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Variations of water quality indicators in closed tropical freshwater systems towards selected climatic and anthropogenic disturbances

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ABSTRACT

Inland waters are nowadays becoming hotspots of endangerment. Disturbance is any change in set of environmental conditions which alter regular ecosystem properties that may be natural or anthropogenic. Disproportionate enrichment due to several point and non-point sources has affected water quality and natural trophic status of inland waters where climate change can be an indirect factor. Lakes are significant indicators of climate change and store house of information about changes in catchment characteristics. Climate change may affect tropical lakes more comparatively. Water temperature affects a number of lake properties that influence the wellbeing of lake ecosystem. Increasing temperature and deviation of normal rainfall pattern have been evidently studied for changes in chemical composition of lakes. The present study is an effort to investigate the effects of change which can be direct or indirect occurring over a period of time in a closed system (Purohitokatalab) of Udaipur, Southern Rajasthan with reference to alteration in its water quality subjected to several tourist activities within recent years. Such isolated lakes lack self cleansing mechanism due to absence of strong flow. The values and alterations of parameters i.e. pH, TDS, conductivity, turbidity, total hardness, chlorides, sulphates, nitrates, phosphates, DO, BOD indicate the quality of lake water. Several samples of water from the periphery of this closed lake system were collected during year 2017 and 2021 and these water quality parameters were analysed. Results indicated high variation in the N:P ratio within the freshwater body. It also demonstrated increasing trends in nitrate concentrations, alkalinity and biological oxygen demand over the time period with change in temperature and rainfall variations. Major changes in the catchments characteristics and measures for its management were also discussed to avoid further deterioration of the closed natural ecosystem. Here future monitoring of water quality indicators is crucial to assess the impact of climate change on such tropical closed systems as it is a potential threat stimulating the precursors of eutrophication and overall alteration of ecological state of lakes.

Key words *: Water pollution, Water quality indicators, Climate change, Anthropogenic activities*

Introduction

Lakes are one of the most important fresh water resources. Closed lake systems play an important role in recharging groundwater, acting as sponges to control floods and supporting biodiversity. Tourism

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near these lakes is an important business and source for well-being of the local community. Such isolated closed ecosystems have low flow rates and higher water residence time. Physicochemical as well as hydro-geo-morphological elements and climatic conditions of lakes affect the biological elements inside it. Shallow lakes are more sensitive to warming caused by climate change. The impact of climate change on lakes depends on duration of dry periods and number of flushing episodes (Arnell *et al.*,2015). Changes in temperature and rainfall regime cause alteration in physico chemical properties and biogeochemical processes of lakes. Temperature affects the kinetics of chemical reactions whereas changes in rainfall pattern affect the transport of nutrients, sediments and pollutants (Whitehead *et al.*, 2009). The trends of mean and annual average rainfall and temperature of major urban centers in Rajasthan make clear their deviating patterns due to climate change (Pingale *et al.*, 2009). It has been found that in Udaipur district of Rajasthan, rainfall trend has been decreased in winters whereas increased in monsoon (Rana *et al*., 2019). Lower flows due to reduced rainfall increase toxic blooms and decrease dissolved oxygen levels while increase in rainfall may cause an upsurge of flushing of input solutes to the lakes (Whitehead *et al.*, 2009). Change in aquatic plant communities, their nutrient content and palatability is found to be affected by climate warming. Fish communities and feeding patterns of different species get disturbed likewise (Zhang *et al*., 2019).

The average global temperature has risen up by 1.5° F in the last century and is expected to increase between 0.5°F to 8.6° F in this century (Dutta and Dutta, 2016). According to (Pant and Kumar, 1997) in India the annual air temperature is increasing at a rate of 0.57°C/100 year. These changes also affect water bodies prominently. The present study is an effort to explore the impact of climate change and anthropogenic disturbances on isolated lakes.Recent years have shown that heavy downpours are more frequent within Udaipur region which may affect lake water quality by increased run off. High catchment to lake area ratio can also affect the water quality due to catchment properties which is shown in present study. Water quality renewal rate also increases possibility of eutrophic conditions. Present study was carried out to ascertain the changes in water quality indicators of an isolated lake due to anthropogenic activities during five years period and to explore their link to climate change and its resultant long-term impact.

Study Area

Study was carried out on 'Purohito KaTalab' situated in Udaipur district of Rajasthan. Figure showsclosed isolated freshwater system situated around 12 kilometresaway from Udaipur city andlake is surrounded by lush green hills of Aravalli Range Mountains and cemented construction on its one side.

Seasonal sampling was doneduring year 2017 at lakePurohitokatalav wherewater samples in triplicate were collected in pre- sterilized BOD bottles directly from below the water surface between 08:00 and 10:00 am. Samples were properly labeled and bought to the lab for further analysis. Temperature and pH were measured on the site itself.

(Map showing the Google location of PurohitokaTalab in Udaipur district of Rajasthan)

Other parameters wereanalyzed following the standard protocols of (APHA, 2017) in the laboratory.

To study the long term changes as impact, another seasonal sampling was done during year 2020-2021 to assess the influence of climate change and gradual increase in tourist activities which occurred during five year period.

Results and Discussion

Table 1 represented monthly variations in temperature. Relative humidity and average rainfall with mean values during 5 year period.

Table 2 represents the mean values of water quality indicators during year 2017 and 2021. A slight change was observed in the pH, turbidity, conductivity and TDS. Although TDS and conductivity have not shown much deviations but they are relatively high to reflect an increase in salts concentration an indicator of watershed and surrounding geological impacts on lake. High EC values indicate saline nature of the lake and more dissolved inorganic substances (Mathur *et al.*, 2007). Dissolved ion concentration play pivotal role in survival, growth or reproduction of aquatic biota of lakes. Higher TDS can be toxic to aquatic life by altering composition of the water pH and total alkalinity are indicative to the rock types of the region that define its alkaline status. Other factor that affects pH and alkalinity is CO_2 dynamics in lake water. High alkalinity within these five years may be linked mainly to anthropogenic activities in catchment along with increased average temperature of the region. High weathering due to temperature increase and heavy rainfalls contribute for higher alkalinity as rocks in this dry region are of calcareous nature (Verma and Pandey, 2017) and soils are semi alkaline to alkaline nature (Das and Singh, 1994).

There is a significant rise in mean total hardness from 343.33 mg/l (2017) to 439.33 mg/l (2021) with a decrease in mean value of Ca from 39.33 mg/l to 23.66 mg/l and a noteworthy increase in mean Mg value from 51.73 mg/l to 90.8 mg/l respectively. The rise in concentration of total hardness gives an indicationof human generated contamination in the catchment. Several marble industries are situated within catchment of the lake which adds Mg, Caand S through runoff from their slurry during heavy rains. One such spot is situated at South West direction above 5 km far from Purohitokatalab. A long term deposition of marble slurry may react with ground water and increase Mg concentration in water there as well.

Mean chloride value also show considerable changes from 169.33 mg/l (2017) to 188.33 mg/l (2021) which indicates higher degree of organic pollution. It may be due to tourism activities or wild animals and cattle waste in the lake surroundings Significant increase in mean nitrate levels from 3.0 mg/l (2017) to 15.33 mg/l (2021) was also observed though phosphate and sulphatevalues have not much changed. As this may be due to dependency on hydrological conditions and not on land cover properties (Laszewski *et al.*, 2021). Thus P becomes limiting and N as dominating nutrient in the lake. Extreme precipitation events (which is increased in the region during recent years) have enhanced N loading from terrestrial watershed to the lakes consisting of vegetational debris and animal waste. Increase in nitrate concentration can also take place as a result of anthropogenic disturbances andenhanced microbially fixed-N (Pandey and Verma, 2004).

Table 1. Temprature(°C), RH % and Rainfall (mm) data of Udaipur district for year 2017-2021

Months	2017			2018			2019			2020			2021		
	T	RH %	Rainfall	T	RH %	Rainfall	T	RH %	Rainfall	T	RH %	Rainfall	T	RH %	Rainfall
Jan	21	54	3	21	56	0	19	51	0	19	62	0	20	60	552.67
Feb	24	43	0	24	50	0	22	50	0	23	50	0	23	52	
Mar	28	34	0	29	39	0	28	40	0	27	46	26	29	42	
Apr	32	39	0	33	39	1	33	35	5	34	39	3	33	40	
May	35	46	13	35	49	0	35	47	7	36	43	18	33	54	
Jun	33	64	152	34	56	94	33	64	181	32	69	26	32	69	
Jul	28	87	367	29	81	202	32	71	133	31	79	118	31	76	
Aug	29	81	157	29	79	150	29	83	537	28	89	500	30	76	
Sep	30	78	60	29	73	61	29	86	236	30	79	230	28	87	
Oct	29	58	0	30	53	0	28	68	74	29	59	15	28	67	
Nov	24	64	0	26	52	0	26	70	16	24	56	0	25	51	
Dec	21	60	0	21	52	0	21	61	0	21	59	0			
Average	27.83	59	752	28.33	56.58	508	27.92	60.5	1189	27.83	60.83	936	28.36	61.27	

Source: timeanddate.comSampling and analysis

Here temperature increase accelerates denitrification and nitrogen fixtion and may change plant community structure by altering plant biodiversity (Feuchtmayr *et al.,* 2009). Higher nitrate concentration also accelerates algal growth and stimulate eutrophication. Climate change may aggravate eutrophication even at constant or reduced p concentration (Vyastavna *et al*., 2017).

A remarkable observation in the study is the amplification of N:P ratio i.e. about more than five times. This is a crucial outcome of the study since N:P ratio have an imperative function in determining the composition of phytoplankton community of the lake.

Mean DO showed decreasing trend up to 6.13 in 2021 from 8.43 in 2017 whereas BOD values showed an increase from 2.63 (2017) to year 10.33 (2021). Although the changes are moderate in DO and BOD values but they indicate the gradual degradation of water quality of the isolated lake. Solubility of DO in water decreases with increase in water temperature. Another reason for declining DO along with rising BOD is decomposition of organic matter which entered the lake from surrounding hills with rain water and human activities. DO along with temperature and pH controls microbial activities in lake and therefore also affect the eutrophication procedure.

Table 3 represents the t test applied between water quality indicators during year 2017 and 2021 showing significant p values for all parameters except turbidity, conductivity, TDS and phosphates. Thus the variations in water quality indicators within five year period clearly explain the effect of direct or indirect human activities.

Tourism is immensely affecting the lakes directly and indirectly i.e. through commercial activities in and around Udaipur region. These impacts depend on lake type, size and catchment characteristics (Dokulil and Teubner, 2010). In addition the climate change has resulted in alteration of weather conditions that affect the lakes' water quality. Increase in air temperature causes changes in distribution and intensity of rainfall. More intense rainfall lead to in-

Table 3. Paired t test between Water Quality values of the study lake (PKT) during 2017 and 2021

VARIABLES	p value
Temperature ©	0.0572
pH	0.0059
Turbidity (NTU)	0.2254
Conductivity (µs/cm)	0.0702
Total hardness (mg/l)	0.0017
Chloride (mg/l)	0.0325
Total dissolved solids (mg/l)	0.7069
Sulphate (mg/l)	0.0377
Alkalinity (mg/l)	0.0089
Calcium (Ca) (mg/l)	0.0005
Magnesium (Mg) (mg/l)	0.0001
Nitrate (mg/l)	0.0094
Phosphate (mg/l)	0.7295
Dissolved oxygen (mg/l)	0.0025
Biological oxygen demand (mg/l)	0.0087

Table 2. Water Quality indicators of the (PKT) during year 2017 and 2021

VARIABLES	Year 2017	Year 2021
Temperature (°C)	27.63±0.25	27.37±0.15
pH	8.67±0.058	8.23±0.058
Turbidity (NTU)	0.27±0.058	0.37±0.058
Conductivity (µs/cm)	1313.33±5.508	1296.67±2.887
Total hardness	343.33±5.77	439.33±1.155
Chloride	169.33±5.03	188.33±2.887
Total dissolved solids	861.33±18.90	859.67±21.455
Sulphate	5.00±0.00	6.67±0.577
Alkalinity	276.67±46.188	548.33±2.887
Calcium (Ca)	39.33±1.155	23.67±0.577
Magnesium (Mg)	51.73±1.50	90.80±0.69
Nitrate	3.00±1.00	15.33±1.155
Phosphate	0.13±0.038	0.12±0.01
Dissolved oxygen	8.43±0.351	6.13±0.15
Biological oxygen demand	2.63±0.321	10.33±1.528

Except temperature, pH, turbidity and conductivity all other parameters are in mg/l
Values are (mean ± 1 SD; n=3)

creased access of terrestrial matter into the lakes (Meunier *et al*., 2015). Besides direct impact of altered temperature and precipitation, lakes are also affected by climate change induced modifications in surrounding watershed i.e. landscape weathering, vegetation and soil properties. Global climate change has amplified the addition of diffused nutrients losses from catchment to the total nutrient load in water bodies (Li *et al.,* 2015). The nature and pattern of rainfall have been disturbed in this region which can be due to substantial deforestation and rapid urbanization in last few decades ensuing microclimatic alterations. The number of rainy days and the quantity of monsoon rainfall been declined severely during last few decades (Rathore and Verma, 2013). Considerable increasing trend in annual maximum temperature of Udaipur district has been reported (Pingale *et al*., 2014). This study helps to relate the impact of climate change on a lake due to shifts in trends of ambient temperature and precipitation..

Conclusion

Being a semi arid region the lakesin Udaipur district of Southern Rajasthan are an important source of water for daily activities of local people. Therefore monitoring of lake water quality indicators is crucial to detect changes in lake environmentover time. The present study has relevance for exploring the alterations in an isolated lake system due to climatic changes and anthropogenic activities i.e. mainly tourism. The altered values of alkalinity, nitrates, DO and BOD which are directly related to the increased temperature and heavy rains, both are the consequences of climate change. Major impact of climate change can be seen in the region in the form of frequent short duration heavy rainfall episodes and lesser steady rainfall events in monsoon season. In addition the local temperature has also increased in region because of diminishing trees and increasing urban pockets. There is an urgent need to discontinue the cutting of trees and boostup rigorous plantations with in the Udaipur region.

The nutrient addition of animal and plant origin from catchment also seems to be affecting the lake to a remarkable extent. The ways to prevent the entry of cattle generated waste in this isolated lake are required to be implemented. Local community should be made aware of such impact on an isolated system and how to minimize these activities. Although marble slurry has been situated at about 5 km distance but its impact through leaching need to be controlled stringently.

Hence the study reveals direct and indirect impact of human activities and shifts in local weather activities due to climatic alterations with consequent modifications in water quality indicators of an isolated lake.The study is useful in predicting the future possibility of lake water deterioration and eutrophication and the ways to prevent the lake from being polluted.Restoration efforts in lakes are affected negatively by climate change.Looking at the significance of water resources in this semi arid region the management and conservation efforts around lake are essential for ecosystem upkeep and local people's necessities.

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