**Spatio- Temporal Variation of Sediment Quality of a River in South India with Special Reference to Organic Carbon Content – A Case Study**

**ABSTRACT**

Sediment is an imperative part of fresh water systems which comprises loose sand, silt and other soil particles. They provide suitable habitat and rearing areas for fresh water organisms. Temporal and spatial variations in the sediment characteristics from four stations of Achenkovil River, Kerala were studied. Percentage composition of sand varied from 59.01% to 93.48%. Silt composition from 1.10% to 30.36% while clay composition varied from 4.90% to 17.50%. Textural analysis revealed higher percentage of sandy fraction in the sediment at all the stations during most of the months. Organic carbon and sediment texture showed direct relationship at Station 2 and 3. Mean organic carbon of the river ranged from 0.88% (Station 4) to 5.24% (Station 3). Seasonal changes in organic carbon content were evident. Organic carbon was highest during post monsoon at Station 4 and during monsoon at the remaining stations.

*Key words: Sediment; Texture; Sand mining; Organic carbon*

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1. **INTRODUCTION**

River systems are potent sources of fresh water and plays a pivotal role in the sustenance of life (Sirsat & Kamble, 2020). Sediments are layers of finely divided matter constituting complex mixtures of clay, silica, organic matter, carbonates, minerals etc covering bottom of fresh water bodies, bays, estuaries, and oceans. They serve as habitat for benthic macro-invertebrates and major site for organic matter decomposition by bacteria (Abowei & Sikoki, 2005; Adesuyi et al., 2015). They boost algal blooms, and primary productivity in aquatic system by releasing chemical compounds to overlying water column. Sediment plays an important role in the hydrological and geomorphological functioning of river basins and in natural ecosystems, it originates from weathering of rocks, erosion of soil, landslides etc. Sediment texture is one of the stable properties that determine the agricultural potential of soil and also provide general information on the intrinsic properties within the sediments (Arun et al., 2019). Enormous variety of species present in the fresh water sediments contribute to the organic carbon processing, nitrogen recycling and breakdown of pollutants (Palmer et al., 1997). Several authors have studied the sediment characteristics of various river systems (Babale et al., 2011; Manivel et al., 2016; Arun et al., 2019; Dani et al., 2024). An understanding of chemical nature of sediments in an aquatic system may serve as an effective tool for assessing the quality of overlaying water. The present investigation on the sediment characteristics was taken to elucidate the environmental quality of a tropical perennial river in Southern Kerala State, India.

1. **MATERIALS AND METHODS**

**Study area**

 The state of Kerala located at 8017’30’’and 12047’40’’N. latitudes and 74024’47’’ E. longitude is rich in water resources. The River Achenkovil is the ninth largest river in Kerala State in terms of catchment area lies between latitudes 90 01' 0" to 90 18' 30" North latitudes and longitudes 760 23' to 770 16' East longitudes (Figure 1).

**Sample collection and analysis**

For the present study four different stations were selected along the course of river. Station 1 was situated in the upstream part of river with average depth of 1metre. Station 2 is located at 15.21Km away from Station 1 with average depth of 2.5 m. Station 3 located 52.40 Km away from Station 2 with average depth of 2.7 m. Station 4 located near the river mouth, 31.30 Km away from Station 3 with average depth of 3.2metre. Sand mining was rampant at Stations 2 and 3.

Sediment samples were collected in triplicate from the selected stations in Achenkovil River in the months of February, March, April and May representing pre-monsoon period June, July, August and September representing Monsoon period, October, November, December and January representing the post monsoon period using a metal corer. Samples were brought to laboratory in clean dry polythene containers. Sediment temperature was recorded on spot with mercury thermometer to the nearest 0.1 0C. pH was determined using portable pH meter. One portion of each of sample was air dried for analysis of textural features and other portion was oven dried at 60-70oC and pulverized to estimate organic carbon. Textural Analysis of sediment sample was carried out using pipette analysis method (Carver, 1971; Lewis, 1984). Sediment composition was expressed in percentage. Organic carbon content of the sample was determined very rapidly by the method described by Jhingran *et al*., (1988) which was proposed by El-Wekeel and Riley (1957). The values were expressed in percentage. To find out the relationship between various sediment factors, multiple correlation analysis was done (Snedecor & Cochran, 1967).



Figure 1. Achenkovil River Basin

1. **Results and Discussion**

Sediments are complex mixtures of organic matter, inorganic particles, various absorbed and dissolved constituents and nutrients (Xu et al., 2016). They had significant role in hydrological cycle and act as a sink for various aquatic pollutants and the sediment contamination may result in the lethal as well as sublethal effect on benthic organisms (Achi et al., 2021). Therefore, protecting sediment quality is necessary for restoration of biological integrity of water bodies (Ravichandran & Sharma, 2014). Sediment is characterized by some readily measurable physical features that can provide useful information regarding the provenance, depositional micro environment and pollutants (Ganesh et al., 2013). Mean values with standard deviation of sediment characteristics recorded from selected stations of Achenkovil River are given in Table 1. Correlation analysis was carried out and ‘r’ values showing correlation if any between sediment parameters at the four stations are shown in Table 2. Sediment temperature in Achenkovil River was observed to fluctuate in harmony with temperature of the water column overlying it and also with seasonal atmospheric temperature. sediment temperature varied from 22.750C to 30.750C. Maximum temperature was recorded in the pre monsoon period, at all the stations during which atmospheric and water temperature was elevated whereas minimum temperature was recorded during the monsoon period at Station 4 and post monsoon period at the remaining stations. pH and ionic conditions of sediment largely influence the soil reaction as well as control the availability of nutrients in the water column which in turn influence the production of fish food organisms and there by providing a congenital healthy environment for the survival of aquatic biotic communities. There was no perceptible variation in sediment pH in Achenkovil River during the study period, and pH levels were generally lower than those of the overlying water. pH varied from 6.35 during post monsoon at Station 4 to 6.99 during monsoon at Station 3. The low sediment pH can be attribute to the occurrence of substantial amounts of organic matter, CO2 production and nitrogen mineralization. Generally high pH values are observed during monsoon period at all stations except in the upstream region, where high values were obtained during the pre-monsoon period. Addition of new sediments and bed load transport may be ascribed to the increased pH during the monsoon period.

**Table 1**

**Mean and standard deviation values of sediment characteristics**

 **recorded from selected stations of Achenkovil River**

|  |
| --- |
| **Station 1** |
| **Sediment Characters** | **Pre monsoon**  | **Monsoon**  | **Post Monsoon**  | **Average**  |
| **Temperature ( 0C)**  | 24.50 ± 1.50 | 24.25 ± 0.43 | 22.75 ± 1.92 | 23.83 ± 1.62 |
| **pH** | 6.89 ± 0.08 | 6.54 ± 0.34 | 6.58 ± 0.18 | 6.73 ± 0.21 |
| **Sand (%)** | 93.48 ± 5.30 | 84.11 ± 6.57 | 74.00 ± 14.86 | 83.86 ± 12.67 |
| **Silt (%)** | 1.10 ± 0.26 | 4.28 ± 4.04 | 18.12 ± 17.39 | 7.83 ± 12.68 |
| **Clay (%)** | 5.43 ± 5.25 | 9.13 ± 4.28 | 7.88 ± 3.29 | 7.48 ± 1.54 |
| **Organic Carbon (%)** | 2.43 ± 0.58 | 3.05 ± 0.15 | 2.24 ± 0.60 | 2.57 ± 0.35 |
| **Station 2** |
| **Temperature ( 0C)**  | 29.50 ± 0.87 | 26.38 ± 1.47 | 26.25 ± 0.43 | 27.38 ± 1.82 |
| **pH** | 6.87 ± 0.14 | 6.92 ± 0.23 | 6.68 ± 0.21 | 6.79 ± 0.21 |
| **Sand (%)** | 85.07 ± 6.10 | 79.59 ± 4.87 | 86.38 ± 6.12 | 83.68 ± 6.44 |
| **Silt (%)** | 2.21 ± 0.10 | 6.79 ± 2.31 | 7.25 ± 8.24 | 5.42 ± 2.28 |
| **Clay (%)** | 11.45 ± 5.16 | 13.63 ± 3.99 | 6.38 ± 5.39 | 10.49 ± 3.04 |
| **Organic Carbon (%)** | 1.65 ± 1.22 | 2.75 ± 0.47 | 2.68 ± 0.31 | 2.36 ± 0.50 |
| **Station 3** |
| **Temperature ( 0C)**  | 30.75 ± 0.83 | 28.25 ± 0.43 | 27.75 ± 0.83 | 28.92 ± 1.50 |
| **pH** | 6.95 ± 0.19 | 6.99 ± 0.09 | 6.65 ± 0.18 | 6.84 ± 0.22 |
| **Sand (%)** | 75.25 ± 13.82 | 62.54 ± 7.65 | 59.01 ± 20.03 | 65.60 ± 16.29 |
| **Silt (%)** | 9.76 ± 10.11 | 20.00 ± 5.20 | 30.36 ± 18.30 | 20.03 ± 8.41 |
| **Clay (%)** | 15.00 ± 3.91 | 17.50 ± 5.11 | 10.63 ± 6.07 | 14.38 ± 2.84 |
| **Organic Carbon (%)** | 3.13 ± 1.19 | 5.24 ± 1.33 | 3.13 ± 0.83 | 3.83 ± 0.99 |
| **Station 4** |
| **Temperature ( 0C)**  | 30.25 ± 0.80 | 27.00 ± 1.22 | 28.70 ± 1.09 | 28.67 ± 1.70 |
| **pH** | 6.38 ± 0.34 | 6.77 ± 0.15 | 6.35 ± 0.10 | 6.50 ± 0.29 |
| **Sand (%)** | 85.89 ± 1.79 | 91.75 ± 3.72 | 89.65 ± 2.92 | 89.09 ± 3.79 |
| **Silt (%)** | 8.10 ± 4.34 | 1.63 ± 1.63 | 5.45 ± 4.02 | 5.06 ± 2.66 |
| **Clay (%)** | 6.10 ± 3.71 | 9.13 ± 5.25 | 4.90 ± 3.75 | 6.71 ± 1.78 |
| **Organic Carbon (%)** | 0.88 ± 0.28 | 1.68 ± 0.59 | 2.20 ± 0.47 | 1.59 ± 0.54 |

**Table 2**

**Correlation between different sediment parameters**

 **at the four stations in the Achenkovil River**

|  |
| --- |
| **Station I** |
| **Parameters** | **Sed.Temp.** | **Sed.pH** | **Sand** | **Silt** | **Clay** | **Org.carb.** |
| **Sed.Temp.** | 1.000 |  |  |  |  |  |
| **Sed.pH** | -0.186 | 1.000 |  |  |  |  |
| **Sand** | 0.632\*\* | -0.292 | 1.000 |  |  |  |
| **Silt** | -0.711\*\* | 0.124 | -0.928\*\* | 1.000 |  |  |
| **Clay** | -0.002 | 0.334\* | -0.310 | 0.006 | 1.000 |  |
| **Org.carb.** | 0.514\*\* | 0.391\*\* | 0.315 | -0.561\*\* | 0.509\*\* | 1.000 |
| **Station II** |
| **Parameters** | **Sed.Temp.** | **Sed.pH** | **Sand** | **Silt** | **Clay** | **Org.carb.** |
| **Sed.Temp.** | 1.000 |  |  |  |  |  |
| **Sed.pH** | 0.031 | 1.000 |  |  |  |  |
| **Sand** | 0.227 | -0.262 | 1.000 |  |  |  |
| **Silt** | -0.390\* | 0.322 | -0.514\*\* | 1.000 |  |  |
| **Clay** | 0.030 | -0.017 | 0.612\*\* | -0.319 | 1.000 |  |
| **Org.carb.** | -0.416\* | 0.124 | -0.554\*\* | 0.369\* | 0.420\* | 1.000 |
| **Station III** |
| **Parameters** | **Sed.Temp.** | **Sed.pH** | **Sand** | **Silt** | **Clay** | **Org.carb.** |
| **Sed.Temp.** | 1.000 |  |  |  |  |  |
| **Sed.pH** | 0.059 | 1.000 |  |  |  |  |
| **Sand** | 0.453\*\* | -0.218 | 1.000 |  |  |  |
| **Silt** | -0.452\*\* | 0.012 | -0.928\*\* | 1.000 |  |  |
| **Clay** | -0.146 | 0.551\*\* | -0.375\* | 0.029 | 1.000 |  |
| **Org.carb.** | -0.349\* | 0.531\*\* | -0.219 | 0.103 | 0.357\* | 1.000 |
| **Station IV** |
| **Parameters** | **Sed. Temp.** | **Sed. pH** | **Sand** | **Silt** | **Clay** | **Org.carb.** |
| **Sed.Temp.** | 1.000 |  |  |  |  |  |
| **Sed.pH** | 0.419\* | 1.000 |  |  |  |  |
| **Sand** | -0.317 | 0.116 | 1.000 |  |  |  |
| **Silt** | 0.687\*\* | 0.251 | -0.497\*\* | 1.000 |  |  |
| **Clay** | -0.452\*\* | -0.387\* | -0.073 | -0.689\*\* | 1.000 |  |
| **Org.carb.** | 0.015 | -0.016 | -0.222 | 0.244 | -0.061 | 1.000 |

 Significant at \*\* P>0.01, \* P>0.05

Sediment deposition is evident in water bodies. Erosional process attributes to disintegration of soil into sand, silt, organic carbon and clay constituents which later upon transport, settle as sediment in water bodies ( Junakova & Balintova, 2014; Luvai et al., 2022). Understanding textural characteristics are relevant in sedimentological studies of rivers. Textural attributes of sediments are largely affected by composition at the source area of adjacent lands, climate and energy that transport sediment as well as redox condition near the depositing environment (Fralick & Kronberg, 1997). In the present study, percentage composition of sand varied from 59.01% during post monsoon at Station 3 to 93.48% at Station 1 in pre-monsoon. While silt composition varied from 1.10% at Station1 in pre monsoon to 30.36% at Station 3 in post monsoon. Clay composition varied from 4.90% in post monsoon at Station 4 to 17.50% at Station 3 in monsoon period. The data on the textural analysis of the sediments revealed that the sediments at all stations in the river basin were composed of relatively higher percentage of sandy fraction during most of the months. Sediments in the head water station contain higher proportion of sand and a gradual decline of sand fraction was observed in the remaining stations, whereas silt and clay fractions followed a reverse trend in distribution, increasing towards downstream stations. These observations were in harmony with the observation of Cummins (1975), Simpson *et al.* (1986) and Arun et al., (2019). However, comparatively lower proportion of sand and higher proportion of silt and clay at Station 3 is apparently due to unabated sand mining going on at these areas and higher proportion of sand during the monsoon and the post monsoon periods at Station 4 indicate its deposition following heavy rainfall (Kumar & Das, 2021). Statistical analysis also gave clear confirmation to these contrasting trends where sand fraction has a highly significant inverse relationship with silt and clay fractions at all stations. A similar negative correlation between sand, silt and clay components was observed by Nair & Ramachandran (2002).

A systematic evaluation of organic carbon content in the bottom sediment indicates the origin, fate and distribution of organic matter in the fresh water ecosystem. It has an important implication on the productivity, biogeochemical characteristics and adsorption capacity of aquatic system (Allois et al., 2022) used as an indicator of ecological health of the system (Kumar & Das, 2021). Organic carbon in the present study varied from 0.88% during pre-monsoon at Station 4 to 5.24% at Station 3. Similar values were observed in various water bodies ( Adeola et al., 2016; Dani et al., 2024). Organic carbon values were higher at Station 3. Organic carbon was correlated negatively with sand and positively with silt and clay components at Stations 2 and 3. Positive relationship of total organic carbon with clay and silt indicates its size dependent scavenging. Similar observation has been reported by Sarkar et al., (2016). Larger surface area of fine sediment particles can absorb colloidal and dissolved organic matter (Daka & Moslen, 2013).

 It was experimentally proved that various clay minerals adsorb substantial amount of organic matter formed by the decomposition of phytoplankton. Seasonal changes in organic carbon content of sediment were evident. Organic carbon was highest during the post monsoon period at Station 4 and during monsoon at the remaining stations. The monsoon maxima of soil organic carbon content suggest a general trend of accumulation of soil organic carbon under the impact of monsoon which subsequently gets translocated during the pre-monsoon floods. However, in downstream locations at Station 4, sandy nature of the substratum together with the dilution caused by the monsoon floods appeared to have brought down the sediment organic carbon during monsoon season. Comparatively higher percentage of organic carbon at the upstream region when compared to downstream stations was presumably due to land drainage and possible organic supply from tributaries in the upstream region.

**4.** **CONCLUSION**

Sediment quality influences both biotic and abiotic components in the river system. Hence it is imperative to study quality of bottom deposits. The bottom sediments of Achenkovil River varied from finer to coarser sand as one moved from the lower reaches to the upper reaches of the river. Silt, clay fractions were very low and the total organic carbon values ranged from 0.88 % to 5.24%. Highest total organic carbon recorded was 5.24% in Monsoon at Station 3. There was also no significant difference in the values of total organic carbon between the stations. Comparatively higher silt and organic carbon at Station 3 was indicative of the effect of sand mining in this part of the river. In short, the varying levels of sediment fractions is reflected in organic matter content distribution and has implicated not only to anthropogenic inputs and also to sedimentary or depositional nature of the river system.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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