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### RESEARCH ARTICLE

#### WATER QUALITY ASSESSMENT OF TWO CONSTRUCTED LAKES (ARITAR LAKE & CHAYA TAAL LAKE) IN SIKKIM DURING WINTER & SUMMER SEASON.

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#### Abstract

The present study focused on the comparative study and assessment of water quality of two constructed lakes, Aritarlake (East Sikkim) and Chaya Taal Lake (West Sikkim) during the dry period i.e. winter and summer season. The study showed that pH values of Aritar lake water was just below the neutral level (6.45), with higher dissolved oxygen (DO) content (2.3 mg/L) as compared to Chaya Taal (pH=7.7, DO=1.6 mg/L). Aritar lake water samples exhibited higher concentrations of total dissolved solids (TDS), total hardness (TH), chloride (Cl<sup>-</sup>), sulphate (SO<sub>4</sub><sup>2-</sup>), phosphate (PO<sub>4</sub><sup>3-</sup>), nitrate (NO<sub>3</sub><sup>-</sup>) and soluble iron (Fe) content in comparison to water samples collected from Chaya Taal lake. This situation can be linked to higher density of visitors and increased recreation/human activity in and around the lake area. Except EC and TDS, remaining parameters of examined lakes water samples exhibited lower values in winter season. The values of water parameters from these two lakes were very much under the acceptable range for surface water standards (IS:2296) during winter and summer season, therefore not tend to have any effect/threat on biotic components of lake ecosystem.

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#### Introduction:-

Water is the most vital resources for all kinds of life on the earth and essential for the sustainability of the earth's ecosystem (UNESCO 2003) Fresh water is one of the most important natural resources crucial for the survival of all living beings. A lake is a large body of water surrounded by land, inhabited by various aquatic life forms. Lakes are also subjected to various natural processes taking place in the environment like the hydrologic cycle, with unprecedented developmental activities. Lake water is a source of drinking and domestic use water for rural and urban population in India (Singh et al., 2012). The availability and quality of water always have played an important role in determining the quality of life. Water quality is closely linked to water use and to the state of economic development (Chennakrishnan et al., 2008). India is facing a serious problem of natural resource scarcity, especially that of water in view of population growth and economic development (Garg et al., 2009). The increased demand of water as a consequence of population growth, agriculture and industrial development has forced environmentalists to determine the chemical, physical and biological characteristics of natural water resources (Regina and Nabi et al.,

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2003). The health of aquatic ecosystem is depended on its physico-chemical and biological characteristics (Venkatesharaju et al., 2010). The important physical and chemical parameters influencing the aquatic environment are temperature, rainfall, pH, salinity, dissolved oxygen and carbon dioxide and these parameters are the limiting factors for the survival of aquatic organisms (Lawson et al., 2011). Sikkim, nested in eastern Himalayan region, is one of the rapid growing states in recent time in India and rich in biological diversity and natural resources. However, an increase in the rate of development and urbanisation has its own negative consequences on nature and natural resources.

#### **Description of study area:-**

Aritar lake (also known as Lampokhari) is one of the oldest freshwater lake in Sikkim, situated at Aritar, under Rongli subdivision of East Sikkim (**Figure 1**). The lake is positioned at an elevation of 4600ft on the edge of the Himalayas, surrounded by dense forest and lush greenery. By origin this lake is a natural water body which has been reconstructed in recent time, and provided with concrete embankment to facilitate recreation/tourism activity. It is the first lake in Sikkim introduced boating facility for the visitors (Web Ref. 1 & 2).

Chaya Taal lake is the second artificially constructed lake after Lampokhari at Aritar. Chaya Taal lake is located at an altitude of 6500ft near Hee Bazar, under Maneybong-Dentam constituency, West Sikkim (**Figure 1**). The lake was inaugurated on May 11, 2007 and become a centre for recreational activities for the local residents and visitors. The region is characterized by lush forest and mountains. Both these lakes are fed by artificial supply of water, surface run-off from surroundings and atmospheric precipitation during the rainy season (Web Ref. 1 & 2). The main objectives of the study was to assess **(a)** the physico-chemical characteristics and water quality of two constructed lakes under the human influence and **(b)** the variation in water quality parameters during winter and summer season.

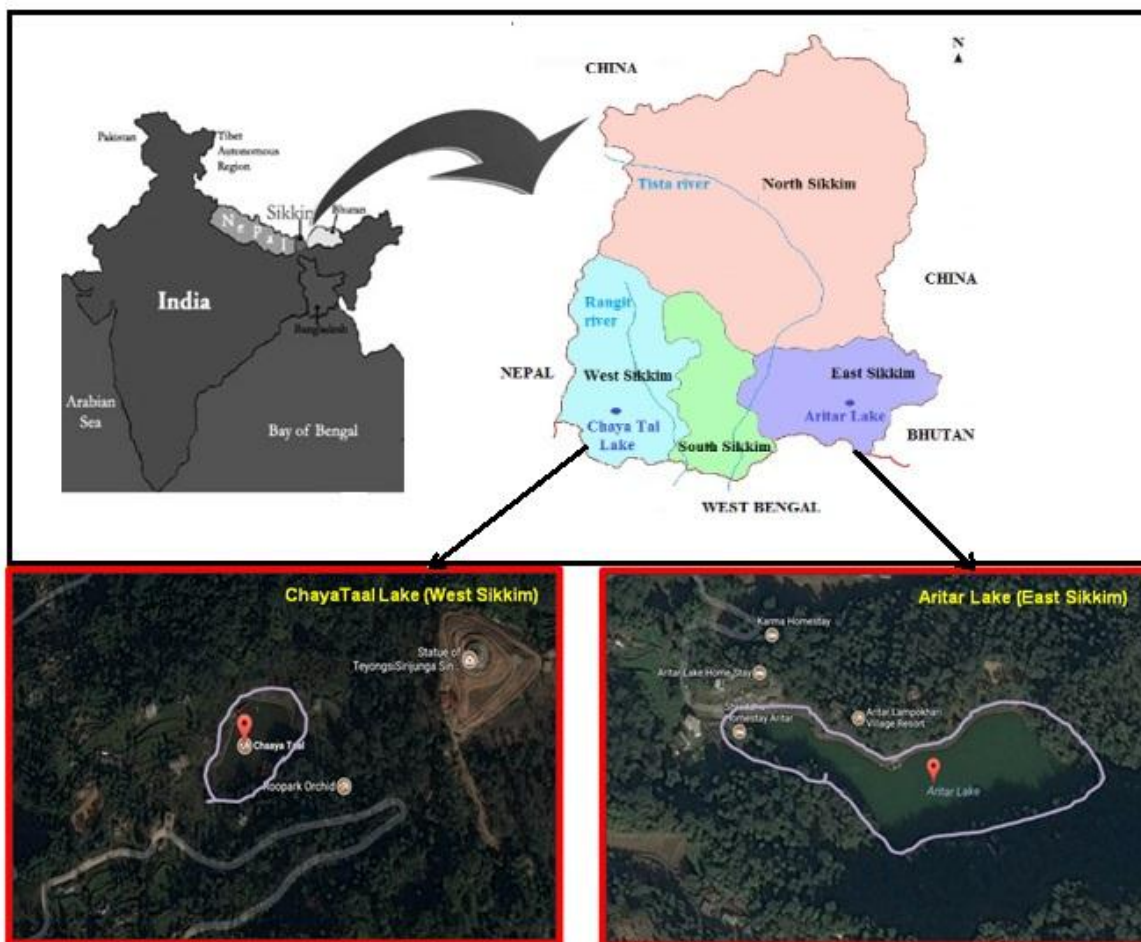
#### **Materials and Methods:-**

##### **Collection of water samples:-**

Field investigation and sampling of water were performed during the dry season (December to May) which includes winter (December to February) and summer (March – May). We were unable to monitor and collect the water samples from lakes during the wet season monsoon (June to September) due to poor transport and conveyance facility, which was badly affected by the heavy rainfall and landslides. The water samples were collected from Aritar lake and Chaya Taal from four different sampling points on regular interval basis covering winter and summer season. Water samples were collected in pre-washed acid plastic bottles of 1 litre capacity in a replicate of three. Collected samples were brought immediately to the laboratory for further analysis of various physicochemical parameters. Sample collection and preservation were done according to Standard Methods (APHA, 1998).

##### **Analysis of collected water samples:-**

Water temperature, pH, Electric conductivity (EC), Total Dissolved Solids (TDS) and Dissolved Oxygen (DO) were measured on spot by using portable hand analyzer (Eutech instruments pH/Ion 510, Con 510). Turbidity, free carbon-dioxide ( $\text{CO}_2$ ), total alkalinity (TA), total hardness (TH), chloride ( $\text{Cl}^-$ ), sulphate ( $\text{SO}_4^{2-}$ ), phosphate ( $\text{PO}_4^{3-}$ ), soluble iron ( $\text{Fe}^{2+}$ ) were analysed as per Standard Methods (APHA, 1998).



**Figure 1:-** Satellite view of the study area Aritar lake and Chaya TaaL lake of Sikkim.

### Results and Discussion:-

The analysed results of collected water samples from Aritar lake and Chaya TaaL lake during winter and summer season are presented in **Table 1**. Marked variations were observed in different water parameters due to changes in temporal condition, and also because of anthropogenic influences.

**Temperature** of water is one of the most important factors in an aquatic environment as it affects various reactions in aqueous system. During the investigation, the temperature of Aritar lake ranged between 6-10<sup>0</sup>C in winter and 15-18<sup>0</sup>C in summer, and in Chaya TaaL lake between 7-12<sup>0</sup>C in winter and 16-22<sup>0</sup>C in summer. Less temperature of Aritar lake water can be explained because of its higher depth and extensive vegetal coverage especially higher tall plants along the peripheral region of the lake which provided shaded condition.

**pH** of water is an indicative of negative logarithm of H<sup>+</sup> ion activity in aqueous/aquatic condition. The pH of water affects the solubility of many toxic and nutritive chemicals; therefore, the availability of these substances to aquatic organisms is affected (Roy et al., 2013). The pH of examined water samples of Aritar lake ranged from 6.4–6.7 and Chaya TaaL lake from 7.6-7.9 with an average value of 6.45 and 7.7 respectively. Less pH value of Aritar lake water can be explained by higher organic load and subsequent release of organic acids by microbial decomposition.

**Electric conductivity (EC)** indicates the water's ability to conduct an electric current, and is largely dependent on the concentrations of dissolved ions such as inorganic salts and organic matter in the water (Radojevic and Baskin et al., 2007). The EC value of Aritar lake water samples were 67.2-84.4 $\mu$ S and Chaya Taal lake were 52.7-76.9 $\mu$ S.

**Turbidity** in natural waters is caused by clay, silt, organic matter, phytoplankton and other microscopic organisms (Mathur et al., 2008). Turbidity is considered as a vital limiting factor for productivity of an aquatic body. In the present study, the turbidity of samples of Aritar lake ranged 15.6-23.8 NTU and Chaya Taal lake 10.5-17.6 NTU. The higher turbidity of Aritar lake can be corresponded with an increased rate of tourist/visitors and higher recreation activity in and around the lake area.

**Total Dissolved Solid (TDS)** originates from dissolution or weathering of rocks and soils, including dissolution of lime, gypsum and slowly dissolved soil minerals (Chandra et al., 2012). TDS is used as an indicator of aesthetic characteristics of drinking water and as an aggregate indicator of presence of a broad array of chemical contaminants as well as metal ions in water (Emoyan et al., 2005). The TDS value of Aritar lake was between 32.5-47.2 mg/L, and Chaya Taal lake between 24.2-36.5 mg/L.

**Dissolved oxygen (DO):** Presence of dissolved oxygen is a positive sign of a healthy water body, and is essential to all forms of aquatic life including those organisms responsible for the self-purification processes in natural water (Graney and Eriksen et al., 2004). In the present investigation, the average value of dissolved oxygen in water samples of Aritar lake and Chaya Taal lake were between 1.9-2.6 mg/L and 1.2-2.0 mg/L respectively. Higher values of DO in Aritar lake water are due to its large surface area.

**Total hardness (TH)** in water is the sum of the concentration of alkaline earth metal cations such as  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ; includes sulphates, chlorides of calcium and magnesium (Rafiullah et al., 2012). During the investigation, total hardness of Aritar lake samples were 18.2-25.8 mg/L and Chaya Taal lake 12.6-20.4 mg/L with average concentrations of 21.6 and 17.4 mg/L respectively.

**Estimation of Chloride (Cl<sup>-</sup>):** Excess chloride content in surface water is considered as an index of pollution from anthropogenic sources. Cl<sup>-</sup> is widely distributed in nature in the forms of salts of Na, K and Ca. (Mathur et al., 2008). In this study, chloride concentration in Aritar lake was found to be within 4.3-6.6 mg/L and Chaya Taal lake 3.2-3.9 mg/L. Higher concentrations of Cl<sup>-</sup> in Aritar lake water are a clear indication of anthropogenic load and contribution/discharges from nearby residential/guest houses.

**Estimation of Sulphate (SO<sub>4</sub><sup>2-</sup>):** Sulphate concentrations in surface water can be associated to geogenic sources as well as anthropogenic contributions. In the present investigation, the sulphate content in the sample of Aritar lake ranged between 0.07-0.12 mg/L and Chaya Taal lake from 0.04-0.08 mg/L.

**Estimation of Phosphate (PO<sub>4</sub><sup>3-</sup>):** Phosphate occurs in natural water in low quantity as many aquatic plants absorb and store PO<sub>4</sub><sup>3-</sup> many times of their actual needs (Mahananda et al., 2010). Phosphate content in water samples of Aritar lake were 0.11 - 0.17 mg/L and Chaya Taal lake 0.05-0.09 mg/L. Higher concentrations of PO<sub>4</sub><sup>3-</sup> in Aritar lake can also be attributed to higher dominance of aquatic vegetation along the peripheral zones.

**Estimation of Nitrate (NO<sub>3</sub><sup>-</sup>):** Nitrate (NO<sub>3</sub><sup>-</sup>), the most highly oxidized form of nitrogen compounds is commonly present in surface water. It is the end product of the aerobic decomposition of organic nitrogenous matter. NO<sub>3</sub><sup>-</sup> concentrations of Aritar lake were found to be within 0.8-1.6 mg/L and Chaya Taal lake: 0.5-1.2 mg/L.

**Estimation of Soluble Iron (Fe<sup>2+</sup>):** Present study shows that concentrations of soluble iron (Fe<sup>2+</sup>) in the sample of Aritar lake ranged from 0.09-0.14 mg/L and Chaya Taal lake from 0.06 - 0.09 mg/L, the average iron content of Aritar lake and Chaya Taal was 0.06 and 0.09 mg/L respectively.

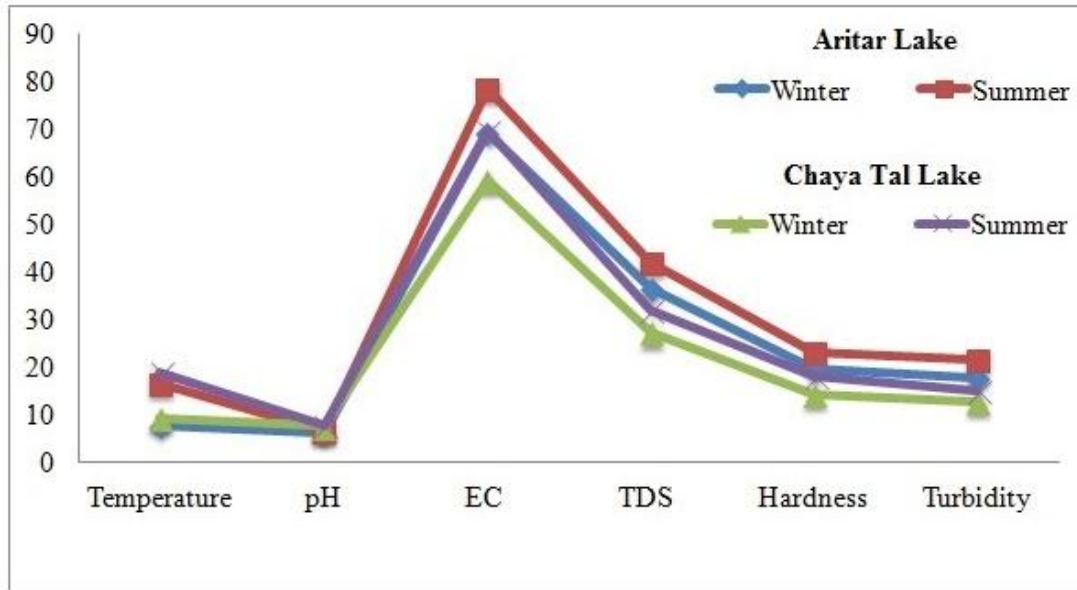


Figure 2a

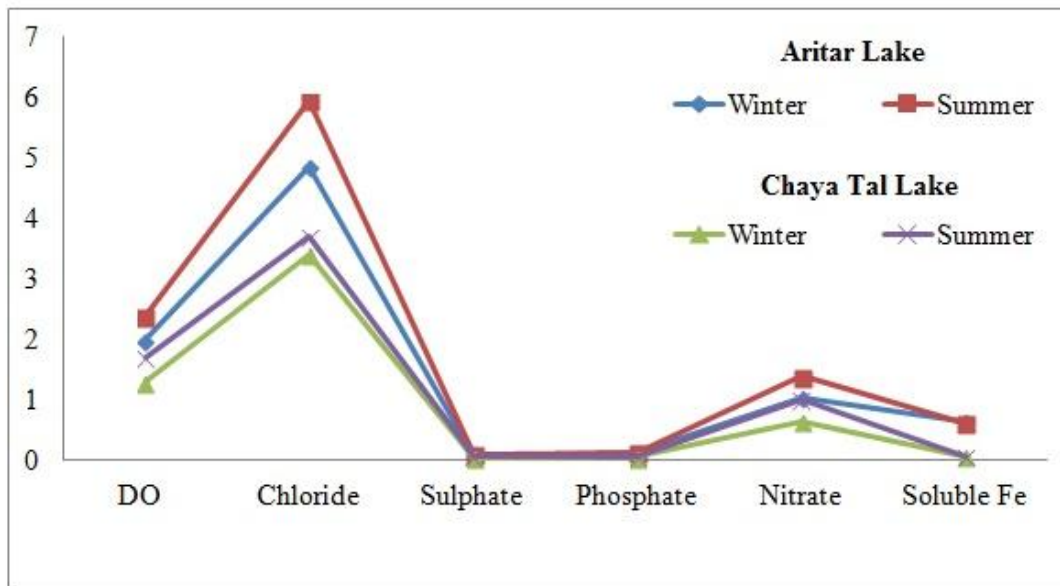


Figure 2b

Figure 2a and 2b:- Graphical representation of variation in water parameters of Aritar lake and Chaya Taal lake during winter and summer season.

**Variation in water quality during winter and summer season:-**

Though water samples from both the lakes were monitored and assessed during dry period (i.e. winter and summer season), but certain variations in the water quality parameters were observed in winter and summer season (Table 1). Most distinct variations were noted for temperature of lake water samples, besides, DO content in both the lake water were much low during winter season in comparison to summer. Higher values of EC and TDS in winter season can be linked to influx of surface run off as a result of heavy rainfall during monsoon (June-September). This also led higher turbidity of lakes in winter. Lesser values of pH, total hardness,  $SO_4^{2-}$  and soluble Fe in lake water during the winter season may be explained due to the dilution and increase in lake water volume as a result of post

monsoon effects after heavy rainfall. Higher values of  $Cl^-$  in both the examined lakes during summer season can be attributed higher influx of tourists/visitors, and anthropogenic contribution from nearby human settlement. Higher values of  $NO_3^-$  and  $PO_4^{3-}$  in both the lakes were observed during summer which can be attributed to higher rate of photosynthetic activity and biological decomposition which get accelerated in warm condition. In spite of seasonal variations (Figure 2a & 2b) all the measured water parameters from both the lakes were very much within the permissible limit as per Indian standards (IS: 2296) for inland surface water (Table 1).

**Table 1:-** Assessment of water samples from Aritar lake and Chaya Taal and its comparison with IS standards for surface water.

Measured lake water parameters	Aritar Lake						Chaya Taal Lake						(IS: 2296) For inland surface water
	Winter (Dec – Feb)			Summer (Mar – May)			Winter (Dec – Feb)			Summer (Mar – May)			
	Min.	Max.	S.D.	Min.	Max.	S.D.	Min.	Max.	S.D.	Min.	Max.	S.D.	
Temp. in °C	6.00	10.00	2.83	15.00	18.00	2.12	7.00	12.00	3.54	16.00	22.00	4.24	-
pH	6.40	6.60	0.14	6.50	6.70	0.14	7.60	7.75	0.11	7.70	7.90	0.14	6.5-8.5
EC(µS/cm)	67.20	75.80	6.08	72.60	84.40	8.34	52.70	66.30	9.62	62.50	76.90	10.18	-
TDS(mg/L)	32.50	40.80	5.87	36.70	47.20	7.42	24.20	30.60	4.53	27.40	36.50	6.43	500-1500
TH(mg/L)	18.20	21.60	2.40	20.80	25.80	3.54	12.60	16.40	2.69	15.80	20.40	3.25	300
Turbidity(NTU)	15.60	20.40	3.39	19.20	23.80	3.25	10.50	15.20	3.32	12.80	17.60	3.39	-
DO( mg/L)	1.90	2.10	0.14	2.20	2.60	0.28	1.20	1.40	0.14	1.40	2.00	0.42	4
Chloride(mg/L)	4.30	5.40	0.78	5.30	6.60	0.92	3.20	3.60	0.28	3.50	3.90	0.28	250
Sulphate (mg/L)	0.07	0.10	0.02	0.09	0.12	0.02	0.04	0.06	0.01	0.05	0.08	0.03	400
Phosphate(mg/L)	0.11	0.14	0.02	0.12	0.17	0.04	0.05	0.07	0.01	0.06	0.09	0.03	-
Nitrate(mg/L)	0.80	1.30	0.35	1.20	1.60	0.28	0.50	0.80	0.21	0.80	1.20	0.28	20-50
Sol. Iron(mg/L)	0.09	1.20	0.78	1.10	0.14	0.68	0.06	0.08	0.01	0.07	0.09	0.01	0.3

### Conclusions:-

The study revealed that the water samples of Aritar lake were lower in pH value in comparison to Chaya Taal lake water. Total dissolved solids, chloride and soluble iron were higher in concentrations in Aritar lake, which clearly indicates higher anthropogenic influence on this water body. Higher values of hardness, chloride, sulphate, phosphate, nitrate and soluble iron content in Aritar lake water can be attributed to higher density of tourists/visitors, recreation activity, and anthropogenic influences/contribution from surrounding areas. Distinct variations were observed in certain water quality parameters during winter and summer season for both the lakes. Water samples from both the lakes showed values for EC and TDS in winter season, while other water parameters exhibited their higher values during summer. All the measured parameters of water samples from both Aritar lake and Chaya Taal lake were within the recommended limit for surface water standards (IS: 2296) for inland surface water, therefore not tend to have any effect on aquatic biota present in lake water. Prolong monsoon season (heavy atmospheric precipitation coupled with surface run off from lake surrounding area) may have significant influence on these water body. Therefore complete study on water quality parameters throughout the annual cycle (including all three season) could provide more meaningful data/information about the overall quality of lake water for its better management practices, and to improve its quality for future uses and ecological sustainability.

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