The present study reveals that the pilgrimage season (post monsoon) than the off seasons (monsoon and summer) and
especially studies on contamination of water bodies are grossly polluted. The situation has become alarming. Consequ
tently, studies on surface sources like rivers, canals and lakes. Disposal of wastes has caused immense problems
to human beings but also to the aquatic environment. Surface sources serve as the best sinks for the discharge of
drinking water requirement. The maintenance of healthy aquatic ecosystem is depended on the physico-chemical properties and biological diversity. A regular monitoring of water bodies with required number of parameters with reference to the quality of water not only prevents the outbreak of diseases and occurrence of hazards but checks the water from further deterioration. Bacteriological assessment, particularly for coliforms – the indicators of contamination by faecal matters- is therefore routinely carried out to ascertain the quality and potability of water to ensure prevention of further dissemination of pathogens through agency of water under investigation. This communication deals with the bacteriological and physico-chemical characteristics and their seasonal pattern in the Pamba river water of Kerala during 2010 to 2011 in relation to Sabarimala pilgrimage.

Kerala is one among the most thickly populated region in the world and the population is increasing at a rate of 14% per decade. As a result of the measures to

Water Quality Assessment of Pamba River of Kerala, India in Relation to Pilgrimage Season

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Abstract: In the present study microbiological and physico-chemical water quality of the River Pamba, Kerala, India was determined during Sabarimala Pilgrimage season and off seasons. Pamba River with a length of 176 kms is a major river of Kerala. Sabarimala, one of the major pilgrimage centers of South India is located on the banks of the river Pamba. The pilgrimage season is from December to February every year. Pilgrims use river water for various sanitary purposes. The river water is also influenced by various other anthropogenic activities. The microbiological and physico-chemical characteristics like Total Plate Count (TPC), Total Coliform Count (TC), Temperature, pH, Dissolved Oxygen and Free Carbon dioxide were studied and analyzed during July 2010 – April 2011 using standard procedures. The water samples were collected from three different sites, Upstream – Triveni, Midstream - Chenganoor and down stream - Veeyapuram of the river channel. The results revealed that all the studied sites showed more pollution during the pilgrimage season (post monsoon) than the off seasons (monsoon and summer) and also showed fluctuations in microbiological and physico-chemical parameters. Triveni segment of Pamba showed most pollution and Veeyapuram showed least. Pollution of river water can be reduced by providing proper sanitation facility to pilgrims and by providing proper methods for dumping of sewage and wastes. Almost all parameters showed significant (P<0.05) seasonal variation between segments and was determined by analysis of variance (ANOVA).

Keywords: Microbiological analysis, Pamba River water, Physico chemical parameters, Sabarimala pilgrimage.

Introduction

Of all the natural resources, water is unarguably the most essential and precious. Life began in water and life is nurtured with water. It is a universal solvent and as a solvent it provides the ionic balance and supports all forms of life [1]. Surface water resources have played an important role throughout history in the development of human civilization. About one third of the drinking water requirement of the world is obtained from surface sources like rivers, canals and lakes. But, these sources serve as the best sinks for the discharge of domestic as well as industrial wastes. This unscientific disposal of wastes has caused immense problems not only to human beings but also to the aquatic environment world wide. In India, this problem started long back but intensified during the last few decades and now the situation has become alarming. Consequently, studies on the major river ecosystems indicate that the major Indian rivers are grossly polluted [2].
satisfy the needs of the huge population, the rivers of Kerala have been increasingly polluted from the industrial and domestic waste and from the pesticides and fertilizer in agriculture. Industries discharge hazardous pollutants like phosphates, sulphides, ammonia, fluorides, heavy metals and insecticides into the downstream reaches of the river. The river Periyar and Chaliyar are very good examples for the pollution due to industrial effluents.

Pamba River which is popularly called as Dakshina Ganga is the third longest river in Kerala State (8° 17’ 30” and 12° 47’ 40” N latitude and 74° 24’ 47” E longitude), India with a length of 176 kms. It is formed by several streams having their origin in the Pullichi Malai, Naga Malai and Sundara Malai in the Peerumedu plateau of Western Ghats at an altitude of about 1650 M above M .S.L. This river spreads in Triveni, Vadasserikara and Aranmula region of Pathanamthitta district and enters Alappuzha district at Chengannur and flows through Pandanad, Veeyapuram and plunges into Vembanad Lake through several branches which in turn connected to the Arabian Sea. At its lower reaches, the rivers Achencovil and the Manimala join the Pamba. The catchment area of this river is 1987.17 Sq.Km. The basin extends over an area of 2235 km². The basin is bounded by the west by Western Ghats and on the west by Arabian Sea. Manimala basin forms the northern boundary of the basin while Achankovil basin forms southern boundary.

The famous Sabarimala temple dedicated to lord Ayyappa is located on the banks of the river Pamba. Sabarimala is one of the major pilgrimage centers of Kerala. The Sabarimala pilgrimage season is from December to February and is the largest annual pilgrimage in India with an estimated 45–50 million devotees visiting every year. The pollution of Pamba River is due to the Sabarimala pilgrimage, free flow of sewage, domestic waste and faecal matters into the river and intrusion of sea water[3]. Pilgrims use the water of Pamba river for various sanitary purposes. The present study is to analyze the water quality of Pamba River during Sabarimala Pilgrimage season and off seasons.

Material and Methods
Water Quality Analysis: Water samples were collected from three study sites of river Pamba.
1. Upstream stretch (S1): Triveni, located at latitude 9° 30’ 45.27” N and longitude 76° 25’ 41.36’ E with an elevation of 879 ft above MSL. The place near Sabarimala temple in the district of Pathanamthitta, Kerala. Pilgrims use the water in this region of the Pamba River for various purposes.
2. Midstream stretch (S2): Chengannur, located at latitude 9° 19′ 48’ N and longitude 76° 40′ 48’ E with an elevation of 23 ft above MSL. A municipal town in Alappuzha district of the state of Kerala. The Shiva temple, Chengannur Mahadeva Kshetram is situated on the banks of river Pamba and large number of pilgrims visits this site during Sabarimala season.
3. Down stream stretch (S3): Veeyapuram, located at latitude 9° 19’ 29.07’ N and longitude 76° 27’ 54.31’ E with an elevation of 6 ft above MSL. A village near Harippad town in Alappuzha district. Veeyapuram is having some geographical importance that the Pamba river and the Achencovil river meet together here.

**Figure 1: A Lay Out of the Pamba River**
The samples were collected at monthly intervals between July 2010 to April 2011, covering three seasons i.e. Monsoon-Before Sabarimala Pilgrimage Season (July to October 2010), Post Monsoon - Pilgrimage Season (November 2010 to January 2011) and summer - After Pilgrimage Season (February to April 2011). Six water samples were collected from each site at a distance of 500 mts each. Biological parameters like Total plate count and Total coliform bacteria count and the physico-chemical parameters like Temperature, Dissolved Oxygen, pH, Total Dissolved solids were measured. Standard methods \(^4\) were used for collection, preservation and estimation of water samples.

One liter of water sample from each location was collected in to pre-sterilized bottles. All samples were collected with precautions required for microbiological analysis, held on ice in an icebox and transported to the laboratory for microbial analysis. The water samples are subjected to 10\(^{-5}\) serial dilution. The bacterial population in different samples was estimated by pour plate method on nutrient agar for Total Plate Count (TPC) and on McConkey agar for Total Coliform Count (TC). All specific media plates were incubated at 37°C for at least 24 to 48 h and final colonies were noted and counted. Typical colony characteristics are listed below:

- Nutrient Agar: All colonies grown on medium are counted as total viable count or total plate count.
- McConkey Agar: All pink colonies grown on plates are counted as total coliforms.

Surface water samples were collected in 1L sterilized plastic containers for physico-chemical analysis and analyzed according to the standard procedures of APHA, 2005. Water temperature was estimated on the spot with a mercury thermometer. The DO was done within 3 hour after sampling of water.

Statistical Procedures: Microbiological and physico-chemical parameters of the water samples were presented in terms of Mean ± SD. The descriptive statistics were conducted while statistical significance of differences (\(P<0.05\)) was determined by analysis of variance (ANOVA). Graphical representation is carried out by Microsoft Excel software.

Results and Discussion
Seasonal variations in microbiological and physico-chemical parameters from three sampling sites of the river Pamba are shown in Figs. 2 to 7. The average values of microbiological and physico-chemical parameters (Mean ± SD) are given in Table 1, 2 and 3 respectively.

Microbiological Analysis:
Total Plate Count (TPC): Total Plate Count, also termed as Total Viable Count (TVC), gives information about the number of aerobic bacteria present in a sample. All the samples were found to have TPC. In this study, the TPC was higher in all the studied sites of river Pamba during the Sabarimala pilgrimage season (post monsoon season) compared to off seasons. The TPC was in the range of 3.07(x10\(^3\)) mL\(^{-1}\) to 7.86 (x10\(^3\)) mL\(^{-1}\) before pilgrimage season, 4.38(x10\(^3\)) mL\(^{-1}\) to 12.1(x10\(^3\)) mL\(^{-1}\) during season and 3.78 (x10\(^3\)) mL\(^{-1}\) to 9.85(x10\(^3\)) mL\(^{-1}\) after the pilgrimage season during the study period (Table 1). Triveni shows the highest TPC of 7.86(x10\(^3\)) mL\(^{-1}\), 12.1(x10\(^3\)) mL\(^{-1}\) and 9.85(x10\(^3\)) mL\(^{-1}\) and Veeyapuram shows least TPC of 3.07(x10\(^3\)) mL\(^{-1}\), 4.38(x10\(^3\)) mL\(^{-1}\) and 3.78(x10\(^3\)) mL\(^{-1}\) in all seasons i.e. before pilgrimage season, during pilgrimage season and after pilgrimage season respectively. The site Chenganoor shows the value of 5.56 (x10\(^3\)) mL\(^{-1}\), 7.12(x10\(^3\)) mL\(^{-1}\) and 6.73(x10\(^3\)) mL\(^{-1}\) respectively. (Figure 2)

### Table 1

<table>
<thead>
<tr>
<th>Study Sites</th>
<th>Before Pilgrimage Season (monsoon) (x10^3) mL(^{-1})</th>
<th>Pilgrimage Season (post monsoon) (x10^3) mL(^{-1})</th>
<th>After Pilgrimage Season (summer) (x10^3) mL(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triveni</td>
<td>7.86 ± 0.8</td>
<td>12.1 ± 0.2</td>
<td>9.85 ± 0.2</td>
</tr>
<tr>
<td>Chenganoor</td>
<td>5.56 ± 0.1</td>
<td>7.12 ± 0.2</td>
<td>6.73 ± 0.2</td>
</tr>
<tr>
<td>Veeyapuram</td>
<td>3.07 ± 0.3</td>
<td>4.38 ± 0.2</td>
<td>3.78 ± 0.7</td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>Study Sites</th>
<th>Before Pilgrimage Season (monsoon) (x10^3) mL(^{-1})</th>
<th>Pilgrimage Season (post monsoon) (x10^3) mL(^{-1})</th>
<th>After Pilgrimage Season (summer) (x10^3) mL(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triveni</td>
<td>5.98 ± 0.1</td>
<td>8.36 ± 0.1</td>
<td>6.53 ± 0.1</td>
</tr>
<tr>
<td>Chenganoor</td>
<td>3.5 ± 0.1</td>
<td>4.46 ± 0.3</td>
<td>3.74 ± 0.2</td>
</tr>
<tr>
<td>Veeyapuram</td>
<td>1.92 ± 0.2</td>
<td>3.16 ± 0.1</td>
<td>2.41 ± 0.8</td>
</tr>
</tbody>
</table>
Total Coliform Count (TC): Commonly, the Total Coliforms (TC) count is also relatively higher in Sabarimala pilgrimage season (post monsoon) than the off seasons. TC is registered with in the range of $8.36 \times 10^3$ mL$^{-1}$ to $1.92 \times 10^3$ mL$^{-1}$. T.C was between $1.92 \times 10^3$ mL$^{-1}$ to $5.98 \times 10^2$ mL$^{-1}$ before pilgrimage season, $3.16 \times 10^2$ mL$^{-1}$ to $8.36 \times 10^1$ mL$^{-1}$ during season and $2.41 \times 10^1$ mL$^{-1}$ to $6.53 \times 10^0$ mL$^{-1}$ after the pilgrimage season during the study period (Table 2). Here also Site Triveni has highest and Site Veeyapuram has the least TC count. Triveni shows the values of $5.98 \times 10^3$ mL$^{-1}$, $8.36 \times 10^2$ mL$^{-1}$ and $6.53 \times 10^1$ mL$^{-1}$ and Veeyapuram gives $1.92 \times 10^3$ mL$^{-1}$, $3.16 \times 10^2$ mL$^{-1}$ and $2.41 \times 10^1$ mL$^{-1}$ before season, during season and after season respectively. Chenganoor gives the value of $3.5 \times 10^3$ mL$^{-1}$, $4.46 \times 10^2$ mL$^{-1}$, $3.74 \times 10^1$ mL$^{-1}$. (Fig.3)

Chenganoor shows moderate amount of pollution. The high coliform count obtained in the samples may be an indication that the water sources are faecally contaminated. [6,7] Like, in gangetic river sites witness holy dip and mass bathing by a large number of pilgrims as an old age ritual in India, which is a constant source of contamination of water bodies. [8] According to a study by Baxter-Potter and Gilliland [9] on straight river water shed when precipitation and stream flows are high, the influence of continuous sources for pollution. It is a common practice for people living along the river catchments to discharge their domestic and agricultural wastes as well as human excreta/wastes into rivers. In addition to using the river as a source of drinking water people use the source for bathing, washing of clothes and for recreational purposes such as swimming. The seasonal variation in water TPC and TC were statistically significant (P<0.05).

**Physico-chemical Parameters:** The physico-chemical parameters are presented in Table 3.

**Temperature:** In the present study the temperature showed drastic difference at all the sites in all the seasons. The temperature of Pamba River water at up stream – Triveni, mid stream – Chengannor and down stream – Veeyapuram sites varied between 30.6°C (Triveni, Before Pilgrimage Season i.e. monsoon) to 35°C (Chenganoor, After Pilgrimage Season i.e. summer). The mean temperature value was 31.26 ± 0.13, 33.9 ± 0.053, 87.9 ± 5.80, 33.6 ± 0.046 in, upstream, middle stream and downstream respectively (Table 3.)

The marked temperature difference in four season showed high anthropogenic disturbances expects Veeyapuram. Fig.4. Steady change in the atmospheric temperature with the change in the seasons results in the corresponding change in the water temperature. There is a very close similarity between the temperature of atmosphere and water due to the depth of the river. High summer
temperature and bright sunshine accelerate the process of decay of organic matter resulting into the liberation of large quantities of CO2 and nutrients. Narasimha and Jaya [10] observed that rise in temperature can be resulted in high rate of evaporation, may cause decline in water level during summer months.

Table 3
Physico-chemical parameters in different sites and seasons in Pamba River water (Mean ± SE)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Triveni</th>
<th>Chenganoor</th>
<th>Veeyapuram</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before Pilgrimage Season (M)</td>
<td>Pilgrimage Season (P.M)</td>
<td>After Pilgrimage Season (S)</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>----------------</td>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Temp. (°C)</td>
<td>30.6± 0.1</td>
<td>31.0± 0.1</td>
<td>32.2± 0.2</td>
</tr>
<tr>
<td>pH</td>
<td>7.00± 0.02</td>
<td>7.00± 0.02</td>
<td>7.00±0.00</td>
</tr>
<tr>
<td>Dissolved Oxygen ml/L</td>
<td>6.8± 0.03</td>
<td>6.7± 0.02</td>
<td>6.6± 0.01</td>
</tr>
<tr>
<td>Dissolved CO2 ml/L</td>
<td>0.90± 0.03</td>
<td>0.81± 0.2</td>
<td>1.20± 0.01</td>
</tr>
</tbody>
</table>

Figure 4: Seasonal variation of temperature in Pamba river water pH

The pH is affected not only by the reaction of carbon dioxide but also by organic and inorganic solutes present in water. Any alteration in water pH is accompanied by the change in other physicochemical parameters. pH maintenance (buffering capacity) is one of the most important attributes of any aquatic system since all the biochemical activities depend on pH of the surrounding water. The BIS (Bureau of Indian Standards) limits of pH for drinking water are 6.5–8.5. In the present study, pH values in the water samples of Pamba river water ranged between 7 (Triveni in all seasons) to 7.13 (Veeyapuram, Pilgrimage Season i.e. post monsoon) with mean pH value (Mean±SD) of 7.0 ± 0.023, 7.10 ± 1.026, and 7.20 ± 0.086 in Triveni, Chenganoor and Veeyapuram respectively. (Table 3). The pH values of all the surface water sources during the sampling period were within the prescribed limits (6.5–8.5) as per BIS with respect to the drinking water standard. pH of the water was neutral at Triveni in all the seasons and slightly alkaline at Chenganoor and Veeyapuram in all the seasons which may be attributed to presence of effluents. Figure 5.

Figure 5: Seasonal variation of pH in Pamba river water

Dissolved oxygen (DO): DO is of great importance to all living organisms. It may be present in water due to direct diffusion from air and photosynthetic activity of autographs. [11] Concentration of DO is one of the most important parameters to indicate water purity and to determine the distribution and abundance of various algal
Dissolved oxygen is also important for the microbial breakdown of waste in the water and for chemical reactions. The DO content in water samples depend on a number of physical, chemical, biological and microbiological processes. DO values of flowing water also show spatial changes depending on industrial and anthropogenic activities in its course. The DO content of river water at Pamba varied from 6.2 mg/L (Chenganoor, After Pilgrimage Season i.e. Summer) to 6.8 mg/L (Triveni, Before Pilgrimage season i.e. Monsoon). Table 3. The mean value of DO (Mean±SD) was 6.7± 0.02, 6.3 ± 0.13 and 6.43 ± 0.086 in, upstream, middle stream and downstream, respectively. Fig. 6. In the present study the dissolved oxygen level was very high in all the study sites through out the study seasons. The values were less during summer indicating more consumption of dissolved oxygen at higher temperature. Lower DO in summer may be due to high temperature and low solubility of oxygen in water consequently affecting the BOD. The low value at the Chenganoor (mid stream) may be due to mixing of oxygen depleting waste of township.

The seasonal variation in water temperature, pH, Dissolved Oxygen and Free Carbon dioxide were statistically significant (P<0.05).

The Physico-chemical features of river showed moderate to adequate levels of parameters like temperature, pH, dissolved oxygen, and dissolved carbon dioxide. The present study shows detailed microbiological and physico-chemical characteristics and quality of water in Pamba River of Kerala in relation to pilgrimage season and off season. The monsoon (before pilgrimage season), Post monsoon (Pilgrimage Season) and summer (After Pilgrimage season) show different seasonal fluctuations in the studied sites of the river.

Results of the study indicate that the water of Pamba River is highly contaminated especially during Sabarimala pilgrimage season than the off season because pilgrims use the river water for various sanitary purposes. From this study it was revealed that deterioration of quality of water was very high at Triveni, the site near the Sabarimala Temple during all the studied seasons. This is due to high anthropogenic disturbances associated with Sabarimala pilgrimage. The lowest bacterial density at Veeyapuram is due to less anthropogenic disturbances. Chenganoor showed moderate water quality. Among the different studied seasons, monsoon season i.e the season before the pilgrimage, showed improved water quality.

Conclusion

The maintenance of a healthy aquatic ecosystem is dependent on the physico-chemical properties of water and the biological diversity. Now-a-days, the ecology of it is under stressed condition due to fast pace of development, deforestation, cultural practices and agriculture. This study would help the water quality monitoring and management in order to improve the quality of water with maintaining better sustainable management. Pollution of river water can be reduced by providing proper sanitation facility and information to pilgrims and also by providing proper methods for dumping of municipal sewage, domestic wastes etc. The water quality can be improved by creating awareness in local public about the degrading status of river, by making farmers understand about proper use of fertilizers and pesticides in farms and also formulating action plan to save the river from drastic pollution. Some steps and awareness programs must need to educate local villagers to safeguard the precious river and its surrounding.

References


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