| 5 | Ananth Wires and Allied Industries Ltd. (Kalamassery). | SSI | | Solid | 0.2 | |

Contd....

Table 3.4.3.3 Contd...

| Sr. No. | Name of the Industry | Type | Chemical Characteristics | Waste Type | Waste Quantity (tpa) | Management Practices |
|---|---|---|---|---|---|---|
| **Ernakulam District** | | | | | | |
| 6 | Binani Zinc Ltd. (Aluva) | LSI | Zn-6.13%, Cd-0.2027%, Fe-19.2%, Pb-6.8% | Semi Solid<br>Solid<br>Residue | 6000<br>260<br>12 | Stored in ponds lined with polyethylene |
| | | | Zn-10%, Cd-3.55%, Cu-25% | Primary Cake residue | | |
| | | | Zn-27.89%, Cd-0.264%, Cu-17.44%, Cd-0.393%, Oil | Secondary cake residue | | |
| 7 | Carbon & Chemicals Vadavucode) | LSI | | | 9<br>30<br>0.3 | |
| 8 | Cochin Refineries And Balmer Lorries Ltd.<br>(Kochi) | LSI | Oil | | 3.8<br>2 | |
| 9 | Cochin Refineries Ltd. (Kochi) | LSI | COD-0.2%, $Fe(OH)_2$-0.25%, Sand-2.5%, Carbon-5.0%, Sulphate-2%, Moisture-45%, Silica and Alumina-N.Quantified | Tarry wastes and discarded waste<br>ETP sludge<br>Metal finishing<br>Non-halogenated HC<br>Halogenated HC | 200<br>90<br>NQ | Off specifications<br>Used for land filling |
| 10 | Fertilizers and Chemicals Travancore Ltd. (Aluva) | LSI | Pb-ND, Zn-78.4mg/kg, Cd-3.2 mg.kg, Hg-0.6 mg/kg, Fluoride-3260 mg/kg, Phosphate-18410 mg/kg | ETP Sludge | 3000 | Stored in hanger store Periodically dumped in the LDPE lined gypsum pond |
| | | | Oil | Waste Oil | | |

**Contd....**

Table 3.4.3.3 Contd...

| Sr. No. | Name of the Industry | Type | Chemical Characteristics | Waste Type | Waste Quantity (tpa) | Management Practices |
|---|---|---|---|---|---|---|
| **Ernakulam District** | | | | | | |
| 11 | Hindustan Organic Chemicals Kochi) | LSI | Dry Sludge : Phenol-11.2 ppm, $N_2$-ND, $PO_4$- 36.14ppm,Chloride-107.7 ppm, Sulphide-ND, $SO_4$- 0.19%, Moisture-5.5% | Slurry from ETP<br>Solvents<br>ETP Sludge | 12<br>300<br>45 | Land filling in factory premises |
| 12 | Hindustan Insecticides Ltd. (Udyogmandal ) | LSI | 1-1.5% HCCP and high polymers, Oil, $CaCo_3$- 45%, CuSO-40%, Soluble Salt-5%, Silica-9%, D.D.T., D.D.E.-trace | Solid<br>Solid<br>Oil<br>ETP Sludge<br>Process<br>Solid waste | 65<br>65<br>3<br>100<br>0.5 | Washing and selling<br>Stored in concrete pits, incinerated<br>Stored and incinerated<br>Off specifications and discarded material |
| 13 | Hindustan Machine Tools (Kalamassery) | LSI | Sodium Cyanide | Sodium Cyanide in Aqueous ash<br>Solid<br>Semi Solid<br>Solid | 0.38<br>1.2<br>0.01 | Stored in masonry pits, oil recovered and sold<br>Oil recovered and sold<br>Chemical treatment in affected |
| 14 | Indian Aluminium Co. (Kalamassery) | LSI | Hydratd Silica of Calcium and Magnesium | Asbestos Waste<br>Solid | 1 | Stored under water in a pit and later disposed as landfill |
| 15 | O/E/N India Ltd. (Mulanthuruthy) | MSI | | Semi. Solid | 1 | Disposed in concrete pits |
| 16 | OEN Connectors (Mulanthuruthy) | MSI | | Solid | 15 | |
| 17 | Periyar Chemicals (Kochi) | LSI | | | 1.5 | |

Contd....

Table 3.4.3.3 **Contd...**

| Sr. No. | Name of the Industry | Type | Chemical Characteristics | Waste Type | Waste Quantity (tpa) | Management Practices |
|---|---|---|---|---|---|---|
| **Ernakulam District** | | | | | | |
| 18 | South India Wire Ropes Ltd. (Aluva) | MSI | | Acidic sludge | 336 | Sold |
| 19 | Travancore Chemical & Manufacturing Co. (Kalamassery) | MSI | | Semi Solid<br>Semi Solid | 1<br>9 | Disposed in concrete pits<br>Disposed in concrete pits |
| 20 | Benz Motors (Edapally) | | Oil | Waste Oil | | |
| 21 | Best Trades Agencies (Aluva) | SSI | | Oil | | Not quantified by the industry |
| 22 | Brahmapuram Diesel power plant | LSI | Oil | | 290 | |
| 23 | Cee Gee Lubricants | SSI | | Oil | NQ | |
| 24 | Coastal Trade Links (Kochi) | SSI | | Oil | NQ | |
| 25 | Cochin Chemicals (Edayar) | MSI | | Acidic sludge | 6 | |
| 26 | Cochin Leathers Ltd. (Muppathadam) | MSI | | ETP Sludge | 6 | Landfill |
| 27 | Cochin Minerals And Rutiles Ltd. (Aluva) | LSI | | | 580<br>20 | |
| 28 | Cochin Shipyard Ltd. (Kochi) | LSI | Oil | | 35 | |
| 29 | Enviro Designs equipments, (Edayar) | SSI | | Oil | | |
| 30 | Fertilizer & Chemicals Travancore Ltd Cochin Division (Kochi) | LSI | | SEMI Solid | NQ<br>530000<br>NQ | Washed empty containers are crushed with liners and is disposed in R.C.C. pits |

**Contd....**

Table 3.4.3.3 Contd...

| Sr. No. | Name of the Industry | Type | Chemical Characteristics | Waste Type | Waste Quantity (tpa) | Management Practices |
|---|---|---|---|---|---|---|
| **Ernakulam District** | | | | | | |
| 31 | Fertilizers & Chemicals Travancore Ltd. Petrochemical Division (Udyogmandal ) | LSI | Moisture-48.2%, $P_2O_5$-2.31%, T.Kj.N-0.55%, Hg-ND, Zn-0.014%, Pb-ND, Fe-2.58%, Cr-0.024%, Ni-0.016%<br>Oil | Bio sludge<br>Solid<br>ETP Sludge | 1.6<br><br>23.4 | Stored in steel drums and sold out<br>Stored in protected enclosures |
| | | | | Waste Oil | | |
| 32 | Hindustan Lever (Tatapuram) | LSI | | | 60 | |
| 33 | I.S.R.O Ammonium Perchlorate plant (Aluva ) | MSI | | Semi Solid | 0.03 | Disposed in concrete pits |
| 34 | Indus Motors (Edapally) | SSI | | Oil | | |
| 35 | Kerala Electrical and Allied Company Ltd. (Ernakulam) | LSI | Oil | Semi Solid | 11<br>NQ | |
| 37 | Kreala Agro Machinery Corporation (Ernakulam) | MSI | | Oil | | |
| 38 | KSRTC (Ernakulam) | SSI | | Oil | | |
| 39 | Merchem Ltd.(Aluva) | MSI | | Solid | NQ | |
| 40 | Shalimar Printing Ink Machine. (Cochin) | LSI | Oil | Semi solid | 9 | Evaporation at $120^0$C and reuse |
| 41 | T V Sundaran Iyengar and sons (Kaloor) | SSI | | Semi Solid<br>Semi. Solid | 0.5<br>12 | |
| 42 | Travancore Cochin Chemicals (Udyogmandal) | L6 | onsistency-24.4%, $Na_2SO_4$-0.4%, $BaSO_4$-2.2%, $CaCO_3$-6.7%, $Mg(OH)_2$-2%, $Fe(OH)_2$-.05% | Semi Solid<br>Slurry | 650 | Stored in concrete pits |
| | | | $aSO_4$-0.3%, $BaSO_4$-24.9%, $CaCO_3$-14.0%, $g(OH)_2$-3.9%, $Fe(OH)_2$-0.1%, Acid insoluble ther than $BaSO_4$-6.1%, NaCl-10.9%, Hg on et basis-5 ppm, Hg on dry basis-8ppm | Filercake | | |

Contd....

Table 3.4.3.3 Contd...

| Sr. No. | Name of the Industry | Type | Chemical Characteristics | Waste Type | Waste Quantity (tpa) | Management Practices |
|---|---|---|---|---|---|---|
| **Ernakulam District** | | | | | | |
| 43 | Travancore Rayons Ltd. (Perumbavoor) | LSI | and-26.65, Calcium Compound as a-26.8%, Zn-1.34%, Pb-trace, ron and Aluminium as $R_2O$=3.$_{2\ 66\%}$ | Solid<br>Sludge Oil<br>ETP Sludge | 160<br>1000<br>NQ | Open yard dumping<br>Dumping in concrete pits not quantified by the industry |
| **Kottayam District** | | | | | | |
| 44 | Canara paper Mills (P) Ltd. (Changanassery) | MSI | | ETP Sludge | 75 | Land filled |
| 45 | Hindustan News Print (Vaikam) | LSI | | Solid,<br>ETP Sludge | | Disposed in low lying area |
| 46 | MRF Ltd. (Kottayam) | MSI | | | 155.5 | |
| 47 | T.V. Sundaram Iyengar and son (Kottayam) | SSI | | | | |
| 48 | Tata Tea Ltd. (Munnar) | SSI | | | | |
| 49 | TECIL Chemicals & Hydro Power Ltd. (Kottayam) | LSI | | Semi Solid | 10890 | Disposed in low lying area |
| **Thrissur District** | | | | | | |
| 50 | Carboradum Universal Ltd. (Koraty) | MSI | | Semi Solid | Waste Quantity | Land filled |
| 51 | Associated Chemicals Ltd. | SSI | | Solid | | |
| 52 | Chackson Chemicals (P) Ltd. (Thrissur) | MSI | | ETP Sludge | 24 | Stored in concrete tanks and incinerated |
| 53 | Kerala Chemicals & Proteins (Koratty) | SSI | | Semi Solid<br>Oil | 2920<br>NQ | Land filled |
| 54 | KSRTC (Thrissur) | SSI | | Oil | | |
| 55 | Kuttakaran Engine Rebuilders | SSI | | Oil | 8.5 | |
| 56 | Malabar Building Products | SSI | | Solid | 60000 | |

**Source** : Secondary data collected by KSPCB

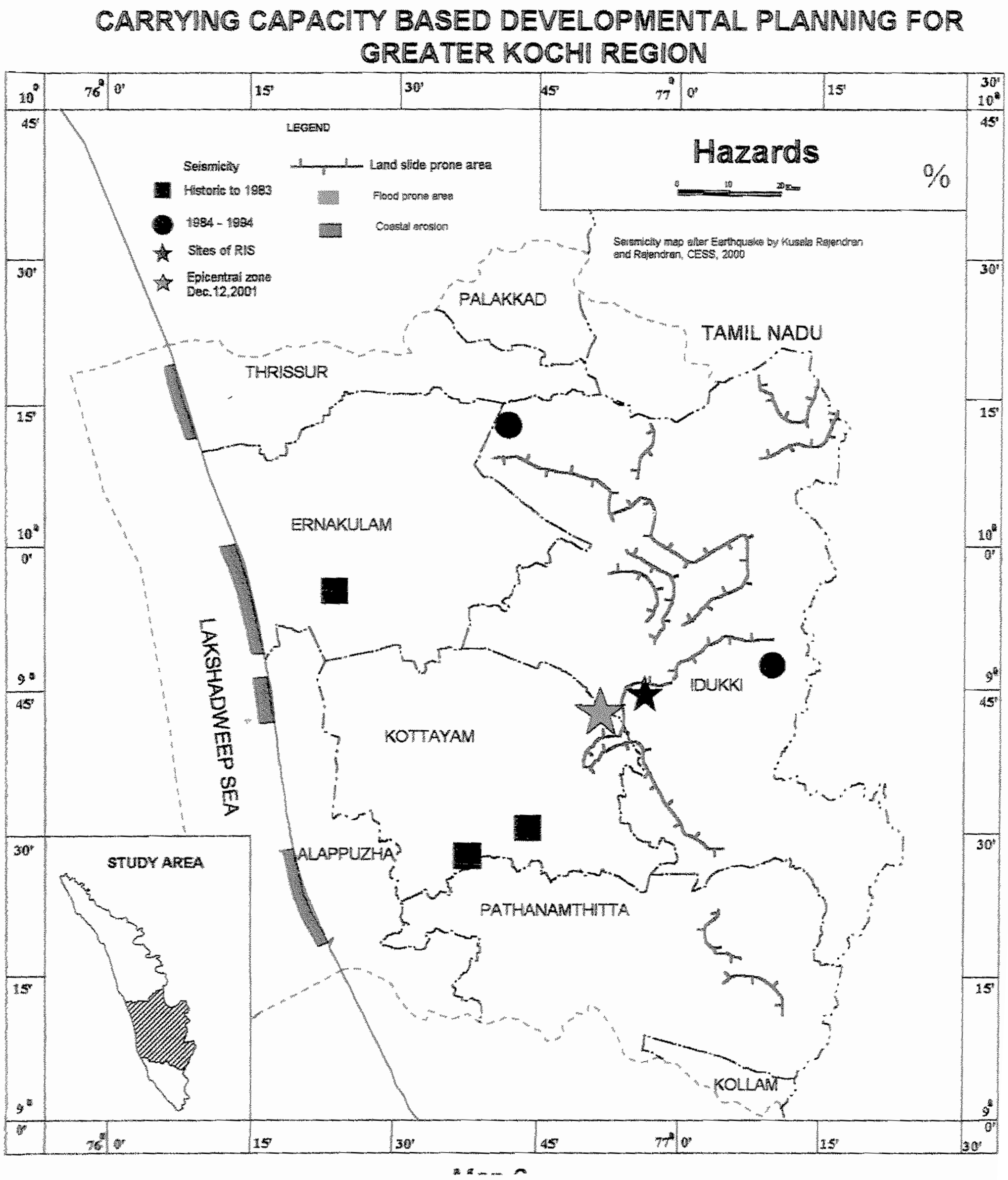



**Fig. 3.4.1.1 : Landslide Hazard Zonation and Locations of Seismic Occurrences in GKR**

CARRYING CAPACITY BASED DEVELOPMENTAL PLANNING FOR GREATER KOCHI REGION

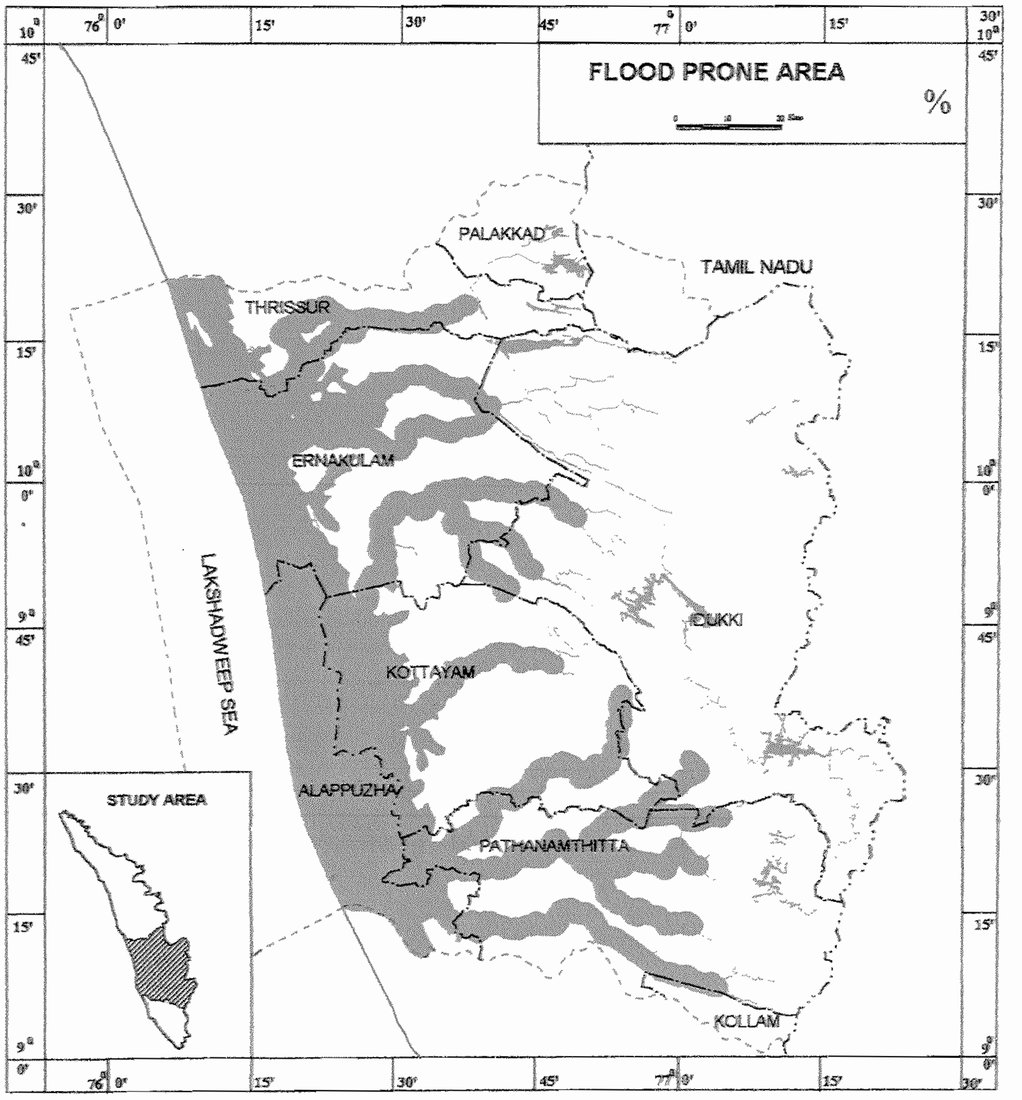



Fig. 3.4.1.2 : Flood Prone Areas in GKR

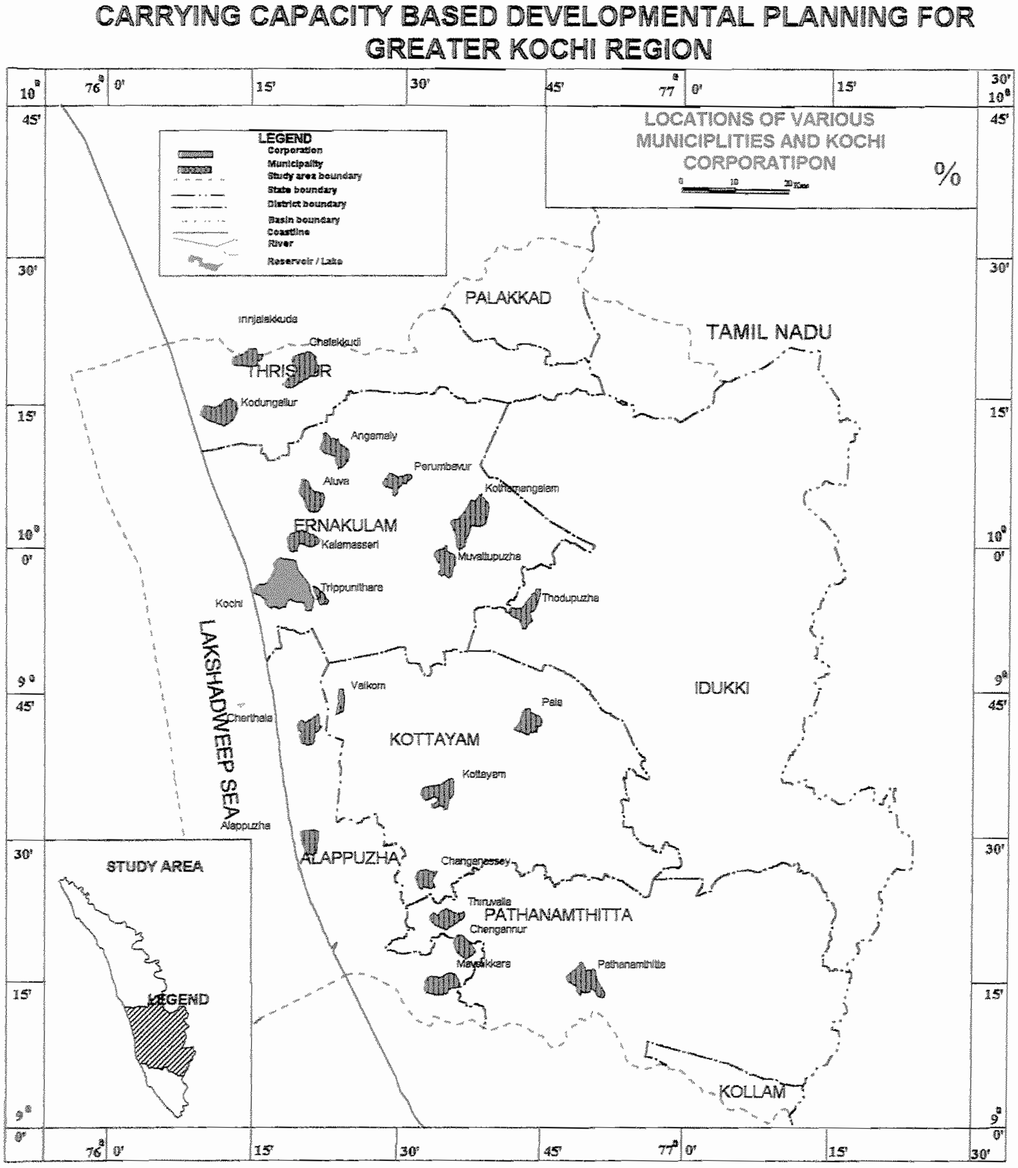



**Fig. 3.4.2.1 : Locations of Various Municipalities and Kochi Corporation in GKR**

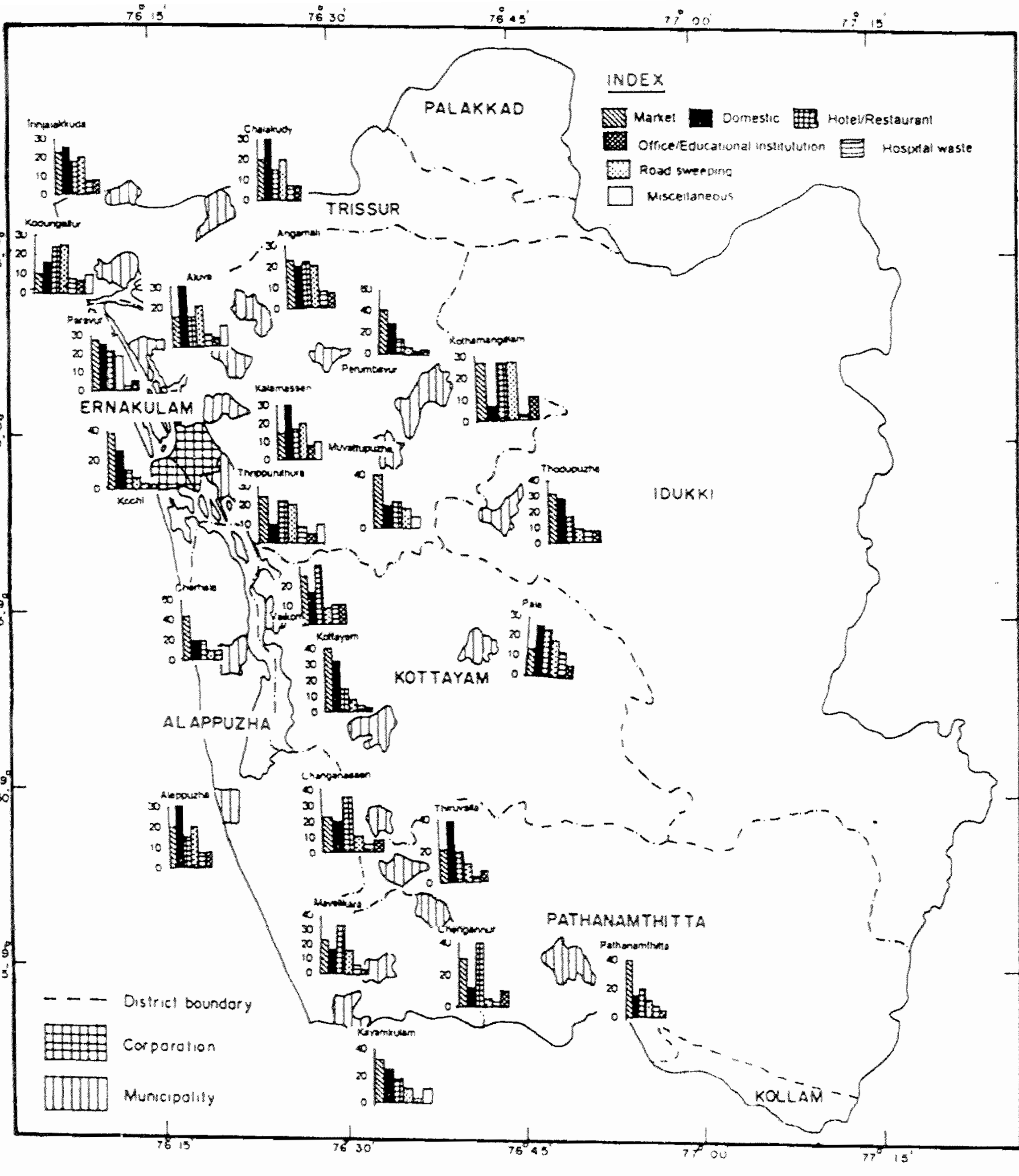



Fig. 3.4.2.2 : Percentage Contribution of Municipal Solid Waste from Major Waste Generation Centres of Various Municipalities/Corporation Areas of GKR

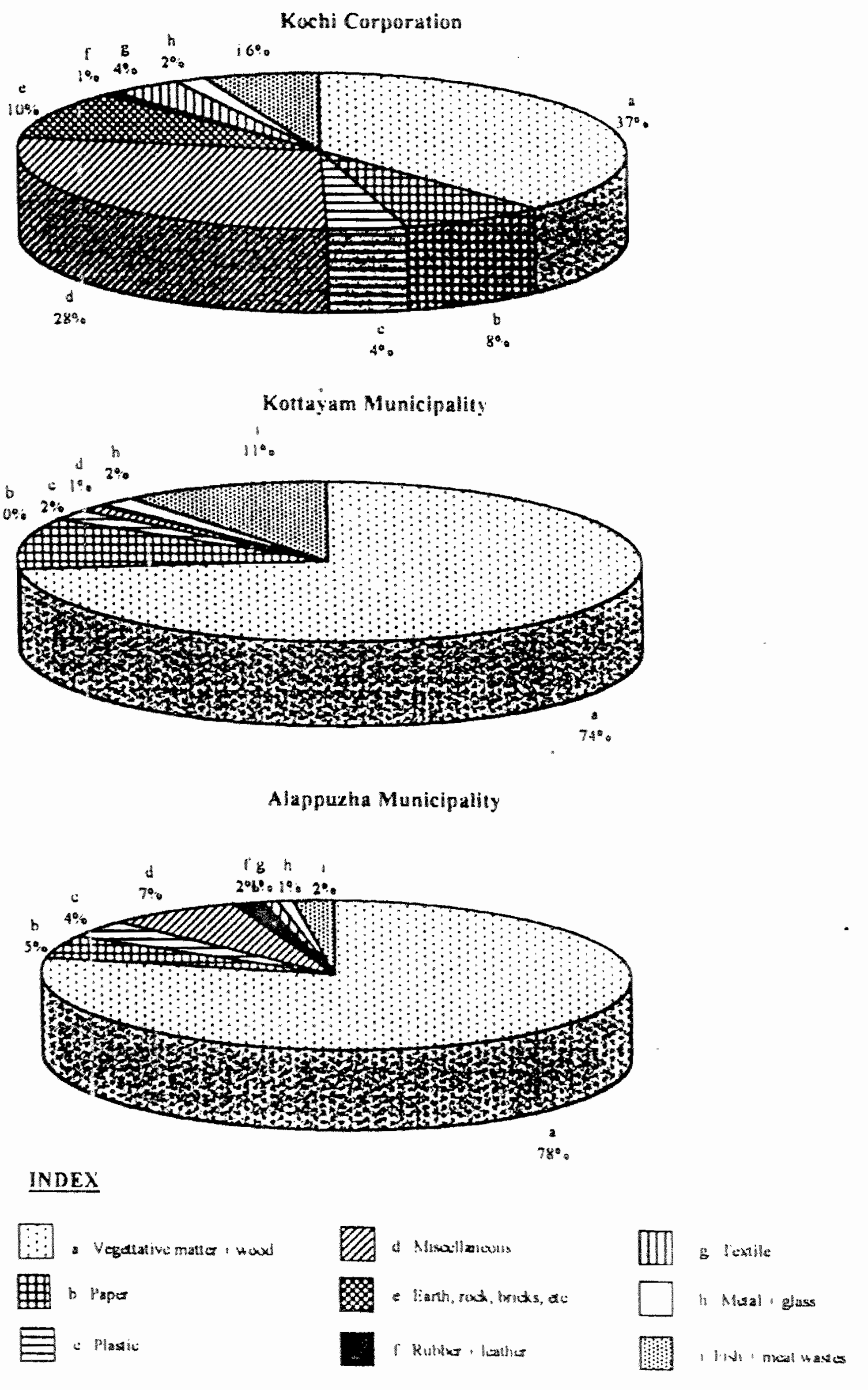



Fig. 3.4.2.3 : Average Composition of Solid Waste Samples of Some Major Towns of GKR (Expressed as Percentage by Weight)

## 3.5 Biological Environment

### 3.5.1 Terrestrial Biology

Phytogeographically, the GKR falls within the natural zone of India, otherwise known as the Western Ghats, which lies more or less between the Palghat gap in the north and the Achankoil valley in the south. Situated near the equator, the area enjoys a tropical humid climate. There are a number of ecological niches in this region depending upon altitude, rainfall and edaphic factors favoring diverse vegetation and species composition. True evergreen forests exist in the hilly regions, whereas, mangroves occur along the backwaters but scarcely along the seacoast. The entire area in the coastal plains and midlands are under intensive cultivation. Naturally, this zone is poor in native biota but rich in agro-biodiversity.

The most outstanding feature of this part of the Malabar botanical province of the country is the development of equatorial type of forests. The diversity of climatic, edaphic and biotic regimes shaped the evolution of the flora to the present level. It could also traced to the immigration and colonization of Malesian, Tibetan, Chinese, African and Australian elements in the geologic past. The characteristic evergreen vegetation and its typical flora are seen on the windward side between 500-1500 m. In low rainfall regions, moist deciduous type prevails with transition to semi evergreen or savannah type according to local climate and topography. Ignoring the high mountain regions, which support Mediterranean and temperate flora, the following 4 rainfall/ vegetation zones with characteristic flora is generally recognized in Western Ghat :

- The wet evergreen zone (rainfall over 250 cm)
- The intermediate zone (rainfall between 200-100 cm)
- The dry zone (100-50 cm)
- The arid zone (less than 50 cm)

The GKR region is not only rich in species diversity but also in habitat diversity. As per the records of the forest department, 28.9% of the geographical area of Kerala is under forests. While considering the forest area diverted for non-forestry purposes, the effective area under forest cover works out to only 24.2%. Out of the 0.94 million ha of forest reported, 83.25% contribute to the reserved forests and the rest fall under the reverted forest category. Per capita forest area is only 0.04 ha as against the all India average of 0.11 ha per person. Forests occupy about 50% of the land area of Idukki and Pathanamthitta districts and it is less than 8% of the geographical area of Kollam and Trichur districts. Alappuzha district has no forest tract at all. The littoral areas are virtually devoid of natural vegetation except for the presence of sparse mangroves along its backwaters. The Sacred groves are seen in lowlands and midlands as remnants of the forest vegetation once spread throughout the area. Forests thickly cover the highland. The Anaimudi (2694 m) is the highest peak south of Himalayas clothed with forests surrounding it. The High Range-Cardamom hill zone is considered as one of the richest zones of habitat diversity in the state. Here, one can see dry deciduous forest to sub temperate sholas, and all possible vegetation types in between along a transect of less than 20 km length.

### 3.5.1.1 Principal Forest Types

The Principal criterion that underlies the division of the forest cover is the monsoon pattern of rainfall. Soil also plays a considerable part along with topography of the area. The main forest types met within the study area are :

- West Coast tropical evergreen forest (Evergreen)
- West Coast semi evergreen forest (Semi evergreen)
- Southern Moist mixed deciduous forest (Moist deciduous)
- Southern Hill top tropical evergreen forest (Hill top evergreen)
- Southern Montane wet temperate forest (Shola) and
- Southern Wet Montane grasslands (Grasslands)
- South Indian Sub tropical hills savanna (Savannah)
- Specialized and local forests (tidal forests, mangroves, fresh water swamps, riverine forests, etc.)

The last two zones are poorly represented in Kerala but occur along the leeward side of the mountains. The sandal bearing forests of Anjanad valley is the only dry deciduous tract lying adjacent to GKR.

The tropical forests are seen almost throughout the hilly regions with minor modifications of semi-evergreen or moist deciduous types. The montane sub tropical and temperate forest types are met within widely separated hilltops of the High ranges and Cardamom hills. The littoral forests represent the best-known tropical forests such as mangroves. Beaches and sand dunes have plants of less saline tolerance limits.

#### *3.5.1.1.1 West coast Tropical Evergreen Forests*

This forest type is found in Mankulam and adjacent regions, Parambikulam-Sholayar, and Periyar where the attitude varies from 100-1300m. Tall trees with straight trunks are found in these forests. Major tree associations are *Mesua - Palaquium - Cullenia* and *Hopea - Dipterocarpus - Vateria* and *Polyalthia - Myristica -Calophyllum*. Second canopy trees are *Diospyros, Drypetes, Garcinia, Hydnocarpus, Semecarpus, Knema* etc. Lower storey trees are members of Orophea, *Meiogyne, Goniothalamus, Aphanamixis,* etc. Shrub layer constitutes *Psychotria, Glycosmis, Strobilanthes, Strychnos,* ferns and palms.

#### *3.5.1.1.2 West Coast Semi Evergreen Forests*

This is a more or less degraded form of wet evergreen forest with the presence of canopy trees like *Terminalia, Ficus, Syzygium, Tetrameles, Toona* etc. wherever disturbance had occurred to the primary vegetation. Middle layer comprises of *Litsea, Syzygium, Dimocarpus, Diospyros, Cinnamomum, Croton* etc. Lower story trees are *Clausena, Ixora, Memecylon, Syzygium* etc. Shrubs constitute *Cipadessa, Psychotria, Gomphandra, Allophyllus, Strobilanthes* and a variety of herbaceous undergrowth of *Psychotria, Ophiorrhiza, Amomum*, grasses, ferns and orchids.

*3.5.1.1.3 Southern Moist Mixed Deciduous Forest*

This forest type is the most prevalent form in the study area. Major forest patches have been converted into plantations. The general floristics is such that the top canopy layer comprises of Pterocarpus, *Tectona, Terminalia, Actinodaphne, Dalbergia, Grewia, Sterculia*, etc. The middle canopy is that of *Wrightia, Elaeocarpus, Sterculia, Diospyros*, etc. *Helicteres, Clausena*, etc. form the lower storey. Shrubs and herbaceous ground growth have been removed in some cases for plantations.

*3.5.1.1.4 Southern Hill Top Tropical Evergreen Forest*

This type of forest is found between 1300-1700 m. *Dysoxylum, Palaquium* and *Cullenia* association is found in the area. *Mesua, Artocarpus, Meliosma, Litsea, Syzygium*, etc. are the major trees in other areas. Second canopy trees include *Casearia, Hydnocarpus, Elaeocarpus, Diospyros, Drypetes, Aglaia*, etc. The lower storey trees are *Meiogyne Psychotria, Ixora, Acronychia*, etc. and *Dichapetalum, Tabernaemontana, Euonymus, Amomum*, ferns, orchids, etc.

*3.5.1.1.5 South Indian Sub Tropical Hill Savanna*

This forest type has a complex of grasses, herbs, undershrubs and shrubs as seen in Periyar Tiger reserve and elsewhere. The common grasses belong to *Dichanthium, Eulalia, Agrostis, Andropogon, Arundinella, Bromus, Chrysopogon, Indochloa, Isachne, Tripogon* etc. Orchids like *Habenaria, Malaxis, Satyrium* and *Spiranthes* are common. Herbs commonly found are: Crotalaria, *Dichrocephala, Drosera, Gentiana, Geranium, Hedyotis, Hypericum, Impatiens, Justicia, Leucas, Osbeckia, Pimpinella, Senecio* and *Swertia.* In marshes, *Burmannia, Eriocaulon, Fimbristylis, Lobelia, Utricularia* etc. thrive well.

There are vast stretches of grasslands often with very shallow soil depth. About 15-20 % of these grasslands are subjected to grazing pressure.

*3.5.1.1.6 Southern Montane Wet Temperate Forests (Shola) & Southern Wet Montane Grasslands (Shola-wooded)*

The vegetation consists of vast expanse of grasslands interspersed with a number of compact woods locally known as sholas. These sholas are usually confined to sheltered valleys, glens, hollows and depressions where there is adequate moisture and good drainage. Roughly the grasslands constitute about 75% of the area and the woods 25%. The trees comprising the sholas are evergreen and short boled the height of which does not exceed more than 6 m. at higher elevations. The boles are often clothed with thick growth of lichens, mosses, ferns, orchids and other epiphytes. The species growing on the margins are light demanders and do not enter the forest. The grasslands are extensive and include a complex of grasses, herbs, undershrubs and a few shrubs. Growing amidst these grasses are orchids, and other herbaceous vegetation including species of *Nilgirianthes (Strobilanthes)*.

These wooded places and grasslands are often considered as separate types as: (a) southern montane wet temperature forest and (b) southern montane wet grasslands, the latter being considered as a degraded stage. Some authors even consider a third category viz. shola, tree-shrubby shola and shrub-savanna.

The species growing on the margins of sholas are light demanders and do not enter the forests. The shrub savanna is a zone of herbs and shrubs mixed with grasses. Principal trees are *Actinodaphne, Elaeocarpus, Ilex* and *Syzygium*. Eurya, Photinia, Rhododendron, Rhodomyrtus, Ternstroemia, Turpinia, Berberis, Euphorbia, Diospyros, Goultheria, Hedyotis, Jasminum, Leucas, Smithia, etc often cover fringes of the sholas.

Undergrowth in the shola is made up of *Elatostemma, Impatiens, Psychotria, Strobilanthes, Asplenium, Piper, Tylophora, Arasaema,* etc. Epiphytic orchids and ferns are plenty.

### 3.5.1.2 Plantations

Extensive plantations have been raised inside the forest areas, after clear felling natural forests and in fallow lands and grasslands. Teak, eucalyptus, softwood, bamboo, wattle, etc. form the important forest plantations. Plantations of tea, cardamom, pepper, coffee, rubber, etc. are more common in the area. In the lower reaches, industrial and fuel wood plantations are very common.

### 3.5.1.3 Growing Stock in Forests

The forests of the tract are rich in growing stock of timber. A total growing stock of 200 million $m^3$ has been estimated from Kerala forests. Out of this, nearly 63% is accounted for evergreen forests, 36% moist forests and 1-2% plantations: Man made forests constitute 16.5% of the effective forest area. Besides, reeds and bamboo brakes are common in moist forest tracks of Pooyamkutty, Idamala, and Periyar regions.

### 3.5.1.4 Forest Dwellers in the Region

There are 38000 forest dwellers in the region according to the tribal survey conducted by the Kerala Forest Department (1992). Females constitute 49.67% percent of the dwellers. Among the twenty different tribes in the region, prominent groups are Muthuvas, Ooralies, Hill Pulayas, Mannans, Malayarayas and Ulladans. 45.82% of the population is dependent on forest resources for their livelihood. 22.96% of the population is employed as wage labourers.

Income accrued through various activities is listed in **Table 3.5.1.1**. Agricultural activities inside the forests, collection of Non Wood Forest Produce (NWFPs) hunting, fishing, cottage industries and household works are categorised as forest dependent activities. Income obtained from forestry related works, often as wages obtained from forestry related works by wage labourers is taken into account.

Higher altitudes of the high ranges are predominantly occupied by the Muthuvas. They practice shifting cultivation and derive additional income through collection and marketing of Non Wood Forest Produce (NWFPs). Tribal settlements at Idamalakudy in the Idamala-Pooyamkutty basin have significant high number of Muthuvas as residents. Shifting cultivation and cardamom cultivation is the major income generating activities. Land holdings of individual households under cardamom ranges from 5-70 acres. Drastic decline in cardamom prices has affected households in the region. This has prompted them to collect other NWFPs from the surrounding forests to meet subsistence needs. This cluster of remote settlements has a collection depot of GSCS to collect the forest products, exchanging rice and other grocery items. Decreasing market prices for the forest products and increasing prices for all grocery items has been the trend for the past few years. This widening gap between the market prices could probably build enormous pressure on the surrounding forests in the years to come.

Other pockets of settlements of Muthuvans are in the upper reaches of Anamalais, Chinnar Wildlife Sanctuary and Sholayar. Dispersed settlements in and around Sholayar namely Chinnapparakudi, Thumbiparakudy, Malakkapara, Adichitithotty, Andavarkudy, Pudukudy etc substantiate higher proportion of their income through collection and sales of Non Wood Forest Produce (NWFPs).

### 3.5.2 Terrestrial Habitats

#### 3.5.2.1 Terrestrial Flora

The habitats and ecosystems of GKR are of significant importance with its unique assemblage of species, high rate of endemism, biodiversity, rarity and vulnerability. A lionshare of the biodiversity of the State is represented in GKR and hence conservation of habitats and protection of biodiversity should be a major goal in the development planning of the region.

Biodiversity rich terrestrial habitats include forests of the Western Ghats and sacred groves & agro-forestry systems from the non-forested lands.

GKR constituting 30% of the area of the State contains 80% of the angiosperms. Of the 3800 species of angiosperms reported from the state 3049 have been reported in GKR (**Table 3.5.2.1**, **Appendix 3.5.2.1**). Among the 3049 species of flowering plants, 95 species are of algae 106 species of fungi, 32 species of bryophytes and 157 species of pteridophytes. Of the 1272 endemics 80% are reported in this region. Of the 460 species, which fall under the rare, threatened, vulnerable and endangered categories 44% of them are reported to be present in this region. This highlights the floristic richness and biodiversity rich habitats of the region. Besides angiosperms, GKR abodes a lionshare of the 6235 plant species of the State which include algae, fungi, bryophytes and pteridophytes as listed in **Appendices 3.5.2.2, 3.5.2.3, 3.5.2.4 and 3.5.2.5** respectively.

Around 70 ha of land under sacred groves are present in GKR with a major (67%) share represented from Alappuzha and Ernakulam (**Table 3.5.2.2**). 400 plant species are recorded of which 24 are rare and endangered. 80 medicinally important (**Appendix 3.5.2.6**) and 45 species of animals are found inhabiting these habitats (**Table 3.5.2.3**).

### 3.5.2.2 Terrestrial Fauna

Region abode an array of habitats, which support rich fauna. Relative density of animals in the contiguous forests of the region indicates high degree of habitat utilisation. A lionshare of the faunal diversity of the State is found to be utilising the habitats of GKR. An estimate of the faunistic diversity with in the region is also provided in **Table 3.5.2.4**. High species diversity of insects and fishes is documented in Thrissur, amphibians, reptiles and mammals in Idukky and birds in Ernakulam. Habitats of Thrissur, Idukky and Ernakulam were found to be faunistically rich with a good representation of diverse species. Terrestrial fauna include 497 species of insects, 126 species of fishes, 47 species of amphibians, 89 species of reptiles, 410 species of birds and 116 mammals.

Species that are recorded to be present in certain habitats of a district but not recorded in other districts, with in the region is estimated. Number of species of insects, fishes and birds exclusively found in Thrissur are high. Number of species of amphibians and reptiles in Ernakulam and Idukky respectively, was also recorded to be high (**Table 3.5.2.5**).

A check list of insects, amphibians, reptiles, birds and mammals of GKR in various district with in the region is provided in **Appendices 3.5.2.7, 3.5.2.8, 3.5.2.9, 3.5.2.10** and **3.5.2.11** respectively. According to a checklist of Indian mammals compiled by Nameer (1998) the total number of mammals distributed in GKR is estimated to be 116 as listed in **Appendix 3.5.2.12**. Of the 116 mammals, 12 are vulnerable, 7 endangered and 3 critically endangered. For 16 mammals data are deficient and 39 are categorized as "lower risk-near threatened" and 28 "lower risk- least concerned".

Among the faunistically rich areas in the region, attempts were carried out to find out the areas with in the region of higher conservation value in terms of habitat preferences of a wider array of larger mammals. Wildlife census of the State conducted by the Kerala Forest Research Institute and Kerala Forest Department in the year 1993 is used for the study. Relative density of sixteen mammals in different areas of the region was estimated (**Table 3.5.2.6**). The area with high population density of each species is identified. The contiguous forests of Vazhachal and Malayattoor and the forests of PTR and Ranni support high faunal diversity with relatively high density. These areas in the region deserve immediate attention in terms of relatively high habitat preference of highly dense and diverse fauna. These areas are also considered to be a hot spot of high conservation value.

### 3.5.3 Aquatic Biology

#### 3.5.3.1 Mangroves

Mangroves are halophytic vegetation thriving in discrete patches in estuaries, backwaters and lagoons where the water is quiet. At present, mangroves are thriving in Vypin, Kannamali, Kumbalam, Maradu and Thripunithura, Kumarakam, etc. bordering the Vembanad Lake. Total area under mangroves is about 25 ha in Alappuzha, 250 ha in Ernakulam and 20 ha in Kottayam districts. Puthuvaipu supports mangroves along the accreting seascoast. Mangrove species of *Rhizophora, Bruguiera, Sonneratia, Kandelia, Derris, Acanthus,* and *Acrostichum* are common. There are about 18 true mangrove species and 17 associated ones. They are just remnants of an extensive mangrove forest thrived all along the intertidal regions (now defaced under human intervention) of Vembanad Lake in the near past. Mangroves ecosystem support a variety of organisms. 35 species of mangroves are reported to be present in GKR. 42 species of algae and 28 spp. of macro invertebrates are reported to be associated with mangrove species **(Appendices 3.5.3.1** and **3.5.3.2)**.

#### 3.5.3.2 Aquatic Habitats (Flora & Fauna)

Biodiversity rich aquatic habitats comprise of fresh water sources, backwater and marine systems. Among the aquatic habitats 124 and 150 fishes from the fresh waters and back waters respectively, has been reported. Migratory marine fishes in the backwaters are reported to be 41 euryhaline and 48 stenohaline species. There are 168 sp. of benthos in the backwaters, majority being represented by the polychaetes (32%), protozoans (29%) and crustaceans (23%). 25 species of zooplanktons are also reported. Marine organisms include 65 species of phytoplanktons, 89 sp. of zooplanktons 88 species of benthos, 113 finfishes and 31 shellfishes. 21 species of mammals comprised of whales, dolphins and dugongs are also reported. The details are given in the subsequent sections.

*3.5.3.2.1 Fresh waters*

Major phytoplankton genera observed in the fresh water bodies are blue green algae. green algae and diatoms. The filamentous algae Microspora sp. had the maximum density followed by Monostroma sp. The blue green algae, especially Anacystus sp., Spirulina sp. are the major constituent of the phytoplanktons. The Desmids and Diatoms are comparatively less in the lentic water bodies. Presence of phytoplankton genera like Pediastrum, Staurastrum, Treubaria, Dinobryon, Peridinium, Gonyaulax, Asterionella etc. are indicators of eutrophic status of the water quality. 37 spp. of phytoplanktons and 102 species of fishes are documented to inhabit the fresh water bodies of the region. Check lists of phytoplanktons and fishes inhabiting the fresh water bodies of the region is provided in **Appendices 3.5.3.3 and 3.5.3.4**.

Among the 102 spp of fishes, 6 belong to the endangered category, ten vulnerable and 8 spp belong to the rare and endemic category. Details are provided in **Appendix 3.5.3.5.**

Herbaceous fresh water vegetation is found in lakes, ponds and similar habitats where the water contains enough nutrients. The wetlands and rice fields are important habitats for seasonal flora and notorious weeds like water hyacinth and *Salvinia*.

*3.5.3.2.2 Backwaters*

**Primary Production : Organic Carbon**

Sediments are indicators of the quality of water overlying them and hence, useful in the assessment of environmental pollution. Variations in colour and texture of sediments were brought about by changes in the grain size and state of oxidation of organic matter. The colour of the sediment varied from greyish black at stations 5,6,7, brownish at stations 1,2,3 and black at stations 11,12 and 13 with sulphur granules at the industrial area.

Organic carbon content in the sediments of the estuarine-riverine system is of considerable interest as a potential food for the benthic fauna. Generally, the state of preservation depends partly on its texture as well as microbial and redox potential of the sediment. High organic carbon noticed at station 7 may be due to the dredging activities. Land run off and terrigenous sources contributed to monsoonal increase of organic carbon content. Station 1 and 2 with sandy bottom and low organic carbon content showed a healthy population of bivalves mainly constituted by *Villorita cyprinoides*. Stations with silty clay and high organic content supported abundant and diverse fauna.

Seasonal study on the standing crop in terms of chlorophyll, primary productivity and total phytoplankton cells present at 14 station grids has shown that there were regional and seasonal variations in the magnitude of phytoplankton production in the Cochin backwaters. Two seasonal peaks of primary productivity were noticed in almost all the stations, a primary peak during pre-monsoon season and a secondary peak during the post monsoon season as reported in the earlier studies. During the peak periods, the phytoplankton mainly includes diatoms. The major diatoms noticed were Skeletonema costatum, Coscinodiscus sp and Nitzchia sp. Silicoflagellates such as Distephanus and Dictyocha were present in lesser numbers during the pre-monsoon months. A few members of the blue green algae such as species of Oscillatoria, Trichodesmium, Meresmopedia and Synechocystis were found in lesser numbers during the post-monsoon months. Fresh water desmids, Cosmarium, Micrasterias, Desmidium and filamentous green algae Spirogyra, Oedogonium and Cladophora species were seen during the monsoon season. Seasonal variation in Chlorophyll and primary productivity recorded is summarised in **Table 3.5.3.1** at surface and bottom of the each station.

Vembanad Lake (Kochi back waters) is the largest estuarine and brackish water system not only in GKR, but also in Kerala. This system is connected to the sea at Kochi and Azhikode (Munambam). This backwater system has been a nursery ground for several marine species.

150 species of fishes and 168 species of benthos have been reported from the backwaters in the region. 23 species of mollusks, 38 species of crustaceans,

53 species of polychaetes, 5 species of coelenterates, and 49 species of protozoans represent the benthos of the region. There are 25 groups of zooplanktons of which 20 are of holoplanktons and 5 meroplanktons as listed earlier in **Table 3.5.3.2.**

The exploited fishery resources of the lake are constituted by 15 species of fishes belonging to 84 genera, 6 species of penaeid prawns, 4 species of palaemonid prawns and 3 species of crabs. Fishes dominated the catches from July to December, especially in the southern sector of the lake. The distribution and abundance of fishes in the Vembanad Lake is mainly dependant on the prevailing environmental conditions, the most important among them being salinity and annual floods.

The fishery resources of the lake is sustained either by migrant species from the adjoining sea, rivers or resident estuarine population. The 128 species of fishes and crustaceans constituting the fishery of the lake can thus be grouped as 68 marine migrant species (60 fish, 6 prawns, 2 crabs), 17 resident estuarine forms (fishes), 17 resident common species (15 fishes, 1 crab, 1 palaemonid), 16 oligohaline species (fishes) and 10 limnetic migrant forms (7 fish, 3 palaemonids) (**Table 3.5.3.3**). A month wise analysis of the contribution of migrants and residents in the catches from the lake revealed that resident common group showed its predominance in almost all months, followed by marine migrants and resident estuarine forms. The yield/ha of the marine migrants is seen to be primarily correlated with the availability of the penaeid prawns.

Aroor area offers an ideal nursery ground for penaeid prawns whereas in the harbour area the penaeid prawn landing is composed of both the migratory sub-adult prawn as well as the stock sustained by the lake. Moreover, these 2 areas have dual advantages, when compared to other regions of the lake. The availability of marine migrants is always high due to either the direct ingress from the sea or massive outward migration from the upper reaches. The maximum yielding zones and peak fishing seasons in the Vembanad Lake are provided in **Table 3.5.3.4**.

*3.5.3.2.3 Biological Characteristics :(Flora & Fauna)*

*Chlorophyll-'a', POC and Suspended Sediment*

The primary data collected during October 1997 indicated that the chlorophyll content in the surface waters varied from 0.67 to 13.36 mg/m$^3$ and from 0.21 to 12.69 mg/m$^3$ in the bottom waters **(Table 3.5.3.5).** The POC varied from 0.1 to 4.0 mg/L in the surface and 0.1 to 5.0 mg/L in the bottom waters. The suspended sediment load varied from 0.4 to 53 mg/L in the surface and from 3.2 to 140 mg/L in the bottom waters.

The average chlorophyll value for the water column of the 9 transects from Kodungallur to Thottappally observed during February 99 varied from 0.21 to 8.60 mg/m$^3$, the highest being off Chethi beach (T4) and lowest off Azhikode (T9). The particulate organic carbon content was low and the average values were below 1mg/L 0.00-2.52 mg/L. The highest value was at the transect between Thottappally and Alappuzha and lowest at Kodungallur. The highest suspended load (avg 66.95 mg/L) was observed off Thottappally. Rest of the values were < 20 mg/L.

The pigment content of the water column of the study area showed a wide range between 1.02 mg/m$^3$ (station 18) and 11.33 mg/m$^3$ (station 22). Along 5 m depth contour the values fluctuated between 1.35 mg/m$^3$ off Kannamaly and 6.20 mg/m$^3$ off Edavanakkad with an average value of 3.29 mg/m$^3$. Chlorophyll values at 10 m depth contour varied from 1.14 mg/m$^3$ (off Azhikode) to 11.33 mg/m$^3$ (off Andhakaranazhi) with an average value of 4.09 mg/m$^3$. At 20 m depth line the values fluctuated between 1.02 mg/m$^3$ (off Mararikkulam) and 9.14 mg/m$^3$ (off Andhakaranazhi), and the average being 3.25 mg/m$^3$. Beyond 20 m depth zone, the values fall within the range of 1.11 mg/m$^3$ (off Andhakaranazhi) and 6.40 mg/m$^3$ (off Edavanakkad) with a low average value of 2.80 mg/m$^3$.

Transect-wise distribution of chlorophyll recorded a peak value (6.11 mg/m$^3$) along transect 5 off Andhakaranzhi and a second peak (5.31 mg/m$^3$) along transect 8 off Edavanakkad. Transects 1, 3 and 7 showed the same patterns in distribution of chlorophyll whereas other transects showed more or less the same trend. In general, the near shore stations registered comparatively high values.

POC values were comparatively higher during November and varied from 0.52 to 3.78 mg/L (**Table 3.5.3.5**). Most of the values were between 0.1 and 2 mg/L. Transect-wise distribution showed that the average values for different transects ranged between 0.96 and 1.91 mg/L with an average of 1.77 mg/L for the entire study area. Transect 3 showed peak value and minimum value was recoded along transect 7. Depth-wise distribution of POC showed a decreasing trend towards offshore with a value of 1.87, 1.76, 1.62 and 1.19 mg/L at 5, 10, 20 m and > 20m depth respectively, thus showing a positive correlation with chlorophyll content.

Suspended load of the area during November varied from 5 to 53 mg/L. Most of the values were within the recorded values for coastal waters. Transect-wise average for suspended load was high along transect 9 and low along transect 2, showing moderate values along other transects. Depth-wise average was high at 5 m depth line compared to other depth zones.

## Species Abundance and Distribution

Salinity characteristics, tidal patterns and seasonal variations influence the hydrographic features of the estuary from one region to another. Therefore, the estuary region described in the present report mainly refers to the area between Pathalam bund in the North to Aroor in the south. Approximately 500 species belonging to various invertebrate and vertebrate phyla were collected. Information on the temporal and spatial distribution of fauna from the secondary data confirm the fact that monsoon is the major phenomenon which controls the occurrence of fauna in the estuary. List of Fauna inhabiting the Cochin backwaters is given in **Table 3.5.3.2**, whereas the secondary information on benthos is given in **Table 3.5.3.6**. Salinity was apparently found to be the major factor influencing the distribution of fauna in the estuary. The salient features abundance and their distribution are :

- Temporal and spatial abundance of fauna in the backwaters is clearly affected by the monsoon. Copepods formed the major constituent of the zooplankton in the estuary, comprising 30.9% of the annual zooplankton count.
- During pre and post-monsoon months, when flushing is not effective, there is a build up of pollutants in the middle reaches of the estuary which also play a vital role in the distribution of the fauna. Dominance of *Capitella capitata*, an indicator of pollution showed removal of more sensitive species from that part of the estuary which was directly under the influence of organic and inorganic pollution.
- *Sagitta inflata* (a chaetognath), a continuous breeder has established resident population in the estuary.
- Areas with fine sediments and rich organic matter support abundant and diverse fauna. The middle reaches of the estuary with sandy bottom and low organic carbon content showed healthy concentration of bivalves mainly *Villorita cyprinoides*. The effluent discharge site at Udyogmandal with silty sediment was mainly marked by the presence of *capitellid polychaetes*.
- The distribution of fauna in the estuary is influenced by the salinity in the region. Lower reaches of the estuary near the barmouth are inhabited by calcareous species of Foraminifera. Siliceous and chitinous forms are dominant in the upper reaches where fresh water conditions prevail.
- Post larvae and young ones of commercially important prawns were encountered in the estuarine area throughout the year with peak periods of abundance. *Metapenaeus dobsoni,* which can tolerate wide fluctuations in salinity, was found to be the dominant species in the backwaters throughout the year. On the whole, 32 species of prawns and shrimps were recorded from the Cochin backwaters
- Freshwater forms like *Macrobrachium* sp. move into the estuaries for spawning. These are found in estuarine regions with salinity of 6-17.5 ppt during the post monsoon periods.
- Of the 150 species of fish identified in the estuary, about 10 species of the true estuarine fishes were found to inhabit all the sectors of the lake and were commercially important. Maximum fish species diversity was found in the pre-monsoon season, but the closure of Thannirmukkom bund during this season has resulted in the complete absence of euryhaline as well as stenohaline marine species in the southern sector of the Vembanad Lake.
- *Crocodilus porosus*, the estuarine crocodile, which existed in the once abundant marshy regions of the Cochin backwaters, is now reported to be non-existent. Polychaetes constituted the largest assemblage of benthic forms in the estuary.

### Zooplankton Count

Copepods, decapod larvae, cladocerans and cirripede larvae constitute the predominant component of zooplankton. Of these, copepods are the most dominant group constituting 55-85% of the total annual zooplankton counts. Distribution of Zooplankton count at different sampling stations during monsoon & post-monsoon seasons are given in **Table 3.5.3.7.**

Distribution pattern of zooplankton in the backwater suggests that salinity is the major limiting factor controlling the abundance of most of them. All groups of zooplankton exhibit a seasonal pattern in distribution reflecting the seasonal changes in salinity. The entire estuary becomes rich in animal life during the pre-monsoon period, and according to the secondary data, about 90% of the common species occurring in the estuary register their peak abundance during this period.

Zooplankton density falls during monsoon since the water becomes practically fresh and renders it unstable for the sustenance of zooplankton except for a few low saline species. A gradual repopulation of the estuary following a recovery of the salinity begins in the post monsoon season. During the post monsoon months, the larval forms of benthic invertebrates, eggs and larvae of fishes and holoplankters such as copepods and cladocerans largely constitute zooplankton.

The major groups observed during the study period were :

- **Hydromedusae** : seen in post monsoon in the harbour area.
- **Chaetognaths** : Present only at stations 6,8 & 9 (harbour area) during monsoon, which gradually reappear in the lower reaches of the estuary with the increase in salinity.
- **Copepods :** Present throughout the backwaters in both monsoon and post monsoon, but abundantly during post monsoon.
- **Cladocera** : Present in large numbers during monsoon
- **Amphipoda** : Not found in monsoon, but present in small numbers during post monsoon.
- **Lucifers** : Rarely seen during monsoon, however, it gradually increase in post monsoon.
- **Brachyuran zoeae** : Found abundantly in the estuary.
- **Fish eggs and larvae** : Number high in monsoon and post monsoon.

### Benthic Fauna

In the Cochin backwaters, except for a few coelenterates and a few gobiod fishes collected from the barmouth region, the bottom fauna composed mainly of polychaetes, crustaceans and molluscs. Mainly amphipods, isopods, tanaids, cumaceans, penaeid prawns and brachyurans represent crustacean fauna.

*Villorita cyprinoides* and its variety *cochinensis* are the most common molluscs in the upper reaches of the estuary.

In the case of benthos also, salinity is the master ecological factor controlling their seasonal distribution and abundance. The maximum benthic population occurs during pre-monsoon period and minimum during monsoon. This is most obvious at the barmouth area. A fairly rich fauna occurs during pre and post monsoon, but it nearly disappears during the heavy monsoon period.

Distribution of macrofauna at different stations during monsoon & post-monsoon seasons is summarized in **Table 3.5.3.8.**

*3.5.3.2.3 Costal Waters*

**Primary Production**

The levels of gross primary production off Kochi area increased from 0.83 to 1.624 gC/$m^3$ per day in correspondence with the increasing rainfall during April to June 1986. A similar increase in production from 0.597 to 0.975* gC/$m^3$ /day was observed to coincide with increasing monthly rainfall from May to June and in August 1987.

Chlorophyll-'a' concentration in the surface water showed a decreasing trend from pre-monsoon to monsoon and monsoon to post monsoon months. This has been attributed to the physiological state and productive potential of phytoplankton during the sampling period. The studies also revealed that productivity at 10m stations was around 50% of the productivity in the 20m-depth zone. Gross primary production also showed positive correlation with abundance of nutrients such as phosphates and nitrates in the inshore waters, which in turn is attributed to coastal upwelling. The annual net primary production of euphotic waters off Kochi was estimated as 731.43 MT Carbon/$km^2$ indicating high productivity **(Table 3.5.3.9).**

**Primary Production during February 1999**

Measurements of production were carried out using $C^{14}$ technique. High productivity values were observed in the inshore region and diminished towards offshore **(Table 3.5.3.10).** Generally it was observed that the primary production was higher at surface at all stations except the deeper water of transects II, III & I. The primary production ranges from 519.35 mgC/$m^3$/day at Pathirappally to 1.14 mgC/$m^3$/day at Chellanam. The column productivity ranges from 1529 mgC/$m^2$/day at Pathirappally to 42 mgC/$m^2$/day at Thumboli.

**Phytoplankton**

Primary data on Phytoplankton collected during October 1997 and February 1999 are given in **Table 3.5.3.11.**

## Species Diversity of Phytoplankton

About 65 species of phytoplankton are reported from the study area. List of groups/species of phytoplankton compiled from available data for the study area is given below

**Diatoms**

**Coscinodisceae**
*Skeletonema costatum*
*Planktoniella* sol.
*Coscinodiscus* sp.
*Coscinodiscus marginatus*
*Coscinodiscus eccentricum*
*Cyclotella* sp.
*Melosira* sp.
*Thalassiosira subtilis*

**Solenieae**
*Rhyzosolenia* sp.
*Rhizosolenia alata*
*Rhyzosolenia cylindrus*
*Rhizosolenia stoltesfothii*
*Rhizosolenia setigera*
*Rhizosolenia styliformis*
*Rhizosolenia delicatula*
*Rhizosolenia hebatula*
*Leptocylindrus danicus*
*Lauderia glacialis*
*Lauderia annulata*

**Chaetocereae**
*Chaetoceros* sp.
*Chaetoceros affinis*
*Chaetoceros diversus*
*Chaetoceros compressus*
*Chaetoceros decipiens*
*Chaetoceros varians*
*Chaetoceros schuttii*
*Chaetoceros holsaticus*
*Chaetoceros teres*
*Chaetoceros curvisetus*
*Chaetoceros constrictus*
*Chaetoceros didymis*

**Biddulphieae**
*Climacodium biconcavum*
*Biddulphia* sp.
*Biddulphia sinensis*
*Biddulphia aurita*
*Biddulphia mobiliensis*
*Eucampia* sp.
*Streptotheca indica*
*Ditylum* sol
*Triceratium favus*

**Hemiaulineae**
*Cerataulina bergonii*

**Fragilarioideae**
*Thalassiothrix frauenfeldii*
*Rhabdonema mivificum*
*Thalassionema* sp.
*Thalassionema nitzschioides*
*Climacosphaenia* sp.
*Fragilaria oceanica*

**Naiculoideae**
*Pleurosigma* sp.
*Pleurosigma elongatum*
*Navicula* sp.

*Diploneis* sp.

**Nitzschiaceae**
*Nitzschia closterium*
*Nitzschia seriata*
*Nitzschia longissima*
*Nitzschia pungens*
*Nitzschia bilobata*
*Nitzschia directa*

**Dinoflagellates**
*Ceratium* sp.
*Ceratium bucephalum*
*Ceratium fusca*
*Ceratium macroces*
*Peridinium* sp.

**Cyanobacterium**
*Trichodesmium* sp.

## Secondary production: Zooplankton

Secondary production off Kochi was recorded maximum during monsoon, which decreased through post-monsoon and reached minimum during premonsoon period **(Table 3.5.3.12).** Annual net secondary production off Kochi was reported to be 6.652 MT carbon/km$^2$.

Zooplankton abundance and biomass off Kochi and Alappuzha are given in **Tables 3.5.3.13**. Copepods were the dominant group of zooplankton present in the coastal waters varying in its numerical abundance with season. The decapod larvae represented the second abundant group. Blooms of species *noctiluca* and other dinoflagellates were common especially during monsoon and post monsoon months in the offshore waters. Other dominant groups reported were fish eggs and larvae, cladocera, polychaetes, chaetognaths and hydromedusae. Among the decapod larvae, prawn larvae were common in the inshore waters indicating that the region was breeding area of prawns.

Primary data collected during October in the study area **(Table 3.5.3.14)** indicates that maximum zooplankton biomass was 0.81 ml/m$^3$ and minimum 0.08 ml/m$^3$. Numerical abundance of zooplankton was maximum (10359 No./m$^3$) at station 30 and minimum (2329 No./m$^3$) at station 49. Copepods were the most abundant species found in zooplankton (508820 No./100m$^3$). Fish larvae varied from 2 to 570 No./100m$^3$ and fish eggs from 17 to 47500 No./100m$^3$.

Average zooplankton biomass along the transects parallel to the coast recorded a maximum of 6 ml/100m$^3$ along the offshore transect 3 and a minimum 1.5 ml/100m$^3$ along the near shore transect 1 **(Fig. 3.5.3.1),** along the middle transect 2, the biomass was 6.5 ml/100 m$^3$. The numerical abundance of zooplankton along the transects parallel to the coast showed a maximum of 80000 No./100 m$^3$ along the depth of 20 m (midshore) and along the coast the zooplankton abundance was 45000 No./100 m$^3$ .

The primary data collected from 45 stations during February '99 showed marked variation in the abundance of various groups of zooplankton **(Table 3.5.3.15).** Biomass of the zooplankton varied from 0.05-14.3 ml/100 m$^3$. The near shore stations showed a varied distribution ranging from 3482 ml/100 m$^3$ at station 1 and 226809 ml/100 m$^3$ at station 40. Maximum value of 296620 ml/100 m$^3$ was seen in the offshore region. In the midshore station, a maximum of 629033 ml/100 m$^3$ was noted at station 23 and a minimum of 6328 ml/100 m$^3$ at station 43. Copepod species showed a maximum of 624759 ml/100 m$^3$ near Manakkodam station **(Fig. 3.5.3.2)**

During November 2000, the biomass varied between 0.1 to 9.2 ml/100 m$^3$ at different stations along the depth zones in coastal waters **(Table 3.5.3.15)**. Distribution of benthic biomass, benthic density, zooplankton biomass and abundance of zooplankton during November 2000 is projected in **Fig. 3.5.3.3**. Low biomass was observed at many stations. Highest biomass was observed at station 36 off Kochi area. In the middle zone, the variation observed was 0.15 to 5.1 ml/100 m$^3$. The minimum variation of 0.7 to 1.1 ml/100 m$^3$ was encountered in the offshore. Minimum population density of 112/100 m$^3$ was observed at the near shore station off Alappuzha and maximum density of 64945/100 m$^3$ was encountered at station 43 in the middle transect off Azhikode. The density variations were 112 to 17727, 4312 to 19456 and 502 to 56008 No./100 m$^3$ in the near shore, mid-shore and offshore zones respectively. The average biomass in the near shore and offshore zones was 0.2 ml/100 $m^3$ and 1.44 ml/100 $m^3$ respectively. The average density was also low in the near shore zone (6937/100 $m^3$) as compared to that in the offshore (13192/100 $m^3$).

Among the nine transects studied during November transect-wise average biomass was minimum (0.5 ml/100 $m^3$) along transect 6 (off Kannamaly) and maximum (4.2 ml/100 $m^3$) was along transect 9 (off Edavanakkad). The densities ranged between 2975/100 $m^3$ to 39891/100 $m^3$ along transect 3 (off Alappuzha) and along transect 9 (off Azhikode).

The number of groups of zooplankton encountered during November along different transect ranged between 8 and 14 (avg 13). Minimum number of groups of zooplankton was found off Thottapally and Kannamaly and maximum off Mararikulam (Chethi beach, transect 4) and Edavanakkad (transect 8). Copepods constituted the bulk of the population forming 40.1 to 99.4%. Decapods were not abundant this period and contributed only 0.1 to 5.5%. Fish eggs were abundant at some stations especially along transects 3 and 4 forming up to 62.7% of the total population in transect 4 off Mararikulam. Fish larvae were not present in significant number during February as well as during November. Chaetognaths were moderately observed (3 to 23.2%). Appendicularians contributed up to 28.4% off Alappuzha. Cladocerans were abundant at transect 9 forming 28.1% at station off Azhikode.

Biomass was found low during November 2000 as compared to February 1999, and the difference between the three zones (near shore, mid shore and offshore) was not so well marked. In February (pre-monsoon), the middle and offshore zones sustained more or less similar biomass while during post-monsoon (November) the coastal and offshore zones showed comparable biomass (1.02 ml/100 $m^3$) and a slightly higher biomass (1.14 ml/100 $m^3$) in the middle zone. During November the average biomass for the whole area was 1.16 ml/100 $m^3$ and density 9760 /100 $m^3$.

During pre-monsoon (February 1999), both biomass and density average for the whole area was high namely 4.28 and 63929 /100 $m^3$ showing nearly four times higher biomass and seven times higher density compared to post-monsoon.

**Species Composition of Zooplankton**

About 87 species of zooplankton are reported from the study area. List of groups/species of zooplankton compiled from available data for the study area is given below.

**Copepods**
***Calanidae***
*Cosmocalanus darwini (Lubbock), Undinula vulgaris (Dana), Canthocalanus pauper (Giesbrecht), Neocalanus gracilis (Dana),*

***Eucalanidae***
*Eucalanus attenuatus (Dana), E. mucronatus (Giesbrecht), E. pileatus (Giesbrecht), E. subtenuis (Giesbrecht).*

*E. crassus (Giesbrecht)* *E. subcrassus (Giesbrecht),*
*Rhincalanus rostrifrons (Dana),* *R. nasutus (Giesbrecht),*

**Paracalanidae**
*Parvocalanus crassirostris (Dahl),* *P. aculeatus (Giesbrecht),*
*Acrocalanus monachus (Giesbrecht),* *A. gibber (Giesbrecht),*
*Bestiolina similis (Sewell,* *Calocalanus pavo (Dana),*

**Euchaetidae**
*Euchaeta rimana (bradford),*

**Tortanidae**
*Tortanus forcipatus (Giesbrecht),* *T. gracilis (Brady),*

**Pseudodiaptomidae**
*P. serricaudatus ( T. Scott),* *P. mertoni (Fruchtl),*
*P. aurivilli (Cleve),* *P. jonesi (Pillai),*
*P.ardjuna (Brehm),* *P.bowmani (Walter),*

**Acartiidae**
*Acartia negligens (Dana),* *A. danae (Giesbrecht),*
*A. amboinensis (Carl),* *A. spinicauda (Giesbrecht),*
*A. erythraea (Giesbrecht),* *A. southwelli (Sewell),*
*A. bilobata (Abraham),* *A. bolomoni (T. Scott),*

**Cladocera**
*Evadne tergestina,* *Penilia avirostris,*

**Ctenophora**
*Pleurobrachia globoa,* *Beroe sp.,*

**Hydromedusae**
*Podocoryne carnea,* *Eutima commersalis,*
*Phialidium brunescens,* *P. rangiroae,*
*Eucheilota menoni,* *Obelia spp.,*

**Chaetognatha**
*Sagitta bedoti,* *S. enflata,*
*S. robusta,* *Krohnitta enflata,*

**Decapods**
*Lucifer hanseni,* *L. typus,*
*Acetus indicus,* *A. erythraeus,*
*Penaeus indicus,* *P. monodon,*
*P. semisulcatus ,* *P. canaliculatus,*
*P. merguiensis,* *Metapenaeus dobsoni,*
*M. affinis,* *M. monoceros,*
*M. brevicornis,* *Parapenaeopsis stylifera,*
*P. Sculptilus,* *Penaeopsis rectacuta,*
*Parapenaeus investigatoris,* *P. longipes,*

*Metapenaeopsis mogiensis,*
*Atypopenaeus stenodactylus,*
*Macrobrachium rosenbergi,*
*Trachypenaeus curvirostis,*
*Funchalia woodwardi,*
*M. idae,*

***Appendicularians***

*Oikopleura sp,.*
*Fritillaria sp.,*

***Fish larvae***

*Sardinella longiceps,*
*Stolephorus sp.,*
*Dorosoma sp.,*
*Thrissocles,*
*C. brevis,*
*C. puncticeps,*
*Thryssa purava,*
*Mugil cephalus,*
*Ambassis sp.,*
*Cynoglossus macrostomus,*
*C. lida,*
*Solea heinii,*

**Biodiversity Based on Zooplankton Distribution**

The average richness in the study area is 2.8465 with 53.66% spatial variation while average group diversity is 1.012 with 95.7% spatial variation. The average concentration is 0.3147 with 57.55% variation over space. Species evenness distribution on the average is 0.3023 with 80.25% over the study area. Species dominance is 0.6425 on the average with 52% variation spatially. Since the diversity is much less than 3, it indicates that the study area is not very rich with respect to secondary production and dominated by some particular group/species with less evenness in distribution as indicated by low values for diversity and evenness indices and moderately high values for dominance index. Diversity remains more stable in the coastal region than in the offshore region. The stations in the offshore region present more number of species than those near the coast. On the whole the zooplankton distribution cannot be considered to be highly even in the study area. Diversity, evenness, richness, concentration, dominance indices and number of zooplankton in the study area are given in **Fig 3.5.3.4.**

**Benthos**

Polychaetes, amphipods, molluscs, gastropods, dentalium and foraminifera mainly constitute Benthic production in the study region. The bottom sediment off Kochi is mostly constituted of clay (80 to 90%). Therefore, the predominant benthic organism of the region is polychaete. In the near shore area off Alappuzha up to 10m depth, the bottom sediment is clayey (50%) and silty (40%), and from 10 to 20 m depth it is sandy (75%) with little clay. Therefore, the fauna of the region mainly comprises of molluscs with small numbers of polychaetes and crustaceans.

The benthic biomass and density showed a wide range between 0.01 - 334.85 g/m$^2$ and 21 - 5876 No. /m$^2$ respectively **(Table 3.5.3.16)**. Polychaetes dominated the bottom fauna constituted by 48 species followed by molluscs, which include bivalves, gastropods and scaphopods. The crustaceans encountered were amphipoda, tanadaceans, mysids, decapods, sergestids, cumaceas, copepods, balanus, insects' etc. Juveniles of fishes were also noticed.

Other rare groups observed are echiuroidea, ophiuroidea, planaria, sipunculids, phoronids etc. In general, the area is rich and diverse in bottom fauna.

Primary data on benthos collected during February 1999 **(Table 3.5.3.16)** indicates that the average benthic density in the coastal waters of the study area **(Fig. 3.5.3.5)** varied from 21 to 13651 /m$^2$. The highest density was observed off Kochi and lowest off Manakkodam. The high density off Kochi was due to the presence of polychaete, Terebellid sp. and *Magelonid capensis* in large numbers at station 15 in this transect. Biomass also peaked at station 15. The average biomass of the different transects varied from 13.3 g/m$^2$ (Kodungallur) to 25.4 g/m$^2$ (Transect 8, between Alappuzha and Thottappally). Regarding the composition of the fauna, polychaetes formed the major group constituting 26 species. Other forms are crustaceans, which include Amphipods, Tanidaceans, Mysids, Isopods, Cumacea, Decapods, Lobsters, Copepods and Ostracods. Molluscs include Bivalves, Gastropods and Scaphopods. Other rare groups noticed during the study are juvenile fishes, Echinoderms and Flat worms.

During November 2000, the benthic biomass of the study area showed a wide range between 0.85 g/m$^2$ at station 3 and 153.93 g/m$^2$ at station 26 **Table 3.5.3.16** and **Fig. 3.5.3.6**. The density of different stations varied from 84 /m$^2$ at station 32 to 9980 /m$^2$ at station 10. Transect-wise distribution showed the lowest average biomass of 3.58 g/m$^2$ along transect 4 off Mararikulam and peak average value of 73.48 g/m$^2$ along transect 6 off Kannamaly. Average population density of different transects varied from 325 /m$^2$ along transect 4 off Mararikulam to 2607 /m$^2$ along transect 2 off Pazhyangadi. Depthwise distribution of benthos showed high density (avg 2049 /m$^2$) along 5m depth contour, high biomass (avg 54.25 g/m$^2$) along 20 m depth contour, and low density (avg 508 /m$^2$) and biomass (avg 8.48 g/m$^2$) along 10 m depth contour. The average biomass and population density recorded for the entire area were 35.17 g/m$^2$ and 1171 /m$^2$. Polychaete dominated at most of the stations.

**Bottom fauna**

A list of groups/species of bottom fauna reported for the Kochi region as compiled from different secondary sources is given below:

<u>**MEIOBENTHOS**</u>
Foraminifera,
Turbellaria,
Nematoda,
Polychaeta,
Kinorhyncha,
Ostracod,
Copepods,
Cumacea,
Isopoda,
Amphipoda,
Crustacean nauplii,
Acarina,
Lamellibranchiata,
Gastropoda,

**POLYCHAETES**
**Family-Aphroditidae**
*Lepidonotus* sp.,
*Parahalosydna capensis,*
*Sthenelais boa,*

**Family-Glycerida**
*Glycera longipinnis,*
*Glycera benguallana,*
*Glycera alba,*
*Glycera unicornis,*

*Aphrodita alta*,
**Family-Iospilidae**
*Iospilus* sp.,
**Family-Amphinomidae**
*Amphinoma rostrata*,
**Family-Pilargidae**
*Sigambra* sp.,
**Family-Hesionidae**
*Ancistrosyllis constricta*,
**Family-Alciopidae**
*Vanadis formosa*,
**Family-Syllidae**
*Syllis spongicola*,
**Family-Orbiniidae**
*Scoloplos madagascariensis*,
**Family-Nereidae**
*Lycastis indica*,
*Dendronereis aestuarina*,
*Platynereid* sp.,
*Perinereis cavifrons*,
*Nereis* sp.,
**Family-Nephthydidae**
*Nephthys dibranchis*,
*Nephthys polybranchia*,

**Family-Eunicidae**
*Lumbrinereis impatiens*,
*Lumbrinereis latreilli*,
*Lumbrinereis aberans*,
*Lumbrinereis hartmani*,
*Lumbrinereis simplex*,
*Lumbrinereis notocirrata*,
*Lumbrinereis polydesma*,
*Lumbrinereis pseudobifilaris*,
*Arabella iricolor*,
*Ninoe* sp.,
*Drilonereis falcata*,
*Marphysa mossambia*,
*Diopatra neapolitana*,

**Family-Maldanidae**
*Maldane sarsi*,
*Maldanella capensis*,
*Euclymene insecta*,
*Euclymene watsoni*,
**Family-Sternaspidae**
*Sternaspis scutata*,
**Family-Oweniidae**

*Glycera rouxii*,
*Goniada emerita*,
*Goniada incerta*,
*Goniadaopsis Maskallensis*,
**Family-Spionidae**
*Scolelepis indica*,
*Spiophanes bombyx*,
*Prionospio cirrifera*,
*Prionospio pinnata*,
*Prionospio polybranchia*,
*Prionospio cirrobranchiata*,
*Prionospio* sp.,
**Family-Disomidae**
*Disoma obisscea*,
**Family-Magelonidae**
*Magelona capensis*,
*Magelona longicornis*,
**Family-Chaetopteridae**
*Mesochaetopterus* sp.,
**Family-Cirratulidae**
*Cirratulus cirratus*,
*Cirriformia afer*,
*Cirriformia filigera*,
**Family-Paraonidae**
*Aricidea capensis*,
**Family-Ophelidae**
*Armandia intermedia*,
**Family-Cossuridae**
*Cossura coasta*,
**Family-Capetellidae**
*Capitella capitata*,
*Pulliella armata*,
*Notomastus fauveli*,
*Notomastus aberans*,
*Notomastus latericeus*,
*Heteromasdes similes*,
*Heteromastus filiformis*,
*Heteromastus bifidus*,
*Mediomastus capensis*,
*Leiochrides africanus*,
*Scyphoproctus djiboutiensis*,
*Paraheteromastus tennuis*,
**ISOPODS**
Anthuridae,
**TANAIDACEANS**
*Apseudes chilkensis*,
*Apseudes gymnophobium*,
*Gymnophobium*,
*Tanais cavolini*.
Mysids,

*Owenia fusiformis,*
**Family-Flabelligeridae**
*Bradavillosa capensis,*
Pherusa inflata,
**Family-Sabellariidae**
*Sabellaria cementarium,*
**Family-Pectinariidae**
*Pectinaria koreni cirrata,*
**Family-Ampharetidae**
*Ampharete capensis,*
**Amphicteis gunneri**
**Family-Arenicolidae**
*Branchiomaldane vincenti,*
**Family-Maldanidae**
*Maldane sarsi,*
**Family-Terebellidae**
*Terebellides stroemi,*
*Lysilla ubianensis,*
*Pista indica,*
*Terebellobranchia natalensis,*
*Polycirruss coccineus,*
**Oligochaeta**
***Family- Archiannelidae***
*Polygordius sp.,*
**CRUSTACEANS**
Amphipods,
*Quadrivisio bengalensis,*
*Eriopisa chilkensis,*
*Grandidierella bonneri,*
*Grandidierella gilesi,*
*Corophium triaenonyx,*
**Melita zylanica**
Caprillidae,

**MISCELLANEOUS GROUPS**
Ophiuroidea,
Echiuroidea,
Anthozoa,
Planaria,
Sipunculids,
Phoronids, Flatworms,
(Unidentified) Worm,

Cumacea,
Sergestidae,
Decapods,
Lobsters,
Benthic copepods,
Ostracods,
Lepas,
Balanus,
**MOLLUSCS**
Gastropods,
*Nassarius trivittatus,*
*Calliostoma bairdii,*
*Terebellidae,*
*Solariella lacunella,*
*Solariella obscura,*
*Marginella angustate,*
*Strombus labiosus,*
*Buccinum abyssorum,*
*Phalium granulatum,*
*Epitonium* sp.,
*Prunum roscidum,*
*Cavolina* sp.,
*Litiopa* sp.,
*Colus* sp.,
*Conus* sp.,
*Murex* sp.,
*Dentalium* sp.,
Littorina littorea,
*Gastropod* sp.,
Bivalves,
*Tellina* sp.,
*Bivalve* sp.,
*Cardium* sp.,
*Modiolus striatulus,*
*Meritrix* sp.,
*Villorita cyprinoides,*
*Nucula* sp.,
*Pendore flexosa,*
*Paphia papilliens,*
**INSECTA,**
Insect larvae,
*Diamesa,*
Chironomid larvae,
Fishes,
Juvenile fish,
*Chironomid Larvae,*

## Biodiversity of Benthos in the Study Area

Based on the benthic distribution species average richness was 6.1725, which was nearly three times that of zooplankton and with 52.8% spatial variation. Average species diversity index was 1.5205 with 51.3% variability over space. The stations 16-20, 23-26, 31-34 and 41-46 have diversity index approximating 2.02. Species concentration factor was showing a spatial variation of 54.29% with an average of 0.5119. Evenness in distribution was 0.7848 and dominance factor was 0.7437 with 51.33% variability over the study area. Regarding the benthic distribution, the species richness showed a decreasing gradient towards the coast even though the overall gradient was not so steep. This observation was opposite to that of zooplankton distribution.

Taking into consideration the abundance and number of species, that is, giving importance to the relative abundance of each species and benthic diversity of the stations along the 10° 05' S to 10° 10' S, it can be observed that the diversity increases towards offshore while in the stations between 9°00 S and 10° 00' S it increases towards the coast. Generally, at the stations in the middle part of the transects, a lower diversity was observed. The uniformity in the benthic distribution was greater than that of the zooplankton distribution. The trend in variation in the evenness distribution was similar to that observed in the case of diversity. The study area is richer, more diverse and exhibits more uniformity in the distribution of the benthos than in the zooplankton distribution.

The biodiversity of Benthos during October 1997, February 1999 and November 2000 is given in **Tables 3.5.3.17 to 3.5.3.19.** Diversity, evenness, richness, concentration, dominance indices and number of species of benthos in the study area in October are given in **Fig. 3.5.3.7.**

### *Species Diversity of Fishes*

Species composition of finfishes and shellfishes reported from Kerala coast as also applicable to GKR is given in **Table 3.5.3.20.**

### Marine Mammals

The marine mammals of India comprise of whales, dolphins and dugongs. They are represented by 21 species. Information regarding the cetaceans is restricted mainly to the stranding and occasional observations on their behaviour.

Indian Ocean is declared as a sanctuary for the whales. Dugongs have been declared as endangered species. The dugongs are mainly reported for the East Coast especially in the Gulf of Mannar and Palk Bay. Though there is no fishery for dolphins and whales along the Indian coasts, the smaller cetaceans like dolphins are at times caught in the gill nets. No definite statistics are available on this. The whales are generally found in the deep sea, they occasionally stray into the coastal waters and get stranded near shore. All the records of occurrence of whales are based on their stranding. One species of whales reported from the Kerala coast is ***Megaptera novaeangliae* Borowski (Humpback whale).** The commonly occurring dolphins along the Indian coast as well as Kerala coast are:

- *Stenella longirostris* Gray (Spinner dolphin)
- *Tursiops truncatus aduncus* Ehrenberg (Bottle-nose dolphin)
- *Delphinus delphis* Linnaeus (Saddle-back dolphin)
- *Sousa chinensis* Osbeck (Hump-back dolphin)

### Endangered Species of Riverine, Estuarine and Marine Fishes

Due to the rapid advancement in civilization, man brought about many changes in the estuarine systems, which adversely affect the shellfish life. The important human activities causing environmental damages are (1) large-scale reclamation, bulk heading, destruction of mangroves (2) construction of salt water barriers, spill ways, tide control structures, barrages, upstream dams, etc. and (3) water pollution. These alter the physicochemical properties such as tidal effects, water circulation, currents, salinity, turbidity, fertility, bottom conditions, etc. and degrade the ecosystems restricting the distributions, etc. and the survival of the various species.

The Thaneermukkom barrage constructed in the Vembanad Lake in Kerala is an ideal example of man made barrier, which have reduced the tide fed areas occupied by prawns. The distributional range of penaeid prawn juveniles in the lake has become considerably reduced because of this barrage. Salinity exclusion barriers, irrigation projects, hydroelectric projects, etc hamper the breeding migration of species of Macrobrachium.

*Macrobrachium rosenbergii* , a shell fish found in the backwaters is listed in the endangered category. Similarly *M. dobsoni* a prawn and crab, *Scylla serata* are vulnerable species of the backwaters **(Table 3.5.3.21)**. A checklist of endangered and vulnerable marine fauna is given in **Table 3.5.3.22.**

### Marine fishes that migrate into the backwater system

Based on the salinity tolerance, marine fishes inhabiting the lake are classified into Euryhaline and Stenohaline marine fishes. Euryhaline marine fishes extend into estuaries, and some of them may reach even a salinity of 5%. The euryhaline marine fishes were very common in the lake during the post and pre-monsoon seasons. During the pre-monsoon season, the physico-chemical parameters of the mouth and lower reaches of Cochin and Azheekode regions are very similar to that of the adjacent sea. A checklist of 39 eurhaline and 48 stenohaline marine fish species found in the Vembanad Lake is provided in **Table 3.5.3.23.**

Table 3.5.1.1

## Division wise Distribution of Tribal Population According to the Types of Main Employment

| Division | Male | Female | Total | Forest Activities | | | | | | | | Wage Labourers | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
| Parambikulam | 415 | 433 | 848 | 290 | 0 | 0 | 3 | 76 | 109 | 142 | 16 | 0 | 79 | 63 | 16 | 0 | 54 |
| Nenmara | 432 | 400 | 832 | 832 | 72 | 0 | 0 | 43 | 45 | 187 | 4 | 3 | 140 | 12 | 1 | 29 | 27 |
| Chalakkudy | 750 | 766 | 1516 | 1516 | 223 | 1 | 10 | 233 | 400 | 234 | 25 | 41 | 137 | 24 | 9 | 1 | 97 |
| Vazhachal | 507 | 506 | 1013 | 1013 | 199 | 0 | 1 | 27 | 83 | 158 | 34 | 14 | 204 | 2 | 5 | 3 | 87 |
| Malayatoor | 942 | 857 | 1799 | 1799 | 26 | 0 | 4 | 365 | 33 | 705 | 75 | 5 | 0 | 0 | 3 | 0 | 60 |
| Kothamangalam | 3349 | 3309 | 6658 | 6658 | 1 | 0 | 4 | 1564 | 1710 | 270 | 367 | 418 | 3 | 4 | 160 | 3 | 50 |
| Munnar | 4645 | 4520 | 9165 | 9165 | 103 | 7 | 10 | 1923 | 1359 | 2122 | 380 | 1555 | 76 | 4 | 36 | 5 | 215 |
| Kottayam | 4265 | 4249 | 8514 | 8514 | 10 | 5 | 14 | 1650 | 1942 | 472 | 486 | 1224 | 487 | 11 | 225 | 1 | 598 |
| Idukki | 1421 | 1440 | 2861 | 2861 | 2 | 1 | 0 | 453 | 429 | 143 | 298 | 114 | 24 | 0 | 9 | 0 | 726 |
| Ranni | 2148 | 2169 | 4317 | 4317 | 33 | 2 | 18 | 1097 | 842 | 627 | 176 | 860 | 105 | 40 | 56 | 10 | 124 |
| Konni | 137 | 113 | 250 | 250 | 93 | 0 | 0 | 30 | 4 | 30 | 37 | 0 | 8 | 0 | 0 | 2 | 8 |
| Achencoil | 114 | 113 | 227 | 227 | 1 | 0 | 0 | 59 | 46 | 35 | 0 | 19 | 14 | 35 | 0 | 1 | 3 |
| **Total** | **19125** | **18875** | **38000** | **7152** | **763** | **16** | **64** | **7520** | **7002** | **5125** | **1898** | **4253** | **1277** | **306** | **520** | **55** | **2049** |

**Forest activities**
A – Farming; B – Collection of NWFPs; C – Hunting and fishing; D – Cottage industries; E – Household work; F – Student; G – Unemployed; H – Others
**Wage Labourers**
I – Agricultural labourer; J – Forest plantation labourer; K – Tree cutting, loading work; L – Government work; M –Collection of NWFPs (Labourer); N – Others
**Source :** Tribal survey conducted by Kerala Forest Department (1992)

## Table 3.5.2.1

## Floristic Diversity in the Region

| Sr. No. | Area | Angio-sperms | Exclusive Species | | Endemic | | Rare/ Threatened/ Vulnerable/ Endangered | |
|---|---|---|---|---|---|---|---|---|
| | | | No. | % | No. | % | No. | % |
| 1 | Kerala | 3800 | -- | -- | 1272 | 33.5 | 460 | 12.1 |
| 2 | GKR | 3049 | -- | -- | 1015 | 33.3 | 203 | 7.3 |
| 3 | Periyar Tiger Reserve (PTR) | 1965 | 777 | 39.5 | 515 | 26.2 | 150 | 7.6 |
| 4 | Pathanamthitta | 1250 | 202 | 16.2 | 253 | 20.2 | 175 | 14 |
| 5 | Thrissur | 1200 | 162 | 13.5 | 258 | 21.5 | 51 | 4.3 |
| 6 | Eravikulam | 274 | 138 | 50.4 | 62 | 22.6 | 29 | 10.6 |
| 7 | Kottayam | 885 | 211 | 23.8 | -- | -- | -- | -- |

**Source :** Secondary data collected by KFRI

## Table 3.5.2.2

## Districtwise Distribution of Sacredgroves

| Sr. No. | District | No. of Groves | Total Area Protected (ha) |
|---|---|---|---|
| 1 | Alappuzha | 65 | 25 |
| 2 | Ernakulam | 12 | 22 |
| 3 | Idukki | 5 | 2 |
| 4 | Kottayam | 45 | 10 |
| 5 | Pathanamthitta | 32 | 5 |
| 6 | Thrissur | 19 | 6 |
| | **Total** | **198** | **70** |

## Table 3.5.2.3

## Biodiversity of the Sacredgroves

| Sr.No. | Particulars | No. of Species |
|---|---|---|
| 1. | Total no. of plant species | 400 |
| 2. | Rare and endangered plants | 24 |
| 3. | Medicinally important plants | 80 |
| 4. | Total no. of animals | 45 |

## Table 3.5.2.4

### Faunistic Richness/ Diversity

| Regions | Insects | Fishes | Amphib-ians | Reptiles | Birds | Mammals |
|---|---|---|---|---|---|---|
| Kottayam | 114 | 43 | 27 | 64 | 266 | 53 |
| Thrissur | 12 | 83 | 15 | 32 | 145 | 37 |
| Pathanamthitta | 311 | 101 | 17 | 48 | 279 | 43 |
| Alappuzha | 26 | 32 | 22 | 44 | 148 | 44 |
| Ernakulam | 7 | 53 | 15 | 30 | 146 | 13 |
| Idukky | 133 | 40 | 16 | 37 | 291 | 33 |
| **GKR** | **497** | **126** | **47** | **89** | **410** | **61** |
| % of the State | 8.28 | 64.29 | 54.65 | 62.68 | 86.32 | 81.33 |
| State | 6000 | 196 | 86 | 142 | 475 | 75 |
| World | 751000 | 19056 | 4184 | 6300 | 9040 | 4000 |

## Table 3.5.2.5

### Exclusive Species found in the Region

| District | Insects | Fishes | Amphibians | Reptiles | Birds | Mammals |
|---|---|---|---|---|---|---|
| Idukky | 71 | 7 | 6 | 10 | 39 | 2 |
| Kottayam | 6 | 1 | - | - | - | - |
| Thrissur | 247 | 18 | 1 | 4 | 50 | - |
| Pathanamthitta | 12 | 4 | 3 | 2 | 1 | 1 |
| Alappuzha | 4 | 1 | - | 1 | 1 | - |
| Ernakulam | 81 | 4 | 7 | 4 | 39 | - |

**Source :** Data Collected by KFRI

## Table 3.5.2.6

### Percent Relative Density of Larger Mammals in the Region

| Forest Divisions | Lion tailed mac-aque | Bonnet Macaque | Nilgiri Langur | Com-mon langur | Elephant | Gaur | Sambar | Spotted deer | Barking deer | Mouse deer | Wild boar | Sloth Bear | Wild dog | Porcu-pine | Small Indian civet | Toddy cat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nenmara | 11.1 | 3.7 | 0.5 | -- | 1.4 | 0.6 | 1.14 | 0.62 | 1.57 | 1.25 | 2.31 | 10.95 | 2.92 | 0.49 | 1.19 | -- |
| Parambikulam | 11.1 | 3.1 | 4.4 | -- | 1.7 | 36.7 | 9.15 | 7.79 | 2.79 | 2.22 | 3.32 | 18.99 | 2.77 | 2.79 | 9.89 | -- |
| Thrissur | -- | 3.1 | -- | -- | -- | 0.82 | 15.63 | 20.53 | 4.87 | 6.38 | 3.69 | 26.84 | 6.38 | 27.37 | 48.41 | -- |
| Chalakkudy | 3.7 | 7.1 | 0.8 | -- | 0.5 | 0.36 | 3.5 | -- | 2.75 | 0.96 | 4.78 | -- | 15.85 | 6.65 | -- | -- |
| Vazhachal | 22.2 | 15.7 | 10.7 | -- | 7.8 | 10.4 | 1.89 | 4.06 | 43.31 | 6.70 | 2.44 | -- | 16.18 | 2.24 | 3.23 | 10.43 |
| Malayatt-oor | 7.4 | 8.6 | 0.5 | -- | 7.2 | 0.13 | 13.11 | -- | 5.57 | 10.51 | 8.27 | 1.27 | 8.32 | 4.57 | 10.33 | 13.03 |
| Kotha-managalam | -- | 4.8 | -- | -- | 2.3 | -- | 6.18 | -- | 3.61 | 10.76 | 5.96 | 6.78 | -- | 1.75 | 1.74 | 3.51 |
| Mankulam | -- | 1.2 | -- | -- | -- | 32.64 | 5.37 | -- | 5.57 | 4.59 | 5.24 | 9.51 | 6.33 | 2.63 | 2.58 | 16.68 |
| Munnar | 3.7 | 14.4 | 6.9 | -- | 8.6 | 3.15 | 0.81 | 0.94 | 5.65 | 7.66 | -- | -- | -- | 2.15 | -- | 2.84 |
| Idukki (WL) | -- | 9.03 | 4.2 | 100 | 5.3 | 8.02 | 8.4 | 62.26 | 4.96 | 15.32 | 8.16 | 2.02 | 13.93 | 22.98 | 14.95 | 5.84 |
| Kottayam | 3.7 | 4.5 | -- | -- | 1.4 | 0.06 | 9.02 | 0.94 | 5.14 | 7.96 | 3.39 | 1.18 | 1.57 | 3.98 | 1.79 | 5.72 |
| Periyar Tiger Reserve | 22.2 | 2.8 | 64.2 | -- | 33.9 | 6.6 | 8.83 | -- | 2.77 | 6.13 | 3.75 | 17.42 | 9.61 | 10.75 | 5.22 | 18.19 |
| Ranni | 14.8 | 15.7 | 7.9 | -- | 23.9 | 0.25 | 11.65 | -- | 8.05 | 16.99 | 45.16 | 3.87 | 9.56 | 10.44 | 0.65 | 19.39 |
| Konni | -- | 6.1 | -- | -- | 6.1 | 0.19 | 5.31 | 2.86 | 3.39 | 2.55 | 3.53 | 1.17 | 6.55 | 1.26 | -- | 4.37 |

Relative density = Ratio of individual mammal in a forest division to the total individual category mammals in all the forest divisions.
**Source** : Secondary data collected by KFRI,1993

Table 3.5.3.1

**Seasonal Variations in Chlorophyll and Primary Productivity Recorded at Different Sampling Stations**

| Sr. No. | Station | Monsoon | | | Post Monsoon | | | Pre Monsoon | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Chlorophyll ($mg/m^3$) | | Primary Productivity ($gc/m^2/day$) | Chlorophyll ($mg/m^3$) | | Primary Productivity ($gc/m^2/day$) | Chlorophyll ($mg/m^3$) | | Primary Productivity ($gc/m^2/day$) |
| | | **S** | **B** | | **S** | **B** | | **S** | **B** | |
| 1 | Thannermukham bund south | 3.6 | 3.3 | 0.15 | 37.4 | 57.6 | 0.79 | 11.3 | 2.3 | 0.7 |
| 2 | Thannermukham bund After | 1.9 | 3.4 | 0.12 | 74.3 | 76.7 | 1.03 | 21 | 16.5 | 0.9 |
| 3 | Ithipuzha | 2.8 | 6.8 | 0.21 | 58.6 | 57.8 | 1.03 | 20.8 | 8 | 0.9 |
| 4 | Murinjapuzha | 3.2 | 2.1 | 0.15 | 43.4 | 41.4 | 1.67 | 29.7 | 34.9 | 1.4 |
| 5 | Perumbalam | 4.4 | 3.9 | 0.18 | 40.0 | 63.9 | 0.95 | 11.6 | 11.6 | 0.7 |
| 6 | Thevara | 3.4 | 3.6 | 0.15 | 12.5 | 24.2 | 0.87 | 71.1 | 24.8 | 0.7 |
| 7 | Off. Marine Science jetty | 3.8 | 4.8 | 0.18 | 8.5 | 28.7 | 0.64 | 6.8 | 54.4 | 0.4 |
| 8 | Fisheries harbour | 4.5 | 3.3 | 0.17 | 4.4 | 13.7 | 1.31 | 13.2 | 35.6 | 1.2 |
| 9 | Barmouth | 3.0 | 5.8 | 0.19 | 7.7 | 38.6 | 1.26 | 14.8 | 6.7 | 0.9 |
| 10 | Bolghatty | 3.5 | 6.1 | 0.21 | 9.9 | 10.8 | 2.85 | 4.7 | 1.9 | 0.9 |
| 11 | Vaduthala | 5.1 | 5.6 | 0.24 | 1.1 | 1.0 | 2.54 | 4.8 | 37.5 | 0.5 |
| 12 | Varapuzha-Cheranellor jetty | 1.5 | 1.3 | 0.06 | 16.8 | 63.3 | 0.72 | 3.4 | 54.8 | 0.4 |
| 13 | Eloor, below FACT | 1.9 | 4.4 | 0.14 | 30.3 | 45.0 | 0.95 | 7 | 52.4 | 0.9 |
| 14 | Above Pathalam bund | 4.6 | 1.6 | 0.14 | Not sampled | | Not sampled | Not sampled | | Not sampled |

S - Surface, B – Bottom

**Source :** Primary data collected by CUSAT



3.5.28

## Table 3.5.3.2

## List of Benthos in the Cochin Backwaters

| Sr. No. | Name of Species | Remarks |
|---|---|---|
| **A** | **PHYLUM PROTOZOA** | |
| 1 | **Foranirifera** | |
| | *Reophax scotti, R cattella Ammobaculites taylorensis, A. foliaceous, Textuaria agglutinans, T. foliacea, T. conica, Quinqueloculina agglutinans, Q. bicornis, Q. costata, Spiroloculina canaliculata, S. excavata, Triloculina insignis, T. tricarniata T. oblonga, Dentalina communis, Bolivina striatula, B. nobilis, L. laevis, Nonion boueanum, N. sloani, N. scaphum* | |
| | *Elphidiun craticulatun* | The genera Rotalia, Elphidium and Quinqueloculina account for about 85% of the total calcareous species |
| | *E. macellum* | Highly tolerant euryhaline forms, most often encountered as true estuarine species |
| | *E. advenun, E. crispum, Operculinella cumingii, Operculina granulose, O. complanata, Spirillina limbata var denticulina, S. vivipara, Discorbis opercularis, D. orbicularis, D. globularis, Rotalia beccarii, R. calcar, Globigerina bulloides, Trochammina inflata, T. nitida, Quinqueloculina seminulum, Discorbis rosacea* | |
| | *Ammonia beccarii* | Predominant species in the lower reaches and forms more than 50% of the total population in that area |
| | *A. calcar, Miliammina fusca, Saccammina sphaerica* | |
| | *Cibicides lobatulus* | Stenohaline marine forms, occurrence restricted to bar mouth |
| | *Amphistegina lessonii, Planorbulina mediterransis* | |
| 2 | **Ciliates** | |
| | *Zoothamnium rigidum, Lagenophrys cochinensis, Thiomozoon fencheli, Boveria teredinidi, Trichodina balakrishnia, Nucleocorbula adherens, Nyctotherus marina* | Colonial ciliate, Solitary ciliate Endocommensalic ciliate |

Contd...

Table 3.5.3.2 Contd...

| Sr. No. | Name of Species | Remarks |
|---|---|---|
| B | **PHYLUM COELLENTERATA** | |
| | *Cavernularia sp.* | Pre monsoon Cochin offshore |
| | *Virgularia, Sagartia sp.* | |
| | *Diphyes chamissonis* | Pre monsoon |
| | *Ciriarthus sp.* | Cochin barmouth area |
| C | **PHYLUM ANNELIDA** | |
| 1 | **Polycheata** | |
| | *Amphicteis gunneri* | Cochin Offshore, Mangrove area |
| | *Euclymene insecta, E. watsoni, Cossura caasta, Diopatra neapolitana* | Pre monsoon |
| | *Prionospio pinatta, Disoma orissae, Glycera longipinnis, G. rouxii* | Pre & post monsoon |
| | *Paraheteromastus tenuis, G. convoluta, Mesochaetopterus sp. Sabellaria cementarium, Sternapsis scutata* | Highly tolerant euryhaline forms found through out the estuary |
| | *Lumbriconereis latreilli* | Cochin Barmouth area throughout the year |
| | *Heteromastus similis, Pista indica, Hesione pantherina* | Pre monsoon |
| | *Dendronereis aestuarina* | Harbour area, Post monsoon |
| | *Perinerieis cavifrons, Marphysa gravelyi* | Pre monsoon |
| | *Lumbriconereis simplex* | Pre monsoon & monsoon |
| | *Glycera alba* | Monsoon |
| | *Ficopomatus macrodon* | Post monsoon |
| | *Capitella capitata, Prionospio polybranchiata, Nepthys oligobranchia, Ancistrosyllis constricta, Prionospio cirrifera, Phyllodoce gracilis, Lycastis indica, Eulalia viridis, Fabrica sp* | Indicator of pollution, found in large numbers in the industrial area of Udyogamandal |
| | *Lepidonotus tenisetosus* | Cochin Barmouth area |
| | *Marcierella enigmatica, Sthenelais boa, Syllis cornuata, Marphysa sanguinea, Loimia medusa, Lumbriconereis heteropoda* | |
| | *Talehsapia annandalei, Branchiocapitella singularis, Ceratonereis costae, Dendronereis heteropoda, D. arborifera, Eunica tubifex, Goniada emerita, Lumbriconereis pseudofiliaris, Marphysa stragulum, Nereis kauderni, N. chilkensis, N. glandicincta, Pulliella armata* | Mangrove area |

Contd...

Table 3.5.3.2 Contd...

| Sr. No. | Name of Species | Remarks |
|---|---|---|
| 2 | **Crustacea** | |
| | *Lucifer sp., Ampelisca cyclops* | |
| | *Carybdis sp.* | Post monsoon |
| | *Iphinoe sp.* | Monsoon |
| | *Ampelisca zamboangae* | |
| | *Squilla nepa, Eucuma sp.* | Post monsoon |
| | *Parapenaeopsis stylifera, Metapenaeus dobsoni, Alpelisca zamboangae* | Pre monsoon |
| | *Centrophages orisinni, C. tenuremis* | Post monsoon |
| | *Chironomous larvae, Balanus sp.* | Usually found in highly polluted areas of the estuary like Eloor industrial belt |
| | *Alpheus malabaricus, A. paludicola* | Monsoon & Post monsoon |
| | *Anthuridea sp.* | Pre monsoon |
| | *Apseudes chilkensis* | Monsoon & Post monsoon |
| | *A. gymnophobia* | Post monsoon |
| | *Cirolana fluviatilis, Corophium triaenonyx, Gammarus sp., Grandiderella gilesi* | Monsoon & post monsoon |
| | *Litocheira, Metapenaeus affinis* | Post monsoon |
| | *M. dobsoni, M. monoceros, Penaeus indicus* | Pre monsoon |
| | *Rynchoplax sp.* | |
| | *Scylla serrata, Synidotea variegata* | Through out the year |
| | *Eriphia smitha* | Cochin barmouth area, Monsoon & post monsoon |
| | *Dotilla sp.* | |
| | *Uca annulipes, Uca marioni snitidus, Sphaeroma, Palaemon sp., Viaderiana sp.* | Mangroove forests |
| 3 | **Mollusca** | |
| | *Nerita albicilla* | Found during late pre monsoon in the Cochin harbour region |
| | *Littorina undulata* | |
| | *Cerithidea fluvialitis* | Extensive beds may be found near the shore at Aroor region |
| | *Perna viridis* | Abundant during post and pre monsoon |

Contd...

**Table 3.5.3.2 Contd...**

| Sr. No. | Name of Species | Remarks |
|---|---|---|
| | *Meretrix casta* | Economically important species found during pre monsoon and monsoon close to bar mouth |
| | *M. ovum* | |
| 4. | **Fishes** | |
| | *Gobius cristatus, G. microlepis* | Pre monsoon |
| | *Villorita cyprinoides* | Purely brackish water, cannot with stand high salinity. Found in region where salinity does not exceed 15 ppt |
| | *V. Cyprinoids var. cochinensis* | Can tolerate upto 34 ppt of salinity. Found in the harbour area, avoids silt |
| | *Theora opalina* | Marine species obtained from the bar mouth during pre monsoon |
| | *Solen aquae – dulcioris* | Common backwater species found during dry months |
| | *Martesia striata* | Prolific wood borer found extensively on timber structures in the harbour area |
| | *Modiolus undulatus* | |
| | *Modiolus striatulus* | Occurs in the harbour region during post and pre-monsoon |
| | *Arca indica* | Found in the harbour region |
| | *Paphia mormorata* | Found during post and premonsoon close to the bar mouth region |
| | *Dosinia cretacea* | Found mostly in the bar mouth area during post and pre monsoon |
| | *Cressostrea madrasensis, Teredo furcifera* | |
| | *Nuculana mauritiana* | Rarely found in the bar mouth area |
| | *Sunneta scripta* | Post monsoon |
| | *Standella pellucida* | Found in areas with a silty bottom during post and monsoon when the salinity is high |
| | *Tellina pirguis* | Found in the harbour entrance |
| | *Musculista senhausia* | |
| | *Trypauchean vagina* | Monsoon and post monsoon |

**Contd...**

**Table 3.5.3.2 Contd...**

| Sr. No. | Name of Species | Remarks |
|---|---|---|
| | *Anguilla bicolor bicolor, Amblypharyngodon mola, Puntius filmen tosus, Puntius sarana, P. amphibius, Labeo dussumieri, Mystus malabaricus, M. oculatus, Horabagrus brachysoma, Wallago attu, Ompok bimaculatus, Heteropneustes fossilis, Xenentodon cancilla, Ambssis thomassi, A. dayi, Nandus marmortalus, Stenogobius malabaricus, Channa striata, Anabas testudineus, Mastacembelus guentheri, M. armatus, Tetrodon leopardus, Dayella malabarica* | These are the permanent inhabitants of the lake under oligohaline conditions seen in Thanneermukkom and Alleppy regions |
| | *Tachysurus maculatus, Ambassis gymnocephalus, Gerres filamentosus, G. setifer, Daysciaena albida, Scatophagus argus, Etroplus auratensis, Liza parsia, Glossogobius giuris, Brachiurus orientalis* | Throughout the estuary. No defined salinity preferences i.e., can exist in a wide range of salinities |
| | *Austrobatrachus dussumieri,* *Strongylura strongylura, Platycephalus crocodiles, Therapon jarbua, Sillago vincenti, S. sihama, Caranx sexfas ciatus, Lutianus argentima culatus, Dendrophysa russelli, Mugil cephalus, Valamugil cunnesius, Liza macrolepis, Cyanoglossus puncticeps, Chelonodon patoca, Leiognathus brevirostris, L. equulus* | Limited to the high salinity areas. During monsoon, their occurrence is limited to the mouth and lower reaches |
| | *Megalops cyprinoides, Mystus gulio, Tachysurus subrostatus, Hyporamphus xanthopterus, H. limbatus, Sarotherodon mossambicus, Etroplus maculatus, Oxyurichthys tentacularis, O. microlepis, O. nijssani, Glossogobius biocellatus, Ehirava Fluviatiles* | Inhabits the gradient zone. Found at Narakkal, Perumbalam area; can tolerate a salinity range of 2-25 ppt |

**Contd...**

**Table 3.5.3.2 Contd...**

| Sr. No. | Name of Species | Remarks |
|---|---|---|
| | *Dasyatis sephen, Elops machnata, Muraenesox bagio, Pisodonophis boro, Esculosa thoracata, Nematulosa nasus, Anodontostoma chacunda, Ilisha sinisai, I. melastoma, Stolephorus commersonii, S. waitei, S insularis, Thryssa mystax, T. purana, T. kammalensis, Chanos chanos, Zenarchopterus dispar, Strongylura leiura leiura, Gambusia affinis patruelis, Atherina duodecimalis, Platycephalus indicus, Lates calcarifer, Ambassis commersoni, Epinephelus tauvina, Carangoides praeustus, Lutianus johni, Pomadasya hasta, Drepane punctata,Liza subveridis, Sphyraena jello, Eleutheronema tetradactylun.* *Awaous stamineus, Acentrogobius viridipunctatus, A. cerinus, Siganus javus, S. canaliculatus, Psuedorhombus arsius, Tricanthus brevirostris, Leognathus splendens, Secutor ruconius* | Euryhaline marine species entering the estuary from September onwards along with the increasing salinity. Found in all areas from Thannirukkom to Alleppey and Eloor |
| | *Dasyatis uarnak, Thrysoidea macrurus, Dussumieria acuta, Sardinella longiceps, S. gibbosa, Stolephorous indicus, Thryssa setirostris, Saurida undosquamis, Rhynchor hampus georgii,, Megalaspis cordyla, Alectis indicus, Alepes djeddaba, Scomberoides tala, S. tol, Trachinotus blochil, Lutjanus fulviflamma, L. russelli, L. rivulatus, Gerres abbreviatus,* | These appear in the estuary either due to regular or accidental migration. Their occurrence in sporadic and do not constitute any local fishery. Not found in areas where salinity falls below 25 ppt. With the onset of monsoon they also disappear |
| | *Plectorhynchus nigrus, Lethrinus microdon, Mylio berda, Protonibea diacanthus, Johnius belangerri, Upeneus sulphureus, U. vittatus, Parupeneus indicus, Valamugil seheli, V. speigleri, Eleotris fusca, Butis butis, Bunaka gyrinoideas, Gobiopsis macrostomus, Teenioides buchanani, T. cirratus, Trypauchen vagina, Acanthurus matoides, Sigamus lineatus, Synbranchus bengalensis, Solea ovata, Synaptura commersoniana, Cyanoglossus bilineatus, Tetrodon fluviatilis, Leiogna thus bindus, L. daura, L. berbis, Secutor ruconius, Gazza minuta.* | |

**Source** : Secondary data collected by CUSAT, 1958-1994

## Table 3.5.3.3

### Status of Residents and Migrants in Production

| Group | Species | Number | Production/ Annum (MT) | Area of Dominant Catch |
|---|---|---|---|---|
| Marine migrants | Fishes<br>Prawns<br>Crabs | 60<br>6<br>2 | 3899 | Aroor, Kumbalam, Vaikom |
| Resident Estuarine Species | Fishes | 17 | 1389 | Harbour, Aroor, Kumbalam, Vaikom |
| Resident Common Species | Fishes<br>Crab<br>Palaemonid Prawn | 15<br>1<br>1 | 117 | Vaikom, Thannirmukkom Muhamma, Alapuzha |
| Oligohaline Species | Fishes | 16 | 165.5 | Thannirmukkom, Muhamma, Kumarakom, Alapuzha |
| Limnetic Migrants | Fishes<br>Palaemonid Prawns | 7<br>3 | 122.7 | Thannirmukkom, Muhamma, Kumarakom, Alapuzha |

**Source :** Data collected by CUSAT

## Table 3.5.3.4

### Maximum Yielding Zones and Peak Fishery Seasons: Vembanad Lake

| Group | Major species | Maximum Yielding Zone (Period) | Minimum Yielding Zone | Peak Fishery Season |
|---|---|---|---|---|
| Fishes | | Murinjapuzha Alapuzha (July-Dec) | | Monsoon |
| *Penaeids* | *M. dobsoni* (74.2%) *M.monoceros* (10.3%) *P. indicus* (14.9%) | Harbour and Aroor (Jan-June) | Muhamma Alappuzha | Premonsoon |
| Palaem-onids | M. rosenbergii, M.idella | Murinjapuzha Thannirmukkom (July-Oct) | Alappuzha | Monsoon |
| Crabs | *S. serrata* | Harbour Kumbalam (Feb-June, major) (Oct-Dec, minor) | Thannirmukkom, Alappuzha | Pre-monsoon, Post-monsoon (Moderate) |

**Source :** Data Collected by CUSAT

Table 3.5.3.5

**Chlorophyll-a, POC and Suspended Load in Coastal Waters: Primary Data (1997- 2000)**

| Parameter | | Chlorophyll-a ($mg/m^3$) | | | | POC (mg/L) | | | | Suspended Load (mg/L) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min | Max | Avg | SD | Min | Max | Avg | SD | Min | Max | Avg | SD |
| **During October 1997** | | | | | | | | | | | | | |
| I | S | 1.06 | 4.92 | 2.67 | 1.02 | 0.13 | 4.03 | 0.93 | 1.05 | 0.4 | 53.2 | 7.24 | 10.91 |
| (1-24) | B | 1.29 | 8.79 | 3.53 | 1.74 | 0.13 | 2.27 | 0.57 | 0.58 | 3.2 | 140 | 30.98 | 32.71 |
| II | S | 0.67 | 13.36 | 4.17 | 2.37 | 0.13 | 3.28 | 0.64 | 0.80 | 0.6 | 30.4 | 7.85 | 6.00 |
| (25-56) | B | 0.21 | 12.69 | 3.74 | 2.55 | 0.13 | 5.04 | 0.92 | 1.24 | 3.4 | 122 | 23.11 | 26.79 |
| **During February 1999** | | | | | | | | | | | | | |
| I & II | S | 0.21 | 6.57 | 2.35 | 1.96 | 0.13 | 1.64 | 0.45 | 0.46 | 1.8 | 32.8 | 10.72 | 12.50 |
| (1-10) | B | 0.38 | 7.66 | 2.79 | 2.20 | 0.00 | 2.14 | 0.56 | 0.68 | 0.8 | 65.6 | 13.38 | 20.13 |
| III & IV | S | 0.99 | 5.95 | 2.23 | 1.73 | 0.13 | 1.89 | 0.67 | 0.58 | 0.2 | 43.2 | 7.53 | 13.56 |
| (11-20) | B | 1.43 | 7.44 | 3.63 | 2.32 | 0.00 | 2.52 | 0.55 | 0.81 | 0.8 | 79 | 23.42 | 26.21 |
| V & VI | S | 0.44 | 8.60 | 3.42 | 2.56 | 0.13 | 1.39 | 0.52 | 0.42 | 0.6 | 36.6 | 6.84 | 10.87 |
| (21-30) | B | 1.26 | 14.40 | 5.65 | 4.46 | 0.13 | 1.39 | 0.68 | 0.42 | 3.4 | 33 | 18.82 | 11.77 |
| VII | S | 1.23 | 4.60 | 3.01 | 1.62 | 0.13 | 1.64 | 0.58 | 0.67 | 0.4 | 14.4 | 5.36 | 5.42 |
| (35-35) | B | 1.26 | 7.17 | 3.88 | 2.45 | 0.13 | 1.51 | 0.56 | 0.57 | 1.6 | 53.6 | 24.96 | 25.01 |
| VIII & IX | S | 1.67 | 5.20 | 2.61 | 1.15 | 0.25 | 2.02 | 0.81 | 0.56 | 1.5 | 104.2 | 34.97 | 33.26 |
| (36-45) | B | 1.02 | 7.79 | 3.59 | 2.35 | 0.13 | 1.76 | 0.86 | 0.51 | 7.1 | 156.2 | 66.95 | 50.20 |
| **During November 2000** | | | | | | | | | | | | | |
| I & II | S | 1.23 | 7.75 | 2.36 | 1.86 | 0.6 | 2.95 | 1.78 | 0.62 | 5.00 | 25.00 | 11.90 | 6.81 |
| (1-10) | B | 1.28 | 6.39 | 3.16 | 1.76 | 1.05 | 2.99 | 1.68 | 1.47 | 7.00 | 53.00 | 17.70 | 13.05 |
| III & IV | S | 0.40 | 7.84 | 3.37 | 1.95 | 1.10 | 2.30 | 1.68 | 0.41 | 5.00 | 33.00 | 16.40 | 9.43 |
| (11-20) | B | 0.76 | 3.83 | 2.14 | 0.92 | 0.60 | 2.56 | 1.58 | 0.74 | 5.00 | 41.00 | 17.90 | 10.92 |
| V & VI | S | 0.20 | 7.86 | 3.37 | 2.47 | 0.65 | 2.73 | 1.75 | 0.68 | 0.40 | 29.00 | 13.00 | 6.91 |
| (21-30) | B | 0.99 | 12.50 | 4.90 | 4.57 | 1.04 | 2.99 | 1.96 | 0.57 | 13.00 | 41.00 | 26.80 | 7.92 |
| VII | S | 1.69 | 6.13 | 3.45 | 1.47 | 0.78 | 1.17 | 0.96 | 0.13 | 17.00 | 19.00 | 18.20 | 0.74 |
| (31-35) | B | 1.22 | 4.95 | 3.25 | 1.67 | 1.04 | 1.30 | 1.13 | 0.11 | 18.00 | 29.00 | 20.80 | 4.11 |
| VIII & IX | S | 1.06 | 9.75 | 4.65 | 3.56 | 0.52 | 2.21 | 1.36 | 0.59 | 7.00 | 38.00 | 19.80 | 9.20 |
| (36-45) | B | 1.22 | 5.52 | 1.91 | 1.29 | 0.14 | 3.78 | 1.91 | 1.15 | 7.00 | 43.00 | 22.70 | 10.66 |

**Source** : Primary data collected by NIO

## Table 3.5.3.6

### Summary of Statistical Parameters for Benthic Abundance in Coastal Waters

| Parameters | Average | Standard Deviation | Coefficient of Variation | Correlation with Benthos |
|---|---|---|---|---|
| Temperature | 29.015 | 1.7293 | 5.9601 | 0.0330 |
| Salinity | 32.803 | 1.0764 | 3.2814 | 0.1407 |
| Diss.Oxygen | 3.1946 | 0.5197 | 16.2670 | -0.1394 |
| BOD | 1.4344 | 0.9089 | 63.3671 | -0.0306 |
| $NO_2$-N | 0.4508 | 0.2751 | 61.0279 | 0.1983 |
| $NO_3$-N | 2.2456 | 1.6501 | 73.4828 | 0.1535 |
| $NH_4$-N | 2.0014 | 5.4551 | 272.5658 | -0.1974 |
| $PO_4$-P | 0.9218 | 0.5567 | 60.3899 | 0.2423 |
| Silicate | 6.4450 | 2.5825 | 40.0694 | 0.0678 |

## Table 3.5.3.7

### Distribution of Plankton in different Stations during different Seasons

| Species | Station Identified with the Species during | | | |
|---|---|---|---|---|
| | Monsoon | | Post Monsoon | |
| | August | September | January | March |
| Copepods | 1, 2, 5, 6, 7, 8, 9, 10 (0-6) | - | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 (11-3580) | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 (8-2017) |
| Cladocerans | 2, 9 (0-5) | 9 (1) | 7,9 (2-15) | 4, 7, 8, 9, 10 (2-20) |
| Fish larvae | 1,2,5,6,7,8 (0-1) | 8 (1) | 3,5,7 (1-3) | 3,6 (1-13) |
| Chaetognaths | 6 (0-1) | - | 2,6,7,8 (2-21) | 2, 5, 6, 8, 9 (1-14) |
| Brachyuran zoea | 1,2,3,4,5,10 (0-2) | 1,2,3,5,8 (1-2) | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 (2-380) | 1, 2, 3, 4, 5, 7, 8, 9, 10 (1-28) |
| Prawn larvae | 5 (0-1) | - | 4, 5, 6, 7, 8, 10 (1-5) | 2, 3, 4, 5, 6, 7, 8, 10 (2-17) |
| Mysids | 1,2,10,14 (0-2) | 11 (1) | 4,5,6,7 (2-20) | 4,5,7,10 (1-14) |
| Ostracods | 2 (1) | - | 4 (1) | 11 (3) |
| Lucifer | - | - | 2, 3, 4, 5, 6, 7, 9 (1-20) | 2, 3, 4, 5, 6, 7, 8, 9, 10 (1-23) |
| Amphipods | - | - | 4, 10, 11 (1-11) | 3, 4, 10, 11 (1-19) |
| Jelly fish | - | - | 5 (11) | - |
| Fish eggs | - | - | 8 (1) | 4, 6, 8 (1-2) |

Values in ( ) indicate the range of species identified in No./ $m^2$

## Table 3.5.3.8

### Distribution of Macrofauna at different Stations during different Seasons

| Species | Station Identified with the Species during | | | |
|---|---|---|---|---|
| | Monsoon | | Post Monsoon | |
| | August | September | January | March |
| Fish | 6,7,8 (20) | 4,7,8 (20-60) | 5,10 (20-40) | 6,11 (20) |
| Polychaetes | 1, 2, 3, 4, 5, 6, 10 (140-560) | 1, 2, 3, 4, 5, 6, 8, 10, 11, 13, 14 (20-1200) | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 (20-2660) | 1, 3, 4, 5, 6, 7, 8, 9, 10 (80-3040) |
| Crabs | 4, 5, 10 (20-560) | 3, 4, 5 (60-540) | 3, 5 (120-220) | 5, 6, 9 (20-140) |
| Amphipods | 1, 2, 4, 5 (20-340) | 1, 3, 4, 10, 11 (40-140) | 2, 3, 4, 5, 6, 11, 12 (20-760) | 1, 3, 4, 6, 7, 9, 10, 11 (20-220) |
| Nemertines | 1,2,4 (20) | - | - | - |
| Molluscs | 3,9 (20-380) | - | 1, 2, 3, 6, 9 (20-3320) | 1, 2, 4 (80-400) |
| Nereids | 1, 2, 3, 9, 10 (100-320) | 1, 2, 3, 9 (40-1360) | 1 (100) | 1 (100) |
| Lumbri-conereids | 3 (140) | - | - | - |
| Prawn | 10 (20) | - | 8 (20) | 3, 5, 6, 10, 11 (20-100) |
| Nematodes | - | 2, 4, 5, 6 (40-240) | 5,6 (1140-2620) | 10 (620) |
| Chironomid larvae | - | 13 (140) | 3 (140) | 13 (40) |
| Tanaids | - | - | 4,5 (20-100) | 11 (1380) |
| Isopods | - | - | 2, 3, 5 (40-4500) | 3 (20) |
| Ophiuroides | - | - | 8 (20) | 9 (40) |
| Prawnmysis | - | - | - | 3 (40) |
| Holithuroides | - | - | - | 6,7 (20) |

Values in ( ) indicate the range of species identified in Nos/$m^2$

Table 3.5.3.9

## Estimated Net Surface and Column Primary Production off Kochi

| Parameters | Net Primary Production (MT of Carbon) | | | |
|---|---|---|---|---|
| | Pre-monsoon (120 days) | Monsoon (92 days) | Post-monsoon (153 days) | Annual (365 days) |
| **Net Surface** | | | | |
| Daily production per km$^2$ area | 0.345 | 0.405 | 0.442 | |
| Seasonal/annual production per km$^2$ area | 41.4 | 37.26 | 67.625 | 146.285 |
| Seasonal/annual production per 1175 km$^2$ area | 48645 | 43780 | 79460 | 171885 |
| Monthly mean per km$^2$ | 10.35 | 12.42 | 13.525 | |
| Percentage of net production in gross production | 51.34 | 37.78% | 57.85 | |
| **Net Column** | | | | |
| Daily production per km$^2$ | 1.725 | 2.025 | 2.21 | |
| Seasonal/annual production per km$^2$ area | 207 | 186.3 | 338.13 | 731.43 |
| Seasonal/annual production per 1175 km$^2$ area | 243225 | 218902 | 397303 | 859430 |
| Monthly mean per km$^2$ | 51.75 | 62.1 | 67.63 | |
| Percentage of net production in gross production | 51.34 | 37.78 | 57.85 | |

**Source :** CMFRI

## Table 3.5.3.10

### Gross Primary Production of Coastal Waters During February 1999

| Stations (Transect) | Station Number | Depth (m) | Gross Primary Production (mgC/m$^3$/day) | | Column Production (mgC/m$^2$/day) |
|---|---|---|---|---|---|
| | | | Surface | Bottom | |
| Off Pallana (I) | 1 | 4 | 398.44 | 24.19 | 845 |
| | 3 | 17 | 24.89 | 15.87 | 347 |
| | 5 | 34 | 10.7 | 15.10 | 439 |
| Off Pazhayangadi (II) | 6 | 34 | 1.14 | 4.04 | 88 |
| | 8 | 16 | 22.98 | 13.51 | 292 |
| | 10 | 5 | 99.72 | 62.64 | 406 |
| Off Alappuzha (III) | 11 | 4 | 72.35 | 32.71 | 210 |
| | 13 | 16 | 3.93 | 1.30 | 42 |
| | 15 | 31.5 | 7.97 | 17.13 | 395 |
| Off Chettri beach (IV) | 16 | 26 | 4.64 | 4.05 | 113 |
| | 18 | 16 | 17.52 | 14.23 | 254 |
| | 20 | 3 | 519.35 | 500.19 | 1529 |
| Off Andhakaranazhi (V) | 21 | 3 | 147.04 | 122.73 | 405 |
| | 23 | 16 | 8.17 | 0.50 | 69 |
| | 25 | 26 | 3.36 | 0.86 | 55 |
| Off Kannamali (VI) | 26 | 31 | 10.14 | 2.67 | 199 |
| | 28 | 16 | 126.97 | 3.73 | 1046 |
| | 30 | 3.5 | 354.59 | 295.51 | 1138 |
| Off Fort Kochi (VII) | 31 | 3.5 | 384 | 240 | 1092 |
| | 33 | 14 | 48.12 | 48.12 | 674 |
| | 35 | 28 | 68.72 | 42 | 664 |
| Off Edavanakkudu (VIII) | 36 | 28 | 40.08 | 1.28 | 579 |
| | 38 | 21 | 66.6 | 26.16 | 974 |
| | 40 | 4 | 120.36 | 151.92 | 545 |
| Off Azhikode (IX) | 41 | 4 | 383.28 | 239.16 | 1245 |
| | 43 | 13 | 101.88 | 11.34 | 736 |
| | 45 | 27 | 49.08 | 2.22 | 693 |

**Source :** Primary data collected by NIO

## Table 3.5.3.11

## Phytoplankton Species in Coastal Waters during October 1997 and February 1999

| Station | Species | Quantity (No/L) |
|---|---|---|
| **During October 1997** | | |
| 11 | *Trichodesmium sp.* | 1000 |
| 25 | *Trichodesmium erythraeum* | 5500 |
| 26 | *Trichodesmium erythraeum* | 1280 |
| 27 | *Trichodesmium* sp. | 7500 |
| 29 | *Nitzschia longissima, Ceratium fusca, Asterionella japonica* | 1000 each |
| | *Nitzschia elongatum* | 2000 |
| | *Ceratium macroceros* | 3000 |
| 30 | *Trichodesmium* sp. | 10000 |
| 31 | *Triceratium robertisianum, Rhyzosolenia sp., Rhyzosolenia costracarica* | 1000 each |
| 32 | *Peridinium* sp. | 7500 |
| **During February 1999** | | |
| 3 | *Trichodesmium sp.* | 10000 |
| 5 | *Peridium sp.* | 6000 |
| 7 | *Peridium sp., Nitzschia clostrum, Surinella flunium, Pleurosigma elongatum, Asterionella japonica, Rhizosoleni castacoci* | 800 each |
| | *Skeletonema costatum* | 14100 |
| | *Nitzschia longissima* | 300 |
| | *Rhabdonema minificum* | 400 |
| 9 | *Trichodesmium* sp. | 5000 |
| 10 | *Pleurosigma elongatum, Ceratium macroceros, Trichodesmium sp., Ceratium fusca, Coscinodiscus sp.* | 10000 eâch |
| 11 | *Biddulphia sinensis* | 5000 |
| | *Rhyzosolenia* sp., *Thalassionema nitzschioides* | 1000 each |
| | *Pleurosigma directum* | 2000 |
| 12 | *Rhizosolenium* sp. | 1000 |
| 14 | *Trichodesmium sp.* | 38000 |
| 16 | *Trichodesmium erythraeum* | 1000 |
| | *Coscinodiscus* sp. | 5000 |
| 18 | *Chaetoceros decipiens* | 3000 |
| | *Trichodesmium erythraeum* | 1000 |
| 20 | *Biddulphia sinensis, Asterionella japonica, Coscinodiscus eccentricum, Pleurosigma directem, Trichodesmium erythraeum, Pleurosigma sp., Triceratium sp.* | 1000 each |
| 21 | *Coscinodiscus eccentricum* | 1000 |
| 23 | *Ceratium bergonii* | 5000 |
| | *Trichodesmium erythraeum, Coscinodiscus marginatus, Peridinium sp., Rhizosolenia sp., Dinophysis* | 1000 each |

Contd...

Table 3.5.3.11 contd...

| Station | Species | Quantity (No/L) |
|---|---|---|
| 24 | *Trichodesmium erythraeum, Chaetoceros messannensis. Fragilaria oceanic,* | 3000 each |
| 25 | *Trichodesmium sp.* | 30000 |
| 26 | *Trichodesmium erythraeum* | 17000 |
| | *Coscinodiscus eccentricum* | 1000 |
| 28 | *Rhizosolenium styliformis sp.* | 10000 |
| 29 | *Ceratium macroceros, Pleurosigma elongatum, Cheetoceros sp., Trichodesmium sp.* | 1000 each |
| 30 | *Guinardia flaccida* | 2840 |
| 31 | *Guinardia flaccida* | 260 |
| | *Ditylum brightwelli* | 243 |
| | *Chaetoceros curvisetum* | 250 |
| | *Chaetoceros messanensis* | 504 |
| | *Chaetoceros diversus* | 246 |
| | *Asterionella japonica* | 268 |
| | *Leptocylindrus danicus* | 276 |
| 32 | *Thalassiothrix frauenfeldii, Chaetoceros curvisetus, Rhabdonema minificum, Rhizosolenia alata, Asterionella japonica, Pleurosigma sp., Cerataulina bergonii, Thalassionema nitzschioides, Biddulphia sinensis, Peridinium sp., Chaetoceros diversus, Coscinodiscus eccentricum, Ditylum brightwellii* | 1000 each |
| | *Chaetoceros messanensis* | 4000 |
| 35 | *Trichodesmium erythraeum* | 300 |
| 36 | *Trichodesmium sp.* | 120000 |
| 37 | *Trichodesmium sp.* | 10000 |
| 38 | *Peridinium sp.* | 20000 |
| | *Ditylum brightwelli, Coscinodiscus sp., Schraderelia delicatula, Rhizosolenium robasta, Rhizosolenium styliformis, Chaetoceros sp.* | 10000 each |
| 39 | *Peridinium sp.* | 10000 |
| | *Ceratium macroceros* | 30000 |
| | *Nitzschia longissima, Thalassiothrix frauenfeldii, Rhizosoleni styliformi, Lanlani annulata, Trichodesmium sp., Skeletonema costatum* | 10000 each |
| | *Chaetoceros sp.* | 20000 |
| 40 | *Nitzschia longissima* | 4000 |
| | *Plerosigma elongatum* | 2000 |
| | *Biddulphia sinensis, Coscinodiscus eccentricum, Thalassionema nitzschioide, Asterionella japonica* | 1000 each |
| 41 | *Peridinium sp., Nitzschia longissima, Trichodesmium sp., Cerataulina bergonii, Ditylium brightwellii, Thalassiothrix frauenfeldii, Lauderia annulata* | 1000 each |
| | *Pleurosigma elongatum* | 3000 |
| 42 | *Peridinium sp., Coscinodiscus marginatus, Pleurosigma normanii, Rhizosolenia sp., Eucampia zoodiacus* | 1000 each |
| | *Trichodesmium erythraeum* | 2000 |
| 44 | *Rhizosolenia* sp., *Ceratium* sp. | 1000 each |
| 45 | *Trichodesmium sp.* | 10000 |

**Source** : Primary data collected by NIO, 1997-1999

## Table 3.5.3.12

### Estimated Seasonwise Secondary Production off Kochi

| Parameter | Secondary Production (MT of Carbon/1175 km$^2$) | | |
|---|---|---|---|
| | Premonsoon | Monsoon | Postmonsoon |
| Mean seasonal production | 922 | 5309 | 1575 |
| Mean monthly production | 231 | 1774 | 315 |
| Seasonal mean production /km$^2$ | 0.79 | 4.52 | 1.34 |

**Source** : CMFRI

## Table 3.5.3.13

### Biomass and Abundance of Zooplankton during October 1997

| Station | Transect I (1-24) | | Transect II (25-56) | |
|---|---|---|---|---|
| | Range | Average | Range | Average |
| **Biomass (ml/100m$^3$)** | **0.5-18.4** | **6.5** | **0.1-18.4** | **4.2** |
| **Taxa (No./100m$^3$)** | | | | |
| Forminifera | - | - | - | 19* |
| Hydromedusae | 19-3382 | 1207 | 6-8075 | 1786 |
| Siphonophora | 2-19 | 11 | - | 57* |
| Ctenophora | 3.8-38 | 21 | - | 2* |
| Anthozoa | - | - | - | 2* |
| Polychacta | 19-38 | 25 | 2-380 | 104 |
| Cladocera | 947-98800 | 25805 | 48-140600 | 26179 |
| Copepoda | 8930-159030 | 81850 | 207-508820 | 72722 |
| Sergestidae | 19-4934 | 931 | 2-20900 | 2597 |
| Pteropoda | - | - | - | 38* |
| Catetognatha | 14-7087 | 789 | 8-3990 | 785 |
| Copelata | 266-4750 | 1689 | 95-3610 | 1220 |
| Fish eggs | 11-1767 | 776 | 17-47500 | 3939 |
| Fish larvae | 2-209 | 55 | 2-570 | 89 |
| Decapod larvae | 475-4750 | 1091 | 28-5700 | 842 |
| Zoea | 19-38 | 29 | 190-1520 | 855 |
| Gastropod | - | 2* | - | - |
| Bivalves | - | - | 11-114 | 71 |
| **Total** | **7978-226248** | **104716** | **312-653847** | **96731** |

* Single observation

**Source** : Primary data collected by NIO

## Table 3.5.3.14

### Zooplankton Biomass and Abundance off Kochi and Alappuzha

| Years | Depth (m) | Total (No./$m^3$) | Biomass (ml/$m^3$) |
|---|---|---|---|
| **Off Kochi** | | | |
| October 1987 | 5 | 9486 | 0.40 |
| | 10 | 8346 | 0.61 |
| | 15 | 6193 | 0.81 |
| October 1988 | 5 | 10171 | 0.11 |
| | 10 | 8990 | 0.10 |
| | 15 | 6810 | 0.10 |
| October 1990 | 5 | 8244 | 0.08 |
| | 10 | 7050 | 0.10 |
| | 15 | 8899 | 0.18 |
| 1991-92 | 5 | 1975 | 0.22 |
| | 10 | 2329 | 0.19 |
| | 15 | 2381 | 0.18 |
| 1993 | 5 | 7901 | 0.23 |
| | 10 | 10359 | 0.80 |
| | 15 | 10302 | 0.75 |
| **Off Alappuzha** | | | |
| October 1990 | 5 | 8161 | 0.08 |
| | 10 | 4844 | 0.09 |
| | 15 | 9129 | 0.10 |
| 1993 | 5 | 1732 | 0.02 |
| | 10 | 8317 | 0.11 |
| | 15 | 4451 | 0.09 |

**Source**: Secondary data collected by NIO

## Table 3.5.3.15

### Biomass & Abundance of Zooplankton in Coastal Waters during February 1999 & November 2000

| Parameters/ Species | Transect I & II (1-10) | | Transect III & IV (11-20) | | Transect V & VI (21-30) | | Transect VII, VIII & IX (31-45) | |
|---|---|---|---|---|---|---|---|---|
| | Range | Average | Range | Average | Range | Average | Range | Average |
| **During February 1999** | | | | | | | | |
| Biomass (ml/100m$^3$) | 0.05-14.2 | 4.2 | 0.8-14.3 | 4.5 | 1.3-14.3 | 6.4 | 0.7-12 | 7.3 |
| Taxa (No./100m$^3$) | - | - | - | - | - | - | - | - |
| Forminifera | 22-174 | 79 | 39-171 | 88 | 36-215 | 102 | 50-58 | 54 |
| Hydromedusae | 6-64 | 34 | 2-31 | 15 | 4-99 | 41 | 8-51 | 28 |
| Siphonophora | 4-135 | 48 | 6-149 | 44 | 9-68 | 41 | 11-106 | 40 |
| Polychaeta | 3-339 | 95 | 2-20 | 9 | 9-45 | 27 | - | 58* |
| Cladocera | 104-733 | 144 | 297-4270 | 1434 | 874-6248 | 2682 | 1178-45448 | 4815 |
| Ostracoda | 15-312 | 115 | 8-56 | 32 | - | - | - | - |
| Amphipoda | 12-406 | 159 | 3-15 | 9 | - | 4* | - | 27* |
| Copepoda | 2984-36039 | 10759 | 5070-142443 | 45733 | 32980-624759 | 179849 | 6081-248700 | 15668 |
| Sergestidae | 4-346 | 147 | 3-417 | 109 | 44-518 | 176 | 31*4134 | 704 |
| Heteropoda | - | - | 2-37 | 15 | 17-22 | 20 | - | - |
| Pteropoda | 4-135 | 38 | 15-56 | 29 | 41-54 | 49 | 22-63 | 44 |
| Catetognatha | 75-4672 | 1208 | 393-4104 | 1595 | 155-5017 | 1460 | 57-5572 | 707 |
| Salps | 17-541 | 139 | 2-703 | 278 | 15-964 | 465 | 76-160 | 107 |
| Doliolids | 4-68 | 29 | 10-95 | 46 | - | - | - | - |
| Copelata | 10-203 | 73 | 507-3622 | 2012 | 60-945 | 278 | 84-26028 | 3065 |

Contd...

Table 3.5.3.15 contd..

| Parameters/ Species | Transect I & II (1-10) | | Transect III & IV (11-20) | | Transect V & VI (21-30) | | Transect VII, VIII & IX (31-45) | |
|---|---|---|---|---|---|---|---|---|
| | Range | Average | Range | Average | Range | Average | Range | Average |
| Fisn eggs | 17-86 | 40 | 19-124 | 56 | 9-313 | 77 | 22-2631 | 314 |
| Fish larvae | 4-25 | 11 | 1-20 | 8 | 9-60 | 25 | 8-42 | 23 |
| Decapod larvae | 8-203 | 45 | 6-65 | 18 | 13-157 | 81 | 31-147 | 74 |
| Zoea | 4-37 | 15 | 2-71 | 27 | 9-82 | 46 | 10-29 | 21 |
| Megalopa | - | 5* | 6-10 | 8 | - | 4* | - | - |
| Stomatopod | 5-68 | 34 | 1-16 | 9 | - | 30* | 27-54 | 41 |
| Isopod | - | - | - | 1* | - | - | - | - |
| Crab | - | - | - | 17* | - | - | - | - |
| Insect | - | 3* | - | 10* | - | - | - | - |
| Gastropod | 5-34 | 14 | 2-142 | 64 | 11-144 | 70 | 25-1136 | 166 |
| Bivalves | 5-12 | 9 | * | 10* | - | 36* | - | - |
| **Total** | **3482-37274** | **12726** | **10011*143290** | **49904** | **34792-629033** | **201957** | **6328-296623** | **135513** |
| **During November 2000** | | | | | | | | |
| Biomass (ml/100m$^3$) | 0.4-2.9 | 1.1 | 0.1-3.0 | 0.8 | 0.2-1.4 | 0.5 | 0.3-9.2 | 2.5 |
| Taxa (No./100m$^3$) | | | | | | | | |
| Foraminifera | 25-361 | 64 | - | - | - | - | 18-1834 | 176 |
| Medusae | - | 2* | 1-4 | 1 | - | - | 1-26 | 5 |
| Siphonophore | - | - | 6-28 | 5 | - | - | 23-336 | 29 |
| Cresis | - | - | 6-11 | 2 | - | 12* | 9-21 | 2 |
| Heteropods | - | - | 32-33 | 7 | - | 10* | 9-16 | 4 |
| Gastropods | - | - | 16-115 | 15 | - | 13* | 10-22 | 2 |
| Evadina | 88-128 | 36 | 28-586 | 119 | 223-276 | 100 | 8-13266 | 1380 |
| Copepods | 3009-42223 | 17258 | 80-9741 | 2035 | 1510-7406 | 4294 | 340-58328 | 13850 |
| Amphipods | - | 2* | 12-164 | 27 | - | - | 3-67 | 8 |

**Contd...**

Table 3.5.3.15 contd..

| Parameters/ Species | Transect I & II (1-10) | | Transect III & IV (11-20) | | Transect V & VI (21-30) | | Transect VII, VIII & IX (31-45) | |
|---|---|---|---|---|---|---|---|---|
| | Range | Average | Range | Average | Range | Average | Range | Average |
| Lucifer | 10-22 | 11 | 1-167 | 27 | - | 7* | 3-54 | 7 |
| Zoea | 9-67 | 28 | 2-64 | 11 | 7-127 | 28 | 8-198 | 31 |
| Other decapods | 29-107 | 35 | - | - | 5-223 | 54 | 12-127 | 24 |
| Alima larvae | 7-29 | 6 | - | 1* | 2-6 | 2 | - | - |
| Chaetognatha | 10-922 | 237 | 1-666 | 187 | 115-892 | 280 | 9-1116 | 282 |
| Appendicularia | 89-2398 | 458 | 9-1578 | 437 | 12-1526 | 419 | 9-292 | 82 |
| Salps | - | - | - | - | - | - | - | 3* |
| Fish eggs | 35-845 | 315 | 7-524 | 108 | 12-58 | 29 | 16-630 | 96 |
| Fish larvae | 15-87 | 27 | 1-18 | 3 | 6-26 | 9 | 9-23 | 12 |
| **Total** | **1449-46670** | **16307** | **112-11077** | **2984** | **1820-9592** | **5259** | **790-64945** | **16163** |

* Single observation

**Source** : Primary data collected by NIO

Table 3.5.3.16

Biomass and Density of Benthos in Coastal Waters(1997-2000)

| Station No. | October 1997 | | February 1999 | | November 2000 | |
|---|---|---|---|---|---|---|
| | Benthos Biomass ($g/m^2$) | Benthic Density ($No./m^2$) | Benthos Biomass ($g/m^2$) | Benthic Density ($No./m^2$) | Benthos Biomass ($g/m^2$) | Benthic Density ($No./m^2$) |
| 1 | 0.01 | 105 | 5.07 | 900 | 0.80 | 292 |
| 2 | 6.88 | 715 | 2.03 | 273 | - | - |
| 3 | 6.21 | 357 | 6.42 | 210 | 0.41 | 3480 |
| 4 | 8.30 | 105 | 1.41 | 105 | - | - |
| 5 | 18.51 | 125 | 51.55 | 1170 | 135.55 | 2170 |
| 6 | 39.11 | 147 | 16.76 | 882 | 34.87 | 671 |
| 7 | 17.78 | 357 | 2.31 | 378 | 47.64 | 924 |
| 8 | - | - | 44.36 | 669 | 95.81 | 856 |
| 9 | - | - | 7.04 | 252 | 7.36 | 480 |
| 10 | - | - | 4.07 | 231 | 41.94 | 9980 |
| 11 | 12.55 | 335 | 1.67 | 63 | 0.58 | 791 |
| 12 | - | - | 2.47 | 273 | 19.95 | 565 |
| 13 | 2.48 | 21 | 14.33 | 273 | 9.58 | 1294 |
| 14 | 7.00 | 1169 | 1.38 | 273 | 2.46 | 209 |
| 15 | 6.91 | 210 | 65.09 | 13651 | 13.83 | 4589 |
| 16 | 3.96 | 4920 | 2.65 | 399 | 5.38 | 251 |
| 17 | 10.56 | 1627 | 6.39 | 815 | 0.85 | 210 |
| 18 | 3.65 | 920 | 5.18 | 1875 | 6.01 | 356 |
| 19 | 1.57 | 377 | 7.46 | 501 | 1.69 | 336 |
| 20 | 28.52 | 438 | 2.34 | 272 | 3.97 | 189 |
| 21 | 202.77 | 105 | 0.28 | 63 | - | - |
| 22 | 196.05 | 189 | 10.9 | 189 | 11.81 | 1255 |
| 23 | 185.46 | 647 | 10.8 | 189 | 107.39 | 357 |
| 24 | 22.31 | 858 | 20.66 | 2192 | 2.83 | 1838 |
| 25 | 11.82 | 1795 | 11.60 | 3651 | 7.62 | 711 |
| 26 | 7.98 | 1939 | 51.64 | 399 | 153.93 | 1358 |
| 27 | 2.94 | 126 | 14.70 | 168 | 114.77 | 669 |
| 28 | 1.16 | 42 | 28.18 | 629 | 80.89 | 671 |
| 29 | 1.93 | 251 | 6.58 | 315 | 16.63 | 357 |
| 30 | 180.50 | 2317 | 0.20 | 21 | - | - |

Contd...

Table 3.5.3.16 Contd...

| Station No. | October 1997 | | February 1999 | | November 2000 | |
|---|---|---|---|---|---|---|
| | Benthos Biomass ($g/m^2$) | Benthic Density ($No./m^2$) | Benthos Biomass ($g/m^2$) | Benthic Density ($No./m^2$) | Benthos Biomass ($g/m^2$) | Benthic Density ($No./m^2$) |
| 31 | 201.07 | 941 | 4.47 | 21 | 53.69 | 1834 |
| 32 | 2.63 | 271 | 3.34 | 315 | 2.15 | 84 |
| 33 | 0.02 | 21 | 21.31 | 565 | - | - |
| 34 | 4.72 | 272 | 4.12 | 294 | - | - |
| 35 | 14.65 | 2319 | 1.25 | 147 | - | - |
| 36 | 76.37 | 774 | 2.07 | 336 | 0.89 | 315 |
| 37 | - | - | 61.37 | 378 | 27.78 | 1417 |
| 38 | 26.77 | 63 | 24.38 | 462 | 110.54 | 668 |
| 39 | 74.79 | 335 | 37.97 | 147 | 4.25 | 336 |
| 40 | 19.39 | 753 | 1.17 | 356 | 40.73 | 960 |
| 41 | 8.76 | 794 | 2.15 | 84 | 56.01 | 2354 |
| 42 | - | - | 39.53 | 168 | 4.05 | 356 |
| 43 | 18.36 | 315 | 8.99 | 441 | 23.46 | 335 |
| 44 | 67.17 | 293 | 35.41 | 983 | 39.91 | 583 |
| 45 | 15.01 | 523 | 2.9 | 273 | 48.53 | 356 |
| 46 | 8.73 | 1273 | - | - | - | - |
| 47 | 5.12 | 668 | - | - | - | - |
| 48 | 3.34 | 1250 | - | - | - | - |
| 49 | 1.09 | 126 | - | - | - | - |
| 50 | 8.01 | 856 | - | - | - | - |
| 51 | 125.87 | 2943 | - | - | - | - |
| 52 | 14.27 | 377 | - | - | - | - |
| 53 | 206.3 | 5876 | - | - | - | - |
| 54 | 334.85 | 5329 | - | - | - | - |
| 55 | 140.2 | 377 | - | - | - | - |
| 56 | 36.67 | 2027 | - | - | - | - |

**Source** : Primary Data collected by NIO

Table 3.5.3.17

Biodiversity of Benthos in Coastal Waters during October 1997

| Sr. No. | Type of Species | Station Number and Number of Species Observed |
|---|---|---|
| **A** | **POLYCHAETES** | |
| 1 | **Family-Aphroditidae** | |
| a | *Aphrodita* sp. | 2(127), 24(21), 31(125), 32(21), 55(63) |
| b | Aphroditidae (big) | 22(21), 55(21) |
| c | *Sthenelais boa* | |
| 2 | **Family-Amphinomidae** | 2(21) |
| 3 | **Family-Hesionidae** | |
| a | *Ancistrosyllis constricta* | 7(42), 23(21), 25(21), 29(21), 32(21), 35(42), 39(21), 40(21), 56(21) |
| 4 | **Family-Syllidae** | |
| a | *Syllis spongicola* | 16(84), 24(21), 34(21), 40(21), 43(21), 46(63), 51(210) |
| 5 | **Family-Nereidae** | |
| a | *Nereis* sp. | 1(42) |
| b | *Lycastis indica* | 1(21) |
| c | *Perinereis cavifrons* | 3(21) |
| d | Platynereidae | 21(21), 34(21) |
| 6 | **Family-Nephthydidae** | |
| a | *Nephthys dibranchis* | 30(21), 46(21) |
| 7 | **Family-Glycerida** | |
| a | *Glycera alba* | 16(21), 26(21), 30(21) |
| b | *Goniada incerta* | 31(42) |
| 8 | **Family-Eunicidae** | |
| a | *Diopatra neopolitana* | |
| b | *Lumbrinereis simplex* | 43(42) |
| c | *Lumbrinereis impatiens* | 11(21), 44(21) |
| d | *Lumbrinereis pseudobifilaris* | 19(84) |
| e | *Lumbrinereis aberrans* | 38(21) |
| f | *Lumbrinereis hartmani* | 3(21), 7(21), 11(21), 14(105), 15(21), 16(480), 17(126), 18(105), 19(104), 20(167), 24(21), 25(21), 26(42), 29(125), 30(63), 31(21), 35(688), 34(21), 40(21), 45(84), 46(792), 47(84), 49(21), 50(479), 51(313), 52(21), 53(42) |

Contd...

Table 3.5.3.17 Contd...

| Sr. No. | Type of Species | Station Number and Number of Species Observed |
|---|---|---|
| 9 | **Family-Arabellidae** | |
| a | *Arabella iricolor* | 54(42) |
| b | *Drilonereis falcata* | 30(21) |
| 10 | **Family-Spionidae** | |
| a | *Prionospio cirrifera* | 7(63), 11(21), 24(21), 25(21), 26(186), 40(42), 41(167), 44(21), 56(188) |
| b | *Prionospio pinnata* | 2(21), 3(21), 7(42), 11(188), 14(791), 15(63), 16(2395), 17(520), 18(42), 19(21), 20(21), 22(42), 23(458), 24(63), 30(147), 32(229), 35(42), 36(21), 43(42), 46(250), 48(791), 49(84), 50(21), 51(21), 52(42), 54(21) |
| c | *Prionospio polybranchia* | 24(84), 34(21) |
| d | *Prionospio* sp. | 11(21), 29(21) |
| e | *Polydora ligni* | 3(21), 18(21), 25(854), 27(1396), 39(63), 40(291), 43(21), 53(21) |
| 11 | **Family-Orbiniidae** | |
| a | *Scoloplella capensis* | 26(21), 40(21), 41(21), 43(63), 56(63) |
| 12 | **Family-Magelonidae** | 30(21), 46(21), 51(21), 52(21) |
| 13 | **Family-Cirratulidae** | |
| a | *Cirratulus cirratus* | 18(84), 24(21), 35(21), 36(21), 40(63), 41(42), 43(21) |
| b | *Tharyx* sp. | 40(42), 41(42), 56(105) |
| 14 | **Family-Paraonidae** | |
| a | *Aricidea capensis* | 30(42), 54(21) |
| b | *Paraonella platybranchia* | 23(84), 24(84), 25(355), 39(63), 40(63), 41(167), 56(1042) |
| 15 | **Family-Ophelidae** | |
| a | *Ophelia accuminata* | 35(42), 56(21) |
| 16 | **Family-Cossuridae** | |
| a | *Cossura coasta* | 3(42), 4(21), 14(84), 16(1396), 17(375), 18(105), 22(21), 26(21), 28(42), 35(21), 45(21), 46(42), 50(105) |
| 17 | **Family-Capetellidae** | |
| a | *Capitella capitata* | 19(21), 22(21), 30(21), 31(21), 39(146), 40(21), 41(250), 48(21), 54(21), 55(42), 56(188) |
| b | *Mediomastus capensis* | 41(21), 56(21) |
| c | *Notomastus latericeus* | 27(21), 35(21), 45(21), 52(42) |

Contd...

Table 3.5.3.17 Contd...

| Sr. No. | Type of Species | Station Number and Number of Species Observed |
|---|---|---|
| d | *Scyphoproctus djibontiensis* | 7(21), 30(21), 44(21) |
| e | *Paraheteromastus tennis* | 4(21), 19(21), 22(21), 24(21), 25(84), 26(105), 35(21), 40(21), 46(63), 51(21) |
| 18 | **Family-Maldanidae** | |
| a | *Maldanella capensis* | 2(21), 31(21), 38(21) |
| b | *Maldane sarsi* | 31(21), 51(42) |
| 19 | **Family-Oweniidae** | |
| a | *Owenia fusiformis* | 24(21), 40(21), 56(42) |
| 20 | **Family-Sternaspidae** | |
| a | *Sternaspis scutata* | 2(21), 3(63), 14(42), 16(126), 17(42), 29(84), 31(63), 35(63), 41(21), 47(21), 50(42), 51(63), 55(21) |
| 21 | **Family-Flabelligeridae** | |
| a | *Pherusa inflata* | 56(42) |
| 22 | **Family-Terebellidae** | |
| a | *Pista indica* | 13(21), 24(21), 25(167), 31(21), 40(21), 41(21), 56(21) |
| 23 | **Family-Sabellidae** | 39(21) |
| | **Oligochaeta** | 21(42), 22(21), 40(21) |
| B | **CRUSTACEANS** | |
| 1 | Amphipods | |
| a | *Quadrivisio bengalensis* | 1(21), 17(63), 31(21), 56(63) |
| b | *Eriopisa chilkensis* | 1(21), 41(21), 56(21) |
| c | *Grandidierella gilesi* | 2(21), 30(271), 51(126), 52(21) |
| d | *Grandidierella bonneri* | 34(21) |
| C | **ISOPODS** | 26(42), 40(21) |
| 1 | TANAIDACEANS | |
| a | *Apseudes chilkensis* | |
| b | *Apseudes gymnophobium* | |
| c | Copepods | 7(21), 31(21) |
| d | Mysids | |
| e | Cumacea | 31(42), 35(105), 51(126) |
| f | Sergestidae | 17(21), 30(42) |

Contd...

Table 3.5.3.17 Contd...

| Sr. No. | Type of Species | Station Number and Number of Species Observed |
|---|---|---|
| g | Decapods | 44(21) |
| h | Lobsters | 52(21) |
| I | Lepas | |
| j | Balanus | 31(63) |
| 2 | INSECTA | |
| a | Insect larvae | |
| b | *Diamesa* | 35(21) |
| c | Chironomid larvae | |
| D | **MOLLUSCS** | |
| 1 | **Gastropods** | |
| a | *Calliostoma bairdii* | 14(21), 20(125), 34(167) |
| b | *Dentalium* sp. | 6(63), 17(21), 25(21), 35(167), 36(84), 38(21), 44(21), 45(21), 52(21), 53(145), 54(21), 55(42), 56(21) |
| c | *Conus* sp. | 2(21), 3(21), 14(63), 15(42), 17(271), 36(84), 45(250) |
| d | *Litiopa* sp. | 45(21) |
| e | *Murex* sp. | 53(21) |
| f | *Solariella obscura* | 2(21), 3(42), 4(42), 5(125), 6(63), 7(21), 11(42), 14(21), 15(84), 17(125), 19(84), 20(125), 24(291), 25(125), 26(105), 30(63), 31(125), 36(375), 39(21), 40(21), 41(21), 43(63), 44(167), 45(42), 46(21), 47(42), 48(42), 50(125), 51(1895), 52(188), 53(271), 54(3640), 56(63) |
| g | *Cardium* sp. | |
| h | *Marginella angustata* | 45(21) |
| I | *Strombus labiosus* | 54(21) |
| j | *Cavolina* sp. | 11(21), 16(146), 24(84), 27(105), 31(63), 35(105), 43(21), 50(42), 36(21), 53(42), 54(125), 55(21), 56(63) |
| k | *Gastropod* sp. | 2(42), 7(84), 19(21), 36(168), 51(105), 53(5313), 54(1396), 55(167) |
| 2 | **Bivalves** | |
| a | *Modiolus* sp. | |
| b | *Villorita* sp. | 2(42), 3(63), 7(21), 17(63), 18(563), 48(333), 45(21), 48(333) |
| c | *Tellina* sp. | 7(21), 14(21), 48(42) |
| d | Meritrix *sp.* | |

Contd...

Table 3.5.3.17 Contd...

| Sr. No. | Type of Species | Station Number and Number of Species Observed |
|---|---|---|
| e | *Nucula* sp. | 16(21) |
| f | *Bivalve* sp. | 2(252), 3(21), 6(21), 14(21), 16(251), 24(84), 25(84), 30(1563), 31(208), 33(21), 35(960), 40(21), 47(521), 48(21), 49(21), 50(42), 56(21) |
| | Fishes | |
| | Juvenile fish | 25(21), 54(21) |
| E | **MISCELLANEOUS GROUPS** | |
| a | Ophiuroidea | 2(84), 3(21), 24(21), 25(21), 31(42) |
| b | Echiuroidea | 21(42), 23(63), 53(21) |
| c | Anthozoa | 4(21) |
| d | Planaria | 2(21), 19(21), 22(42), 31(21) |
| e | Sipunculids | 43(21) |
| f | Phoronids | 44(21) |

**Source** : Primary data collected by NIO

Table 3.5.3.18

Biodiversity of Benthos in Coastal Waters during February 1999

| Sr. No. | Type of Species | Station Number and Number of Species |
|---|---|---|
| **A** | **POLYCHAETES** | |
| **1** | **Family-Aphroditidae** | |
| a | *Lepidonotus* sp. | 17(21) |
| b | *Parahalosydna capensis* | 15(21), 24(84) |
| c | *Sthenelais boa* | 43(21) |
| **2** | **Family-Iospilidae** | |
| a | *Iospilus* sp. | 37(21) |
| **3** | **Family-Hesionidae** | |
| a | *Ancistrosyllis constricta* | 1(42), 6(63), 7(21), 13(21), 16(84), 17(63), 20(21), 23(21), 24(42), 26(21), 27(21), 28(84), 29(105), 30(21), 32(21), 38(42), 40(188), 42(42), 43(63), 44(21) |
| **4** | **Family-Nereidae** | |
| a | *Lycastis indica* | 3(21) |
| b | *Dendronereis aestuarina* | 36(42), 37(21), 43(63) |
| c | *Platynereid* sp. | 1(63), 23(42), 24(21), 29(42), 35(21), 44(42) |
| d | *Perinereis cavifrons* | 3(21), 6(21) |
| **5** | **Family-Nephthydidae** | |
| a | *Nephthys dibranchis* | 2(105), 6(42), 7(63), 8(21), 9(63), 13(21), 14(21), 18(21), 23(21), 24(21), 25(21), 26(21), 27(42), 28(42), 29(21), 32(21), 33(42), 34(42), 36(21), 37(42), 38(42), 43(21), 44(21) |
| **6** | **Family-Glycerida** | |
| a | *Glycera longipinnis* | 24(21) |
| b | *Glycera alba* | 15(42), 24(63) |
| c | *Glycera unicornis* | 6(21), 10(21), 33(21) |
| d | *Goniada emerita* | 3(21), 15(21) |
| **7** | **Family-Eunicidae** | |
| a | *Lumbrinereis impatiens* | 14(63) |
| b | *Lumbrinereis latreilli* | 1(146), 6(84), 10(21), 16(42) |
| c | *Lumbrinereis aberrans* | 8(21), 43(21) |
| d | *Lumbrinereis hartmani* | 1(42), 2(63), 5(126), 6(105), 7(21), 8(21), 11(42), 12(63), 13(21), 17(21), 19(42), 22(21), 23(21), 25(42), 26(42), 27(42), 28(84),32(21), 33(84), 34(105), 36(21), 38(84), 40(84), 41(21), 43(21), 45(21) |
| e | *Arabella iricolor* | 2(21), 6(21), 24(42), 35(21), 44(21), 45(21) |

Contd...

Table 3.5.3.18 Contd...

| Sr. No. | Type of Species | Station Number and Number of Species |
|---|---|---|
| 8 | **Family-Spionidae** | |
| a | *Spiophanes bombyx* | 8(21), 9(21), 15(42), 16(21), 24(21), 33(21), 44(21) |
| b | *Prionospio cirrifera* | 4(21), 5(21), 6(63), 10(21), 21(21), 23(42), 25(42), 26(42), 35(21), 37(21), 43(63), 44(42) |
| c | *Prionospio pinnata* | 1(125), 5(63), 7(42), 8(21), 10(21), 12(21), 16(21), 34(21), 25(63), 37(63), 26(105), 40(42), 27(42), 43(42), 28(63), 45(21), 17(42), 20(21), 24(42) |
| d | *Prionospio polybranchia* | 1(105), 5(42), 7(21), 22(21), 28(21), 36(21) |
| e | *Prionospio* sp. | 5(42), 6(42), 37(21) |
| 9 | **Family-Magelonidae** | |
| a | *Magelona capensis* | 5(416), 6(84), 12(21), 15(1044), 16(105), 17(42), 18(146), 20(42), 21(21), 24(1583), 25(3064), 32(21), 33(21), 37(42), 41(63), 43(21), 44(500) |
| b | **Family-Cirratulidae** | |
| c | *Cirratulus cirratus* | 4(21), 6(21), 8(21), 10(21), 12(21), 24(21), 25(42), 33(21), 38(21), 45(42) |
| d | *Cirriformia afer* | 28(42) |
| e | *Cirriformia filigera* | |
| 10 | **Family-Paraonidae** | |
| a | *Aricidea capensis* | 6(21), 44(84) |
| 11 | **Family-Ophelidae** | |
| a | *Armandia intermedia* | |
| 12 | **Family-Cossuridae** | 9(126), 11(21), 12(63), 13(21), 14(21), 24(21), 28(21) |
| a | *Cossura coasta* | 2(42), 7(42) |
| | | |
| 13 | **Family-Capetellidae** | 19(21), 20(21), 22(42), 28(146), 29(63), 32(210), 33(42), 34(105), 38(105), 39(21), 42(42) |
| a | *Capitella capitata* | 2(21), 7(42) |
| b | *Pulliella armata* | 1221, 13(42), 14(21), 19(42), 29(21), 35(21) |
| c | *Notomastus fauveli* | 6(21) |
| d | *Heteromastus bifidus* | 3(21) |
| e | *Scyphoproctus djibontiensis* | 3(21), 4(21), 6(21), 14(21), 17(21) |
| f | *Paraheteromastus tennis* | |
| 14 | **Family-Maldanidae** | 24(21) |
| a | *Maldane sarsi* | 1(105), 2(21), 3(21), 5(63), 7(21) |

Contd...

Table 3.5.3.18 Contd...

| Sr. No. | Type of Species | Station Number and Number of Species |
|---|---|---|
| **15** | **Family-Šternaspidae** | 9(21), 10(21), 12(21), 24(84), 25(21) |
| **a** | *Sternaspis scutata* | 6(42), 8(21) |
| **16** | **Family-Flabelligeridae** | 10(21), 13(21), 14(42), 15(105), 16(21), 26(21), 28(21), 37(42), 43(42), 44(105), 45(42) |
| **a** | *Brada villosa capensis* | 4(21), 6(21) |
| **b** | *Brada villosa capensis* | 10(21), 35(21), 36(105), 45(42) |
| **17** | **Family-Pectinariidae** | |
| **a** | *Pectinaria koreni cirrata* | 1(105), 44(21) |
| **18** | **Family-Ampharetidae** | |
| **a** | *Ampharete capensis* | 35(42) |
| **19** | **Family-Terebellidae** | |
| **a** | *Terebellides stroemi* | 3(21), 15(105), 17(21), 25(63), 26(21), 38(84), 42(42), 44(21) |
| **b** | *Lysilla ubianensis* | 10(42) |
| **c** | *Pista indica* | 5(21), 24(21), 27(21) |
| **d** | *Terebellobranchia natalensis* | 24(42), 44(21) |
| | **Oligochaeta** | 12(21), 15(12208), 16(105), 17(500), 18(1708), 19(250), 20(167), 25(167) |
| **B** | **CRUSTACEANS** | |
| **1** | **Amphipods** | |
| **a** | *Quadrivisio bengalensis* | 1(125), 5(229), 6(42), 8(21), 15(21), 25(21), 40(42) |
| **b** | *Eriopisa chilkensis* | 12(21), 14(63) |
| **c** | *Grandidierella bonneri* | 1(42), 5(21), 6(21), 24(21) |
| **d** | *Corophium triaenonyx* | 15(21) |
| **e** | Caprillidae | 36(21) |
| **C** | **ISOPODS** | 13(21) |
| **1** | Anthuridae | 25(63), 36(21) |
| | **TANAIDACEANS** | |
| | Tanais cavolini | 4(21), 5(63), 25(21) |
| | Mysids | 17(21) |
| | Cumacea | 36(21) |
| | Sergestidae | 7(84), 21(21) |
| | Decapods | 13(42), 14(21), 15(21), 17(21), 24(21), 25(21), 28(42), 32(21), 33(21), 36(21), 44(21), 45(21) |
| | Lobsters | 29(21) |
| | Benthic copepods | 3(21), 5(21), 10(21), 36(42), 43(21) |

Contd...

Table 3.5.3.18 Contd...

| Sr. No. | Type of Species | Station Number and Number of Species |
|---|---|---|
| | Ostracods | 17(42), 45(42) |
| | **MOLLUSCS** | |
| | **Gastropods** | |
| | *Nassarius trivittatus* | 31(21) |
| | *Teretellidae* | 38(21) |
| | *Solariella lacunella* | 3(21), 6(21), 8(417), 10(21), 19(21), 22(105), 23(21), 26(21), 28(21), 29(42), 33(229), 34(21), 37(42), 39(42), 42(42), 44(21) |
| | | |
| | *Buccinum abyssorum* | 5(21), 7(21) |
| | *Phalium granulatum* | 26(21) |
| | *Epitonium* sp. | 26(21) |
| | *Prunum roscidum* | 13(21) |
| | *Litiopa* sp. | 3(21), 6(84), 13(42), 23(21), 28(21), 38(42), 43(21) |
| | *Colus* sp. | 39(21) |
| | *Dentalium* sp. | 26(42), 39(21), 43(21) |
| | **Bivalves** | |
| | *Cardium* sp. | 26(21), 37(42) |
| | *Cavolina* sp. | 19(125), 33(42), 37(21) |
| | *Tellina* sp. | 28(21), 39(21) |
| | *Bivalve* sp. | 8(21) |
| | **Fishes** | |
| | Juvenile fish | 38(21) |
| | **MISCELLANEOUS GROUPS** | |
| | Ophiuroidea | 33(21) |
| | Flatworms | 6(21) |
| | (Unidentified) Worm | 8(63) |

**Source** : Primary data collected by NIO

## Table 3.5.3.19

### Biodiversity of Benthos in coastal waters November 2000

| Sr. No. | Type of species | Station Number and Number of Specimens Observed |
|---|---|---|
| A | **POLYCHAETES** | |
| 1 | **Family-Aphroditidae** | |
| a | *Sthenelais boa* | 5(21), 10(42), 25(42), 26(21), 37(42), 40(813) |
| 2 | **Family-Hesionidae** | |
| a | *Ancistrosyllis constricta* | 8(21), 12(42), 13(21), 15(21), 22(42), 23(21), 24(21), 25(84), 29(21), 32(21), 39(42), 41(42), 44(21) |
| 3 | **Family-Nereidae** | |
| a | *Dendronereis aestuarina* | 10(21) |
| b | *Platyneris calodonta* | 10(21), 39(21), 41(21) |
| c | *Perinereis cavifrons* | 1(125), 10(42), 40(105) |
| 4 | **Family-Nephthydidae** | |
| a | *Nephthys dibranchis* | 18(21), 19(21), 23(21), 25(21), 26(21), 29(21), 37(42), 39(42), 42(21) |
| 5 | **Family-Glyceridae** | |
| a | *Glycera longipinnis* | 5(84), 11(21), 12(42), 15(63), 19(21), 20(63), 22(84), 24(42), 26(21), 28(42), 36(42) |
| b | *Goniada emerita* | 17(21), 24(21), 36(21), 43(21), 45(21) |
| 6 | **Family-Eunicidae** | |
| a | *Lumbrinereis aberrans* | 6(21), 27(21), 28(84) |
| b | *Lumbrinereis hartmani* | 6(21), 8(21), 9(125), 11(21), 19(21), 20(21), 22(84), 27(21), 29(63), 37(21),39(105), 42(84), 43(21), 44(21), 45(42) |
| c | *Arabella iricolor* | 5(21), 15(21) |
| 7 | **Family-Spionidae** | |
| a | *Prionospio cirrifera* | 7(21), 14(21), 17(21), 18(21) |
| b | *Prionospio pinnata* | 1(146), 3(63), 5(42), 7(21), 8(21), 9(229), 10(8375), 11(416), 12(42), 13(84), 14(42), 15(63), 19(21), 20(84), 22(313), 23(63), 24(126), 25(21), 26(146), 27(63), 28(42), 29(21), 31(21), 32(21), 37(395), 38(21), 39(42), 41(541), 42(125), 43(21), 44(84), 45(42) |
| c | *Prionospio polybranchia* | 7(21), 24(21), 25(21), 26(21), 42(21) |
| d | *Prionospio sexoculata* | 24(21), 26(21) |
| 8 | **Family-Orbiniidae** | |
| a | *Haploscoloplos* sp. | 15(21), 16(21), 24(42), 25(63), 36(42) |
| 9 | **Family-Magelonidae** | |
| a | *Magelona capensis* | 5(792), 6(210), 7(250), 8(21), 15(4085), 22(42), 24(1146), 25(333), 26(708), 27(42), 32(21), 37(354), 42(21) |
| 10 | Family-Psammodrillidae | 7(21), 39(21) |

Contd...

Table 3.5.3.19 Contd...

| Sr. No. | Type of species | Station Number and Number of Specimens Observed |
|---|---|---|
| 11 | **Family-Cirratulidae** | |
| a | *Cirratulus cirratus* | 5(21), 7(21), 17(42), 25(21) |
| 12 | **Family-Paraonidae** | 5(21), 6(21), 15(21), 17(21), 32(21) |
| 13 | **Family-Cossuridae** | |
| a | *Cossura coasta* | 3(21), 5(21), 7(21), 8(42), 9(21), 10(42), 11(270), 12(229), 13(979), 15(42), 26(42), 27(21), 28(42), 29(126), 37(208), 38(21), 42(42) |
| 14 | **Family-Capetellidae** | |
| a | *Capitella capitata* | 7(21), 13(42), 16(42), 37(21), 44(42) |
| b | *Heteromastus bifidus* | 3(42), 12(21), 19(21) |
| c | *Scyphoproctus djibontiensis* | 12(21) |
| 15 | **Family-Maldanidae** | |
| a | *Maldane sarsi* | 12(63), 41(21) |
| 16 | **Family-Sternaspidae** | |
| a | *Sternaspis scutata* | 13(63), 18(21), 24(21), 26(84), 27(21), 37(21), 38(21) |
| 17 | **Family-Flabelligeridae** | 24(21) |
| 18 | **Family-Pectinariidae** | 37(21), 40(21) |
| a | *Pectinaria koreni cirrata* | 22(21) |
| 19 | **Family-Terebellidae** | 18(21) |
| B | **CRUSTACEANS** | |
| 1 | Amphipoda | |
| a | *Quadrivisio bengalensis* | 5(42), 6(63), 8(21), 9(63), 10(291), 11(21), 13(42), 15(63), 17(21), 22(21) |
| b | *Eriopisa chilkensis* | 3(84), 13(21), 14(21), 15(21), 16(21), 25(21) |
| c | *Grandidierella gilesi* | 1(21), 6(21), 7(21), 10(375), 24(84), 43(42) |
| d | *Grandidierella bonneri* | 7(63), 18(21), 19(84) |
| 2 | **ISOPODA** | |
| a | *Cirrolina fluviatilis* | 17(21) |
| b | Anthuridae | 17(42), 45(21) |
| 3 | TANAIDACEANS | 5(21) |
| 4 | Mysidacea | 17(21), 18(21), 19(21), 43(21) |
| 5 | Cumacea | 18(21), 19(63), 22(42) |
| 6 | Decapoda | 5(42), 6(21),20(21), 24(21) |
| 7 | Ostracoda | 25(21) |

Contd...

Table 3.5.3.19 Contd...

| Sr. No. | Type of species | Station Number and Number of Specimens Observed |
|---|---|---|
| C | **MOLLUSCS** | |
| 1 | **Gastropoda** | |
| a | *Solariella* sp. | 3(3270), 6(84), 7(317), 8(688), 13(21), 19(21), 23(84), 25(42), 26(63), 27(63), 29(105), 39(42), 43(146) |
| b | *Gastropod* sp. | 5(1021), 6(125), 7(42), 9(42), 18(104), 22(314), 23(84), 24(146), 26(63), 27(42), 28(210), 36(210), 37(208), 38(354), 42(42), 44(144), 45(125) |
| c | *Dentalium* sp. | 7(84), 13(21), 15(63), 16(146), 18(42), 22(292), 23(42), 24(42), 26(63), 27(375), 28(188), 38(146), 43(42), 44(250), 45(84) |
| d | *Cavolina* sp. | 5(21), 6(84), 8(21), 18(63), 23(21), 25(21), 26(21), 28(63), 37(63), 38(105), 43(21), 44(21), 45(21) |
| 2 | **Bivalves** | |
| a | *Bivalve* sp. | 10(771), 11(42), 12(105), 15(84), 16(21), 19(42), 24(63), 26(63), 31(1813), 37(21), 39(21), 40(21), 41(1729) |
| D | **MISCELLANEOUS GROUPS** | |
| a | Amphioxus | 14(125), 15(21) |
| b | Echinoderm | 23(21) |

**Source** : Primary data collected by NIO

## Table 3.5.3.20

## Species Composition of Commercially Important Fin and Shellfishes of Kerala

| Groups/Scientific Name | Common Name | Vernacular Name |
|---|---|---|
| **FISHES** | | |
| **ELASMOBRANCHS** | | |
| **SHARKS** | | |
| **Family-Hemiscyllidae** | | |
| *Chiloscyllium indicum* | Ridge-back cat shark | Etti, Udumbansravu |
| **Family-Rhiniodontidae** | | |
| *Rhineodon typus* | Whale shark | Thimingalasravu, Pulliudumbu |
| **Family-Stegostomatidae** | | |
| *Stegostoma fasciatum* | Zebra shark | Zebra sravu |
| **Family-Carcharhinidae** | | |
| *Carcharhinus melanopterus* | Black-finned shark, Blacktip shark | Mookansravu |
| *Galeocerdo cuvieri* | Tiger shark | Palsravu |
| *Rhizoprionodon acutus* | Grey dog- shark | Palsravu |
| *Scoliodon laticaudus* | Yellow dog- shark | Pooyi sravu, Alupidiyan |
| **Family-Sphyrnidae** | | |
| *Eusphyra blochii* | Arrow-headed hammer-head shark | Kannankodi |
| *Sphyrna zygaena* | Hammer-head shark | Chattithalayan sravu |
| **Skates** | | |
| **Family-Rhinobatidae** | | |
| **Rhinobatos granulatus** | Granulated shovel-nose-ray | Kalpoonthi |
| *Rhynchobatus djiddensis* | Guitarfish / White spotted | Varithala |
| **Family-Pristidae** | | |
| *Anoxypristis cuspidata* | Pointed saw fish | Makarasravu / Kompansravu |
| **Rays** | | |
| **Family-Trygonidae** | | |
| *Himantura bleekeri* | Whip-tail sting-ray | Thirandi |
| *H. uarnak* | Marbled sting ray | Manalthirandi / Pulliyanthirandi |
| *Hypolophus sephen* | Cowtail ray | Adavalanthirandi |
| **Family-Myliobatidae** | | |
| *Aetobatus narinari* | Spotted eagle-ray | Pulli / Kakkathirandi |
| *Aetomylaeus maculatus* | Batray / Mottled eagle-ray | Kaniyanthirandi |
| *Mobula diabolus* | Lesser devil-ray | Komanthirandi / Koormanthirandi |
| *Rhinoptera javanica* | Javanese cow-ray | Neithirandi |

Contd...

Table 3.5.3.20 Contd...

| Groups/Scientific Name | Common Name | Vernacular Name |
|---|---|---|
| **Shads & Sardines** | | |
| **Family-Clupeidae** | | |
| *Anodontostoma chacunda* | Chacunda gizzard-shad | Thodi |
| *Dussumieria acuta* | Rainbow sardine | Kokkola chala |
| *Escualosa thoracata* | White sardine | Veloori / Chooda |
| *Hilsa ilisha* | Indian shad / Hilsa shad | Hilsa |
| *H. toli* | Chinese herring / Toli shad | Hilsa |
| *Ilisha elongata* | Bigeye ilisha / Slender shad | Puvali |
| *Opisthopterus tardoore* | Long-finned herring | Thada / Ambatta |
| *Pellona ditchela* | Indian pellona | Kannanmathi |
| *Sardinella fimbriata* | Fringe-scale sardine | Chalamathi / Karichala |
| *S. albella* | Short-body sardine | Parappanchala / Vattamathi |
| *S. longiceps* | Indian oil-sardine | Neichala / Mathi / Nallamathi |
| **Anchovies** | | |
| **Family-Engrantidae** | | |
| *Coilia dussumieri* | Gold-spotted granadier-anchovy | Kathimanangu / Valamanangu |
| *Stolephorus bataviensis* | Batavian anchovy / Whitebait | Kozhuva / Netholi |
| *Thryssa malabarica* | Malabar anchovy | Kavumanangu |
| *T. mystax* | Moustached anchovy | Nedumanangu |
| **Wolf herring** | | |
| **Family-Chirocentridae** | | |
| *Chirocentrus dorab* | Dorab wolf-herring | Mulluvala |
| *C. nudus* | White-fin wolf-herring | Mulluvala |
| **Milk fishes** | | |
| **Family-Chanidae** | | |
| *Chanos chanos* | Milk fish | Poomeen |
| **Lizard fishes** | | |
| **Family-Synodontidae** | | |
| *Saurida tumbil* | Greater lizard-fish | Aranameen / Uluvachi / Veempili |
| **Catfishes** | | |
| **Family-Aridae** | | |
| *Arius dussumieri* | Dussumier's cat-fish | Valiya etta |
| *A. jella* | Small-eye cat-fish | Vella etta |
| *A. sona* | Dusky cat-fish | Navetta |
| *A. thalassinus* | Giant cat-fish | Komanetta |

Contd...

Table 3.5.3.20 Contd...

| Groups/Scientific Name | Common Name | Vernacular Name |
|---|---|---|
| **Eels & morays** | | |
| **Family-Muraenidae** | | |
| *Gymnothorax fimbriatus* | Black eel / Dark-spotted moray | Kariaarel / Vlangu |
| **Family-Muraenesocidae** | | |
| *Congresox talabanoides* | Common eel / Indian pike-conger | Aarel / Pambumeen |
| **Fullbeaks (Gar fishes)** | | |
| **Family-Belonidae** | | |
| *Strongylura stongylura* | Round-tail alligator-gar | Kolan / Kola / Koyala |
| **Halfbeaks** | | |
| **Family-Hemiramphidae** | | |
| *Rhynchorhamphus georgii* | Long-billed halfbeak | Pookola / Kolan / Koyala |
| **Flyingfishes** | | |
| **Family-Exocoetidae** | | |
| *Cypselurus cyanopterus* | Blue-spot flyingfish | Paravakola |
| *Exocoetus volitans* | Two-winged flyingfish | Paravakola |
| **Barracuda** | | |
| **Family-Sphyraenidae** | | |
| *Sphyraena jello* | Banded baracuda | Cheelavoo / Thinda / Poolavu |
| **Mullets** | | |
| **Family-Mugilidae** | | |
| *Liza parsia* | Gold-spot mullet | Malan |
| *Mugil cephalus* | Flat-head grey mullet | Thirutha / Soda kanambu |
| *Valamugil speigleri* | Speigler's grey mullet | Kanambu / Malan |
| **Threadfins** | | |
| **Family-Polynemidae** | | |
| *Eleutheronema tetradactylum* | Indian salmon / Four-finger | Vazhameen / Thamuthi |
| *Polynemus heptadactylus* | Seven-finger thread-fin | Nurakudian / Vazhameen |
| *Polynemus indicus* | Indian thread-fin | Cheeral / Vazhameen |
| **Sea perches** | | |
| **Family-Ambassidae** | | |
| *Ambassis commersoni* | Glassy perchlet | Nandan / Vadakken veloori |
| **Family-Centropomidae** | | |
| *Lates calcarifer* | Giant sea-perch | Narimeen / Kodumthala / Kalanchi |
| **Reef cods** | | |
| **Family-Serranidae** | | |
| *Epinephelus malabaricus* | Malabar reef-cod | Kalava / Varayan kalava |
| *E. melanostigma* | Spotted reef-cod | Kalava / Kadal karoop / Pullikalava |

Contd...

**Table 3.5.3.20 Contd...**

| Groups/Scientific Name | Common Name | Vernacular Name |
|---|---|---|
| *E. morrhua* | Banded-cheek reef-cod | Morikalava |
| *Epinephelus tauvina* | Greasy reef-cod | Pannikalava |
| **Tiger perches** | | |
| **Family-Tereponidae** | | |
| *Pelates quadrilineatus* | Four-lined tiger perch | Keeli / Keeri |
| *Therapon jarbua* | Crescent tiger perch | Keeri / Varayankeeri |
| **Whiting** | | |
| **Family-Sillaginidae** | | |
| *Sillago sihama* | Silver whiting | Kathiran / Kalimeen / Pooyan |
| **Whitefish** | | |
| **Family-Lactiridae** | | |
| *Lactarius lactarius* | Whitefish / Big-jawed jumper | Parava / Adavu |
| **Cobias** | | |
| **Family-Rachycentridae** | | |
| *Rachycentron canadus* | Blank king-fish / Cobia | Kadalvaral |
| **Carangids** | | |
| **Family-Carangidae** | | |
| *Alepes djeddaba* | Djeddaba trevally | Ovupara / Vattapara |
| *A. para* | Golden scad | Para |
| *Atropus atropus* | Kuweh trevally | Kannipara |
| *Caranx sexfasciatus* | Dusky trevally / Six-banded trevally | Varayanpara |
| *C. melampygus* | Black-tipped trevally | Velpara |
| *Decapterus russelli* | Russel's scad | Champan / Kanniayala / Kozhuchala / Thiriyan |
| *Megalaspis cordyla* | Hardtail scad | Kanayan para / Vangada / Kanameen |
| *Scomberoides lysan* | Talang queen-fish / Leather skin | Palakameen / Palameen / Pola |
| *Selar crumenophthalmus* | Bigeye scad | Kanni / Champan |
| *Trachinotus blochii* | Snubnose pompano | Valavodu |
| **Black pomfret** | | |
| *Parastromateus niger* | Black pomfret | Karuthavoli / Machan |
| **Dolphin fish** | | |
| **Family-Coryphaenidae** | | |
| *Coryphaena hippurus* | Common dolphin-fish | Chainkaver / Naeimeen |
| **Snappers** | | |
| **Family-Lutjanidae** | | |
| *Lutjanus argentimaculatus* | Mangrove red-snapper | Chemballi |
| *L. malabaricus* | Malabar red-snapper | Chemballi |

Contd...

Table 3.5.3.20 Contd...

| Groups/Scientific Name | Common Name | Vernacular Name |
|---|---|---|
| **Threadfin breams** | | |
| **Family-Nemipteridae** | | |
| *Nemipterus japonicus* | Japanese thread-fin-breams | Kilimeen / Chenkalava / Puthiaplakora |
| **Tripletail** | | |
| **Family-Lobotidae** | | |
| *Lobotes surinamensis* | Brown tripletail | Parrandee / Karuppatti / Aeri |
| **Silverbelly (Ponyfish)** | | |
| **Family-Leiognathidae** | | |
| *Leiognathus splendens* | Pony fish | Karal / Mullan / Nallamullan |
| **Mojarra** | | |
| **Family-Gerreidae** | | |
| *Gerres filamentosus* | Whip-fin mojarra | Prachil / Pranjil / Prayal |
| **Grunters** | | |
| **Family-Haemulidae** | | |
| *Pomadasys hasta* | Lined silver-grunt | Karukaruppan / Korkka |
| *Pomadasys maculatus* | Blotched grunt | Eruttumkora / Korkka |
| **Croakers** | | |
| **Family-Sciaenidae** | | |
| *Johnieops aneus* | Grey-fin croaker | Cherukora / Chemkuttan |
| *J. sina* | Sin croaker | Kora / Muttikora |
| *J. vogleri* | Drab croaker | Pallikora |
| *Johnius dussumieri* | Bearded croaker | Cherukora |
| *Otolithes cuvieri* | Lesser tiger-toothed croaker | Pallikora / Pallimeen |
| *Otolithoides biauritus* | Bronze croaker | Kora |
| *Protonibea diacanthus* | Spotted croaker / Jewfish | Katla |
| **Emperor bream** | | |
| **Family-Lethrinidae** | | |
| *Lethrinus frenatus* | Bridled emperor-bream | Chemballi / Pullivalameen / Valameen |
| **Silver bream** | | |
| **Family-Sparidae** | | |
| *Acanthopagrus berda* | Picnic silver-bream | Aree |
| **Goat fish** | | |
| **Family-Mullidae** | | |
| *Upeneus sulphureus* | Yellow goat-fish | Keerimeen / Killivarandu |
| **Spade fish** | | |
| **Family-Ephippididae** | | |
| *Tripterodon orbis* | Common spade-fish | Thavanakary |

Contd...

Table 3.5.3.20 Contd...

| Groups/Scientific Name | Common Name | Vernacular Name |
|---|---|---|
| **Sickle fish** | | |
| **Family-Drepanidae** | | |
| *Drepane punctata* | Spotted sickle-fish | Painthi / Parinthumeen |
| **Butter fish** | | |
| **Family-Scatophagidae** | | |
| *Scatophagus argus* | Spotted butter-fish | Nutchara / Natchaka |
| **Ribbon fishes (Hairtails)** | | |
| **Family-Trichiunidae** | | |
| *Lepturacanthus savala* | Silver ribbon-fish / Small-head hair tail | Chunnambuvala / Kasithalayan / Pampada |
| *Trichiurus lepturus* | Grey ribbon-fish / Large-head hair tail | Vellithalayan |
| **Tunas, Mackerel & Seer fishes** | | |
| **Family-Scombridae** | | |
| *Auxis thazard* | Frigate tuna | Elichoora |
| *Euthynnus affinis* | Little tuna | Choora / Sooda / Kudutha |
| *Thunnus albacares* | Yellowfin tuna | Manjachoora |
| *Rastrelliger kanagurta* | Indian mackerel | Aiyala |
| *Scomberomorus commerson* | Narrow-barred seer-fish | Neimeen / Varimeen / Ayakora |
| *S. guttatus* | Indo-pacific seer-fish | Varimeen |
| **Sail fish (Marlin)** | | |
| **Family-Istiophoridae** | | |
| *Istiophorus platypterus* | Sail fish | Olameen / Mayilmeen / Olapadavan |
| **Sword fish** | | |
| **Family-Xiphiidae** | | |
| *Xiphias gladius* | Sword fish | Vallmeen |
| **White pomfrets** | | |
| **Family-Stromateidae** | | |
| *Pampus argenteus* | Silver pomfret | Veluthavoli |
| *Pampus chinensis* | Chinese pomfret | Veluthavoli |
| **Flatheads** | | |
| **Family-Platicephalidae** | | |
| *Platycephalus indicus* | Indian flat-head | Eriyan / Orathal / Vettan / Kaivetti |
| **Flatfishes** | | |
| **Family-Psettodidae** | | |
| *Psettodes erumei* | Indian halibut | Ayirampalli / Paanjukadiyan |
| *Pseudorhombus arsius* | Large-toothed flounder | Nallamanthal / Vattathi |

Contd...

Table 3.5.3.20 Contd...

| Groups/Scientific Name | Common Name | Vernacular Name |
|---|---|---|
| **Family-Paralichthyidae** | | |
| *Cynoglossus dubius* | Tongue sole | Nangu / Manthal / Elapatti |
| *C. macrostomus* | Malabar tongue-sole | Nangu / Manthal |
| **CRUSTACEANS** | | |
| **Penaeid prawns** | | |
| **Family-Penaeidae** | | |
| *Metapenaeus affinis* | Jinga prawn / Brown shrimp | Kazhanthan chemmeen |
| *M. dobsoni* | Flower-tail prawn | Poovalan chemmeen |
| *M. monoceros* | Speckled prawn / Brown shrimp | Choodan chemmeen |
| *Parapenaeopsis stylifera* | Kiddi prawn | Karikkadi chemmeen |
| *Penaeus indicus* | Indian white-prawn | Naran chemmeen / Vella chemmeen |
| *P. japonicus* | Kuruma prawn / Bamboo flower | Flower |
| *P. monodon* | Giant tiger-prawn / Black tiger | Kara chemmeen |
| *P. semisulcatus* | Green tiger-prawn / Flower | Kara chemmeen |
| **Lobsters** | | |
| **Family-Palinuridae** | | |
| *Panulirus polyphagus* | Rock lobster / Banded spiny-lobster | Chittakonchan / Kadalkonchu |
| **Family-Scyllaridae** | | |
| *Thenus orientalis* | Mud / Sand lobster | Adippan |
| **Crabs** | | |
| **Family-Portunidae** | | |
| *Portunus pelagicus* | Reticulate crab / Blue crab | Kavalan njandu |
| *P. sanguinolentus* | Spotteed crab | Kavalan njandu |
| *Charybdis cruciata* | Cross crab | Kurisa njandu |
| *Scylla serrata* | Green mud-crab | Njandu |
| **Stomatopods** | | |
| *Oratosquilla nepa* | Mantis shrimp | Chelli |
| **MOLLUSCS** | | |
| **Gastropod** | | |
| **Family-Vasidae** | | |
| *Xancus pyrum* | Sacred chank | Sankh |
| **Bivalves** | | |
| **Family-Ostreidae** | | |
| *Crassostrea madrasensis* | Edible oyster | Muringa |

Contd...

**Table 3.5.3.20 Contd...**

| Groups/Scientific Name | Common Name | Vernacular Name |
|---|---|---|
| **Family-Veneridae** | | |
| *Villorita cyprinoides* | Black clam | Karuthakakka |
| *Meretrix meretrix* | Yellow clam | Manja kakka |
| *M. casta* | Yellow clam | Manja kakka |
| *Marica opima* | clam | Poovankakka |
| *Paphia malabarica* | Textile clam | Poovankakka |
| **Family-Mytillidae** | | |
| *Perna indica* | Brown mussel | Chippi |
| *P. viridis* | Green mussel | Kallummekaya |
| **Cephalopods** | | |
| *Sepia aculeata* | Needle cuttle-fish | Kallankanava |
| *S. pharaonis* | Pharaoh cuttle-fish | Kallankanava |
| *Sepiella inermis* | Spineless cuttle-fish | Kallankanava |
| *Loligo duvaucelli* | Indian squid | Koonthal / Olakkanava |
| *Doryteuthis spp.* | Arrow squid | Soochikkanava |
| *Sepioteuthis lessoniana* | Palk bay squid / Bigfin reef-squid | Sikkandikkanava |
| *Octopus spp.* | Octopus | Neerali / Kinavalli |

**Source**: CMFRI

**Table 3.5.3.21**

**Endangered and Vulnerable Fauna of Backwaters of GKR**

| Species Name | Common Name | Status |
|---|---|---|
| *Marobrachium rosenbergii* | Shell fish | Endangered |
| *Macrobrachium dobsoni* | Prawn | Vulnerable |
| *Scylla serata* | Crab | Vulnerable |

**Source**: Data Collected by NIO

**Table 3.5.3.22**

**Endangered and Vulnerable Marine Fauna**

| Sr. No. | Species Name | Common Name | Status |
|---|---|---|---|
| 1 | *Rhiniodon typus* | Finfishes | Endangered |
| 2 | *Chelonia mydas* | Sea Turtles | Endangered |
| 3 | *Tachysurus dussumieri* | Finfishes | Vulnerable |
| 4 | *T. tenuispinis* | Finfishes | Vulnerable |
| 5 | *T. serratus* | Finfishes | Vulnerable |
| 6 | *T. thalassinus* | Finfishes | Vulnerable |
| 7 | *Lactarius lactarius* | Finfishes | Vulnerable |
| 8 | *Platycephalus maculipinna* | Finfishes | Vulnerable |
| 9 | *Panulirus homarus* | Spiny Lobster | Vulnerable |
| 10 | *P. pencillatus* | Spiny Lobster | Vulnerable |
| 11 | *P. longipes* | Spiny Lobster | Vulnerable |
| 12 | *P. polyphagus* | Spiny Lobster | Vulnerable |
| 13 | *P. ornatus* | Spiny Lobster | Vulnerable |
| 14 | *Solenocera hextii* | Deep Sea Prawns | Vulnerable |
| 15 | *Hetrocarpus woodmasoni* | Deep Sea Prawns | Vulnerable |
| 16 | *Aristeus alococki* | Deep Sea Prawns | Vulnerable |
| 17 | *Metapenaeus andamanensis* | Deep Sea Prawns | Vulnerable |
| 18 | *Puerulus sewelli* | Deep Sea Lobsters | Vulnerable |
| 19 | *Palinustus mossambicus* | Deep Sea Lobsters | Vulnerable |

**Source** : Data Collected by NIO

## Table 3.5.3.23

## Migratory Marine Fishes to Vembanad Lake

| Sr. No. | Euryhaline Marine Fishes | Stenohaline Marine Fishes |
|---|---|---|
| 1 | *Dasyatis (P.)sephen* | *Dasyatis (H) uarnak* |
| 2 | *Elops machanata* | *Thysoidea macrurus* |
| 3 | *Muraenesox bagio* | *Dussumieria acuta* |
| 4 | *Pisodonophis boro* | *Sardinella (S) longiceps* |
| 5 | *Escualosa thoracata* | *S.(c)gibbosa* |
| 6 | *Nematulosa nasus* | *Stolephorus indicus* |
| 7 | *Anodontostomachacunda* | *Thryssa setirostris* |
| 8 | *Ilisha sirishai melastoma* | *Saurida undosquamis* |
| 9 | *Stolephorus commersonii* | *Rhynchorhamphus georgii* |
| 10 | *S. waitei* | *Megalaspis cordyla* |
| 11 | *S. insularis* | *Alectis indicus* |
| 12 | *Thryssa mystax* | *Alepes djeddaba* |
| 13 | *T. purava* | *Scomberoides tala* |
| 14 | *T. kammalensis* | *S. tol* |
| 15 | *Chanos chanos* | *Trachinotus blochil* |
| 16 | *Zenarchopteros dispar* | *Lutjanus fulviflamma* |
| 17 | *Strongylura leiura* | *L. russelli* |
| 18 | *Tylosurus crocodilus* | *L. rivulatus* |
| 19 | *Gambusia affinis patruelis* | *Gerres abbreviatus* |
| 20 | *Atherina duodecimalis* | *Plectorhynchus nigrus* |
| 21 | *Platycephalus indicus* | *Lethrinus microdon* |
| 22 | *Lates calcarifer* | *Mylio berda* |
| 23 | *Ambassis commersoni* | *Protonibea diacanthus* |
| 24 | *Epinephelus tauvina* | *Johnius (J) belangerri* |
| 25 | *Carangoides praeustus* | *Upeneus(U)sulphureus* |
| 26 | *Lutianus johni* | *U. vittatus* |
| 27 | *Pomadasya hasta* | *Parupeneus indicus* |
| 28 | *Drepane punctata* | *Valamugil seheli* |
| 29 | *Liza subveridis* | *V. speigleri* |
| 30 | *Sphyraena jello* | *Eleotris fusca* |
| 31 | *Eleutheronema tetradactylum* | *Butis butis* |

Contd...

Table 3.5.3.23 Contd...

| Sr. No. | Euryhaline Marine Fishes | Stenohaline Marine Fishes |
|---|---|---|
| 32 | *Awaous stamineus* | *Bunaka gyrinoideas* |
| 33 | *Accentrogobius viridipunctata ceninus* | *Gobiopsis macrostomus* |
| 34 | *Siganus javus* | *Taenioides buchanani* |
| 35 | *S. canaliculatus* | *T. cirratus* |
| 36 | *Pseudorhombus arsius* | *Trypauchen vagina* |
| 37 | *Tricanthus brevirostris* | *Acanthurus matoides* |
| 38 | *Leiognathus splendens* | *Sigamus lineatus* |
| 39 | *Secutor ruconius.* | *Synbranchus bengalensis* |
| 40 | | *Solea ovata* |
| 41 | | *Synaptura commersoniana* |
| 42 | | *Cynoglossus bilineatus* |
| 43 | | *Tetraodon fluviatilis* |
| 44 | | *Leiognathus bindus* |
| 45 | | *L. daura* |
| 46 | | *L. berbis* |
| 47 | | *Secutor ruconius* |
| 48 | | *Gazza minuta* |

**Source:** Secondary data collected by NIO

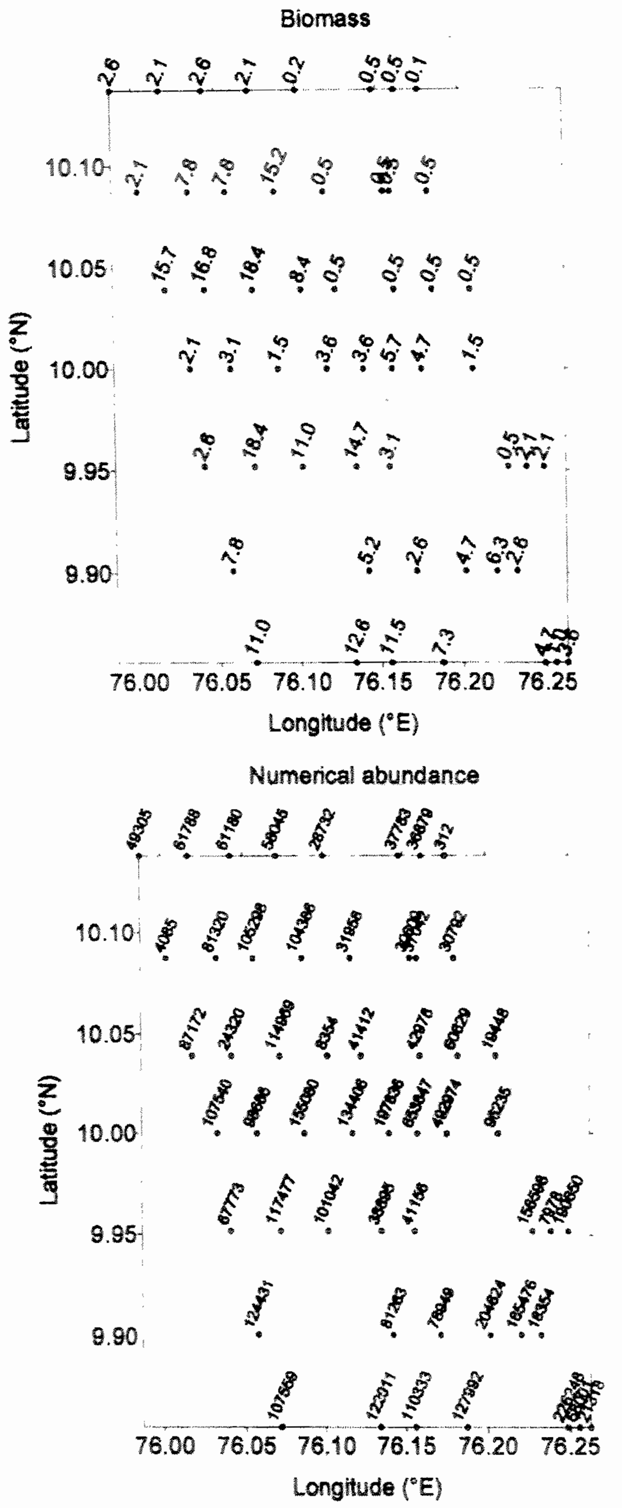
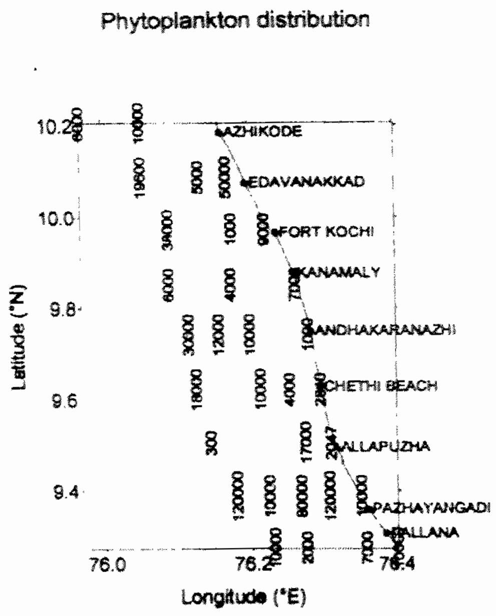
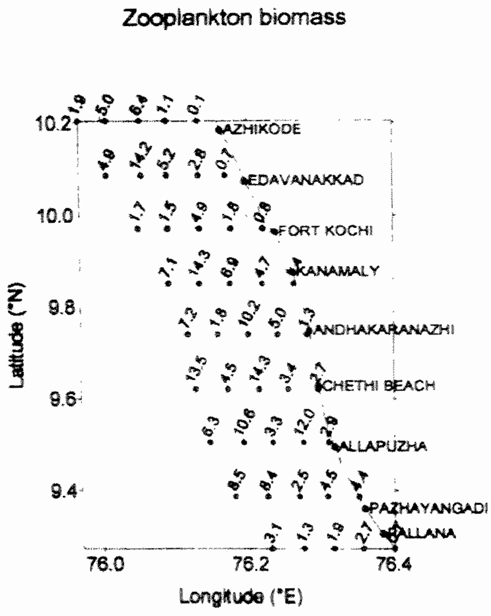



Fig. 3.5.3.1 : Distribution of Zooplankton Biomass (ml/100m$^3$) and Numerical Abundance (No./100m$^3$) in Coastal Waters during October, 1997



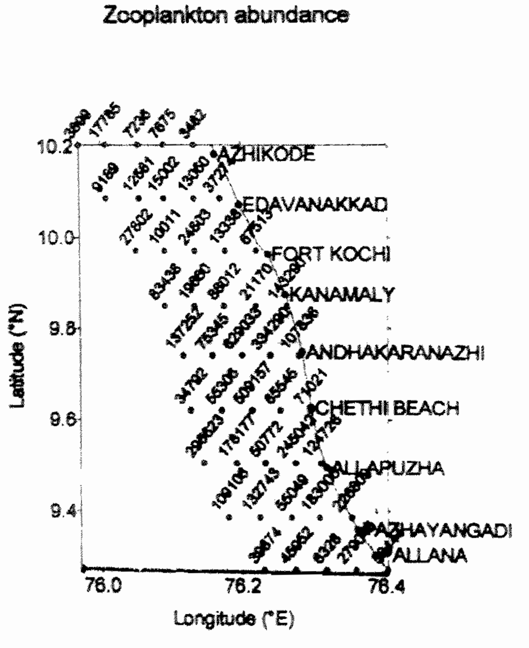




**Fig. 3.5.3.2 : Distribution of Phytoplankton (no/L), Zooplankton Biomass (ml/100m$^3$) and Zooplankton Abundance (no./100m$^3$) in Coastal Waters during February, 1999**

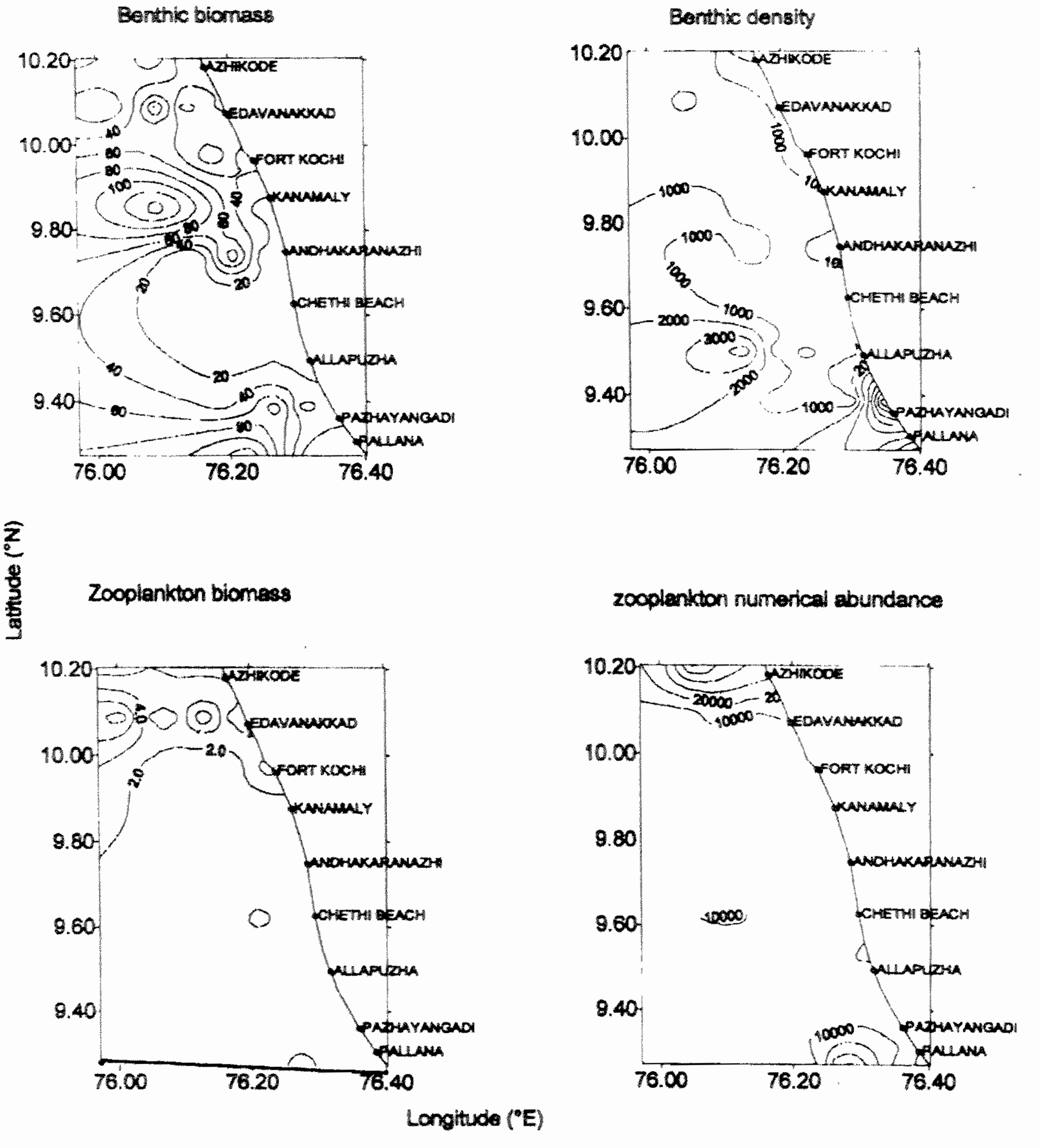



Fig. 3.5.3.3 : Benthic Biomass ($g/m^2$), Benthic Density ($No./m^2$), Zooplankton Biomass ($ml/100m^3$) and Numerical Abundance of Zooplankton ($No./100m^3$) during November, 2000

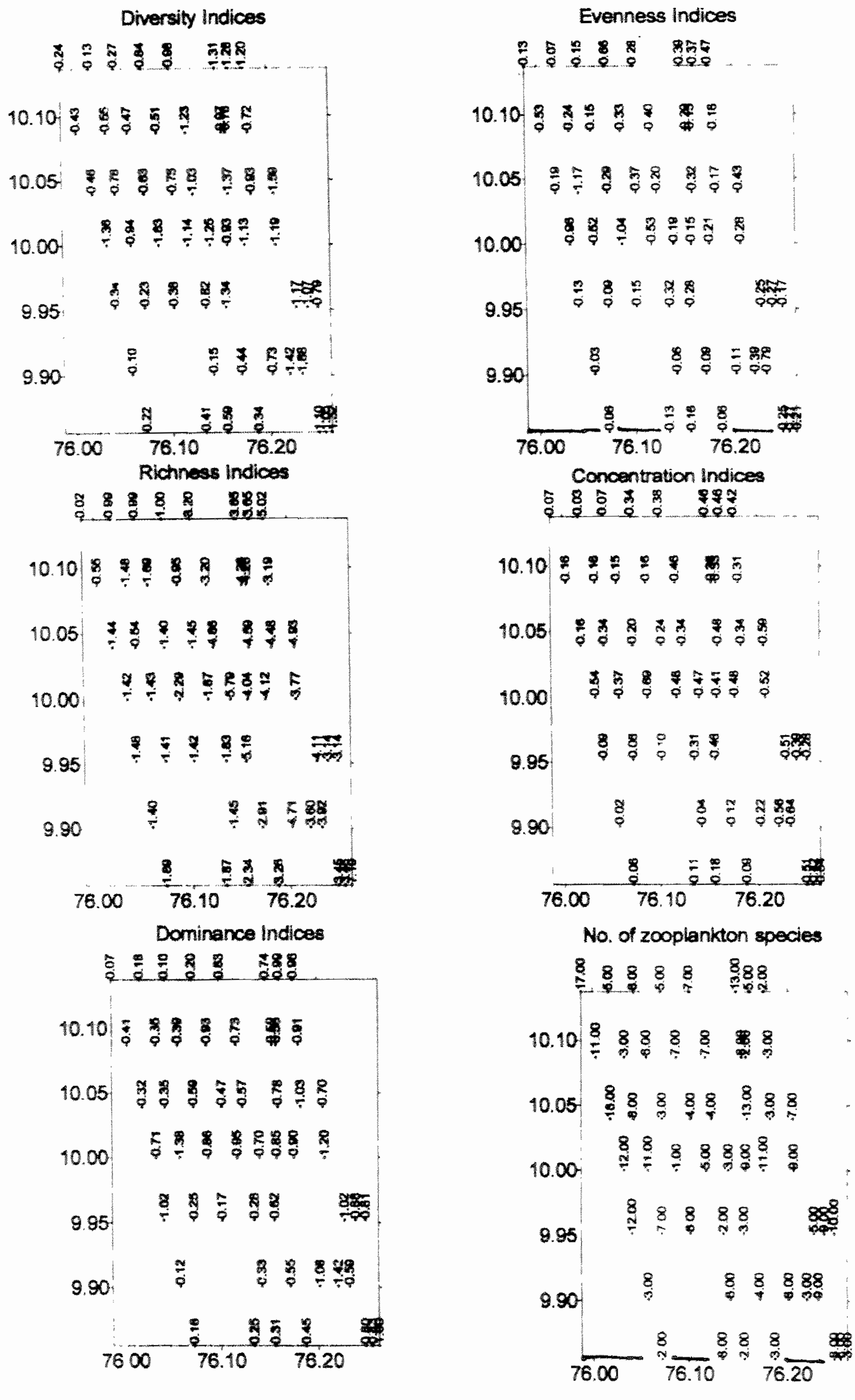



Fig. 3.5.3.4 : Horizontal Distribution of Diversity, Evenness, Richness, Concentration, Dominance Indices and No. of Zooplankton Species during October, 1997

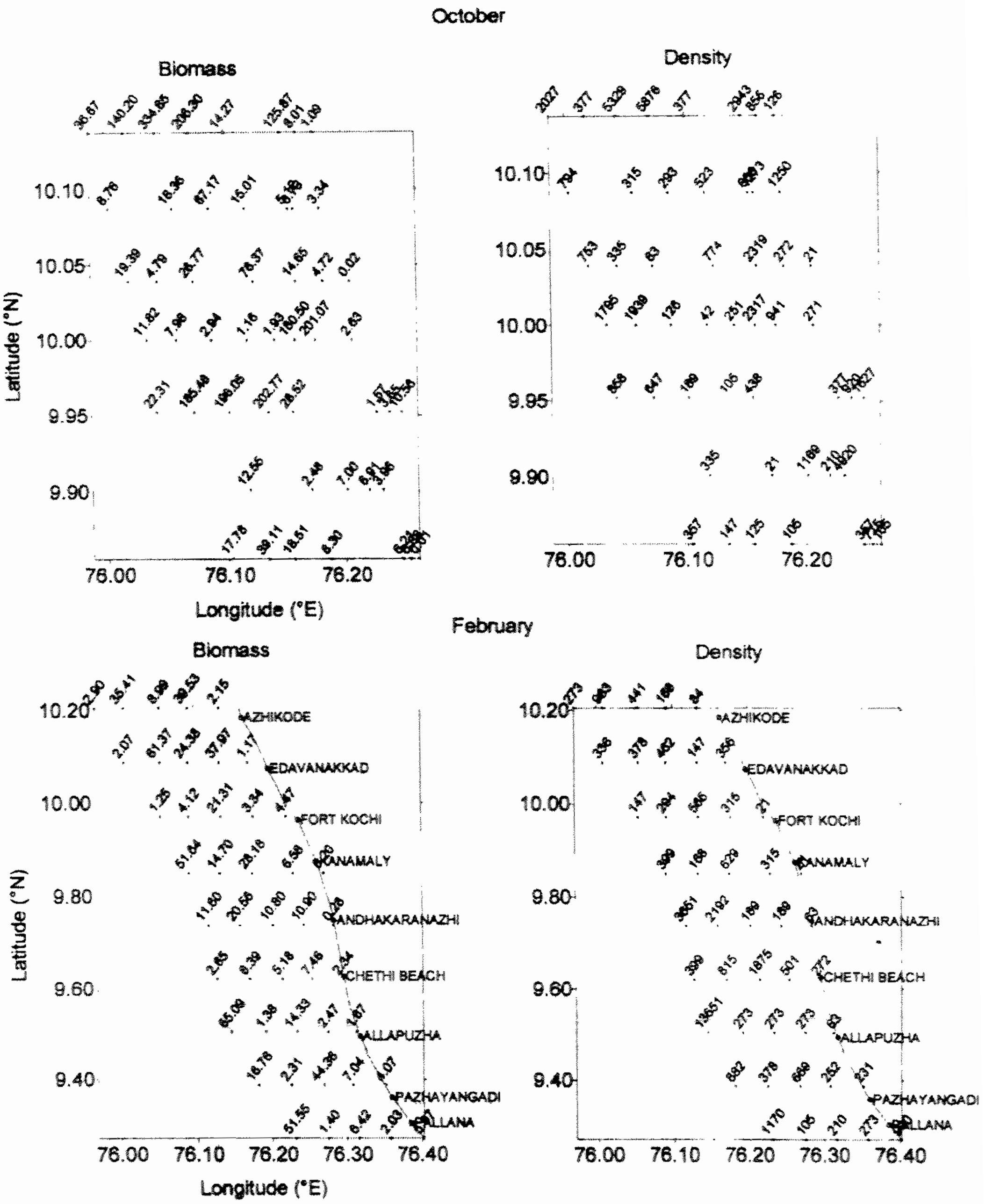



**Fig. 3.5.3.5 : Distribution of Benthic Biomass (g/m$^2$) and Benthic Density (No./m$^2$) during October and February in Coastal Waters**

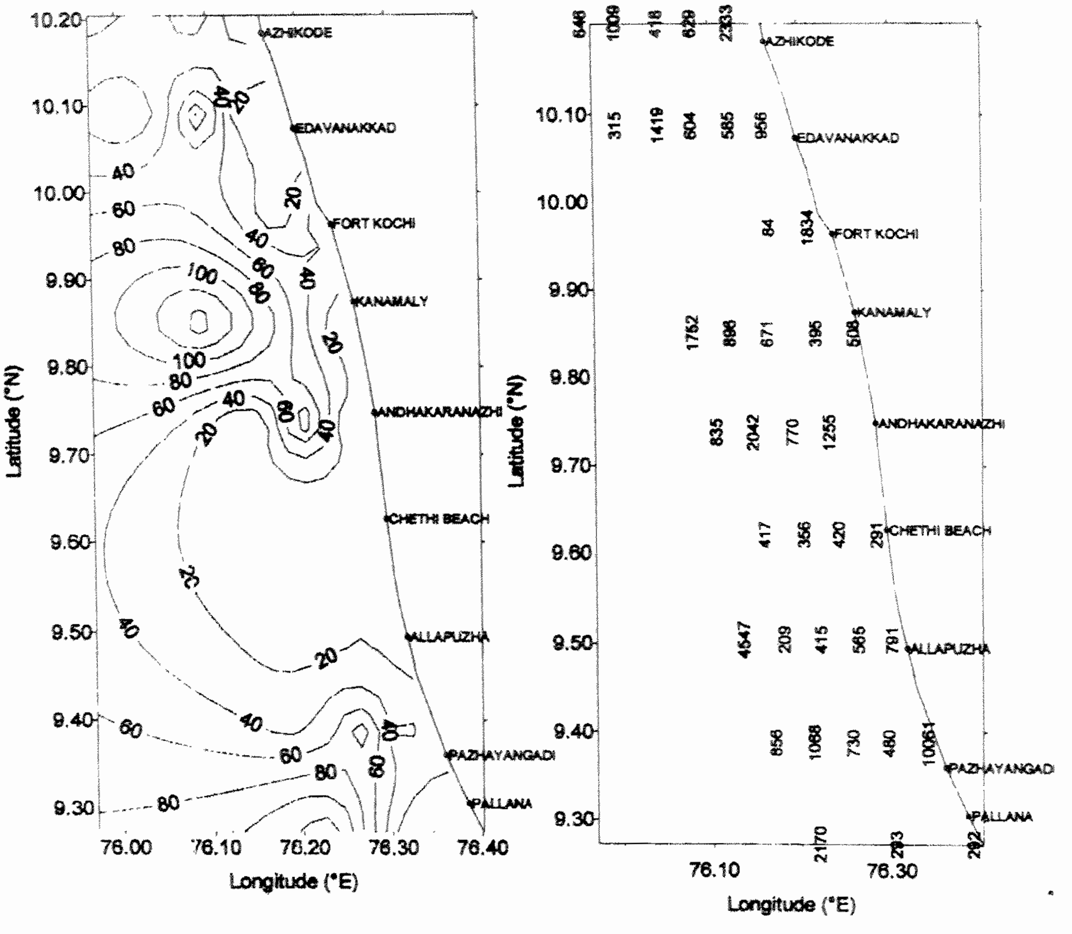


Fig. 3.5.3.6 : Distribution of Benthic Biomass (g/m$^2$) and Benthic Density (No./m$^2$) during November 2000

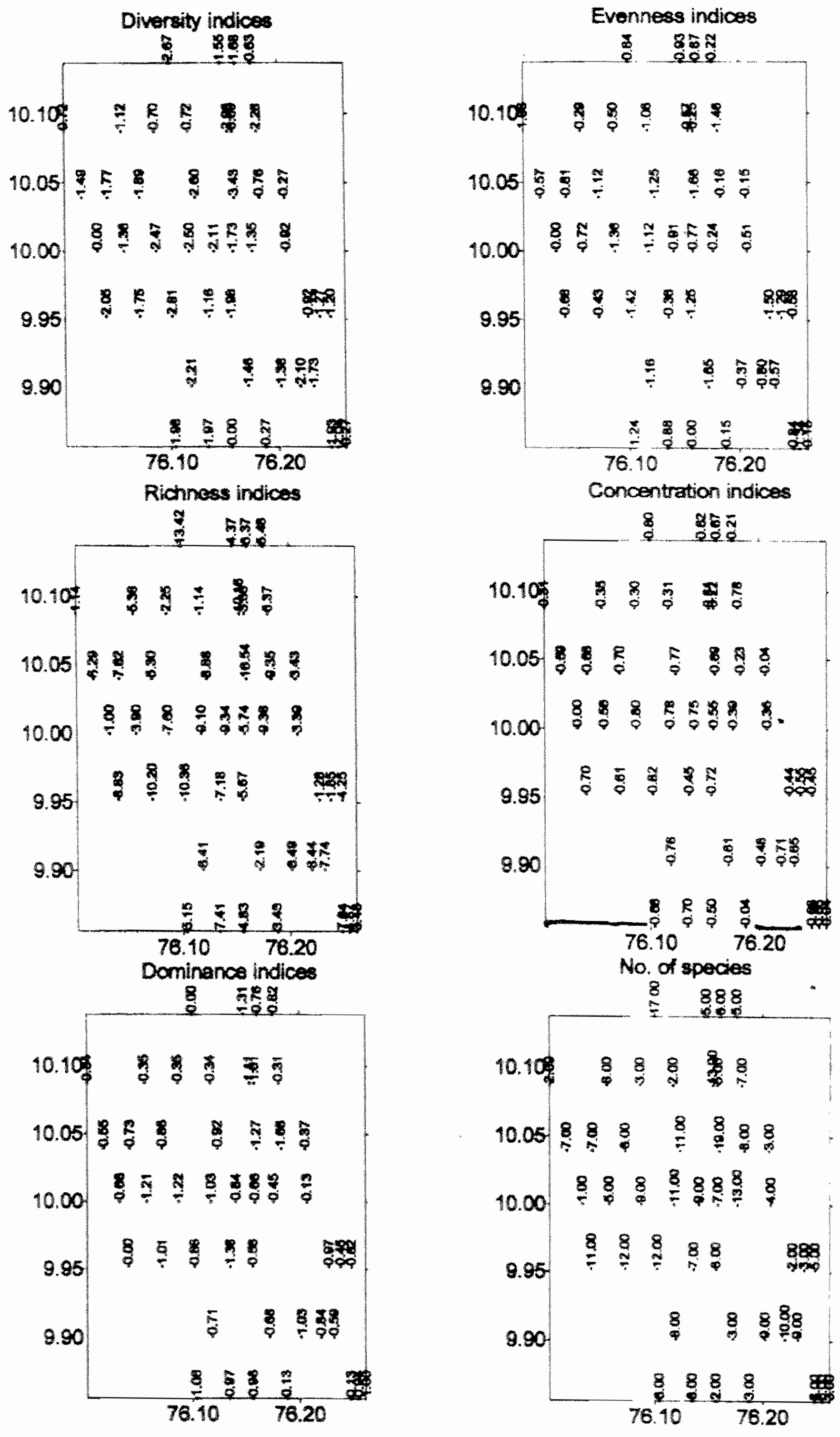



Fig. 3.5.3.7 : Horizontal Distribution of Diversity, Evenness, Richness, Concentration, Dominance Indices and No. of Benthos during October, 1997

## 3.6 Socio-Economic Environment

### 3.6.1 Methodology for Estimation of Quality of Life Indices

#### 3.6.1.1 Cumulative Quality of Life Index

The quality of life in a given region is a function of the objective conditions and subjective attitudes of the population in the area of concern. The objective conditions are defined as numerically measurable artifacts of a physical event, sociological event or economic event. Objective conditions may be defined by numbers, which stand for a given quantity of a variable of interest so long as it is independent of subjective opinion. The subjective attitudes are primarily concerned with affective and cognitive dimensions and are specifically concerned with how aspects of cognition vary as objective conditions vary.

Objective and subjective quality of life of the region have been estimated using the data collected through a socioeconomic survey for which about 20% of the total number of wards in each panchayath/municipality/corporation were selected on a random basis. From each selected ward, 5% of the households were selected again randomly. Thus a total of 17463 households covering all the panchayaths, municipalities and corporation in GKR were included in the socio-economic survey studied. The approach adopted for the socioeconomic survey is elaborated in the **Fig. 3.6.1.1.**

In order to estimate the quality of life (QOL) of the people living in the region, the selected parameters were given weightages using Delphi procedure and weightages were normalized to obtain the objective and subjective quality of life levels. The QOL of the region was estimated on the basis of objective conditions prevailing in the households and subjective attitudes of the people. Accordingly, objective quality of life (QOLo) and subjective quality of life (QOLs) levels were determined as indices ranging between zero and one. The cumulative quality of life (QOLc) was calculated as an average of the above two.

A list of selected parameters is given in **Table 3.6.1.1** alongwith assigned weightages. The basis for assigning weights to individual parameters is discussed below:

1. **Housing -** First the average plinth area of houses was calculated and based on the multiples of that average, points as 1.0, 0.8, 0.5, 0.4 and zero for 3 x average, 2 x average, 1.0 x average and 0.2 x average were assigned respectively. Further, houses were classified and accordingly values were assigned as: kutcha houses-0.4, semi pucca-0.7 and pucca-1.0

2. **Clothing -** Percapita expenditure for clothing was determined accordingly, values 0.4, 0.6, 0.8, and 1 were assigned.

3. **Education –** Based on the literacy level the points assigned were:
   Illiterate, Pre-primary and Primary -0.0, Upper primary and high School - 0.4, Higher secondary and Graduation - 0.6 and Post graduation and above (Professional) - 1.0

4. **Culture** – In the survey form, for each box 0.1 points were assigned.

5. **Social Security -** For two types of savings, 1.0 point and for one type of saving 0.5 point were assigned while for no saving the value was 0.

6. **Human rights -** If people cast their vote, 1.0 point was assigned otherwise it was 0.

7. **Employment -** If nobody is employed, 0 points were assigned, while if one 0.0 points, and for more than one person were employed, 0.5 & 1.0 points were assigned.

8. **Transport and communication -** For bicycle, 0.5 and for other vehicles 1.0 point were assigned, other wise 0. For telephone owned, 1.0 point was assigned otherwise 0.

9. **Energy -** Out of 3% weightage, 1.5% each weightage was given to lighting and cooking. Under cooking, for firewood 0.5, for LPG 0.8 and for electricity 1 point were assigned. Under Lighting, for the electrified house - 1 point otherwise 0 points were assigned.

10. **Sanitation -** Type of latrine was selected. For open latrine - 0, pit latrine - 0.5, and for pucca latrine - 1 point were assigned.

11. **Water supply -** Source: If unprotected–0.0, untreated water/well water–0.8, and for treated water 1.0 point were assigned.

12. **Health -** For members with permanent/occupational diseases in the household - 0.2 points and for members with common diseases - 0.5 points were assigned.

13. **Environment -** For physical environmental problem - .0, for two physical environmental problems - 0.7 and for more than two problems 0.4 points were assigned.

14. **Food and nutrition -** For per capita calorific value 2000 Cal - 0.5, 2000-2400 Cal - 0.8 and above 2400 Cal-1 points were assigned. The protein value of food items was determined and points as 0.5, 0.8 and 1.0 for below 60% of minimum required, above 60% of minimum required and 10% of the minimum required and below respectively were assigned.

In addition to the above indices, two new indices of quality of life as Family Assets and Facilities (FAF) index and Accessibility index were prepared.

### 3.6.1.2 FAF Index

Unlike the other parts of the country, Kerala is unique in having the highest population density and a mixed type of economic status of population. It was not possible to classify the population or households traditionally into low, middle and high-income groups spatially. However, it could be classified based on the family assets and facilities (FAF) of households. For this purpose, the assets and facilities in a household were rated as an index based on their current prices. A maximum of 15 items were selected as a standard and a household was rated as having an index expressed as:

FAF index = Total cost of selected 15 items in a household / Total cost of 15 selected standard items

The items chosen for the FAF index calculation were radio, TV, mixer-grinder, washing machine, fridge, cooking range, microwave oven, pressure cooker, scooter, motor bike, car/jeep, cycle, computer, telephone, fax machine, water pump, vacuum cleaner etc.

Further based on the FAF index of households, it was possible to classify the households into three strata, namely; Low Income Group (LIG), Middle Income Group (MIG) and High Income Group (HIG), with FAF index in the range 0 - 0.1 were as LIG, 0.1 - 0.5 as MIG, > 0.5 - 1.0 as HIG. The percentage of households in each FAF index range is given in **Table 3.6.1.2,** whereas district-wise breakup is projected in **Fig. 3.6.1.2**

### 3.6.1.3 Accessibility Index

The accessibility to the infrastructure facilities available in the region was considered an important parameter contributes to the objective quality of life of the community. Since it also influences the subjective attitudes of people, it has a bearing upon the subjective QOL also. Therefore, a comparison of the accessibility of people to different infrastructure facilities will give a critical support to the objective and subjective QOL determined by household survey. The accessibility of people to different infrastructure facilities like education, health, transport, communication, culture & religion and shopping facilities were used to determine a composite index. This index may be compared with the cumulative index of QOL. If the two indices are comparable for a given community, one cannot expect any anomaly in it. But a high value of cumulative QOL index and a low value of accessibility index for the same community will give an additional weight to the cumulative index of QOL. Similarly a low cumulative index and a high accessibility index will indicate a highly miserable condition of the people.

#### Methodology of Estimation of Accessibility Index

The following points are assigned to different distances to the availability of infrastructure facilities. Walkable up to 1 km: 6 points, 1-3 km: 5 points, 3-7 km: 4 points, 7-15 km: 3 points, 15-35 km: 2 points and for above 35 km: 1 point. Average of the distance from each selected ward is calculated and proportional marks are given to the calculated averages.

- Educational facilities are given a maximum of 36 points since there are 6 type of educational institutions, like High school, UPS, LPS, Pre-primary schools, Colleges and Technical institutions.

- Health parameters have a maximum of 12 points because there are 2 types of medical facilities measured such as distance to hospitals and distance to nearest medical college. Maximum points that each can take is 6.

- Transport has been given total 24 points because there are four facilities in the collected data such as distance to nearest railway station, bus station/bus stop, state highway/national highway and nearest coastal zone/port/water transport centre.

- Communication has been given 12 points. Two aspects, distance to nearest Post/Telegraph office and Public telephone booth are considered.

- Culture and religious facilities are given 24 points. There are 4 aspects measured and each has a maximum of 6 points.

- Shopping facilities is given 12 points since the distance to nearest public market and public distribution shop are measured. Each has 6 points and the total points given are 12. Thus, the total points assigned to all the above facilities come to 120.

## 3.6.2 District wise Status of the Individual Indicators of QOL in GKR

### 3.6.2.1 Quality of Housing

District wise distribution of different quality houses in GKR is given in **Table 3.6.2.1**. Primary data collected on the quality of housing showed that 64.57% of the residential houses in GKR were pucca, whereas 30% of the houses are semi pucca and a minimum of 5.43% of the houses are of very low quality huts. Percentage of Pucca houses is maximum in Ernakulam district and it is minimum in Pathanamthitta neglecting Thrissur where only three panchayats have been studied. Percentage of huts was maximum in Alappuzha district (8.65%) and minimum in Idukki district (2.3%). The difference between pucca and semi pucca houses is minimum in Pathanamthitta district and the difference is maximum in Ernakulam district (**Fig. 3.6.2.1**).

This result shows that the quality of housing in Ernakulam district is good and for other districts, it is medium. For Alappuzha district, total pucca and semi pucca houses are 91.34% only, which is lowest as compared to the same in other districts of GKR. The corresponding GKR average value is 94.57% and Alappuzha district has this percentage far below the GKR average.

The plinth area of houses in different districts of GKR is given in the **Table 3.6.2.2**, which shows that 37.66% of the residential houses have 300-500 sq. feet as plinth area and 27.36% of the houses have even more plinth area of 500-1000 sq. feet. About 65% of the residential houses have medium (not too low or too high) plinth area. Out of the remaining 35% of houses, 25.71% of the houses have very low plinth area (300 sq. feet and below) and 9.24% of the houses have above medium area (above 1000 sq. feet) plinth area.

Pathanamthitta district has maximum percentage of semi pucca houses and also plinth area of housing (above 1000 sq.ft.). This gives additional weightage to the quality of semi pucca housing in Pathanamthitta district. The percentage of houses with more than 1000 sq.ft. plinth area is minimum in Idukki district and in Idukki 60.59% of houses are pucca also. This means that the pucca houses in Idukki district are not having enough living space as required by its quality. The percentage of houses with medium plinth area (300-1000 sq. ft.) is maximum (80.2%) in Idukki which means that the pucca houses in Idukki are with medium plinth area and houses with minimum plinth area (12.4%) are also in Idukki. The minimum slab of plinth area of houses, below 300 sq.ft. is maximum for Alappuzha district (40.99%). The number of huts is also maximum in Alappuzha. This means that the Alappuzha district as a whole, is a problem area for housing (**Fig. 3.6.2.2**).

In Greater Kochi Region, on an average 93.29% of settlements are independent houses. Except in Idukki, in all other districts, the percentage of independent houses is above the GKR average. In Idukki district 16.65% of the settlements is in quarters owned by plantation owners (**Table 3.6.2.3**).

Slum areas with very poor quality of housing, sanitation and drainage facilities are reported from almost all districts in very low percentages. Eventhough they represent relatively less percentage in the total settlement pattern of GKR, these areas require special attention as they are the epicenters of most of the severe physical as well as social environmental problems in the urban areas (**Fig. 3.6.2.3**). Slum areas in Kochi Corporation and Kottayam municipality suffer from sanitation and drainage problems. Drinking water supply by pipe lines in many areas have chances of getting polluted by mixing with drainage from latrines and damaged public comfort stations.

### 3.6.2.2 'Clothing

**Table 3.6.2.4** showing annual expenditure on clothing indicates that 32.82% of households in GKR have expenditure between Rs. 501 and 1000, 30.20% have Rs. 1001 to 2000, 19.54% have more than Rs. 2000, 13.34% fall in the range Rs. 100 to 500 and only 4.1% of households have less than Rs. 100 expenditure on clothing annually (**Fig. 3.6.2.4**).

### 3.6.2.3 Education

Data on educational level of population in different districts of GKR is given in **Table 3.6.2.5**. On an average, a majority of 51.46% of the population in GKR is educated up to higher secondary level followed by 28.12% up to primary education. About 3% are illiterates and among them 66.64% are females. About 7.3% are graduates and the percentage population with education above graduation is still less. Excluding Thrissur district, the highest percentage of illiterates is in Idukki and the highest percentage of graduates is in Ernakulam district. District-wise distribution of population having different education levels in GKR is projected in **Fig. 3.6.2.5**.

#### 3.6.2.4 Cultural Facilities

Analysis of data on the recreational facilities availed by the households in GKR shows that cinema theatres are the prime cultural and recreation facilities availed by the households. About 55.12% of households in GKR use this facility, while the recreation facility used by the households in the second order of importance is festivals and melas. The details of cultural facilities in different districts of GKR are given in **Table 3.6.2.6**. A district-wise comparison of the different types of the cultural and recreational facilities in GKR shows that in Idukki district, a maximum of 74.77% of the households go to cinema theatres for recreation. This is minimum (24.2 %) in Pathanmthitta district. Maximum percentage of households opting for festivals and melas or recreation is in Alappuzha (43.77%) and minimum (7.46%) is in Kottayam district (**Fig. 3.6.2.6**).

Only 5.92 % of households use sports club facility in GKR. Alappuzha district has a maximum of 14.71% and Ernakulam district has a minimum of 0.46% using the facility. The percentage of households using other facilities like arts clubs, parks etc. are negligible in all the districts of GKR.

#### 3.6.2.5 Social Security and Social Welfare

The social security of a community is directly dependent on the savings, which they possess. **Table 3.6.2.7** shows the type of institutions used by the households and percentage of households using each type of institutions for saving. Nationalized banks are the main types of institutions used for savings in GKR. About 31.95% of households in GKR use nationalized banks for savings, 4.74% use scheduled banks, 16.74% use cooperative banks, 14.81% use post offices, 4.37% use Life Insurance Corporation of India, 2.73% depend on money lenders, 0.27% use stock market and 0.44% use Kerala State Financial Enterprises for savings. Use of commercial banks for savings is highest in Idukki district (32.98%). Use of Nationalized banks for savings is maximum in Pathanamthitta (38.01%) and it is minimum (26.34%) in Idukki district. District wise distribution of households based on the type of institutions used for savings is projected in **Table 3.6.2.7**.

#### 3.6.2.6 Employment Status

The employment status of population in GKR and in the districts of GKR is given in **Table 3.6.2.8** alongwith the percentage of males and females under each type of employment. The Table shows that maximum population (24.57%) in GKR is engaged in house management, out of which 98.14% are women. This is a part of a general picture shown by Kerala. Students, with the sex ratio of 1:1, manage another 24.23% of households. The unemployed people in GKR are 7.88%, of which about 54% are females. The retired people, dependents and those who are unable to do work are about 7.39%. This means that only 45.93% of the population in GKR is engaged in productive employment sectors. The population in GKR working abroad is only 0.83%, of which 91.92% are males and 8.08% are females. Out of the 45.93% of population, a maximum of 15.2% of the people are employed as casual labourers in agricultural or non agricultural sectors, 9.27% are salaried or regular wages earners, 4.41% are self employed in agricultural sector and another 4.41% are self employed in non agricultural sectors. The non-agricultural sector mainly includes the small industrial sector and the service sector like business establishments.

Among the districts of GKR, people working abroad are 1.46% in Pathanamthitta district whereas it is 0.1% only in Idukki. In Pathanamthitta district, the remittance from abroad is centered on Thiruvalla municipality and it has created relatively higher difference between the rural and urban areas in the district compared to the difference in other districts. Also, it can be seen that Thiruvalla municipality records the highest value of subjective quality of life among all the municipalities in the GKR.

The percentage of unemployed people varies from 5.65 in Idukki to 10.19% in Alappuzha district. Casual labourers are maximum (19.24%) in Idukki district and lowest in Pathanamthitta district (8.86%). People engaged in self-employment in agricultural sector are more in Idukki district whereas those self-employed in non-agricultural sector are more in Alappuzha district. The percentage of salaried or regular wage earners is highest in Pathanamthitta district. The comparison shows that Pathanamthitta district has a relatively higher status in the employment sector, as the rate of unemployment is less, salaried or regular wage earners are more and a higher proportion of remittances from abroad.

**Table 3.6.2.9** shows the percentage of households under each income-generating group. In GKR, the primary, secondary and tertiary sectors have almost equal contribution to the net income of the households with 33.52%, 36.83% and 29.65% respectively.

The highest percentage of households (60.87%) depends on the primary sector in Idukki district and the lowest are in Ernakulam district (20.76%). Secondary sector has maximum contribution (46.11%) from Ernakulam district. The lowest percentage of households (18.57%) with secondary sector as the income-generating group is in Idukki district. Maximum contribution of tertiary sector is from Pathanamthitta district, with 36.57%. This further supports the view that Pathanamthitta has relatively better place in the employment sector (**Fig. 3.6.2.8**).

The main source of income of households is given in **Table 3.6.2.10**, which shows that 38.63% of the households in GKR depend on casual labour for their income. About 26.84% have salaried or regular wage earning jobs, 17.55% have self-employment as their main source of income, and 12.66% of the households depend on agriculture as their main source of income and 3.15% depend on the remittances from abroad for their livelihood. District wise comparison of households based on the type of main source of income is projected in **Fig. 3.6.2.9**.

Migration of people for employment is a common feature in Kerala. District wise status of household based on the place of their work is given in **Table 3.6.2.11** and a comparison is projected in **Fig. 3.6.2.10**. Perusal of which indicates that migration of people to outside state is maximum in Pathanamthitta district and minimum in Idukki district, whereas interstate migration of people for employment is higher in Alappuzha district.

### 3.6.2.7 Transport and Communication

In GKR, 35.1% of the households have their own vehicles. Ernakulam district ranks first with 47.45% of households with own vehicles and Idukki district with 8.49% ranks last (**Fig. 3.6.2.11**). District wise distribution of households having own vehicles and telephone connections is given in the **Table 3.6.2.12**. About 19.74% of the households in GKR have own telephone connections. Pathanamthitta district ranks first with 26.25% followed by Kottayam, Thrissur and Ernakulam districts (**Fig. 3.6.2.12**).

### 3.6.2.8 Energy

The type of stove used for cooking is considered an indicator of the income of a household. The type of stove used by rural poor in Kerala is either open Chulha or mason made Chulha. The use of fuel-efficient Chulha of low cost is being encouraged by non-governmental organizations and government agencies. But this study indicates that in GKR, 24.68% of households use open Chulha and 39.29% use mason made Chulha. Fuel-efficient stoves are being used by only 2.88% of the households. LPG stoves are used by 28.33%, electric stoves by 0.2% and another 12.44% are kerosene stoves. Gober gas stove is used by only 0.15% and 0.03% of the households use a very rare type of stove called the sawdust stove in which sawdust is the fuel.

The above facts and figures are supported by the fact that about 85.43% of the households in GKR come under the low-income group, 10.8% under the middle and 3.76% under the high-income group. Kerosene stove and middle-income group people mostly use gober gas stoves. Some of the middle and all the high-income group people use LPG and electric stove. The details are summarized in **Table 3.6.2.13** and **Fig. 3.6.2.13**.

The percentage of households using open Chulha and mason made Chulha is highest (79.22%) in Idukki district and it is lowest (42.34%) in Ernakulam district. This is further supported by the fact that highest percentage of households in the low-income group is in the Idukki district and the lowest percentage of low-income group is in the Ernakulam district. Percentage of households using kerosene stove and percentage of middle-income group are maximum in Ernakulam district and minimum in Idukki district.

District wise details of the type of fuel used for cooking are summarized in **Table 3.6.2.14**, which indicates that in GKR, 34.14% of households use firewood collected free of cost for cooking, 28.83% use LPG, and 23.68% use firewood (purchased). Among the districts, LPG consumption is maximum in Ernakulam district and it is minimum in Idukki district. Firewood consumption is highest (73.70 %) in Idukki district. (**Fig. 3.6.2.14**)

The types of fuel used for lighting in GKR are kerosene, electricity and other fuels like candle. The electrification of the house is an indicator of the economic status of the household and their quality of life. Majority of the houses (82.24%) in GKR are electrified and only 17.59% of the households use kerosene for lighting (**Table 3.6.2.15**). Maximum percentage of electrified houses is in Ernakulam district, (90.38%), whereas lowest percentage is in Idukki district (72.75%). District wise comparison of different fuels used for lighting is projected in **Fig. 3.6.2.15**.

The data on the monthly expenditure of households on fuel use for cooking and lighting has been collected during household surveys in three slabs; Rs.500, Rs.500-1000 and Rs. 1000-2000. For the Greater Kochi region covering six districts, 98.21% of the households have monthly expenditure on fuel below Rs.500. 1.78% of the households have this expenditure in between Rs.500 and 1000 and only very negligible percentage of households have monthly expenditure on fuel between Rs.1000 & 2000 and that too only in Ernakulam district (**Table 3.6.2.16** and **Fig. 3.6.2.16**).

### 3.6.2.9 Water Supply

District wise status of households who depend on each type of source of drinking water is presented in **Table 3.6.2.17**. On an average, 56.73% of households in GKR depend on untreated well water, 34.56% use treated potable pipe water and 8.71% depend on open water bodies like tanks, rivers and canals for drinking water. Ernakulam district ranks first in the use of treated pipe water with 50.94% of households, while Pathanamthitta district ranks last with 16.85%. About 72.83% of the households of Pathanamthitta district use untreated well water and 10.32% depend on other open water bodies for drinking water. The usage of well water and water from open water bodies in Idukki district is 27.67% and 27.96% respectively. Only 44.37% of people use treated water in Idukki district. In Kottayam district 18.73% of people use treated water, 75.84% use untreated well water and 5.43% use water from surface water bodies (**Fig. 3.6.2.17**). Even though the above statistics speak well of Ernakulam district, present field studies reveal that even in Ernakulam district with maximum percentage of households using treated water, there are places of water scarcity. One such zone is a Vypin island. Struggle for drinking water is a common scene in panchayats like Elamkunnapuzha, Kuzhipilly etc. in Vypin block.

### 3.6.2.10 Health Status

To assess the health status of population in GKR, data was collected on the households suffering with various diseases during the twelve months period. District-wise details are given in **Table 3.6.2.18**.

For GKR as a whole, 92.61% of the households were affected by air borne, 2.55% by water borne, 0.61% by occupational, and 4.24% by other diseases. A district-wise comparison of the diseases reported by the households reveals that water borne diseases are maximum in the Alappuzha district (7.3%), which is far above the GKR average (2.55%). About 97.7% of households in Ernakulam district reported air borne diseases where as 81.65% in Alappuzha reported air borne diseases. Occupational diseases reported from Alappuzha district comes to a maximum of 1.37% and from Idukki district it comes to a minimum of 0.042%.

The people's perception about physical environment problems in different districts of GKR shows that about 21.4% of the households in Alappuzha district have reported the occurrence of water logging and flooding. This seems to have a direct bearing on the report of maximum number of water borne diseases from this district. (**Fig. 3.6.2.18**)

A comparison of the system of medicines preferred for treatment by the households in GKR as a whole and different district in GKR reveals that about 86.69% of households in GKR depend on the allopathic system of medicine for treatment, whereas 8.98% and 2.04% of households prefer Ayurvedic and homeopathic systems respectively. With respect to the cost of treatment, the allopathic system comes first among all the systems of medicine. So the system of medicine preferred by the households for treatment is related to their cost of living. But the fact that one prefers Allopathy for treatment does not mean that his quality of life is high because there is a general feeling among the Keralites that Allopathy is superior to all other systems of medicine. It is interesting to know that Ernakulam district with maximum value of objective QOL index and with maximum percentage of households (91.14%) is depending on Allopathy for treatment and in Idukki district with minimum objective quality of life, only 79% of households use Allopathy, but 20.01% of households use Ayurvedic system for treatment (**Table 3.6.2.19** and **Fig. 3.6.2.19**).

Details on the type of hospital preferred such as government, private or government and private given in **Table 3.6.2.20** indicates that 60.39% households in GKR prefer private hospitals for treatment, 31.82% prefer government hospitals, whereas 7.79% prefer both types of hospitals. Among the districts of GKR, 72.27% of households in Ernakulam district and 77.6% in Idukki district prefer private hospitals. Treatment in government hospitals is preferred in Alappuzha district (54.4%). District wise status and comparison is depicted in **Fig. 3.6.2.20**.

### 3.6.2.11 Food and Nutrition

The calorific value of food items consumed by the households per capita per day is calculated from the data collected on the food and nutrition through household survey. 89.92% of the households in GKR have per capita daily consumption of food items with calorific value below 2000 calories. About 6.6 % households take food with calorific value 2000-2400 calories and only 3.4 % take food above 2400 calories. This means that the majority of the population in the region is consuming food items with calorific value below the stipulated is minimum value required. Among the districts of GKR, 93.11% of households in Ernakulam district are with per capita daily consumption of food items having calorific value below 2000 calories and 4.72% of households is with 2000-2400 calories food consumption per capita per day. District-wise status of food intake with per capita calorific value is presented in **Table 3.6.2.21** along with the per capita monthly expenditures on food items **Fig. 3.6.2.21**, shows that Ernakulam and Pathanamthitta districts are problem areas with respect to food and Nutrition in the GKR.

**Fig. 3.6.2.22** presents the total cost of per capita monthly consumption of items of food and nutrition, which indicates that the average cost of food items consumed per month in GKR as a whole is Rs.292. All the districts except Ernakulam and Kottayam show values greater than the GKR average values. Ernakulam district has a minimum of Rs.290 as the cost of food items consumed by the people per month. The calorific value of food items consumed by the households in Ernakulam district is the least. This may be due to the consumption of food items with lower calorific values or it may be due to the lower average quantity of food items consumed. Kottayam also presents the same pattern. The households in Alappuzha district consume food items with an average cost of Rs.300 per month. The cost of food items consumed in Alappuzha is the highest. Idukki district in which the calorific value of food items consumed per day is maximum has the average monthly consumption of food with a cost of Rs. 297. In Pathanamthitta even though the calorific value of food items is not high the cost of monthly consumption of food is not so low. These variations in most of the cases may be due to the local variations in cost of food materials.

#### 3.6.2.12 Environment

People's perception about the environmental quality and problem is given in the **Table 3.6.2.22** as the percentage of households showing concern about each type of environmental problems in each district of GKR. The highest percentage of households (14.5%) reported water logging as an environmental problem; followed by soil erosion, water pollution and air pollution problems. Around 10% households in Kottayam, Alappuzha and Ernakulam districts reported air pollution problem. The main problems reported from Alappuzha are water pollution, water logging and flooding. In Ernakulam district also water logging is the main problem along with air pollution and problems associated with waste disposal. Soil erosion, storms and landslides are the main environmental problems felt by households in Idukki district. In Kottayam district, water pollution, air pollution and noise pollution are the main problems. Soil erosion is the prominent problem in Pathanamthitta district.

## 3.6.3 Status of the QOL Indices in GKR

### 3.6.3.1 District & Physiographic Divisions wise Status of the Socio-economic Indices

The quality of life indices, namely; subjective, objective and cumulative indices and the accessibility index and FAF index are calculated for different physiographic divisions of GKR, namely; lowland, midland and highland regions. District-wise comparison of the socio-economic indices for different physiographic divisions of GKR is presented in **Table 3.6.3.1** and projected in **Fig. 3.6.3.1**. The variation of the above indices is not uniform for different districts, indicating variations in the life style and distribution of different QOL elements in different parts of GKR.

Perusal of figures shows that the midland region is with the highest QOL(s), QOL(o), QOL(c), accessibility index and FAF index. But the difference between average values of indices for lowland, midland and highland are not very high except in the case of accessibility index in which the average value of the index is much higher for midland compared to lowland and highland. This is because of the fact that the midland region has relatively more access to infrastructure facilities like education, health, transportation and communication. People in the midland have relatively more accessibility to both the national highway and state highways for transportation. But on an average, the accessibility of people in the highland to the infrastructure facilities is very less owing to the less availability of these facilities in the highland region and the control, which the physiography has on these facilities. It is also significant that there is not much difference between lowland and midland in the accessibility index, but the difference between the highland and midland in terms of accessibility to infrastructure is much more. The above facts clearly indicate that there is much difference between the three physiographic divisions of GKR in terms of physical development and the quality of life. On a macro scale, there should be some measures to ensure equitable resource allocation to these areas. Analysis of this factor on a micro scale will reveal some more different types and degrees of management plans required for each district of the GKR.

Comparison of the average values of different indices for GKR reflects that, the accessibility index is higher than all the other indices. This indicates that the physical and subjective achievements in QOL, which the people of the area have attained is less than that would have been possible. Also, it should be noted that the average subjective QOL values for all the physiographic divisions are slightly higher than the corresponding objective and cumulative indices. This character is almost the same for all the districts in GKR. This further indicates that on an average, the satisfaction levels of people are slightly higher than the objective conditions available. But on a micro scale, below the district level, the picture may be different. Variation in QOL indices and accessibility & FAF indices for different districts of GKR is further elaborated here as shown in **Fig. 3.6.3.1.**

### Alappuzha District

In Alappuzha district, lowland and midland region have almost the same values of all the indices. But still except in the case of FAF index, the lowland has all the indices slightly higher than that of midland region.

### Ernakulam District

In Ernakulam district, the pattern of variation in the QOL indices between low, mid and highland is almost similar to GKR averages except in the case of the accessibility index. The difference between low, mid and highland in terms of the accessibility to different infrastructure facilities is almost equal. But a very slight difference can be noted between the three physiographic divisions based on this index. Lowland has slightly higher accessibility to infrastructure facilities than midland, which in turn has slightly more accessibility to infrastructure than the highland region has. This slight variation can be safely attributed to the presence of relatively more developed industrial belt (Edayar-Eloor belt) and Kochi Corporation, which is the lone corporation area in GKR in the lowland of Ernakulam district. But it is interesting to note that this variation is not reflected in the other indices for Ernakulam district.

For all other indices, the midland has relatively higher values than lowland and highland. In the case of subjective index, the difference between three physiographic divisions is more distinct. The QOL(s) index for midland is much higher than that of lowland and highland. For the highland region in this district, the lower value of QOL(s) index is due to the non-availability of enough objective conditions. But almost the same QOL(o) value of lowland and midland and a less value of QOL(s) for lowland compared to that of midland suggest that even though the objective conditions are almost the same for lowland and midland of Ernakulam district, the subjective attitudes of people in lowland towards their quality of life is less than that in the midland.

This is a typical case of less degree of satisfaction of people on their living conditions irrespective of the higher objective conditions and accessibility to different infrastructure facilities. The subjective attitudes of people are directly or indirectly influenced by the environmental conditions prevailing in the region. About 20% of the large-scale industries in Kerala are concentrated in the lowland region of Ernakulam district. Further, the highly urbanised Kochi Corporation and a part of the critically polluted Vembanad estuary are in this part of Ernakulam district.

**Idukki District**

About 86% panchayats in Idukki district are in the highland region and the remaining 14% are in the midland region. The variation in all the indices between midland and highland region is almost similar to the GKR averages. The values of all the indices are higher for midland region as compared to the highland. The accessibility index for highland of Idukki district is lower or equal to the other indices for highland. This shows that one of the predominant factors that need attention in the highland region is the need for provision of sufficient infrastructure facilities. But another aspect is that the QOL indices for Idukki district are more or less the same as that of other districts of GKR. The subjective QOL index is relatively more than the objective and cumulative QOL indices, which indicates that within the limits of available objective conditions, people are satisfied.

**Kottayam District**

About 60% of the panchayats in Kottayam district are in the midland region, 20% in the lowland and another 20% in the highland. When Compared with GKR averages, the variation in QOL indices for lowland, midland and highland is different. The accessibility to different infrastructure facilities is maximum for lowland than that of the midland and highland. The subjective, objective, cumulative and FAF indices are less for lowland than that of midland and highland regions. The lowland region of Kottayam district is the region bordering Alappuzha district and Vembanad estuary. Here also the midland region has relatively higher QOL. But the highland of the district which boarders the Idukki district also has almost the same QOL levels as that of the midland. Despite the highest value of accessibility index for lowland area, its QOL indices are less than that of the other two physiographic divisions.

### Pathanamthitta District

In Pathanamthitta district, 56.5% of the panchayaths are in the midland, 35% in the highland and 8.5% in the lowland region. The lowland region of the district is the region bordering Alappuzha district. This district is different from the GKR averages in terms of the variations of the different indices in the three physiographic divisions. The accessibility to different infrastructure facilities is less than the other QOL indices, indicating that the QOL of the different physiographic divisions is not controlled by accessibility to infrastructure. Further the subjective, objective and cumulative indices are higher for lowland region as compared to other two regions. But the difference between the midland and lowland in terms of the objective index is less than that difference in terms of subjective index. There is relatively higher difference between lowland and other two regions in terms of average subjective index.

### 3.6.3.2 District and Area (Rural and Urban) wise Status of the QOL Indices

The quality of life indices namely Subjective, Objective, Cumulative, Accessibility and FAF indices is compared for the rural and urban areas of the districts and GKR in general. The panchayat areas in the districts are included in the rural areas and municipalities and corporation areas are included in the urban areas.

The QOL indices for all the districts of GKR with rural-urban breakup is given in **Table 3.6.3.2** and projected in **Fig. 3.6.3.2.** The average subjective QOL index of GKR is 0.705. The objective QOL is: 0.575; and the cumulative index is 0.641. The accessibility and FAF index are 0.724 and 0.068 respectively. The highest value of subjective QOL index is reported for Idukki district and the highest objective QOL index is reported for Ernakulam district.

The rural and urban areas in GKR as a whole do not differ much in the QOL indices except in the case of accessibility index and FAF index. The accessibility to different infrastructure facilities is slightly more for the urban areas compared to the rural and total areas. Similarly, FAF index is also greater when compared with that of the rural and total. But the individual revenue districts in GKR do not show this pattern of variation. All the districts of GKR except Alappuzha have urban areas with higher QOL indices (except FAF indices) in comparison to rural areas. For Ernakulam district rural-urban difference is negligible except for accessibility index and FAF. This is almost similar to GKR average. Idukki district has high difference in the accessibility index between rural and urban areas. The urban area, which is represented by Thodupuzha municipality has the accessibility to different infrastructural facilities more than that is available in rural areas. The subjective attitude of people towards their QOL is less in Idukki urban areas.

In Kottayam district higher value of QOL conditions exist in urban areas when compared with that of rural areas. All the QOL indices are higher in urban than in rural areas. Maximum difference between urban and rural areas is seen in Pathanamthitta district in terms of QOL indices. The urban centres in Pathanamthitta district are Thiruvalla municipality and Pathanamthitta municipality. The rural urban difference in this district shows that there is every chance of these centres getting developed into more developed urban centres in the future. In Thrissur district only three panchayts were included in the study, where the value of QOL indices were found more or less in the source range of other districts

### 3.6.3.3 Status of QOL Indices in Kochi Corporation Area

Kochi Corporation is unique in GKR owing to the fact that it is the only Corporation in the project area and its proximity to Vembanad estuary and the critically polluted Edayar-Eloor industrial belt makes it a candidate for special attention in terms of quality of life analysis. Comparison of QOL indices for municipalities in different districts under GKR is presented in **Table 3.6.3.3** and projected in **Fig. 3.6.3.3.**

The subjective QOL index of Kochi Corporation is 0.621.This value is not only less than the highest subjective QOL index of municipalities in Ernakulam district but also less than the highest subjective QOL index values of municipalities in all the other districts of GKR. Only Thrippunithura in Ernakulam district and Vaikom in Kottayam district have subjective index lower than that of Kochi Corporation. An almost similar picture is observed with respect to objective quality of life also. Except Thodupuzha municipality in Idukki district, the highest objective QOL indices of municipalities in all the other districts are greater than the objective QOL of Kochi Corporation (0.601).

In the case of cumulative index, the picture is exactly similar to that given by subjective index. Aluva and Alappuzha municipalities have accessibility index greater than that of Kochi Corporation and all the minimum values of accessibility indices among municipalities are less than that of Kochi Corporation. The FAF index of Kochi Corporation is 0.101. This is less than the maximum value of FAF among the municipalities in GKR except Thodupuzha in Idukki district.

While collecting the data for estimating the subjective quality of life index of Kochi, the problem projected by maximum number of households (73.33%) in Kochi Corporation is non-availability of drinking water. The other problems are non- availability of fuel, social security problems, physical environment problems etc.

The above considerations and comparisons suggest that even though the physical development in Kochi Corporation is higher than any other municipality in other districts of GKR; this corporation is not ahead of any other municipality in the QOL except Thrippunithura (Idukki) (Ernakulam), Vaikom (Kottayam) and Thodupuzha municipality.

### 3.6.3.4 Status of the QOL Indices for Different Blocks in GKR

The different QOL indices, namely; Subjective, Objective, Cumulative, Accessibility and FAF indices are compared for different blocks and municipalities in different constituent districts of GKR. The QOL indices for different blocks and the remarks on the QOL indices are given in **Table 3.6.3.4** in the comprehensive. The salient findings for each district are discussed here.

### Alappuzha District

Thykattusery block has maximum value of subjective QOL index (0.864) and the minimum value of 0.561 is given by Veliyanadu block. Among the municipalities Kayamkulam municipality ranks first in the subjective QOL index (0.773) and Cherthala municipality with 0.657 ranks last. Objective QOL is highest for Kanjikuzhi block adjacent to Thykattusery block. The objective QOL is also minimum for Veliyanadu block (0.549). Objective index varies from 0.582 (Cherthala) to 0.653 (Mavelikkara). The cumulative index of QOL is maximum (0.711) for Thykkattussery block and minimum (0.555) for Veliyanadu block.

Among the municipalities, Mavelikkara with 0.711 ranks first and Cherthala with 0.619 ranks last. The accessibility to different infrastructural facilities is maximum (0.887) for Ambalapuzha and minimum (0.653) for Mavelikkara block. For the municipalities in Alappuzha district, the accessibility index varies from 0.73 for Mavelikkara to 0.89 for Alappuzha municipality. The FAF index is maximum for Chengannur block and minimum for Veliyanadu block. The above comparison shows that the Veliyandu block in Alappuzha district has least QOL and Thykattusery has maximum objective and cumulative QOL index. Among the municipalities, Cherthala has least QOL and Kayamkulam has maximum subjective and Mavelikkara has maximum objective QOL status.

### Ernakulam district

In Ernakulam district, the subjective and cumulative indices are maximum for Mulanthuruthy block. The objective and FAF indices are maximum for an adjacent block; Vadavukode. The accessibility index is maximum for Vytila block. The lowest value of subjective and cumulative indices is given by Palluruthy block which is a coastal block. Paravoor block is giving lowest values of objective and FAF indices. The accessibility index is minimum for Pampakuda block, which has borders with Thodupuzha block of Idukki district.

One significant aspect that has to be noted is that Vytila block has a very low value of subjective index (0.474), but its accessibility to different infrastructural facilities is the highest among the blocks in Ernakulam district. Vypin block is another block with a lowest value of FAF index.

Among the municipalities and corporation when considered together. Perumbavoor municipality, which is in the central part of Ernakulam district ranks first in the subjective and cumulative indices and Aluva municipality ranks first in the objective, FAF and accessibility indices. Thrippunithura municipality, which is a suburb adjacent to Kochi Corporation ranks last in the subjective and cumulative indices. Kothamangalam, which has borders with Adimali and Elamdesam blocks of Idukki district ranks last in the objective quality of life. Paravor municipality has lowest values of FAF and accessibility indices.

The above comparison shows that coastal blocks like Palluruthy, Vypin, Paravoor are having relatively lower QOL. Thrippunithura municipality adjacent to Kochi Corporation also has lower QOL levels. Kochi Corporation has less subjective QOL indices than other municipalities except Thrippunithura and Paravoor. The objective and cumulative QOL are also less than those for other municipalities except two. But the accessibility to infra-structural facilities is second to the corresponding value for Aluva municipality. Thus Kochi corporation is a typical example of the fact that urbanization need not necessarily lead to an increase in QOL but that may reduce it in most of the cases.

**Idukki District**

In Idukki district the subjective QOL index varies from 0.726 for Devikulam block to 0.776 for Azhutha block. The highest values for objective QOL, Cumulative QOL and accessibility to different infrastructural facilities are given by Thodupuzha block which surrounds the only one municipality in Idukki i.e., Thodupuzha municipality. The highest value of FAF indices is in Elamdesam block. The lowest value of objective QOL is for Adimali block and that for cumulative, subjective and accessibility indices are for Devikulam block.

Thodupuzha municipality is the only municipality in Idukki district, which falls under GKR study area. It is to be noted that subjective objective and cumulative indices of Thodupuzha municipality is less than the corresponding values for the Thodupuzha block, which surrounds this municipality. The accessibility to infrastructure and FAF indices are higher for Thodupuzha municipality in comparison to that of the Thodupuzha block.

**Kottayam District**

In Kottayam district, Pallam block has the highest subjective QOL index (0.754) and cumulative quality of life index (0.659). The highest value of objective QOL index (0.594) and accessibility index (0.870) are given by Ettumanur block. The FAF index is maximum for Lalam block (0.087). The lowest value of subjective index (0.542) and cumulative index are in Vaikom municipality. The objective QOL index is minimum for Pambady block (0.543). The accessibility to infrastructure facilities is minimum for Erattupetta block. The FAF index is minimum for Kaduthuruthy block (0.042).

Among the municipalities in Kottayam district, Pala municipality has a maximum subjective QOL index of 0.777 and it has the minimum value of accessibility index 0.71. Vaikom municipality has a maximum accessibility index of 0.86 but it ranks last in subjective quality of life index (0.612), objective quality of life index (0.577), cumulative index (0.595) and FAF index (0.071). Kottayam municipality ranks first in objective QOL index (0.625), cumulative index (0.687) and FAF index (0.129).

**Pathanamthitta District**

In Pathanamthitta district, Pulikeezhu block ranks first in subjective QOL index (0.844), objective QOL index (0.587) and cumulative index (0.716). One of the adjacent blocks namely Mallappally has the highest value of accessibility index (0.721) and FAF index (0.105). Ilanthur block ranks last in subjective QOL index (0.516), objective quality of life index (0.535) cumulative index (0.526) and FAF index (0.050). In the case of accessibility index, Ranni block ranks last.

There are two municipalities in the project area, which fall within Pathanamthitta district area. They are Thiruvalla municipality and Pathanamthitta municipality. Thiruvalla municipality has higher values of all the indices. Pulikkeezhu block, which surrounds the Thiruvalla municipality with maximum subjective QOL has higher levels of quality of life situation.

### 3.6.3.5 Panchayat-wise Comparison of the QOL Indices

The QOL indices and the remarks on subjective QOL indices for all the panchayats in the GKR are given in **Annexure 3.6.3.1**.

**Table 3.6.1.1**

**Parameters Considered and Weight Assigned**

| Group/Parameters | Weightage % |
|---|---|
| **Group I** | **50** |
| Housing | 12 |
| Clothing | 8 |
| Education | 10 |
| Culture | 10 |
| Social Security and Human Rights | 10 |
| **Group II** | **40** |
| Sanitation | 5 |
| Water Supply | 5 |
| Health | 5 |
| Environment | 10 |
| Food and Nutrition | 15 |
| **Group III** | **10** |
| Employment | 4 |
| Transport and Communication | 3 |
| Energy | 3 |
| **Total** | **100** |

**Table 3.6.1.2**

**Districtwise Distribution of Households under each FAF Index Range**

| District | % Households with | | |
|---|---|---|---|
| | Low Income (0-0.1) | Middle Income (0.1-0.5) | High Income (0.5-1) |
| Alappuzha | 88.32 | 9.23 | 2.45 |
| Ernakulam | 79.77 | 16.42 | 3.81 |
| Idukki | 94.15 | 3.87 | 1.98 |
| Kottayam | 86.26 | 9.12 | 4.62 |
| Pathanamthitta | 84.70 | 9.35 | 5.95 |
| Thrissur | 81.25 | 9.03 | 9.72 |
| GKR | 85.43 | 10.81 | 3.76 |

Table 3.6.2.1

**Districtwise Distribution of Households based on Quality of House**

| Districts | % Households with the type of House | | |
|---|---|---|---|
| | Hut | Semi Pucca | Pucca |
| Alappuzha | 8.65 | 30.04 | 61.30 |
| Ernakulam | 3.50 | 21.10 | 75.38 |
| Idukki | 2.30 | 37.09 | 60.59 |
| Kottayam | 7.08 | 30.97 | 61.94 |
| Pathanamthitta | 6.15 | 42.76 | 51.08 |
| Thrissur | 2.77 | 52.77 | 44.44 |
| **GKR** | **5.43** | **30.00** | **64.57** |

**Source** : Primary data collected by KSSP

Table 3.6.2.2

**Districtwise Distribution of Households based on Plinth Area**

| Districts | % Households with Plinth Area of House (in sq ft) | | | | | | |
|---|---|---|---|---|---|---|---|
| | <100 | 100-300 | 300-500 | 500-1000 | 1000-1500 | 1500-2000 | >2000 |
| Alappuzha | 11.76 | 29.23 | 31.43 | 20.76 | 4.81 | 1.41 | 0.57 |
| Ernakulam | 2.30 | 16.38 | 38.74 | 34.28 | 6.69 | 1.58 | 0 |
| Idukki | 1.56 | 12.40 | 57.70 | 22.50 | 4.03 | 1.23 | 0.53 |
| Kottayam | 5.40 | 24.07 | 34.96 | 25.84 | 7.81 | 1.73 | 0.16 |
| Pathanamthitta | 3.97 | 21.93 | 26.39 | 28.66 | 14.57 | 3.58 | 0.87 |
| Thrissur | 4.86 | 28.47 | 38.19 | 15.97 | 10.41 | 2.08 | 0 |
| **GKR** | **4.95** | **20.76** | **37.66** | **27.36** | **7.15** | **1.77** | **0.32** |

**Source** : Primary data collected by KSSP

Table 3.6.2.3

## Districtwise Distribution of Households based on the Type of Settlements

| Districts | % Households with Type of Settlement | | | | | |
|---|---|---|---|---|---|---|
| | Independent House | Slum | Housing Colonies /Flat | SC/ST Colonies | Other type of House | Quarters |
| Alappuzha | 96.59 | 0.60 | 0.69 | 1.41 | 0.63 | 0.05 |
| Ernakulam | 97.90 | 1.09 | 1.69 | 0.49 | 0.06 | 0.44 |
| Idukki | 79.06 | 1.48 | 1.48 | 0.82 | 0.49 | 16.65 |
| Kottayam | 94.05 | 2.17 | 1.49 | 1.08 | 0.86 | 0.32 |
| Pathanamthitta | 94.81 | 0.435 | 0.87 | 3.19 | 0.67 | 0 |
| Thrissur | 100 | 0 | 0 | 0 | 0 | 0 |
| **GKR** | **93.29** | **1.19** | **1.31** | **1.16** | **0.50** | **2.55** |

**Source** : Primary data collected by KSSP

Table 3.6.2.4

## Districtwise Distribution of Households based on Annual Expenditure on Clothing

| District | % Households with type of Settlement | | | | |
|---|---|---|---|---|---|
| | < Rs. 100 | Rs. 100-500 | Rs. 501-1000 | Rs. 1001-2000 | > Rs. 2000 |
| Alappuzha | 2.83 | 20.14 | 27.02 | 26.07 | 23.93 |
| Ernakulam | 1.29 | 5.8 | 32.68 | 35.81 | 24.43 |
| Idukki | 17.7 | 15.02 | 34.09 | 28.88 | 3.71 |
| Kottayam | 2.18 | 18.06 | 36.99 | 27.55 | 15.23 |
| Pathanamthitta | 1.7 | 13.25 | 34.49 | 29.51 | 20.05 |
| Thrissur | 0 | 0 | 1.39 | 7.64 | 90.97 |
| **GKR** | **4.1** | **13.34** | **32.82** | **30.20** | **19.54** |

**Source** : Primary data collected by KSSP

## Table 3.6.2.5

### Districtwise Distribution of Population based on the Educational Level

| District | % Population based on the Educational Level | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | ILL | NEW | PRE | PRMY | HS | GR | PGR | DR | OT |
| **Alappuzha** | | | | | | | | | |
| Total | 3.31 | 1.07 | 5.81 | 32.63 | 49.78 | 6.20 | 1.04 | 0.10 | 0.03 |
| Male | 28.40 | 39.76 | 45.04 | 48.72 | 52.64 | 51.61 | 51.49 | 43.75 | 40.00 |
| Female | 71.60 | 60.24 | 54.96 | 51.28 | 47.36 | 48.39 | 48.51 | 56.25 | 60.00 |
| **Ernakulam** | | | | | | | | | |
| Total | 2.92 | 0.55 | 7.47 | 26.47 | 53.27 | 8.44 | 0.83 | 0.01 | 0.003 |
| Male | 32.45 | 44.75 | 48.03 | 47.78 | 52.17 | 56.04 | 52.77 | 33.33 | 0 |
| Female | 67.55 | 55.25 | 51.97 | 52.22 | 47.83 | 43.96 | 47.23 | 66.67 | 100 |
| **Idukki** | | | | | | | | | |
| Total | 4.21 | 1.90 | 9.21 | 31.88 | 46.97 | 4.97 | 0.81 | 0 | 0.09 |
| Male | 39.92 | 37.56 | 46.27 | 53.29 | 52.39 | 52.72 | 29.76 | 0 | 0 |
| Female | 63.08 | 62.44 | 53.73 | 46.71 | 47.61 | 47.28 | 70.24 | 0 | 0 |
| **Kottayam** | | | | | | | | | |
| Total | 2.60 | 1.11 | 8.14 | 25.82 | 52.76 | 7.94 | 1.53 | 0.04 | 0.01 |
| Male | 28.04 | 46.23 | 44.77 | 48.85 | 52.55 | 52.94 | 49.60 | 62.50 | 66.66 |
| Female | 71.96 | 53.77 | 55.23 | 51.15 | 47.45 | 47.06 | 50.40 | 37.50 | 33.34 |
| **Pathanamthitta** | | | | | | | | | |
| Total | 1.85 | 1.17 | 10.65 | 25.19 | 51.87 | 7.40 | 1.65 | 0.05 | 0.12 |
| Male | 32.54 | 44.85 | 43.19 | 48.77 | 51.64 | 52.22 | 52.98 | 40.00 | 90.90 |
| Female | 67.46 | 55.15 | 56.81 | 51.23 | 48.36 | 47.78 | 47.02 | 60.00 | 9.10 |
| **Thrissur** | | | | | | | | | |
| Total | 5.15 | 3.43 | 8.90 | 22.81 | 48.59 | 10.00 | 1.09 | 0 | 0 |
| Male | 39.39 | 68.18 | 52.63 | 52.73 | 54.01 | 51.56 | 57.14 | 0 | 0 |
| Female | 60.61 | 31.82 | 47.37 | 47.27 | 45.99 | 48.44 | 42.86 | 0 | 0 |
| **GKR** | | | | | | | | | |
| **Total** | **3.00** | **1.05** | **7.89** | **28.12** | **51.46** | **7.32** | **1.12** | **0.041** | **0.027** |
| **Male** | **33.36** | **42.98** | **45.89** | **49.17** | **52.33** | **53.77** | **49.49** | **46.88** | **66.67** |
| **Female** | **66.64** | **57.02** | **54.11** | **50.89** | **47.67** | **46.23** | **50.50** | **53.12** | **33.33** |

ILL - Illiterate; NEW - New literate; PRE - Pre Primary; PRMY - Primary; HS- High school; GR - Graduate; PGR - Post Graduate; DR - Doctorate/ Post Doctorate; OT – Other

**Source** : Primary data collected by KSSP

### Table 3.6.2.6

### Districtwise Distribution of Households based on the use of Cultural Facilities

| District | % of Households using Cultural facilities | | | | | | |
|---|---|---|---|---|---|---|---|
| | Cinema | Sports | Fine Arts | Picnics | Festivals | Parks | Other |
| Alappuzha | 51.85 | 14.71 | 1.01 | 1.61 | 43.77 | 1.10 | 1.56 |
| Ernakulam | 65.47 | 0.46 | 0.32 | 1.32 | 20.74 | 2.40 | 2.48 |
| Idukki | 74.77 | 7.17 | 0.99 | 0.66 | 26.34 | 0.08 | 0.54 |
| Kottayam | 45.03 | 8.17 | 2.47 | 1.66 | 7.46 | 0.16 | 2.52 |
| Pathanamthitta | 24.21 | 1.07 | 1.45 | 1.21 | 8.67 | 0.15 | 3.92 |
| Thrissur | 96.53 | 0.00 | 0.00 | 0.00 | 1.39 | 0.00 | 0.00 |
| **GKR** | **55.12** | **5.92** | **1.13** | **1.33** | **21.70** | **1.06** | **2.19** |

Cinema - Cinema Theatres; Sports - Sports & Arts - Clubs; Fine Arts - Membership in Fine Arts Societies; Picnic - Picnic/ Excursions; Festivals - Festivals/Fares/Melas; Parks - Park/Beach/Resorts; Other - Other Places/Institutions

**Source** : Primary data collected by KSSP

### Table 3.6.2.7

### Districtwise Distribution of Household based on the Institutions used for Savings

| District | % of Households with the type of Savings | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | NB | SB | CB | ML | SM | PO | LIC | KSFE |
| Alappuzha | 26.85 | 4.96 | 12.92 | 9.05 | 0.40 | 12.92 | 9.23 | 1.15 |
| Ernakulam | 33.46 | 6.84 | 9.11 | 0.33 | 0.09 | 19.08 | 0.32 | 0.02 |
| Idukki | 26.34 | 3.34 | 32.98 | 1.07 | 0.12 | 17.11 | 0.04 | 0.00 |
| Kottayam | 33.20 | 2.52 | 24.38 | 0.79 | 0.14 | 11.70 | 7.82 | 0.92 |
| Pathanamthitta | 38.01 | 3.15 | 10.70 | 4.16 | 1.02 | 10.12 | 6.63 | 0.10 |
| Thrissur | 71.53 | 19.44 | 27.08 | 1.39 | 0.00 | 0.69 | 0.00 | 0.00 |
| **GKR** | **31.95** | **4.74** | **16.74** | **2.73** | **0.27** | **14.81** | **4.37** | **0.44** |

NB - Nationalised Banks; SB - Scheduled Banks; CB - Co-operative Banks; ML - Money Lenders; SM - Stock Market; PO - Post Office Savings; KSFE - Kerala State Financial Enterprises

**Source** : Primary data collected by KSSP

## Table 3.6.2.8

## Districtwise Distrbution of Population based on Employment Status

| District | % of Population Employed | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AGR | NGR | SAL | CAL | UMP | STU | HWF | PEN | UDW | ABR | RET | DEP |
| **Alappuzha** | | | | | | | | | | | | |
| Total | 3.03 | 8.29 | 8.44 | 16.62 | 10.19 | 23.49 | 20.66 | 1.54 | 5.95 | 1.05 | 0.16 | 0.53 |
| Male | 83.81 | 69.19 | 77.18 | 77.05 | 40.33 | 52.90 | 2.49 | 72.76 | 48.62 | 93.41 | 88.88 | 37.64 |
| Female | 16.19 | 30.81 | 22.82 | 22.95 | 59.67 | 47.10 | 97.51 | 27.24 | 51.38 | 6.59 | 11.12 | 62.36 |
| **Ernakulam** | | | | | | | | | | | | |
| Total | 1.76 | 6.10 | 9.85 | 16.69 | 7.38 | 23.67 | 27.09 | 1.21 | 5.13 | 0.92 | 0.15 | 0.003 |
| Male | 95.84 | 92.46 | 80.20 | 88.54 | 49.01 | 49.32 | 1.16 | 88.25 | 52.86 | 92.91 | 94.87 | 100 |
| Female | 4.16 | 7.54 | 19.80 | 11.46 | 50.99 | 50.68 | 98.84 | 11.75 | 47.14 | 7.09 | 5.13 | 0 |
| **Idukki** | | | | | | | | | | | | |
| Total | 11.16 | 2.97 | 9.49 | 19.24 | 5.60 | 24.53 | 22.20 | 0.07 | 4.57 | 0.10 | 0 | 0 |
| Male | 94.28 | 79.2 | 71.48 | 72.92 | 37.58 | 52.32 | 1.001 | 87.50 | 45.87 | 0.90 | 0 | 0 |
| Female | 5.72 | 20.78 | 28.52 | 27.08 | 62.42 | 47.68 | 98.99 | 12.50 | 54.13 | 9.10 | 0 | 0 |
| **Kottayam** | | | | | | | | | | | | |
| Total | 5.40 | 5.88 | 8.28 | 12.79 | 8.26 | 25.58 | 24.85 | 1.12 | 6.84 | 0.62 | 0.10 | 0.20 |
| Male | 94.91 | 90.24 | 73.79 | 88.30 | 49.89 | 50.72 | 1.97 | 74.46 | 48.16 | 83.65 | 88.88 | 44.11 |
| Female | 4.98 | 9.76 | 26.21 | 11.70 | 50.11 | 49.28 | 98.03 | 25.54 | 51.84 | 16.35 | 11.12 | 55.89 |
| **Pathanam-thitta** | | | | | | | | | | | | |
| Total | 4.98 | 5.78 | 10.54 | 8.86 | 7.46 | 24.51 | 26.13 | 2.62 | 7.60 | 1.43 | 0.01 | 0 |
| Male | 94.96 | 89.62 | 71.32 | 87.56 | 51.90 | 49.53 | 3.63 | 85.89 | 49.21 | 94.77 | 100 | 0 |
| Female | 5.0 | 10.38 | 28.68 | 12.44 | 48.10 | 50.47 | 96.37 | 14.11 | 50.79 | 5.23 | 0 | 0 |
| **Thrissur** | | | | | | | | | | | | |
| Total | 2.35 | 2.35 | 10.97 | 20.68 | 4.54 | 21.63 | 27.74 | 1.09 | 4.23 | 0 | 0 | 0 |
| Male | 86.66 | 86.66 | 91.42 | 75.00 | 75.86 | 48.55 | 2.82 | 71.42 | 92.59 | 0 | 0 | 0 |
| Female | 13.34 | 13.34 | 8.58 | 25.00 | 24.14 | 51.45 | 97.18 | 28.58 | 7.41 | 0 | 0 | 0 |
| **GKR** | | | | | | | | | | | | |
| **Total** | **4.41** | **4.41** | **9.27** | **15.20** | **7.88** | **24.23** | **24.57** | **1.27** | **5.87** | **0.83** | **0.10** | **0.15** |
| **Male** | **93.25** | **93.25** | **76.18** | **83.18** | **46.31** | **50.75** | **1.86** | **81.19** | **49.79** | **91.92** | **91.76** | **40.00** |
| **Female** | **6.75** | **6.75** | **23.82** | **16.82** | **53.69** | **49.25** | **98.14** | **18.81** | **50.21** | **8.08** | **8.24** | **60.00** |

AGR - Self Employed in Agriculture; NGR - Self Employed in Non Agricultural Sector; SAL - Salaried; CAL - Casual labours; UMP - Unemployed; STU - Student; HWF - Housewife; PEN - Pensioner; UDW - Unable to do work; ABR - Working abroad; RET - Retired; DEP - Dependents

**Source** : Primary data collected by KSSP

### Table 3.6.2.9

### Districtwise Distribution of Households based on Income Generating Group

| District | % of Income Generating Group | | |
|---|---|---|---|
| | Primary | Secondary | Tertiary |
| Alappuzha | 25.88 | 42.84 | 31.28 |
| Ernakulam | 20.76 | 46.11 | 33.13 |
| Idukki | 60.87 | 18.57 | 20.56 |
| Kottayam | 39.79 | 34.99 | 25.22 |
| Pathanamthitta | 39.72 | 23.71 | 36.57 |
| Thrissur | 4.32 | 73.38 | 22.30 |
| **GKR** | **33.52** | **36.83** | **29.65** |

**Source** : Primary data collected by KSSP

### Table 3.6.2.10

### Districtwise Distribution of Households based on the Type of Main Source of Income

| District | % of Households with Type of Income | | | | | |
|---|---|---|---|---|---|---|
| | SE | SAL | CAL | REA | OTH | AGR |
| Alappuzha | 19.85 | 26.84 | 40.92 | 4.71 | 1.38 | 6.27 |
| Ernakulam | 18.1 | 30.66 | 41.82 | 3.03 | 1.27 | 5.09 |
| Idukki | 5.52 | 20.25 | 40.84 | 0.37 | 0.041 | 32.96 |
| Kottayam | 19.09 | 24.39 | 36.59 | 1.84 | 0.76 | 17.3 |
| Pathanamthitta | 23.28 | 28.77 | 26.44 | 6.45 | 2.37 | 12.66 |
| Thrissur | 21.83 | 21.83 | 47.88 | 3.52 | 1.4 | 3.52 |
| **GKR** | **17.55** | **26.84** | **38.63** | **3.15** | **1.14** | **12.66** |

SE - Self-Employment; SAL- Salaried Job/Regular Wage; CAL - Casual Labour; REA - Remittance from Abroad; OTH - Any other Source; AGR – Agriculture
**Source** : Primary data collected by KSSP

## Table 3.6.2.11

### Districtwise Distribution of Households based on Place of Work

| District | % of Households with Place of Work | | | | | |
|---|---|---|---|---|---|---|
| | INVIL | INTAL | INDIS | INST | INCO | OSWC |
| Alappuzha | 64.18 | 18.63 | 5.89 | 4.66 | 3.25 | 3.33 |
| Ernakulam | 63.05 | 28.31 | 6.43 | 0.58 | 0.26 | 1.37 |
| Idukki | 90.26 | 8.25 | 0.84 | 0.37 | 0.14 | 0.14 |
| Kottayam | 73.22 | 16.93 | 6.50 | 1.72 | 0.49 | 1.05 |
| Pathanamthitta | 72.78 | 11.20 | 5.75 | 2.02 | 2.30 | 5.91 |
| Thrissur | 80.36 | 14.29 | 0.89 | 2.68 | 0.00 | 1.79 |
| **GKR** | **71.00** | **18.90** | **5.30** | **1.76** | **1.1.0** | **1.95** |

INVIL - Within the Village/Ward; INTAL - Outside the Village but within the Taluk; INDIS - Outside the Taluk but within the District; INST - Outside the District but within the State; INCO - Outside the State but within the Country; OSWC - Outside the State/Country

**Source :** Primary data collected by KSSP

## Table 3.6.2.12

### Districtwise Distribution of Households based on Ownership of Vehicles and Telephone Connections in GKR

| District | % of Households with Own Vehicles | | % of Households with Own Telephone | |
|---|---|---|---|---|
| | Yes | No | Yes | No |
| Alappuzha | 46.04 | 54.06 | 15.40 | 84.60 |
| Ernakulam | 47.45 | 52.55 | 21.53 | 78.47 |
| Idukki | 8.49 | 91.51 | 11.17 | 88.83 |
| Kottayam | 23.97 | 76.03 | 22.96 | 77.04 |
| Pathanamthitta | 32.35 | 67.65 | 26.25 | 73.75 |
| Thrissur | 49.31 | 50.69 | 22.92 | 77.08 |
| **GKR** | **35.10** | **64.90** | **19.74** | **80.26** |

**Source :** Primary data collected by KSSP

### Table 3.6.2.13

### Districtwise Distribution of Households based on type of Stove used

| District | % of Households using type of Stove | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **OC** | **MC** | **FC** | **KS** | **ES** | **LPG** | **GS** | **SS** |
| Alappuzha | 34.52 | 23.27 | 1.90 | 18.70 | 0.72 | 20.33 | 0.43 | 0.09 |
| Ernakulam | 14.64 | 27.70 | 0.42 | 20.14 | 0.04 | 36.92 | 0.14 | 0.00 |
| Idukki | 19.37 | 59.85 | 0.87 | 4.58 | 0.08 | 15.21 | 0.04 | 0.00 |
| Kottayam | 34.64 | 20.36 | 9.93 | 6.22 | 0.11 | 28.58 | 0.08 | 0.08 |
| Pathanamthitta | 22.28 | 34.29 | 1.26 | 4.99 | 0.10 | 37.08 | 0.00 | 0.00 |
| Thrissur | 52.78 | 0.00 | 0.00 | 16.66 | 0.00 | 30.56 | 0.00 | 0.00 |
| **GKR** | **24.68** | **30.29** | **2.88** | **12.94** | **0.20** | **28.83** | **0.15** | **0.03** |

OC - Crude/Open Chulha; MC - Mason Made Chulha; FC - Fuel Efficient Chulha;
KS - Kerosene Stove; ES - Electric Stove; LPG - LPG Stove; GS - Gober Gas Stove;
SS - Saw Dust Stove

**Source** : Primary data collected by KSSP

### Table 3.6.2.14

### Districtwise Distribution of Households based on the Type of Fuel used for Cooking

| District | % of Households using Type of Fuel for Cooking | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **WP** | **WC** | **CD** | **KS** | **LPG** | **GG** | **SD** | **EL** |
| Alappuzha | 43.05 | 16.64 | 0.00 | 18.74 | 20.33 | 0.43 | 0.09 | 0.72 |
| Ernakulam | 23.78 | 18.96 | 0.02 | 20.13 | 36.93 | 0.14 | 0.00 | 0.04 |
| Idukki | 6.35 | 73.70 | 0.04 | 4.58 | 15.21 | 0.04 | 0.00 | 0.08 |
| Kottayam | 19.87 | 45.01 | 0.05 | 6.22 | 28.58 | 0.08 | 0.08 | 0.11 |
| Pathanamthitta | 17.09 | 40.68 | 0.05 | 4.99 | 37.09 | 0.00 | 0.00 | 0.10 |
| Thrissur | 37.50 | 15.28 | 0.00 | 16.66 | 30.56 | 0.00 | 0.00 | 0.00 |
| **GKR** | **23.68** | **34.14** | **0.03** | **12.94** | **28.83** | **0.15** | **0.03** | **0.20** |

WP - Firewood Purchased; WC - Firewood Free Collection; CD -Cow Dung;
KS - Kerosene; LPG - LPG Stove; GB - Gober Gas; SD - Saw Dust; EL - Electricity

**Source** : Primary data collected by KSSP

Table 3.6.2.15

**Districtwise Distribution of Households based on the Type of Fuel used for Lighting**

| District | % of Households using Type of Fuel for Lighting | | |
|---|---|---|---|
| | Kerosene | Electricity | Other Fuel |
| Alappuzha | 20.30 | 79.12 | 0.58 |
| Ernakulam | 9.60 | 90.38 | 0.02 |
| Idukki | 27.13 | 72.75 | 0.12 |
| Kottayam | 16.94 | 82.92 | 0.14 |
| Pathanamthitta | 25.08 | 74.87 | 0.05 |
| Thrissur | 15.97 | 84.03 | 0.00 |
| **GKR** | **17.59** | **82.24** | **0.17** |

**Source** : Primary data collected by KSSP

Table 3.6.2.16

**Districtwise Distribution of Households based on the Monthly Expenditure for Fuel**

| District | % of Households with Monthly Expenditure on Fuel | | |
|---|---|---|---|
| | < 500 | 500-1000 | 1000-2000 |
| Alappuzha | 98.90 | 1.10 | 0.00 |
| Ernakulam | 97.60 | 2.38 | 0.02 |
| Idukki | 97.92 | 0.08 | 0.00 |
| Kottayam | 98.02 | 1.98 | 0.00 |
| Pathanamthitta | 97.00 | 3.00 | 0.00 |
| Thrissur | 99.31 | 0.69 | 0.00 |
| **GKR** | **98.21** | **1.78** | **0.01** |

**Source** : Primary data collected by KSSP

## Table 3.6.2.17

### Districtwise Distrbution of Households based on the Source of Drinking Water used

| District | % of Households with Drinking Water Source | | |
|---|---|---|---|
| | **TW** | **BW** | **TNK** |
| Alappuzha | 29.58 | 60.18 | 10.24 |
| Ernakulam | 50.94 | 47.75 | 1.31 |
| Idukki | 44.37 | 27.67 | 27.96 |
| Kottayam | 18.73 | 75.84 | 5.43 |
| Pathanamthitta | 16.85 | 72.83 | 1.32 |
| Thrissur | 2.78 | 96.53 | 0.69 |
| **GKR** | **34.56** | **56.73** | **8.71** |

TW - Treatable Potable Pipe Water; BW - Well/Bore Well;
TNK - Tanks/Public Wells/Rivers/Canal/Streams
**Source :** Primary data collected by KSSP

## Table 3.6.2.18

### Districtwise Distribution of Households based on the type of Diseases Reported

| District | % of Households Suffering with the Disease | | | |
|---|---|---|---|---|
| | **Water Borne** | **Air Borne** | **Occupational** | **Others** |
| Alappuzha | 7.30 | 81.65 | 1.37 | 9.69 |
| Ernakulam | 0.71 | 97.70 | 0.11 | 1.47 |
| Idukki | 1.42 | 96.99 | 0.04 | 1.55 |
| Kottayam | 2.32 | 92.94 | 0.70 | 4.04 |
| Pathanamthitta | 1.66 | 90.59 | 1.26 | 6.49 |
| Thrissur | 0.70 | 96.48 | 0.00 | 2.82 |
| **GKR** | **2.55** | **92.61** | **0.61** | **4.24** |

**Source :** Primary data collected by KSSP

## Table 3.6.2.19

### Districtwise Households based on the System of Medicine Preferred

| District | % of Households Prefering type of Medicine Treatment | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | AL | AY | HO | NAT | OTH | AY/AL | AL/HO | AY/HO |
| Alappuzha | 82.94 | 8.23 | 4.28 | 0.27 | 0.12 | 2.51 | 1.62 | 0.03 |
| Ernakulam | 91.14 | 5.52 | 1.61 | 0.23 | 0.04 | 0.97 | 0.41 | 0.09 |
| Idukki | 79.00 | 20.01 | 0.66 | 0.25 | 0.00 | 0.00 | 0.00 | 0.00 |
| Kottayam | 86.46 | 8.61 | 1.75 | 0.00 | 0.00 | 2.49 | 0.55 | 0.05 |
| Pathanamthitta | 89.12 | 7.82 | 1.85 | 0.34 | 0.05 | 0.68 | 0.15 | 0.00 |
| Thrissur | 99.31 | 0.69 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **GKR** | **86.69** | **8.96** | **2.04** | **0.22** | **0.04** | **1.41** | **0.58** | **0.05** |

AL - Allopathic; AY - Ayurveda; HO - Homeo; NAT – Naturopathy; OTH - Other Systems; AY/AL -Ayurveda/Allopathy; AL/HO - Allopathic/Homoeo; AY/HO - Ayurveda/Homoeo

## Table 3.6.2.20

### Districtwise Households based on the Type of Hospital Preferred

| District | % of Households Prefering type of Hospital | | |
|---|---|---|---|
| | Govt. | Pvt. | Govt. & Pvt. |
| Alappuzha | 54.40 | 34.22 | 11.38 |
| Ernakulam | 26.56 | 72.27 | 1.17 |
| Idukki | 5.73 | 77.60 | 16.67 |
| Kottayam | 37.52 | 51.42 | 11.06 |
| Pathanamthitta | 31.81 | 63.87 | 4.32 |
| Thrissur | 0.00 | 100 | 0.00 |
| **GKR** | **31.82** | **60.39** | **7.79** |

## Table 3.6.2.21

### Districtwise Households based on Percapita Calories Intake

| District | % of Households Consuming Percapita Calories | | | Monthly Expenditure on Food (Rs.) |
|---|---|---|---|---|
| | < 2000 | 2000-2400 | > 2400 | |
| Alappuzha | 86.10 | 8.74 | 5.16 | 300 |
| Ernakulam | 93.11 | 4.72 | 2.17 | 290 |
| Idukki | 85.12 | 10.63 | 4.25 | 297 |
| Kottayam | 90.20 | 6.22 | 3.58 | 278 |
| Pathanamthitta | 92.88 | 3.92 | 3.20 | 298 |
| Thrissur | 86.80 | 10.42 | 2.78 | 304 |
| **GKR** | **89.92** | **6.60** | **3.40** | **292** |

**Source** : Primary data collected by KSSP

## Table 3.6.2.22

### District wise Distribution of Households based on Physical Environmental Problems

| District | % of Households Expressing Physical Environmental Problems | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AP | WP | NP | WD | VP | SWI | WL | LWT | LV | SE | LS | MRS | FD | CE | APS | TDP | SN | RWD | SBE |
| Alappuzha | 10.27 | 21.40 | 5.59 | 7.38 | 2.34 | 6.06 | 21.80 | 9.34 | 5.82 | 2.68 | 0.29 | 1.12 | 15.80 | 0.32 | 1.18 | 3.95 | 0.03 | 0.12 | 0.12 |
| Ernakulam | 10.04 | 3.91 | 2.70 | 10.43 | 2.38 | 0.83 | 25.28 | 5.13 | 0.41 | 4.49 | 0.07 | 0.02 | 1.15 | 0.56 | 0.51 | 0.33 | 0.04 | 0.00 | 0.09 |
| Idukki | 0.54 | 0.49 | 0.21 | 0.70 | 0.04 | 0.04 | 3.01 | 5.36 | 3.63 | 63.85 | 31.45 | 0.04 | 3.71 | 0.00 | 0.00 | 0.25 | 35.90 | 0.00 | 0.00 |
| Kottayam | 10.80 | 11.29 | 8.06 | 1.28 | 5.32 | 0.43 | 5.54 | 3.56 | 0.08 | 3.28 | 0.49 | 0.76 | 3.12 | 0.14 | 2.09 | 1.74 | 1.03 | 0.49 | 0.38 |
| Pathanamthitta | 4.89 | 4.36 | 3.29 | 0.87 | 1.55 | 0.10 | 2.52 | 1.02 | 0.15 | 9.49 | 0.53 | 1.26 | 2.62 | 0.48 | 0.58 | 0.15 | 2.71 | 0.15 | 0.05 |
| **GKR** | **8.30** | **8.56** | **4.14** | **5.37** | **2.57** | **1.59** | **14.55** | **5.18** | **1.84** | **12.78** | **4.65** | **0.55** | **5.03** | **0.33** | **0.92** | **1.32** | **5.59** | **0.14** | **0.14** |

AP - Air Pollution, WP - Water Pollution, NP - Noise Pollution, WD - Waste Disposal, VP - Vehicular Pollution, SWI - Saline Water Intrusion, WL - Water Logging, LWT - Lowering of Water Table, LV - Loss of Vegetation SE - Soil Erosion. LS - Landslides, MRS - Mining of River Sand, FD - Flooding, CE - Coastal Erosion, APS - Accumulation of Plastic and Synthetic Wastes, TDP - Pollution Due to Pesticides, SN - Storms, RD – Rubber waste Dumping, SBE - Stream Bank Erosion

**Source** : Primary data collected by KSSP

## Table 3.6.3.1

## Districtwise Comparison of the Socio Economic Indices for Physiographic Division of GKR

| District | Physiographic Division | QOL (s) | QOL (o) | QOL (c) | Accessibi-lity Index | FAF Index |
|---|---|---|---|---|---|---|
| Alappuzha | Low Land | 0.695 | 0.572 | 0.634 | 0.770 | 0.050 |
| | Mid Land | 0.672 | 0.565 | 0.628 | 0.690 | 0.052 |
| | High Land * | - | - | - | - | - |
| Ernakulam | Low Land | 0.640 | 0.592 | 0.616 | 0.760 | 0.05 |
| | Mid Land | 0.717 | 0.606 | 0.661 | 0.740 | 0.081 |
| | High Land | 0.547 | 0.576 | 0.561 | 0.710 | 0.039 |
| Idukki | Low Land * | - | - | - | - | - |
| | Mid Land | 0.766 | 0.616 | 0.691 | 0.780 | 0.064 |
| | High Land | 0.746 | 0.541 | 0.644 | 0.640 | 0.032 |
| Kottayam | Low Land | 0.624 | 0.571 | 0.598 | 0.800 | 0.059 |
| | Mid Land | 0.708 | 0.579 | 0.643 | 0.750 | 0.071 |
| | High Land | 0.694 | 0.570 | 0.625 | 0.660 | 0.067 |
| Pathanamthitta | Low Land | 0.842 | 0.581 | 0.712 | 0.670 | 0.087 |
| | Mid Land | 0.678 | 0.569 | 0.623 | 0.680 | 0.089 |
| | High Land | 0.602 | 0.536 | 0.569 | 0.630 | 0.057 |
| Thrissur | Low Land* | - | - | - | - | - |
| | Mid Land | 0.762 | 0.605 | 0.684 | 0.780 | 0.109 |
| | High Land* | - | - | - | - | - |
| **GKR** | **Low Land** | **0.700** | **0.579** | **0.640** | **0.750** | **0.062** |
| | **Mid Land** | **0.860** | **0.590** | **0.655** | **0.880** | **0.077** |
| | **High Land** | **0.647** | **0.556** | **0.600** | **0.660** | **0.049** |

* – No High/low Land Region in the District
**Source :** Primary data collected by KSSP

**Table 3.6.3.2**

**District wise QOL Indices for Rural and Urban Zones of GKR**

| District | Area | QOL(s) | QOL(o) | QOL(c) | Accessibi-lity Index | FAF Index |
|---|---|---|---|---|---|---|
| Alappuzha | Rural | 0.690 | 0.568 | 0.631 | 0.763 | 0.046 |
| | Urban | 0.594 | 0.508 | 0.551 | 0.675 | 0.077 |
| | Total | 0.692 | 0.572 | 0.634 | 0.767 | 0.049 |
| Ernakulam | Rural | 0.689 | 0.600 | 0.645 | 0.744 | 0.066 |
| | Urban | 0.675 | 0.608 | 0.641 | 0.786 | 0.110 |
| | Total | 0.674 | 0.588 | 0.631 | 0.733 | 0.069 |
| Idukki | Rural | 0.750 | 0.550 | 0.650 | 0.656 | 0.036 |
| | Urban | 0.724 | 0.603 | 0.664 | 0.83 | 0.075 |
| | Total | 0.749 | 0.551 | 0.650 | 0.659 | 0.037 |
| Kottayam | Rural | 0.686 | 0.574 | 0.630 | 0.735 | 0.066 |
| | Urban | 0.718 | 0.600 | 0.659 | 0.803 | 0.101 |
| | Total | 0.688 | 0.575 | 0.632 | 0.739 | 0.068 |
| Pathanamthitta | Rural | 0.660 | 0.556 | 0.608 | 0.657 | 0.075 |
| | Urban | 0.786 | 0.613 | 0.699 | 0.755 | 0.149 |
| | Total | 0.666 | 0.559 | 0.612 | 0.661 | 0.078 |
| Thrissur | Rural | 0.762 | 0.605 | 0.684 | 0.783 | 0.109 |
| | Total | 0.762 | 0.605 | 0.684 | 0.783 | 0.109 |
| **GKR** | **Rural** | **0.706** | **0.576** | **0.641** | **0.723** | **0.066** |
| | **Urban** | **0.699** | **0.586** | **0.643** | **0.770** | **0.102** |
| | **Total** | **0.705** | **0.575** | **0.641** | **0.724** | **0.068** |

**Table 3.6.3.3**

**Comparision of the QOL Indices for the Municipalities in GKR**

| Municipality/ Corporation | QOL(s) | QOL(o) | QOL(c) | Accessibility Index | FAF Index |
|---|---|---|---|---|---|
| Kochi Corporation | 0.621 | 0.609 | 0.615 | 0.870 | 0.101 |
| Aluva | 0.748 | 0.636 | 0.692 | 0.890 | 0.280 |
| Angamali | 0.737 | 0.598 | 0.668 | 0.750 | 0.091 |
| Kalamassery | 0.773 | 0.601 | 0.687 | 0.660 | 0.116 |
| Kothamangalam | 0.670 | 0.572 | 0.621 | 0.830 | 0.056 |
| Muvattupuzha | 0.658 | 0.614 | 0.636 | 0.730 | 0.081 |
| Paravoor | 0.611 | 0.600 | 0.606 | 0.680 | 0.047 |
| Perumbavoor | 0.776 | 0.631 | 0.703 | 0.860 | 0.129 |
| Trippunithura | 0.480 | 0.610 | 0.545 | 0.800 | 0.090 |

**Source :** Primary data collected by KSSP

Table 3.6.3.4

**Block-wise Comparison of Socio-Economic Indices for the Districts of GKR**

| Block / Municipality / Corporation | QOL(s) | QOL(o) | QOL(c) | Accessibility Index | FAF Index |
|---|---|---|---|---|---|
| **Allappuzha District** | | | | | |
| Ambalapuzha | 0.642 | 0.591 | 0.617 | 0.887 | 0.037 |
| Aryad | 0.708 | 0.570 | 0.639 | 0.733 | 0.028 |
| Chambakulam | 0.654 | 0.573 | 0.614 | 0.783 | 0.047 |
| Chengannur | 0.685 | 0.555 | 0.620 | 0.729 | 0.061 |
| Haripad | 0.646 | 0.565 | 0.606 | 0.758 | 0.053 |
| Kanjikuzhi | 0.708 | 0.600 | 0.654 | 0.732 | 0.035 |
| Mavelikkara | 0.685 | 0.575 | 0.655 | 0.653 | 0.057 |
| Pattanakkad | 0.764 | 0.575 | 0.600 | 0.785 | 0.053 |
| Thykattusery | 0.864 | 0.557 | 0.711 | 0.808 | 0.035 |
| Chengannur (m) | 0.700 | 0.628 | 0.664 | 0.810 | 0.095 |
| Cherthala (m) | 0.657 | 0.582 | 0.619 | 0.760 | 0.064 |
| Kayamkulam (m) | 0.773 | 0.583 | 0.678 | 0.860 | 0.108 |
| Mavelikkara (m) | 0.768 | 0.653 | 0.711 | 0.730 | 0.142 |
| **Ernakulam District** | | | | | |
| Alangad | 0.708 | 0.590 | 0.650 | 0.770 | 0.068 |
| Angamali | 0.755 | 0.601 | 0.678 | 0.760 | 0.075 |
| Edappally | 0.642 | 0.584 | 0.613 | 0.720 | 0.032 |
| Koovappady | 0.751 | 0.595 | 0.673 | 0.732 | 0.068 |
| Kothamangalam | 0.663 | 0.593 | 0.628 | 0.719 | 0.060 |
| Mulanthuruthy | 0.761 | 0.637 | 0.700 | 0.755 | 0.076 |
| Moovatupuzha | 0.637 | 0.595 | 0.616 | 0.745 | 0.070 |
| Palluruthy | 0.444 | 0.589 | 0.517 | 0.785 | 0.036 |
| Pambakuda | 0.721 | 0.617 | 0.669 | 0.691 | 0.092 |
| Parakkadavu | 0.735 | 0.570 | 0.653 | 0.740 | 0.051 |
| Paravoor | 0.667 | 0.583 | 0.625 | 0.714 | 0.032 |
| Vadavukode | 0.707 | 0.645 | 0.676 | 0.750 | 0.104 |
| Vazhakkulam | 0.756 | 0.586 | 0.671 | 0.758 | 0.083 |
| Vypin | 0.609 | 0.585 | 0.597 | 0.780 | 0.032 |
| Vytila | 0.474 | 0.612 | 0.543 | 0.850 | 0.055 |
| Kochi (c) | 0.621 | 0.609 | 0.615 | 0.870 | 0.101 |
| Aluva (m) | 0.748 | 0.636 | 0.692 | 0.890 | 0.280 |
| Angamali (m) | 0.737 | 0.598 | 0.668 | 0.750 | 0.091 |
| Kalamassery (m) | 0.773 | 0.601 | 0.687 | 0.660 | 0.116 |
| Kothamangalam (m) | 0.670 | 0.572 | 0.621 | 0.830 | 0.056 |
| Veliyanad | 0.561 | 0.549 | 0.555 | 0.788 | 0.025 |
| Alappuzha (m) | 0.667 | 0.600 | 0.634 | 0.890 | 0.051 |
| Moovattupuzha (m) | 0.658 | 0.614 | 0.636 | 0.730 | 0.081 |
| Paravoor (m) | 0.611 | 0.600 | 0.606 | 0.680 | 0.047 |

Contd...

Table 3.6.3.4 Contd...

| Block / Municipality / Corporation | QOL(s) | QOL(o) | QOL(c) | Accessibility Index | FAF Index |
|---|---|---|---|---|---|
| Perumbavoor (m) | 0.776 | 0.631 | 0.703 | 0.860 | 0.129 |
| Trippunithura (m) | 0.480 | 0.610 | 0.545 | 0.800 | 0.090 |
| **Idukki District** | | | | | |
| Adimali | 0.736 | 0.481 | 0.609 | 0.614 | 0.016 |
| Azhutha | 0.776 | 0.567 | 0.672 | 0.647 | 0.029 |
| Devikulam | 0.726 | 0.488 | 0.607 | 0.550 | 0.021 |
| Elamdesam | 0.750 | 0.596 | 0.673 | 0.720 | 0.061 |
| Idukki | 0.729 | 0.593 | 0.661 | 0.692 | 0.032 |
| Kattappana | 0.747 | 0.543 | 0.645 | 0.621 | 0.043 |
| Nedumkandam | 0.756 | 0.501 | 0.628 | 0.611 | 0.025 |
| Thodupuzha | 0.774 | 0.622 | 0.698 | 0.785 | 0.053 |
| Thodupuzha (m) | 0.724 | 0.603 | 0.664 | 0.830 | 0.075 |
| **Kottayam District** | | | | | |
| Erattupetta | 0.689 | 0.583 | 0.636 | 0.660 | 0.067 |
| Ettumanur | 0.689 | 0.594 | 0.642 | 0.870 | 0.076 |
| Kaduthuruthy | 0.710 | 0.570 | 0.641 | 0.726 | 0.042 |
| Kanjirappally | 0.710 | 0.549 | 0.630 | 0.640 | 0.050 |
| Lalam | 0.716 | 0.577 | 0.647 | 0.753 | 0.087 |
| Madappally | 0.715 | 0.590 | 0.653 | 0.714 | 0.055 |
| Pallam | 0.754 | 0.564 | 0.659 | 0.743 | 0.070 |
| Pambady | 0.587 | 0.543 | 0.566 | 0.710 | 0.068 |
| Uzhavur | 0.700 | 0.587 | 0.643 | 0.758 | 0.085 |
| Vazhur | 0.715 | 0.591 | 0.653 | 0.680 | 0.084 |
| Vaikom | 0.542 | 0.562 | 0.552 | 0.860 | 0.043 |
| Changanassery (m) | 0.732 | 0.604 | 0.668 | 0.810 | 0.128 |
| Kottayam (m) | 0.750 | 0.625 | 0.687 | 0.830 | 0.129 |
| Pala (m) | 0.777 | 0.592 | 0.685 | 0.710 | 0.074 |
| Vaikom (m) | 0.612 | 0.577 | 0.595 | 0.860 | 0.071 |
| **Pathanamthitta District** | | | | | |
| Ilanthur | 0.516 | 0.535 | 0.526 | 0.626 | 0.050 |
| Konny | 0.598 | 0.548 | 0.574 | 0.673 | 0.062 |
| Koipram | 0.802 | 0.577 | 0.690 | 0.682 | 0.096 |
| Kulanada | 0.590 | 0.563 | 0.577 | 0.647 | 0.091 |
| Mallappally | 0.743 | 0.576 | 0.659 | 0.721 | 0.105 |
| Pulikkeezhu | 0.844 | 0.587 | 0.716 | 0.666 | 0.089 |
| Ranni | 0.583 | 0.473 | 0.557 | 0.601 | 0.052 |
| Pathanamthitta (m) | 0.747 | 0.611 | 0.679 | 0.750 | 0.141 |
| Thiruvalla (m) | 0.824 | 0.614 | 0.719 | 0.760 | 0.157 |
| **Thrissur District** | | | | | |
| Chalakuddy | 0.762 | 0.605 | 0.684 | 0.783 | 0.109 |

**Source :** Primary data collected by KSSP

Socio-Economic / Quality of Life Survey

Division of the GKR into 23 Grids based on the Map of Area

Five Grids in Ernakulam District Allocated to the Five Field Assistants in the Project Group

Selection of 18 Parishad Volunteers from the Remaining Grids

Training for the Field Assistants and Field Volunteers on 16/6/98 at Kochi on the Concept of Carrying Capacity Study and Survey Methodology

Sample Survey in the Respective Grids in the Last Week of June 1998

Detailed Training on the Survey Performa in the Respective District Parishad Centres in the Last Week of June 1998

Survey Started On 1st July 1988, in all the Grids

Monthly Meeting of Field Staff with Research Scientists / Technical Assistants at the Respective Parishad Bhavans and Checking of the Filled Up Performa

Quarterly Meeting of all the Field Staff at Kochi Parishad Bhavan with the Whole Project Group

**Fig. 3.6.1.1 : Approach to the Socio-Economic Survey**

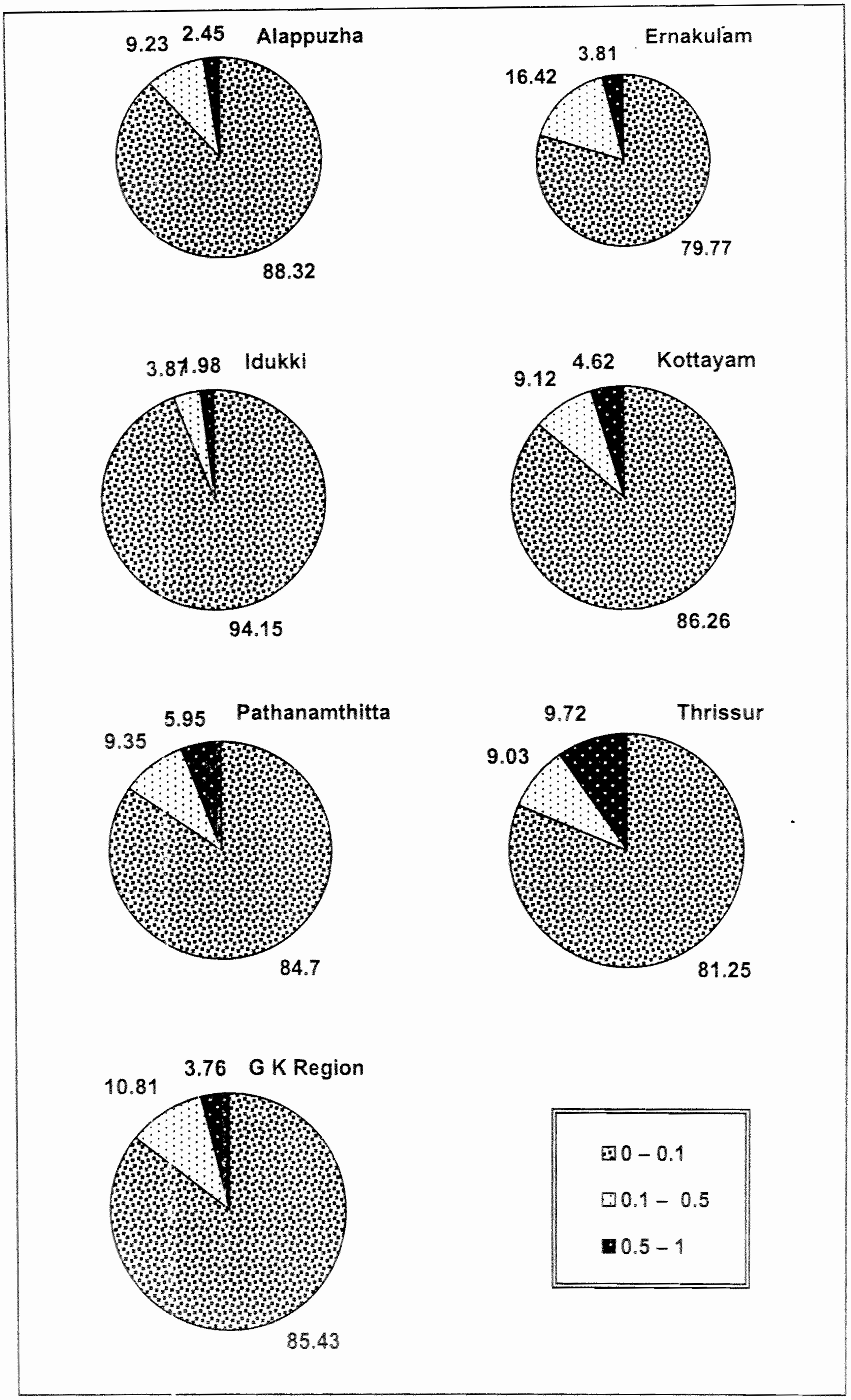



Fig. 3.6.1.2 : Distribution of Households under each FAF Index Range in GKR

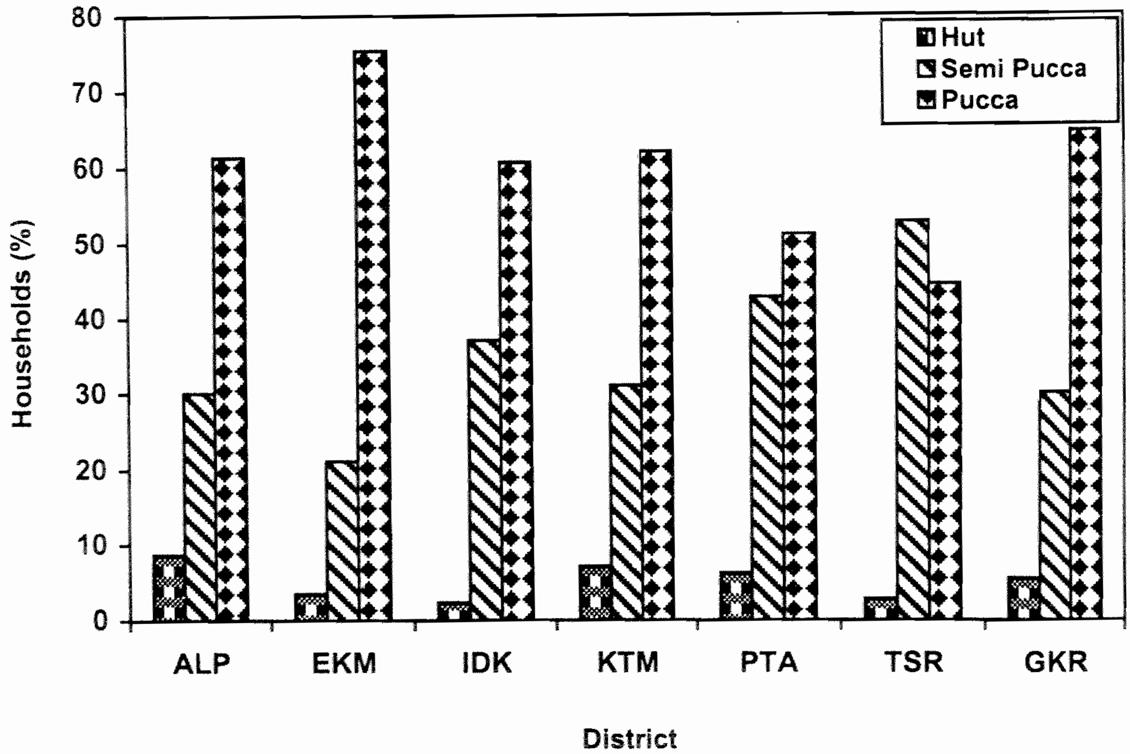



Fig. 3.6.2.1 : District-wise Distribution of Households based on Quality of House

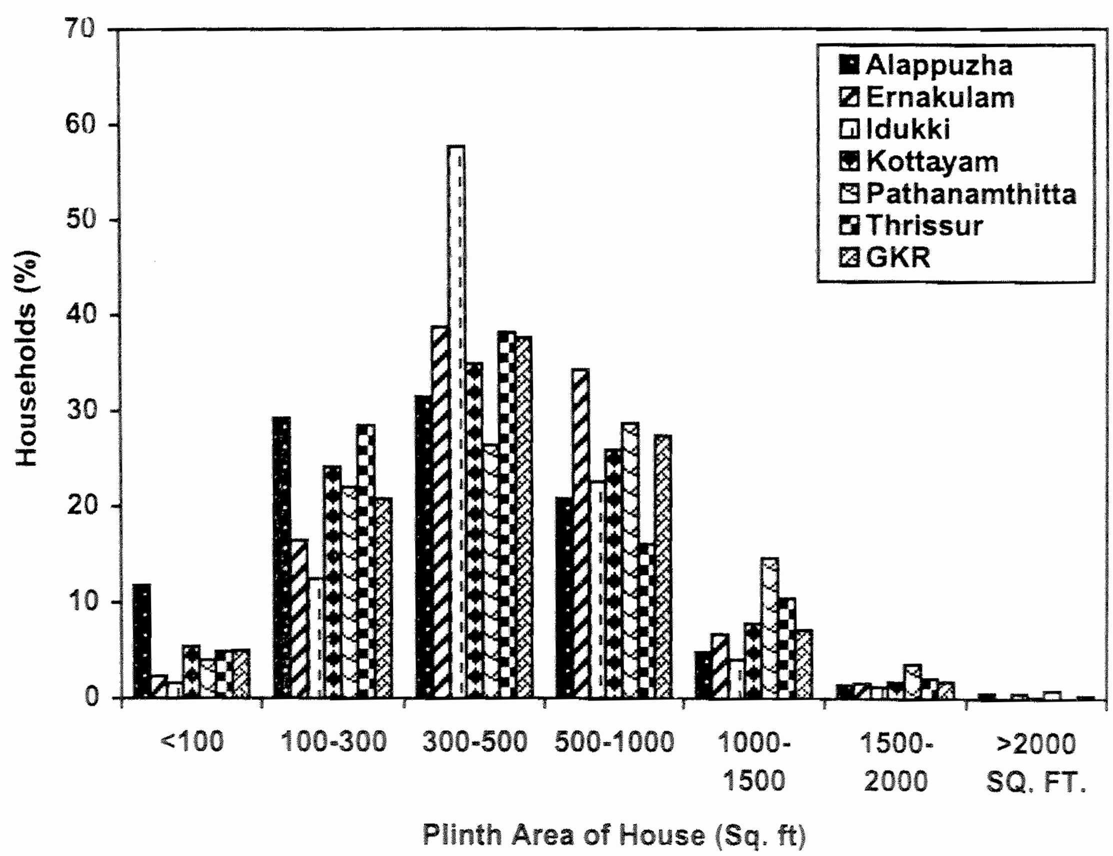



Fig. 3.6.2.2 : District-wise Distribution of Households based on the Plinth Area of House

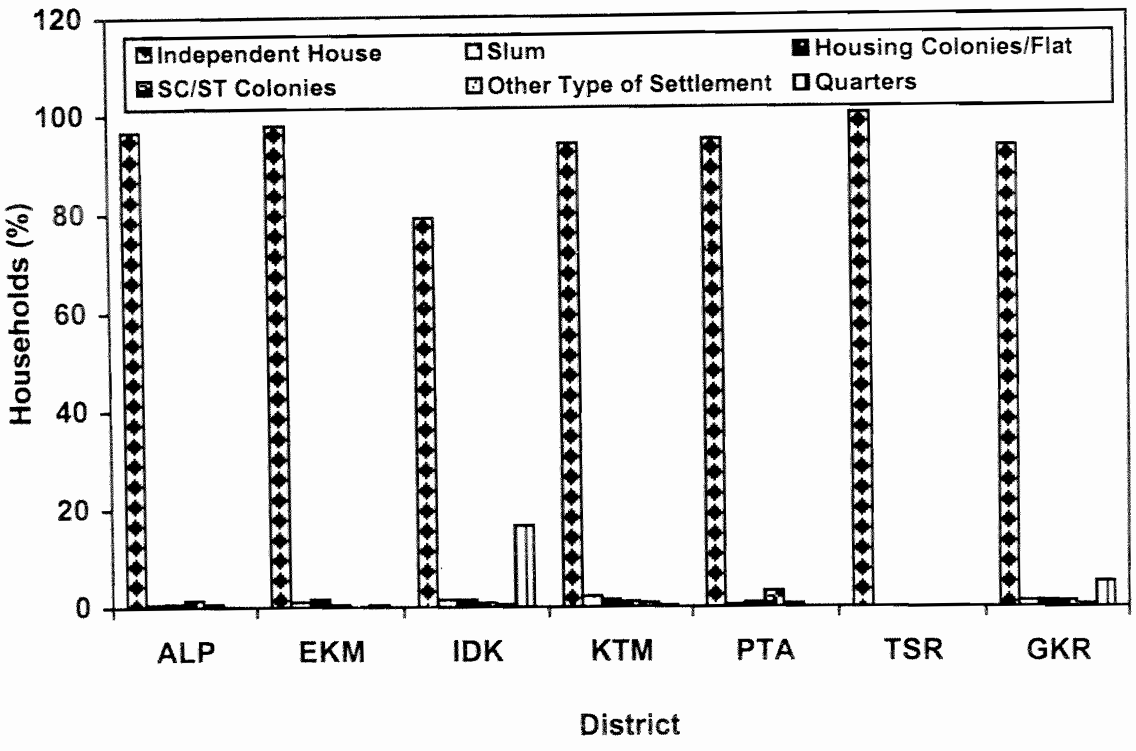



Fig. 3.6.2.3 : District-wise Distribution of Households based on the Type of Settlements

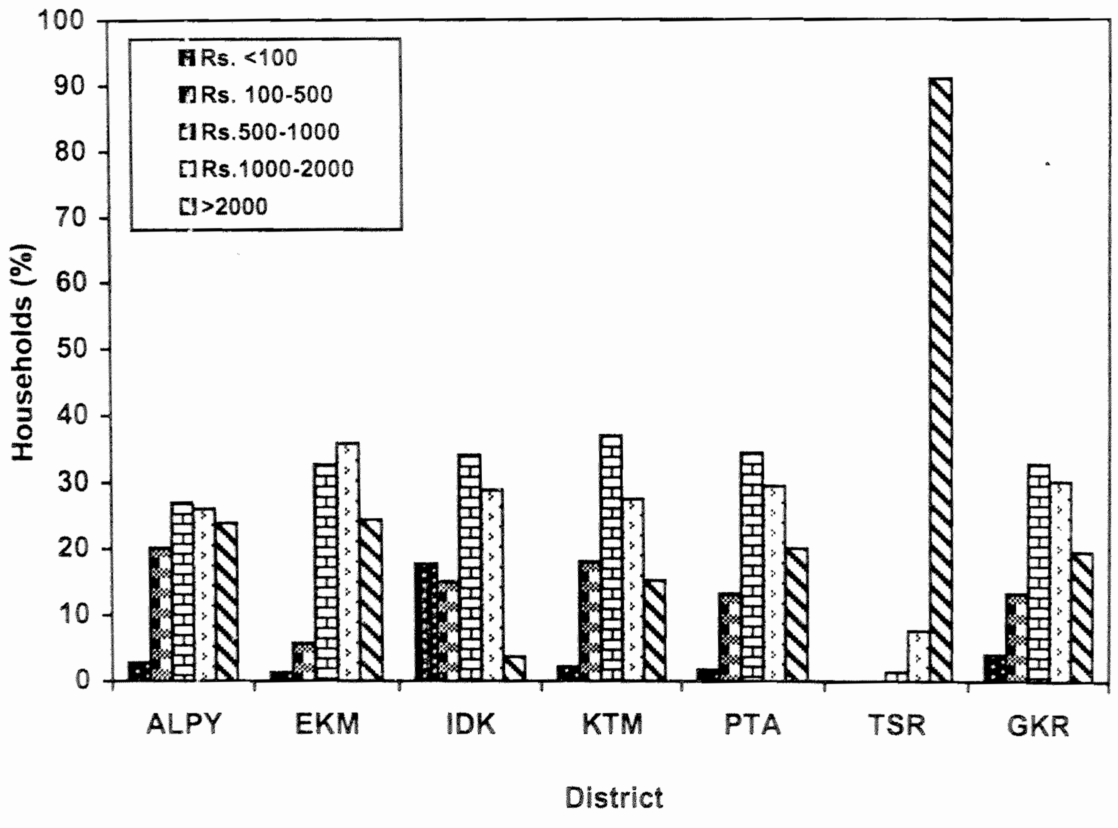



Fig. 3.6.2.4 : District-wise Distribution of Households based on Annual Expenditure on Clothing

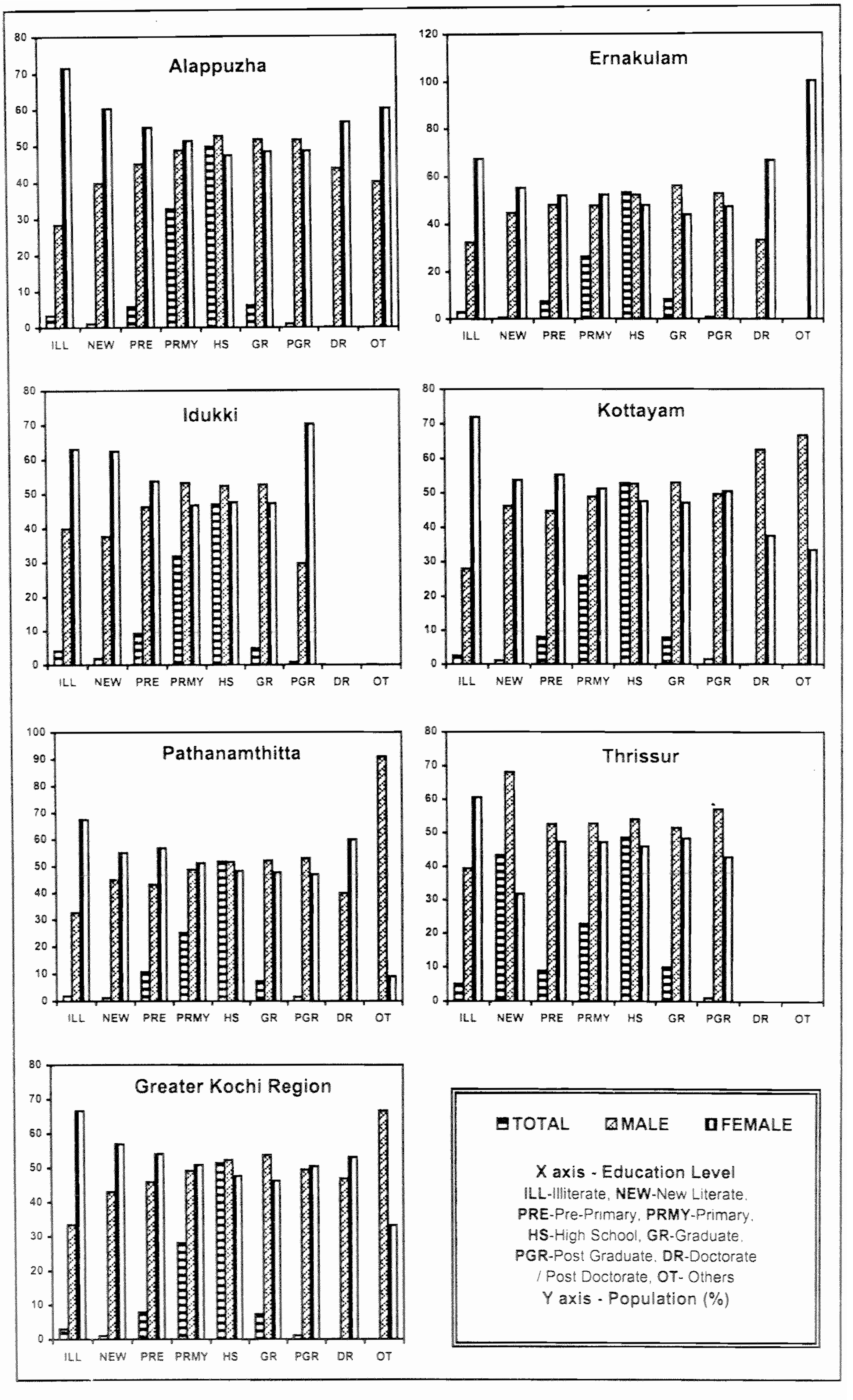



Fig. 3.6.2.5 : District-wise Distribution of Population based on the Educational Level

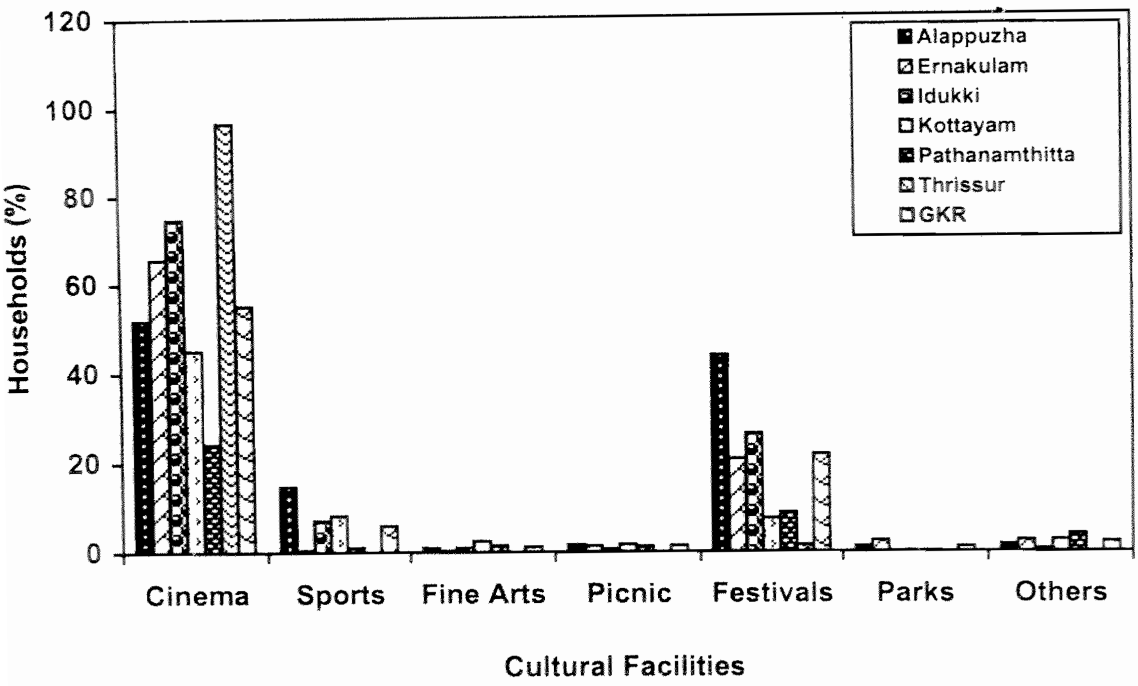
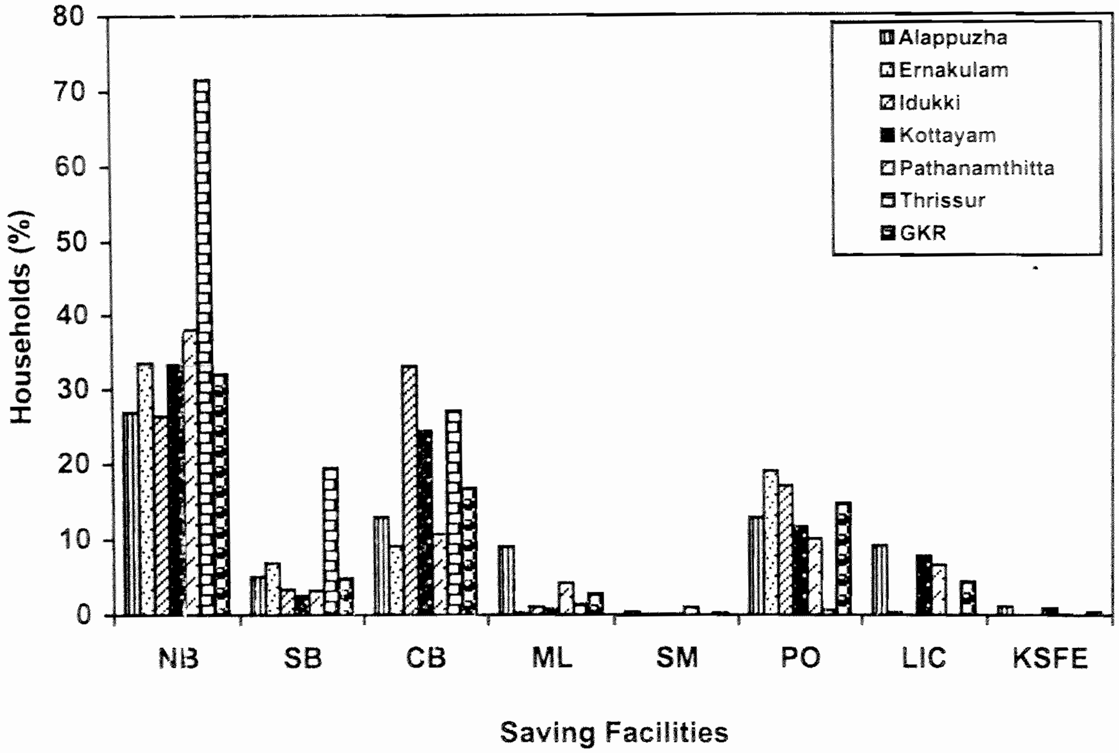



Fig. 3.6.2.6 : District-wise Distribution of Households




**NB**-Nationalized Banks, **SB**-Scheduled Banks, **CB**-Co-Operative Banks, **ML**-Money Lenders, **SM**-Stock Market, **PO**-Post Office Savings, **LIC**-Life Insurance Cooperation, **KSFE**-Kerala State Financial Enterprises

Fig. 3.6.2.7 : District-wise Distribution of Households based on the Institutions used for Savings

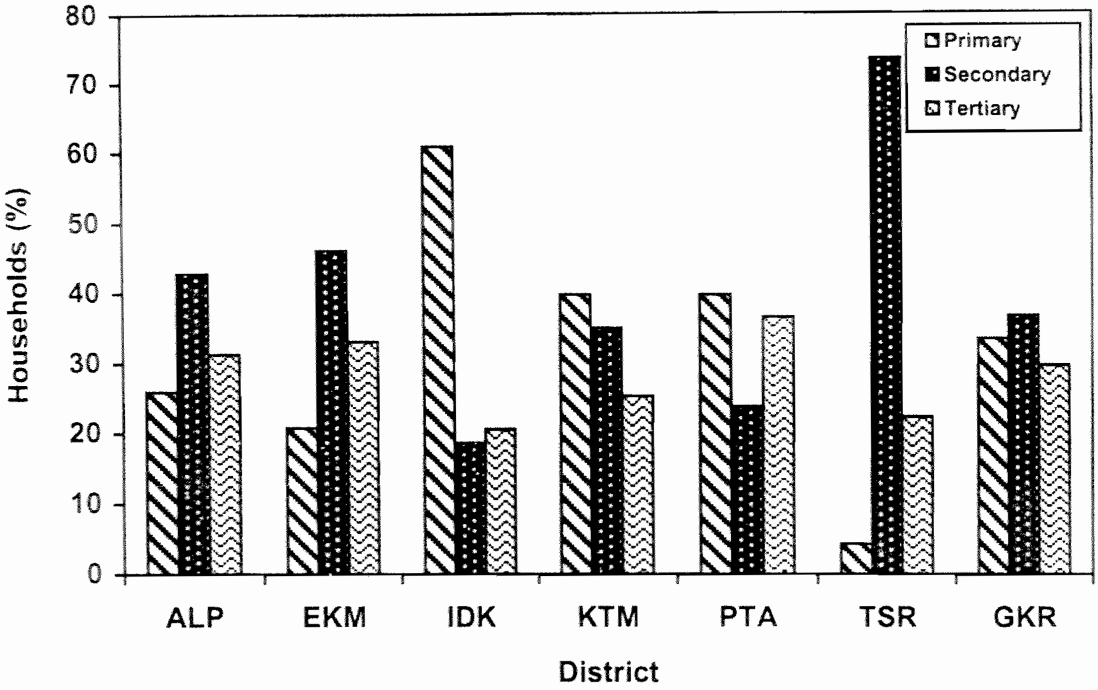
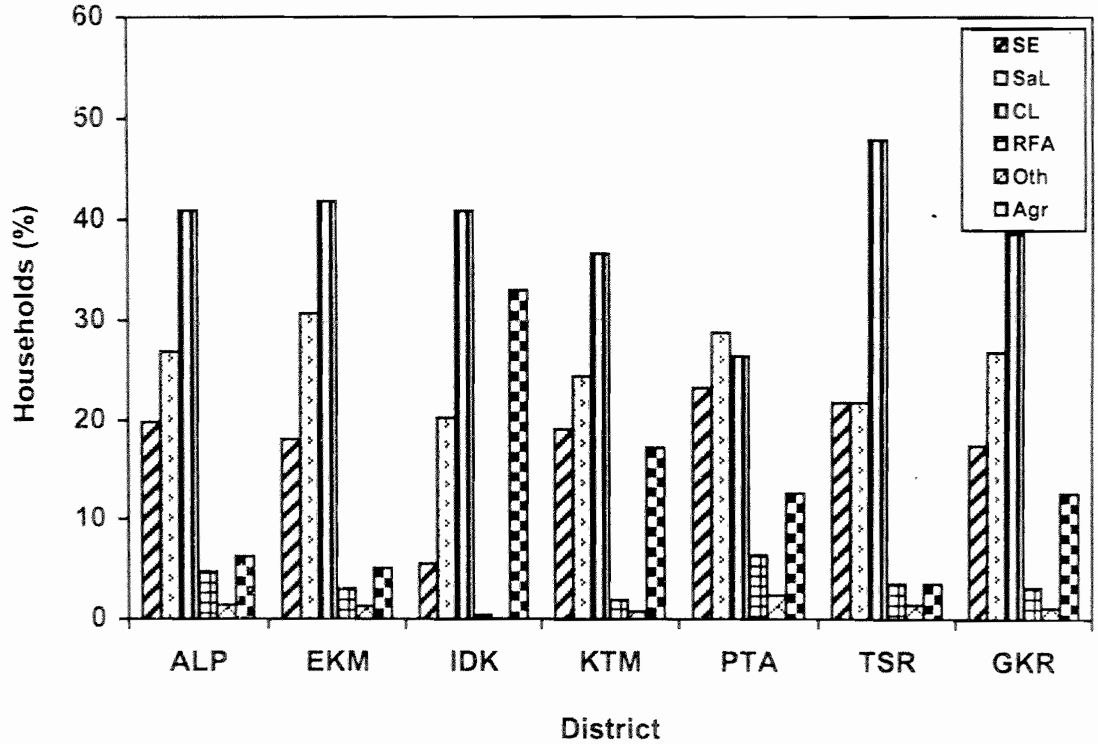
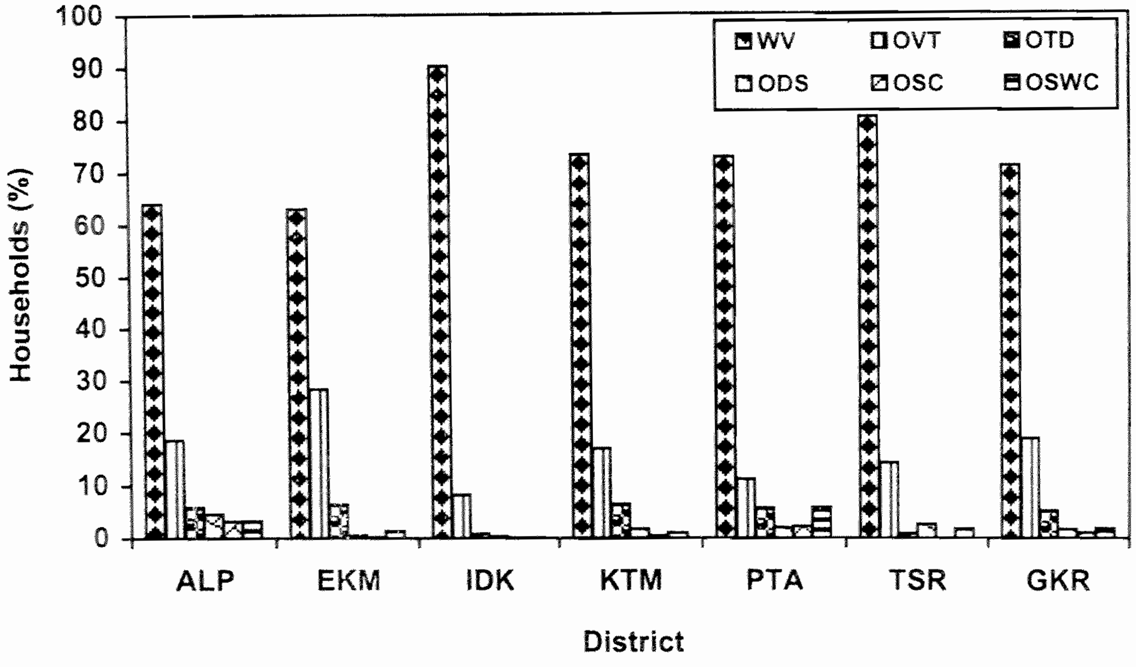



Fig. 3.6.2.8 : District-wise Distribution of Households based on Income Generating Group




**SE**-Self Employment, **SaL**-Salaried Job / Regular Wage, **CL**-Casual labour, **RFA**-Remmittance From Abroad, **Oth**-Any Other Source, **Agr**-Agriculture

Fig. 3.6.2.9 : District-wise Distribution of Households based on Main Source of Income




**WV**-Within the Village / Ward, **OVT**-Outside the Village but within the Taluk, **OTD**-Outside the Taluk but within the District, **ODS**- Outside the District but within the State, **OSC**- Outside the State but within the Country, **OSWC**- Outside the State but within the Country

**Fig. 3.6.2.10 : District-wise Distribution of Households based on the Place of Work**

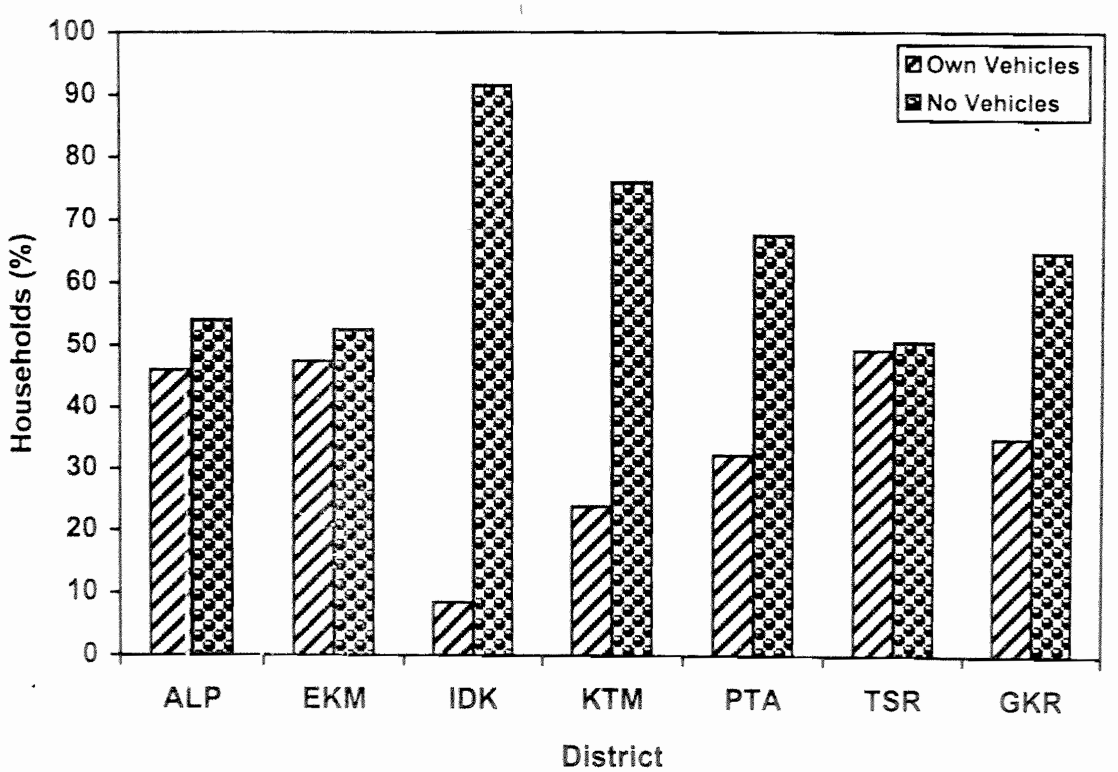



**Fig. 3.6.2.11 : District-wise Distribution of Households based on Ownership of Vehicles**

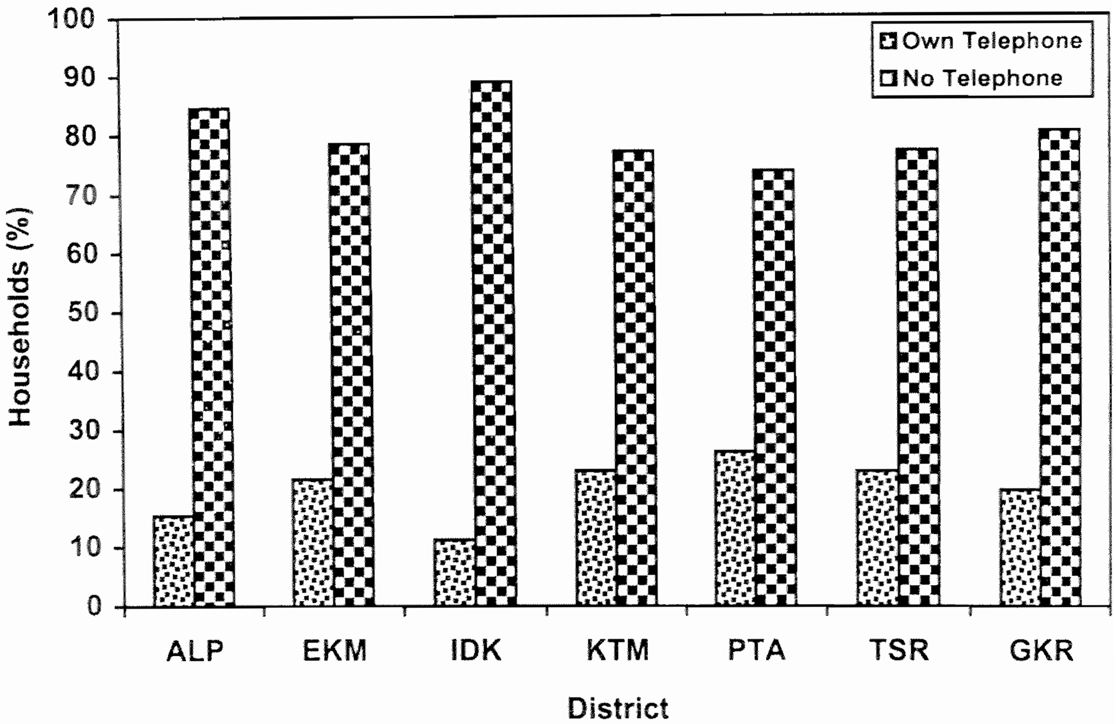
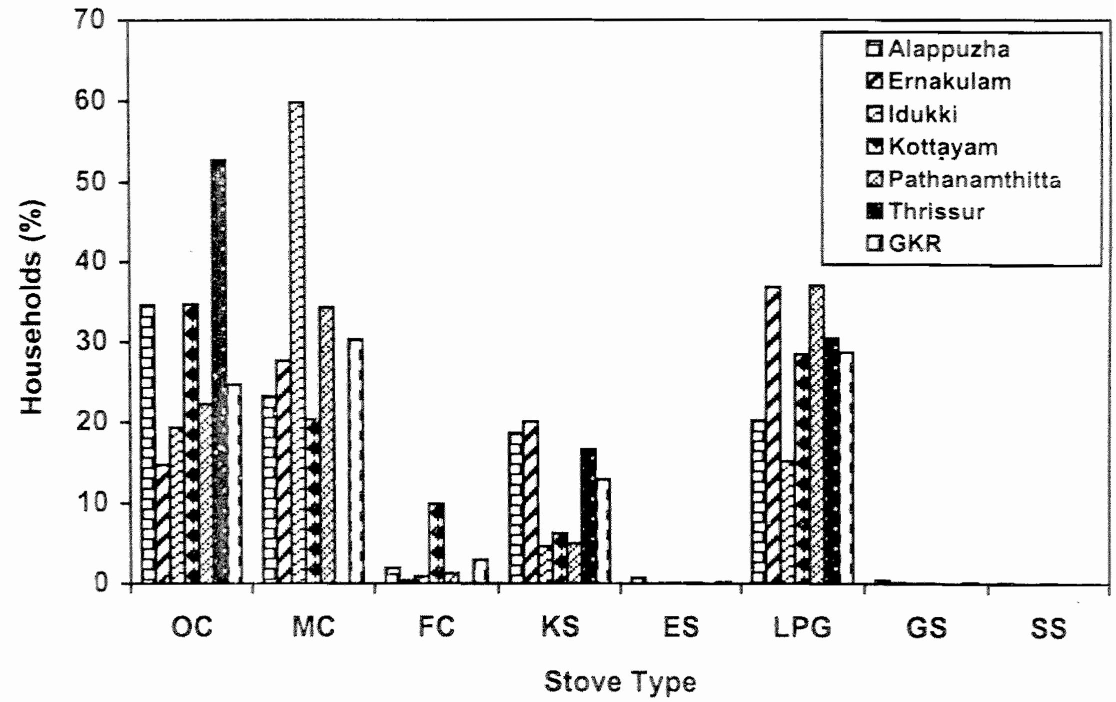
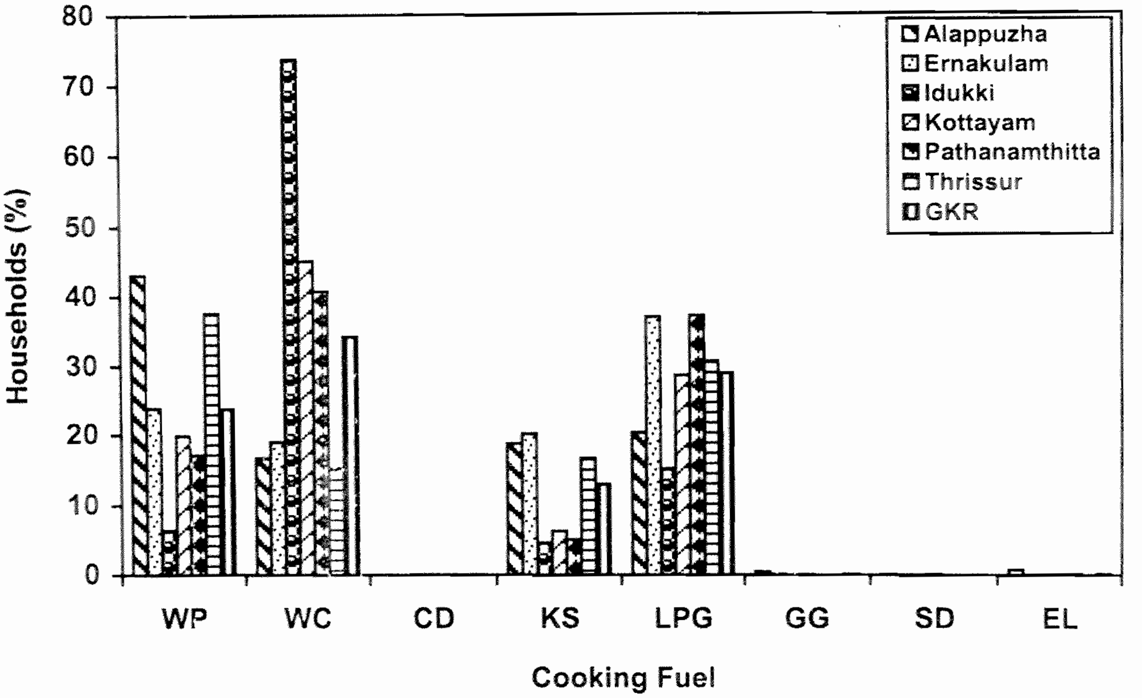



Fig. 3.6.2.12 : District-wise Distribution of Households with Own Telephone Connections




OC-Crude / Open Chulha, MC-Mason Made Chulha, FC-Fuel Efficient Chulha. KS–Kerosene Stove, ES-Electric Stove, LPG-LPG Stove, GS-Gober Gas Stove.

Fig. 3.6.2.13 : District-wise Distribution of Households based on Type of Stove used




WP-Firewood Purchased, WC-Firewood Free Collection, CD-Cow Dung, KS-Kerosene, LPG -LPG Stove, GB-Gober Gas, SD-Saw Dust, EL-Electricity

**Fig. 3.6.2.14 : District-wise Distribution of Households based on Type of Stove used**

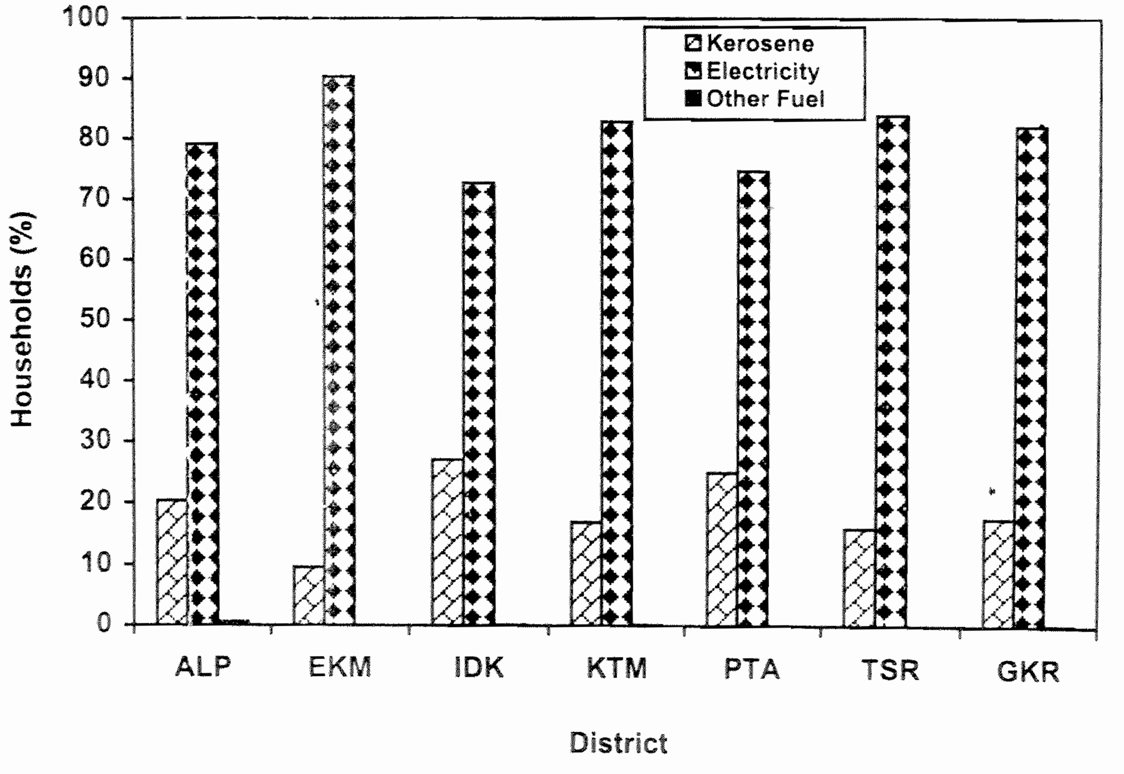



**Fig. 3.6.2.15 : District-wise Distribution of Households based on Type of Fuel used for Lighting in GKR**

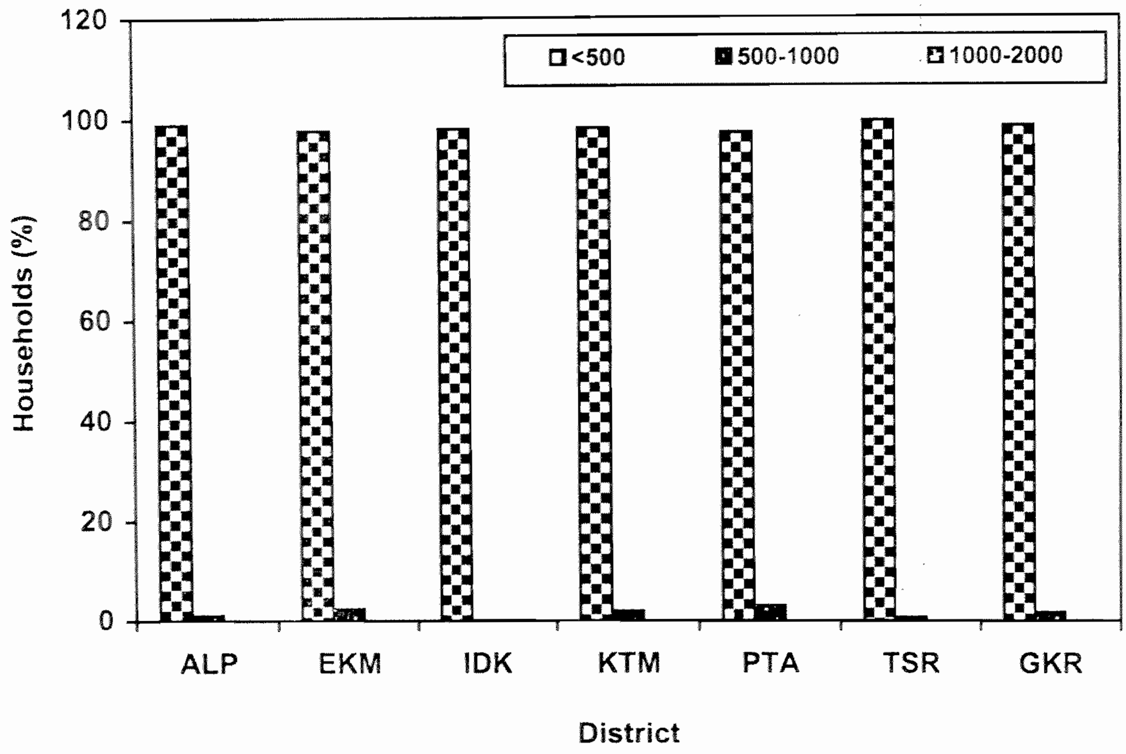
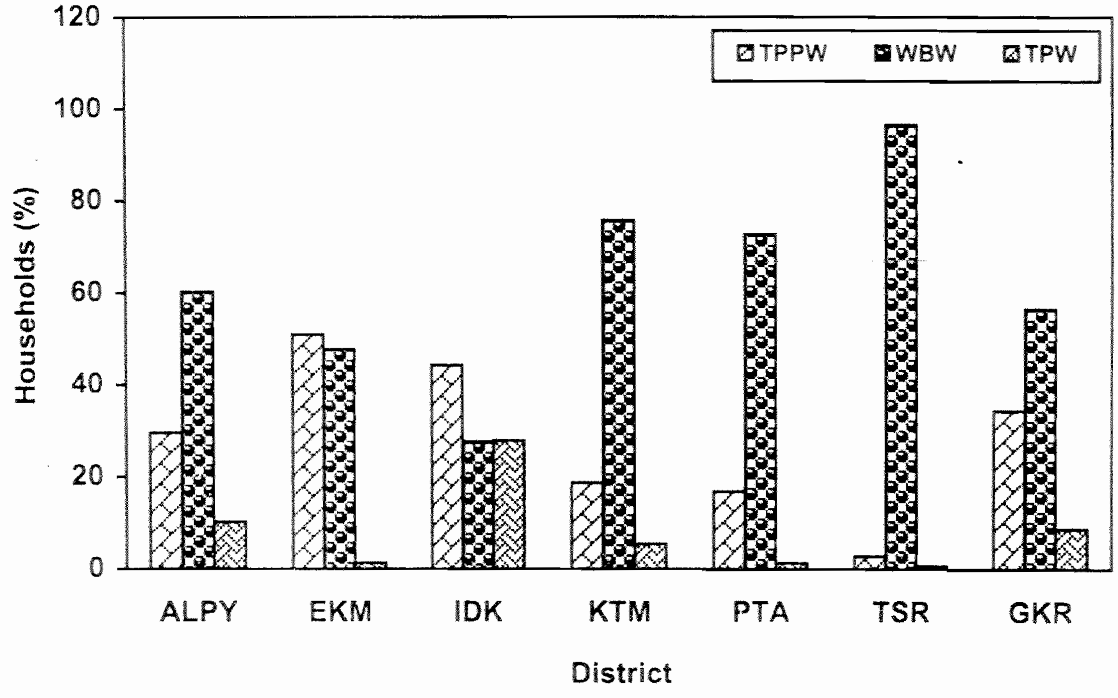



Fig. 3.6.216 : District-wise Distribution of Households based on Monthly Expenditure for Fuel




**TPPW**-Treatable Potable Pipe Water, **WBW**-Well/Bore Well.
**TPW**-Tanks / Public Wells / Rivers / Canal / Streams

Fig. 3.6.2.17 : District-wise Distribution of Households based on Source of Drinking Water

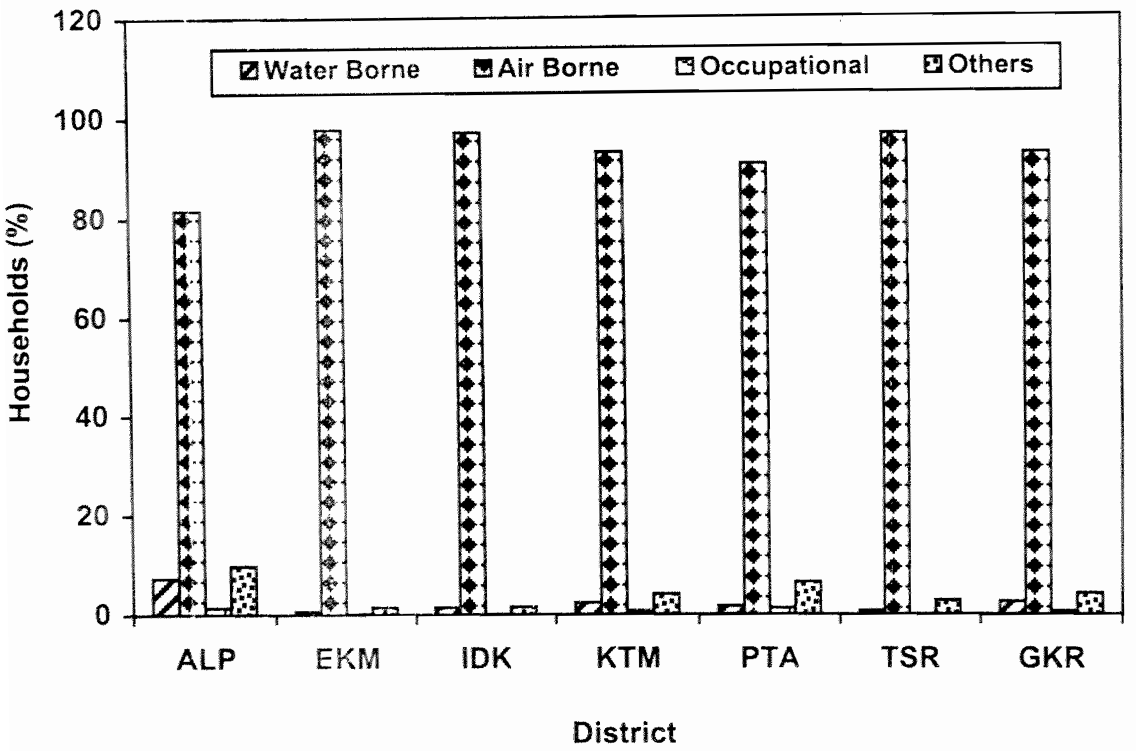



Fig. 3.6.2.18 : District-wise Distribution of Households based on the Type of Diseases Reported

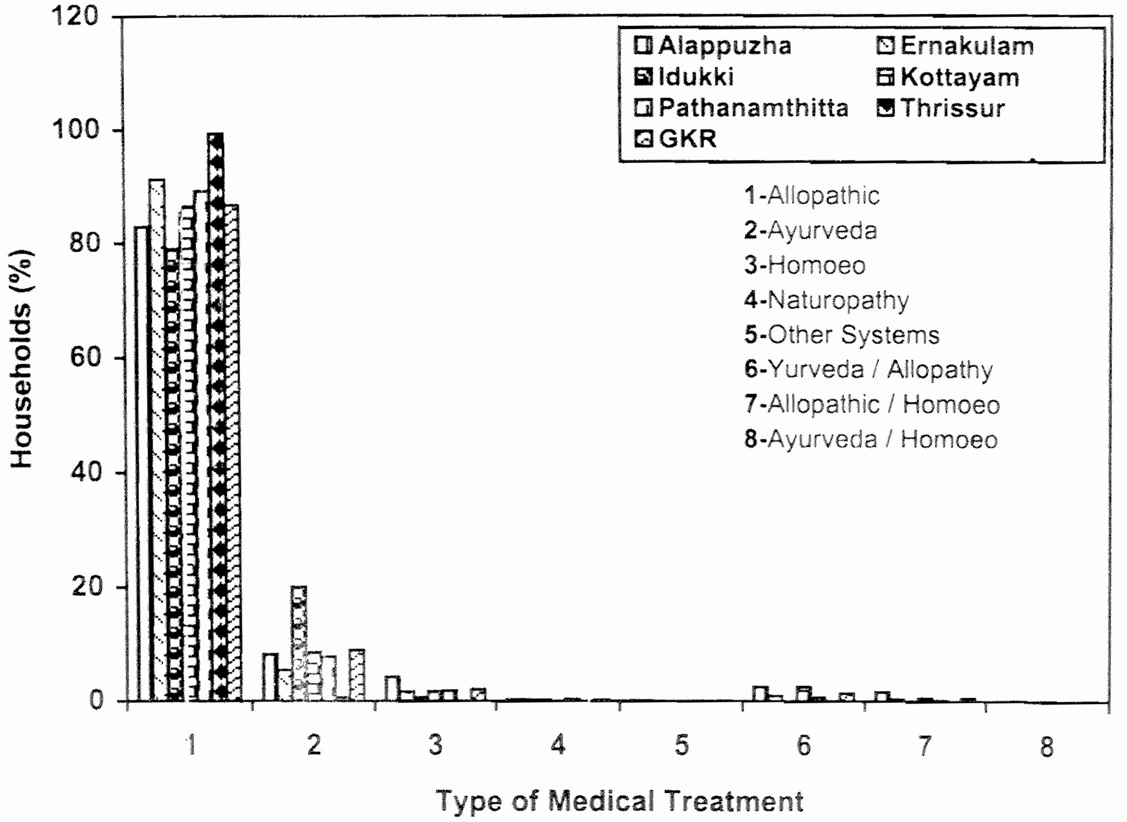



Fig. 3.6.2.19 : District-wise Distribution of Households based on the System of Medicine Preferred

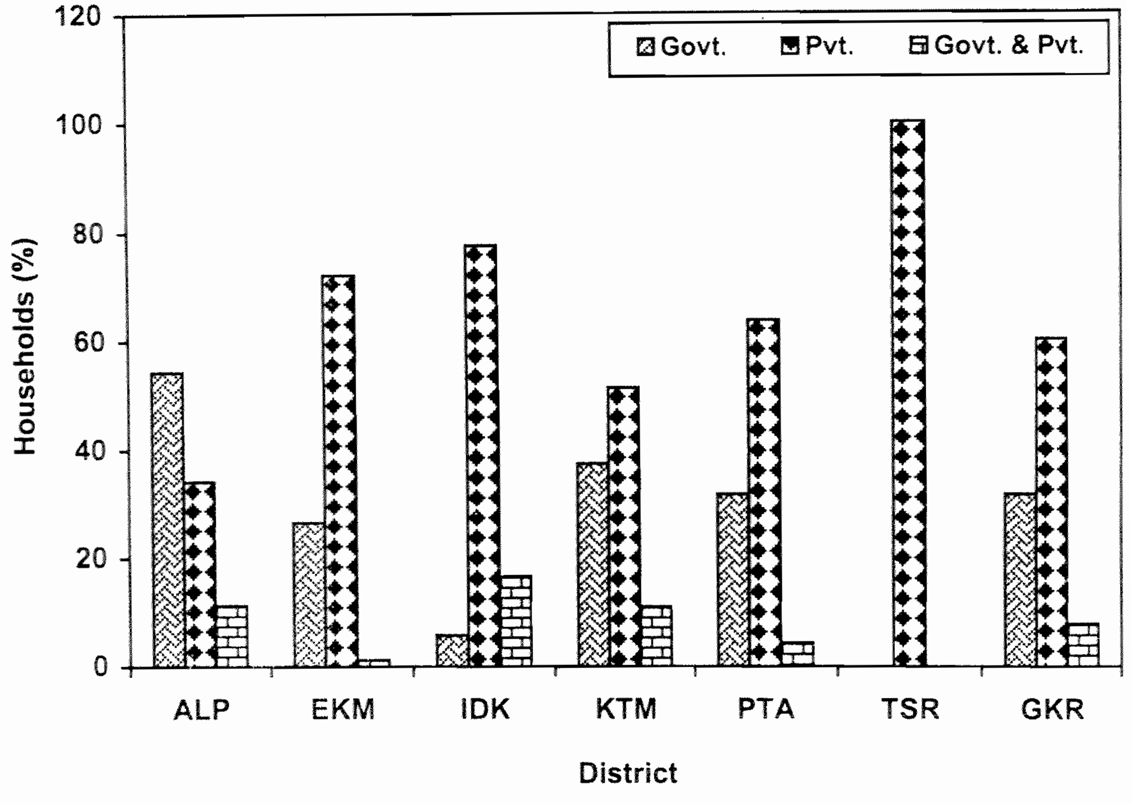



Fig. 3.6.2.20 : District-wise Distribution of Households based on the Type of Hospitals Preferred

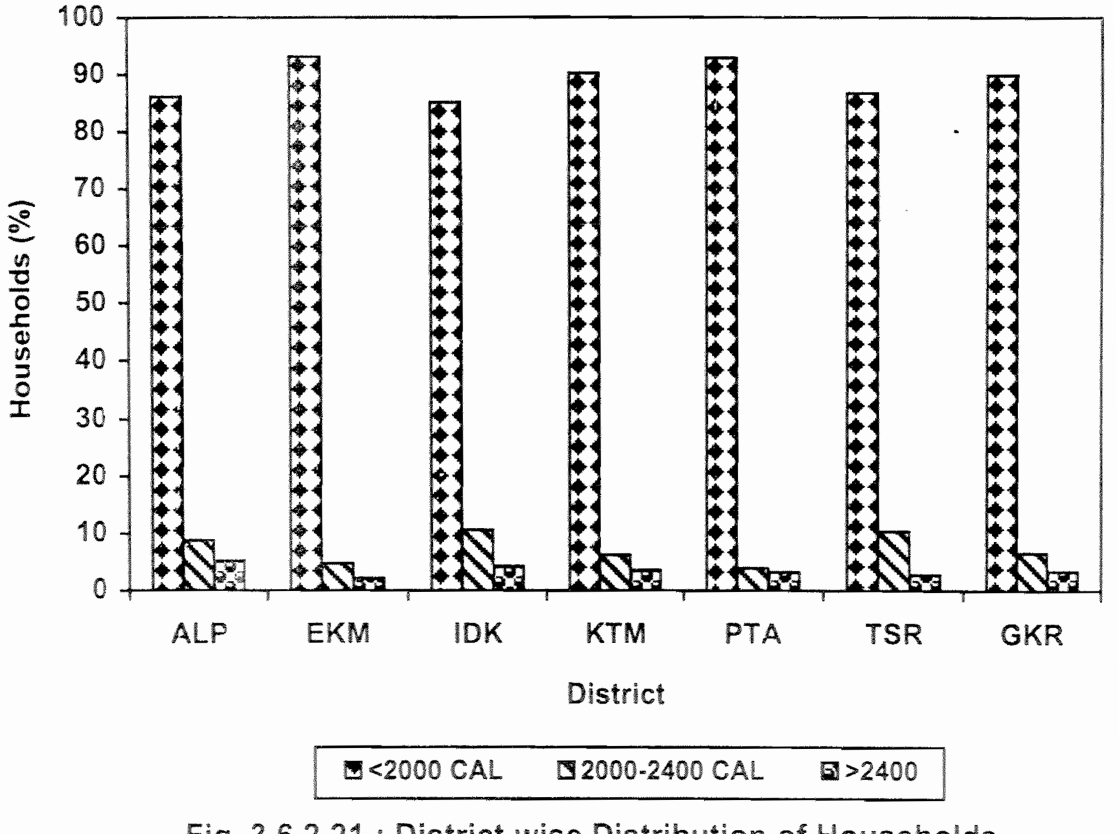



Fig. 3.6.2.21 : District-wise Distribution of Households based on the Per-capita Calorific Value Consumed

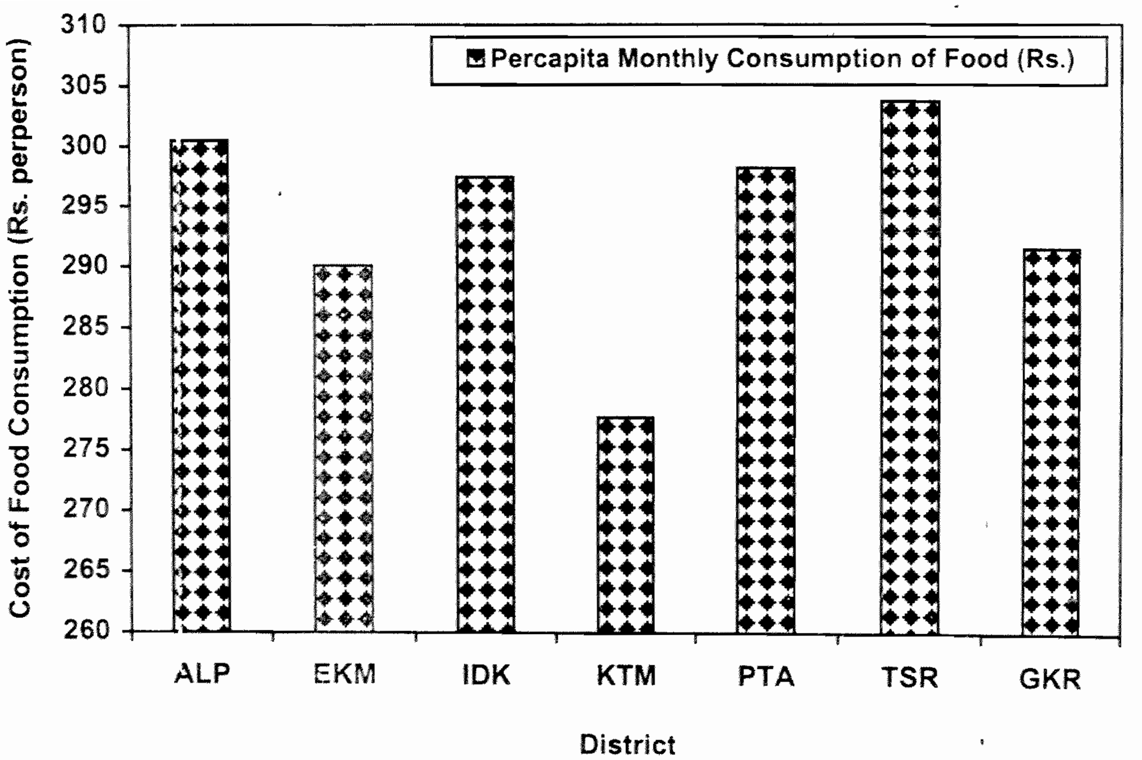



Fig. 3.6.2.22 : District-wise Distribution of Households based on Average Per-capita Monthly Consumption of Food

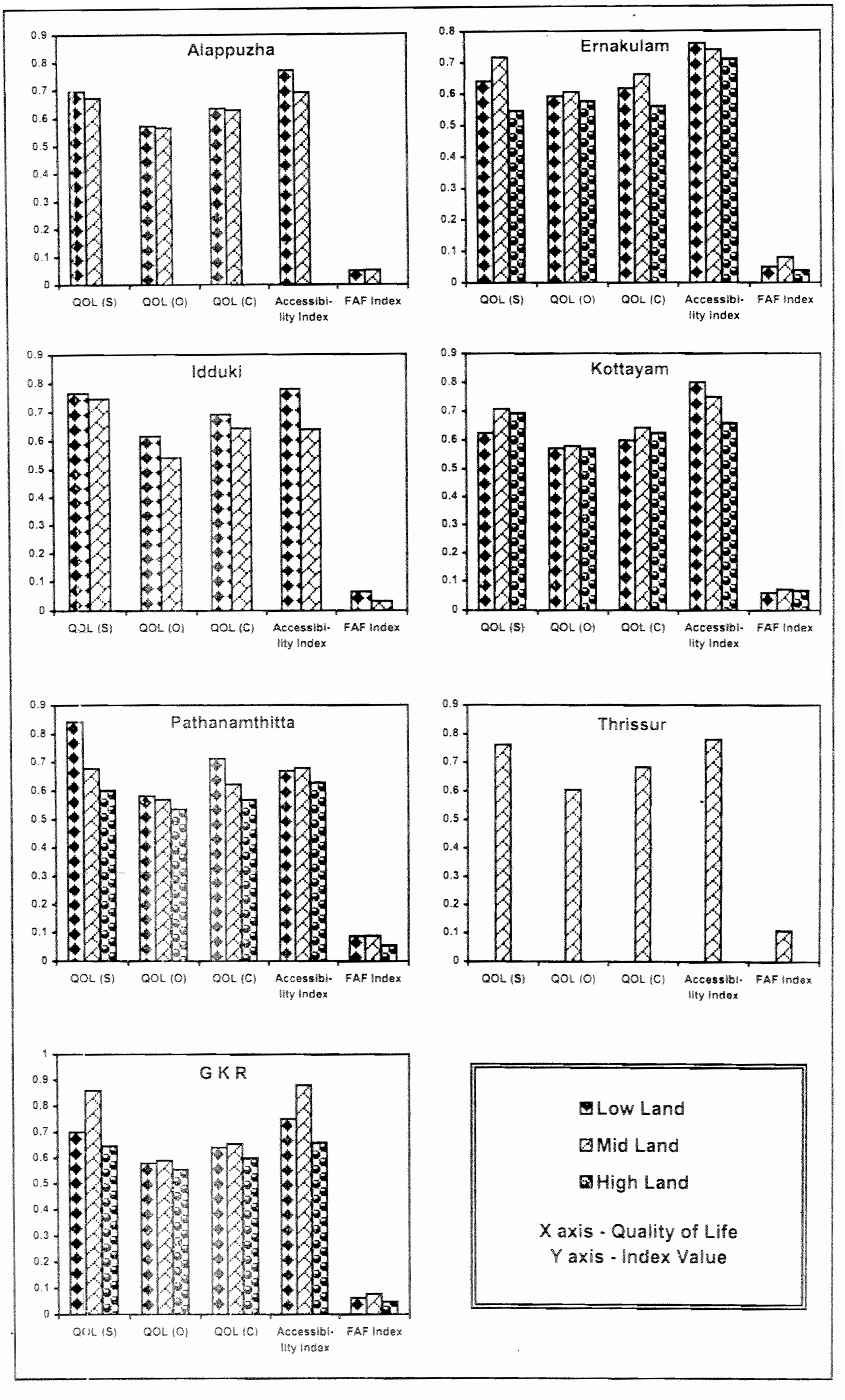



Fig. 3.6.3.1 : District-wise Comparison of Socio-Economic Indices for GKR

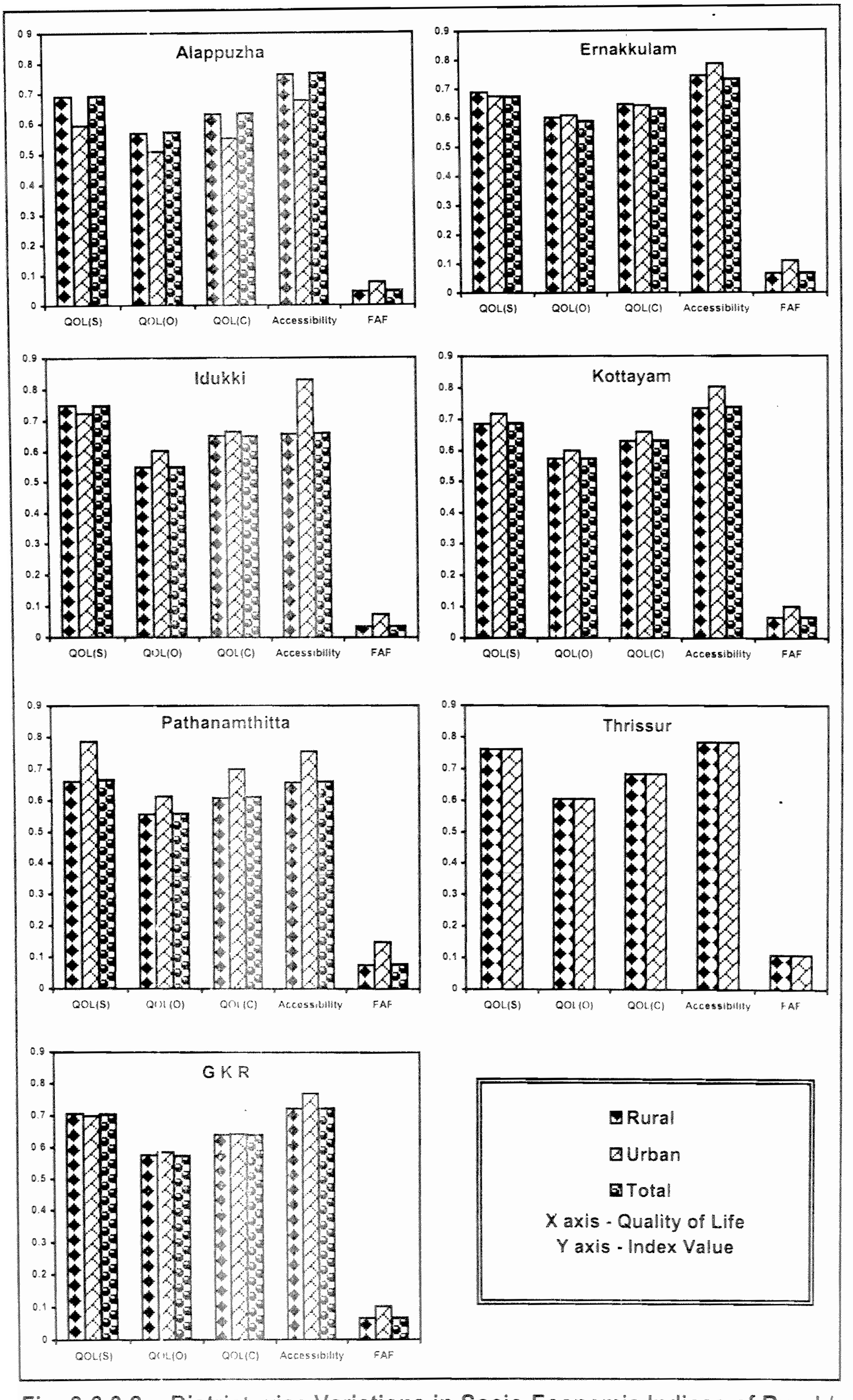



Fig. 3.6.3.2 : District-wise Variations in Socio-Economic Indices of Rural / Urban for GKR

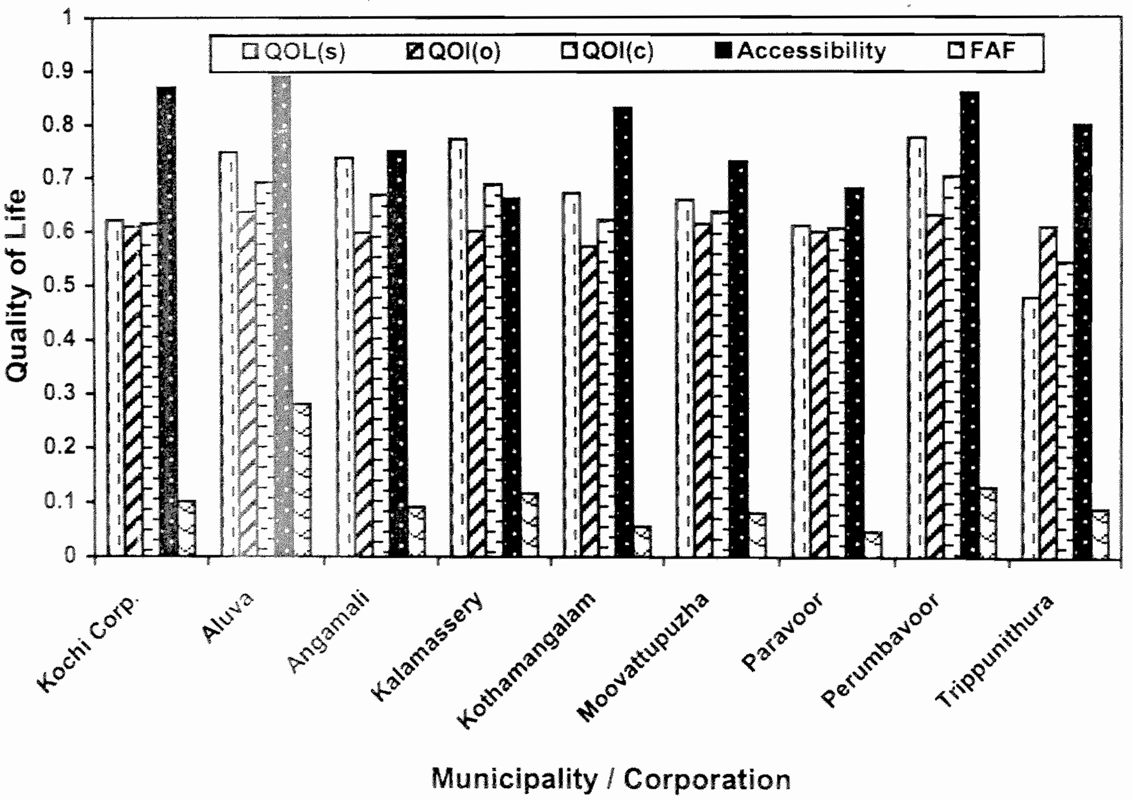



Fig. 3.6.3.3 : Comparison of the Quality of Life Indices for the Municipalities in GKR

# Chapter IV

# Impact of Developmental Activities on Resources and Environmental Quality

# 4.0 IMPACT OF DEVELOPMENTAL ACTIVITIES ON RESOURCES AND ENVIRONMENTAL QUALITY

## Existing and Proposed Developmental Projects in GKR

Since the Kochi region (which is under the jurisdiction of Greater Cochin Development Authority) is the prime center of developmental activities in GKR, data on existing and proposed developmental activities in Kochi region is available. The existing developmental projects may be broadly classified under two categories viz., industrial units and other projects. The location-wise description of the industrial units and other developmental projects in the Greater Kochi Region include the following:

- International airport at Nedumbassery
- Amrita Institute of Medical Sciences at Edappally
- Veegaland amusement park at Pallikkara
- Diesel plant at Brahmapuram
- International convention centre at Maradu
- Kerala water authority stockyard at Maradu
- European Economic Community market at Maradu
- Indian oil corporation bottling plant at Mulanthuruthy
- High rise buildings at Ernakulam

## Proposed Developments in the Immediate Future

- Bombay suburban electrical power project
- Greater Cochin Development Authority housing colony at Kalamassery - it is a Project associated with the proposed Kochi medical college at Kalamassery. This will involve 60 acres of land.
- Waste yard at Cheranelloor - 4.5 acres land requirement. This is proposed for constructing a mechanized composting plant.
- Skyline flats at Kakkanad. It is a project of the Skyline Pvt. Ltd. and it is in the embryonic stage.
- Vypin bridges - It is a project of the Goshree Islands Development Authority. It is proposed to connect the main land to Vypin islands by bridges. The estimated cost of construction is Rs. 40 crores. About 25 ha of backwaters will be reclaimed, which further will contribute to salt-water intrusion upstream. It will have impacts on the fishery activity because this will destroy the feeding grounds of fishes.
- LNG terminal - Petronet - LNG Ltd. proposes to set up a 2.5 million TPA capacity (expandable up to 5 million TPA) of LNG terminal at

Puduvypinnear Kochi. Area of the site is 50 ha. The capital investment of the project is Rs.1600 crores.

- Central Government Employees housing scheme. It is a project of the central PWD which is going to be realized at Ambalamedu.
- Chithrapuzha Bridge. The estimated cost of construction of this bridge is Rs. 7 crores.
- Irumanam railway overbridge. The estimated cost of construction of this bridge is Rs. 5 crores.
- Matanchery bridge - It is a project of Kochi Port trust, and this is still in the planning stage.
- Satelite Township at Udayamperoor - The estimated cost of investment on this project is Rs. 230 crores. Reclamation of the backwater is envisaged under this project.

**Major Developmental Activities in the Region: Coastal Waters**

Further, major ongoing developmental activities in the coastal waters around Kochi barmouth area are the maintenance dredging of the approach channel and dumping of the dredge spoil in the offshore area. The quantum of annual maintenance dredging is about 10 million $m^3$.

Proposed developmental activities in the Kochi area include:

- A thermal power plant at Puduvypu based on LNG
- A SBM (Single Buoy Mooring) facility and associated pipeline off Kandakadavu, south of Kochi barmouth.
- Expansion of existing Kochi Port and a container terminal at Vallarpadom

An LNG terminal is proposed to be set up at Puthuvypu on the northern side of the Kochi barmouth by the Petronet LNG Ltd. with 2.5 MM TPA capacity (expandable to 5 MM TPA). Seawater will be used for vapourising the LNG and the cool water will be discharged into the sea. Apart from seawater intake and discharge, it is also proposed to create marine facilities like jetty for berthing ships, two breakwaters and a harbour basin. The breakwaters are proposed to be constructed in the north (400 m long) and south (800 m long) of the approach channel. The north breakwater will be in the north-south direction attached to the shore and the south breakwater will be a detached one in the east-west direction.

The proposed thermal plant close to the LNG terminal at Puduvypu plans to use LNG fuel and is likely to draw seawater for cooling purposes and desalination, and discharge the effluent into the sea.

The Single Buoy Mooring (SBM) facility proposed to be set up off Kandakadavu, south of Kochi barmouth is for berthing oil tankers in the offshore itself avoiding entry into the harbour and pumping crude oil into the Cochin

Refineries Ltd. through pipelines. The SBM and the associated pipeline in the sea for pumping crude oil to shore station may not result in any discharge into the sea. However, oil leakage during operation and accidental oil spills cannot be ruled out.

Cochin Port Trust proposes to expand the port with container terminal in the backwaters at Vallarpadam Island, and some oil berths in the barmouth area on Puduvypu side. These development activities including LNG terminal warrant large scale capital dredging and maintenance dredging in the navigational channels and harbour basins within the backwaters as well as outside the barmouth. The capital dredging resulting from these developmental activities could be around 25 million $m^3$ and maintenance dredging will also be considerable.

## 4.1 Impact on Resources

### 4.1.1 Impact of Developmental Activities on Landuse Pattern

Some of the major developmental activities that had cast its impact on landuse are listed below:

- Construction of dams and creation of reservoirs
- Agricultural development
- Urbanization
- Tourism development

#### 4.1.1.1 Construction of Dams and Creation of Reservoirs

Because of the terrain conditions and high rainfall, GKR seems to be highly suitable for construction of dams, both for power and irrigation purposes. Power sector development gained importance even before independence because of its great potential, besides being economical. GKR hosts 14 major reservoirs of Kerala. They are:

| | | |
|---|---|---|
| Idukki reservoir | Periyar lake | Tekady reservoir |
| Ponmudi reservoir | Neriyamangalam reservoir | Idamalayar reservoir |
| Pallivasal reservoir | Sholayar reservoir | Mattupetty reservoir |
| Sengulam reservoir | Kundala reservoir | Kakki reservoir |
| Anayirangal reservoir | Pamba reservoir | |

Because of clear felling of forests and mono-cultural plantations, presently, it is not possible to assess the actual nature of landuse existed before 1968-72. However, from the landuse map prepared from the 1968-72 topo-sheets and 1999 IRS imageries, it can be deduced that most of the reservoirs of these dams were under forests of wet evergreen to semi-evergreen types. The trend of change in landuse during the above period indicates that there was an increase in area under water bodies by 4580 ha in GKR, mainly attributable to the reservoirs, which indirectly suggests that more than 4580 ha of forests have been converted /destroyed by the creation of these reservoirs.

Construction of reservoirs and power stations necessitated construction of new roads. This, in turn, facilitated easy accessibility to areas for settlements, which were once inaccessible and inhospitable. To start with, the labourers brought in for construction of dams constituted the bulk of migrants, in addition to plantation labourers. These migrants from lowland-midland regions constituted the nucleus of future migration and settlements. Though on a micro scale, this brought in a lot of change in land use. Annual food crops like tapioca, which need great tillage, were introduced in virgin forest soil, creating augmented soil erosion.

#### 4.1.1.2 Agricultural Development

Over a period of 20 years, there was an increase in area under agricultural plantation by 24.4%, which works out to an area of 2433 $km^2$. The increase in area is mainly attributed to two crops, namely, coconut and rubber.

About 90% of India's rubber is produced in Kerala. Therefore, it is no wonder that among the plantation crops, rubber ranked first, covering an area of 326337 ha in 1995-96 as compared to 150145 ha in 1978-79, registering growth in the area by about 117% in less than 20 years.

According to the Economic Review (1998), the area under food crops declined from 14.8 lakh ha to 8.8 lakh ha, while that of plantation crops increased from 7.0 lakh ha to 19.6 lakh ha. Conversion of forestland and mixed crops also took place on a large scale, especially for rubber. In fact, most of the agricultural and forest plantations, covering an area of 3648 $km^2$, took place at the expense of forests during the first half of the $20^{th}$ century and earlier.

#### 4.1.1.3 Urbanization

Eighty percent of urbanization in Kerala has occurred in GKR. The more important urban centres are: Alappuzha, Chertala, Vaikom, Kochi, Kodungallur, Angamali, Chalakudi, Perumbavur, Kothamangalam, Muvattupuzha, Thodupuzha, Idukki, Pala, Kottayam, Changanacherry, Thiruvalla, Chengannur, Mavelikkara and Pathanamthitta. Of these, Kochi is the most important urban centre with a population of over 5 lakhs (1981) followed by Alappuzha with over 1 lakh population (1981). Rest of the towns is relatively less urbanized and less populated.

Because of industrialization, besides being a commercial centre, urbanization of Kochi had its maximum impact on landuse as compared to other centres. While urban outgrowth of Kochi is on a very fast track, that of others got stagnated, so to say, on account of its stagnant economic activity for several years and, therefore of less significance in terms of landuse change. The more important landuse changes occurred in and around Kochi are:

- Increase in built-up area
- Extensive reclamation of backwaters /wetlands
- Denudation of natural wetland vegetation including mangroves

#### 4.1.1.4 Tourism Development

Tourism industry is fast catching up in Kerala and many believe that this is one of the few sectors Kerala can really depend upon for its future economic development.

There was no drastic landuse change that took place other than a few microlevel destruction of mangroves in Kumarakom in Kottayam district and forests in Idukki district. But one has to be cautious, in future, in developing large scale, capital-intensive tourism, which may kill the rural ambiance of coastal plains of GKR and forest ecosystem of the high ranges.

### 4.1.2 Impact of Land Reclamation Practices on Vembanad Backwaters

Vembanad Lake is the biggest water body found along the Kerala coast. There are five main rivers, viz. Muvattupuzha, Meenachil, Manimala, Pamba and Achenkovil, which drain their waters into the lake.

Area calculation of the maps published by Singh (1985) for the years 1953-54, 1973, 1982 and analysis of 1999 digital data indicates that an area of 6,450 ha of the lake has been reclaimed (**Fig. 4.1.2.1**). This had happened consequent to certain deliberate State policies coupled with private intervention for increasing paddy production. Kuttanad produces, on an average, of about 2,40,600 MT of rice, annually. This production was made possible by increasing the area under paddy cultivation through reclamation, and construction of Thanneermukkam Saltwater Regulator and rigorous application of fertilizers, pesticides etc. However, a series of environmental problems also cropped up, such as:

a. Annually, about 100 MT of different types of pesticides are applied in the rice fields of Kuttanad including organo-chlorine, organo-phosphorus and even DDT. It is argued that these pesticides ultimately find its sink in the fresh water ecosystem of Vembanad, south of Thanneermukkam regulator.

b. Annually, it is estimated that about 8,400 MT of nitrogen, 5,444 MT of phosphates and 6,786 MT of potash are applied in Kuttanad rice fields. The increased eutrophication, leading to excessive weed growth in Kuttanad and adjoining water bodies has been attributed to the above.

c. About 55 % of the diseases that are prevalent in Kuttanad are water borne, like diarrhea, dysentery, typhoid, etc. In a water-logged place like Kuttanad, where people often resort to open defecation and use hanging latrines, this health hazard is expected.

d. The Thottappally spillway, constructed in 1955, was mainly meant to moderate the floods in Kuttanad region. Unfortunately, it could not attain its anticipated potential because of inherent engineering flaws. Only one third of the floodwater is at present being drained through this spillway. Kuttanad region, therefore, reels under floods during monsoons even after the construction of the spillway. It is even argued that, the new

Changanacherry-Alappuzha road has increased the flood proneness because of blockage of drainage avenues.

### 4.1.3 Impact of Change in Landuse Pattern on Groundwater Potential

In order to study the impact of deforestation on hydrology three sets of catchments; Peruvannamuzhi (11° 33' N, 75° 27' E), Vazhani (10° 37' N, 76° 17' E) and Chimoni (10° 26' N, 76° 23' E), in the Western Ghats have been monitored. Each catchment contained dense forest (more than 60% canopy cover), partially exploited (between 30 and 60% canopy cover) and fully exploited (less than 30% canopy cover) sub-catchments, of 2 $km^2$ each. Two sub-catchments, namely; Vazhani and Chimoni were in the river basins draining into the Vembanad-kol wetland system. The study showed that while there was flow of water throughout the year in the dense forest catchments, the flows in the partially exploited and the fully exploited catchments ceased two months after northeast monsoon (February) and immediately after northeast monsoon respectively. Therefore, to maintain the summer crops of the wetlands as well as to ensure proper flushing during dry months, conservation of forested watersheds and acceleration of afforestation programmes is required.

Further, in order to understand the flood characteristics of each catchment, unit hydrographs of 1-hr duration were drawn for all the three types of catchments. The lag time for dense forest catchments at one site was about 35% more than that of partially/fully exploited sites. The difference in lag times between partially and fully exploited sites was minimal. The results indicate that deforestation is a major factor in increasing the impact of floods downstream, especially in wetlands. Wetlands, which have evolved to absorb floods of average size for a number of years, could not efficiently deal with recent floods because of unrestricted exploitation of the forests of the Western Ghats. This explains why the river basins have to be managed appropriately to derive maximum benefit of flood mitigation in the wetlands as well as to maintain summer flows for the wetlands.

As a part of the forest hydrology study of CWRDM (1986), information was collected on the total amount of sediment accumulated from three types of Western Ghats catchments. The sediment yield from the dense forest, partially exploited and fully exploited catchments during the rainy season was 0.75, 4.00 and 4.73 $m^3/km^2$ respectively (Anonymous, 1997). It is very clear from the studies that the wetlands are significantly affected at least by one type of human intervention - deforestation. Sedimentation surveys in one of the reservoirs in the Western Ghats show that almost 20% of the total capacity (121 $Mm^3$) of this reservoir has been lost, mainly because of deforestation in the catchments and changes in the cropping pattern.

### 4.1.4 Impacts of Developmental Activities on Terrestrial Ecology

#### 4.1.4.1 Forest Cover

#### 4.1.4.2 Diversity

#### 4.1.4.3 Rare and Endangered Species

#### 4.1.4.4 Medicinal Plants - Economically Important Plants

#### 4.1.4.5 Migration Corridors

### 4.1.5 Impact of Extraction Pattern on Mineral Resource Base

**Lime Shells**

There are two types of lime shells, which are mined from Vembanad estuary. They are the white shells, which are fossilized ones and the black shells, which are the outer skeletons of the living bivalves. The former is mined using dredgers, whereas, the latter is collected manually. The white shells are commercially mined for Travancore Cements Ltd. (TCL), located at Kottayam. Since mechanical mining (dredging) creates large pits, it has many environmental implications besides depleting the resource base very quickly. Nevertheless, one should also weigh the needs of TCL, which mostly depends on this resource for the manufacture of white cements. In the long run, on the other hand, the sustainable production of cement would depend on black shells, which are renewable.

**Manual Collection of Black Shells**

It is estimated that, on an average, about 30,000 MT of black shells are collected manually every year. The rate of production (**Table 2.4.2, Chapter 2**) of black lime shells for six years has not exhibited any significant change, which would indicate that, probably, the annual catch has not yet exceeded the Maximum Sustainable Yield (MSY). This also suggests that this method of extraction within the limit of MSY is the most ideal one, which would serve the cause of the industry as well as the people, who depend both on its flesh and lime kiln industry.

**Tile and Brick Clay Mining**

Indiscriminate clay mining of flood plains in Chalakkudy, Periyar, Muvattupuzha and Pamba river basins is taking place for meeting the demands of numerous brick kilns and tile factories. The mining is done both manually and mechanically. The products are being transported extensively to places outside the State. Because of great demand outside the State, the manufacture of bricks is on the rise, far exceeding the local needs. This is most likely to affect the resource base, and a stage will come when, the raw material will be inadequate even to meet the local demand.

### Silica Sand Mining

Silica sand mining is done manually and it is one of the easiest methods being practiced. Being a loose material, it is easy to mine and transport. Since it has very high demand in Tamilnadu, it is mined in large quantities and transported as raw material. By doing so, it is the most pure form of silica that is lost for the State for which value added products would have been made.

### Sand Mining from Rivers

Of late, construction activities have been exponentially increasing in Kerala, especially in GKR. This has resulted in very excessive sand mining from riverbeds of all river basins. Although, mining is done manually, annual collection of this building material is so large that a stage will come when this resource will no longer be available, and one has to look for alternative materials.

## 4.1.6 Impact of Mining Practices on Terrestrial Ecosystem

La-Roe (1977) has pointed out that dredging brings about both short and long term changes in water currents, circulation, mixing, flushing, salinity, siltation, pollution etc. It will also lower dissolved oxygen (DO) level. The suspended silt smothers bottom dwelling plants and animals, the gills of fishes get clogged and they are driven out of their habitat. Turbidity reduces vision and masks odors, both important for the survival of many fishes. Bivalves cease feeding under turbid conditions. Water currents carry silts far away from the site of dredging, reducing photosynthesis and DO over a considerable area, even far from the dredging sites.

The dredged out bottom of an estuary is actually a false-bottom and that many of the bottom dwelling animals such as oysters, snails etc. will fail to search for hard bottom and to settle. This brings out, unequivocally, as to how much damage dredging can cause in the living populations of *Villorita* spp (black shell species) in particular and the ecosystem, in general. In other words, the act of large scale dredging for feeding the big factories with fossilized white shells (which is a non-renewable resource) would act back on its own caused by almost completely wiping out the living population of the very same species (which is a renewable resource). In short, it is the sustainability of the highly productive estuarine ecosystem and the industry as such that is under direct threat.

### Sand Mining

Sand is an unavoidable building material for any kind of construction. This is mainly scooped in larger quantities from river channels in all rivers of GKR. Since building activity has been on the increase for the past several decades, mining has been commensurately on the increase. This has often resulted in changing the topography of the river bottom and the general physico-chemical characteristics of the riverine ecosystem. A stage has now reached in GKR when no further sand mining is possible on environmental grounds.

### 4.1.7 Impact of Various Developmental Activities on Inland Fishery Resources

The inland fishery resources constitute about 30% of the total fish production from India. Kerala is endowed with vast areas of the inland water system, yet it doesn't rank among the top states in inland fish production. The environmental factor which governs the distribution and availability of fresh water and brackish water resources are distinctly varied, which include water availability, water flow speed, temperature and monsoon rains. Salinity is the main ecological parameter, which governs the abundance, availability and distribution of fishery resources in the brackish water niche. Unlike the rivers, the brackish water fish fauna is heterogeneous and diversified, comprising of fishes migrating from the adjacent sea or rivers and the truly resident species.

The unrestricted fishing together with the deteriorated environmental conditions resulted in the depletion of the principal species of commercial importance, like the *Liza parsia, Chanos chanos*, *Lates calcarifer* and *Etroplus suratensis* from the brackish water areas and *Labeo dussumieri, Horabagrus brachysoma, Puntius curmuca, P. sarana, Clarius batrachus, Tor khudree and Macrobrachium rosenbergii* from the rivers of Kerala. The renewable resources of the inland water of Kerala showed a tremendous depletion and irrecoverable loss during the recent years and no effort has been made to implement the needed conservation measures. Some of the factors/constraints for the steep decline in the inland fish production are: -

- The changes in ecosystem brought about by the construction of dams, barrages, reservoirs and anicuts resulted in water scarcity, change in water flow speed, penetration of saline water, small scale occasional flooding, deterioration of the water quality due to stagnation etc.
- Reclamation of backwater and the catchments areas of the rivers
- Dumping and disposal of industrial and domestic wastes into the estuary
- Many parts of the backwaters are used for coconut husk retting which leads to high BOD, low oxygen and high sulphide levels
- Prolific spreading of *Salvenia auriculata* reduces primary productivity and dissolved oxygen concentration
- Periodic dredging operations conducted in different parts of the lake increase turbidity, which affects the primary productivity, fish health, etc. Dredging also destroys the bottom fauna, which is the main food of demersal fishes
- Stake net fishing is another threat, which indiscriminately filters juveniles and fingerlings from backwaters
- Fishing using explosives, icthyotoxins, animal poisons etc.

These constraints result in the mass mortality of fishes and crustaceans, avoidance reactions, destruction of nursery grounds, interruption of migration, depletion of future stock. Most of the fishes inhabiting the rivers and brackish water lakes undertake spawning migration during the spawning season either towards the adjacent sea or upstream rivers. The sea going spawners were found to be exploited indiscriminately from the barmouth area, which may result in the depletion of the future stock.

#### 4.1.7.1 Impact of Thannirmukkom Bund on the Fisheries

Prior to the construction of the Thannirmukkom barrier, the entire Vembanad Lake was a single continuous aquatic habitat for foraging to the fry of marine prawns and fishes. With the commissioning of the salinity barrier and also due to the large scale reclamation, the total area got reduced to 50% of what existed earlier, thus bringing about a spectacular difference in the production pattern, migration etc. of animals in the upstream regions of the lake. The salinity barrier at Thannirmukkom prevents the entry of marine migrants and resident estuarine organisms into the southern portion of the lake, thus converting this region into an ecosystem with endemic population. The average depth of the lake at its freshwater zone has been reduced to 2.1 m by 1996 compared to 8-9 m in the 40s.

The barrage remains closed during December to May restricting the tidal influence in the southern sector of 8300 ha waterspread area into a stagnant system. This stagnant period is marked by low concentrations of dissolved oxygen and high sulphide, and nutrient accumulation all along the peripheral areas receiving run of agricultural fields and domestic sewages.

In the southern sector, several holeuryhaline planktonic species were replaced by freshwater and euryhaline species. The area, which was almost clear of weeds are now abundant in noxious vascular hydrophytes like *Salvinia* and *Eichhornia*.

Further, the depletion of the resources is not adequately compensated either by natural propagation of fresh water species or by ranching using fast growing fresh water fishes like carps. Prior to the construction of the barrage, the fishery of this region was also sustained by *P. indicus, P. monodon*, *M. dobsoni, M. monoceros, Mugil cephalus, Liza macrolepis, Chanos chanos* etc. But after the commissioning of the barrage, practically very little catch is obtained from the southern part. Obviously, the estuarine migratory component of the fishery has been lost severely depleting the total yield from the sector. A comparison of annual fish catch in the Northern and Southern sector of Thaneermukkom bund is given in **Table 4.1.7.1**.

Due to the rapid advancement in civilization many changes are brought about by man in the estuarine systems, which adversely affect the shellfish life. The important human activities causing environmental damages are (1) Large scale reclamation, bulk-heading, destruction of mangroves (2) Construction of salt water barriers, spill ways, tide control structures, barrages, upstream dams, etc. and (3) Water pollution. These alter the physicochemical properties such as tidal effects, water circulation, currents, salinity, turbidity, fertility, bottom condition, etc. and degrade the ecosystem restricting the distribution, etc. and the survival of the various species.

The Thaneermukkom barrage constructed in the Vembanad lake in Kerala is an ideal example of man made barriers, which has reduced the tide fed areas occupied by prawns. The distributional range of penaeid prawn juveniles in the lake has become considerably reduced because of this barrage. Salinity exclusion barriers, irrigation projects, etc hamper the breeding migration of species of Macrobrachium.

#### 4.1.7.2 Major Activities which lead to Deterioration and Destruction of Habitats of Inland Fishes

*4.1.7.2.1 Construction of Bunds, Barriers, Weirs, Anicuts, Dams Etc.*

These constructions have made severe alterations in the prevailing ecological conditions of the natural habitat of fishes and also imparted severe interruptions in the life cycle of many species. For e.g., the population of Mahseers and other indigenous carps such as *Labeo dussumeri, Puntius curmuca* etc. has been affected.

*4.1.7.2.2 Shrinkage in the Extent of Inland Water Bodies*

The available reports suggest that the total acreage of Vembanad Lake was 44,000 ha in the beginning of the 19$^{th}$ century while in the 20$^{th}$ century, it was reduced to 21,000 ha due to reclamation for the purpose of agriculture, prawn filtration, urbanization, housing, harbour development etc. The reclamation is done as a part of various developmental schemes of Central and State governments.

*4.1.7.2.3 Reduction in the Depth of Inland Water Bodies*

The reduction in depth is mostly brought about by the deforestation activities taking place in the catchments areas, siltation, sediment deposition, short term flooding etc. Large scale abstraction of water from the rivers for the purpose of agriculture, irrigation etc. will also result in drying up of the rivers during summer months whereby a steady diminution in the fish wealth have taken place due to habitat loss.

*4.1.7.2.4 Deforestation of Mangroves*

70,000 ha of mangroves, which existed in Kerala in early this century have diminished to less than 70 ha. Penaeid prawns and fishes such as *Etroplus*, mullets, *Lates sp.* etc. used to take shelter in mangroves and the destruction of this vegetation found in the fringes of backwater have adversely affected the fishery resources of the state.

*4.1.7.2.5 Aquatic Pollution*

There are over 200 medium and large scale industries and about 2000 small scale industries discharging effluents into the inland water bodies. It is estimated that industrial effluents of the order of 6.5 million $m^3$ are being dumped into the rivers and estuaries of Kerala. Frequent incidences of mass mortality of fishes have become a usual affair in major rivers such as Periyar, Chithrapuzha (mainly due to industrial effluents carrying heavy load of $NH_3$ at the rate of 432-560 ppm), Chaliyar, Kallada and lakes viz., Vembanad, Ashtamudi etc.

The fishes in these areas are facing reproductive hazards, growth retardation, morphological abnormalities, apart from total destruction of eggs and larvae. The fish shoal entering the polluted zone could not tolerate the cumulative effect of pollution and results in heavy mortality. The Eloor-Varapuzha regions of the Cochin backwater have been transferred into a barren contaminated zone.

Paddy fields of Kuttanad receive considerable quantities of pesticides indiscriminately applied. Ten types of pesticides with a total quantity of about 490 MT are used in Kuttanad annually, of which 370 MT are applied for *Punja* and 120 MT for *Virippu.* In the absence of adequate facilities for the disposal of sewage from human settlements, they are directly discharged into the inland water bodies. Hung latrines visible all along the backwater are the major source of faecal contamination.

In Vembanad lake alone, around 245 ha of area is used for husk retting. The presence of noxious gases such as $H_2S$, methane, high BOD, turbidity etc. drives the fishes out of this area.

*4.1.7.2.6 Increased Fishing Pressure*

Based on the survey conducted by the fisheries Dept., there are 12,900 stake nets, 5000 Chinese dip nets and more than 20,000 wandering gears which are in operation. Of the total 12,900 stake nets operated in Kerala, 30% are illegally operated without any valid license and the highest number is recorded from Ernakulam district. In Vembanad Lake also, out of the 3862 stake nets operated, 30% are unauthorized. Among the 4823 Chinese dip nets operated in the backwaters, 1692 are listed as unauthorized. By using stake nets with smaller meshed cod ends, about 7000 MT of juvenile penaeid prawns are indiscriminately filtered from Vembanad lake annually, out of which *P. indicus* alone comes to around 245 million MT. Such activities are disturbing the migration of juvenile prawns and hampering the ecological balance of the natural resources.

*4.1.7.2.7 Destructive Fishing Methods*

Fishing activities like poisoning, dynamiting, electric fishing etc. have resulted in the total devastation of inland resources.

*4.1.7.2.8 Over Fishing*

This is a major contributing factor leading to the depletion of principal fish species of commercial importance. Over fishing of smaller size group is seen in the case of *P. indicus* fishery. The size group contributing to the *P. indicus* fishery in Vembanad Lake was 120-140 mm in 1980, however in 1990, it has declined to 60-80 mm. Indiscriminate exploitation of spawners during the spawning season has a detrimental effect on recruitment, which usually intensifies with the onset of monsoon. The annual exploitation of berried *M. rosenbergii* from the Vembanad Lake is about 30 MT. Due to over exploitation of commercially important food fishes, their niches become occupied by less important fishes. For instance, the backwater area which used to be the habitat of *M. cephalus*, *Lates calcarifer, C. chanos* are now occupied by forage fishes like *Ambassis dayi*, cat fishes etc. In some parts of the lake, *Oreochromis mossambicus* has emerged as the principal species against *E. suratensis*.

*4.1.7.2.9 Clandestine Introduction of Exotic Fishes*

The exotic varieties of fishes like *O. mossambicus, Cyprinus carpio, Ctenopharyngodon idella*, *Gambusia* and African cat fish *Clarius gariepinus* introduced into the inland waters can become a dangerous competitor for space and food indigenous species and are likely to lead to the total depletion of the indigenous species. Clandestine introduction of the predatory and carnivorous African cat fish *Clarius gariepinus* which is bred in controlled systems in Kerala can become a threat to indigenous species of fishes and then affect the livelihood of fish farmers depending on indigenous species. Despite government orders this species is still available in some of the hatcheries in Kerala and grow-outs in Alapuzha, Kottayam, Thrissur and Ernakulam.

*4.1.7.2.10 Fish Diseases*

The deterioration of water quality due to excessive application of pesticides, low pH, excess turbidity, dumping of sewage etc. have resulted in the outbreak of various bacterial, fungal and viral diseases out of which the most virulent and menacing is the Epizootic Ulcerative Syndrome (EUS). The outbreak of EUS was first noticed in Kuttanad in June 1991 and its recurrence in varied intensities could be registered in the last several years in different parts of the state. The species affected are mullets, barbs, pearl spots, snakeheads etc. Due to the outbreak of this disease, the economy of Kerala has crumbled to the tune of 2 crores and has thrown around 25,000 full time and 7,000 part time persons engaged in fishery related activities out of employment.

*4.1.7.2.11 Exploitation of Natural Seed Resource for Aquaculture*

Exploitation of natural seed resources, mainly frys of milk fish, pearl spot, grey mullets, grouper and post larvae of tiger, white and scampi, is growing unabated in the backwaters of Kerala for mainly stocking in Pokkali fields in Kerala and polders of Kuttanad. In this attempt, the by-catch destroyed constitutes frys of both economic and uneconomic varieties.

*4.1.7.2.12 Decrease in Prawn Production from Pokkali Fields*

A total area of 5500 ha of paddy fields is used in Ernakulam and Alappuzha districts for prawn filtration. The production has declined from 1500 kg/ha in 1930 to 1200 kg/ha in 1950, which further declined and stabilized to around 700 kg/ha in recent years. The reason could be reduction in the rate of natural recruitment and illegal filtration of seed.

#### *4.1.7.2.13 Low Fish Production from Reservoirs*

Only 9 out of the 30 reservoirs in the state are commercially exploited which accounts for only 20% of the reservoir area. The yield from managed reservoirs is 23 kg/ha/yr, which is very low.

#### *4.1.7.2.14 Lack of Rules Necessary for Protection of Inland Fishery Resources*

The two regional acts framed based on Inland fisheries Act 1897, i.e., Travancore-Cochin fisheries Act 1950 and Indian fisheries (Madras amendment) Act 1927 are too inadequate to protect, conserve and manage the inland fisheries resources of the state, and needs to be reviewed and reformulated for the present scenario of the Kerala.

### 4.1.7.3 Impact of Aquatic Pollution on Fishes : Heavy Metal Concentration in Fishes

The concentration of Cu, Zn, Mn and Fe have been determined in marine fishes from Kochi area which is one of these major fishing zones along the West coast of India. Concentration of heavy metals varied from species to species. Cu, Zn, Mn and Fe showed increased levels in the alimentary canal (AC) and gut (G) compared to muscle (M). The standard deviation estimation for each metal is Cd (± 7%), Cu (± 5%), Zn (± 11%), Fe (± 19%), Mn (± 15%). Though, the concentration of metals in different tissues of fishes varied widely, the musculature which forms the edible part showed much lower concentration than other tissues **(Table 4.1.7.2)**.

## 4.1.8 Impact of Agricultural Practices including Cropping Pattern

### 4.1.8.1 Cropping Intensity

District wise percentage distribution of operational holdings and area of operational holdings of GKR, Kerala and India for 1990-91 is given earlier in Chapter 2 (**Tables 2.6.11** & **2.6.12**). There are three divisions under the marginal, i.e below 1 ha, namely, below 0.02 ha, 0.02-0.50, 0.50- 1.0 ha. Out of these, below 0.02 ha constitutes 12.83%; 0.02-0.50 ha, 69.67% and 0.50-1.00 ha, 9.34%. About 98% of holdings are Marginal in GKR as compared to 93% of Kerala and 58% of India. Just 0.06% GKR and Kerala comes in Large holding category of above 10.00 ha. These figures indicate as to how fragmented are the holdings of GKR and Kerala, and as to how difficult it would be for the region to introduce any kind of innovative management measures to improve production and productivity.

The intensity of cropping in GKR is 139% as compared to 135% of Kerala. Among the districts of GKR, Palakkad had the maximum intensity of cropping of 161 followed by Alappuzha, 155. The net area sown in GKR was 12.71 lakh ha as compared to the total 22.50 lakh ha of Kerala. The corresponding figures for the total cropped area was 17.66 lakh ha and 30.46 lakh ha respectively.

## Some Maladies in Agriculture

When one considers the indices of area, production and productivity, food crops in general and cereals in particular, registered steep fall in area; the corresponding index number declined from 98.7 to 59.7 during 1978-79 to 1997-98 periods. On the other hand, the non-food crops, especially, plantation crops gained substantially with an increase of about 77 points over the base year index of 100.5.

One of the reasons for the trend has been attributed to the surging pressure for bringing in less labour intensive mono-crop plantations in place of the labour intensive multi food crop farming system. While one can agree with this proposition, the key hidden human element is missing in the analysis. It may not be an exaggeration if one may say that, in the real sense, there are no farmers in Kerala. The stray, award winning "Karshaka Sree" farmers are exceptions. The situation is mired in an array of socio-economic compulsions of rather recent origin. Among them are:

- Farming profession is deemed to have no dignity of labour. Today's farmer has come to occupy a very low profile in society. With the result, the traditional wisdom of a farmer has died out and a stage has come when no farmer would dare to take his son to farming. This has led to an erosion of the number of farmers engaged in the farming system and there happened a 'class' migration of farmers to unproductive white collar jobs and consuming life-style system. No wonder, the average daily wage rates of unskilled workers engaged in agricultural sector increased from Rs.11.13 in 1980-81 to Rs.144.75 for male in 1998, and from Rs.7.91 to Rs.69.35 for females for the corresponding period (Dept. of Economics & Statistics 1997-1998), a staggering 10 to 12 times increase. Concomitantly came the change in cropping pattern from seasonal to perennial; from rice and vegetables to more and more coconut and rubber. The change also heralded a new culture in agriculture. This may be called absentee agriculturism, which suited the white-collar job; which did not demand *in situ* care, as needed for the seasonal crops.
- About 91.53% of area of Kerala belongs to marginal group of holdings of less than 1 ha as compared to 58.07% of India for the same category during 1985-86. In terms of percentage of area, it was 46.02% and 13.18%, respectively, for Kerala and India. The forest land and the marginal holdings together constitute about 74.02% of the geographical area of Kerala. This figure gives a gloomy picture of how fragmented are the holdings in Kerala.
- Group farming has been suggested as a medicine for improving the production and productivity, especially, of food crops. The idea emanated from the innate desire to negate the effects of fragmented holdings and to bring in mechanized farming, irrigation, etc. more effectively and to usher in an era of integrated and intensive farming system which produces more and more per less and less of unit area in less and less of unit time. It is also expected that under the new decentralized planning system, the idea would take root in the ground and bear fruits, as expected.

- Under the spell of the law of inheritance, the fragmentation of holdings will continue to take place in the State. Fuelled by the desire to have a decent chunk of land by the 'under privileged' has already accelerated the process of fragmentation further.

Although the Land Reforms Act of Kerala has helped the socially and economically backward sections to become owners of their house sites (>10 cents), it is also felt that it actually increased the process of fragmentation further at the expense of agricultural productivity.

If one looks at the percentage of operational holdings in GKR and Kerala, on one hand, and that of India, on the other, one would really come to know the tragic stage at which the former stands. The marginal holdings (below 1 ha) comes to over 92% in the case of the former, whereas, it is only 58% in the case of the latter.

As pointed by the Task Force on Plantation Crops (State Planning Board, 1996), Kerala's perennial crops like tea, coffee, cardamom, rubber, etc. are basically dependent on external markets (within and outside the country). An important aspect of growing external market orientation of these crops is that a significant share of the surplus generated and value-added goes out of the State as the controlling interests operate from outside. Access to the surplus generated by the State is insignificant and very often limited to tax on sales, leading to poor R&D effort and resource constraints for reinvestment meant for rejuvenation and replanting of crops.

**Rice**

It can be seen that the area under irrigation was 48.99% in GKR as compared to the State's figure of 45%. On the whole, it has been revealed that, except perhaps in Palakkad district, in all other districts where irrigation has been provided, it has led to serious water stagnation and consequent reduction of yield (Suseelan, Ibid.).

Month-wise farm price of paddy for the years 1981, 82 and 83 reveals that the average farm price for autumn season was about Rs.179.78 per quintal, whereas, the cost of production ranged from Rs.180 to 235 per quintal (Suseelan, Ibid.). In summer, the cost of production was marginally below the reported farm prices. This is an indication as to how non-remunerative is paddy cultivation in the area.

Cost of labour is yet another economic disincentive for paddy cultivation. A study conducted by the Department of Economics and Statistics has shown that cultivators having more than 2 ha of land depend for more than 95% of their requirements on hired labour. It was also revealed that about 51% of the cost of production of rice is accounted for hired human labour. During the period of last 10 years, from 1988-89 to 1998-99, the male labour wages increased by over 4.5 times, whereas, the farm price of paddy did not show corresponding increase. Apart from the high cost of labour, non-availability of labour at the planting and harvesting seasons has been a serious problem confronting the rice cultivators.

Lack of supporting services is yet another concern faced by the rice cultivation. The small holders who form the majority of cultivators cannot afford to have their own farm machinery on individual basis nor can they maintain animals for farm operations because of high cost. Non-availability of sprayers and skilled workers and lack of on-farm development for effective water control, absence of effective agency to procure marketable surpluses at reasonable price etc. are the factors which further complicate the problems confronted by the paddy sector. The data presented in the foregoing paragraphs lead us to the following conclusions.

- Proven technology is available even now to produce the required paddy in GKR
- The reason for not realising this potential is the high cost of production of rice and the loss, the cultivator is incurring for every kg of rice he produces
- Rice production in Kerala will continue to stagnate until the cost of production of rice in Kerala equalises with that of the cost of production of rice in the States from which it is imported to Kerala
- Huge investments made in irrigation so far did not contribute to rice production in a significant manner
- Infrastructure development by way of land development and provision of agro service centers is necessary to realize the rice production potential

**Rubber**

In conformity with the increase in area, the production also increased by 298% and 283%, respectively, for GKR and Kerala. The productivity almost doubled during 1978-79 to 1995-96 interval, from 577 kg/ha to 1061 kg/ha in GKR and 577 kg/ha to 1057 kg/ha in Kerala. Productivity varied between estate sector and small grower sector; the former with a productivity 1110 kg/ha as compared to 904 kg/ha of the latter. The total production of rubber in Kerala was 4,74,555 MT in 1995-96 whereas, that of GKR was 3,54,475. The estimated value of production from GKR would exceed Rs.1600 crores. According to Cyriac (Ibid), it is possible to get an yield of 2000 kg/ha, easily provided the small growers tap the potential of the extension net work of the Rubber Board is fully tapped. Realization of production potential of 2000 kg/ha would mean an estimated value of Rs.3000 crores from GKR alone.

### 4.1.9 Impact of Coconut Diseases on Productivity

In the year 1984, the Central Plantations Crops Research Institute (CPCRI) undertook a massive survey in collaboration with the Directorate of Agriculture, Government of Kerala, the Directorate of Economics and Statistics etc. on the coconut root (wilt) disease that became rampant in the districts of

Kollam, Pathanamthitta, Alappuzha, Kottayam, Idukki, Ernakulam and Thrissur (**Fig. 4.1.9.1**). All these districts are in GKR.

The root (wilt) disease affected palms have an appallingly low average productivity of 19 nuts per year against the root (wilt) free palms having an average productivity of 72 nuts per year. The disease is only debilitating and not lethal. On an average, coconut productivity in GKR has been experiencing massive loss, to the tune of 564 nuts/ha, mainly due to this disease, costing approximately Rs.282 crores (@ Rs.5 per nut) loss of revenue in a year alone (1995-96). Despite the best efforts by several institutions, a solution to this disease still remains elusive.

On the basis of the following observations, the causative agent of coconut root (wilt) disease has been established as Mycoplasma, the smallest and simplest cellular organism known, which have no cell wall, but are bound by a unit membrane:-

- Consistent association of the organism in disease affected palms and its total absence in the disease free palms
- Transmission of the organism through a vegetative vector (dodder) from diseased palms to mycoplasma indicator host plants
- Location of mycoplasma – like organism in the brain and salivary glands of the insect, lace bug, found abundantly in the foliage of root (wilt) affected coconut palms
- The successful transmission trial

To control this disease, application of tetracycline is limited, rather ruled out in view of the possible hazards due to the accumulation of the residues in the plant system, development of resistance by the pathogens and high .cost. Probably, this disease is a grim reminder of an ecosystem disaster afflicting a monocultural agro ecosystem.

The disease is well delineated with a contiguous core in GKR. With the objective of containing the disease within this area, eradication of diseased palms, removal of the foci of infection followed by surveillance was started in 1971 in Shencottah (Tamilnadu) and areas north of Karuvannur river in Trichur District, which is the northern boundary of the diseased tract. The recurrence of the disease was observed only in Varandarappally village where the initial disease intensity was high. This indicated the advantage of eradication of root (wilt) affected palms in isolated mildly affected areas. On the other hand, the strategy for the highly diseased, contiguous tracts of GKR are nothing but proper management coupled with irrigation.

Despite the best efforts, nothing noteworthy has been achieved in terms of productivity and produce of this most important crop of the State. Now Kerala has lost its monopoly as the largest producer of nuts. Only 41% of the total national production comes from the State. However, still the State continues to be the predominant supplier of milling copra. Even this monopoly is losing ground to the neighbouring States, particularly, to Tamil Nadu. The price of copra and coconut oil that was for a long time decided by the market trends in Kochi is gradually losing its grip with the emergence of new assembling centres in Tamilnadu and Karnataka.

In international market, coconut oil is facing serious challenges, mainly from palm oil. The advantage of palm oil is that the productivity of oil from unit area is 3 to 4 times more than that of coconut and, therefore, it is much cheaper than coconut oil. No wonder the market for coconut oil has slumped down today. Malaysia, the leading exporter of palm oil has stepped up plantation of oil palm at the expense of rubber and coconut plantations because of increasing international market. In Kerala's context, and specially so in GKR's, where the productivity is less 1/3 of its potential, it is worth trying, replacing coconut palm with oil palm in areas agroclimatically suited. Impact on coconut root disease can be summarized as:

- Productivity of disease-affected palms can be improved through better management and irrigation. Multiple cropping would enhance productivity per unit area, and, probably, improve the ecosystem stability in an otherwise mono-cultural system.
- Unless value added byproducts are produced and marketed, there is hardly any scope for stabilizing the price structure and ensuring better return from the yield.
- International market in edible oil has been captured by palm oil because of its lower price, borne out of three to four times higher productivity of oil per unit area.
- As is done in Malaysia, replacement of the disease-affected palms of GKR with oil palm, at least, in areas where agro-climatic conditions are favorable, may be looked into.
- Accordingly, all these shall require a farming society with a traditional farming culture.

### 4.1.10 Impact of Monoculture Cropping (Rubber) : A Socio-Economic Concern

While the production of rubber can be increased from the present 3.5 lakh MT (1995-96) to, say, 4 to 5 lakh MT in GKR, the market trend is such that the sharp decline in prices of the commodity has already shattered the livelihood security of about 8 lakh farmers. It has become a real concern in Kerala, in general, and GKR, in particular. According to the Economic Review (1998) report, "During 1998, rubber prices came under pressure and suffered unprecedented fall. Consequent to the liberalization of imports, average prices which stood at a level of Rs. 32.75 per kg for the RSS 4 variety in the first week of August had fallen to Rs. 28.25 by the last week and the prices remained low within the range of Rs. 26 to Rs 28 per kg, throughout the year. In 1995-96 and

1996-97, the average price ranged between Rs. 42 to Rs. 62 and Rs. 42 to 54 per kg.

As a price support measure, the State Trading Corporation of India entered the market with a target of procuring 20000 MT, but they procured only 320 MT. Kerala Government also entered the market through the State Warehousing Corporation and the newly established Co-operative for marketing of rubber namely RUBCO. They together procured around 20000 MT from the open market. Still rubber prices continued to be bearish. The upward revision of the bench mark price of rubber which was remaining untouched since 1994 at Rs. 24.40 a kg to Rs. 34.05 a kg came at a very later stage". In any case, unless the cost of production per unit area comes down, the Indian rubber will not be able to compete in the world market. For this, many interventions are needed as suggested in 5$^{th}$ chapter.

Table 4.1.7.1

Annual Yield of Commercially Important Fishes & Crustaceans in the Sectors North and South of Thannirmukkom Bund

| Species | Catch (Kg/ha/yr) | |
|---|---|---|
| | Northern sector | Southern sector |
| Fishes | | |
| 1. *Daysciaena albida* | 53.22 | 0.15 |
| 2. *Ambassis gymnocephalus* | 39.9 | 0.12 |
| 3. *Etroplus suratensis* | 14.4 | 17.5 |
| 4. *Tachysurus maculates* | 23.6 | 0.13 |
| 5. *T. subrostratus* | 12.9 | 1.5 |
| 6. *Ehirava fluviatilis* | 13.03 | 1.1 |
| 7. *Gerres filamentosus* | 8.1 | 0.15 |
| 8. *Liza parsia* | 10.1 | 0.34 |
| 9. *Mystus gulio* | 8.6 | 0.24 |
| 10. *Hyporamphus xanthopterus* | 0.7 | 4.3 |
| 11. *Ambassis commersoni* | 5.6 | 0.0 |
| 12. *A. dayi* | 2 | 3.1 |
| 13. *Leiognathus brevirostris* | 4.4 | 0.03 |
| 14. *Sillago sihama* | 4.5 | 0.0 |
| 15. *Mugil cephalus* | 4.4 | 0.16 |
| 16. *Amblyphoyngodon mola* | 0.1 | 5.2 |
| 17. *Glossogobius giuris* | 3.4 | |
| 18. *Megalops cyprinoids* | 3.2 | 0.9 |
| 19. *Caranx ignobilis* | 3.9 | 0.13 |
| 20. *Leiognathus equulus* | 2.5 | 0.01 |
| 21. *Liza macrolepis* | 2.7 | 0.0 |
| Crustaceans | | |
| 1. *Metapenaeus dobsoni* | 202.5 | 5.5 |
| 2. *Penaeus indicus* | 43.0 | 0.0 |
| 3. *M. monoceros* | 28.2 | 0.16 |
| 4. *P. monodon* | 0.97 | 0.0 |
| 5. *P. semisulcatus* | 0.81 | 0.0 |
| 6. *Macrobrachium idella* | 5.7 | 2.2 |
| 7. *M. rosenbergii* | 2.5 | 1.8 |
| 8. *Scylla serrata* | 24.0 | 0.2 |

Source : Secondary data collected by CUSAT

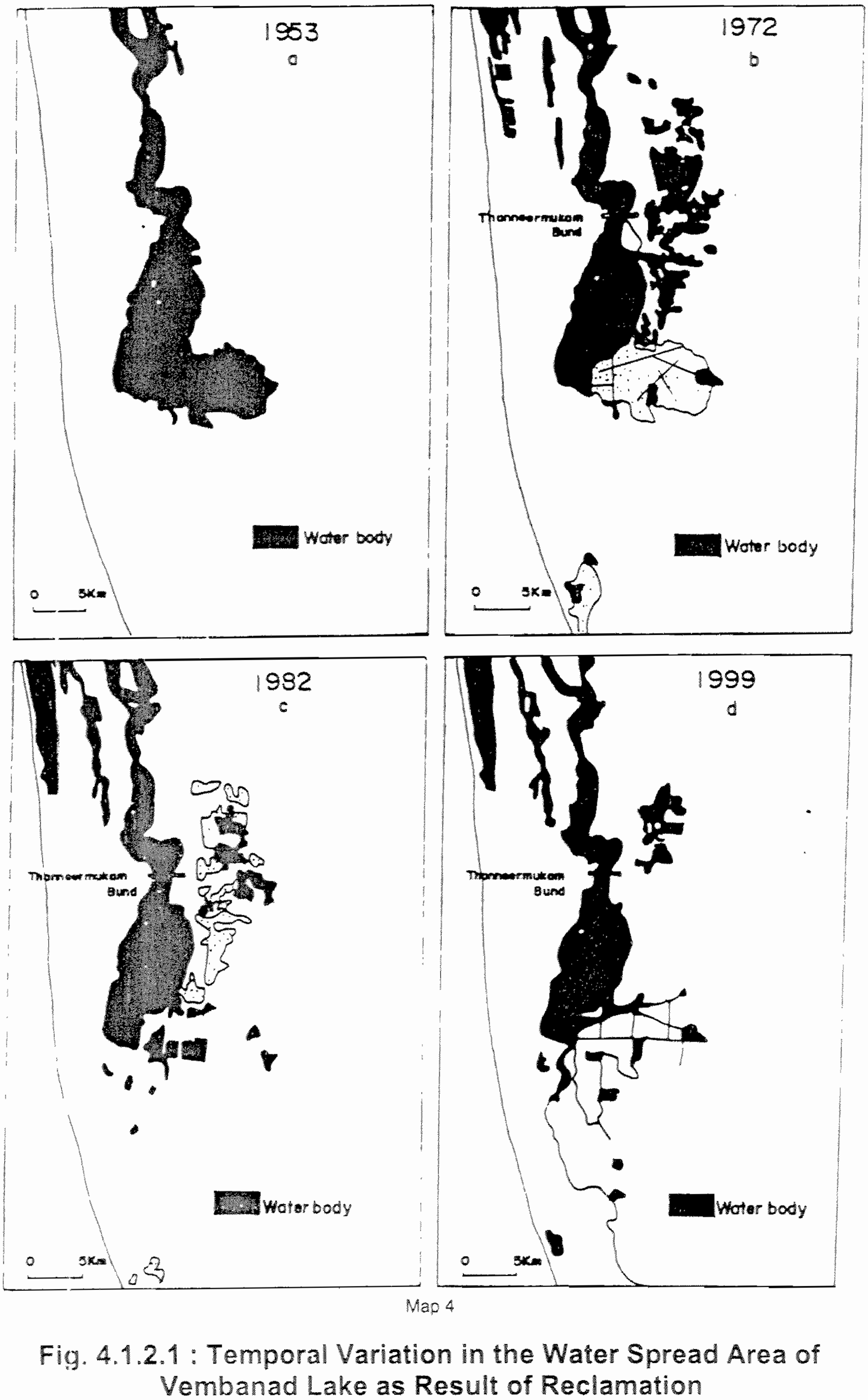
## Table 4.1.7.2

## Average Concentration of Heavy Metals in Marine Fishes

| Species | Common Name | Tissue | Cu (SD) | Zn (SD) | Fe (SD) | Mn (SD) |
|---|---|---|---|---|---|---|
| *Sardinella longiceps* (14) | Indian oil sardine | M | 1.54 (± 0.09) | 20.52 (± 1.80) | 148.50 (± 32.0) | ND |
| | | AC | 6.94 (± 0.41) | 63.42 (11.10) | 2255.40 (±609.0) | 6.14 (±1 10) |
| | | G | 2.72 (± 0 11) | 110.83 (± 12.02) | 428.39 (±68.0) | 16 39 (±2.40) |
| | | M | 1.59 (± 0 06) | 24.63 (± 1.66) | 57.97 (±9.5) | ND |
| *Dussumeria acuta* (8) | Rainbow sardane | AC | 9.92 (± 0.65) | 64.45 (± 9.20) | 376.81 (±80.1) | 8.19 (±1 10) |
| | | G | ND | 58.25 (± 6.67) | 224.63 (±40.4) | 2.73 (±0 60) |
| | | M | 2.20 (± 0.15) | 29.90 (± 3.20) | 119.04 (±18.0) | ND |
| *Stolephorus devisi* (18) | Anchovy | AC | 27.00 (± 0.09) | 123.15 (± 16.09) | 443 84 (±96.0) | ND |
| | | G | ND | 172.41 (± 15.50) | 1009 32 (±122 0) | 64 40 (±8 20) |
| | | M | 2.01 (± 0 12) | 14.99 (± 1.60) | 127 59 (±21.0) | ND |
| *Rastrelliger kanagurta* (4) | Mackeral | AC | 9.28 (± 0.32) | 71.25 (± 6.50) | 3773 30 (±540.0) | 14 68(±2 10) |
| | | G | ND | 117.87 (± 12.00) | 419 25 (±85 4) | 11 70 (±1 20) |
| | | M | 1.52 (± 0.08) | 6.56 (± 0.42) | 33.77 (±6.6) | ND |
| | | L | 16.53 (± 0.74) | 247.62 (± 31.00) | 72 46 (±14.5) | 4 39 (±0.62) |
| *Chirocentrus dorub* (3) | Wolf herring | AC | 4 63 (± 0.21) | 462.64 (± 64.00) | 144 92 (±36.0) | 20.90 (±3 00) |
| | | G | 0.17 (± 0.35) | 396.96 (± 55 .00) | 318.84 (±72.0) | 62.84 (±11.00) |
| | | M | 1.43 (± 0.07) | 19.29 (± 2.10) | 362.32 (±70.0) | 1.36 (±0 22) |
| *Mini maulata* (6) | | AC | 7.71 (± 0.46) | 90.72 (± 8.70) | 833.33 (±178.0) | 2.73 (±0.50) |
| | | G | 4.60 (± 0.25) | 83.74 (± 9.20) | 347.82 (±68.4) | 17.75 (±2.11) |
| | | M | 4.63 (± 0.21) | 38.58 (± 2.90) | 250.00 (±51.0) | 6.83 (±1.02) |
| *Megalapsis lordyla* (9) | Torpedo travally | AC | 15.43 (± 0.69) | 159.68 (± 8.70) | 536.25 (±98.0) | 6.98 (±1 50) |
| | | G | 4.92 (± 0 32) | 137.52 (±9.20) | 692.03 (±125.0) | 25.95 (±2.10) |
| | | M | 1.55 (±0.06) | 19.70 (±2.50) | 79.71 (±11.2) | ND |
| *Pseudosciaena loantis* (11) | Sciaenids | AC | 6.17 (±0.29) | 68.14 (±9 50) | 160.66 (±33.3) | ND |
| | | G | ND | 82.58 (±8.70) | 306.90 (±55.0) | ND |
| | | M | 1.50 (±0.04) | 18.06 (±0.90) | 112.31 (±20.0) | ND |
| *Johnllies* sp. (4) | Jewfish | AC | 9.25 (±0 46) | 67.73 (±8.00) | 239 13 (±49.5) | ND |
| | | G | ND | 66.05 (±7.00) | 306.32 (±61.5) | ND |
| | | M | 1.54 (±0.08) | 13.13 (±0.90) | 90.58 (±16.2) | 1 26 (±0 19) |
| *Sphryna zygaena* | Shark | AC | 15.43 (±0.84) | 58.55 (±5.20) | 173.91 (±35.0) | 4.29 (±0 73) |
| | | G | 3.70 (±0.14) | 54.67 (±2.50) | 49 13 (±2.1) | 3.27 (±0 33) |
| | | L | 35.49 (±2.01) | 341.97 (±49.00) | 94.20 (±11.5) | 4.09 (±0.80) |
| | | M | 1.51 (±0 04) | 26.68 (±1.20) | 72.46 (±17.9) | ND |
| *Mugil cephalus* (4) | Grey mullet | AC | 24.69 (±1.89) | 137.93 (±18.60) | 167 00 (±26.4) | 17 75 (±3 20) |
| | | G | 2.72 (±0.15) | 140.53 (±11 00) | 479.54 (±86.0) | 26.51 (±4 00) |
| | | M | ND | 33 66 (±4 40) | 144 92 (±2.25) | ND |
| *Petrica filamentosa* (3) | Silver bellies | AC | 40.12 (±3 11) | 110.01 (±20 10) | 166 30 (±40.4) | 30.05 (±4 40) |
| | | G | 1 54 (±0 08) | 84 03 (±7.20) | 262 14 (±45.6) | 2.41 (±0 50) |
| | | M | ND | 18.06 (±2 10) | 101 44 (±17 0) | ND |
| *Gobius plassal* (5) | Goboid | AC | 12 34 (±0 73) | 100 16 (±13.00) | 264 49 (±42.3) | 4 09 (±0 [illegible]) |
| | | G | 2.72 (±0 15) | 138.36 (±14.00) | 1419 44 (±320 0) | 2 41 (±[illegible]) |
| | | M | 3.08 (±0 16) | 15 18 (±0 60) | 45 29 (±5.5) | 9 56 (±1 50) |
| *Paratromate c niger* (3) | Black pomfret | AC | 7 71 (±0 48) | 12 15 (±0 90) | 91.66 (±14.07) | 20.49 (±4 90) |
| | | G | 9.25 (±0 44) | 91 54 (±11 00) | 398 55 (±70.4) | 24.59 (±[illegible]) |

M-Muscle; G-Gut; AC- Alimentary canal, L-Liver; SD - Standard Deviation

**Source** : Primary data collected by NIO




Map 4

Fig. 4.1.2.1 : Temporal Variation in the Water Spread Area of Vembanad Lake as Result of Reclamation

CARRYING CAPACITY BASED DEVELOPMENTAL PLANNING FOR GREATER KOCHI REGION

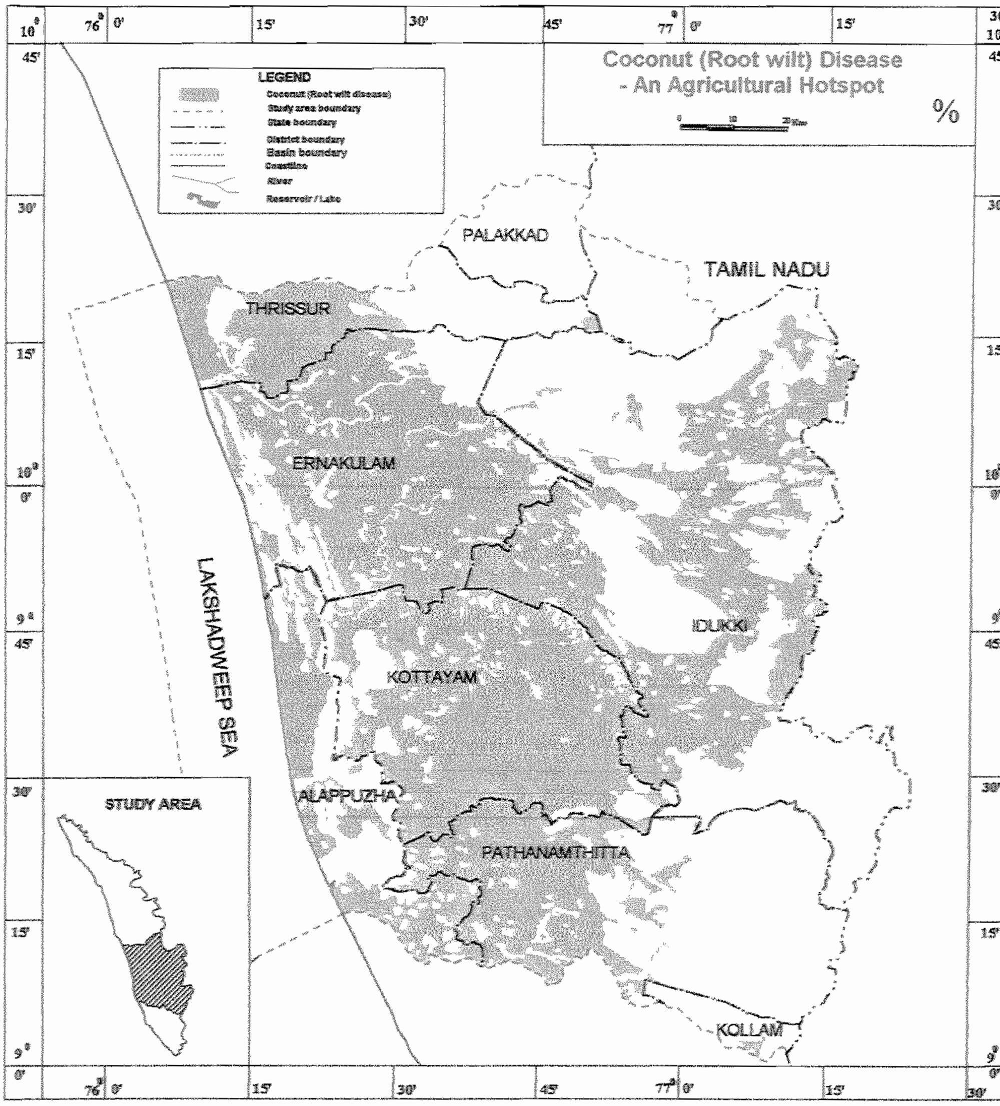



**Fig. 4.1.9.1 : Map Showing an Agricultural Hotspot- Coconut Root-wilt Disease Affected Areas**

## 4.2 Impact on Economy and Quality of Life

### 4.2.1 Impact of Population Growth and Urbanization

### 4.2.2 Impact of Food/Energy Import on GKR

### 4.2.3 Impact on Quality of Life (Income, Employment, Accessibility, Social Security and Welfare)

#### 4.2.3.1 Economy and Quality of Life

The required data on neither the economic costs of various developmental projects nor those of the industrial units are available. But with regard to the economic benefits of these projects to the community in general, these are considered as indicators of benefit on the human resources of the region. In Alappuzha district, about 66% of the population is non-workers and of that 17.85% are job seekers. Among the jobseekers, maximum are in the age group 20-24 both in the rural and urban areas. In the Ernakulam district, the percentage of non-workers is about 66% in which 16% are job seekers. Here also majority of job seekers are in the age group 20-24. The percentage of non-workers is relatively less ie. 60.29% in Idukki district, in which the job seekers are about 14%. But in the Kottayam district, the non workers come to about 69% and 17% of them are job seekers in which the majority are in the age-group of 20-24. In Pathanamthitta district, 70% of the population is non-workers and about 17% of them are job seekers. In the Thrissur district, 68% are non-workers and about 14% of them are job seekers. The above facts and figures show that on an average 17% of the non-workers are job seekers and majority of them are youths. Measures should be adopted to solve this unemployment problem among employable youth by increasing the job opportunities.

Kerala State has recently identified the Tourism sector and Information Technology sector as priority sectors for further development. It is recommended that the development of Tourism should be within the limits permitted by the assimilative capacity of the natural environment as estimated from the other components of the study. But with regards to IT sector, it should be considered as the first preference sector for further development. The IT education sector has to be given maximum priority in the government sector itself so as to make the opportunities available to the rural poor also. Booming of IT-education in the private sector cannot be considered as a remedy to rural unemployment because, its accessibility to the rural poor is limited due to heavy course fees.

To estimate the negative impacts of developmental activities on the quality of life of people, the QOL data given in Section 3.6 can be referred. For the GKR as a whole, the subjective quality of life index is 0.705. The priority problem identified in GKR is non-availability of potable water. About 17% of households in GKR are unsatisfied with the same.

#### 4.2.3.2 Impact of Air Pollution on Human Health

Impact of air pollution in industrial areas was assessed. A questionnaire-based survey was conducted to collect the response of the residents from 168 households and was analyzed. Eloor was found to be the most affected region.

89% of the households in Eloor and Cheranellur area opined that their lives were seriously affected and air quality was deteriorating. Incidence of diseases was also high in Eloor. Details are presented in **Table 4.2.3.1**. To verify this observation the doctors at the Primary Health Centres (PHC) were interviewed and the medical registers were also referred to. Data collected from the primary health centre of Varapuzha and Eloor are given in **Figs. 4.2.3.1** and **4.2.3.2.** Increasing incidences of respiratory and skin diseases were evident among the residents. Decrease in number of patients during the last year as per the records of PHC at Binanipuram could be due to the fact that the condition of the patients in Eloor is often worse and they often go to hospitals in Cochin.

### 4.2.4 Impact of Gulf Money Inflow

### 4.2.5 Impact of Brain Drain

### 4.2.6 Impact of Population Growth/Urbanization on Domestic Waste Water Discharges and Solid Waste Generation

Table 4.2.3.1

**Response of the Residents in and around the Industrial Complex at Eloor**

| Category | Response of Residents (%) | | |
|---|---|---|---|
| | Eloor | Cheranellur | Varapuzha |
| Pollution is seriously affecting their lives | 89 | 89 | 87 |
| Affected with diseases related to pollution | 81 | 56 | 67 |
| Well water is affected | 54 | 70 | 57 |
| Agricultural crops are affected | 42 | 56 | 45 |
| Live stock is affected | 88 | 0 | 27 |
| Agricultural productivity has declined during the past few years | 42 | 56 | 45 |
| Deterioration of air quality during the past few years | 89 | 89 | 87 |
| Deterioration of water quality during the past years | 54 | 70 | 57 |

**Source** : Primary data collected by KFRI

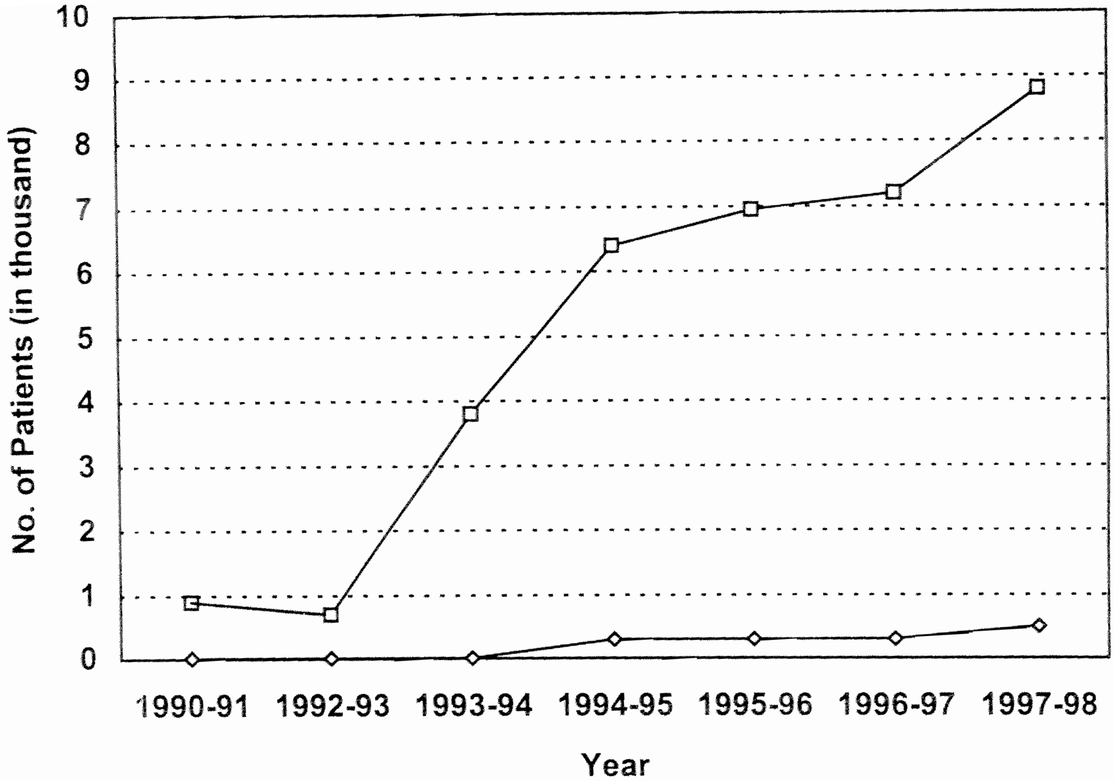



Fig. 4.2.3.1 : Increasing Incidence of Respiratory and Skin Diseases among Residents at Varapuzha

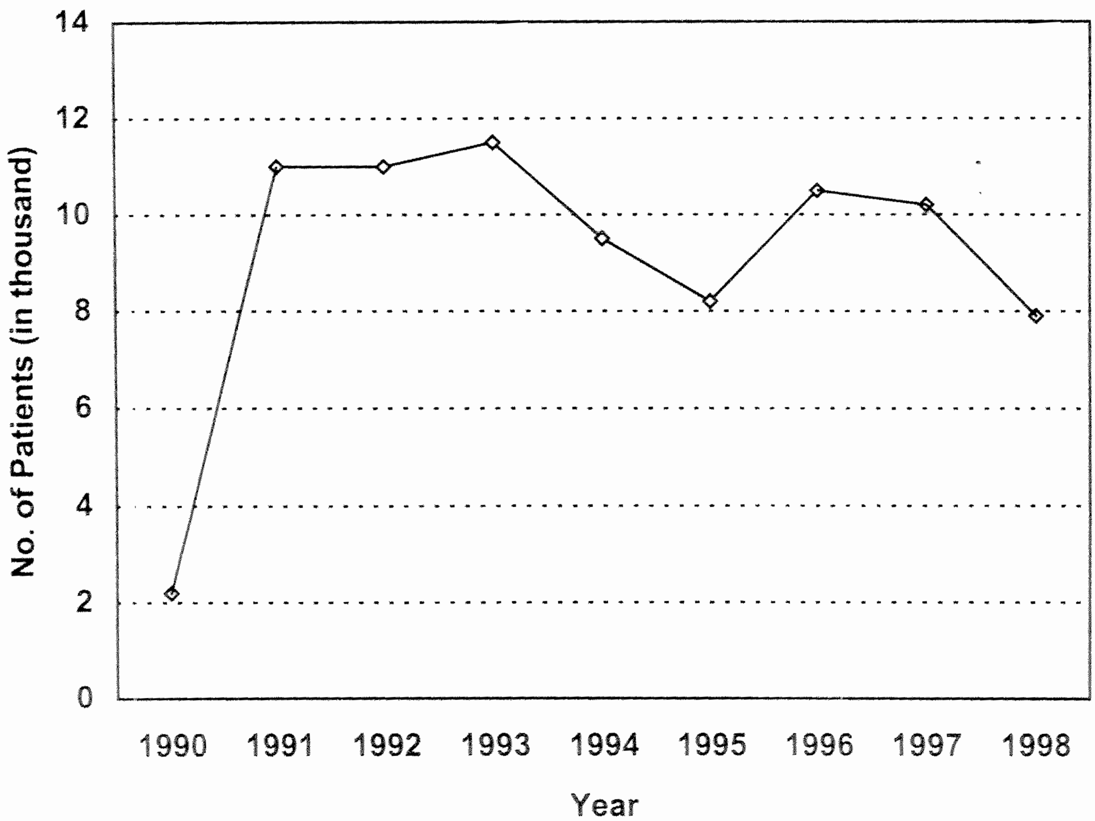



Fig. 4.2.3.2 : Increasing Incidence of Respiratory Ailments among Residents around Eloor

## 4.3 Impact on Environmental Quality

### 4.3.1 Impact of Industrial Emissions of Air Quality

### 4.3.2 Impact of Mining and Domestic Fuels Combustion on Area Source Emission

### 4.3.3 Impact of Air Emissions & Meteorology on Ambient AAQ

### 4.3.4 Impact of Industrial Operations and Vehicular Traffic on Ambient Noise Levels

### 4.3.5 Impact of Wastewater Discharge of River Water Quality : Chithrapuzha River

Chitrapuzha River, one of the tributaries of Periyar River, flows through Amabalamedu, Cochin area, on the southern coast of Indian sub-continent. The river receives a variety of effluents from fertilizer, refinery and other industries, containing ammonia, ammonium sulphate, phosphate, calcium sulphate, nitrate and heavy metals. The total effluent discharge into Chitrapuzha River is about 33,600 $m^3$ per day.

The drainage map of Chithrapuzha sub-basin is shown in **Fig. 4.3.5.1** along with the network of sampling stations at a distance of 8 km. Water samples collected from 13 sampling stations were subjected to various physicochemical analyses. Three well water samples near the affected land were also collected. Flora and fauna of the area with reference to plankton, nekton and benthos from seven stations were also studied.

The physico-chemical features of the river water samples are given in **Table 4.3.5.1** Sampling station-wise status of physico-chemical parameter (pH, EC, TDS, COD, Cl, $SO_4$, $NO_3$, $PO_4$) and metals (Na, Mg, SAR, Zn, FE, Ni & Pb) is projected through **Figs. 4.3.5.2** and **4.3.5.3** respectively.

The water samples were found to be generally alkaline in nature except at discharge site near gypsum settling pond i.e. at the sampling point 8 (SP-8). Electrical conductivity was high at all effluent points and at many of the river water stations. Conductivity values as high as 2080 and 1872 μmhos /cm were recorded at the sampling points SP-1 & SP-8, which are the effluent discharge sites of the fertilizer plant, carrying effluents from ammonia, urea and phosphoric acid plants. This was reflected in corresponding increase in total dissolved solids values also. Ionic concentration of chloride, nitrate-N and calcium were appreciably high at many of the sampling stations. With regard to COD, a maximum value of 304 mg/L was noted at sampling point 12. Fluoride levels at SP-1 & SP- 7 were very high. At times, concentration up to 25 mg/L was noted at SP- 7. The presence of heavy metals like Cu, Zn, Ni, Fe, Mn and Cr was noticed in all the water samples. Concentration of lead was higher than the limit prescribed by BIS specification for industrial discharges into inland surface waters. It was higher than 1 mg/L in all the well water samples also.

The Sodium Absorption Ratio (SAR), which indicates the alkalinity hazard of irrigation water, was found to be below 10, indicating that water is safe for irrigation. However, water samples collected from Irumpanam area (SP-13) had a high SAR value of 21, indicating its unsuitability for irrigation purpose.

Species composition, density and distribution pattern of flora and fauna vary according to the hydrographic conditions of water and environmental status of the area. Stress conditions particularly due to salinity intrusion, discharge of pollutants etc. result in distinct variations in the biotic components.

In the present study, with regard to microplankton, the phytoplankton community predominated indicating the enrichment of nutrients. Euryehaline species, capable of existing in high saline conditions, were not present in the area. Microplankton included a spectrum of fresh water and brackish water species. The density of fresh water species exceeded the brackish water flora. A decreasing trend in abundance of microplankton was observed towards the effluent discharge stations 1 to 3. Phytoplankton species viz. Chlorella sp., Oscillattoria sp. and Nitzchia sp. occurring in polluted water were found to be common and dominant in the area.

The macroflora of the area comprised of major groups like Eichhornia sp. (water hyacinth), Alternanthera philoxeriodes (Amaranthacea) and wild grass (graminae). The macro flora reported is of tolerant variety, capable of accumulating toxicants in high levels. These species were distributed throughout the area extending from effluent discharge site 1 to SP-13.

Zooplankton included a few fresh water species. Density of micro and macro zooplankton was low / scarcely distributed in the study area. Zooplanktons included fresh water species like Oithona sp., Daphnia sp., Isoperlla sp. and Rhabditis sp.

The quality of soil and water is generally indicated by the biomass of worms like polychaetes and nematodes, present in the bottom sediment. Sampling sites were totally devoid of benthic fauna up to effluent discharge sites 1 to 3. Polychaete sp. and Gastropodes were distributed in very low density towards SP-13.

The area was not found to support diverse nektonic species. In the effluent discharge points 1 to 3, nektonic pollution was not reported. Moreover, the varieties like Arius batra chus (CatFish), Talappia sp., Haplochilus sp. and Peneaus indicus were distributed in very low densities near Irumpanam Bridge (SP-13).

The animal and plant tissues of fish, Arius batrachus, Pineaus indicus (Prawn), Eichhornia sp. (Water hyacinth) were subjected to analysis of heavy metals. The concentrations of lead & nickel in animal & plant tissues were high **(Table 4.3.5.2)**. Lead concentration was as high as 68.0 and 76.4 mg/kg in fish and prawn tissues respectively. In plant tissue Eichhornia sp. from sampling sites 12 and 23, lead concentrations were 216 and 239 mg/kg respectively. The nickel content in plant tissue was found to be 239 mg/kg. Similarly, Fe, Zn, K, Mg in plant tissue were also high.

The nutrients and heavy metals are heavily distributed in the Chitrapuzha River resulting in high concentrations of fluoride, sulphate and calcium. The study indicated that prevalence of stress conditions exist in the area from sampling sites 1 to 8. These sites are near to the effluent discharge outlets of the fertilizer industry. Dominance of tolerant species of flora and fauna, low population density of zooplankton, nekton, benthos and higher residual concentration of heavy metals like lead and nickel in plant and animal tissues, presence of tolerant varieties of macro-vegetation indicate the existence of stress conditions in the area. Salinity conditions and species composition of flora and fauna indicate that salinity intrusion does not occur in the area to an extent at which the ecology of the rivers and adjacent landmass are affected.

### 4.3.6 Impact of Change in Landuse Pattern on Surface Runoff

### 4.3.7 Impact of Waste Water Discharges on Estuarine Water Quality

### 4.3.8 Impact of Wastewater Discharges on Coastal Water Quality

Presently, no wastes are directly discharged into the coastal waters except the dredge spoil dumping resulting from the maintenance dredging of the navigation channels of Kochi Port. Industrial and municipal wastewaters are directly discharged into the backwater system. However, the indirect effect of dumping wastes in the backwater system is felt in the near shore waters of the coastal area off Kochi. This can be especially seen in the buildup of nutrients in the Kochi bar mouth area. Moreover, the pollutants dumped in the estuary, which get partially deposited in the sediments of the navigational channels are likely to be part of the dredge spoil dumped in the coastal waters, which is of the order of 10 million $m^3$ per year. The trace metals in dissolved form in water do not indicate any high level, but the sediment in the near shore area is likely to accumulate the trace metals especially in the vicinity of the dumping sites.

### 4.3.9 Impact of Irrigation Schemes on Drinking Water

### 4.3.10 Impact of Burial Grounds on Groundwater Quality

The effect of burial grounds on the quality of well water was studied by collecting 15 samples from Chalakkudy, Cochin, Kottayam and Pathanamthitta areas (**Table 4.3.10.1**, **Fig 4.3.10.1**). The samples were subjected to various physio-chemical and bacteriological analyses and the results are given in **Table 4.3.10.2**, which indicates that, pH, nitrate, calcium, total hardness and coliforms are present in excess. The samples collected from the burial ground in Cochin area near the corporation and masjid contained calcium and total hardness in excess. Phosphate concentration was comparatively high and the samples were found to be bacteriologically contaminated.

Out of the 15 samples collected, six were found to be bacteriologically contaminated. Nitrate and Phosphates were found to be present in high concentrations, as compared to the well water samples, which were taken as controls. Nitrate-nitrogen as high as 26.8 mg/L and maximum phosphate concentration of 0.55 mg/L was detected in the wells of Pathanamthitta and Cochin.

In general, the samples around the burial ground have inferior water quality. Further detailed study using radiotracers or chemical tracers may be required for establishing the deterioration of water quality due to burial grounds.

### 4.3.11 Impact of Industrial Effluents on Groundwater Quality

A study was carried out by CWRDM in 1996-99 on the ' Effect of Industrial Effluents on Groundwater Quality' funded by STEC, Govt. of Kerala. The industrial sites selected were Aluva-Eloor area, Ambalamedu and Cochin area. A total of 23 water samples were collected from these areas. The water samples were subjected to various physico-chemical analyses as per standard procedures. Water sampling locations around Aluva - Eloor and Ambalamedu area are shown in **Figs. 4.3.11.1** and **4.3.11.2** respectively.

The range and average values of various parameters are given in **Table 4.3.11.1**. These results are compared with the maximum permissible limit prescribed by BIS for drinking water as summarized in **Table 4.3.11.2.**

The samples collected from the Eloor Aluva region were found to be contaminated atleast with respect to one of the parameters. It was determined that 65% of the samples analysed contain heavy metals in excess of the permissible limit. Samples were found to be acidic in general. A chloride value of 430 mg/L was noted in some of the wells located near Indian Rare Earths Ltd (IRE) and FACT. The highest concentration of Iron was found in a well near IRE. Heavy metal contaminated wells are found around Binani Zinc (India) Ltd., Binanipuram. The wells have a Chromium concentration as high as 0.71 mg/L, Lead 0.07 mg/L, and Copper 0.16 mg/L and Zinc upto 2.51 mg/L in the wells of this region. There is a solid waste disposal land near the factory, which leads to well water contamination. The concentration of Nitrate-Nitrogen was found to be above the permissible limit in the wells near FACT. Copper, Chromium and Iron were found to be higher than the limit in a well near the solid water disposal site of INDAL Company. The wells near the IRE Ltd have high TDS, Chloride, Chromium, Manganese, Copper, etc.

The samples collected around the Ambalamedu area contain Fluoride concentration of 1.2 mg/L. The concentration of Lead and Nickel was around 1.5 mg/L in these regions. The maximum limit set by BIS is only 0.05 mg/L for these metals.

### 4.3.12 Impact of Bunds/Withdrawal Practices on Salinity Ingression

The Vembanad backwaters (as this estuary is commonly called) is actually the southern half of the larger Vembanad-*Kol* wetland system, the largest and the most complex estuarine system on the west coast of India. The southern part of these backwaters is called the Vembanad Lake upto the famous agricultural Kuttanad area. The Kochi estuary extends southwards a distance of 60 km from its mouth at Kochi. This could be justifiably separated from the northern *Kol* area since the northern rivers i.e. Periyar, Chalakkudy, Karuvannur, Puzhakkal and Kechery drain into the sea mainly through other mouths near Kodungallur and Chettuva.

At Thaneermukkom near Cherthala, there is a major artificial salt water barrier (barrage, regulator; **Plate 4.3.12.1**) constructed during the seventies for regulating salt water from entering the southern most areas and adversely affecting the agricultural operations in the low-lying Kuttanad, which is the Rice Bowl of the State.

The barrage is about 1250 m long with 93 ventways, each 12.2 m wide and 5.5 m high and the sill is at an elevation of 3.38 m below MSL. For navigational purposes, a twin-lock has been provided. The barrage is kept closed all through summer (January-May), and there is no flushing possible in the upper reaches, so much so that the non-point discharge of water containing insecticides and pesticides from the rice fields is trapped on the upstream side of the barrage. This structure has been relatively successful in keeping the water in Kuttanad free from salinity, enabling increased cropping in the dry season. However, these structural measures taken to prevent salinity intrusion without carrying out sufficient detailed study have caused problems to the estuarine ecosystem and the overall ecology of the region. Several drawbacks have been noticed; the major ones are: reduction of upstream migration of marine fish and prawns, increased weed growth upstream which affects inland navigation and severe restriction of natural flushing of pollutants.

Another hydraulic intervention is the Thottapally spillway (**Plate 4.3.12.2**), completed much earlier during 1955, and built in the southernmost part of Kuttanad to divert a part of the combined flood waters of Achencoil, Pamba and Manimala along an easier and more direct outlet to the sea, the flood waters which would otherwise find their exit through the Kochi mouth, after traversing about 75 km. This structure is located at Thottappally across and under National Highway 47, about 27 km south of Alappuzha. It consists of a leading channel about 8 km long, a spillway channel, and 1.3 m long and 365m wide, with a bridge-cum-regulator with 40 gated vents, each having 7.6m clear span. The sill level is 1.82 m below MSL and maximum flood level 1.52 m above MSL. The spillway capacity was later found to be far below the requirements, and is also affected by the bar formation at the mouth.

The estuary is replenished directly with fresh water from 5 river basins; Achencoil, Pamba, Manimala, Meenachil and Muvattupuzha. The first four rivers discharge into the estuary along the upstream (southernmost) Kuttanad area, while Muvattupuzha joins the system somewhat in the middle (downstream of Thanneermukkom barrage), a few kilometers north of Vaikom. While the average annual rainfall in the southernmost part of Achencoil basin is about 2500 mm, it is around 3200 mm in the other basins. However, as the upper (eastern) part of the catchments of Manimala, Meenachil and Muvattupuzha rivers rise to the Western Ghats, rainfall increases very rapidly to almost 5000 mm in some locations. The three major hydrologic interventions are: the hydro-electric storage reservoirs in Pamba basin (12.5% of average annual flow), the Pamba Valley Irrigation Project which diverts part of the tail race water and the Muvattupuzha Valley Irrigation Project (Malankara) which diverts about half the Idukki (in Periyar) tail race water for irrigation.

The construction of Thaneermukkom barrier has created a conflict between the agricultural and fishery sectors, which remains unsolved. A real solution to this problem would require restoration of Vembanad Lake as an estuarine fisheries area without reducing the availability of fresh water for agriculture. Study conducted on the impact of Thanneermukkom salt water barrier revealed that lean flow augmentation to maintain a minimum flow of about 320 $m^3/s$ can altogether eliminate the need to operate the barrier, while the measured summer flow is in the range of 70 to 100 $m^3/s$.

In case Thanneermukkom barrage is kept open, there is a possibility for salinity to propagate to the drinking water supply schemes in the lower reaches of rivers draining into the wetland. In connection with the investigations of the World Bank Projects, it is found that the salinity will propagate up to Peroor, the intake point of Kottayam water supply scheme. All these have been considered while estimating the fresh water flow to control salinity intrusion. It is found that 138.14 $Mm^3$ per month of fresh water is required to maintain the level of salinity at Thanneermukkom to 2 ppt. This means that annual flows required limiting the salinity intrusion to tolerable limits in the Kuttanad belt works out to 1657.7 $Mm^3$. Since the problem is expected to be acute in summer months, the quantum of flows required during the six summer months is half of the total requirements, 828.85 $Mm^3$. However, if flows are maintained for flushing out the pollutants of the wetland system, the salinity intrusion problem also can be controlled.

**Fig. 4.3.12.1** is the daily discharge hydrograph of Vembanad estuary. The longitudinal salinity profiles using depth-mean salinity are plotted in **Fig. 4.3.12.2**, which reveals that there is no salinity problem south of Thanneermukkom bund where the four rivers, Meenachil, Manimala, Pamba and Achencoil join the Vembanad backwaters. As the Muvattupuzha joins the lake north of Thanneermukkom bund, it receives additional water from the Periyar through Idukki dam. It also does not face any salinity problem at present.

Most of the estuaries on this coast are situated in or adjacent to the urban areas and the water supply schemes are situated in the lower reaches of rivers, which are prone to salinity intrusion during the summer months of this humid tropical region. During the summer months of 1982-83, in the Periyar, salinity propagated to a distance of about 30 km upstream of the mouth of the estuary to the intake point of the water supply scheme of Greater Cochin Corporation with a population of 1 million and to the industrial complex near Aluwa. The salinity at the intake point was of the order of 2000 ppm; also, because of the salinity problem, the major chemical, fertilizer and metallurgical factories had to be closed down. As an emergency measure, a temporary earthen embankment was constructed across the main river (bund at Pathalam; **Plate 4.3.12.3**). The Pathalam bund was located across the Eloor branch of the Periyar river. The bund was about 100 m in width with average breadth above water surface of 10 m. It was constructed of clay and grit dredged out from the bed of the river by a number of dredgers. Sand bags and sand coverings were also used. Ever since, during the monsoon, the embankment is washed off and, during summer, it is reconstructed. Because of the embankment, the industrial effluents discharged downstream are not flushed out and also inland navigation is adversely affected.

In the Periyar, downstream of Aluwa, another temporary bund is constructed simultaneously at Manjummel on the Edamula branch. Another branch of Periyar bifurcates just above Aluwa and flows towards northwest and joins Chalakkudy River. On this branch also, a similar temporary bund is constructed every summer at Manjali for prevention of salt water. It is estimated that by maintaining a flow of 25 $m^3/s$ in this river, salinity can be controlled to tolerable limits. This can be accomplished either by regulating the flow from existing reservoirs upstream or by introducing a scheme exclusively for this purpose. The riverflow in Periyar is considerably reduced due to two major interbasin transfers of water from Periyar: one being the transfer of water to Tamilnadu through Mullaperiyar dam and the other to Muvattupuzha basin through the tail race of Idukki hydel project.

A bridge-cum-regulator at Kanakkankadavu across Chalakkudy River in the downstream is being commissioned for prevention of salt water intrusion. The regulator is meant to benefit 2600 ha of paddy fields by halting entry of salt water.

### 4.3.13 Impact of Wastewater Discharges on Aquatic Biological Resources (freshwater, estuarine water and coastal waters)

There are over 200 medium and large scale industries and about 2000 small scale industries are discharging effluents into the inland water bodies. It is estimated that industrial effluents of the order of 6.5 million $m^3$ are being dumped into the rivers and estuaries of Kerala. According to KSPCB, the industrial effluent discharge into the inland water bodies in Kochi area is about 53000 $m^3$ per day. Frequent incidences of mass mortality of fishes have become a usual affair in the lower reaches of rivers such as Periyar, Chithrapuzha and Vembanad Lake in GKR (mainly due to industrial effluents carrying heavy load of $NH_3$ at the rate of 432-560 ppm), and Chaliyar, Kallada and Ashtamudi Lake in Kerala.

The fishes in these areas are facing reproductive hazards, growth retardation, morphological abnormalities, apart from total destruction of eggs and larvae. The fish shoal entering the polluted zone could not tolerate the cumulative effect of pollution and results in heavy mortality. The Eloor-Varapuzha regions of the Cochin backwaters have been transformed into a barren contaminated zone as the main industrial belt is situated in this area and the industries in this area discharge their effluents into the water bodies.

Paddy fields of Kuttanad receive considerable quantities of pesticides indiscriminately applied. Ten types of pesticides with a total quantity of 490 MT are used in Kuttanad annually, of which 370 MT are applied for *Punja* and 120 MT for *Virippu*.

In the absence of adequate facilities for the disposal of sewage from human settlements, they are directly discharged into the inland water bodies in several places through the drainage canals. Moreover, hung latrines are visible all along the backwater system. All this constitutes the major source of faecal contamination and organic pollution. Bacterial count in water at several localities in the backwater system is of high order and alarming.

Coconut husk retting is another source of aquatic pollution. In Vembanad Lake alone, about 245 ha of area is used for husk retting. The presence of noxious gases such as $H_2S$, methane, high BOD, turbidity in this area etc. drives the fishes out of these areas.

All the above factors contributed to the deterioration of the water environment and thus the biological environment. One of the reasons for dwindling fishery resources in the backwater system is the aquatic pollution. Since some of the important marine fishes migrate into the backwater system during their life cycle, the pollution in the backwater system affects the fisheries of the coastal waters also.

**Fish Disease**

The deterioration of water quality due to excessive application of pesticides, low pH, excess turbidity, dumping of sewage etc. have resulted in the outbreak of various bacterial, fungal and viral diseases out of which the most virulent and menacing is the Epizootic Ulcerative Syndrome (EUS). The outbreak of EUS was first noticed in Kuttanad in June 1991 and its recurrence in varied intensities could be registered in the last several years in different parts of the state. The species affected are mullets, barbs, pearl spots, snakeheads etc. Due to the outbreak of this disease, the economy of Kerala has crumbled to the tune of 2 crores and has thrown around 25,000 full time and 7,000 part time persons engaged in fishery related activities out of employment.

### 4.3.14 Impact on Land Degradation due to Mining, Soil Erosion, Salinization and Solid Waste Disposal

### 4.3.15 Impact of Industrial and Domestic Solid Waste Disposal on Ground Water Quality

#### 4.3.15.1 Characteristics of the Substratum of Municipal Waste Dumping Site

The characteristics of the substratum of municipal waste dumping sites in the study region are given in **(Table 4.3.15.1).** Municipalities, which have a permanent waste-dumping yard were visited and 5 soil samples were collected from one meter pits at intervals of 20 cms. Sites at Alappuzha, Chertala, Kayamkulam and Paravur have sandy substratum with over 90% of sand and with 5% clay or even in less quantity. Substratum of sites at Changanasseri, Kothamangalam, Pala and Kodungalloor consisted of 80-90% of sand, of which gravel content was more in the samples from Changanasseri. Substratum composed of 70-80% of sand is observed at Thodupuzha, Chenganoor, Kottayam, Iringalakuda, Aluva, Moovattupuzha and Chenganoor. Of which the last four sites had high gravel content. Percent of clay is high in samples from Kottayam.

The substratum consisted of over 90% of sand in sites such as Alappuzha, Chertala, Kayamkulam and Paravur pose the threat of faster rate of leaching of contaminants into the ground water. Substratum consisted of higher gravel content at sites Moovattupuzha, Irinjalakuda and Aluva even though they had a lateritic substratum, the rate of leaching can be faster, which could be hazardous as the drinking water sources are affected.

#### 4.3.15.2 Chemical Characteristics of the Leachates at Municipal Waste Dumping Sites

Leachates from the municipal sites were analysed to find out the chemical characteristics. Concentration of Sodium, Potassium, Magnesium and Calcium were analysed. The leachates at Changanasseri were the maximum polluted ones with significant high concentrations of all the tested parameters followed by Alappuzha, Paravoor, Aluva and Kayamkulam. Concentration of Sodium is found to be high in the leachates of Kayamkulam and Changanasseri. Potassium is found to be very high in Alapuzha and Changanasseri. Concentration of Magnesium is found to be high in Alappuzha and Changanasseri and calcium in Alapuzha, Paravur and Changanasseri.

Even though dumping at Changanasseri is identified to be the maximum polluted one, tested parameters indicated the well water (drinking water sources within 200 meters) to be safe, with Mg and Ca within permissible limits. This site has hard laterite substratum below 80 cm (from the horizon). Well waters at all tested sites were found to be safe (within the permissible limits) with relatively high concentrations of Potassium in the wells of Alappuzha and Sodium in Kayamkulam, which was also found to be high in the leachates from these sites (**Table 4.3.15.2**).

#### 4.3.15.3 Heavy Metals in Municipal Wastes

Well waters in homesteads, which are the sources of drinking water were tested. Results show that the drinking water was found to be safe with concentrations conforming to permissible limits. Concentrations of heavy metals were more in well water than the leachates in most of the samples. Dumpings in Kottayam had traces of all the heavy metals tested in the leachates in highest concentrations at all sites. Drinking water in Aluva and Kayamkulam showed evidence of accumulation of heavy metals with relatively higher concentration **Table (4.3.15.3)**.

### 4.3.16 Impact of Agricultural Practices on Non Point Source Pollution

- Annually, about 100 MT of different pesticides are applied in the rice fields of Kuttanad including organo-chlorine, organo-phosphorus and even DDT. It is argued that these pesticides ultimately find their sink in the fresh water ecosystem of Vembanad, south of Thanneermukkom regulator.
- Annually, it is estimated that about 8,400 MT of nitrogen, 5,444 MT of phosphates and 6,786 MT of potash are applied in Kuttanad rice fields. The increased eutrophication, leading to excessive weed growth in Kuttanad and adjoining water bodies is mainly due to the above.

## Table 4.3.5.1

## Physico-chemical Characteristics of Chitrapuzha River

| Sr. No | pH | EC | TDS | T | Cl | $SO_4^{2-}$ | $PO_4$-P | COD | $NO_3$-N | Ca | Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 9.62 | 2080 | 1331 | 24 | 150 | 238 | 0.08 | 177.14 | 110 | 6.4 | 1.60 |
| 2 | 9.2 | 728 | 466 | 40 | 60 | 160 | 0.01 | 192 | 520 | 6.4 | 2.12 |
| 3 | 7.53 | 312 | 199 | 42 | 30 | 115 | ND | 272 | 160 | 10.4 | 1.91 |
| 4 | 7.50 | 286 | 183 | 40 | 65 | 120 | ND | 160 | 70 | 8.0 | 1.82 |
| 5 | 8.59 | 494 | 316 | 78 | 30 | 170 | 0.06 | 176 | 120 | 15.40 | 2.94 |
| 6 | 8.38 | 442 | 282 | 22 | 10 | 155 | 0.03 | 192 | 130 | 7.20 | 2.13 |
| 7 | 7.25 | 338 | 216 | 60 | 11 | 153 | 0.002 | 192 | 72 | 10.40 | 3.19 |
| 8 | 9.13 | 1872 | 1198 | 820 | 220 | 215 | ND | 144 | 20 | 830.0 | 1.48 |
| 9 | 6.94 | 286 | 183 | 66 | 13 | 110 | 0.008 | 208 | 80 | 10.40 | 3.53 |
| 10 | 7.87 | 494 | 316 | 90 | 29 | 95 | 0.005 | 192 | 70 | 12.80 | 4.61 |
| 11 | 6.88 | 624 | 399 | 136 | 14 | 120 | ND | 240 | 80 | 23.20 | 4.93 |
| 12 | 6.60 | 1612 | 1032 | 328 | 640 | 125 | 0.01 | 304 | 50 | 40.00 | 5.46 |
| 13 | 6.88 | 2028 | 1298 | 378 | 940 | 237.5 | ND | 272 | 40 | 44.00 | 5.54 |
| 14 | 7.80 | 8055 | 1313 | 72 | 160 | 84 | ND | ND | 25 | 16.00 | 4.52 |
| 15 | 8.39 | 234 | 149 | 206 | 120 | 162 | 0.004 | ND | 10 | 48.00 | 4.80 |
| 16 | 7.04 | 2473 | 1583 | 104 | 156 | 90 | ND | 48 | 35 | 20.80 | 4.80 |

| Sr. No. | Na | K | Fe | Cu | Cd | Zn | Ni | Pb | Salinity | SAR | F |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 32.5 | 9 | 0.46 | 0.07 | ND | 1.70 | 1.32 | 1.85 | 2.72 | 3.28 | 1.80 |
| 2 | 39.3 | 5 | 0.58 | 0.05 | ND | 0.21 | 1.22 | 2.35 | 1.11 | 2.46 | 1.05 |
| 3 | 33.2 | 2 | 0.47 | 0.03 | ND | 0.18 | 1.40 | 1.65 | 0.57 | 3.18 | 0.87 |
| 4 | 33.3 | 5 | 0.10 | 0.03 | ND | 0.10 | 1.46 | 1.65 | 0.15 | 3.61 | 0.89 |
| 5 | 37.9 | 2 | 0.10 | 0.03 | ND | 0.02 | 1.65 | 1.77 | 0.08 | 1.51 | 23.0 |
| 6 | 35.3 | 4 | 0.01 | 0.04 | ND | 0.12 | 1.38 | 1.80 | 0.21 | 0.62 | 0.57 |
| 7 | 41.6 | 5 | 0.04 | 0.02 | 0.10 | 0.16 | 1.41 | 1.75 | 0.23 | 3.18 | 25.0 |
| 8 | 40.8 | 5 | 0.04 | 0.04 | ND | 0.33 | 1.20 | 2.31 | 0.42 | 0.91 | 3.20 |
| 9 | 43.2 | 5 | 0.16 | 0.03 | ND | 0.23 | 1.23 | 1.63 | 0.26 | 0.52 | 3.0 |
| 10 | 69.2 | 7 | 0.09 | 0.03 | ND | 0.03 | 1.50 | 1.66 | 0.05 | 2.39 | 0.44 |
| 11 | 120.7 | 11 | ND | 0.04 | ND | 0.04 | 1.31 | 1.68 | 0.28 | 2.70 | 2.00 |
| 12 | 480.0 | 29 | ND | 0.02 | ND | 0.05 | 1.55 | 1.63 | [illegible] | 1.14 | 2.5 |
| 13 | 562.0 | 33 | 0.13 | 0.03 | ND | 0.06 | 1.48 | 1.62 | [illegible] | 1.45 | 0.77 |
| 14 | 38.0 | 8 | 0.05 | 0.03 | ND | 0.07 | 1.18 | 1.57 | 0.32 | 2.60 | 1.05 |
| 15 | 24.0 | 37 | 0.13 | 0.03 | ND | 0.03 | 1.19 | 1.56 | 0.25 | 1.93 | 0.77 |
| 16 | 41.8 | 24 | 0.09 | 0.03 | ND | 0.04 | 1.35 | 1.57 | 2.83 | 3.18 | 0.77 |

The concentrations except that of pH, EC, Salinity and SAR (Sodium Absorption Ratio) are given in mg/l

Electrical Conductivity (EC) is expressed in μmhos/cm, Salinity in parts per thousand and SAR in meq/l

ND = not detected; TDS = Total Dissolved Solids; TH = Total Hardness

**Source** : Primary data collected by CWRDM ; 1994

## Table 4.3.5.2

### Heavy Metal Concentration in Animal and Plant Tissues

| Name of Species | Point | Concentration of Metal, mg/kg | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | K | Pb | Na | Zn | Cu | Mn | Cd | Fe | Ni | Mg |
| Fish *(Arius batrachus)* | 13 | ND | 68 | 532 | 35 | 1 | ND | ND | 1 | 50 | 28 |
| Prawn *(P. indicus)* | 12 | ND | 76 | 4532 | 6 | 2 | 1.0 | ND | 3 | 64 | 207 |
| Plant *(Eichhornia sp.)* | 13 | 78750 | 216 | 87 | 150 | 25 | 814 | 1.75 | 1631 | 187 | 669 |
| Plant *(Eichhornia sp.)* | 3 & 4 | 31250 | 239 | 5838 | 304 | 44 | 381 | 14.6 | 9808 | 239 | 624 |

**Source :** Primary data collected by NIO

Table 4.3.10.1

**Details of Ground Water Sampling Points Near Burial Grounds**

| Sample | Date | Source | Details of Source |
|---|---|---|---|
| **Chalakkudy** | | | |
| BG-1 | 13-05-99 | Open well | Varghese, Manangadil, Behind St. Mary's Church, Chalakkudi |
| BG-2 | 13-05-99 | Open well | CD Sebastian, Chullikkadan house, Behind St. Mary's Church, Chalakkudi |
| BG-3 | 13-05-99 | Open well | Thressiakutty Kunhuvareed, Malakkaran House. Near Police station, Chalakkudi |
| BG-4 | 13-05-99 | Open well | CK Jose, Chenginimattom. Near ST.Mary's Church, Chalakkudi |
| **Cochin** | | | |
| BG-5 | 15-05-99 | Open well | Sheela, Kanjirathinkal, Water land road, Palluruthy, Near Corporation burial ground |
| BG-6 | 15-05-99 | Tube well | KK Prakash, Krishna Bhavan, Kakkathara, Palluruthy, Kochi-6 |
| BG-7 | 15-05-99 | Open well | Culvath Juma Masjid compound, Fort Kochi |
| BG-8 | 15-05-99 | Open well | MA Ummer, 2/145, Culvathi, Behind Juma Masjid, Fort Kochi |
| **Kottayam** | | | |
| BG-9 | 16-05-99 | Open well | St. Thomas church compound, Nattasseri, Kottayam |
| BG-10 | 16-05-99 | Open well | PK Thomas, Madakkal, St.Thomas church, Nattasseri, Kottayam |
| BG-11 | 16-05-99 | Open well | Indira, Niranghatt, Near St.Thomas church, Nettisseri. Kottayam |
| **Pathanamthitta** | | | |
| BG-13 | 27-05-99 | Open well | Pathanamthitta Juma Masjid, Pathanamthitta |
| BG-14 | 27-05-99 | Open well | Sulaiman, Blahampurayidam, Pathanamthitta |
| BG-15 | 27-05-99 | Open well | Ayishabeebi, Pallipadinhattil, Blahampurayidam, Pathanamthitta |
| BG-16 | 27-05-99 | Open well | Shahul Hameed, Pallipadinhattil, Blahampurayidam, Pathanamthitta |

Table 4.3.11.1

**Summary of Groundwater Samples from Kochi Industrial Area**

| Parameter | Value Range | Average Value |
|---|---|---|
| pH | 5.0-8.4 | 6.3 |
| Electrical Conductivity (EC) | 66-2473 | 604.0 |
| Total Hardness (TH) | 4-228 | 91.1 |
| Chloride (Cl) | 28-432 | 131.0 |
| Fluoride (F) | 0.1-1.05 | 0.4 |
| Sulphate ($SO_4$) | 5.5-162.8 | 30.5 |
| Nitrate ($NO_3$-N) | 0.1-35 | 10.3 |
| COD | 6-78 | 30.5 |
| Calcium (Ca) | 0.8-64 | 24.1 |
| Magnesium (Mg) | 0.49-41.79 | 6.9 |
| Iron (Fe) | 0.05-0.56 | 0.3 |
| Zinc (Zn) | 0.03-2.51 | 0.3 |
| Sodium (Na) | 12-76 | 36.2 |
| Potassium (K) | 0.3-34.5 | 13.1 |
| Chromium (Cr) | 0.04-0.71 | 0.3 |
| Lead (Pb) | 0-1.57 | 0.3 |
| Manganese (Mn) | 0-0.68 | 0.1 |
| Copper (Cu) | 0-0.16 | 0.3 |

EC is represented in µS/cm. All others are in mg/L except pH.

**Source :** Primary data collected by CWRDM

Table 4.3.11.2

## Ground Water Quality Permissible Limits (BIS)

| Parameter | XX | X | Maximum Permissible Limit | Effect by Ingestion through Drinking of Well Water Samples |
|---|---|---|---|---|
| pH | -- | 7 | 6.5-8.5 | |
| Chloride | -- | 2 | 250 | Taste, Corrosion |
| Iron | 2 | 4 | 0.3 | Taste, Staining, Corrosion |
| Nitrate - N | 6 | -- | 10 | Methemoglobinema |
| Fluoride | 3 | -- | 1 | Dental & Skeletal Fluorosis |
| Lead | 1 | -- | 0.05 | Poisonous to central and peripheral nervous system |
| Chromium | 7 | 12 | 0.05 | Exposure to hexavalent Chromium causes Dermatitis, Allergic Skin reactions and Gastro-intestinal Ulcers |
| Manganese | 4 | -- | 0.1 | Chronic exposure to Manganese may cause irreversible brain disease |
| Copper | 12 | -- | 0.05 | Ingestion of 15-75 mg of Copper causes Gastro-intestinal disease |

All values except pH are in mg/L.

## Table 4.3.15.1

### Characteristics of the Substratum of Municipal Waste Dumping Sites

| Sr. No. | Sample Depth (cm) | Gravel (%) | pH | OC (%) | Sand (%) | Silt (%) | Clay (%) | WHC (%) | PS (%) |
|---|---|---|---|---|---|---|---|---|---|
| Alappuzha | | | | | | | | | |
| 1. | 0-20 | 3.0 | 6.0 | 0.11 | 96 | 0 | 4 | 27 | 37 |
| 2. | 20-40 | 0.0 | 5.5 | 0.06 | 96 | 0 | 4 | 23 | 37 |
| 3. | 40-60 | 0.3 | 6.1 | 0.06 | 96 | 0 | 4 | 24 | 37 |
| 4. | 60-80 | 0.0 | 6.3 | 0.06 | 95 | 0 | 5 | 19 | 37 |
| 5. | 80-100 | 0.2 | 6.2 | 0.06 | 96 | 0 | 4 | 24 | 37 |
| Aluva | | | | | | | | | |
| 6. | 0-20 | 41.0 | 4.8 | 0.90 | 73 | 10 | 17 | 51 | 40 |
| 7. | 20-40 | 51.0 | 5.1 | 0.56 | 77 | 16 | 7 | 39 | 42 |
| 8. | 40-60 | 48.0 | 5.0 | 0.73 | 77 | 9 | 14 | 45 | 42 |
| 9. | 60-80 | 50.0 | 4.8 | 1.09 | 72 | 9 | 19 | 52 | 40 |
| 10. | 80–100 | 53.0 | 5.0 | 0.79 | 76 | 17 | 7 | 50 | 45 |
| Changanassery | | | | | | | | | |
| 11. | 0-20 | 58.0 | 5.4 | 1.44 | 87 | 5 | 8 | 48 | 42 |
| 12. | 20-40 | 50.0 | 5.3 | 0.25 | 84 | 6 | 10 | 40 | 37 |
| 13. | 40-60 | 35.0 | 5.4 | 0.17 | 86 | 5 | 9 | 40 | 48 |
| 14. | 60-80 | 52.0 | 5.3 | 0.17 | 85 | 5 | 10 | 36 | 48 |
| Chengannoor | | | | | | | | | |
| 15. | 0-20 | 21.0 | 4.8 | 1.50 | 71 | 12 | 17 | 41 | 47 |
| Cherthala | | | | | | | | | |
| 16. | 0-20 | 0.3 | 5.1 | 0.14 | 95 | 1 | 4 | 27 | 37 |
| 17. | 20-40 | 0.0 | 5.0 | 0.06 | 96 | 0 | 4 | 24 | 37 |
| 18. | 40-60 | 0.3 | 5.2 | 0.08 | 95 | 0 | 5 | 20 | 34 |
| 19. | 60-80 | 0.0 | 4.9 | 0.06 | 96 | 0 | 4 | 24 | 35 |
| 20. | 80-100 | 0.0 | 5.4 | 0.06 | 96 | 1 | 3 | 24 | 36 |
| Irinjalakuda | | | | | | | | | |
| 21. | 0-20 | 52.0 | 4.3 | 1.71 | 73 | 12 | 15 | 48 | 42 |
| 22. | 20-40 | 49.0 | 4.2 | 1.35 | 75 | 9 | 16 | 48 | 39 |
| 23. | 40-60 | 48.0 | 4.5 | 0.87 | 76 | 8 | 16 | 45 | 36 |
| 24. | 60-80 | 48.0 | 4.7 | 0.76 | 74 | 7 | 19 | 46 | 35 |
| 25. | 80-100 | 58.0 | 4.8 | 0.79 | 74 | 6 | 20 | 44 | 30 |
| Kayamkulam | | | | | | | | | |
| 26. | 0-20 | 4.0 | 5.9 | 0.37 | 91 | 4 | 5 | 33 | 41 |
| 27 | 20-40 | 16.0 | 7.3 | 0.40 | 91 | 4 | 5 | 37 | 42 |
| 28 | 40-60 | 14.0 | 7.1 | 0.08 | 92 | 2 | 6 | 31 | 39 |
| 29 | 60-80 | 14.0 | 6.9 | 0.06 | 92 | 1 | 7 | 32 | 51 |
| Kodungaloor | | | | | | | | | |
| 30 | 0-20 | 26.0 | 4.6 | 1.66 | 86 | 6 | 8 | 40 | 36 |
| 31. | 20-40 | 29.0 | 4.8 | 0.31 | 80 | 6 | 14 | 34 | 27 |
| 32. | 40-60 | 36.0 | 4.8 | 0.42 | 74 | 7 | 19 | 34 | 44 |

Contd..

Table 4.3.15.1 (Contd...)

| Sr. No. | Sample Depth (cm) | Gravel (%) | pH | OC (%) | Sand (%) | Silt (%) | Clay (%) | WHC (%) | PS (%) |
|---|---|---|---|---|---|---|---|---|---|
| Kothamangalam | | | | | | | | | |
| 33. | 0-20 | 21.0 | 5.6 | 1.59 | 87 | 7 | 6 | 49 | 43 |
| 34. | 20-40 | 28.0 | 5.6 | 1.10 | 88 | 7 | 5 | 50 | 45 |
| 35. | 40-60 | 17.0 | 7.1 | 1.13 | 83 | 10 | 7 | 42 | 39 |
| 36. | 60-80 | 17.0 | 5.7 | 0.91 | 82 | 12 | 6 | 47 | 42 |
| 37. | 80-100 | 18.0 | 5.7 | 0.31 | 87 | 8 | 5 | 42 | 41 |
| Kottayam | | | | | | | | | |
| 38. | 0-20 | 42.0 | 4.5 | 1.56 | 82 | 6 | 12 | 50 | 28 |
| 39. | 20-40 | 45.0 | 4.4 | 1.10 | 85 | 7 | 8 | 48 | 51 |
| 40. | 40-60 | 18.0 | 4.7 | 0.88 | 78 | 7 | 15 | 50 | 44 |
| 41. | 60-80 | 46.0 | 4.9 | 0.08 | 74 | 6 | 20 | 42 | 43 |
| 42. | 80-100 | 42.0 | 5.4 | 0.91 | 76 | 6 | 18 | 41 | 45 |
| Moovattupuzha | | | | | | | | | |
| 43. | 0-20 | 41.0 | 5.1 | 0.82 | 77 | 12 | 11 | 41 | 48 |
| 44. | 20-40 | 51.0 | 5.4 | 0.59 | 78 | 12 | 10 | 42 | 44 |
| 45. | 40-60 | 55.0 | 5.3 | 0.45 | 78 | 12 | 10 | 40 | 42 |
| 46. | 60-80 | 72.0 | 5.4 | 0.31 | 88 | 6 | 6 | 33 | 44 |
| 47. | 80-100 | 30.0 | 5.4 | 2.52 | 81 | 10 | 9 | 47 | 42 |
| Pala | | | | | | | | | |
| 48. | 0-20 | 28.0 | 5.5 | 1.13 | 87 | 6 | 7 | 40 | 38 |
| 49. | 20-40 | 29.0 | 5.6 | 1.36 | 84 | 7 | 9 | 42 | 38 |
| 50. | 40-60 | 33.0 | 5.5 | 1.13 | 84 | 8 | 8 | 39 | 35 |
| 51. | 60-80 | 23.0 | 5.2 | 0.96 | 79 | 10 | 11 | 43 | 44 |
| 52. | 80-100 | 20.0 | 5.6 | 0.57 | 81 | 9 | 10 | 42 | 41 |
| Paravur | | | | | | | | | |
| 53. | 0-20 | 3.0 | 5.1 | 1.06 | 93 | 2 | 5 | 34 | 44 |
| 54. | 20-40 | 1.0 | 5.6 | 0.39 | 94 | 2 | 4 | 33 | 43 |
| 55. | 40-60 | 2.0 | 6.6 | 0.37 | 94 | 2 | 4 | 33 | 42 |
| 56. | 60-80 | 1.0 | 7.0 | 0.34 | 95 | 1 | 4 | 36 | 43 |
| 57. | 80-100 | 0.6 | 7.0 | 0.31 | 94 | 2 | 4 | 35 | 43 |
| Thodupuzha | | | | | | | | | |
| 58. | 0-20 | 27.0 | 5.8 | 2.15 | 78 | 13 | 9 | 49 | 43 |
| 59. | 20-40 | 26.0 | 5.3 | 1.33 | 80 | 9 | 11 | 48 | 42 |
| 60. | 40-60 | 17.0 | 5.2 | 1.16 | 83 | 8 | 9 | 37 | 46 |
| 61. | 60-80 | 35.0 | 5.3 | 0.96 | 79 | 9 | 12 | 44 | 45 |
| 62 | 80-100 | 39.0 | 4.8 | 0.48 | 81 | 8 | 11 | 45 | 45 |
| Thripunithura | | | | | | | | | |
| 63. | 0-20 | 46.0 | 7.2 | 1.13 | 80 | 9 | 11 | 43 | 53 |
| 64. | 20-40 | 34.0 | 7.4 | 1.63 | 88 | 6 | 6 | 38 | 50 |
| 65. | 40-60 | 27.0 | 7.5 | 2.31 | 93 | 3 | 4 | 47 | 52 |
| 66 | 60-80 | 40.0 | 7.3 | 2.02 | 93 | 3 | 4 | 41 | 48 |
| 67. | 80-100 | 52.0 | 7.8 | 0.84 | 81 | 9 | 10 | 33 | 37 |

WHC = Water Holding Capacity; PS = Porosity; OC = Organic carbon

Table 4.3.15.2

Chemical Characteristics of the Leachates from the Municipal Waste Dumping Sites

| Site | Cation Concentration (mg/L) | | | | |
|---|---|---|---|---|---|
| | pH | Na | K | Mg | Ca |
| **Kodungalloor** | | | | | |
| Leachate | 6.2 | 61.0 | 25.6 | 18.9 | 5.9 |
| Wellwater | 5.4 | 36.1 | 11.5 | 9.0 | 1.2 |
| **Kottayam** | | | | | |
| Leachate | 6.9 | 35.0 | 102.6 | 24.3 | 13.7 |
| Wellwater 1 | 5.5 | 18.1 | 21.5 | 10.4 | 0.5 |
| Wellwater 2 | 5.8 | 17.2 | 11.6 | 7.3 | -1.1 |
| **Allaphuzha** | | | | | |
| Leachate | 7.1 | 161 | 807.9 | 60.3 | 16.9 |
| Wellwater 1 | 7.2 | 25.9 | 71.0 | 14.7 | 7.4 |
| Wellwater 2 | 6.7 | 19.6 | 21.5 | 10.5 | 9.3 |
| **Paravoor** | | | | | |
| Leachate 1 | 7.4 | 60.9 | 411.3 | 39.3 | 15.9 |
| Leachate 2 | 7.8 | 49.3 | 244.2 | 32.5 | 10.5 |
| Leachate 3 | 7.2 | 31.4 | 162.7 | 44.3 | 30.0 |
| Leachate 4 | 7.3 | 39.3 | 47.9 | 13.5 | 15.2 |
| **Irinjalakuda** | | | | | |
| Leachate | 7.1 | 34.1 | 67.0 | 25.4 | 13.6 |
| Wellwater 1 | 4.6 | 51.3 | 61.6 | 15.9 | 1.5 |
| Wellwater 2 | 5.6 | 41.4 | 5.1 | 3.2 | -1.1 |
| **Changanassery** | | | | | |
| Leachate | 7.2 | 207.9 | 812.6 | 65.2 | 17.6 |
| Wellwater 1 | 6.0 | 47.9 | 62.3 | 14.2 | 4 1 |
| Wellwater 2 | 4.5 | 51.5 | 109.5 | 9 1 | 4.0 |
| **Aluva** | | | | | |
| Leachate | 6.5 | 66.3 | 202.9 | 37.6 | 3.2 |
| Wellwater 1 | 5.1 | 36.1 | 41 0 | 17.4 | 0.4 |
| Wellwater 2 | 5.5 | 6.5 | 16.3 | 5 0 | 0.6 |
| **Kayamkulam** | | | | | |
| Leachate | 7.0 | 249.7 | 275.3 | 15.0 | 1.4 |
| Wellwater 1 | 6.4 | 49.7 | 18 9 | 15.5 | 12.6 |
| Wellwater 2 | 6.5 | 37 | 26.9 | 13 1 | 9.0 |
| Permissible limit, Max. | | | | 30.0 | 75.0 |

**Source** : Primary data collected by KFRI

Table 4.3.15.3

Heavy Metals in the Leachates from Municipal Waste Dumping Sites

| Site | Heavy Metal Concentration (mg/L) | | | | |
|---|---|---|---|---|---|
| | pH | Copper | Manganese | Nickel | Lead |
| **Alappuzha** | | | | | |
| Leachate | 8.6 | 0.003 | ND | ND | ND |
| Wellwater | 7.2 | 0.018 | ND | ND | ND |
| **Kayamkulam** | | | | | |
| Leachate | 8.5 | 0.001 | 0.002 | ND | ND |
| Wellwater | 7.8 | 0.022 | ND | 0.018 | 0.048 |
| **Kottayam** | | | | | |
| Leachate | 8.4 | 0.024 | 0.021 | 0.312 | 0.429 |
| Wellwater | 7.1 | 0.006 | 0.004 | ND | ND |
| **Aluva** | | | | | |
| Leachate | 8.2 | 0.004 | 0.003 | 0.016 | 0.024 |
| Wellwater | 7.0 | 0.010 | 0.003 | 0.064 | 0.071 |
| Permissible limit. Max. | | 0.050 | 0.100 | -- | 0.100 |

Source : Primary data collected by KFRI

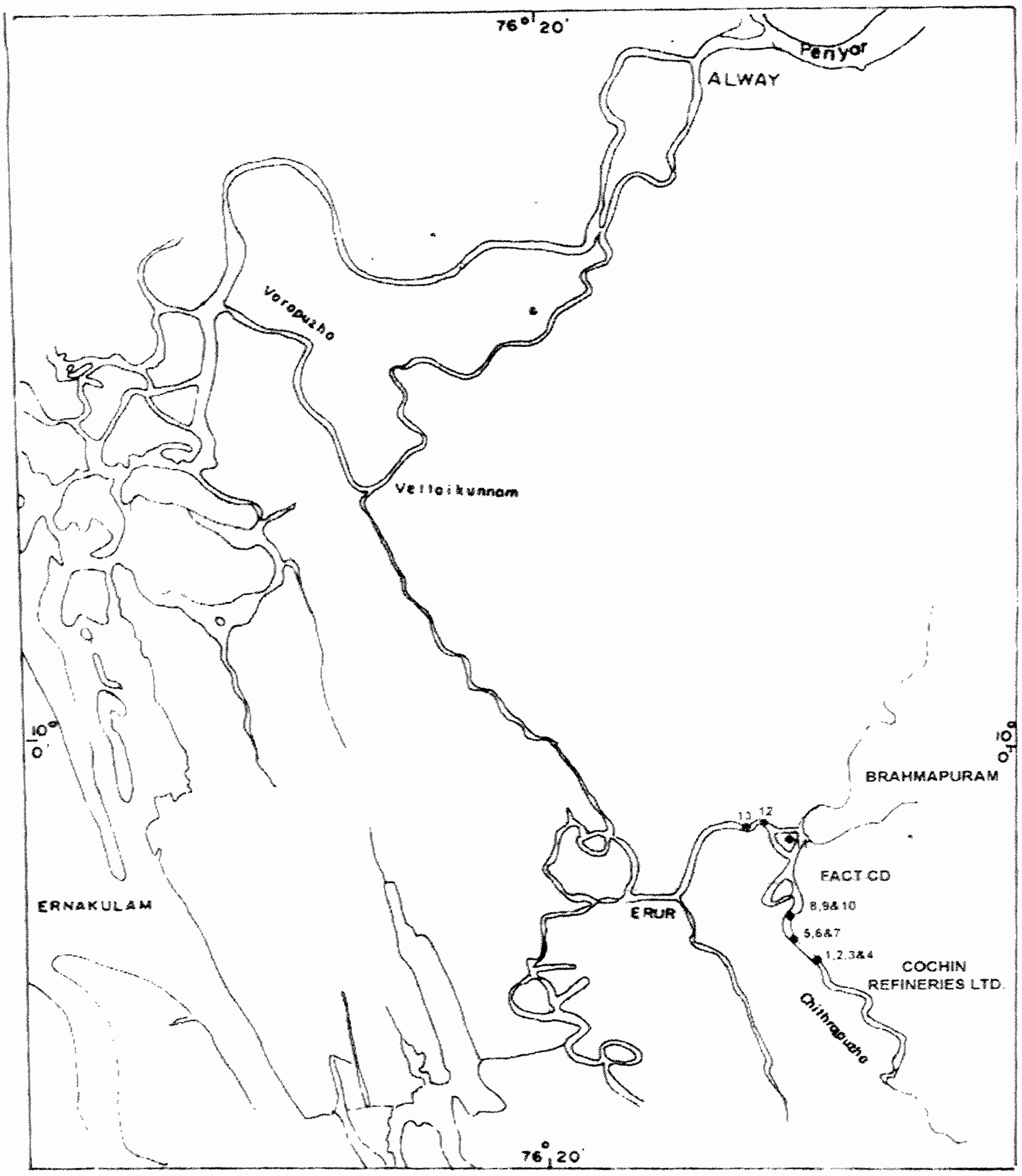



Fig. 4.3.5.1 : Drainage Map of Chithrapuzha Sub-basin with Network of Sampling Stations

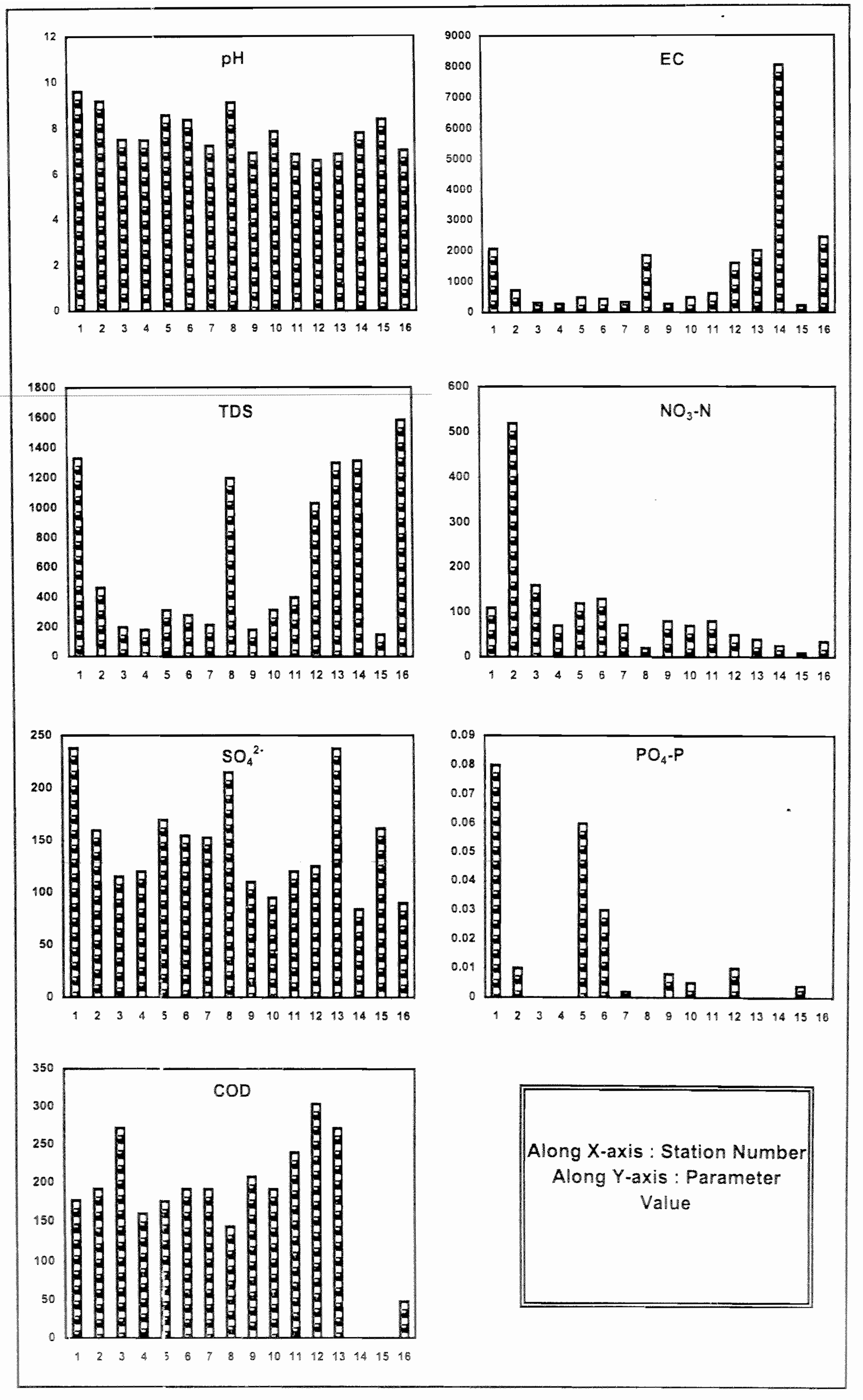



Fig. 4.3.5.2 : Status of Physico-Chemical Parameters in Chitrapuzha River

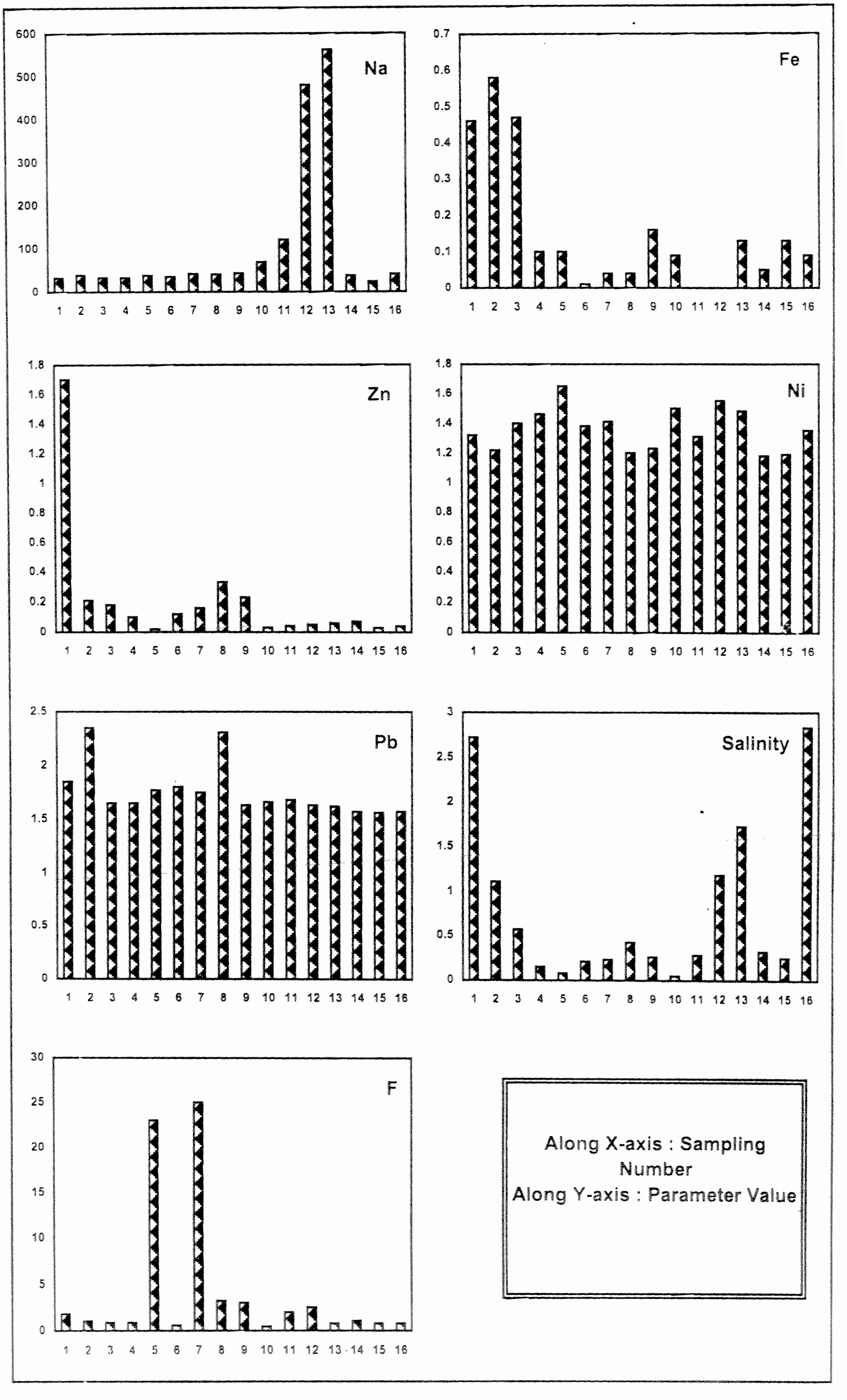



Fig. 4.3.5.3 : Status of Metals and Chemical Parameters in Chitrapuzha River

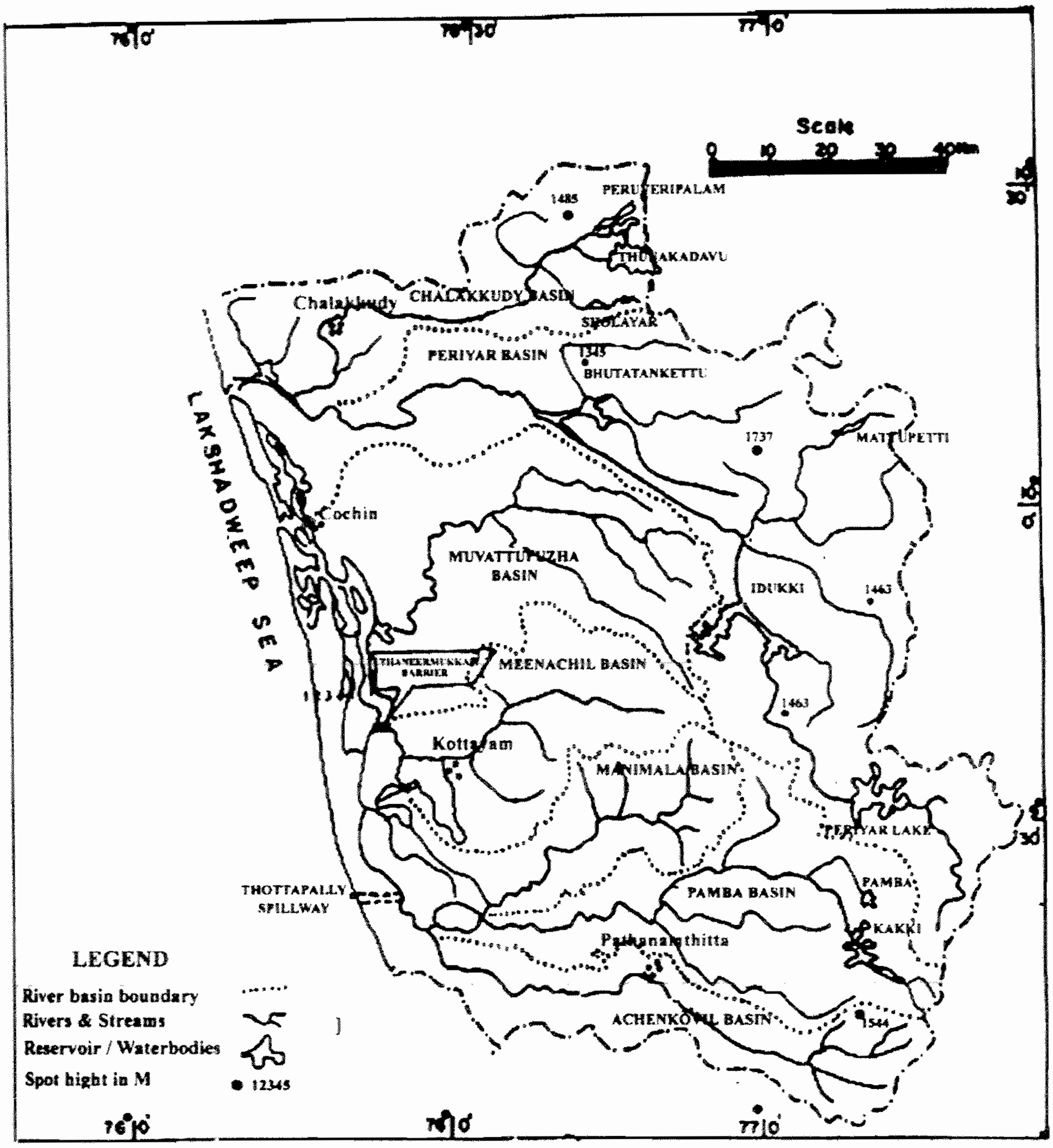



Fig. 4.3.10.1 : Water Sampling Locations near Burial Grounds

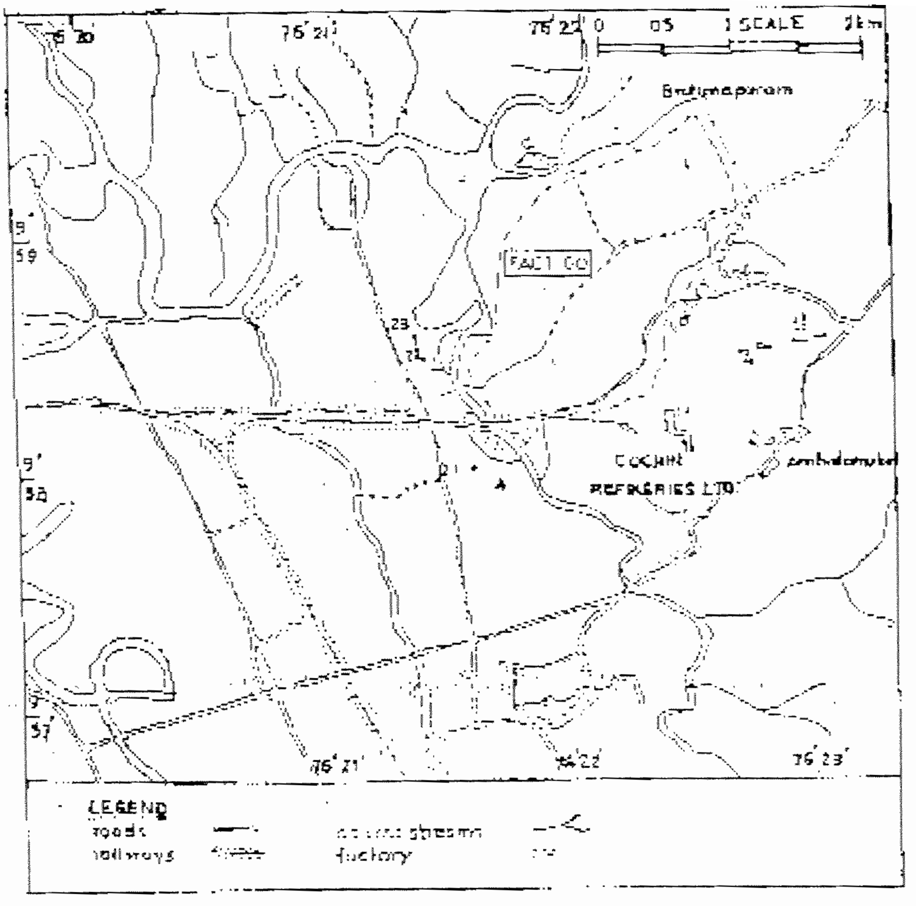



Fig. 4.3.11.1 : Water Sampling Locations Around Aluva-Eloor Area

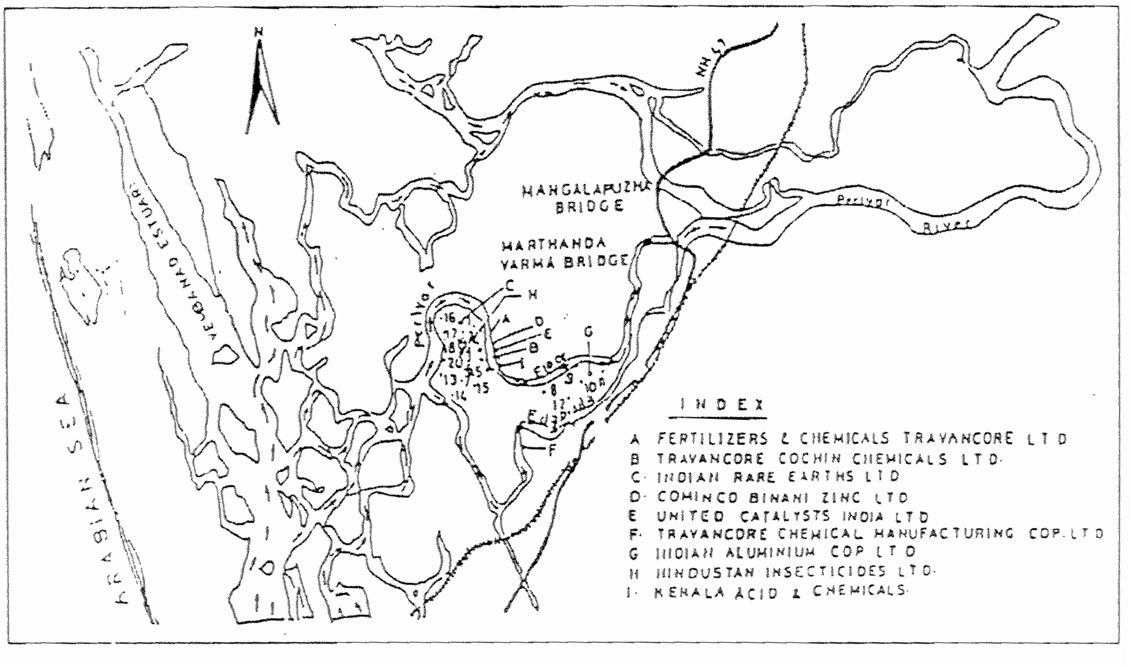



Fig. 4.3.11.2 : Water Sampling Locations Around Ambalamedu Area

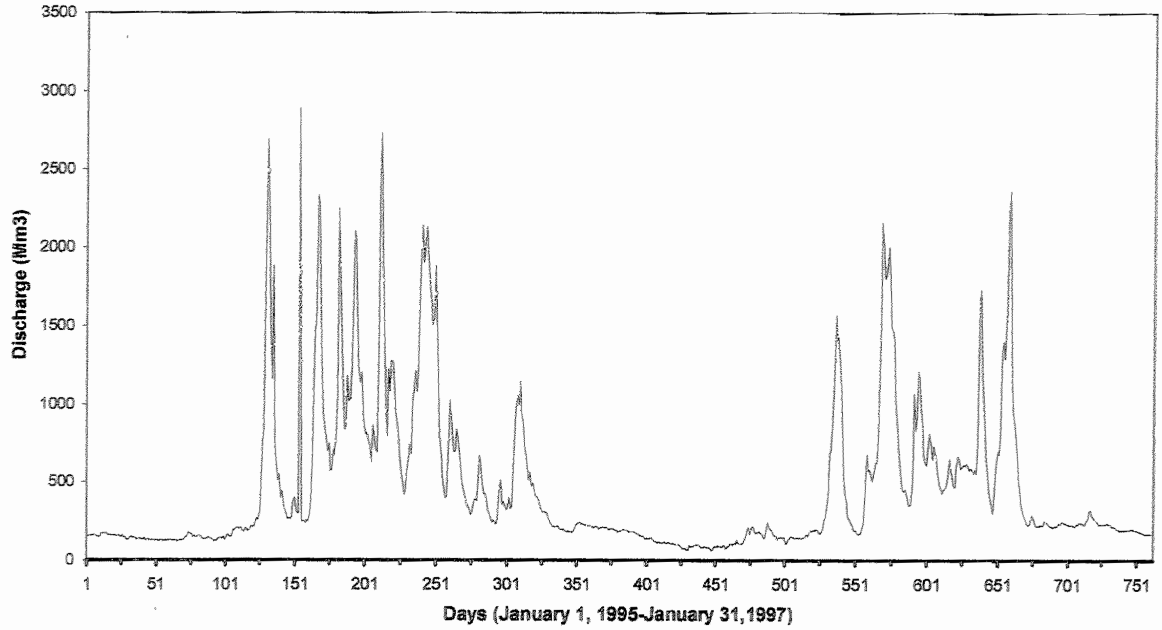



Fig. 4.3.12.1 : Daily Discharge Hydrograph of Vembanad Lake

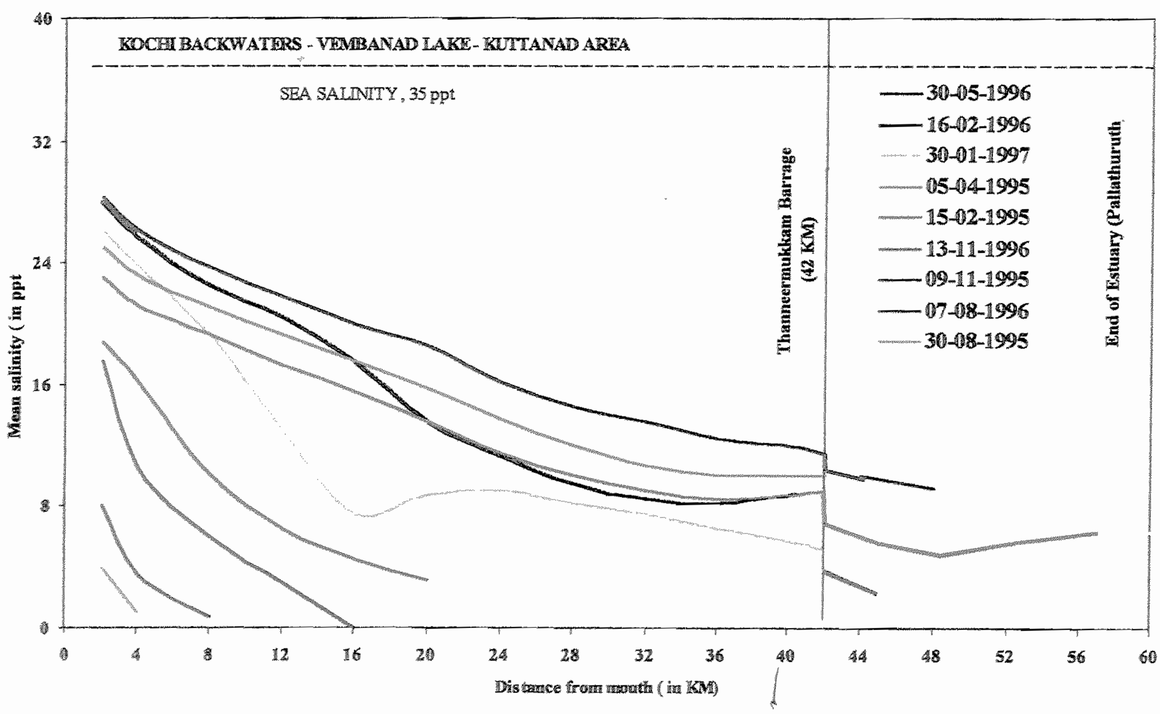



Fig. 4.3.12.2 : Observed Salinity Distribution in the Vembanad Lake

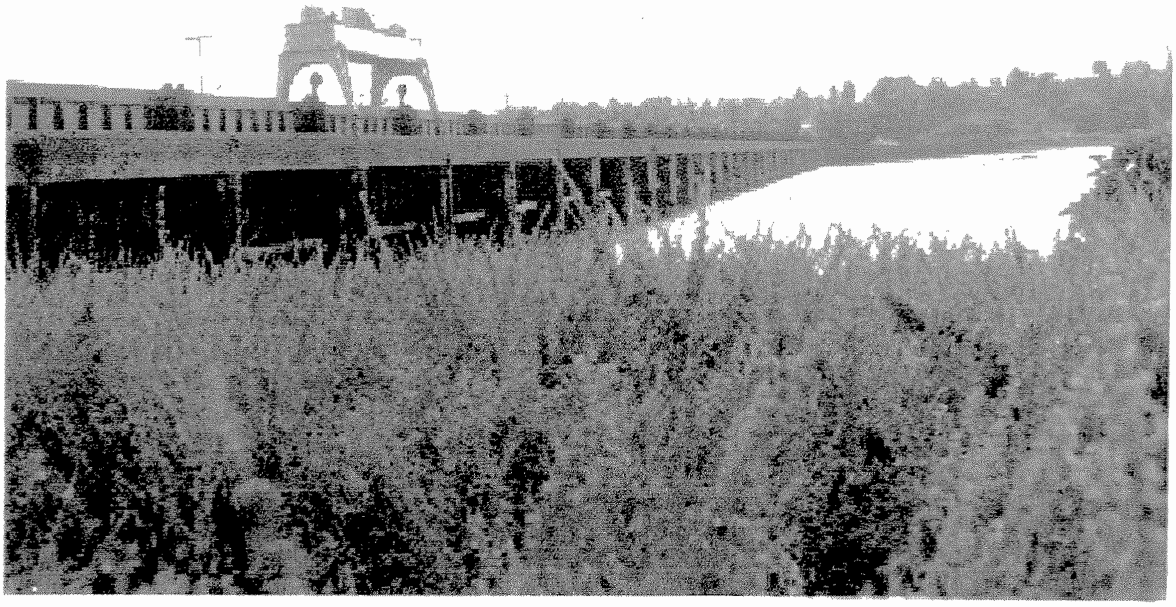


Plate 4.3.12.1 : Thannermukkom Bund

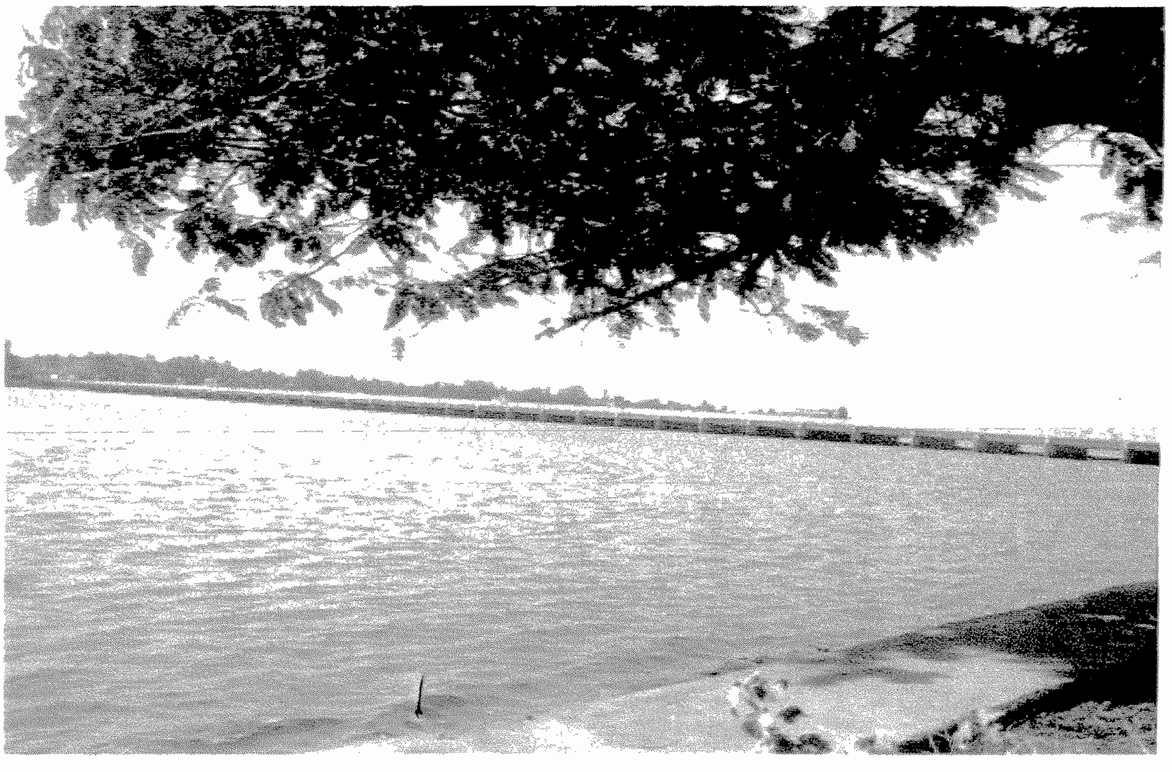


Plate 4.3.12.2 : Thotappally Spillway

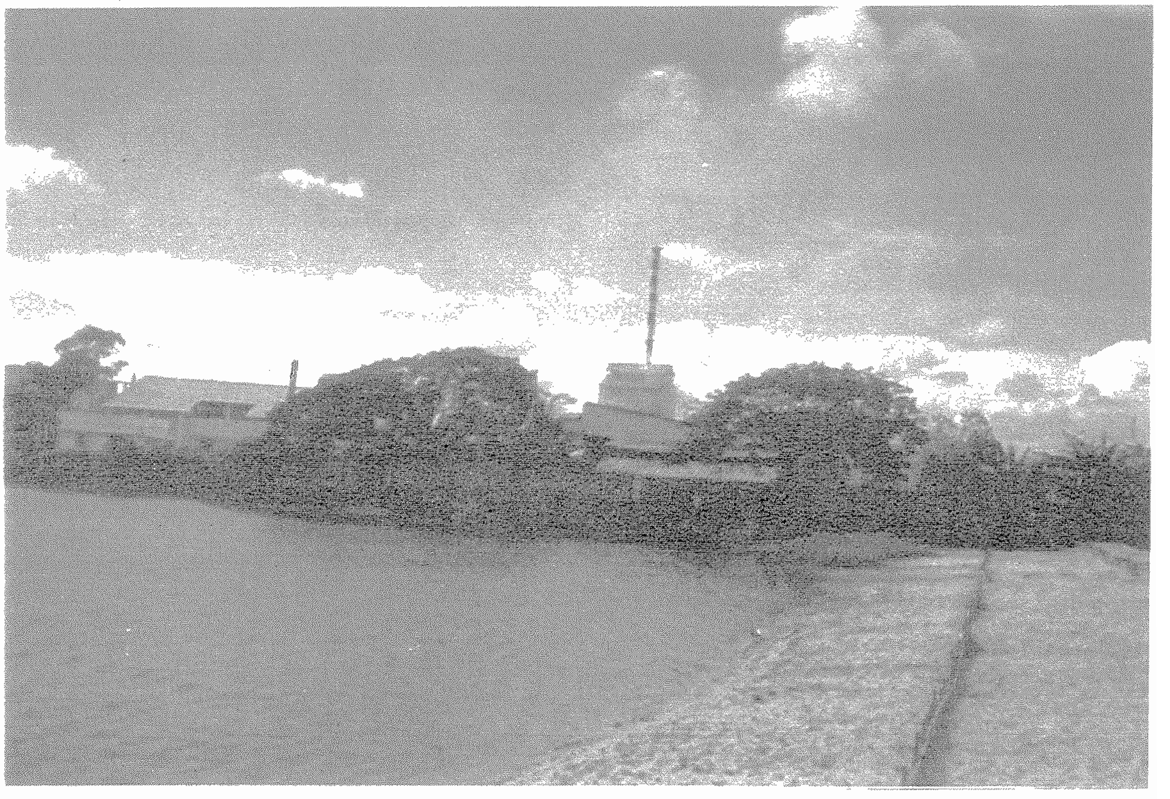


Plate 4.3.12.3 : Pathalam Bund