Water Quality Assessment of Brahma Sarovar: A Sacred Lake at Kurukshetra (India)

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Received: 6 December 2022 / Accepted: 21 February 2023

Abstract. Brahama Sarovar, in Kurukshetra city (India), is an ancient sacred lake where devotees perform various religious activities/offerings on daily basis, and on special occasions of solar and lunar eclipses, millions of pilgrims all over the country have mass bathing (holy-dip) for internal and external purity. Along with religious importance, this artificial lake also acts as a sacred grove/wetland that serves as an important wintering and stopover site for migratory birds from the Palearctic region. The study was carried out with the objective to analyze the improvement in water quality status after the provision of a closed conduit for the supply of fresh water to the lake and additional measures required for public health safety. For this, the water quality of this sacred lake has been spatially analyzed and compared with Indian standards prescribed for 'Designated Best Use Class-B: Outdoor Bathing (Organised)' in the present study. Though the parameters – pH (7.94 within the limits of 6.5-8.5), turbidity (3.63 < 5 NTU), TDS (222.33 < 500 mg/L), TSS (100.25 mg/L) and MPN (239.25 ≤ 500 per 100 ml) were observed to be within the permissible limits, but DO (4.7 ≤ 5.0 mg/L) and BOD (3.54 ≥ 3.0 mg/L) of the lake water were found beyond the permissible limits. Thus, making the lake water unfit for human use for bathing. The comparison with the previous two studies revealed that the lake's water quality has improved in the last couple of years through the provision of a closed conduit, in place of an open channel, for the supply of fresh canal water to the lake. A couple of additional measures have also been suggested to maintain the water quality standards in the lake so as to protect the human health of the devotees and pilgrims.

Key words: Outdoor bathing, human health, sacred grove, BOD, DO, MPN.

1. Introduction

Lakes – natural or artificial are minor element of the hydrosphere, yet these water bodies play a crucial role in biogeochemical cycles of the Earth, and contribute to carbon and nitrogen storage, oxidation, and emission pathways, and are also home to numerous aquatic species (Cole & Curacao, 2001; Sobek et al., 2003; Bastviken et al., 2004; Raymond et al., 2013; Verpoorter et al., 2014; Ho & Goethals, 2020). In many societies and cultures across the globe, just like temples, lakes are also given divine status and considered as sacred pilgrim sites. Such sacred

lakes are believed to have mythological links to their origin, and are thus preserved for their religious sanctity. The reasons for their sacredness are diverse. They may be perceived as – abodes of gods and deities; sources of healing water; places of contact with the spirituality; and sites of revelation and transformation.

India is dotted with a number of artificial and perennial sacred lakes of great historical importance that have a prominent place in mythology and religion. The holy-water of such sacred lakes is being used for rites and rituals and other religious purposes, such as mass bathing; holy rituals in the form of offerings of milk, curd, sweets, oil, flowers, fruits, wheat flour, rice, etc.; feeding of food to fishes; washing of cloths; dispersion of cremation ash; etc. in the lake that adds organic pollutants to the lake system. As a consequence, these sacred lakes are in varying degree of environmental degradation (Pant et al., 1985; Trisal, 1987; Joshi & Sundriyal, 1995; Mohanty, 2004; Manjare et al., 2010; Gupta et al., 2011; Verma & Summarwar, 2012; Abir, 2014; Sharma et al., 2016; Sharma & Kumar, 2017). Further, during the days of solar eclipse and new moon, as well as during festivals, the intensity of religious activities increases due to the arrival of millions of devotees and pilgrims that adversely affects the water quality of the sacred lakes (Sinha et al., 1991; Jain et al., 1999; Kulshrestha & Sharma, 2006; Deswal & Chandna, 2007; Sharma et al., 2012; Bhateria & Jain, 2016; Bhatnagar et al., 2016). The deterioration of water quality not only endangers aquatic life but also harmful to human health, and as a result a lot of pilgrims become sick with waterborne diseases like cholera, diarrhea, typhoid, amebiasis, scabies, hepatitis, giardiasis, worm infections, etc.

As per World Health Organisation (WHO) (1993), almost 80% of all the diseases in human bodies are caused by water. So, monitoring of water quality of sacred lakes must be carried out regularly with focus on analyzing spatial variations in water quality parameters in case of large size sacred lakes where mass bathing takes place. In the present study, a sacred lake – Brahma Sarovar, in the city of Kurukshetra (India), has been considered for finding out its suitability for mass bathing as per the Indian standards prescribed for 'Designated Best Use Class-B: Outdoor Bathing (Organised)'. Though many studies have been reported on the water quality of Brahma Sarovar, but the spatial variations have not been analysed. The main objectives of the study include – current status of water quality with respect to its suitability for mass bathing; improvement, if any, in the water quality of the sacred lake after the provision of closed conduit for the supply of fresh water to the lake by comparing the results with earlier

studies; and additional measures required and suggested so that the public health be not compromised during mass bathing. To achieve these objectives in the study of a large size lake (990 m x 450 m), multiple sampling locations have been selected in the two halves (Eastern and Western) of the Brahma Sarovar so as to analyze the spatial water quality variations (i.e. intra- and inter- variations of two halves) and the reasons thereof.

2. Materials and Methods

2.1 Study Area

Brahma Sarovar is one of the Asia's largest artificial fresh-water lake located towards the north-east of part of Kurukshetra city (29.866 – 30.200°N and 76.416 – 77.066ºE), Haryana (India). Brahma Sarovar (Lake of Brahma) is named so because it is believed in Indian Mythology that Lord Brahma, the creator of the universe, started His creation from the land of Kurukshetra. It is one of the holiest lake in India, and every evening the Brahma Sarovar is being worshipped so as to connect to spirituality by way off a divine ritual of 'aarti' (prayers) performed at Lord Mahadev Temple located in the lake. Devotees and pilgrims take holy dips (bath) and perform 'achaman' (drinking water) every day and make offerings of flowers, flour, oil, cotton, floating lamps, coins, etc. to perform religious rituals. Further, millions of people from all over the country visit Brahma Sarovar on auspicious days of the new moon and solar eclipse to take a holy dip in this lake to pray the Sun God, with the belief that taking a holy dip (bath) would provide eternal salvation. Abul Fazl, a renowned historian, has described this sacred lake as a 'miniature sea' on his visit during solar eclipse.

Along with its religious significance, Brahm Sarovar also acts as a sacred grove/wetland that serves as an important wintering and stopover site for migratory birds coming from the Palearctic region. Kumar & Sharma (2018) identified a total of 88 bird species (26 winter migrants, one summer migrant and 61 residents) during the year at this site, of which two species – *Sterna aurantia* (J.E. Gray, 1831) and *Psittacula eupatria* (Linnaeus, 1766) – are classified as Near Threatened and one species – *Aythya ferina* (Linnaeus, 1766) – as Vulnerable in the International Union for Conservation of Nature (IUCN) Red List. They also reported many taxa of macrophytes in the lake, including the dominant species *Eichhornia crassipes* (Roxb.) Royle (free-floating), *Hydrilla verticillata* (Mart.) Solms (submerged), and *Cynodon dactylon* (L.) Pers (marginal).

Brahma Sarovar also hosts International Geeta Jayanti Festival every year, which is usually a seven days' festival, to celebrate the birth of Bhagavad Geeta. This place becomes too colourful and lively during the festival as people from all over places visit to see various performances, shop handicrafts and eat traditional Indian cuisines.

The aerial view and layout plan of Brahma Sarovar, along with sampling sites, are shown

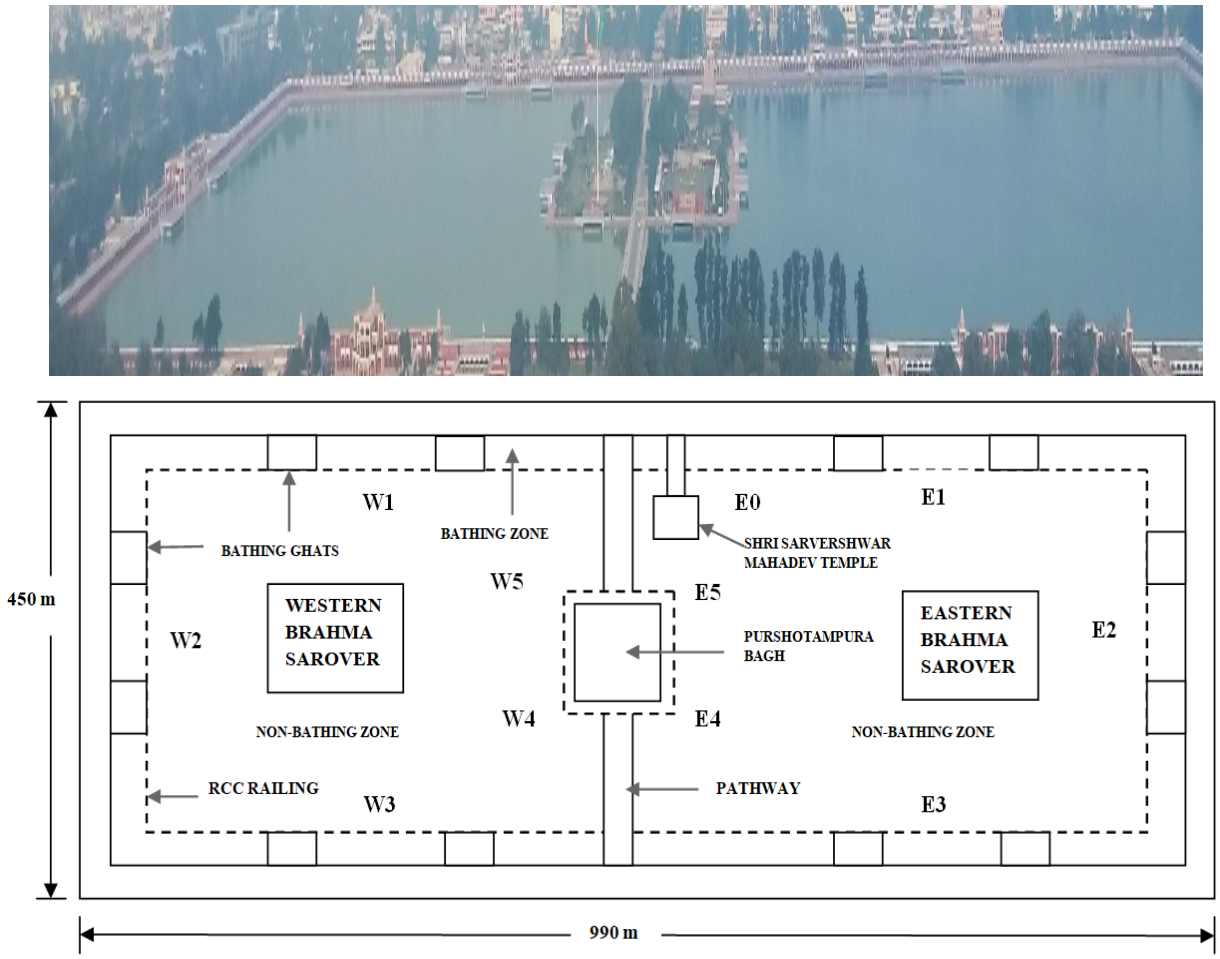

Figure 1. Aerial view and layout plan (with sampling locations) of Brahma Sarovar.

in Figure 1. The lake has a quadrangular layout having a maximum length of 990 meters and a maximum width of 450 meters with a depth of 4.57 meters. The lake has a 12.19 m wide peripheral corridor. As shown in Figure 1, Brahma Sarovar comprises of two halves of almost equal dimensions and similar structures and facilities – the Eastern Brahma Sarovar (540 × 450 × 4.5 m) and the Western Brahma Sarovar (450 × 450 × 4.5 m), physically separated by an island-garden with pathway on either sides and hydraulically connected by an underdrain for the flow

of water (Deswal & Chandna, 2006; Patidar, 2014). Each part of the lake has two zones, namely - bathing zone and non-bathing zone. The stepped bathing zone is provided on the periphery of the holy lake and is separated from the non-bathing zone by an R.C.C railing for safety. The bathing zone is about 11.5 m wide and has a varying water depth having a maximum of 1.2 m near the R.C.C railing (Fig. 1). Within the bathing zone, twelve exclusive covered bathing areas (Bathing Ghats) have been provided for female devotees. The lake water is used for rites and rituals only. Fishing and boating are strictly prohibited.

The water in the sacred lake is replenished with fresh river water by Thanesar Distributary (a closed conduit/channel) that takes off from Narwana Branch Canal (Deswal & Chandna, 2006; Patidar, 2014; Praveen & Setia, 2017a; Kumar & Sharma, 2018). A pumping station near Braham Sarovar is being used for filling the sacred lake, as and when required. The estimated water retention capacitiy of the sacred lake is about 2.05 million m^3 – Eastern Brahma Sarovar:1.14 million m^3 and Western Brahma Sarovar 0.91 million m^3 (Patidar, 2014).

2.2 Sampling

A total of eleven sampling locations were identified, five in Western Brahma Sarovar (W1, W2, W3, W4 and W5) and six in Eastern Brahma Sarovar (E0, E1, E2, E3, E4 and E5) as shown in Figure 1. The sampling locations were selected such that – (i) six sampling locations (W1, W2, W3, E1, E2 and E3) were in the designated bathing zones along the periphery; (ii) four sampling locations (W4, W5, E4 and E5) were near the four edges of the island-garden (Purshotampura Bagh) at the center of the lake; and one sampling location (E0) near the Mahadev Temple where offering being made by devotees on daily basis. The surface water samples were collected in sampling bottles during the forenoon from different locations of Brahma Sarovar during a period of four months (January – April, 2022). The samples were brought to the Environmental Laboratory of NIT Kurukshetra for analysis of different physiochemical and biological parameters; while Temperature (Temp) was measured at the sampling site. The samples were maintained at a low temperature in an insulated sampling box during transportation from site to the laboratory. The parameters were analyzed, in triplicate, as per standard methods (APHA, 2005).

2.3 Analysis Approach

In India, Central Pollution Control Board (CPCB), New Delhi has recommended the standards (permissible limits) of water quality parameters/criteria for Designated Best Uses (DBU) of Water sources and their categorization. Lakes and other water bodies for the DBU for Outdoor Bathing (Organised) have been categorized under Use Class-B (CPCB, 2022). The samples from all locations were examined for the physiochemical and biological parameters included in the CPCB recommendations, that is – pH, Turbidity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) 3 day at 27°C and Most Probable Number (MPN). As the Brahma Sarovar has two halves, the water quality of the lake was first analyzed to interpret spatial variations (i.e. intra- and inter-variations) in both the halves of the lake, followed by the overall water quality of Brahm Sarovar (entire lake including both parts) with respect to CPCB standards for Class-B water bodies for Outdoor Bathing (Organised). The results were than compared with the recent studies.

3. Results and Discussion

3.1 Intra-variation of Water Quality in the Two Halves of the Lake

The intra-variation of water quality at different sampling sites in the two halves of the lake and possible reasons thereof have been presented as under:

3.1.1 Water Quality of Western Brahma Sarovar

In case of Western Brahma Sarovar (Fig. 2A), the pH of water was found to vary from slightly acidic to alkaline (6.9 – 9.2; mean = 8.0), but the values of all locations lie within the permissible standard range. pH was observed to be highest in the southern-part (W3: 9.2) followed by western-part (W2: 8.5), northern-part (W1: 8.2) and lowest (W5: 7.2 & W4: 6.9) in the eastern-part adjoining the Eastern-half of the lake. Turbidity was found to be in the range of 2.5 – 4.0 NTU (mean = 3.62 NTU) and the water was found to be least turbid in the southern-part (W3: 2.5 NTU) followed by western-part (W2: 3.0 NTU), northern-part (W1: 3.8) and most-turbid (W5: 4.8 & W4: 4.0) in the eastern-part. The DO of lake water was found to vary from 3.2 – 5.4 mg/L (mean = 4.46 mg/L), and was lower than the permissible standards (≥5 mg/L) at three locations – W4 (3.2 mg/L), W5 (3.6 mg/L) and W1 (4.9 mg/L). The BOD was found to vary from 3.0 – 4.3 mg/L (mean = 3.66 mg/L), and was higher than the permissible standards (≤3 mg/L) at four locations – W4 (4.3 mg/L), W5 (3.9 mg/L), W1 (3.8 mg/L) and W2 (3.3 mg/L).

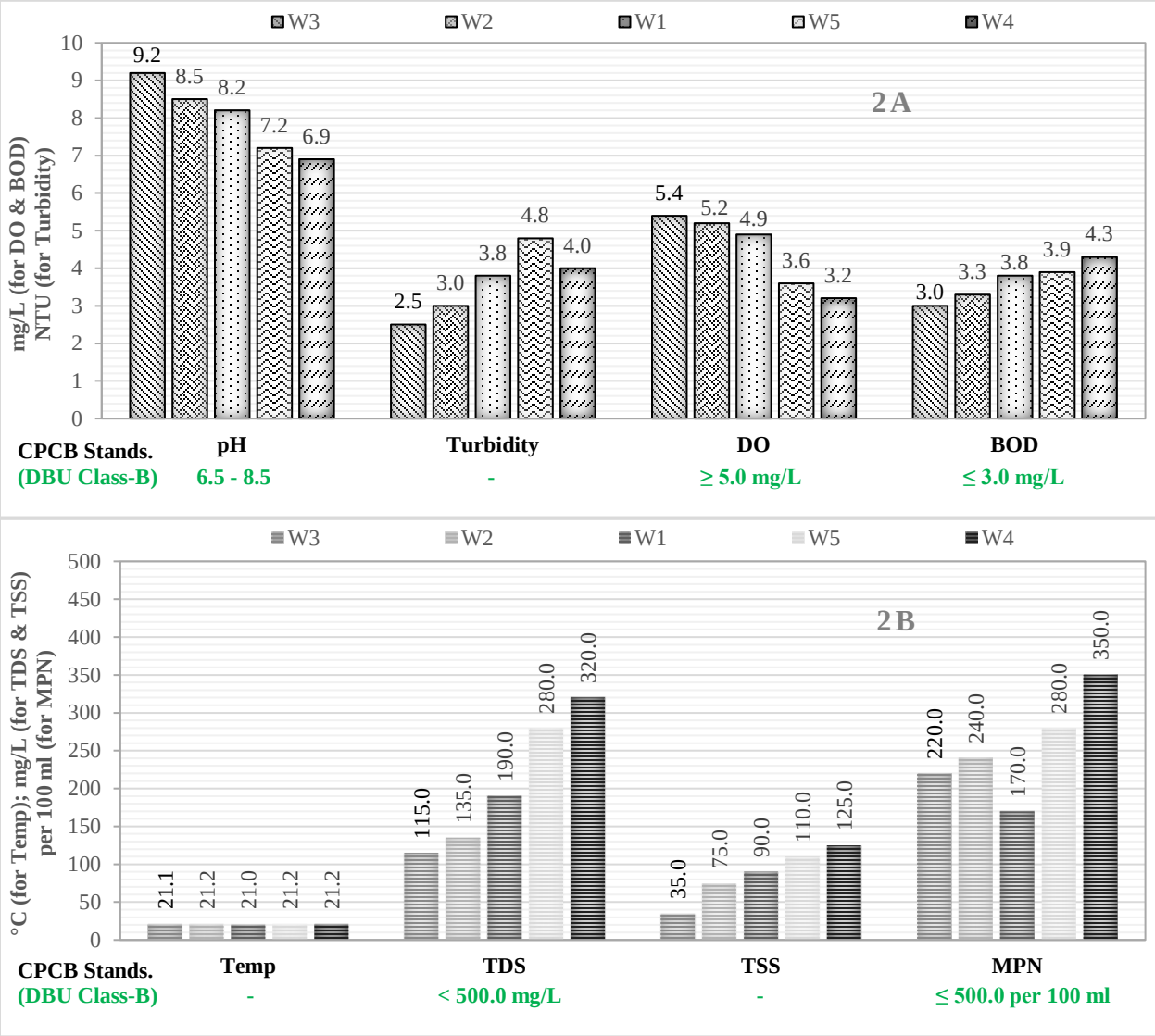

Figure 2. Intra-variation of water quality in Western Brahma Sarovar. **2A.** Variation of pH, Turbidity, DO and BOD; **2B.** Variation of Temp, TDS, TSS and MPN.

Figure 2B shows the intra-variation of Temp., TDS, TSS and MPN in Western Brahma Sarovar. The temperature of the water was observed to be within 21.1±0.1°C. TDS and TSS were found to be in the range of 115 – 320 mg/L (mean = 208 mg/L) and 35 – 125 mg/L (mean = 87 mg/L) respectively. Both, TDS and TSS, were found to be in lower concentrations in the southern-part (W3: 115 & 35 mg/L) followed by western-part (W2:135 & 75 mg/L), northern-part (W1: 190 & 90 mg/L) and highest concentrations (W5: 280 & 110 mg/L; W4: 320 & 125

mg/L) in the eastern-part of the Western Brahma Sarovar. The MPN value was found to vary from 220 – 350 per 100 ml (mean: 252 per100 ml) and lie within the permissible standard range at all locations (Fig. 2B). However, MPN count was least in the northern-part (W1: 170 per 100 ml) followed by southern-part (W3: 220 per 100 ml), western-part (W2: 240 per 100 ml), and maximum (W4: 350 & W5: 280 per 100 ml) in the eastern-part of the Western Brahma Sarovar adjoining the Eastern Brahma Sarovar.

The results revealed that the water quality of the Western Brahma Sarovar deteriorates in clockwise direction from southern-part (W3) to the eastern-part (W4 and W5), adjoining the Eastern-Half of the lake. This is possibly due to two reasons – the inlet (supply of fresh water) is being located in the southern-part; and least human activities (bathing, offerings, etc.) in the southern-part followed by increasing activities in the western-, northern- and eastern-parts of the Western Brahma Sarovar.

3.1.2 Water Quality of Eastern Brahma Sarovar

In case of Eastern Brahma Sarovar (Fig. 3A), the pH of water was found to vary from slightly acidic to alkaline (6.8 – 9.2; mean = 7.88), but the values of all locations lie within the permissible standard range. pH was observed to be highest in the southern-part (E3: 9.2) followed by western-part adjoining the Western Brahma Sarovar (E5: 8.6; E4: 8.2), eastern-part (E2: 7.3), northern-part (E1: 7.2) and lowest near Mahadev Temple (E0: 6.8). Turbidity was found to be in the range of 2.0 – 4.9 NTU (mean = 3.63 NTU) and the water was found to be least turbid in the southern-part (E3: 2.0 NTU) followed by western-part (E5: 3.3 & E4: 3.6 NTU), eastern-part (E2: 3.8 NTU), northern-part (E1: 4.2 NTU) and most-turbid near the temple (E0: 4.9 NTU). The DO of lake water was found to vary from 3.4 – 6.0 mg/L (mean = 4.93 mg/L), and was lower than the permissible standards (≥5 mg/L) at three locations – E0 (3.4 mg/L), E1 (4.4 mg/L) and E2 (4.7 mg/L); whereas, DO was above the permissible value at locations in the southern and western parts. The BOD was found to vary from 2.2 – 4.5 mg/L (mean = 3.42 mg/L), and was higher than the permissible standards (≤3 mg/L) at all the locations – E0 (4.5 mg/L), E1 (3.8 mg/L), E2 (3.5 mg/L), E4 (3.4 mg/L) and E5 (3.1 mg/L), except E3 (2.2 mg/L) in the southern-part.

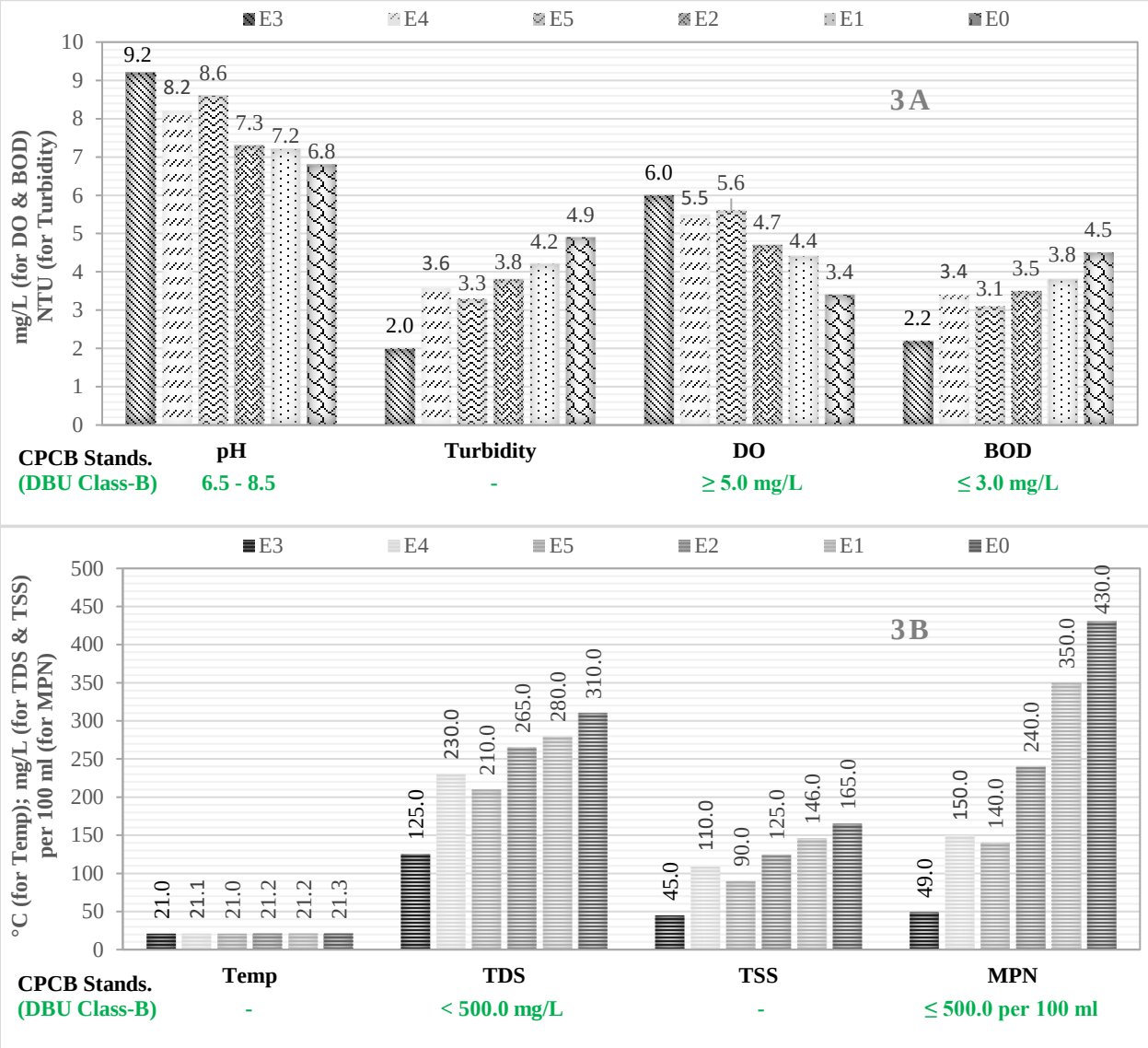

Figure 3. Intra-variation of water quality in Eastern Brahma Sarovar. **3A**. Variation of pH, Turbidity, DO and BOD; **3B.** Variation of Temp, TDS, TSS and MPN.

Figure 3B shows the intra-variation of Temp., TDS, TSS and MPN in Eastern Brahma Sarovar. The temperature of the water was observed to be within 21.1±0.2°C, the highest being at site E0 (near Mahedev Temple). TDS and TSS were found to be in the range of 125 – 310 mg/L (mean = 236.67 mg/L) and 45 – 165 mg/L (mean = 113.50 mg/L) respectively. Both, TDS and TSS, were found to be in lower concentrations in the southern-part (E3: 125 & 45 mg/L) followed by western-part (E5:1210 & 90 mg/L; E4: 230 & 110 mg/L), eastern-part (E2: 265 &

125 mg/L), northern-part (E1: 280 & 146 mg/L) and highest concentrations (E0: 310 & 165 mg/L) near the temple site in the Eastern Brahma Sarovar. The MPN value displayed vide variation in the range of 49 – 430 per 100 ml (mean: 226.5 per 100 ml) and lie within the permissible standard range at all locations. However, MPN count was highest near the temple (E0: 430 per 100 ml) followed by E1 (350 per 100 ml), E2 (240 per 100 ml), E4 (150 per 100 ml), E4 (140 per 100 ml) and E3 (49 per 100 ml).

The results revealed that the water quality of the Eastern Brahm Sarovar was relatively better in south-west area (E3, E4 and E5), deteriorated in the north-east area (E1 and E2)), and worst in the north-west area near the temple (E0). This is possibly due to two reasons – the inlet (supply of fresh water through Western-Half) is being located in the south-west area; the outlet is being located in the eastern part near E3; and most of the human activities (bathing, offerings, etc.) takes place in the northern-part, particularly near the temple (E0).

3.2 Inter-variation of Water Quality in the Two Halves of the Lake

The water quality of the two halves of the lake – Western and Eastern Brahma Sarovar was compared by taking mean values of the measured parameters at all the locations in respective halves of the lake as shown in Figure 4A & 4B. The inter-comparison showed that both the halves of the lake have more or less comparable water quality, with higher TDS and TSS in Eastern Brahma Sarovar probably due to daily offerings at E0 site near temple. Although, the southern parts of both halves, Eastern and Western, were observed to have better water quality and meets the standards, as discussed above and shown in Figure 4A & 4B. But the results revealed that overall mean DO and BOD in both the halves of the lake were not conforming the standards, and thus making the water unfit for as per CPCB criteria for DBU Class-B: Outdoor Bathing (Organised).

3.3 Overall Water Quality of the Brahma Sarovar

The overall water quality of the entire sacred lake, including both the halves (Western and Eastern) has been represented in Figure 4. The average temperature of the lake water during the study period was 21.14°C. Though the water quality parameters of the lake, namely – pH (7.94), Turbidity (3.63 NTU), TDS (222.23 mg/L), TSS (100.25 mg/L) and MPN (239.25 per 100 ml), conformed to the standards; however, DO (4.70 $\leq$ 5.00 mg/L) and BOD (3.54 $\geq$ 3.00 mg/L) of

the lake water were not meeting the standards, indicating the presence of oxygen demanding pollutants and possibility of production of obnoxious (anaerobic) gases. Thus, making the water of lake unfit for DBU Class-B: Outdoor Bathing (Organised). However, lake water met the DBU Class-D: Propagation of Wild life and Fisheries criteria of pH (between 6.5 to 8.5) and DO (> 4 mg/L).

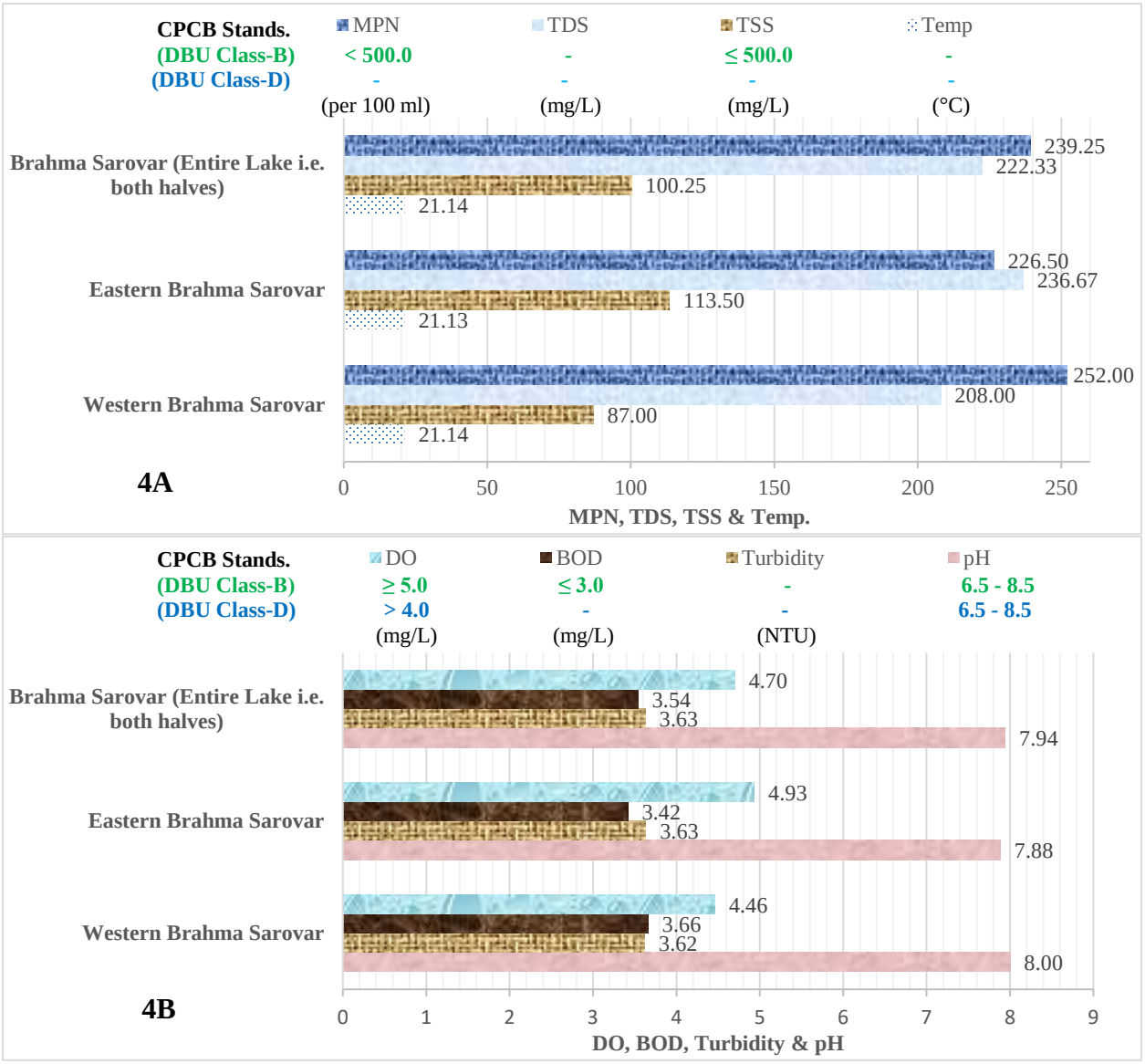

Figure 4. Inter-variation of water quality in the Eastern and Western Brahma Sarovar vis-à-vis overall water quality of the entire lake. **4A**. Variation of MPN, TDS, TSS and Temp; **4B.** Variation of DO, BOD, Turbidity and pH.

The findings of this study were also compared with previous two studies carried out during May 2016-2018 (Kumar et al., 2018) and during 2017 (Praveen & Setia, 2017a). The results of these studies (Table 2) showed that the lake water was neither fit for DBU Class-B; Outdoor Bathing (Organised), nor for DBU Class D: Propagation of Wild life and Fisheries. Both these studies were during the period when river water was being supplied to Brahm Sarovar by Thanesar Distributary which is an open channel lined offtake from Narwana Branch Canal. As the distributary was open channel and passes through human settlements, its water was being polluted during the course of journey due to unhealthy practices (such as human and cattle bathing, washing of clothes, cattle farming, disposal of solid waste, etc.) by the people residing near the banks of the open channel.

Table 2. Comparison of physiochemical and biological parameters of the Brahma Sarovar.

Parameters	**Kumar et al. (2018)**	**Praveen & Setia (2017a)**	**Present Study**
Temperature (ºC)	-	-	21.14
pH	7.60	9.20	7.94
Turbidity (NTU)	3.10	3.00	3.63
DO (mg/l)	2.00	4.00	4.70
BOD, 3 day at 27ºC (mg/l)	24.57	11.00	3.54
TDS (mg/l)	345.00	750.00	222.33
TSS (mg/l)	-	-	100.25
MPN (per 100ml)	-	1,200.00	239.25

However, the open channel has now been replaced by closed conduit with a provision of re-circulation so as to avoid stagnation of water and ensure a constant supply of fresh water in Brahma Sarovar as suggested by Praveen & Setia (2017b). The comparison (Table 1) revealed that there has been marked improvement in the water quality of the lake by the supply of fresh water vis closed conduit and re-circulation of water. But, as the lake water is still not fit for

Designated Best Use for Outdoor Bathing (Class-B), more needs to be done to maintain the required water quality and protect the health of the pilgrims. These may include – increased frequency of fresh water supply and re-circulation, particularly during mass-bathing events; and installation of appropriate aeration/fountain system to augment DO and reduce BOD of the lake water. The aeration/fountain system not only freshen and carry out the mixing of entire water body but also adds to the aesthetics and landscape of the lake.

4. Conclusion

The spatial water quality variations (intra-variations of the two halves of the lake) revealed that water quality of Western Brahma Sarovar deteriorated in clockwise direction from its southern-part towards the eastern-part; whereas, the water quality of Eastern Brahma Sarovar was relatively better in south-west area but deteriorated in the north-east area and was worst in the north-west area near the temple. The inter-variation of water quality between the two halves showed higher TDS and TSS in Eastern Brahma Sarovar due to daily offering at temple site. However, the overall DO and BOD of the lake water are beyond the permissible limits due to holy dip (bathing) and religious rituals/offerings by the devotees, and thus making it unfit for Designated Best Use Class-B: Outdoor Bathing (Organised). Though the findings of the study depict that the water quality of Brahma Sarover has improved by the provisions of closed conduit for the supply of fresh water from a canal, along with re-circulation of water to avoid stagnation of water in the lake, but some additional measures are required to control and maintain the water quality of the sacred lake as per the standards. These may include – increased frequency of fresh water supply and re-circulation, particularly during mass-bathing events; and installation of appropriate aesthetic aeration/fountain system that will increase DO and reduce BOD concentrations.

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