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Trend Analysis of Water Quality Monitoring data of Vembanad Lake: The Largest Ramsar Site on the South West Coast of India

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Abstract*— The present work was carried regarding the 5 year (2013- 2017) trend analysis of Vembanad lake water quality monitoring data. The lake has rich biodiversity and socio-economic importance. Data for analysis procured from CPCB (National Water Quality Monitoring Program) includes the physio-chemical parameters both core and general like the pH, temperature, conductivity, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), alkalinity, nitrate (NO_3), hardness, total dissolved solids (TDS),total suspended solids (TSS), Feacal Coliform (FC) and Total Coliform (TC). The trend graphs were prepared in order to further analyze and compare with the guidelines for drinking purpose suggested by CPCB and BIS. The results show most of the parameters to be fluctuating, while some parameters did show significant changes over the span of the past 5 years. DO, BOD, COD, alkalinity TDS were found to be complying with the standards with a decreasing trend line. Whereas, Fecal Coliform (FC) and Total Coliform (TC) values display a positive trend line showing an improvement in the water quality of the lake. Other general parameters like the pH, conductivity, alkalinity, nitrate, hardness and TSS were found to be fluctuating or moderately varying over the years. Thus, from the trend analysis it can be depicted that the continued degradation of wetlands will result in further impoverishment of human health especially for vulnerable people in developing count. By researching and evaluating the relationship between previous studies and current trend of the water quality, in Vembanad lake development of proper strategies and management plans should take place for the conservation and management of the lake ecosystem.

***Keywords*— Parameters, Standards, Trend analysis, Trend graphs, Vembanad lake water, Water quality**

I. INTRODUCTION

The water quality of various water resources whether lentic or lotic is a growing concern among both researchers as well as common people. Assessing long-term water quality changes is also a challenge for many countries. During the last few decades, there has been an increasing demand for monitoring water quality of many lakes by regular measurements of various water quality variables. The wetlands and rivers, store more than 90% of the liquid fresh water on earth surface, are important for human development due to the important ecosystem and livelihood supports they provide. The environmental conditions of most lakes are in a steady decline due to severe anthropogenic pressures and deserve immediate conservation attention to overcome the imminent water crisis. Vembanad Lake (Kerala) - the largest tropical wetland ecosystem on the southwest coast of India is next to the Arabian Sea which supports maximum livelihood activities in the state. Apart from this, Vembanad Lake has immense conservation importance hence designated as a Ramsar site [1]. Since, livelihood activities of a large number of people are directly dependent on the Lake, the deterioration of extent and quality of the lake leads to increased conflicts. Degradation of Vembanad has significant implications for ecological and economic security of the entire coastal zone of Kerala. The removal of such wetland systems because of factors like urbanization and other anthropogenic factors causes lake water quality to worsen. Wetlands are important feeding and breeding areas for wildlife and provide a stopping place and refuge for waterfowl. As with any natural habitat, wetlands are also important in supporting species diversity and have a complex of wetland values [2].

II. STUDY AREA

Vembanad Lake, a Ramsar site in Kerala, is located in southwest India. It lies 0.6–2.2 m below mean sea level (MSL) along the south west coast of India ($9^0$35/N $75^0$25/E). It is the longest lake in India and a coastal lagoon, with a length of 96 km and a surface area of 2,033 km² with ten rivers draining into it [3]. This wetland system is a complex aquatic system of

coastal backwaters lagoons, marches, mangroves and reclaimed lands inland and intricate network of natural and man-made channels.

The wetland also includes the Kol lands, the fertile low lying fields as the name implies, lying 0.5m to 1m below mean sea level, spread over an area of 136.32 km^2. The lake is bordered by Alappuzha, Kottayam, and Ernakulam districts. Many canals link the lake to other coastal lakes in the north and south. Also the lake surrounds three islands which are Pathiramanal, Perumbalam and Pallippuram [4]. At it's widest point the Vembanad Lake is approximately 14 kilometres. The lake is fed by 10 rivers flowing into it including the six major rivers of central Kerala namely the Achenkovil, Manimala, Meenachil, Muvattupuzha, Pamba and Periyar [5]. In 1976 alterations in natural hydrologic regime of Vembanad wetland occurred due to the commissioning of Thanneermukkom barrage (TMB) across the backwater system to prevent saline water intrusion, which in-turn adversely affected the physic – chemical parameters of the water body. In recent decades, areas near the Vembanad lake have been characterized by fast increasing population density and intense anthropogenic activities followed by construction of regulators, spillways, overexploitation of resources and uncontrolled urbanization that has been adversely affecting effecting the lake's water quality [3].

Fig. 1 Map showing the Sampling Station (Pathramanal) in Lake Vembanad

III. Materials and Methods

Water quality data was obtained from India's National Water Quality Monitoring Program, which is in operation since 1976. Presently the inland water quality-monitoring network is operated under a three-tier programme i.e. Global Environment Monitoring System (GEMS), Monitoring of Indian National Aquatic Resources System (MINARS) and Yamuna Action Plan (YAP). Water samples are being analyzed for 28 parameters consisting of 9 core parameters, 19 other physico-chemical and bacteriological parameters apart from the field observations [6].

The Central Pollution Control Board (CPCB) has established a network of monitoring stations on aquatic resources across the country. The monitoring network covers 235 lakes, 90 ponds and 95 tanks [7]. This research paper particularly deals with Vembanad Lake in Alappuzha, Kerala. The water samples were collected from Vembanad Lake at Pathiramanal (Alappuzha), Kerala station (station code 2312) and then analysed for different parameters during (2013-2017) five year period by the Kerala State Pollution Control Board and Pollution Control Committee. Then, these samples were sent to the laboratory where tests were conducted under controlled conditions to determine the concentration. Results of the performed tests were sent to Central Pollution Control Board (CPCB), Delhi on monthly basis which is further analysed below.

TABLE 1: RECOMMENDED METHODS FOR PHYSIO-CHEMICAL ANALYSIS OF WATER

S.no	Parameter analyzed	Units	Recommended methods
A. Physio-chemical Parameters			
1	pH	_	pH meter
2	Temperature	°C	Thermo metric method
3	Conductivity	mS	Conductometric method
4	DO	mgO_2 /l	Iodomeric method
5	BOD	mgO_2 /l	Dilution method
6	COD	mg/l	Dichromate Reflex method
7	Alkalinity	mg/l	Visual titration method
8	Nitrate	mg/l	Amalgamated Cadmium reduction of nitrate to nitrite by dissociation method
9	Hardness	mg/l	EDTA titrimetric
10	Total Dissolved Solids	mg/l	Gravimetric method
11	Total Fixed Solids	mg/l	Gravimetric method
12	Total Suspended Solids	mg/l	Gravimetric method
B. Bacteriological Parameters			
13	Feacal Coliform	MPN/100ml	Multiple tube dilution or membrane dilution method
14	Total Coliform	MPN/100ml	Multiple tube dilution or membrane dilution method

Source**:** A guide manual by Central Pollution Control Board, New Delhi

IV. RESULTS AND ANALYSIS

A. pH

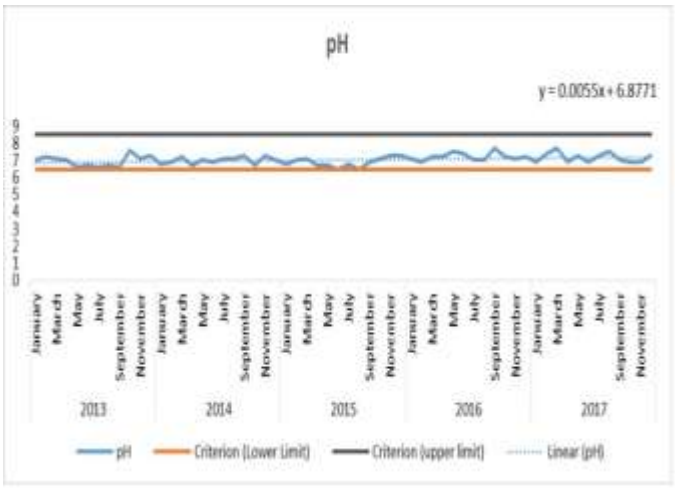

Fig 2: Graphical representation of pH values over the years

Based on the experimental results over the years, the pH was within the limits of the standard values.
For drinking water, a pH range of 6.5 – 8.5 is recommended [8]. According, to BSI Guidelines Value, pH of the lake has been found complying to the recommended range [9]. It has been mentioned that the increasing pH appear to be associated with increasing use of alkaline detergents in residential areas and alkaline material from wastewater in industrial areas [10]. However, on analysing the trend of pH over the years (2013-2017) it was found that pH values are shifting towards alkalinity. Therefore, the pH of Vembanand Lake ranges from 6.5 to 7.7, indicating that water of Vembanand is almost neutral in nature.

B. Temperature

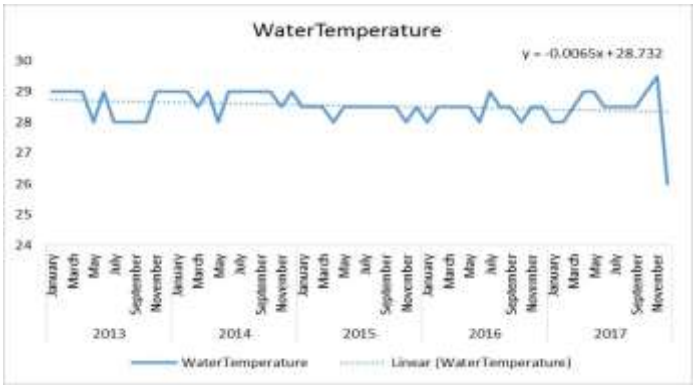

Fig 3: Graphical representation of values of Water Temperature over the years

The temperature of water is one important parameter which directly influences some chemical reactions in the aquatic systems. While analyzing the trends of the temperature variation of Vembanad Lake over the last 5 years, the maximum temperature was recorded in the year 2017 which was 29.5^{0}C and the minimum temperature was recorded in the year 2017 which was 26^{0}C. The significant correlation between ambient temperature and water temperature was studied by (Ganpati 1943, 1962 and Verma 1967) [11]. Due to seasonal variation, temperature fluctuation range was observed to be +1.5^{o}C to -1.5^{o}C in a year. The variation in water temperature may be due to different timing of collection and the influence of season[12]. However, 2017 observed the maximum fluctuation of 3.5^{o}C with 29.5^{o}C recorded in November 2017 and 26^{o}C in December 2017.

C. Conductivity

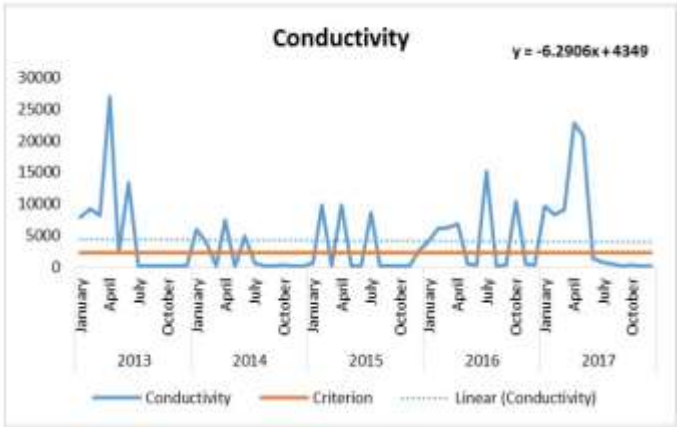

Fig. 1 Graphical representation of conductivity over the years

As per the standards set by CPCB, conductivity is found beyond 2250µS/cm for majority of the time sampling was made in last five years (2013-2017) [9]. Indicating that the conductivity of the lake is non-complying to the standards, it stands unfit for consumption by humans and also for the survival of lake's native flora and fauna. Conductivity is a good and rapid method to measure the total dissolved ions and is directly related to total solids [13]. It makes water hard due to dissolution of magnesium and calcium in water [14]. The higher value of EC is attributed to the high degree of anthropogenic activities like waste disposal, household waste, and chemicals runoff from agricultural and apiculture activities [15]. Altogether, the trend observed for the EC depict decline in conductivity over the years.

D. Dissolved Oxygen

All living organisms are dependent upon oxygen in one form or the other to maintain the metabolic processes that produce energy for groewth and reproduction. Aerobic processes are of great interest, which need free oxygen for wastewater treatment. Dissolved Oxygen (DO) is also important in precipitation and dissolution of inorganic substances in water [16]. The DO values also depend on many factors like temperature, microbial population, pressure, and time of sampling [15]. The value of Dissolved Oxygen is remarkable in determining the water quality criteria of an aquatic system [17]. According to the Indian Standards, minimum DO level is recommended to be 5mg/l below which lake is said to be polluted [9].

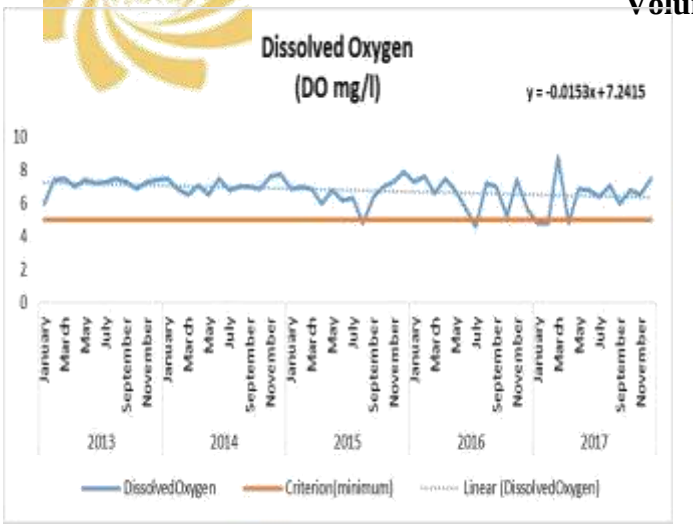

Fig 4 : Graphical representation of values of DO over the years

Although the values of DO are not alarmingly declining only very slight decline has been seen which is expected to further decrease if the cause is not identified and altered. Most waste water contains more oxygen demanding material than the amount of DO available in air saturated water. Low level indicates an excessive demand on the oxygen in the water. The minimum dissolved oxygen limit for fish growth is 4.0 mg/l [18].

E. Biological Oxygen Demand

The Biochemical Oxygen Demand (BOD) measures the amount of oxygen required for aerobic oxidation of decomposable organic matter and certain inorganic matter in water [19]. The test is applied for fresh water sources (rivers, lakes), wastewater (domestic, industrial), polluted receiving water bodies, marine water (estuaries, coastal water) and also for finding out the level of pollution, assimilative capacity of water body and also performance of waste treatment plants [16].

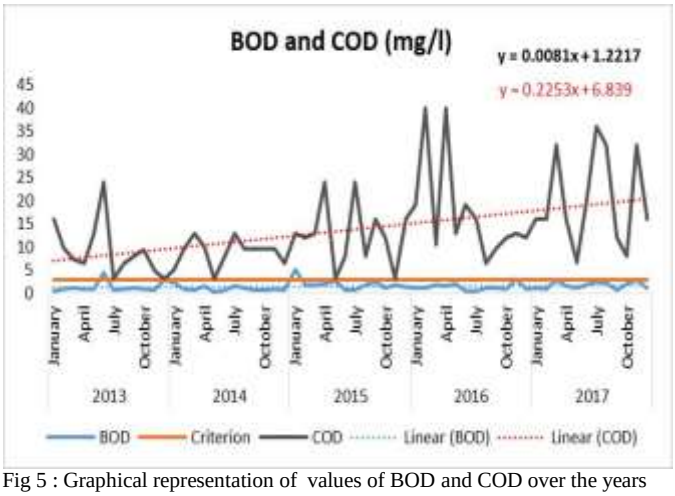

Fig 5 : Graphical representation of values of BOD and COD over the years

The BOD level observed for last 5 years (2013 – 2017) of the Vembanad Lake was found to be complying with the standards whereas when the graphical trend observed, it shall show gradual increase in the values of BOD if the causative agent is not altered. BOD has been a fair measure of cleanliness of any water on the basis that values less than 1-2 mg/l are considered clean, 3 mg/l fairly clean, 5 mg/l doubtful and 10 mg/l definitely. BOD was found to be exceeding the permissible limits in all the stations [20]. Chemical Oxygen Demand (COD) test determines the oxygen requirement equivalent of organic matter that is susceptible to oxidation with the help of a strong chemical oxidant.

It's an important and rapidly measured parameter as a means of measuring organic strength for streams and polluted water bodies. COD must be 4 times of the value of BOD [16]. It can be depicted from the graph made by analysing 5 year data of BOD and COD that the COD values higher than the given criteria i.e. 4 times of BOD. On observing the trend of COD, it was found that concentration of COD has been increasing drastically since 2016.

F. Nitrate

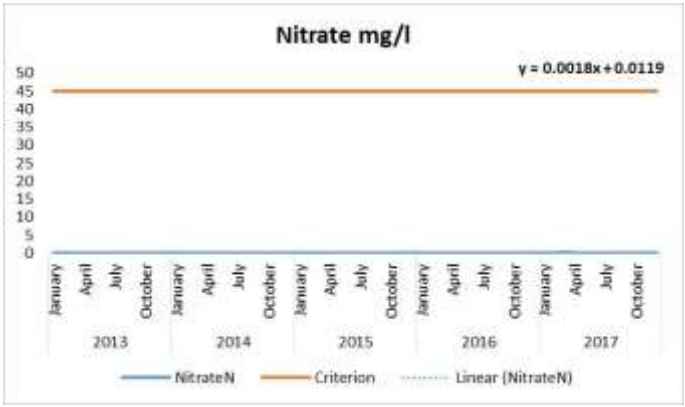

Fig 6: Graphical representation of values of Nitrate concentration over the years

The main sources of nitrate in water are human and animal waste, industrial effluent, use of fertilizers and chemicals, silage through drainage system [21]. According to the Indian standards, Nitrate value beyond 45mg/l makes it unfit for human consumption [9]. Over the years (2013-2017) the standard value is way beyond the observed one. Thus, with respect to nitrate concentration the lake water remains fit for human consumption.

However, equation of the trend line depicts increase in nitrate concentration which stands negligible in terms of pollution.

G. Faecal Coliform

Feacal Coliform (FC) is the most important core parameter for assessment of a water-body. It directly accounts for the intensity of human and animal waste in the water-body. According to the Indian Standards recommended desirable limit for Feacal Coliform is 500MPN/100ml whereas permissible limit is 2500MPN/100ml [9]. Till 2015 Fecal Coliform was above desirable value. The increasing presence of pollution indicator bacteria in river water is a

frequent hitch in urban and rural areas, often leading to outbreaks of serious water-borne diseases like cholera, dysentery, etc [22]

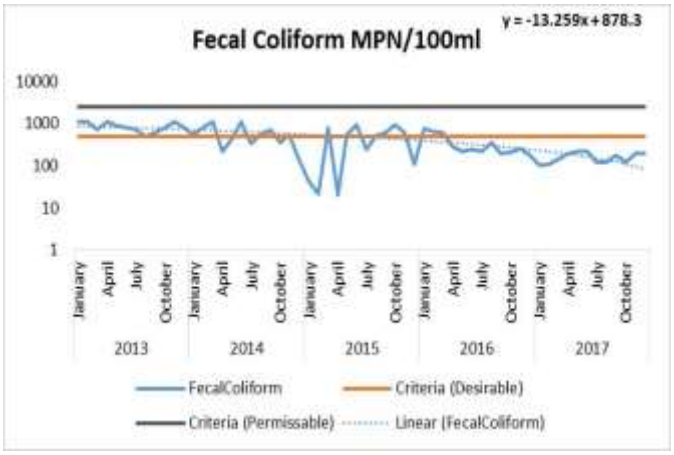

Fig 7: Graphical representation of values of Fecal Coliform over the years

However, from early 2016 the values are complying with the criteria. Also, the graphs depict decreasing trends in its concentration in water. The faecal coliform group is a subset of the total coliform group and comprises bacteria such as *E. coli* and *Klebsiella pneumoniae*. Although still in use in some jurisdictions, the lack of specificity of the coliform test to faecal pollution of drinking water has long been documented [23].

H. Total Coliform

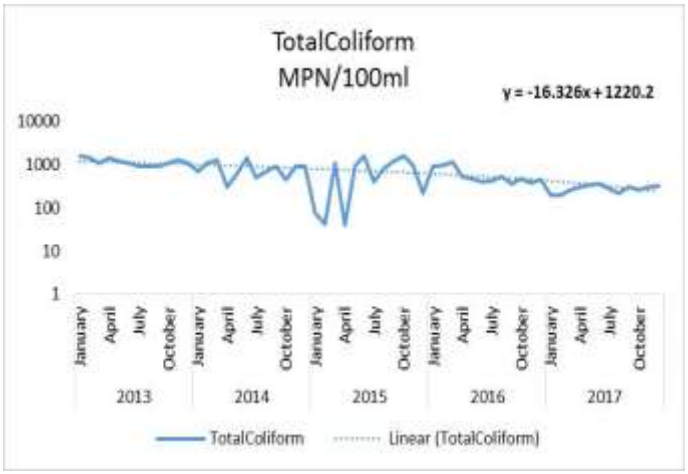

Fig 8: Graphical representation of values of Total Coliform over the years

Coliform bacteria include all aerobic and facultative anaerobic gram negative, non-sore forming, rod shaped bacteria that produce gas upon fermentation in prescribed culture media within 48 hr at 35°C. The new enzymatic definition of total coliform bacteria is based on the presence of β- galactosidase; and that of E. coli is based on the enzymatic action of β-glucuronidase. This aspect is well utilized in developing very sensitive and specific presence-absence (P-A) tests for detection of total coliforms and E. coli [16]. Trend is found to be similar to fecal coliform (FC). Detailed graphical representation of Total Coliform (TC) shows a decrease in trend, which in-turn is an indicator that the lake water quality is seen improving considering this parameter.

I. Alkalinity

Alkalinity of water is its capacity to neutralize acids**.** Total alkalinity of water is due to presence of mineral salt present in it [20]**.** It is primarily caused by the carbonates and bicarbonate ions**.** The Alkalinity value of the lake was found complying with the BIS permissible limit[24]. However, the graphical representation depicts increase in alkalinity over the years and same was observed in January 2017 where its concentration crossed the desirable limit.

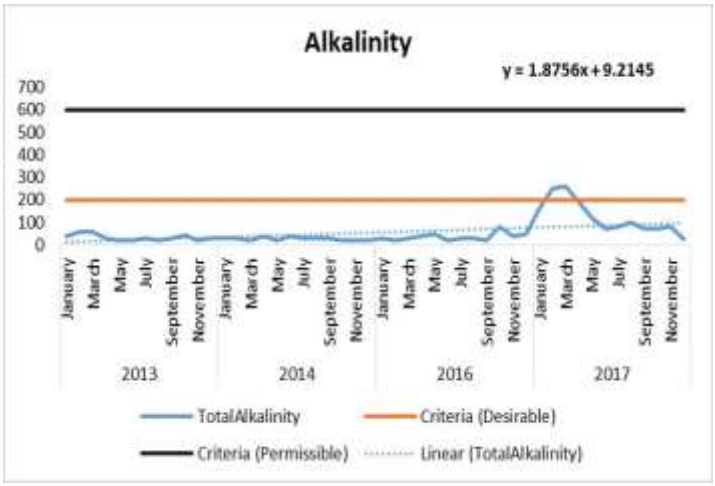

Fig 9: Graphical representation of values of Alkalinity over the years

Although, in later part of the year it has futher declined to reach upto acceptable limits. Absence of Phenolphthalein Alkalinity is an indicator of dominance of Bicarbonate ions (Table 2).

TABLE 2- TYPE OF ALKALINITY

Value of P&T	**Type of Alkalinity**		
	OH	CO_3	HCO_3^-
P=0	0	0	T
P<1/2 T	0	2P	T-2P
P=T	0	2P	0
P>1/2T	2P-T	2(T-P)	0
P=T	0	0	0

Source: A guide manual by Central Pollution Control Board, New Delhi

Above table is used in estimating the types of alkalinity, where P refers to value of phenolphthalein titration which exhibits presence of hydroxide and Carbonates, while titration with methyl orange exhibits presence of Bicarbonate ions. "T" refers to sum of value of titration of phenolphthalein and methyl Orange. P and T relationship is used to estimate the value of different types of alkalinity.

J. Hardness

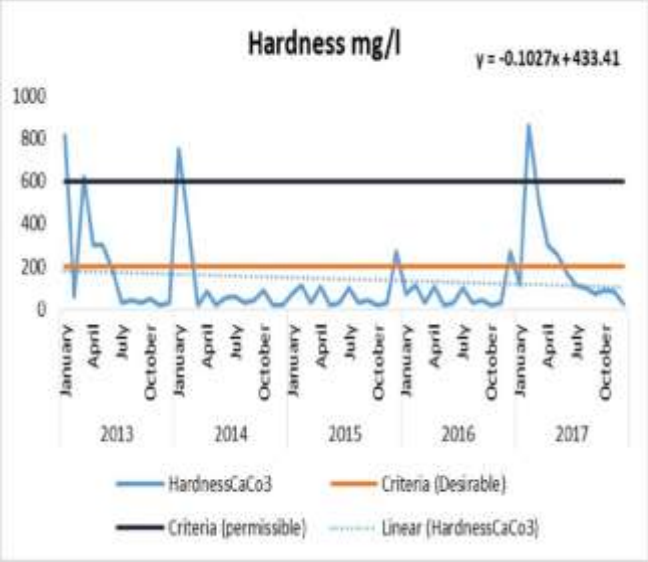

Fig 10: Graphical representation of values of Hardness over the years

In fresh water the principle hardness causing ions are Calcium and Magnesium. Total hardness is defined as the sum of calcium and magnesium concentrations [10]. Total hardness is the parameter used to describe the effect of dissolved minerals, determining suitability of water for domestic, industrial and drinking purpose [20]. The total Hardness level was found exceeding the BIS desirable as well as permissible standards [9].

Permanent hardness of water sample is caused mainly by sulphates and chlorides of metals [25]. However, on analysing the graphical representation of the values, trend line depicts decrease in hardness over the years (2013-2017) although it remains non-complying with the standards.

K. Total Dissolved Solids & Total Suspended Solids

The term "Solids" refers to the matter either filterable or non-filterable that remains as residue upon evaporation and subsequent drying at a defined temperature. Total Solids left after evaporation and subsequent drying are of two types: "Total Suspended Solids" (TSS) and "Total Dissolved Solids" (TDS)**.** TDS is the filterable residues that passed through the standard glass filter disk and remains after evaporation and drying at 180^{o}C [16]. TDS is not seen to be complying with the desirable as well as permissible value as recommended by the BIS [9].

Graphical representation depicts the highest value of TDS was observed in 2017 as compared to other years, making it unfit for consumption and any type of usage by common man. The trend-line from the graph depicts the continuous increase in the TDS values over the years, which is an indication of increasing lake pollution in future if the causative agents are not altered.

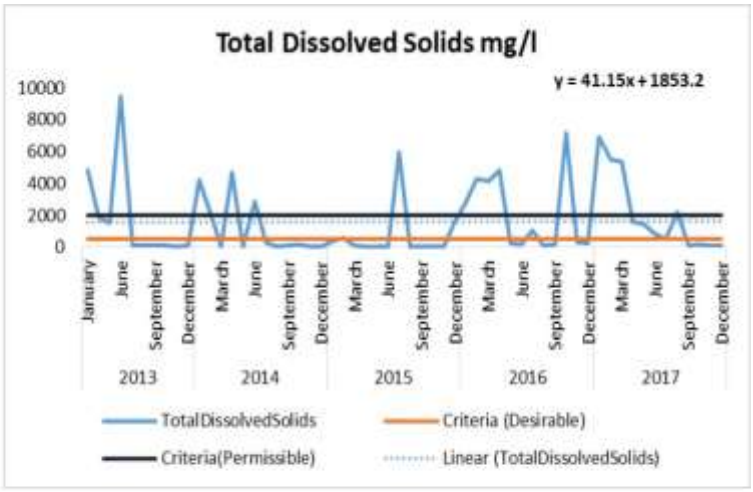

Fig 11: Graphical representation of the values of TDS over the years

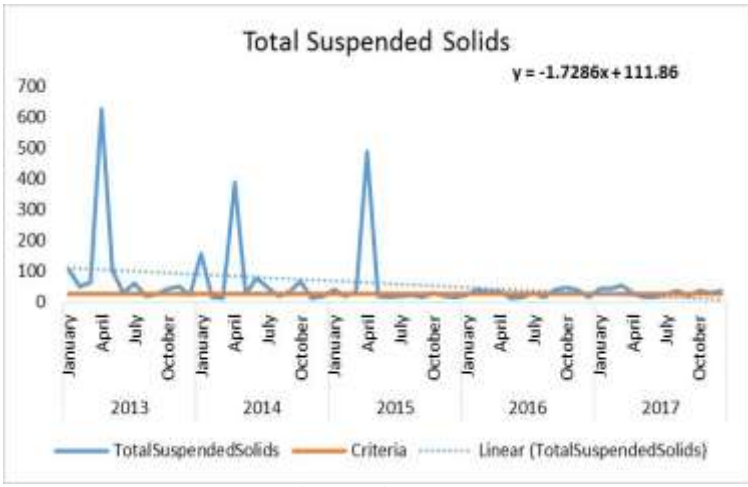

Fig 12: Graphical representation of values of TSS over the years

TSS on the other hand is not complying with the standards recommended by BSI. Whereas, from the data procured it has been observed a drastic decline in TSS values since 2015 till 2017.

V. Conclusion

After doing the trend analysis of the data obtained, apparent variation was seen in almost all physico – chemical parameters examined. Although all parameters were found to be fluctuating, while some parameters have undergone significant changes over the span of the past 5 years. Parameters found to be complying with the standards were DO, BOD, COD, alkalinity TDS which have shown trend of degradation in the water quality. Fecal Coliform (FC) and Total Coliform (TC) values were complying with the standards also they display a positive trend line showing an improvement in the water quality of the lake. With BOD, FC and TC complying within the limits at present it indicates that the water doesn't possess major impact on human health. However, reasons for depleting DO level need to be defined

before it further degrade the lake water quality. All other parameters like the pH, conductivity, alkalinity, nitrate, hardness and TSS are found to be fluctuating or moderately varying over the years.

Therefore, following the above criteria it can be concluded that the 5 year trend analysis (2013-2017) of the water was found to be partially polluted with respect to individual parameters. Considering this also the local population needs to be made aware about the current status and importance of the Vembanad Lake as a natural resource in order to make extra efforts to ward off pollution and maintain its quality.

TABLE 3

TREND OBSERVATION OF WATER SAMPLES TAKEN FROM SAMPLING STATION PATHIRAMANAL ISLAND, VEMBANAD LAKE (ALAPPUZHA, KERALA)

S No.	Parameters	Observed Status	Trend Analysis
1	pH	Complying, Increasing	Increasing
2	conductivity	Non-Complying, Decreasing	Improving
3	DO	Non-Complying, Degrading	Degrading
4	BOD	Complying, Increasing	Degrading
5	COD	Non Complying , increasing	Degrading
6	Alkalinity	Complying, Increasing	Degrading
7	Nitrate	Complying, Increasing	-
8	Hardness	Non-Complying, decreasing	Improving
9	Total Dissolved Solids	Non-complying, increasing	Degrading
10	Total Suspended Solids	Non-complying, Decreasing	Improving
11	Fecal Coliform	Complying, decreasing	Improving
12	Total coliform	Decreasing	Improving

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