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ORIGINAL RESEARCH ARTICLE



Efficiency of Sequential Batch Reactor (SBR) based sewage treatment plant and its discharge impact on Dal Lake, Jammu & Kashmir, India

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ABSTRACT

Dal Lake is the second largest and most beautiful Lake in the state of Jammu and Kashmir and is the major centre of tourist activities. Due to the continuous increase in the population, the generation of domestic wastewater also increased. The present study was carried out to assess the efficiency of Sequential Batch Reactor (SBR) based Sewage Treatment Plant (STP) located at Brari Numbal and its discharge impact on the physicochemical properties of Dal Lake. The sample was collected from the selected sampling sites (inlet and outlet of SBR based STP, upstream, confluence zone, and downstream of Dal Lake) for five months (November 2019 to March 2020) and analysed using the standard methodologies. The plant shows maximum removal efficiency for BOD (79.85%) although the effluent BOD was found above the standard limit. The minimum removal efficiency of the plant was observed in the case of pH (3.46%). The gain in the case of DO was observed +851.55%. All the sites of Dal Lake were found polluted but the confluence zone and downstream were more polluted in comparison to the upstream due to the discharge of STP outlet into Dal Lake with higher BOD and COD (21.39% increase in BOD, 43.29% increase in COD; 80.10% increase in iron, 65.61% increase in ammonical nitrogen, and 101% increase in phosphate concentration). Besides this, discharge of the huge quantity of untreated wastewater from the city into the lake is also responsible for the degraded water quality of Dal Lake. It can be concluded that efficiency of the plant was in moderate condition and it needs further modifications. This is the first study showing the impact of SBR-STP effluent on Dal Lake.

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INTRODUCTION

We live on a blue planet that means the planet is dominated by water (covering more than 70% of the earth's surface). Water is one of the most vital components for the survival of living organisms (Bhutiani *et al.*, 2019; Wani *et al.*, 2016). But a very little portion of this water is available as freshwater. Continuous increase in the population results in urbanization and industrialization which results in a large amount of extraction of groundwater as well as generation of huge amount of wastewater (Bhutiani and Ahamad, 2018; Miller *et al.*, 2010; Habib *et al.*, 2020). A small amount of this wastewater is treated while a

large amount is discharged into the freshwater bodies either in treated or untreated form (Kumar *et al.*, 2018). The wastewater treatment process plays a key role in sustainable development by providing protection to surface waters (Gargosova and Urminska, 2017; Kumar *et al.*, 2020). Increased nutrients are a significant threat to the ecology of freshwater bodies. In developing countries, discharge of treated, partially treated, or untreated sewage in freshwater systems is normal. This sewage contains nitrogen, phosphorus, and the other nutrients needed for the production of biomass (Wani *et al.*, 2016; Santos *et al.*, 2008). Justified concentration of these nutrients is helpful while excess concentration causes algal bloom in water bodies. Out of

22,900 MLDs of wastewater generated in India, only 26% (5,900 MLDs) is treated before disposal while the 17,100 MLD is disposed of untreated (CPCB, 2007). The basic treatment facility is available only in twenty-seven areas while secondary treatments in forty-nine areas. The depletion of water quality is a common concern due to its impacts on humans and the natural values of the environment directly (Jones et al., 2000; Okoh and Igbinosa, 2009; Okoh et al., 2005).

Traditional sludge systems are inefficient for the treatment of domestic wastewater as it requires large size reactors and long processing time. Biological fixed film technology also in trend due to reduced size reactors and processing periods (Moldovan and Nuca, 2019). However, fluidized bed technology is an advanced technology in which the fixed film media consist of thin, non-clogging plastic material. The advantages of this technology include: No backwash, small head loss and special surface of high-speed bio-film. The biological reactions take place in the bioreactor in a stable setting consisting of an aeration grid-containing reservoir. The flowing air provides the dissolved oxygen required for biological reactions. Water is circulated from the base of the tank towards the surface to absorb oxygen into liquids. The reactor comprises millions of these components, and the surface region is used for the development of the bacterial community (Moldovan and Nuca, 2019). The government of Jammu and Kashmir is continuously working for the management of wastewater for the protection of Dal lake. The government established three treatment plants along the periphery of Dal lake for the treatment of domestic wastewater. Therefore there is a need to continuously assess the efficiency of these treatment plants. Several studies were available on the efficiency assessment of these treatment plants but none of the study highlights the impact of discharge of these treatment plants on the health of Dal lake. Therefore, the present study was carried out with the objective of efficiency assessment of the Sequential Batch Reactor (SBR) based Sewage Treatment Plant (STP) and its discharge impact on the physicochemical characteristics of Dal Lake, Jammu and Kashmir, India.

MATERIALS AND METHODS

Study area

The study was carried out at SBR-STP located at Brari Nambal in Srinagar, India. The geographical coordinates of the study sites were 34°08' 69"N, 74°81'39"E. The capacity of the STP was 16.10 million litres per day (MLD). The plant receives wastewater from an area of about 270 hectares. The disposal site for treated sewage (effluent) is Brari Nambal (small freshwater body partially part of Dal Lake). Dal Lake is the most stunning national patrimony. The 11.45 Km² open-air Dal Lake is connected to the south-western capital city. The lake is situated at an altitude of about 1583 meters above sea level.

Sample collection

The present study is related to STP to determine their

performance in biomass production for the reduction of nutrients. All the sampling sites were shown in Table 1 and Figure 1. Water samples from all the five sampling sites viz., Nishat Pipeline Bund (Up-stream of Dal Lake), Charchinari, Kabootar Khana - Nishat Basin (Down-stream of Dal Lake), Brari Numbal (Intlet), and Brari Numbal (Outlet) were collected in the morning hour (between 7 A.M. to 10 A.M.) in the prewashed plastic containers of 2 litres throughout the study period. The sampling was performed for five months (from November 2019 to March 2020). All the selected parameters as air temperature, water temperature, pH, conductivity, total dissolved solids (TDS), total suspended solids (TSS), total solids (TS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total hardness (TH), chloride, sulphate, iron, ammonical nitrogen, and total phosphate were analyzed following the standard methods prescribed (APHA, 2017; Trivedy and Goel, 1986; Khanna and Bhutiani, 2008).

Statistical analysis

The data obtained after analysis was treated statistically. Microsoft excel 2010 was used for the calculation of average (Avg) and standard deviation (SD).

Table 1. Geographical coordinates of different sampling sites.

S.N.	Site Name	Geographical co-ordinates
SS-01	Nishat Pipeline Bund (Up-stream of Dal Lake)	34°07'55.9"N 74°52'35.7"E
SS-02	Charchinari	34°06'17.2"N 74°52'00.8"E
SS-03	Kabootar Khana - Nishat Basin (Down-stream of Dal Lake)	34°05'36.6"N 74°51'23.0"E
SS-04	Brari Numbal (Intlet)	34°05'06.5"N 74°48'53.4"E
SS-05	Brari Numbal (Outlet)	34°05'06.5"N 74°48'53.4"E



Figure 1. Map showing sampling sites at Dal Lake, Jammu & Kashmir, India.

RESULTS AND DISCUSSION

Efficiency of SBR-STP

Physicochemical characteristics of inlet and outlet of STP are given in Table 2. The average temperature in inlet and outlet was found $15.10 \pm 0.84^\circ\text{C}$ and $14.96 \pm 0.87^\circ\text{C}$, respectively. Therefore in case of temperature the reduction efficiency of plant was observed as 0.93%. The ions and salts used in different water-related activities contribute to TDS in the wastewater (Salunke *et al.*, 2014). The average total dissolved solids (TDS) in inlet and outlet were found $234.24 \pm 10.85\text{mg/l}$ and $101.47 \pm 3.59\text{mg/l}$, respectively. Therefore, in the case of TDS, the reduction efficiency of the plant was observed as 68.81%. Ukpong (2013) also reported a decrease in TDS after treatment. The TDS decrease may be due to oxidation of dissolved solid (Singh and Varshney, 2013; Mahvi, 2008; Bhutiani *et al.*, 2016).

TSS is a measure of the floating particulate content of the wastewater and is an indicator of the clarity of the wastewater (Johal *et al.*, 2014). The average total suspended solids (TSS) during the study period in inlet and outlet were found $325.28 \pm 15.35\text{mg/l}$ and $99.16 \pm 1.99\text{mg/l}$ respectively. Therefore in the case of TSS, the reduction efficiency of the plant was observed as 57.67%. The decrease in total solids could be attributed to the sedimentation process undergoing the treatment. A decrease in TSS after treatment has been reported by several researchers (Khan *et al.*, 2014; Mahvi, 2008; Patel *et al.*, 2013; Bhutiani *et al.*, 2016). The average total solids (TS) during the study period in inlet and outlet were found $559.52 \pm 19.30\text{mg/l}$ and $200.63 \pm 3.00\text{mg/l}$, respectively. Therefore in case of TS the reduction efficiency of plant was observed as 64.14%.

Conductivity is a general indicator of wastewater quality, especially a function of the amount of dissolved salt, which contributed to the conductivity (Aguado *et al.*, 2006; Schilperooet *et al.*, 2006). The average conductivity during the

study period in inlet and outlet was found $237.45 \pm 11.21\mu\text{S/cm}$ and $102.65 \pm 2.07\mu\text{S/cm}$, respectively.

Therefore in the case of conductivity, the reduction efficiency of the plant was observed as 56.77%. The high EC value is attributed to the high salinity and high mineral content due to ion exchange and solubilisation in the water (Gautam *et al.*, 2013). The results obtained were according to the findings of Rizvi *et al.* (2015). The removal in EC after treatment is due to the reduction in the concentration of salts-nitrates, ammonium, cations, and associated chemicals (Lamichhane *et al.*, 2011; Jan and Rafiq, 2012).

pH is one of the important parameters in wastewater treatment (Salunke *et al.*, 2014). The average pH during the study period in inlet and outlet was found 8.10 ± 0.10 and 7.82 ± 0.16 respectively. Therefore in case of pH the reduction efficiency of plant was observed as 3.46%. The nature of the effluent was observed alkaline before and after the treatment. Similar findings were observed by several researchers (Gautam *et al.*, 2013; Sharma *et al.*, 2013; Bhutiani *et al.*, 2016). The average dissolved oxygen (DO) during the study period in inlet and outlet was found $0.32 \pm 0.06\text{mg/l}$ and $3.06 \pm 0.51\text{mg/l}$, respectively. Therefore in the case of DO, the gaining efficiency of the plant was observed as 851.55%. The average biochemical oxygen demand (BOD) during the study period in inlet and outlet was found $168.04 \pm 6.88\text{mg/l}$ and $33.86 \pm 5.22\text{mg/l}$, respectively. Therefore in the case of BOD, the reduction efficiency of the plant was observed as 79.85%. BOD removal confirms that biological treatment processes is working efficiently. The reduction in the BOD value of effluent may be due to oxidation of organic matter in batch reactors due to aeration. Wakode and Sayyad (2016) also reported BOD reduction from 134.63 mg/l to 5.36 mg/l , with a removal efficiency of 96% by using the SBR process. Reduction in BOD has also been confirmed by the studies of Kushwah *et al.* (2011) and Ukpong (2013). A more or less similar trend was observed by Bhutiani *et al.* (2017).

Table 2. Percent removal of different parameters of sewage water before and after treatment.

Parameters	Inlet (Average \pm SD)	Outlet (Average \pm SD)	% Removal
Water temperature	15.10 ± 0.84	14.96 ± 0.87	-0.93
TDS	234.24 ± 10.85	101.47 ± 3.59	-68.81
TSS	325.28 ± 15.35	99.16 ± 1.99	-57.67
TS	559.52 ± 19.30	200.63 ± 3.00	-64.14
Conductivity	237.45 ± 11.21	102.65 ± 2.07	-56.77
pH	8.10 ± 0.10	7.82 ± 0.16	-3.46
Dissolved oxygen	0.32 ± 0.06	3.06 ± 0.51	+851.55
BOD	168.04 ± 6.88	33.86 ± 5.22	-79.85
COD	474.26 ± 5.99	165.54 ± 7.45	-65.10
Chloride	48.98 ± 3.70	38.04 ± 5.65	-22.34
Total hardness	79.96 ± 1.89	42.29 ± 2.09	-47.11
Calcium	39.36 ± 1.71	23.62 ± 1.55	-39.99
Magnesium	9.91 ± 0.75	4.56 ± 0.76	-53.97
Sulphate	16.56 ± 1.57	5.66 ± 0.78	-65.82
Nitrate-nitrogen	9.60 ± 0.72	2.17 ± 0.29	-77.40
Ortho-phosphate	3.30 ± 0.42	1.11 ± 0.12	-66.36
Total phosphate	4.16 ± 0.49	1.87 ± 0.07	-55.14

Table 3. Physicochemical parameters of sewage effluent at Nishat pipeline bund: up-stream of Dal Lake (SS-01).

Parameters	November-2019	December-2019	January-2020	February-2020	March-2020	Average
Air temperature	18.90	17.60	20.50	20.50	20.80	19.66
Water temperature	16.00	14.60	12.80	14.10	15.40	14.58
pH	7.94	7.90	7.89	7.47	7.89	7.82
Conductivity	260.00	245.00	362.00	369.00	326.00	312.40
Dissolved oxygen	4.13	4.32	4.76	4.45	4.21	4.37
BOD	9.87	8.76	8.12	8.23	9.43	8.88
COD	98.67	91.32	78.65	86.51	95.32	90.09
Total hardness	42.40	45.70	45.90	41.90	43.20	43.82
Chloride	33.00	31.00	42.00	43.00	35.00	36.80
Total alkalinity	210.00	110.00	263.00	273.00	243.00	219.80
Sulphate	29.90	29.60	30.20	31.30	30.60	30.32
Iron	2.12	1.78	2.10	2.30	1.76	2.01
Ammonical nitrogen	2.32	2.56	2.78	3.12	3.45	2.85
Total phosphate	4.10	4.20	4.00	4.20	4.40	4.18

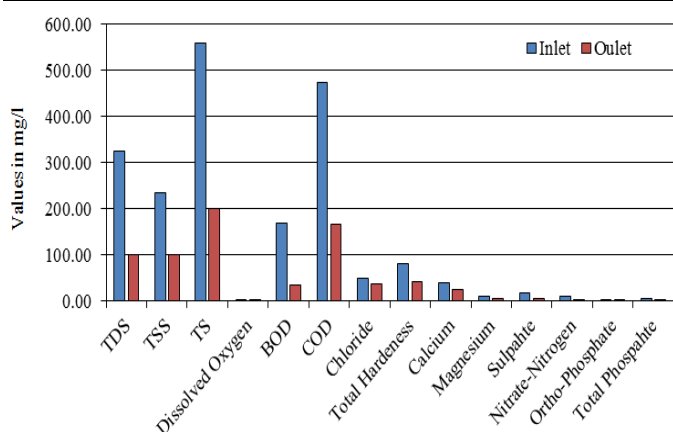


Figure 2. Changes in different parameters of sewage water before and after treatment.

COD is the amount of oxygen required for the breakdown of organic and inorganic matter in water (Akan et al., 2008; Kumar et al., 2018). The average chemical oxygen demand (COD) during the study period in inlet and outlet was found 474.26±5.99mg/l and 165.54±7.45mg/l, respectively. Therefore in the case of COD, the reduction efficiency of the plant was observed as 65.10%. Higher levels of COD in wastewater lead to drastic oxygen depletion once discharged into the water body and adversely affect the biota. The decrease may be linked to the aeration and digestion processes, which has also been confirmed by the researchers (Tian et al., 2011; Ghehi et al., 2014; Johal et al., 2014; Ding et al., 2011). The average chloride (Cl) during the study period in inlet and outlet was found 48.98±3.70mg/l and 38.04±5.65mg/l, respectively. Therefore, in the case of chloride, the reduction efficiency of the plant was observed as 22.34%. A higher concentration of chloride in sewage may result from the higher usage of washing agents like detergents, soaps, and water filtering units, sodium chloride, and also by discharging faecal matter (Von Sperling, 1996). Chloride ion concentration is an important factor to be considered if the effluent is used for irrigation. A more or less similar trend was observed earlier by Bhutiani et al. (2017).

The main sources of Ca and Mg in wastewater are calcite, dolomite, magnesite, anhydrite, gypsum feldspar, pyroxene, and amphiboles present in the catchment. The average total hardness (TH) during the study period in inlet and outlet was

found 79.96±1.89mg/l and 42.29±2.09mg/l, respectively. Therefore in the case of TH, the reduction efficiency of the plant was observed as 47.11%. The average calcium hardness during the study period in inlet and outlet was found 39.36±1.71mg/l and 23.62±1.55mg/l, respectively. Therefore in the case of CaH, the reduction efficiency of the plant was observed as 39.99%. The average magnesium hardness during the study period in inlet and outlet was found 9.91±0.75 and 4.56±0.76, respectively. Therefore, in the case of MgH, the reduction efficiency of the plant was observed as 53.97%. The reduction in hardness has been reported by several researchers (Kushwah et al., 2011; Jan and Rafiq, 2012; Bhutiani et al., 2017). The removal may be due to the grit separation, sedimentation process, and microorganism's uptake of calcium and magnesium ions during treatment (Nathanson, 2003; Showkat and Najar, 2019).

The average sulphate (SO₄²⁻) during the study period in inlet and outlet was found 16.56±1.57mg/l and 5.66±0.78mg/l, respectively. Therefore in case of sulphate the reduction efficiency of plant was observed as 65.82%. The average nitrate-nitrogen (NO₃⁻-N) during the study period in inlet and outlet was found 9.60±0.72mg/l and 2.17±0.29mg/l, respectively. Therefore in case of nitrate-nitrogen the reduction efficiency of plant was observed as 77.40%. Ortho-phosphate or inorganic phosphate becomes easily available to plants and thus is known as reactive phosphorous. It is also an indicator of blooming in water bodies (Wenzel and Ekama, 1997). The average ortho-phosphate (HPO₄²⁻) during the study period in inlet and outlet was found 3.30±0.42mg/l and 1.11±0.12mg/l, respectively. Therefore in the case of ortho-phosphate, the reduction efficiency of the plant was observed as 66.36%. The raw sewage contains nutrient load from the various point and non-point sources i.e., Agriculture runoff, domestic sewage (Koopman et al., 1990; Deepa and Ramachandra, 1999; Fuentes et al., 2020; Morrisison et al., 2001). The low concentration of ortho-phosphate can be because the ortho-phosphate was selectively enriched and large quantities of phosphorous are accumulated within the cells by means of biologically improved phosphorous removal. In this process, the specific bacteria called the polyphosphate accumulators (PAOS). The results are similar to those of Marti et al. (2012).

Table 4. Physicochemical parameters of sewage effluent at Charchinari: Confluence zone (SS-02).

Parameters	November-2019	December-2019	January-2020	February-2020	March-2020	Average
Air temperature	16.50	17.80	13.50	15.50	16.40	15.94
Water temperature	13.70	12.60	12.10	13.50	13.90	13.16
pH	8.13	8.10	8.09	8.11	8.13	8.11
Conductivity	225.00	256.00	245.00	203.00	249.00	235.60
Dissolved oxygen	3.65	3.86	4.10	3.93	3.59	3.65
BOD	9.12	9.05	8.34	8.77	9.57	9.12
COD	89.54	84.31	76.58	81.23	93.34	89.54
Total hardness	40.80	46.50	46.53	43.98	42.87	44.14
Chloride	22.10	23.10	20.90	21.80	23.30	22.24
Total alkalinity	187.12	176.56	180.61	178.92	179.78	180.60
Sulphate	16.50	18.70	18.50	18.56	19.34	18.32
Iron	5.61	4.91	4.32	4.98	3.21	4.61
Ammonical nitrogen	4.12	4.87	4.76	4.64	4.34	4.55
Total phosphate	3.17	3.14	3.18	3.96	3.56	3.40

The total phosphorous in municipal wastewater consists of 70-90% soluble orthophosphates and 30-10% organically bound phosphorous which is insoluble or particulate form, a small fraction of non-biodegradable phosphorous (Ekama and Marais, 1984; Gorecki and Melcer, 2005). Phosphate in sewage effluents arises from human wastes and domestic phosphate-based detergents and soaps (Ogunfowokan et al., 2005). The average total phosphate (PO_4^{3-}) during the study period in inlet and outlet was found $4.16 \pm 0.49 \text{ mg/l}$ and $1.87 \pm 0.07 \text{ mg/l}$, respectively. Therefore in the case of total phosphate, the reduction efficiency of the plant was observed as 55.14%. Adsorption, precipitation, and/or assimilation by microorganisms may be the processes responsible for the removal of total phosphorous (Rajeb et al., 2011). Our results are more or less similar to those of Wakode and Sayyad (2016) which reported 71.79% removal efficiency.

Impact on effluent discharge on Dal Lake

Results of upstream (Site 1), confluence Zone (Site 2) and downstream (Site 3) of Dal Lake are presented in Tables 3-5. Minimum air temperature (13.50°C) was found in the month of January at site-2 while maximum temperature (20.80°C) was found in the month of March at site-1. The average air temperature at site-1, site-2, and site-3 was found 19.66°C , 15.94°C and 18.48°C . Minimum water temperature (12.10°C) was found in the month of January at site-2 while maximum temperature (16.00°C) was found in the month of November at site-1. The average air temperature at site-1, site-2, and site-3 was found 14.58°C , 13.16°C , and 13.60°C . Water temperature is mostly affected by ambient temperature and the effect of all other temperature is very less. A more or less similar trend was observed by Bhutiani et al. (2019) and Schilperooet et al. (2006). Minimum pH value (7.47) was found in the month of February at site-1 while maximum pH value (8.13) was found in the month of November at site-2. The average pH value at site-1, site-2, and site-3 was found 7.82, 8.11, and 7.97. A slight increase in pH is found at confluence zone due to mixing of slightly alkaline nature effluent of cities and outlet of STP plant. Similar pattern

of pH was observed by Appavu et al. (2016). Minimum Conductivity ($203.0 \mu\text{S/cm}$) was found in the month of February at site-2 while maximum ($369.0 \mu\text{S/cm}$) was found in the month of February at site-1. The average conductivity at site-1, site-2, and site-3 was found $312.40 \mu\text{S/cm}$, $235.60 \mu\text{S/cm}$, and $267.00 \mu\text{S/cm}$. A decrease in the ions at confluence zone is the result of sedimentation, precipitation and coagulation due to mixing of effluent (Wani et al., 2014; Howwarth et al., 1996).

Minimum dissolved oxygen (2.56 mg/l) was found in the month of November at site-3 while maximum (4.76 mg/l) was found in the month of January at site-1. The average DO at site-1, site-2, and site-3 was found 4.37 mg/l , 3.83 mg/l , and 3.05 mg/l . Minimum BOD (8.12 mg/l) was found in the month of January at site-1 while maximum (11.98 mg/l) was found in the month of March at site-3. The average BOD at site-1, site-2, and site-3 was found 8.88 mg/l , 8.97 mg/l , and 10.78 mg/l . Minimum COD (76.58 mg/l) was found in the month of January at site-2 while maximum (138.50 mg/l) was found in the month of March at site-3. The average COD at site-1, site-2, and site-3 was found 90.09 mg/l , 85.00 mg/l , and 129.09 mg/l . After confluence zone the decrease in the DO and increase in BOD and COD is the result of mixing of effluent having the BOD above the standard limit of CPCB which also increased the organic matter content of the Dal Lake water resulting in the decrease of DO which is not good for the aquatic animals and plants. A more or less similar trend was observed by Bhutiani et al. (2019), Ram et al. (2007), and Spanhaff et al. (2006). Minimum total hardness (40.80 mg/l) was found in the month of November site-2 while maximum (58.91 mg/l) was found in the month of December at site-3. The average TH at site-1, site-2, and site-3 was found 43.82 mg/l , 44.14 mg/l , and 57.57 mg/l . Minimum Chloride (20.90 mg/l) was found in the month of January at site-2 while maximum (50.92 mg/l) was found in the month of November at site-3. The average chloride at site-1, site-2, and site-3 was found 36.80 mg/l , 22.24 mg/l , and 49.14 mg/l . A slight increase in the concentration of chloride is due to addition of chlorine in the outlet of STP for disinfection colour removal purpose. Aziz et al. (2019) and Okoh et al. (2007) also observed similar results in their studies.

Table 5. Physicochemical parameters of sewage effluent at Kabootar Khana: Nishat Basin Down-stream of Dal Lake (SS-03).

Parameters	November-2019	December-2019	January-2020	February-2020	March-2020	Average
Air temperature	20.2	17.5	16.1	18.7	19.90	18.48
Water temperature	13.80	13.50	13.20	13.40	14.10	13.60
pH	7.91	7.98	8.12	7.98	7.87	7.97
Conductivity	263.00	257.00	277.00	273.00	265.00	267.00
Dissolved oxygen	2.87	3.12	3.53	3.18	2.56	3.05
BOD	11.81	10.23	9.78	10.12	11.98	10.78
COD	134.45	123.40	116.98	132.10	138.50	129.09
Total hardness	56.40	58.91	56.43	58.12	57.98	57.57
Chloride	50.92	45.70	48.61	50.61	49.87	49.14
Total alkalinity	180.91	180.78	176.54	178.12	179.78	179.23
Sulphate	34.21	33.54	32.76	36.98	35.50	34.60
Iron	3.80	3.50	3.94	3.54	3.32	3.62
Ammonical nitrogen	4.98	4.87	4.56	4.87	4.34	4.72
Total phosphate	8.34	9.98	8.12	7.65	8.12	8.44

Minimum total alkalinity (110.00mg/l) was found in the month of December at site-1 while maximum (273mg/l) was found in the month of February at site-1. The average alkalinity at site-1, site-2, and site-3 was found 219.80mg/l, 180.60mg/l, and 179.23mg/l. A more or less similar trend was observed by Bhutiani et al. (2019) and Gandiglio et al. (2017). Minimum Sulphate (16.50mg/l) was found in the month of November at site-2 while maximum (36.98mg/l) was found in the month of February at site-3. The average sulphate at site-1, site-2, and site-3 was found 30.32mg/l, 18.32mg/l, and 34.60mg/l. Minimum Iron (1.76mg/l) was found in the month of March at site-1 while maximum (5.61mg/l) was found in the month of November at site-2. The average iron at site-1, site-2, and site-3 was found 2.01mg/l, 4.61mg/l, and 3.62mg/l. Minimum ammonical nitrogen (2.32mg/l) was found in the month of November at site-1 while maximum (4.98mg/l) was found in the month of November at site-3. The average ammonical Nitrogen at site-1, site-2, and site-3 was found 2.85mg/l, 4.55mg/l, and 4.72mg/l. Minimum Total phosphate (3.14mg/l) was found in the month of December at site-2 while maximum (9.98) was found in the month of December at site-3. The average total phosphate at site-1, site-2, and site-3 was found 4.18mg/l, 3.40mg/l, and 8.44mg/l. Increase in the concentration of all these parameters at confluence zone or after confluence zone was observed due to the mixing of treated and untreated effluent in the Dal Lake. Upper stream was also observed slightly polluted due to mixing of domestic wastewater disposal through different drains in the Dal Lake. Results are in agreement with several researchers (Castellet and Molinos-Senante, 2016; Aziz et al., 2019; Gucker and Branus, 2005; Howwarth et al., 1996).

Conclusion

The present study was undertaken with the aim to assess the efficiency of Brari Numbal SBR based STP and to assess the impact of its discharge on the physicochemical properties of Dal Lake. The overall efficiency of STP was observed satisfactory as most of the studied parameters were found below the limits

(TDS, 325.28 to 101.47mg/l; TSS, 234.24 to 99.16; COD, 474.26 to 165.54mg/l) of WHO and BIS after the treatment except BOD (168.04 to 33.86mg/l). The treatment process needs more aeration and the addition of media to work it more efficiently. All the studied sites of Dal Lake were observed polluted but the concentration of most of the parameters was found highest at and after the confluence zone which shows that discharge is deteriorating the quality of Dal Lake (24.58% decrease in conductivity, 16.47% decrease in DO, 21.39% increase in BOD, 43.29% increase in COD; 31.38% increase in TH; 33.53% increase in Cl, 22.64% decrease in alkalinity, 14.11% increase in sulphate, 80.10% increase in iron, 65.61% increase in ammonical nitrogen, and 101% increase in phosphate concentration). If the mixing of domestic wastewater and outlet of the treatment plant will continuous in the Dal Lake, it will lose its recreational and aesthetic value soon which results in the decrease of the tourist activities and in conclusion to the economic value of the local people. So there is an urgent need for the capacity up-gradation of the existing plants and setup of new treatment plants to manage the wastewater of the cities and industries.

Conflict of interest

The authors declare no conflicts of interest.

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