Comparative Assessment of Water Quality of Ashtamudi Lake through WQI

SuryaLekshmi Prasad[1] K Mophin Kani[2]
[1,2]Department of Civil Engineering
[1]KTU, UKF CET, India [2]UKFCET, Kollam, India

Abstract**—** *the present study was carried out to assess the quality of water and to classify water quality indices at Ashtamudi Lake (Latitude 8º59'N, Longitude76 º 36'E), Kollam district, Kerala, India; is the second largest wetland in Kerala. Due to high anthropogenic activities, urbanization practices, coconut shell retting and fishing activities along the bank habitations increases pollution threat. A Water Quality Index (WQI) is a numeric expression used to evaluate the quality of a given water body and to be easily understood by decision makers. The present study intends to discusses and compares three different water quality indices, viz. arithmetic water quality index, multiplicative water quality index and Oregon water quality index which are considered for characterizing the water quality along Ashtamudi Lake through the assessment of Dissolved oxygen (DO), pH, biochemical oxygen demand (BOD),COD, electrical conductivity, total dissolved solids, turbidity, total alkalinity, total hardness, chloride, nitrate and are used as the parameters for the development of water quality indices. Most of the parameters are not with in the permissible limit except nitrate. Further with the help of software SPSS, the results were correlated. The comparison of different indices gives which water quality index is the best suitable for quality determination. The index function makes easy interpretation of results which in-turn increases the effectiveness of management strategies. The comparison of different indices showed that the arithmetic water quality index is best positively correlated with weighted arithmetic water quality index.*

Keywords— A-WQI, M-WQI, Oregon WQI, Comparison, DO, BOD, COD, EC, TDS, Turbidity, TA, TH

I. INTRODUCTION

Tremendous increase in population caused significant increase for the need of natural resources. The direct consequences are for quantity and quality of the available freshwater to human consumption. Natural water bodies are able to serve many uses, including the transport and assimilation of wastes. But as water bodies integrate these wastes, their quality changes. If the quality drops to the extent that other useful uses are adversely affected, the assimilative abilities of those water bodies have been increased with respect to those affected uses. The most fundamental human needs for water are for drinking, cooking and personal sanitation. To meet these needs, the quality of the water used must pose no risk to human health.

The current study reviews some of the important water quality indices used in water quality assessment by providing their mathematical structure. There are variety in standards of water quality index that are present. The Standards used are Arithmetic Water Quality Index, Multiplicative Water Quality Index, and Oregon Water Quality Index. The water quality of Ashtamudi Lake is worsening specially in the area joining the site with built up area of Kollam city and Neendakara. Lake in this area presently takes all untreated sewage from the Kollam city, effluents from industries, Tourism activity, fish market wastes and household waste. The off shore areas of this Lake are cultivated for coconut plantation and construction purposes resulting in the shrinking of lake. The microbial pollution is high in some sites mainly around the port area and in the Kallada River zone (Asramom, Perumpe, and Vincent Thuruthu). The agricultural practices permit the use of chemical/organic fertilizers and insecticides/pesticides, and the flow in to the lake causing pollution and Water Eutrophication (Increase of N, P, and K). The Southern portion of Ashtamudi Lake is affected by waste disposal from the Coconut husk retting, Paper mills, Tourism activity, Cashew factories and hospitals which caused in the increases of bioaccumulation of sediments. The unprocessed discharges from small-scale industries, unscientific means of fishing, food processing units, boat building yards, oil spillage and slaughterhouses makes the situation even worse [22].

II. OBJECTIVES

- To understand the idea and concepts of water quality index.
- To assess the quality of water from sampling point
- Quality determination using three different WQI methods and compare the results.
- To identify the interrelationship among the physico - chemical parameters of Lake water quality using statistical approach.
- To recommend mitigate measures to overcome the issues prevailed at lake premises

III. MATERIALS AND METHODS

A. Study Area

The maximum polluted area of Ashtamudi Lake is selected as data recording station. Neendakara area is the most polluted region of Ashtamudi Lake. Some samples were collected to measure in Laboratory. Some of the water quality parameters have been measured in situ. Neendakara area where the lake receives maximum disposal of wastes like hotel waste, plastic materials, wash water from household, markets, discharge from house boats. Upstream stream side of Neendakara is Kureepuzha where Kollam City's waste management plant is situated Kerala's only turkey farm and a regional poultry farm are at Kureepuzha. The waste produced at Kollam Corporation was collected from various localities and was dumped at Kureepuzha waste dumping site. It consists of disposal mainly from wash water of transport depot, hydrocarbons from boats, hotel wastes, markets, house hold wastes, commercial wastes. The samples were collected in acid-washed 1.5L plastic bottles every three months continuously (January, February & March-2017). Also two years (2015&2016) data is collected from Pollution Control Board, Kollam.

This study is an effort to assess the water quality of Ashtamudi Lake. For this purpose, eleven water quality parameters have been selected which are: pH, Dissolved Oxygen, Turbidity, Conductivity, Hardness, Chloride, Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Dissolved Solids, and Nitrate. And tests are done by standard APHA methods. In the formulation of WQI, the importance of various parameters depends on the intended use of water. Water quality parameters are studied from the point of view of suitability for human consumption.

Fig. 1: Neendakara.

B. Structure of Selected WQI

Four different water quality indices have been considered for comparison of water quality of Ashtamudi Lake. First one is weighted arithmetic water quality index which was originally proposed by Horton in 1965, it is then developed by Brown et al in 1972. The weighted arithmetic water quality index (WQIA) is in the following mathematical form:

$$\boxed{WQI = \sum QiWi / \sum Wi}$$

Where Q_i = Quality Rating Scale and the equation is,

$$\boxed{Qi = 100[(Vi - Vo/Si - Vo)]}$$

Where, V_i is estimated concentration of i^{th} parameter in the analysed water

V_o is the ideal value of this parameter in pure water

$V_o = 0$ (except pH =7.0 and DO = 14.6 mg/l)

S_i is recommended standard value of i^{th} parameter

The unit weight (W_i) for each water quality parameter is calculated by using the following formula:

$$\boxed{Wi = K/Si}$$

Where, K = proportionality constant and can also be calculated by using the following equation:

$$\boxed{K = \frac{1}{\sum (1/Si)}}$$

The second water quality index is a multiplicative form of index proposed by Brown et al. Later researchers have also employed a weighted geometric mean for aggregation. Here multiplicative water quality index (WQI_M) defined as follows has been used.

$$\boxed{WQI_M = \prod_{i=1}^{n} q_i^{w_i}}$$

These above two categories have been suggested to categorize the water qualities which are summarized in Table.

WQI Value	Rating of water quality
<50	Excellent
50-100	Good
100-200	Poor
200-300	Very Poor(Bad)
>300	Unsuitable For Drinking(Unfit)

Table 1: Rating of Water Quality for AWQI & MWQI.

Last one is oregon water quality index(OWQI). OWQI creates a score to evaluate the general water quality of Oregon's stream and the application of this method to other geographic regions, which combines different water quality variables into a single number. The parameters covered in this method are dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, nitrate nitrogen, total hardness, total dissolved solids, chloride, total alkalinity, turbidity and conductivity. The original OWQI was designed after the NSFWQI where the Delphi method was used for variable selection. It expresses water quality status and trends for the legislatively mandated water quality status assessment. The index is free from the arbitration in weighting the parameters and employs the concept of harmonic averaging. The mathematical expression of this WQI method is given by

$$\boxed{WQI = \sqrt{\frac{n}{\sum_{i=1}^{n} \frac{1}{SI_i^2}}}}$$

Where, n = number of sub-indices

SI = sub index of i^{th} parameter

The rating scale of this OWQI has also been categorized in various classes, which are given in table 2.

WQI Value	Rating of water quality
10-59	Very Poor
60-79	Poor
80-84	Fair
85-89	Good
90-100	Excellent

Table 2: Rating Of Water Quality

IV. Results and Discussion

The factors responsible for weakening of the Ashtamudi backwaters are pollution and encroachment. The cashew industries, tourism activities adjacent to the shores and basin without proper effluent and waste treatment facilities are the major ecological threats. Intensive coconut husk retting, oil and excreta release from house boats together with encroachment are the immediate threats. Qualitative result is obtained with water quality index. Pollution in site comes under poor water quality. The effective WQI standard out of three standard is found out. The three standards were Arithmetic Water Quality Index, Multiplicative Water Quality Index, and Oregon Water Quality Index.

Water quality indices are established from important physico-chemical parameters for different months to understand the lake water quality better for the general public. Various parameters selected for the estimation of different water quality indices are dissolved oxygen, pH, biochemical oxygen demand, chemical oxygen demand, suspended particulate matter, turbidity, nitrate, total alkalinity, total dissolved solids, conductivity and total hardness. Statistics description values of the parameters considered are given in Table below.

	A-WQI	M-WQI	O-WQI
A-WQI	1		
M-WQI	0.86	1	

O-WQI	-0.0069	-0.044	1

Table 3: Pearson Correlation Coefficient

It has been shown that AWQI & MWQI correlate well with each other. Values of the WQI can be used not only to indicate the spatial variation of lake water but also as a good indicator of behaviour of water along environmental gradients.

The results of physicochemical analysis of lake water collected from different seasons are analyzed and discussed hereby.

A. Ph

pH is one of important parameter for water quality which indicates hydrogen ion concentration in water . Present results reveals with the pH ranges 7.3 - 7.9, 6.7 - 7.8 and 7.4 -7.8 respectively for three seasons (pre monsoon, monsoon and post monsoon). Seasonal average showed a high pH in the pre monsoon and low in the monsoon. It might be due to the Industrial influence and gradual dilution of wastewater towards the farther end.

Results of the present study showed significant positive correlation with TDS, Chloride and Nitrate, negative correlation with Turbidity, conductivity, TH, COD and Total Alkalinity during pre-monsoon. In monsoon pH have positive correlation with BOD, COD, TA, best negative correlation with Turbidity. In post monsoon, pH have positive correlation with BOD, COD and best negative correlation with turbidity.

B. DO

Dissolved oxygen refers to the level of free, non-compound oxygen present in water or other liquids. It is an important parameter in assessing water quality because of its influence on the organisms living within a body of water. A dissolved oxygen level that is too high or too low can harm aquatic life and affect water quality.

In the present study when the seasonal mean values were compared, the highest dissolved oxygen was noticed during the monsoon period and the least in the premonsoon period .It was also found that the DO values ranged from of 4.1-5.9 mg/L, 4.5 - 6.8 mg/L, and 3.9-6.1 mg/L respectively in three seasons (pre monsoon, monsoon & post monsoon).

In pre monsoon a significant positive correlation was obtained with Turbidity, Conductivity, Total Hardness, COD and alkalinity. And negative correlation is obtained with BOD, TDS, Chloride, and Nitrate. In monsoon and post monsoon, positive correlation is obtained with pH and best negative correlation with BOD, COD, and TDS.

The high dissolved oxygen content in the monsoon season may be due to the influx of freshwater into the estuarine system and heavy rain fall which lead to the dilution of water Body. Depletion of oxygen in the premonsoon seasons is probably due to the influence of various physico-chemical parameters in the lake waters.

C. BOD

BOD also called biological oxygen demand it is the amount of dissolved oxygen needed by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period. BOD values varied in the present study from 2 – 2.8 mg/L, 2 – 4.6 mg/L, 2 – 3.8 mg/L respectively in pre monsoon, monsoon & post monsoon. A significant positive correlation was obtained between COD, TDS, TH, Total alkalinity, Chloride with three seasons. A significant negative correlation obtained between turbidity and three seasons.

High BOD it is an excellent indicator of the presence domestic and industrial pollutant in the aquatic system. The high BOD values might be due to the mixing of high oxygen demanding substances from the industrial wastewater. Dissolved or suspended organic material in the debris enhances the biochemical oxygen demand of the polluted water. Seasonal variation showed maximum BOD in the monsoon, followed by post monsoon and pre monsoon.

D. Turbidity

The turbidity arises due to the presence of suspended and colloidal matters such as clay, silt, finely divided organic and inorganic matter and plankton and other microscopic organisms in the water body. The turbidity in the water samples from lake ranged from 24 NTU in post monsoon to 26 NTU in monsoon season.

The extent of turbidity in an aquatic system is generally taken as a measure of pollution intensity. The highest turbidity observed in the monsoon season in the estuary might be due to the heavy rain fall, influx of freshwater from the river and heavy wind which stirs up the muddy bottom sediments of the shallow waters of the backwaters.

This could lead to poor light penetration in the monsoon season. The high turbidity (27NTU) in the pre monsoon season lake can be attributed to the poor water circulation and mixing of industrial discharge

Turbidity was found positively correlated with conductivity, total hardness, COD, total alkalinity and negatively correlated with TDS, chloride, nitrate during pre-monsoon. In monsoon and in post monsoon turbidity is positively correlated with total hardness, conductivity, nitrate, COD and negatively correlated with total alkalinity.

E. Conductivity

Electrical Conductivity is a measure of waters capacity to conduct electric current. If conductivity increases, it indicates the presence of dissolved ions. Conductivity can serve as an indicator of water quality problems. Electrical conductivity of samples studied varied from 32.12 to 69.22 µS/cm in pre monsoon, 27.98 to 48.65 µS/cm in monsoon and 31.45 to 57.20 µS/cm in post monsoon.

In the present study high electric conductivity was observed during premonsoon season compared to monsoon season, which might be due to the high salinity and it decreased after rainfall following increase in inflow resulting dilution of water and also due to the high evaporation rate in premonsoon.

Results of present study reveals that significant a positive correlation was obtained between total hardness, COD, Total alkalinity and a negative correlation obtained with TDS, Chloride, Nitrate during pre-monsoon. In monsoon and post monsoon, positive correlation is obtained with total hardness, COD, TDS, Chloride, Nitrate, total alkalinity.

F. Total Hardness

Hardness is caused by carbonates and bicarbonates and is important for aquatic organisms. In this study the hardness values ranged from 4600 mg/L to 6400 mg/L in pre monsoon, 2200 mg/L to 11200 mg/L in monsoon and 3000 mg/L to 12400 mg/L in post monsoon. A high value of total hardness was observed in the post monsoon season and low value in pre monsoon season. As per IS10500-2012 desirable limit of hardness is 200mg/l and permissible limit 600mg/l. The lake water in present study where not within permissible limits.

Results from the present study reveals a significant positive correlation with COD and total hardness in pre monsoon and post monsoon and negative correlation with TDS, Chloride, and nitrate. In post monsoon total hardness give positive correlation with total hardness, COD, TDS, chloride, nitrate and total alkalinity.

G. COD

Chemical oxygen demand (COD) is an important parameter in judging organic pollution. Seasonal variation in COD was 48 mg/l to 129 mg/l in pre monsoon, 48 mg/l to 96 mg/l in monsoon, 48 mg/l to 128 mg/l in postmonsoon. The maximum average COD value was obtained in premonsoon. COD measures the total quantity of oxygen required to oxidize all organic materials into carbon dioxide and water by chemical oxidation. The major COD materials are reduced chemicals other than organic matter, therefore higher values of COD indicate the presence of oxidisable organic matters. COD tests also measure the oxygen demand created by toxic organic and inorganic compounds as well as by biodegradable substances. The present study revealed that the COD values in most of the stations appear to be higher than the acceptable limit for drinking water (4 mg/l). Though the COD values are very high in the premonsoon season, there was a significant decline during monsoon season probably due to the influx of freshwater and heavy rain fall resulting in the dilution of estuarine water to some extent. COD has best positive correlation with turbidity, total hardness and DO, negative correlation with BOD in premonsoon. In monsoon and post monsoon, best positive correlation with total hardness and conductivity and best negative correlation with BOD.

H. TDS

The TDS from three seasons varies from 22942 mg/L to 48581 mg/L in premonsoon, 19985 mg/L to 57200 mg/L in monsoon, 22150 mg/L to 4000 mg/L. The highest value of TDS was in the monsoon.

High levels of dissolved solids reduce solubility of gases and utility of water for drinking, influence osmoregulation of freshwater organisms, irrigation and industrial purpose and also increase the density. In the present investigation the high TDS level is generally due to the accumulation of different pollutants.

TDS have positive correlation with total alkalinity in premonsoon. In monsoon and post monsoon, turbidity is positively correlated with chloride, nitrate, and total alkalinity.

I. Chloride

It is one of the important indicators of pollution. Form the present study chloride content in water samples ranged from 13200mg/L to 24500mg/L in premonsoon, 3000mg/L to 21700mg/L in monsoon, 10900 mg/L to 21700mg/L. Seasonal data showed that the lowest value was obtained in the monsoon season. Maximum value in the premonsoon season. The seasonal average showed that highest value in the pre monsoon followed by post monsoon and monsoon season. Chloride is found positively correlated with BOD, TDS and negatively correlated with total alkalinity in pre monsoon, monsoon and post monsoon.

J. Nitrate

It is the oxidized form of nitrogen and the main source of inorganic and organic nitrogen in estuary. The main sources of nitrogen are municipal and industrial wastewater, fertilizers, atmospheric fall out, soil organic matter etc. The seasonal variations of nitrate in the Ashtamudi Lake are 1.2 mg/L to 3 mg/L in pre monsoon, 1.4 mg/L to 1.9 mg/L in monsoon, 1.2 mg/L to 4.8 mg/L in post monsoon. A low concentration of nitrate was observed in monsoon season. It determines the organic pollution in water. In the present study high concentration of nitrate was noticed (4.8 mg/L in post monsoon). Highest concentrations of nitrate indicate the influence of industrial discharge to enhance the high nutrient level in the estuary. Generally nitrate was found maximum during post monsoon season followed by pre monsoon and monsoon. Because in post monsoon the contribution from both sides almost equal and in pre monsoon season the riverine contribution became very small. Nitrate showed positive correlation with Turbidity and Total Hardness and negative correlation with DO, pH.

K. Total Alkalinity

The alkalinity measures the capacity of water to neutralize acids. The total alkalinity ranged from 98 mg/L to 160 mg/L in the pre monsoon season, from 76 mg/L to 168mg/L in the monsoon and from 88 mg/L to 168 mg/L during post monsoon. Alkalinity measures the capacity of water to neutralize acids and is influenced by the presence of alkaline compounds in the water such as bicarbonates, carbonates, and hydroxides. The measured alkalinity value includes borates, phosphates, silicates and other bases present in the water body (APHA, 1995).

Best positive correlation with pH in pre monsoon, best negative correlation with nitrates and turbidity in pre monsoon. During monsoon best positive correlation with chloride and TDS, and negative correlation with DO, turbidity and nitrate. In post monsoon there is a best positive correlation between pH.

L. Comparison of WQI

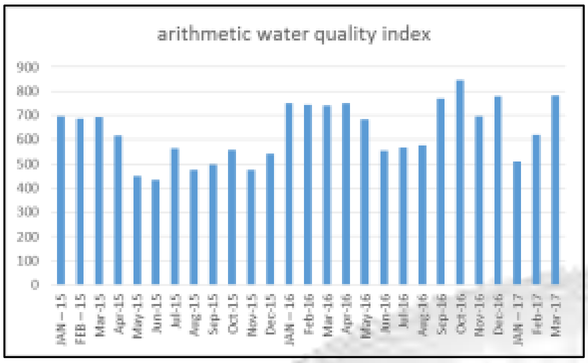

Fig. 2: Graphical representation of Arithmetic WQI from January2015 to March2017

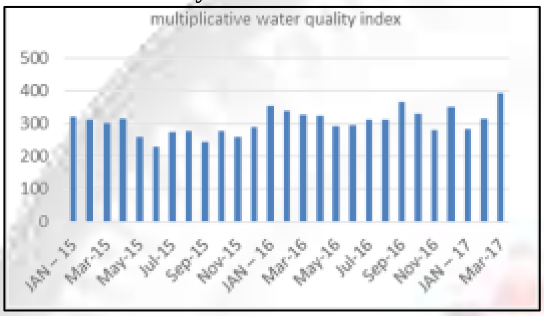

Fig. 3: Graphical representation of Multiplicatie WQI from January2015 to March2017

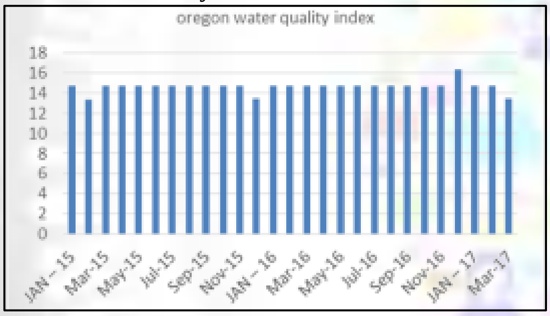

Fig. 4: Graphical representation of Oregon WQI from January 2015 to March2017

The results of arithmetic water quality index show no expected development except that lower value of water quality index has been observed in May & June 2015.A water quality index appears to meet the requirements as a tool designed to advise decision makers and the public of the water quality levels but does not show the specific pollution problem of a water body. In other words, an index will provide a general indication of water quality but will not indicate which pollution related parameters exceed the required criteria, which uses are impaired, and why a particular poor (or good) condition exists. In all the three cases water quality is very poor.ie in A-QWI, obtained WQI value is > 400. From the rating chart (1.4.1) water is unsuitable for drinking. Similar with M-WQI. The third index which is Oregon WQI gives an average index value of 14.From the rating chart of O-WQI, Index value between 10 to 59 comes in poor water quality. Also O-WQI graph is more constant.

Water quality is a qualitative concept subject to personal interpretation. The above mentioned approach to the development of a water quality index attempts to quantify this concept through aggregating related parameters. An index is designed to measure water quality, not to predict water quality. In essence, a water quality index should be viewed as a way to interpret raw water quality data or as a level of data analysis. This level of analysis is different from the study of individual water quality parameters in that it is more general and incorporates a greater degree of subjectivity. Because of this subjective nature, development of a meaningful index is very difficult, not to mention its verification. Based on the experience gained a widely-accepted water quality index would have to possess the following important features:

- Be easily understood by the public.
- Include major pollutants and be capable of including potential pollutants.
- Relate to water quality criteria and goals for different water uses.
- Not be inconsistent with the perceived water quality levels.
- Be based on a reasonable scientific premise.
- Be calculated in a simple manner using reasonable assumptions.

At the present time, an index meeting the above features or criteria is non-existent. It is apparent that further refinement, verification and application of the existing indices are needed before they can be relied upon for measuring water quality, and in turn, for generating public concern for the aquatic environment.

M. Merits & Demerits of A-WQI

Table below lists the advantages and disadvantages of an arithmetic water quality index.

Advantages	Disadvantages
Incorporate data from multiple water quality parameters into a mathematical equation that rates the health of water body with number.	WQI may not carry enough information about the real quality situation of the water.
Less number of parameters required in comparison to all water quality parameters for particular use.	Many uses of water quality data cannot be met with an index
Useful for communication of overall water quality information to the concerned citizens and policy makers.	The eclipsing or over-emphasizing of a single bad parameter value
Reflects the composite influence of different parameters. i. e. important for the assessment and management of water quality.	A single number cannot tell the whole story of water quality; there are many other water quality parameters that are not included in the index.
Describes the suitability of both surface and groundwater sources for human consumption.	WQI based on some very important parameters can provide a simple indicator of water quality.

Table 4: Merits & Demerits of A-WQI

N. Merits & Demerits of M-WQI

Advantages	Disadvantages
Measures general water quality	Does not measure water pollution
Single number for overall water quality	Insensitive to individual problem parameters
Good for communicating with the layman	Poor for addressing particular technical problems
Standardized so that different geographic areas can be directly compared	Does not take into account local natural background water quality effects
Many water experts' opinions taken into account when formulating WQI	Somewhat arbitrary and lack of a firm scientific basis

Table 4: Merits & Demerits of M-WQI

O. Merits & Demerits of Oregon WQI

Advantages	Disadvantages
Un-weighted harmonic square mean formula used to combine sub-indices allows the most impacted parameter to impart the greatest influence on the water quality index.	Does not consider changes in toxics concentrations, habitat or biology.
Method acknowledges that different water quality parameters will pose differing significance to overall water quality at different times and locations.	To make inferences of water quality conditions outside of the actual ambient network site locations is not possible.
Formula is sensitive to changing conditions and to significant impacts on water quality.	Cannot determine the water quality for specific uses nor can it be used to provide definitive information about water quality without considering all appropriate physical, chemical and biological data. Also cannot evaluate all health hazards (toxics, bacteria, metals, etc.).

Table 4: Merits & Demerits of O-WQI

V. Conclusion

The aim of study was to calculate water quality index and to determine water quality of lake water. The results reveal that the lake water quality is not agreeable with IS standards recommended for drinking purposes. Only nitrate level was found to be present within permissible limit. WQI of lake by three methods is calculated and it showed that the water quality comes under very poor water quality. It has been shown that AWQI & MWQI correlate well with each other. Out of which multiplicative WQI correlative well with arithmetic WQI.

According to the Wetland (Conservation and Management) Rules, 2010, formulated by the Ministry of Environment, Forest and Climate Change, the water bodies listed under the Ramsar Convention are not to be polluted or encroached upon. In the case of Ashtamudi Lake have been polluting and encroaching upon the lake. Mitigation measures that can be taken are Pollution sources should be identified and priority list is to be prepared, Plan of actions to reduce pollution load is to be made, Reclamation of lake is to be halted, Stop sand mining, Upgrade sanitation facilities, boat fuelling area and better drainage systems near the lake to keep fish quality at its best, Can continue coir retting but phase out the waste pith before it pollute water, alternative waste disposal site and waste by products can be identified and used as a manure, municipal solid waste disposal system should be used in an effective way, A comprehensive public awareness programme is to be conducted to improve the aesthetic environment near the Lake.

References

[1] A. K. Gupta (2007), "A Comparison Of Water Quality Indices For Coastal Water, Journal Of Environmental Science And Health" , Vol. A38, No. 11, pp. 2711–2725
[2] A.L. Muthulakshmi (2013)," Assessment Of Water Quality Through Indices Around Kalpakam, South East Coast Of India ", Arch. Environ. Sci., Vol 7
[3] Arthur Mynett et al (2013),"On Challenges For 2d Water Quality Modelling Of Lake Taihu In China", Environmental Engineering and Management Journal, Vol.12, No. 5, 1031-1044
[4] B. Rajesh(2015), "Assessment Of Ground Water Quality Using Water Quality Index", Journal of Environmental Engineering, Volume 11, Issue 1,61-69
[5] Curtis G. Cude (2001), "Oregon Water Quality Index A Tool For Evaluating Water Quality Management Effectivesness", Journal Of The American Water Resources Association , Vol. 37, No. 1 , 125-136
[6] D.Dhaarani (2015), "Water Quality Analysis on Yercaud Lake ", The Asian Review of Civil Engineering, Vol. 4 No. 1, pp.28-31
[7] Dilip H. Tambekar(2011), "Groundwater quality and water quality index at Bhandara District", Journal Of Environmental Monitoring Assessment, Vol 179,issue 1,619-625.
[8] Fernando Bezerra Lopes (2014),"Water quality index calculated from biological, physical and chemical attributes", Journal Of Environmental Monitoring Assessment, Vol 10, 1-15
[9] Fredy Solano(2004), "Physico-chemical water quality indices – A Comparative Review", Journal Of Food & Agriculture, Vol 1,1-16
[10] G. Deepa(2014), "Water Quality Index Of Chitrapuzha River, Ernamkulam, Kerala, India" International Journal of Research Studies in Science, Engineering and Technology,Vol 1(7), 17-23
[11] Gopal Krishan(2016),"Water Quality Index of Groundwater in Haridwar District, Uttarakhand, India", Water & Energy International,Vol 58(10),55-58
[12] Manish Pal(2016),"Water Quality Index for Assessment of Rudrasagar Lake Ecosystem", International Journal Of Engineering Research And Applications, Vol6(1),98-101

[13] Irena Naubi (2016)," Effectiveness of Water Quality Index for Monitoring Malaysian River Water Quality", Pol. J. Environ. Stud. ,Vol. 25, No. 1, 231-239
[14] Jithu U. Krishnan (2015), "Pollution Status of Ashtamudi Lake, Kerala, India and Its Impact on Some Key Stone Mangrove Species - A Case Study", International Journal of Innovative Studies in Aquatic Biology and Fisheries, Volume 1, Issue 2, Jul-Sep 2015, pp 17-22.
[15] K. Siva Rama Krishna (2005), "Determining Water Quality Index for the Evaluation of Water Quality of River Godavari", International Journal Of Engineering Research And Applications,Vol 1(2),174-182
[16] Mano Mohan Antony (2016) , "A Hydrological Study of Ashtamudi Lake, Kerala, India with Special Reference to its Ecological Difference" , International Journal of Science and Research, Vol 5 , Issue 8, August 2016
[17] Mohammad Taghi Vakili (2015),"Prediction of water quality index in free surface constructed wetlands", Journal Of Environmental Earth Sciences,Vol 75(2),1-12
[18] Monika Dubey (2016), "Water Quality Index (WQI) of Sarangpani Lake,Bhopal (India)",Journal of environment & ecology,Vol34(4),2475-2479
[19] Munirah Abdul Zali (2011),"Sensitivity Analysis for Water Quality Index (WQI) Prediction for Kinta River, Malaysia", World Applied Sciences Journal, Vol 14,60-65
[20] Muslimin (2013)," Study of water quality status in Gajahwong river using several water quality indices", Lingkungan Tropis, Vol. 6(2), 91-103.
[21] Nagaraj Sitaram (2014)," Impact Of Urbanisation On Water Quality Parameters – A Case Study Of Ashtamudi Lake Kollam", International Journal of Research in Engineering and Technology, Vol 3, Issue 6,May 2014.
[22] Ohiemi Michael (2012),"Underground Water Assessment using Water Quality Index", Leonardo Journal of Sciences, Vol 21,33-42.
[23] Paiu Madalina (2012), "Water quality index – An instrument for water resources management", Journal of environment & ecology,Vol3,15-21
[24] Prasoon Kumar Singh (2013), "Water Quality Indices Used For Water Resources Vulnerability Assessment Using GIS Technique: A Review in the year 2013", International Journal of Earth Science Engineering, Vol(6),1594-1600
[25] Prerna Sharma (2014), "Changes in water quality index of Ganges river at different locations in Allahabad", Sustainability of Water Quality and Ecology, Vol 3(4),67–76
[26] Purushottam Sarda (2015),"Water Quality Index and Management of Surface Water using Soft Tool", International Journal of Science, Engineering and Technology Research (IJSETR), Volume 4, Issue 9
[27] Nagaraj Sitaram (2014),"Impact of Urbanisation on Water Quality Parameters", International Journal of Research in Engineering and Technology , Vol 3,Issue 6
[28] Ragunadhan MB(2007),"Faunal Diversity of Ashtamudi Wetlands",Kerala, Occasional Paper No.276
[29] Razeena Karim et al (2012) ," Muncipal Solid Waste Dumping On Ashtamudi Lake,Kollam, Kerala ,An Overview", An International Quarterly Journal Of Environmental Sciences, Vol 1,278-286
[30] Sikder M.T(2015), "Vulnerability assessment of surface water quality with an innovative integrated multi-parameter water quality index ", Journal of Pollution, Vol 1(3): 323-336
[31] Shweta Tyagi (2013)," Water Quality Assessment in Terms of Water Quality Index", American Journal of Water Resources, Vol. 1, No. 3, 34-38
[32] S. Kalavathy (2011), "Water Quality Index of River Cauvery in Tiruchirappalli district, Tamilnadu", Arch. Environ. Sci., Vol 5,55-61
[33] Srikanth Satish Kumar Darapu (2015)," Determining Water Quality Index for the Evaluation of Water Quality of River Godavari ", International Journal of Engineering Research and Applications, Vol. 1, Issue 2, pp.174-182
[34] S. Suratman (2015), "The Priliminary Study Of Water Quality Index In Teregganu River Basin Malasia" ,Sains Malasia ,Vol 44 , Issue 1 , pp 67- 73
[35] Suman Singh (2010),"Evaluation Of Ganga Water For Drinking Purpose By Water Quality Index At Rishikesh, Uttarakhand, India", Arch. Environ. Sci., Vol 4,595-601
[36] Suma.S (2012), "Analysis Of Effluents Discharged To Ashtamudi Lake From China Clay Industries", International Journal of Chemistry Research ISSN, Vol 3, Issue 1
[37] Sundara Kumar Kusuma (2015), "Assessment Of Ground Water Quality Using Water Quality Index", International Journal of Innovative Research in Advanced Engineering, Vol 2,Issue 3
[38] Tahera Akter (2016)," Water Quality Index for measuring drinking water quality in rural Bangladesh: a cross sectional study", Journal of Health, Population and Nutrition , Vol 35 , Issue 4
[39] Tirkey Poonam (2013), "Water Quality Indices-Important Tools For Water Quality Assessment A Review", International Journal of Advances in Chemistry (IJAC) , Vol.1, No.1, November 2013 , pp 15-28