**Poll Res. 41 (3) : 931-940 (2022)**

ISSN 0257–8050
**DOI No.: http://doi.org/10.53550/PR.2022.v41i03.024**

# WATER QUALITY INDEX AS A TOOL TO ASSESS WATER QUALITY OF SASTHAMKOTTA FRESHWATER WETLAND, A RAMSAR SITE IN INDIA

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(Received 14 September, 2021; Accepted 28 November, 2021)

## ABSTRACT

**Lakes are versatile ecosystems that perform valuable functions such as recycling nutrients, attenuating floods, recharging groundwater and also serve the water needs of the human populace. Nowadays the quality of surface water is getting deteriorating at a rapid pace due to excess water withdrawal and various anthropogenic activities. In this study, the water quality status of Sasthamkotta lake, a fresh water wetland in the south western part of India which is also a Ramsar site is determined in terms of Central Pollution Control Board National Sanitation Foundation Water Quality Index. The study was carried out from the month of October 2018 to the month of September 2019 and parameters namely dissolved oxygen, faecal coliform, pH and biochemical oxygen demand were analysed to determine the water quality status of the lake and the same was mapped using Geographical Information System. It was found that major part of the lake comes under the category good (Central Pollution Control Board National Sanitation Foundation Water Quality index [CPCB-NSFWQI] ranging from 78 to 80). Localised moderately good water quality (CPCB-NSFWQI ranging from 76 to 78) was observed at sampling stations namely Bharanikkavu and Anjalimooduand very good water quality(CPCB-NSFWQI ranging from 80 to 82) was found at the sampling stationnamely Kerala Water Authority main pumping station during the post-monsoon and the pre-monsoon season respectively. It was also found that the major portion of the north eastern part of lake comes under moderately good water quality during the monsoon season. Densely populated catchment area of the lake, physical setting of the lake characterised by steep slopes on three sides and excess runoff during rainfall could be attributed to the moderately good water quality of the lake. Water quality parameters namely faecal coliform exceeded the permissible limits as per the Bureau of Indian Standards for drinking purpose at all the sampling stations throughout the study period. The designated best use of Sathamkotta lake belongs to the category ClassA (non-polluted source) (as per the various classes given by the Central Pollution Control Board based on the CPCB-NSFWQI values obtained during the study period.**

**KEY WORDS:** Water quality status, Sasthamkotta fresh water wetland, Ramsar site, Central Pollution Control Board National Sanitation Foundation Water Quality index, Mapping using Geographical Information System.

## INTRODUCTION

Lakes are versatile ecosystems which are beneficial to mankind by way of being the source of drinking water, water storage, flood control, recharge, flora and fauna habitats, recreational opportunities and they provide livelihood to many. The ground truth regarding our lakes and rivers is that only a meagre 0.01% of the global water volume is available in these sources (Kumar *et al.*, 2017). Now-a-days due to demographic pressure, rapid industrialisation and climate change, surface water quality deterioration has become a serious concern worldwide. World Health Organization (WHO) has reported that at least 2 billion people on a global basis consumes drinking water source contaminated with faecal matter (Matta *et al.,* 2020). WHO also has stated that by the year 2025, half of the global population will be living in water-stressed areas (Jehan *et al.,* 2020). Poor quality in water has been linked to public health concerns, mainly through the transmission of water-borne diseases. However, according to United Nations International Children's Emergency Fund, improving the water supply remains a challenge, especially in South Asia. Such deterioration threatens the use of water resources, especially the drinking water supply and economic development (Mir and Gani, 2019).

The Ministry of Environment, Forests and Climate Change (MoEFCC), Govt. of India has specified water quality criteria based on the types of uses and activities. Central Pollution Control Board (CPCB), Govt. of India has established a nationwide network of water quality monitoring comprising of 1019 stations in our country. The water quality monitoring network covers 592 rivers, 65 lakes and 321 wells (CPCB, 2010). The water quality monitoring results obtained indicate that the organic pollution and bacterial contamination continues to be crucial in theabove water bodies. The problem of water pollution in India due to the discharge of industrial and domestic wastewater into our aquatic environment is constantly on the rise as well. It is estimated that 70% of surface water in India is unfit for human consumption (Upadhyay *et al.,* 2013).

In the southern part of India, in Kerala there is rise in environmental degradation, because of urbanisation, industrialisation and agricultural activitiesas the same is evident from the population growth rate of 14% per decade (Mahadevan *et al.,* 2020). As on today Kerala has to confront with a number of epidemic diseases namely cholera, chikungunya, dengue fever, malaria, hepatitis etc., (ENVIS, 2007). The study carried out by Jacob *et al.,* (2004) reported that there is a pronounced increase in water borne diseases in the State of Kerala. The above study also reports that the major water quality problem associated with rivers of Kerala is bacteriological pollution. The first outbreak of epidemics like chikungunya, occurred in the State of Kerala in the coastal areas of Kollam, Alappuzha and Thiruvananthapuram districts (George and Sushamabai, 2009). The important problems faced by the lake system in general are water quality deterioration, siltation, eutrophication, shrinkage in water spread, reclamation, encroachment, pollution resulting from natural as well as anthropogenic sources, excessive tourism load and overfishing (Sheela *et al.,* 2013). Absence of proper treatment facilities for sewage and garbage generated in the urban areas are the main reasons for the degradation of water quality. Therefore, many countries have implemented water quality protection measures and monitoring regimes (Dutta *et al.,* 2018). Furthermore, to better understand health of water bodies, it is critical toassess water quality, especially the major contributors to its spatial and temporal variations. Thus constant monitoring of water bodies is a prime step towards restoration of existing water quality.

Many studies have established various methods to assess water quality, which is a measure of the physical, chemical, and biological characteristics of water (Harkins, 1974). Water quality status of surface as well as subsurface sources now-a-daysare commonly evaluated by a single unit less number called water quality index (WQI), that expresses overall water quality (health of water bodies) at a certain location based on large number of water quality parameters (Shil and Mehta, 2019). This number is placed on a relative scale to justify the water quality in categories ranging from very bad to excellent and the same can be easily interpreted and understood by political decision makers, administrators and the general public.

The concept of WQI was proposed by Horton (1965) and Brown (1970) and has been further developed by various researchers and today a great deal of consideration has been given to the development of various WQI methods. As a result, a number of water quality indices namely Weight Arithmetic Water Quality Index (WAWQI), National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), Oregon Water Quality Index (OWQI) etc. have been formulated by various organisations (Salin and Sreedevi, 2013). These water quality indices have been applied based on the number of water quality parameters chosen and the respective standards followed in that particular region (Sukanya and Joseph, 2020). Although various formulae are available to calculate the WQI, all of them effectively convert numerous physical, chemical and bacteriological water quality parameters into a single value that reflects the water quality level, thus reducing the differences between the water quality parameters chosen individually in assessing water quality.

Typically a WQI comprises of four components. First, specific water quality parameters of interest are selected. The water quality data are properly analysed and for each individual water quality parameter, the corresponding concentration are converted to a single-value dimensionless sub-index value. Thereafter, for the selected water quality parameter the weighting factor is determined, and the final step is the calculation of a final single value water quality index by an aggregation function using the said sub-indices and weighting factors for the selected water quality parameters (Uddin *et al.,* 2021).

NSFWQI proposed by Brown, with the support of the United States National Sanitation Foundation (US NSF) was developed as an excellent management and general administrative tool in communicating water quality information (Sheela *et al.,* 2011). This index has been widely field tested and applied to data from a number of different geographical areas all over the world (6). This method uses nine parameters namely dissolved oxygen (DO), faecal coliform (FC), biochemical oxygen demand (BOD), pH, water temperature, phosphate, nitrate, total suspended solids (TSS), and turbidity for the calculation of the said water quality index based on the weightage provided by the water quality expert panel. The mathematical expression for assessing the water quality in terms of NSFWQI can be determined using equation (1).

$$NSFWQI = \sum_{i=1}^{n} WiQi \qquad (1)$$

Where Wi represents the standard weightage of $i^{th}$ water quality parameter, Qi represents the evaluated concentration of $i^{th}$ water quality parameter and 'n' is the number of total water quality parameters considered for assessing the water quality. After evaluating the NSFWQI value, water quality status is ranked into five classes and each class is assigned a descriptive word. Thus the NSFWQI rating scale is divided into five water quality classes for ranking purpose and the descriptor words for the same are very bad water quality (NSF WQI ranging from 0 to 25), bad water quality (NSF WQI ranging from 26 to 50), medium water quality (NSF WQI ranging from 51 to 70), good water quality (NSF WQI ranging from 71 to 90) and excellent water quality (NSFWQI ranging from 91 to 100). (Noori *et al.,* 2018).

Later NSFWQI was modified for applying them on the Indian conditions. (Anonymous, 1986). The parameters namely DO, FC, pH and BOD were considered as significant water quality parameters for water quality classification in India. CPCB has modified the original NSFWQI weightages considering the parameters namely, DO, FC, pH and BOD and the same is given in Table 2 and the mathematical expression for assessing the water quality in terms of CPCB-NSF WQI can be calculated as per equation (2). Central Pollution Control Board (2001) has also given the NSFWQI values based on which water bodies can be classified for various designated best use as Class A, Class B, Class C, Class D and Class E respectively and the same is given in table 4.

To carry out studies on water bodies of large extent, conventional land based techniques must be complemented by using remote sensing and geographical information system (Che *et al.,* 2009). Remote sensing can also be implied in computing water quality parameters namely pH, chlorophyll concentration, turbidity, salinity etc. (Ballatore *et al.,* 2014).

Geographical Information System (GIS) is an excellent tool in mapping water quality parameters as well as delineating freshwater bodies. Remote Sensing (RS) carried out with the use of satellite imagery can be considered as an inexpensive alternative to the conventional water quality monitoring method. With recent advances in remote sensing, faster updates are possible in a short time interval with high resolution sensors and repeated area coverage (Chan and Bing, 2013). Remote sensing approach can be used where in situ monitoring of water bodies is financially, institutionally and spatially constrained (Lu, 2013). Thus, Geographic Information System (GIS) coupled with Remote Sensing (RS) offers an integrated scheme for mapping and modelling water quality of lakes with location-based observations (Wang *et al.,* 2008).

This study focuses on determining the water quality status of Sasthamkotta lake which is a fresh water wetland in Kollam district (in Kerala State) in the south western part of India which is also a Ramsar site (declared in the year 2002) in terms of Central Pollution Control Board National Sanitation Foundation Water Quality index (CPCB-NSF WQI) during October 2018 to September 2019.

## MATERIALS AND METHODOLOGY

Sasthamkotta lake lies between $9^{0}1'$N to $9^{0}4'$N latitude and $76^{0}36'30''$ E to $76^{0}39'$E longitude and is located in Kunnathur taluk of Kollam district in the south western part of India in Kerala. Sasthamkotta lake is the largest freshwater lake in Kerala and the catchment area of the lake spreads out in three Panchayats namely, Sasthamkotta, Mynagapally and Western Kallada. Physiographically the lake is located in the midland region (elevation between 7.5 m and 75 m above Mean Sea Level) and the highest elevation of the lake catchment area is 33 m above Mean Sea Level in the northern part of the lake. The study area experiences a tropical humid climate with mean annual air temperature varying between 26.7 ºC and 29.2 ºC and an annual average rainfall of 2398 mm due to south west and north east monsoon rainfall. (Prakasham, 1991). The lake is surrounded by small residual hills on three sides and an artificial bund in the south eastern part of the lake constructed in the year 1956 which separates the lake from the surrounding lowland (Salin and Sreedevi, 2013). Water has been extracted from Sasthamkotta lake since 1956 for drinking purpose and this freshwater lakecaters to the drinking needs of more than 10 lakh people in Kollam district (Raj and Kani, 2018). The contour of the lake is irregular with an inverted F shape which extends into the lake as pockets at several places. Though detailed investigations on the ecology of some important South Indian lakes were carried out, a holistic study on the ecology of Sasthamkotta lake is still lacking (Prakasham, 1991). The south western tip of the lake corresponding to the Anjalimoodu region, south eastern portion of the lake corresponding to the bund that separates the lake from the surrounding paddy fields, Ambalakadavu region and Bharanikkavu region of Sasthamkotta lake has turned lush grassland over the years and the same is utilised by local farmers for cultivation and grazing their livestock. Hence there is a need for protecting and conserving the said lake ecosystem. Fig. 1 shows the location map of Sasthamkotta lake and the same was digitized from the Survey of India Toposheet 58C12 1967, using ArcGIS software.

Twelve sampling stations were selected along the lake stretch and the same is shown in Fig. 2.

The co-ordinates of the twelve sampling stations were recorded using hand-held GPS (GARMIN eTrex® 30) and the same is given in table 1.

Water samples were collected once in every month during the study period from the month of October 2018 to the month of September 2019. Thereafter the water samples were taken to the Environmental Engineering laboratory, Department

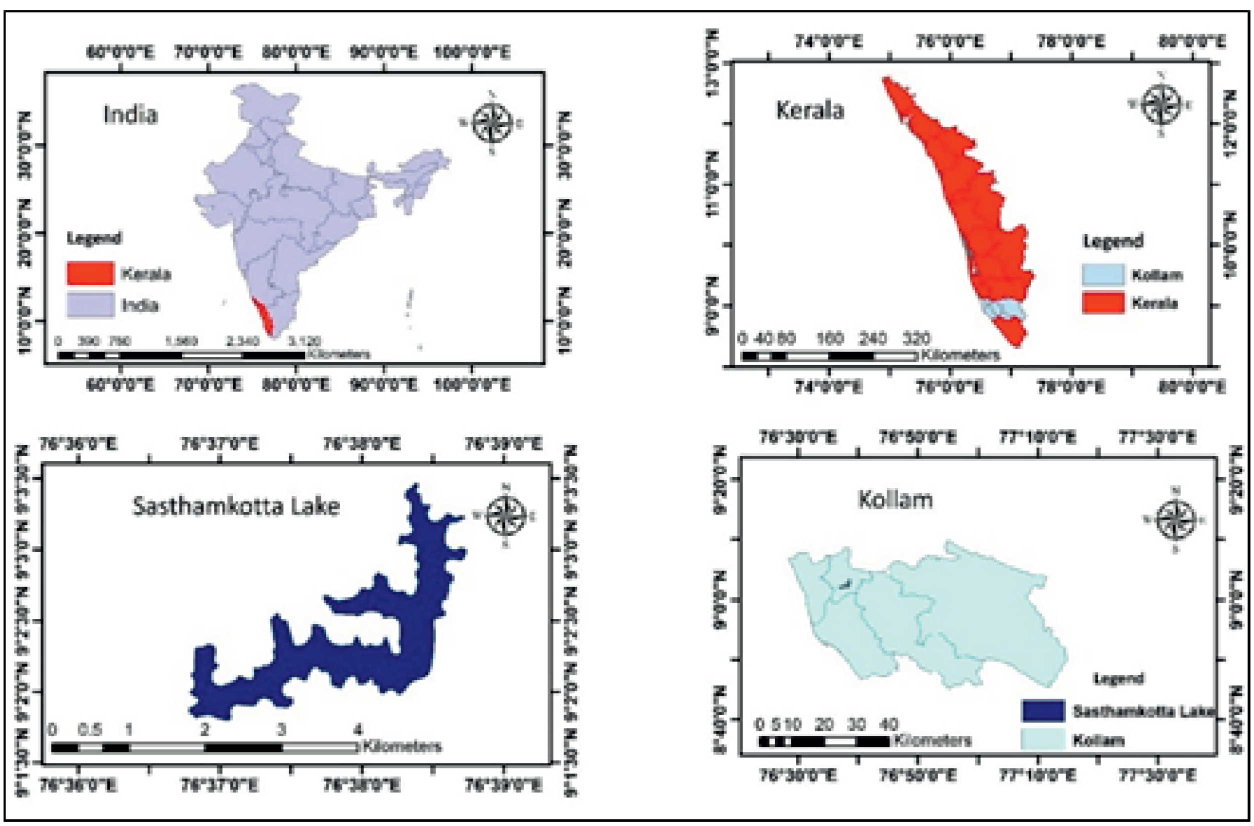


**Fig. 1.** Location map of Sasthamkotta lake.

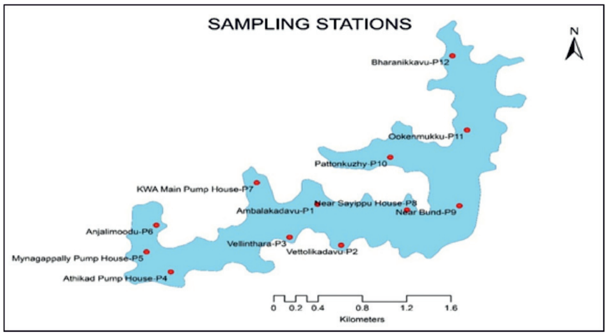


**Fig. 2.** Sampling stations in Sasthamkotta lake.

of Civil Engineering, College of Engineering Trivandrum where the analysis of parameters namely Dissolved Oxygen (DO), Faecal Coliform (FC), pH and Biochemical Oxygen Demand (BOD) were carried out using standard procedures (APHA, 2005). Thereafter the water quality of the lake under study was determined in terms of CPCB-NSF WQI and the same was calculated as per the mathematical expression given as equation(2) (Abba *et al.*, 2015).

$$CPCB - NSF\ WQI = \frac{\sum Qvalue\ X\ Weight}{\sum Weight} \quad (2)$$

Where Qvalue represents the qualitative parameter value and Weight represents the modified weights of the water quality parameter considered. The NSF-WQI was calculated by using sub-index equation of each parameter and their corresponding weightages. The said modified weights (Wi) and the sub-indexequations are given in Table 2 and 3 respectively. Thereafter the water quality of the lake as a whole was determined in terms of CPCB-NSF WQI for all the selected sampling stations during the post-monsoon season (from the month of October 2018 to the month of February 2019), pre-monsoon season (from the month of March 2019 to the month of May 2019) and monsoon season (from the month of June 2019 to the month of September 2019) respectively. Based on the values of CPCB-NSFWQI values for the lake under study, the water quality rating scale was divided into four water quality classes and the same were ranked related to the descriptive categories namely slightly good water quality (CPCB-NSFWQI ranging from 74 to 76), moderately good water quality (CPCB-NSF WQI ranging from 76 to 78), good water quality (CPCB-NSF WQI ranging from 78 to 80) and very good water quality (CPCB-NSFWQI ranging from 80 to 82).

CPCB-NSFWQIvaluesfor all the sampling stations during the study period were calculated as per equation (2) and the same were interpolated using the Inverse Distance Weighted (IDW) interpolation method provided by the ArcTool in the ArcGIS software. Thereafter the water quality status of the lake during the post-monsoon season, pre-monsoon season and monsoon season were mapped

**Table 2.** Original and Modified Weights for the computation of NSF WQI Based on DO, FC, pH and BOD (Abba *et al.*, 2015).

| Water Quality parameter | Original weights from NSFWQI | Modified weights by CPCB |
|---|---|---|
| DO | 0.17 | 0.31 |
| FC | 0.15 | 0.28 |
| pH | 0.12 | 0.22 |
| BOD | 0.1 | 0.19 |
| Total | 0.54 | 1.00 |

**Table 1.** Name and co-ordinates of the sampling stations selected.

| Designation of the sampling station | Name of the sampling station | Latitude | Longitude |
|---|---|---|---|
| P1 | Ambalakadavu | 9° 2′19.11"N | 76°37′43.38"E |
| P2 | Vettolikadavu | 9° 2′3.67"N | 76°37′50.29"E |
| P3 | Vellinthara | 9° 2′6.69"N | 76°37′35.21"E |
| P4 | Athikad Pump House | 9° 1′ 53.64" N | 76° 37′ 0.54" E |
| P5 | Mynagappally Pump House | 9° 2′ 1.14" N | 76° 36′ 53.46" E |
| P6 | Anjalimoodu | 9° 2′ 11.22" N | 76° 36′ 56.34" E |
| P7 | *KWA Main Pump House | 9° 2′27.22"N | 76°37′25.64"E |
| P8 | Near Sayippu House | 9° 2′17.00"N | 76°38′9.48"E |
| P9 | Near Bund | 9° 2′18.54"N | 76°38′24.79"E |
| P10 | Pattonkuzhy | 9° 2′ 36.84" N | 76° 38′ 4.62" E |
| P11 | Ookenmukku | 9° 2′47.09"N | 76°38′27.07"E |
| P12 | Bharanikkavu | 9° 3′15.07"N | 76°38′22.75"E |

*Kerala Water Authority

**Table 3.** Sub-index equations for the selected Water Quality Parameters (Abba *et al.*, 2015).

| Water Quality Parameter | Range Applicable | Sub-index equations |
|---|---|---|
| DO | 0-40% saturation | IDO = 0.18+0.66 x (% Saturation DO) |
| (Percent saturation) | 40-100% saturation | IDO = -13.55 +1.17 x (% Saturation DO) |
| | 100-140% saturation | IDO = 163.34 – 0.62 x (% Saturation DO) |
| BOD | 0-10 | IBOD = 96.67 – 7 (BOD) |
| (mg-1) | 10-30 | IBOD = 38.9 – 1.23 (BOD) |
| | >10 | IBOD = 2 |
| pH | 2-5 | IpH = 16.1 + 7.35x (pH) |
| | 5-7.3 | IpH = -142.67 +33.5x (pH) |
| | 7.3-10 | IpH = 316.96 – 29.85 x (pH) |
| | 10-12 | IpH = 96.17 – 8.0 x (pH) |
| | <2,>12 | IpH = 0 |
| Fecal Coliform | $1\text{-}10^3$ | IFC = 97.2 – 26.6 x log (FC) |
| (count per 100ml) | $10^3\text{-}10^5$ | IFC = 42.33 – 7.75 xlog (FC) |
| | $>10^5$ | IFC = 2 |

Where IDO, IBOD, IpH and IFC are the sub-index values.

**Table 4**. CPCB-NSF WQI of water bodies for various Designated Best Use (Abba *et al.*, 2015).

| Serial No. | CPCB-NSF WQIvalue | Description of Water Quality (1978) | Water body class by CPCB | Remarks |
|---|---|---|---|---|
| 1 | 63-100 | Good to Excellent | A | Non polluted |
| 2 | 50-63 | Medium to Good | B | Non polluted |
| 3 | 38-50 | Bad | C | Polluted |
| 4 | 38 and less | Bad to very Bad | D,E | Heavily polluted |

respectively using Geographical Information System.

## RESULTS AND DISCUSSION

CPCB-NSFWQI values for all the twelve sampling stations for the post-monsoon season (from the month of October 2018 to the month of February 2019) were calculated as per equation (2) and the average value of the same for the said five months are also given in table.5.

The average CPCB-NSF WQI values mentioned in Table 5 were interpolated using the Inverse Distance Weighted (IDW) interpolation method and the water quality status of the lake during the post-monsoon season was mapped using Geographical Information System and the same is shown in fig.3. It was observed that during the post-monsoon season, a major portion of the lake belonged to good water quality status. Localized moderately good

**Table 5.** CPCB-NSFWQI values in the post-monsoon season.

| Month Sampling stations | October 2018 | November 2018 | December 2018 | January 2019 | February 2019 | Average CPCB NSFWQI |
|---|---|---|---|---|---|---|
| P1 | 75.97857 | 76.59898 | 77.24412 | 81.02119 | 81.61622 | 78.49182 |
| P2 | 78.00054 | 75.21846 | 78.79808 | 81.12866 | 81.10329 | 78.84981 |
| P3 | 79.5405 | 79.62835 | 76.28201 | 81.0145 | 79.12349 | 79.11777 |
| P4 | 78.59339 | 74.65385 | 73.70908 | 83.07732 | 85.73168 | 79.15306 |
| P5 | 77.32958 | 74.37593 | 74.72675 | 77.88612 | 75.58347 | 75.98037 |
| P6 | 81.94095 | 76.46689 | 76.46422 | 83.24595 | 76.61999 | 78.9476 |
| P7 | 81.43559 | 81.82793 | 77.78231 | 78.20866 | 81.99361 | 80.24962 |
| P8 | 78.67024 | 77.62129 | 73.88155 | 79.76943 | 80.59353 | 78.10721 |
| P9 | 81.41226 | 76.07554 | 79.47021 | 78.75324 | 83.4254 | 79.82733 |
| P10 | 82.89502 | 77.28946 | 76.86358 | 83.80793 | 79.04029 | 79.97926 |
| P11 | 79.5795 | 76.95172 | 73.94317 | 81.69772 | 82.34938 | 78.9043 |
| P12 | 75.94578 | 79.35823 | 75.25742 | 75.90015 | 76.99484 | 76.69128 |

water quality status were observed at sampling stations namely P5 (Mynagappally Pump House) and P12 (Bharanikkavu). Direct wastewater discharge from the adjoining Bharanikkavu town near the sampling station namely P12 (Bharanikkavu) may be the reason for comparatively lower CPCB-NSFWQI value in the said sampling station compared to others.Water quality parameter namely FC (ranged from 40 CFU 100 ml-1 to 240 CFU 100 ml-1) exceeded the permissible limits as per the Bureau of Indian Standards (BIS) for drinking purpose at all the sampling stations throughout the post-monsoon season. The exposure of lake to human faecal matter due to the densely populated catchment area of the lake and wastewater discharge from theadjoining Bharanikkavu town and Sasthamkotta town may be the reason for high FC count in the lake throughout the post-monsoon season. The lowest and highest value of CPCB-NSFWQI during the post-monsoon season were observed at sampling stations namely P5 (Mynagappally Pump House) and P7 (KWA Main Pump House) indicating slightly good and very good water quality status respectively. The rainfall data collected from the Indian Meteorological Department (IMD) for the study area was analysed and it was found that, the average rainfall in the post-monsoon season was 55.4 mm/month. The runoff due to the said rainfall from the rubber plantation near P5 (Mynagappally Pump House) and the physical setting of the lake characterised by steep slope towards north east in the catchment area may be the reason for the lowest value of CPCB-NSF WQI compared to other sampling stations during the post-monsoon season.

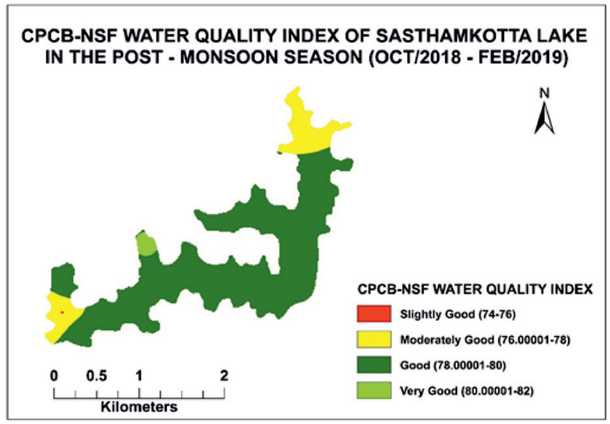


**Fig. 3.** CPCB-NSFWQI status of Sasthamkotta Lake (Post-monsoon season).

CPCB-NSF WQI values for all the twelve sampling stations for the pre-monsoon season (from the month of March 2019 to the month of May 2019) were calculated as per equation (2) and the average value of the same for the said months are also given in table 6.

The average CPCB-NSFWQI values mentioned in table 6 were interpolated using the Inverse Distance Weighted (IDW) interpolation method and the CPCB-NSFWQI status of the lake during the pre-monsoon season was mapped using Geographical Information System and the same is shown in Fig. 4. It was observed that during the pre-monsoon season, a major portion of the lake showed good water quality status. Localized very good water quality status were observed at sampling stations namely P3 (Vellinthara) and P7 (KWA Main Pump House). The lowest and highest value of CPCB-NSF WQI during the pre-monsoon season were observed

**Table 6.** CPCB-NSFWQI values inthe pre-monsoon season.

| Month Sampling stations | March 2019 | April 2019 | May 2019 | Average CPCB NSFWQI |
|---|---|---|---|---|
| P1 | 80.38794 | 74.12898 | 80.33084 | 78.28259 |
| P2 | 75.85661 | 74.98414 | 81.11313 | 77.31796 |
| P3 | 80.33991 | 79.75119 | 82.68094 | 80.92401 |
| P4 | 79.83337 | 76.27172 | 83.20219 | 79.76909 |
| P5 | 76.96858 | 73.76031 | 80.93844 | 77.22244 |
| P6 | 76.13086 | 76.81378 | 79.46602 | 77.47022 |
| P7 | 78.40383 | 79.14143 | 86.03678 | 81.19401 |
| P8 | 73.33698 | 77.60462 | 79.22083 | 76.72081 |
| P9 | 80.70131 | 76.0811 | 81.13201 | 79.30481 |
| P10 | 77.59701 | 80.43623 | 79.79311 | 79.27545 |
| P11 | 76.77288 | 76.87447 | 81.29447 | 78.31394 |
| P12 | 75.8655 | 77.2444 | 80.92652 | 78.01214 |

at sampling stations namely P8 (Near Sayippu House) and P7 (KWA Main Pump House) indicating moderately good and very good water quality status respectively. The reason for high CPCB-NSFWQI value at the sampling station P7 (KWA Main Pump House) may be due to low inhabitation as the area near sampling station P7 (KWA Main Pump House) is acquired by Kerala Water Authority as the same is the intake point for the adjacent water treatment plant. Moderately good water quality status were observed at sampling stations namely P5 (Mynagappally Pump House) and P6 (Anjalimoodu). Lack of rainfall and low runoff in the pre-monsoon season compared to that of the monsoon season could be the reason for moderately good water quality status in localised portions of the lake. Water quality parameter namely FC (ranged from 60 CFU 100 ml-1 to 290 CFU 100 ml-1) exceeded the permissible limits as per the BIS for drinking purpose at all the sampling stations throughout the pre-monsoon season. The exposure of lake to human faecal matter due to the densely populated catchment area of the lake and wastewater discharge from the adjoining Bharanikkavu town and Sasthamkotta town may be the reason for high FC count in the lake throughout the pre-monsoon season.

CPCB-NSFWQI values for all the twelve sampling stations for the monsoon season (from the month of June 2019 to the month of September 2019) were calculated as per equation (2) and the average value for the said four months are also given in Table. 7.

The average CPCB-NSFWQI values mentioned in Table 7 were interpolated using the Inverse Distance Weighted (IDW) interpolation method and the

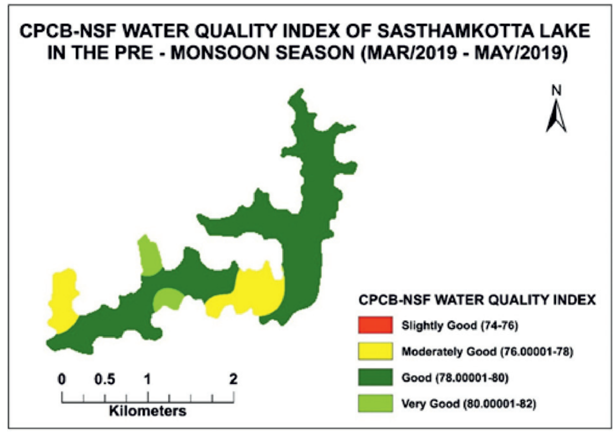


**Fig. 4.** CPCB-NSFWQI status of Sasthamkotta Lake (Pre-monsoon season).

CPCB-NSFWQI state of the lake during the monsoon season was mapped using Geographical Information System and the same is shown in Fig. 5. It was observed that during the monsoon season, the north eastern portion of the lake belonged to moderately good water quality status whereas the south western portion of the lake maintained good water quality status. The sampling station namely P6 (Anjalimoodu) recorded moderately good water quality status during the monsoon period. As the lake is surrounded by hills on three sides (In the south – east part of the lake, an artificial bund has been constructed in the year 1956 separating the lake from the surrounding lowland) and very sparse vegetation on the banks of the lake, heavy rainfall might have accelerated the surface pollutants to reach the lake through runoff from the lake catchment area which could be attributed to low CPCB-NSFWQI values observed in the north eastern portion of the lake compared to other

**Table 7.** CPCB-NSFWQI values in the monsoon season.

| Month Sampling Stations | June 2019 | July 2019 | August 2019 | September 2019 | Average CPCB NSFWQI |
|---|---|---|---|---|---|
| P1 | 76.25476 | 81.28289 | 79.71359 | 81.8714 | 79.78066 |
| P2 | 73.232 | 78.53221 | 78.45418 | 79.05338 | 77.31794 |
| P3 | 76.15382 | 82.61279 | 78.56353 | 79.88506 | 79.3038 |
| P4 | 78.91821 | 78.50789 | 76.15752 | 78.79035 | 78.09349 |
| P5 | 77.16395 | 80.92702 | 77.99511 | 78.2426 | 78.58217 |
| P6 | 76.99875 | 77.27414 | 77.4741 | 79.78125 | 77.88206 |
| P7 | 75.84914 | 81.80594 | 80.59215 | 81.25715 | 79.87609 |
| P8 | 73.56663 | 79.33249 | 78.24413 | 79.59087 | 77.68353 |
| P9 | 78.23989 | 77.41783 | 75.5444 | 77.3734 | 77.14388 |
| P10 | 76.47724 | 77.27306 | 77.62767 | 78.1476 | 77.38139 |
| P11 | 77.29983 | 80.16945 | 75.91382 | 77.94384 | 77.83173 |
| P12 | 78.73088 | 78.72187 | 74.30835 | 76.86015 | 77.15531 |

portions of the lake. Water quality parameter namely FC (ranged from 40 CFU 100 ml-1 to 200 CFU 100 ml-1) exceeded the permissible limits as per the Bureau of Indian Standards for drinking purpose at all the sampling stations throughout the monsoon season. The exposure of lake to human faecal matter due to the densely populated catchment area of the lake, runoff due to heavy rainfall in the monsoon compared to other seasons and wastewater discharge from the adjoining Bharanikkavu town and Sasthamkotta town may be the reason for high FC count in the lake throughout the monsoon season. The lowest and highest value of CPCB-NSF WQI during the monsoon season were observed at sampling stations namely P12 (Bharanikkavu) and P7 (KWA Main Pump House) indicating moderately good and good water quality status respectively. The average rainfall in the said monsoon season as per IMD was 104.4 mm/month. The runoff due to the said rainfall, discharge of effluent from the nearby Bharanikkavu town, soil erosion due to destruction of hillocks (in the north eastern portion of the lake) and the physical setting of the lake characterised by steep slope towards north east in the lake's catchment area may be the reason for the lowest value of CPCB-NSF WQI at the sampling station namely P12 (Bharanikkavu) during the monsoon season.

## CONCLUSION

In this study CPCB-NSFWQI was used to determine the water quality status of Sasthamkotta lake, a Ramsar site in the South western part of India. The results from this study indicates that the water quality of major portion of the lake falls under good category throughout the study period except the

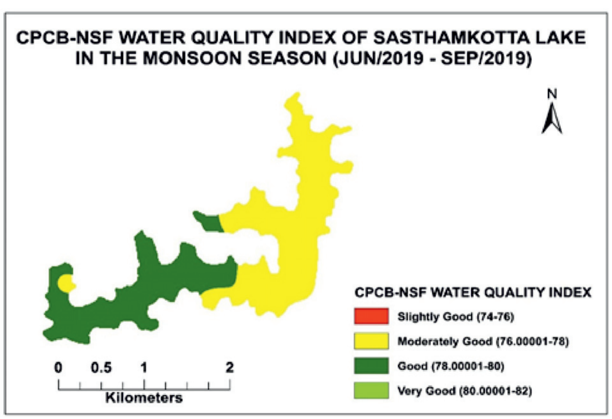


**Fig. 5.** CPCB NSFWQI status of Sasthamkotta Lake (Monsoon season).

north eastern portion of the lake which belonged to moderately good water quality status in the monsoon season. Sampling station P7 (KWA Main Pump House) reported very good water quality status in the post-monsoon season as well as in the pre-monsoon season. Moreover it could be observed that the water quality status of the lake in the monsoon season was lower compared to that of the pre-monsoon and post-monsoon seasons. As per the classification given by the Central Pollution Control Board (2001), for best designated use of water bodies, the freshwater wetland Sasthamkotta lake belongs to the category Class A during the study period. During the field visits for sampling, it was observed that the lake area is shrinking at the south western part of Anjalimoodu, Ambalakadavu and south eastern part of the bund region especially in the pre-monsoon season. As the lake is surrounded by hills on three sides and very sparse vegetation on the banks of the lake, the runoff due to rainfall, discharge of effluent from the nearby Bharanikkavu town (near P12) and Sasthamkotta town (near P8), local people using the lake water for their daily necessities (near P1 and P2), soil erosion due to destruction of hillocks (in the north eastern portion of the lake) (near P11), excess nutrient rich water flowing from the Karali marshy land (near P4) and from the agricultural fields surrounding the lake during rainfall may lead to a still lower water quality of the lake in the years to come. The FC count in the lake during the study period due to the exposure of lake to human faecal matter is alarmingly high as well. A holistic study including lake water quality, aerial shrinkage of the lake, changes in land use land cover and sediment deposition in the adjoining areas of the lake is very much essential for the conservation of the freshwater wetland Sasthamkotta lake, only after which a sustainable management plan can be arrived at.

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