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Assessment of Physicochemical and Bacteriological Parameters of Sukhna Lake in Chandigarh, India

Jyoti Dadwal[1], Achal Bhatnagar[2], Sandeep Kumar[3]

[1, 2, 3]Sri Guru Gobind Singh College (Affiliated to Panjab University Chandigarh),
Sector-26, Chandigarh, Pin code-160019, India

Abstract: ***The study was conducted to assess the water pollution and specifically the sanitary-bacteriological state of Sukhna lake. Water samples were collected from six different sites every alternate month for the year 2013. Water samples were analysed for physicochemical parameters such as pH, temperature, color, total dissolved solids (TDS), dissolved oxygen (DO) and biological and chemical oxygen demand (BOD and COD). Bacteriological analysis included total viable count of bacteria (TVC), total number of coliform (TC), faecal coliform (FC) and faecal Streptococci (FS) by multiple tube fermentation methods. The values for most of the parameters were within the criteria limit set by Central Pollution Control Board (CPCB) and BIS standards for a freshwater lake suitable for recreational activities and propagation of fisheries and wild life. Maximum BOD values were recorded during the months of May and July, when the water levels were lowest for the year and ranged from 3.7mg/l to 5.8mg/l for all the six locations suggesting moderate organic pollution during these months only. TVC and TC values does confirm presence of coliforms in the lake water and likewise high TC and FC counts in three sites (A,C and D) during the months of May and July 2013, suggest slight to moderate organic and sewage pollution. In conclusion, the water of Sukhna lake at all sites falls in the category of fresh water suitable for different recreational activities as well as for the fish and duck population of the lake for the greater part of the year.***

Keywords: coliforms, physicochemical parameters, sewage pollution, Sukhna lake.

1. Introduction

Sukhna Lake in Chandigarh, India is an artificial lake at the foothills of the Himalayas, the Shivalik hills. Sukhna Lake is an invaluable asset for the Union Territory of Chandigarh. Although approved on the ground of maintaining water table of the city, it has emerged as the great contributor to the soul of this city beautiful. It is a sanctuary for many exotic birds like the Siberian ducks, storks and cranes and has been declared as a protected national wetland by Government of India. It is a hot spot for not only tourists to this city but also a centre of recreational activities such as boating, sailing and kayaking.

The manmade Sukhna lake was brought into existence in 1958 through blocking of the water flow in the Sukhna choe originating from Shivalik hills by raising of stone-cum-earthen embankments. Roughly kidney shaped, the lake is located at 32°42' N Latitude and 76°54' E Longitude with its concavity facing the Shivalik hills. The lake is 1.52 km long and 1.49 km wide with initial storage capacity of 1,074 ha-m of water. Two seasonal tributaries namely Kansal and Saketri mainly contribute water to the Sukhna lake (Siddiqui *et al*., 2013). About 20% of the lake catchment area is in plains which include villages of Kaimbwala, Kansal and Khuda Ali Sher [Fig.1(B)]. Untreated sewage and other domestic wastes like runoffs from cattle sheds of villages find their way to lake during the rainy season (Chaudhry *et al*., 2013).

The existence of lake and its water quality in recent years have been affected by many problems. Rapid urbanization around the lake, heavy siltation, drying up of the lake in summers, weed overgrowth, heavy tourist activities, storm water run off and sewerage pollution from the surrounding areas of the lake are some reasons of concern for the overall health of the lake (Chaudhry *et al*., 2013; newspaper reports).

Organic pollution index for recreational lakes is based on BOD and COD levels. Sewage effluents contain a wide range of human enteric pathogens, which may pose a health hazard to the exposed human population when they are discharged into natural waters. Sewage pollution in a water body is usually analysed by the presence of indicator coliform bacteria in the water. The higher the level of indicator bacteria, higher will be the level of faecal contamination and greater the risk of water borne diseases. The total coliform is further narrowed down to the faecal coliforms and faecal *Streptococci* (Kistemann *et al*., 2002).

Water quality monitoring helps in evaluating the nature and extent of pollution control measures already in existence. It also helps in drawing the water quality trends and prioritizing pollution control efforts (Bharadwaj, 2005). Although there have been a few reports on the assessment of various physicochemical parameters of the lake (Sharma *et al*., 2010; Tyor and Chawla, 2012; Chaudhry *et al*., 2013). Authors have come across with only one scientific report on the bacteriological assessment of Sukhna lake water (Sharma *et al*., 2010). Considering the importance of Sukhna lake for Chandigarh and very little information available on its sanitary bacteriological condition, the present study was undertaken to assess bacteriological as well as physicochemical parameters of the lake water to ascertain the presence of organic waste as well as sewage pollution for the time period of November-2012 to September-2013.

2. Materials and Methods

2.1 Water Sampling Sites

Six sites were selected to ensure that maximum area of the Sukhna lake is covered for the study (Fig.1; Table.1).

2.2 Collection of Water Samples

Water samples were collected from six different sites of the lake (Fig.1) in the months of November- 2012, January-2013, March-2013, May-2013, July-2013and September-2013. The samples were collected in the sterile 1 litre plastic (polyvinylpropylene) bottles. The bottles were labeled A, B, C, D, E, and F as per the locations of sample collection (Table.1; Fig. 1). Bottles were dipped completely in the water taking care to avoid mixing of air bubbles in water sample. The bottles were filled up to rim and screwed tightly. Samples were immediately transferred to the laboratory. They were refrigerated at 4°C and analysed within 48 hrs. All the parameters for each water sample were measured in triplicate and the mean values were considered. The results represent the average/ mean of six alternate months' data for each site.

Table 1: Location of six sites of the Sukhna Lake selected for sampling.

Site name	Location
A	Lake front (tourist spot)
B	Near Observation Tower
C	Near mobile tower
D	Near lake club
E	Extreme right corner (opposite to garden of silence)
F	Middle of forest trail ahead of site E

2.3 Analysis of Physicochemical Parameters

The temperature of surface water for all sites was recorded on their respective spots while sample collection with a thermometer. pH of water samples were measured using a pH meter calibrated at 4.0, 7.0 and 9.0 pH buffers immediately after bringing the water samples to the laboratory. The color of water samples was measured spectrophotometrically at 254 nm against the distilled water which was taken as blank as described by (Tchobanoglaus *et al*., 2009). The total dissolved solids were analysed using a water analysis kit (Deluxe Water analysis Kit, Model 191E). Dissolved oxygen was measured by using Winkler' method. Biological oxygen demand BOD_3 was calculated from the difference of DO concentration after 3 days of incubation at 27°C. Chemical Oxygen Demand of water was measured by potassium dichromate method.

2.4 Analysis of Bacteriological parameters

Immediately after bringing the water samples to the laboratory, total count as colony forming units per milliliter (CFU/ml) of bacteria was analysed by pour plating 0.1ml and 1ml water samples on to labeled plates with liquefied nutrient agar. The plates were then incubated at 37°C for 24 hours. The number of colonies in the plate by the sample size.

Figure 1: A: Map showing sampling sites of Sukhna lake in Chandigarh, India. B: Map showing catchment areas around Sukhna lake. (Maps Courtesy Google maps and The Tribune resp)

Total coliforms and faecal coliform were detected by standard most probable number (MPN) method. Different water volumes were inoculated in lactose broth medium supplemented with bromocresol purple and incubated at 37°C for TC and 44.5°C for FC for 24-48h. The tubes were examined for production of acid (change of medium colour to yellow) and gas. The tubes showing the positive test result were counted and used to obtain MPN/100ml referring a MPN index table Taras *et al*. (1998). The presence of coliforms specifically *Escherichia coli* was confirmed by streaking the culture from positive lactose broth tubes on to Eosin methylene blue agar medium, a selective differential medium for coliforms. For FS, the azide dextrose broth tubes were inoculated with different volumes of water sample and incubated at 37°C for 48h. Faecal *Streptococci* in the water sample were thus detected by using azide dextrose broth in a similar manner as TC and FC.

3. Results and Discussion

3.1 Physicochemical Parameters

pH values recorded for all the six sites A, B, C, D, E and F were between 7.0 -7.8.The prescribed limit of pH set by the CPCB is 6.5-8.5. The pH values recorded for the lake were well within this limit and essentially neutral to slightly alkaline in nature. Alkaline pH were also recorded by (Tyor and Chawla, 2012; Chaudhary *et al*., 2013) reflecting that the lake is bicarbonate type.

Average surface water temperatures for all the six sites were similar and consistent. The minimum temperatures were recorded around 13.0°C for the month of January and maximum temperatures were recorded around 30.5°C for the month of July.

Color of the lake water was analysed by measuring its absorbance at 254nm. The absorbance values ranged from as low as 0.10 to as high as 0.40. When compared with the typical absorbance values for various waste waters according to Tchobanoglous *et al*.(2009), the values do not show significant presence of any colored matter (inorganic compounds such as copper, iron etc. or organic compounds such as organic dyes, humic substances etc).

Values for TDS in all the six sites were less than 1000mg/l, suggesting that the lake comes under the category of fresh water lake. Total dissolved solids were high during the months of March, May and July as compared to the months of September and November. The TDS values were high for Site A (520-820mg/l) and Site D (540- 800mg/l). Site A and Site D represent lake front (tourist spot) and Lake club site respectively. Sukhna lake receives heavy amount of silt and dissolved minerals from the catchment areas resulting in high TDS values(Chaudhry *et al*.,2013). Other reason could be the greater human activity around these spots leading to organic and sewage pollution and very low levels of water during the summer. The people feed the small population of ducks present at the Lake front area and the eatables that are thrown everyday into this area may also be contributing to water pollution. The permissible TDS values for drinking water is around 500mg/l (BIS 10500, 1991, specification) which implies that water of Sukhna lake is not potable.

Table 2: Results for Physicochemical parameters of Sukhna lake (Average for the months of Nov-2012, Jan-2013, Mar-2013, May-2013, July-2013 and Sept-2013.

Parameter		*Site A*	*Site B*	*Site C*	*Site D*	*Site E*	*Site F*
pH	Range	7.0-7.8	7.0-7.5	7.0-7.2	7.0-7.2	7.0-7.3	7.1-7.5
	Mean±SD	7.2±0.30	7.15±0.18	7.11±0.075	7.06±0.75	7.08±0.11	7.23±0.17
Temp (°C)	Range	13.5-30	13.5-30	13.0-30.0	13.5-30.5	13.5-30.0	13.5-30.0
	Mean±SD	23.16±6.31	23.16±6.31	23.16±6.31	23.5±6.300	23.48±6.31	23.41±6.38
Color A_{254nm}	Range	0.175-0.469	0.110-0.404	0.110-0.511	0.104-0.53	0.100-0.414	0.105-0.472
	Mean±SD	0.272±0.125	0.225±0.09	0.205±0.155	0.232±0.152	0.196±0.113	0.195±0.138
TDS (mg/l)	Range	520-820	310-780	410-760	540-800	410-790	480-783
	Mean±SD	693.3±120.56	642±172.8	655±140.96	681.16±99.64	642.16±164.87	645.5±121.29
DO (mg/l)	Range	5.86-19.5	7.46-20.0	7.2-20.6	6.4-22.8	6.1-21.0	4.0-23.2
	Mean±SD	9.27±5.12	10.16±4.86	10.8±5.60	11.81±7.48	11.73±6.25	10.93±8.36
BOD (mg/l)	Range	1.9-4.67	1.3-4.8	1.11-5.0	1.8-4.4	1.2-5.8	1.2-3.7
	Mean±SD	3.07±1.17	2.68±1.20	2.46±1.45	2.95±0.88	3.64±1.99	2.22±0.943
COD (mg/l)	Range	9.0-12.0	6.0-14.0	1.10-11.0	11.0-13.0	2.1-10.2	1.1-9.4
	Mean±SD	9.9±1.1	8.0±2.8	6.8±4.4	7.5±4.4	7.6±3.0	6.2±3.6

SD: Standard deviation

Table 3: Results for Bacteriological parameters of Sukhna lake (Average for the months of Nov-2012, Jan-2013, Mar-2013, May-2013, July-2013 and Sept-2013.

Parameter	Site A		Site B		Site C		Site D		Site E		Site F	
TVC (cfu/ml)	Min-Max	Av	Min-Max	Av	Min-Max	Av	Min-Max	Av	Min-Max	Av	Min-Max	Av
	75-148	107.8	40-99	72.3	70-169	112.2	99-118	106.6	90-182	142	50-174	129.6
TC (MPN/100ml)	43-1600	303.6	11-280	107.5	110-910	405	32-540	289.5	41-350	171	16-280	101.8
FC (MPN/100ml)	5-220	72.3	0-170	42.5	9-170	71.6	7-210	79.6	0-170	55.5	0-110	23.3
FS (MPN/ml)	4-43	12.5	2-11	5.3	4-14	5.8	0-4	2.3	4-11	6.8	2-7	3.5

Dissolved oxygen varied from 4.0 mg/l in the month of May and 23.2mg/l in the month of September for the Site F. Low DO was recorded, possibly owing to stagnation and drying up of water at this site and high DO may result from the flow of rain water from nearby areas during the month of September. In general the DO values showed a regular trend throughout the year for all the six sites with maximum concentration of dissolved oxygen during monsoon season and minimum during summer season. According to CPCB (2007) the quality criteria of fresh water for the propagation of fisheries and wildlife requires the DO of water to be 4mg/l or more. Since all the DO values are above 4mg/l, lake water does not pose any threat to aquatic population and wild life in and around the lake.

Organic index for recreation lakes is based on BOD and COD level. These are indicators of organic pollution. BOD levels between 3-6mg/l come under the category of moderately polluted and BOD less than 3mg/l is considered be relatively clean (Bharadwaj, 2005). The standard limits of BOD are 3mg/l or less for fresh water for outdoor bathing (CPCB, 2007). BOD was above 3mg/l for almost all the sites

in the summer for the months of May and July when the water level of lake was at its lowest suggesting that lake was moderately polluted during the month of summer when there was very less flow of water. During rest of the year BOD values were well below 3mg/l suggesting its relatively clean status for greater part of the year. COD values when considered along with BOD is helpful in knowing the toxic conditions and biologically resistant organic substances. The values ranged from a minimum of 1.1mg/l for site C to a maximum of 14.0mg/l for site B. The little variation in BOD and COD levels suggest absence of significant amount of any such organic matter which is biologically non-oxidisable.

3.2 Bacteriological Parameters

Total viable count of bacteria for lake samples varied from 40cfu/ml to 174cfu/ml. Heavy tourist influx, duck population and some sewage inflow may be contributing towards high TVC counts. Highest average TVC values were obtained from Site E (lake end near the Garden of Silence). The reason could be the stagnation of water at this end and religious human activities. Although banned but a large number of puja paraphernalia is immersed (flowers, small idols, coconuts etc) at this end during the festive seasons (Navratras).

Total coliform values ranged between 11-1600 per 100 ml of water sample. Maximum MPN/100ml values of around 1600/100ml were obtained for the Site A in the month of May. Site C and D also showed significant TC values. Since these areas lie near to Kansal area some sewage entry from there cannot be ruled out. Highest Faecal Coliforms were observed for Site A (220/100ml) followed by Site C and D with the values 170/100ml and 210/100ml respectively for the month of May. September month samples showed none or very less FC values for all the six sites. In general FC values ranged from 0-220/100ml. Faecal *Streptococci* (FS) values for all the sites of Sukhna lake were low (0-43/100ml).Maximum FS values were however observed for Site A which is inhabited by a large population of ducks. The values for TC, FC and FS were higher than those reported by Sharma *et al*., in 2010.

Of all the six sites, Site A seems to be loaded with greater bacteriological population followed by Site D and C. These areas see greatest human activity. Site A being the most active tourist area and Site C and D owing to their proximity to inhabited areas of Kansal from where the leakage of sewage pipelines has been reported in the newspapers (see references).

The values for bacteriological parameters for all the six sites showed a regular trend in accordance to seasonal changes vis- a- vis summer, monsoon and winter. The bacterial counts were high in the month of May and July when the water levels were at its lowest and low for the month of September when the Sukhna lake was brimming with water resulting in dilution of bacteria.

4. Conclusion

Although TDS, TVC, TC, FC and FS values were still in the permissible limits for a Lake meant for recreational purposes the numbers have risen drastically when compared with the reports of (Sharma *et al*., 2010) whereas the values recorded for DO, BOD and COD in the present study are in accordance to the values reported by them. The increase in bacterial and especially the sanitary bacteria (FC and FS) numbers suggest inflow of organic or sewage waste into the lake in the recent times. These findings suggest the need to monitor the pollution level especially sewage pollution for the Sukhna lake.The various results suggest that although the lake can still be considered as relatively clean for greater part of the year but conditions during the month of May and subsequently June and July are indicative of moderate water pollution in the lake. Setting aside the seasonal fluctuations the sanitary and bacteriological as well as the TDS and BOD levels of lake need to be monitored to maintain the quality of water in Sukhna lake. Measures are needed to stop the inflow/ leakage of Sewage from the villages located in the catchment area of the lake as also advocated by Chaudhry *et al*., in 2013.

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