*International Research Journal of Environmental Sciences*_____ ISSN 2319–1414
Vol. **11(1),** 1-8, January **(2022)** *Int. Res. J. Environmental Sci.*

# Evaluation of water quality and trophic status of Aruvikkara Reservoir, Kerala, India

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**Available online at: www.isca.in, www.isca.me**
Received 15th December 2020, revised 8th August 2021, accepted 9th September 2021

## Abstract

*The study attempts to analyze the physico–chemical and bacteriological quality of water samples from Aruvikkara reservoir in Kerala, South India. Most of the values obtained from the physico-chemical analysis are within the permissible limits prescribed by BIS and is suitable for all purposes including drinking after proper filtration and treatment. The bacteriological analysis (MPN) revealed that the water is severely contaminated with coliform bacteria and proper attention should be given for avoiding the contamination before used for drinking. The Carlson Trophic State Index indicates that the reservoir is in mesotrophic condition. Proper management measures are required to remove solid wastes from the nearby areas of the reservoir to reduce the pollution of this reservoir, a major drinking water source of Thiruvananthapuram city.*

**Keywords:** Aruvikkara reservoir, water quality, Carlson trophic state index, Coliforms.

## Introduction

Water pollution is one of the major global environmental problems which needs continuous evaluation and monitoring. Freshwater quality is reportedly deteriorating because of rapid industrial development, population growth, and poor watershed management that eventually resulted in drastic environmental degradation[1,2]. Eco-degradation of reservoirs has been on the increased state, due to the rapid pace of industrialization, poor environment management in the catchment and a variety of other factors which can contribute to pollution. Apart from the direct entry of the wastes from the catchment area, the pollution load carried by the upstream rivers also accumulate in the reservoirs. Hazardous substances such as pesticides and heavy metals are carried to the reservoirs through the effluents and the rain washings from the catchment area. These hazardous substances are highly persistent in the environment and thus imbalance the entire biogeochemical processes occurring in static aquatic systems similar to reservoirs.

Water quality status of an aquatic ecosystem is vibrant in nature and is generally evaluated by analyzing the degree of fluctuation of physicochemical parameters[3]. The rate of eutrophication of lakes and reservoirs is rapidly increasing due to excessive release of effluents with excess nutrient load, originating from anthropogenic establishments like industry and improper agricultural practices in basin areas[4,5]. The most commonly used method for eutrophication assessment is the trophic state index related to biomass, established by Carlson[6] and this uses, chlorophyll-a concentration, Secchidisc transparency and total phosphorus concentration measurements of water samples for trophic status estimation. The biological response for nutrient additions to the water bodies at a specific location and time is referred to as Trophic status[7].

The study area, Aruvikkara reservoir is situated in the banks of Karamana River basin, Kerala, South India. The dam was constructed in 1931 to facilitate the supply of piped drinking water to Thiruvananthapuram, the capital city of Kerala. The water flow into this reservoir is modulated by Peppara dam, which is built 20 km upstream of Aruvikkara reservoir, by unifying all the upper tributaries of Karamana river. Inappropriate management of the reservoir area has been contributed to the degradation of aesthetic quality of the reservoir and a major portion of the reservoir area is inhabited by aquatic weeds and virulent phytoplanktons. The present study aims to assess the water quality status and trophic status index of Aruvikkara reservoir.

## Materials and methods

**Study area:** Aruvikkara Reservoir is situated in Nedumangadu Taluk of Thiruvananthapuram district, Kerala between the co-ordinates 80 56’ 77’’ N and 770 01’ 88” E. The location map of the study area is given in Figure-1. A detailed survey was conducted in the study area during the pre-monsoon season of the year 2019 to select the sampling locations. The ten sampling stations were selected for the collection of water samples.

**Methodology:** The water samples were collected in clean, dry and sterilized bottles from the ten selected sampling stations, 3 to 4 kilometers apart and analyzed the physico-chemical parameters and bacteriological parameters following the standard procedures of APHA[8] and Senior[9] respectively.

Trophic Status Index: The Trophic Status Index (TSI) is a cataloging system to evaluate the biological productivity of individual lake, pond and reservoir water. Factors such as chlorophyll 'a', Secchi disc transparency and Total phosphorus have been considered for generating TSI of the reservoir[10]. The general Trophic Status Index of a reservoir can be calculated by taking the average TSI values for total phosphorus, chlorophyll 'a' and the Secchi disc transparency.

Transparency of the water was measured by using Secchi's disc of 20c.ms in diameter and the values are expressed in meters. Concentrations of total phosphorus in water samples were analyzed by the standard method suggested by APHA[8], and concentration of chlorophyll 'a' in water samples were estimated spectrophotometrically. Chlorophyll 'a' concentration in the extract was calculated using the below given equation.

µg Chl.a/gram tissue=12.7(A660)–2.69(A620)x[10/(1000x10)]

The trophic status index (TSI) of Carlson[6] was calculated using the following formulae,

a. TSI value for Secchi disc transparency (TSI. SD) = 60-14.41x log. Secchi depth (Meters)

b. TSI value for Chlorophyll 'a', (TSI.CHL) = 9.81xlog. Chlorophyll-a (µg/l)+30.6

c. TSI for Total Phosphorus concentration (TSI.TP) = 14.42x log. Total phosphorous (µg/l) + 4.15

Where, TSI is Carlson Trophic Status Index.

Carlson's Trophic Status Index = [TSI(SD)+TSI(CHL)+TSI (TP)]/3.

The range of the Carlson's trophic status index values and classification of lakes are depicted in Table-1.

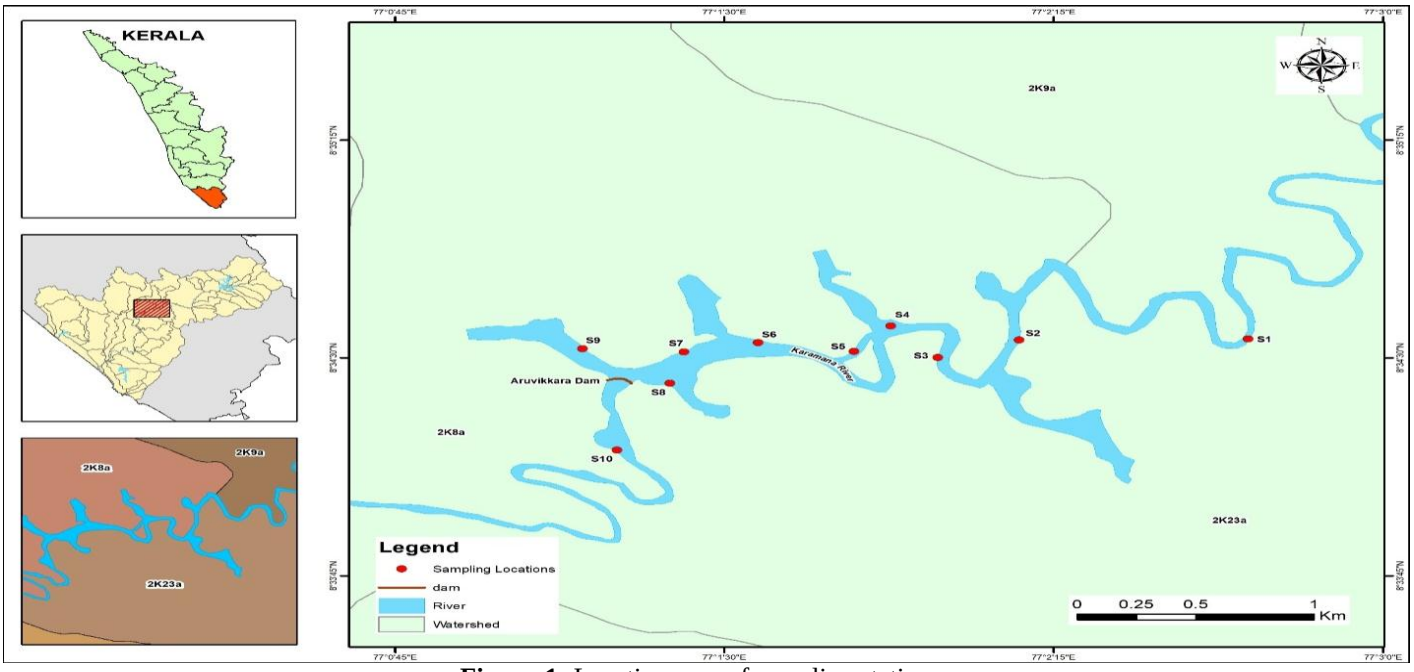


**Figure-1:** Location map of sampling stations.

**Table-1:** Standard table of Trophic Status Index values and categorization of lakes/Reservoir by Carlson[6].

| TSI range | Trophic Status | Characteristics |
|---|---|---|
| < 30 | Oligotrophic | Sufficient Oxygen throughout the year in the hypolimnion, Clear water |
| 30-40 | Oligotrophic | Reservoir will show oligotrophy, but some shallower water body will be in anoxic condition during the summer |
| 40-50 | Mesotrophic | Moderately clear water, but increasing probability of anoxic state during summer season |
| 50-60 | Eutrophic | Lower margin of typical eutrophic condition: Lowered transparency |
| 60-70 | Eutrophic | Wide-spread macrophyte problems, Dominance of blue-green algae |
| 70-80 | Eutrophic | Often hyper-eutrophic, Dense algal blooms throughout the summer |
| >80 | Eutrophic | Presence of algal scum, few macrophytes |

## Results and discussion

**Physico-chemical quality of water:** The dam was not opened during the sampling period and only limited water flow was allowed through the dam. The results of the physico-chemical analysis of water samples are depicted in Figure-2 to Figure-17.

Temperature of the water samples were analyzed at the sites with the help of a thermometer. The values ranged between $29^0$C and $32^0$C (Figure-2). High fluctuation in temperature is mainly due to climatic change[11]. pH of the water samples are analyzed using electric pH meter (Model: ELICO L1 615, India). The pH values ranged from 7.2 to 8.0 (Figure-3). The values are within the acceptable limit specified by Bureau of Indian Standards (BIS) drinking water quality standards[12], which indicates the convenience of water for using all purposes. Highest pH value (pH: 8) was noted in the sample 10. The values are within the permissible limit of WHO prescribed drinking water quality standards, 2008[13]. Electrical conductivity (E.C.) related to the total ionic strength of the water. The E.C. value ranged between 50.67µS/cm and 72.46µS/cm (Figure-4). The highest value (72.46µS/cm) was noted in sample from station 9, which is nearer to the dam. The values are within the acceptable limit prescribed by BIS[12]. The Total Dissolved Solids (TDS) are between 26.12ppm and 37.40ppm (Figure-5). The highest value was noted in the sample which is collected from the station nearer to the dam. This may be due to the accumulation of the dissolved solids in the area from the upstream to the dam side.

The values of the Dissolved Oxygen (DO) of water samples are between 5.30mg/l and 6.80mg/l. (Figure-6), highest value of D.O. was noted in the sample of upstream stations and lower values are noted in samples of dam region, and are within the acceptable limit prescribed by BIS[12]. Biochemical Oxygen Demand (BOD) values are ranged between 1.6mg/l and 3.0mg/l. (Figure-7). The BOD values are not within the permissible limits of Central Pollution Control Board[14]. The Total alkalinity values ranged between 60.0mg/l and 160.0mg/l (Figure-8). The values are within the permissible limit (200mg/l) mandated by BIS.

Total hardness values ranged between 30.0mg/l and 66.0mg/l (Figure-9) and it is within the permissible limit. From the analysis of calcium, water from station 4 has highest concentration of calcium. The lowest value is observed in the sample collected from station 6. The calcium content ranged from 4.81mg/l as $CaCO_3$ to 12.83mg/l as $CaCO_3$ (Figure-10). The concentration of magnesium in the samples are ranged from 5.76mg/l to 11.80mg/l (Figure-11). The concentration of calcium and magnesium are within the acceptable limits by WHO drinking water quality standards. The chloride content ranged from 11.36mg/l to 28.40mg/l. Salinity is the mass of dissolved salts water mainly due to the presence of chloride ions. The values of salinity ranged from 20.53g/l to 51.59g/l (Figure-13), which is within the acceptable limit prescribed by WHO and BIS.

The inorganic phosphate values of the sample analyzed are between 0.025mg/l and 0.049mg/l (Figure-14). The nitrate values are in the range of 0.0027mg/l and 0.0132mg/l (Figure-15). Both inorganic phosphate and nitrate values are within the permissible limit mentioned by BIS[12]. The sulphate concentration ranged from 0.0598mg/l to 0.068mg/l, which is within the acceptable limit. The results of the fluoride analysis revealed that the concentration is between 0.05mg/l and 0.29 mg/l (Figure-17) in the water samples. Lowest concentration of fluoride was noted in the water sample from station 10, which is in located in the downstream of reservoir area. The values are below the maximum acceptable limit of water quality standards by BIS[12] (<1 mg/l) and WHO[13] (<1.5 mg/ l).

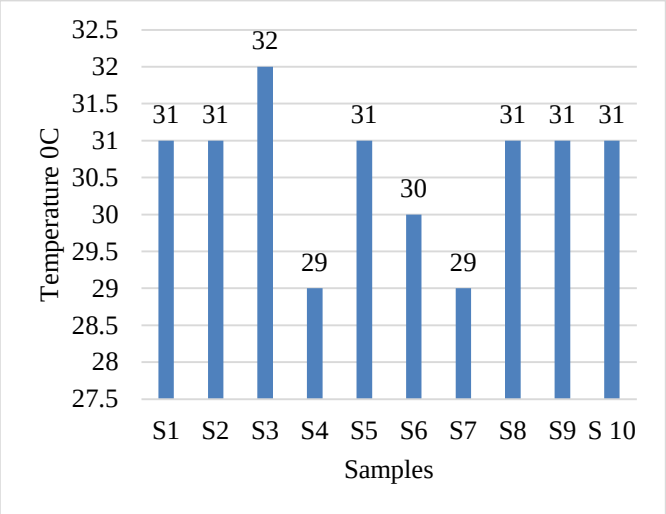


**Figure-2:** Temperature of water samples.

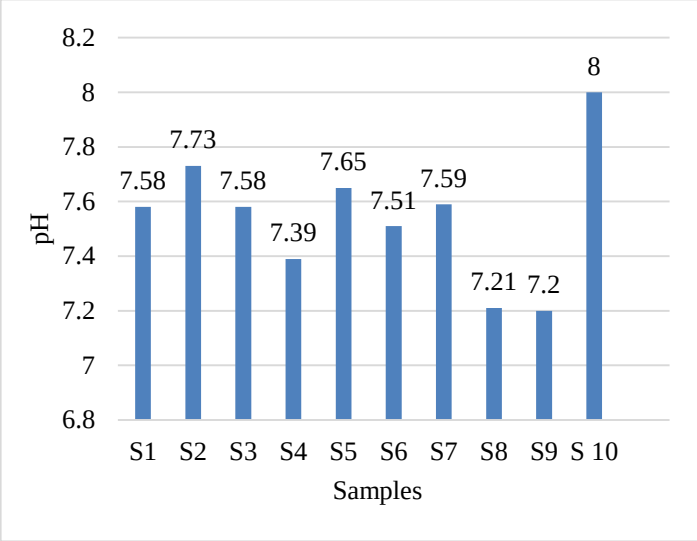


**Figure-3:** pH of water samples.

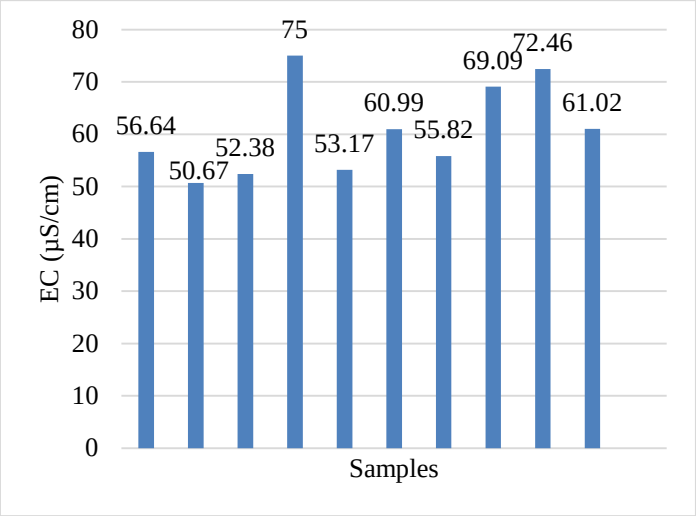


**Figure-4:** E.C. of water samples.

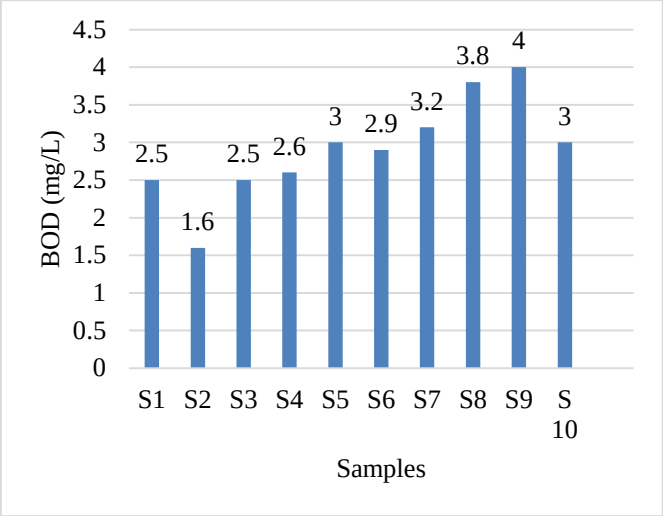


**Figure-7:** B.O.D. of water samples.

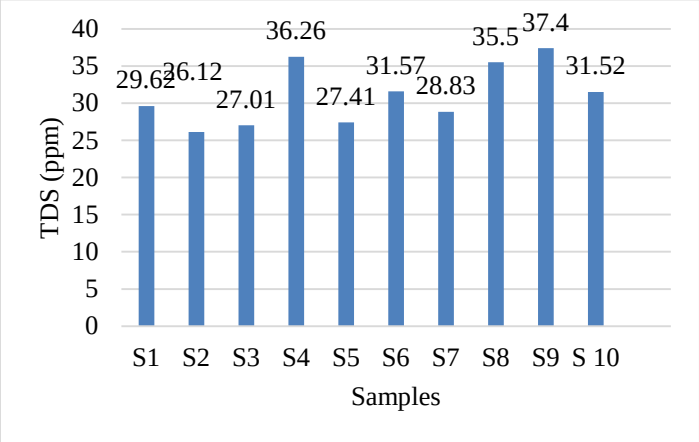


**Figure-5:** T.D.S of water samples.

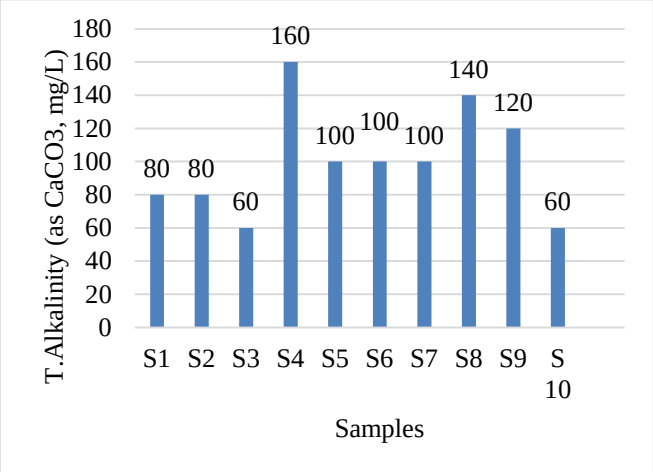


**Figure-8:** Total Alkalinity of water samples.

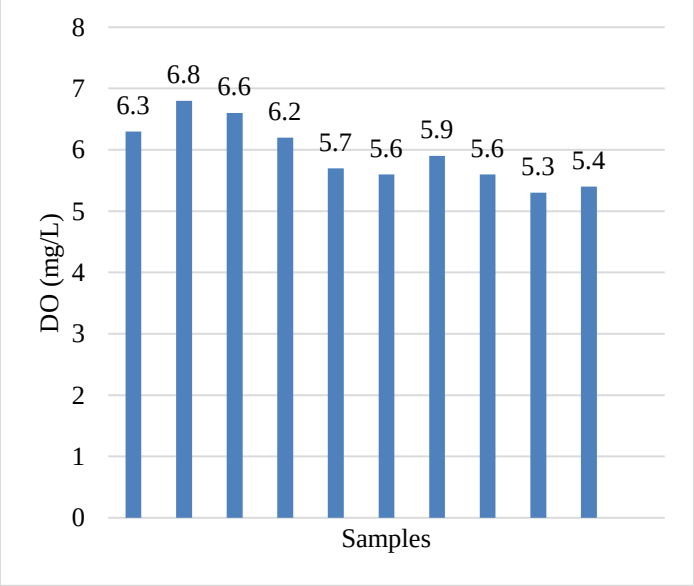


**Figure-6:** D.O. of water samples.

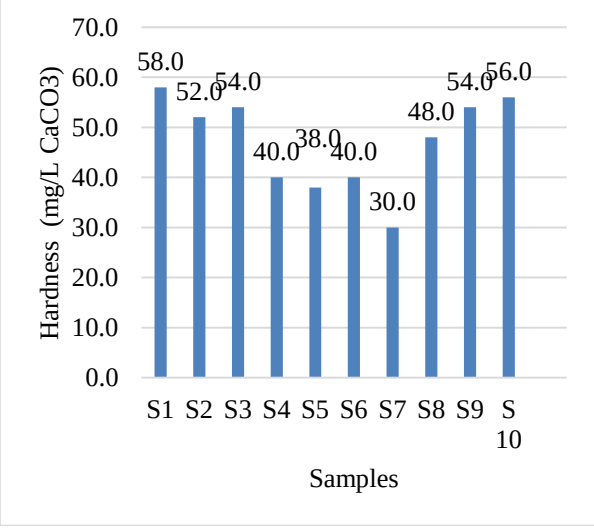


**Figure-9:** Total Hardness of water samples.

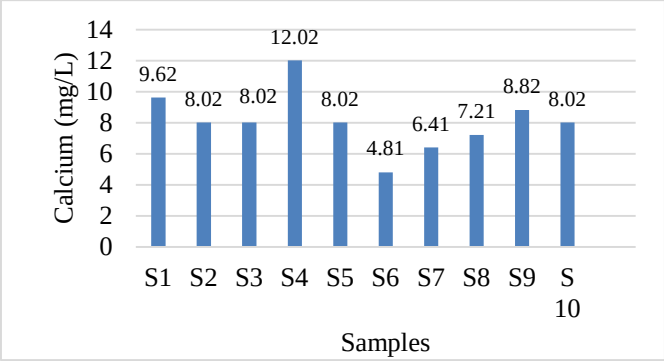


**Figure-10:** Calcium content of water samples.

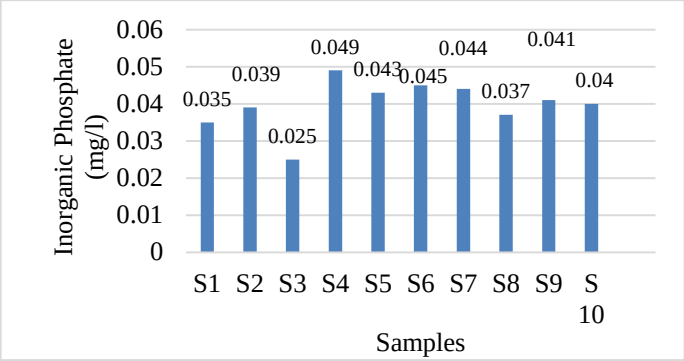


**Figure-14:** Inorganic phosphate content in water samples.

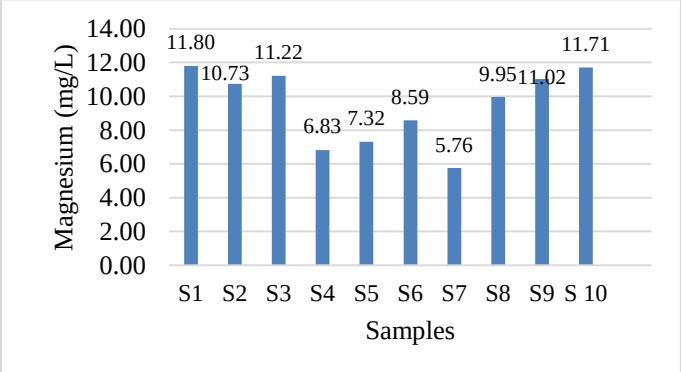


**Figure-11:** Magnesium content of water.

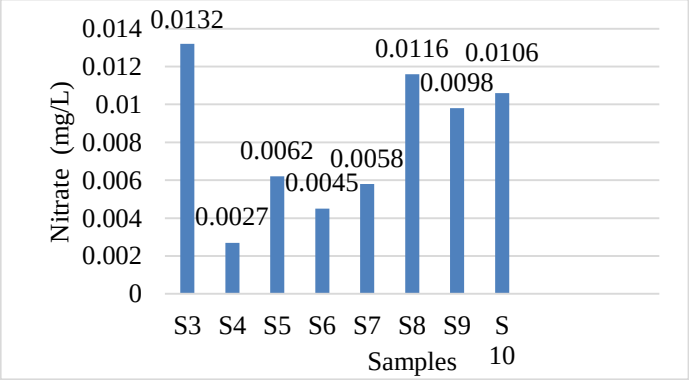


**Figure-15:** Nitrate content in water samples.

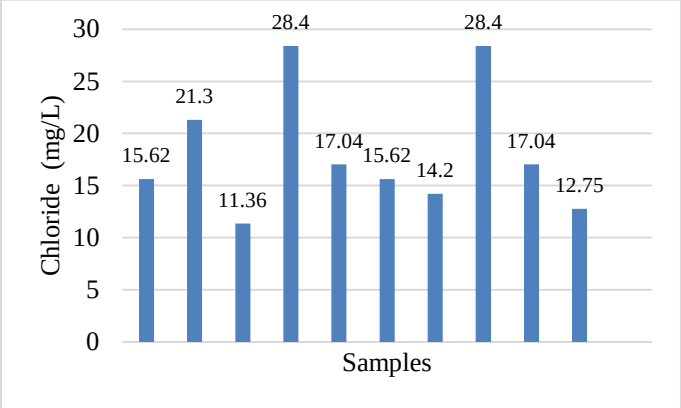


**Figure-12:** Chloride content of water samples.

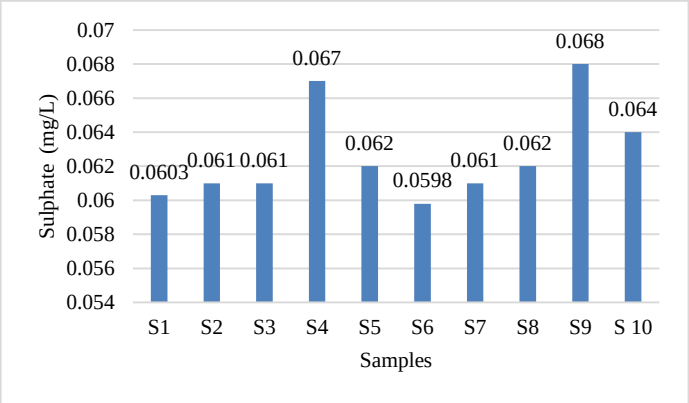


**Figure-16:** Sulphate content in water samples.

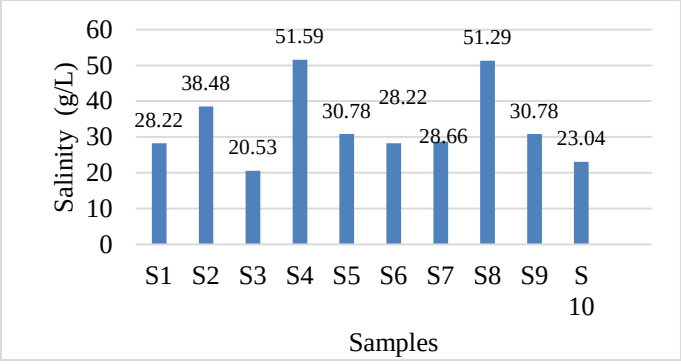


**Figure-13:** Salinity of water samples.

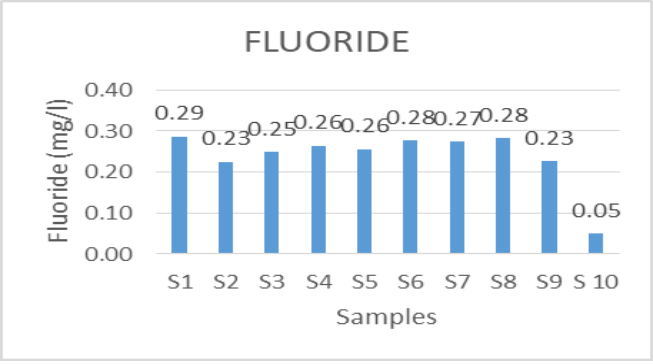


**Figure-17:** Fluoride content in water samples.

**Bacteriological quality of water:** The water consumption suitability is determined by the total coliform bacteria test. It helps to measure out the concentration of total coliform bacteria in water samples and the possible presence of disease causing organisms. The results obtained from the bacteriological analysis of the study are given in Figure-18. All the water samples analyzed were contaminated with coliform bacteria. Highest number of total coliform was noted in four samples collected from the reservoir area. According to UNEP/WHO guideline[16], the drinking water should be free of total coliforms, and if present, will be below 10MPN/100ml. Fecal coliform bacteria are that originate from intestinal tract of homeo-thermic animals and their presence in water indicate fecal contamination[15]. Fecal coliform contamination was detected in 40% of samples collected from of the reservoir stations. Dumping of domestic wastes including the septic tank waste in the remote areas of the reservoir causes this type of contamination of water. Since fecal coliforms are indicators of pathogenic organisms, there should not be any such organisms in drinking water. The bacteriological analysis indicates that all the water samples collected from the Aruvikkara reservoir were contaminated with coliform bacteria, and it is unfit for drinking without boiling for 20 minutes as prescribed by BIS.

**Trophic Status Index (TSI) evaluation:** The results of the Trophic Status studies are given in Table-2 and Figure-19. Trophic State Index studies revealed that all the stations in the reservoir area are in mesoptrophic condition. The average Trophic Status Index values are higher in the regions which are nearer to the dam. The highest and lowest trophic status index values are recorded in station 9 and station 2 respectively. The last station (station 10), which is located the downstream of the dam was also in mesotrophic condition. This may be due to the limited flow of water through the dam towards the downstream. Since many of the stations of the reservoir are in mesotrophic condition, the water body will become completely eutrophicated in the near future. Trophic Status Index studies conducted by Shibu and Ajitkumar[17] also revealed that majority of the sites analyzed in the Aruvikkara reservoir were in the mesotrophic condition. They have stated that if this condition exists longterm, the micro and macro flora will be dominant in the water body and this can bring about eutrophic state and thus leads to the death of the reservoir.

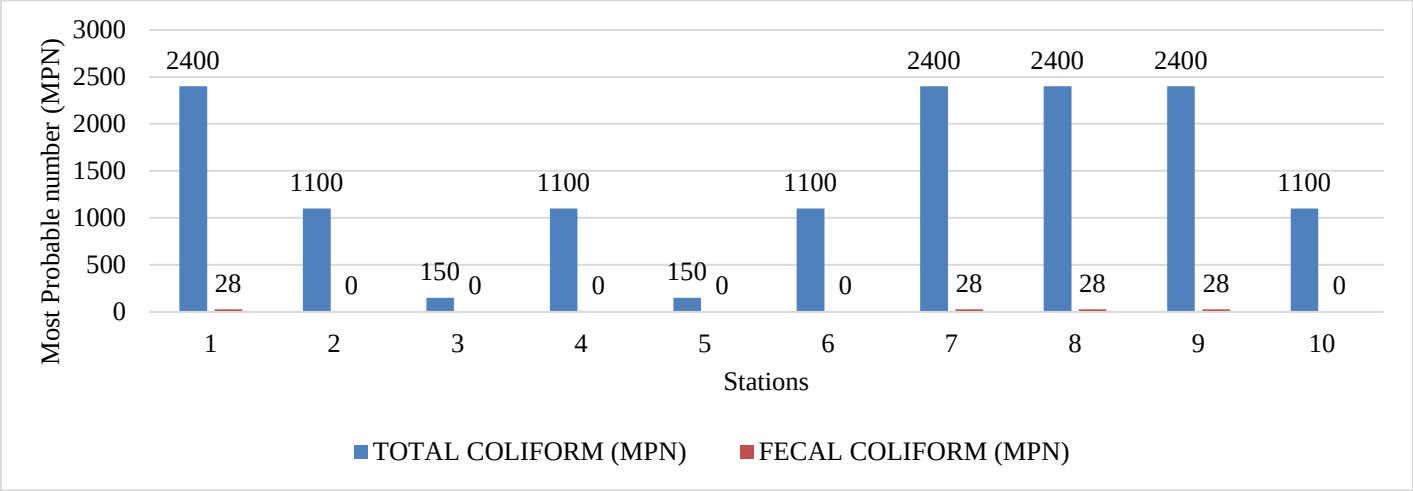


**Figure-18:** Bacteriological parameters of reservoir water.

**Table-2:** Trophic Status Index (TSI).

| Stations | TSI (SD) | TSI (CHL) | TSI (TP) | Carlson Trophic State Index |
|---|---|---|---|---|
| 1 | 56.78 | 11.85 | 61.49 | 43.38 |
| 2 | 54.16 | 12.39 | 58.39 | 41.65 |
| 3 | 56.78 | 11.63 | 59.26 | 42.56 |
| 4 | 58.63 | 10.21 | 62.66 | 43.83 |
| 5 | 56.78 | 10.73 | 61.91 | 43.14 |
| 6 | 58.63 | 10.03 | 63.08 | 43.91 |
| 7 | 58.63 | 9.49 | 63.74 | 43.95 |
| 8 | 60.00 | 9.03 | 63.48 | 44.17 |
| 9 | 60.00 | 9.20 | 64.02 | 44.41 |
| 10 | 58.63 | 9.72 | 60.19 | 42.85 |

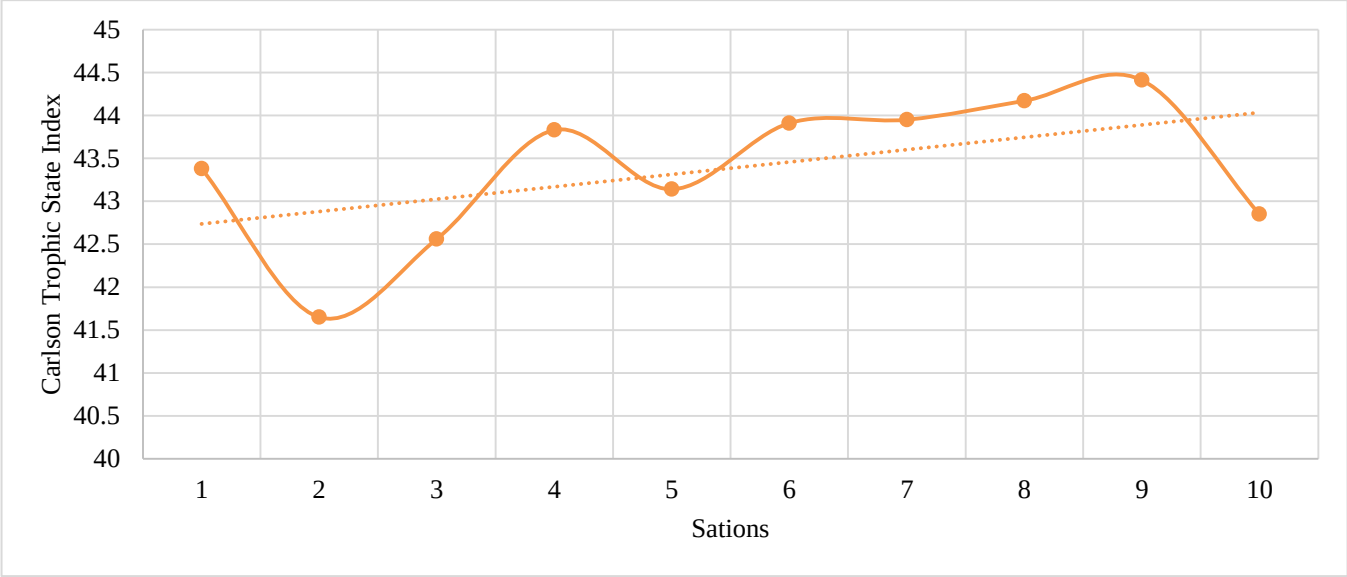


**Figure. 19.** Carlson Trophic State Index of selected stations

## Conclusion

The present study on the water quality assessment of the Aruvikkara reservoir revealed that it is suitable for all purposes, since the values of physico-chemical parameters are confined to the acceptable limits of drinking water quality standards. However the bacteriological studies suggest that the water become portable only after proper treatment, since it is contaminated with coliform bacteria. The Trophic State Index values show that all the selected stations are in mesotrophic condition. If proper management measures are not taken, the reservoir will face a complete eutrophic condition in near future and this will lead to decrease of storage capacity and aesthetic quality of the reservoir and finally will lead to the drinking water shortage in Thiruvananthapuram city.

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