

A study of water quality of Bolgoda North Lake

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Abstract

Bacterial populations were investigated in relation to the environmental parameters in Bolgoda Lake for a period of six months from January 2000 to June 2000. Surface water samples were collected from six sampling stations in the Bolgoda Lake at monthly intervals. Total viable bacterial colony forming units (assumed to be equal to the density of bacterial population), total coliforms and faecal coliforms were studied as biological indicators. Physico-chemical environment parameters included, temperature, pH, electrical conductivity, salinity, Secchi disk depth, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand(COD), orthophosphate and nitrate contents. These were measured using standard methods. Correlations among bacterial densities and selected water quality parameters were investigated. High densities of bacterial

populations were recorded at several sampling points in the vicinity of outlet drains which bring domestic and industrial effluents. Low densities of bacterial populations were recorded in samples taken at up stream and down stream of the North Lake. Results also revealed that some chemical parameters may have an effect in the density of bacterial populations. Density of bacterial populations showed a significant negative correlation with Biochemical Oxygen demand (BOD) and with phosphate concentration. However, the density of bacterial population did not show a significant correlation with the nitrate content of the surface waters of the Lake. Further the DO, BOD values and PO_4^{3-} content indicated organic and inorganic nutrient pollution of surface waters of Bolgoda Lake. However, samples collected from down stream had lower values for above parameters indicating that self- purification is taking place to a certain extent in the lake. However, results revealed that at present Bolgoda Lake is heavily exposed to pollution from industrial and residential effluents. To avoid catastrophe, measures should be taken to reduce pollution by curtailing sewage disposal and treatment of effluents of near by factories before being discharged into this Lake.

Key Words: Water quality, Bolgoda Lake, Evaluation of water quality

Introduction

The pollution of water bodies has become a national issue. In the past often rivers and lakes were the dumping grounds for garbage. Industrial effluent, raw sewage and animal carcasses would often be dumped into waterways, without much thought of contamination and downstream neighbors. This practice started changing in the later part of 20th century as people became aware of the importance of clean water to health. However, as more industries and people moved closed to water bodies, more rivers and lakes became polluted.

The term water pollution is referred to, addition to water excessive materials harmful to human, animal and to aquatic life

or otherwise, cause significant departures from the normal activities of various living communities in or associated with water bodies. Haphazard use of agrochemicals and chemical fertilizers, release of untreated industrial effluents, disposal of domestic waste and sewage and dumping of solid waste into water ways have resulted in severe pollution of water bodies. Invariably, activities associated with urbanization result in pollution of receiving water bodies. Quantities of waste discharged through these activities often exceed the carrying capacity of a given water body to naturally purify itself. Water pollution affects the health of the waterway, the health of the organisms living in and around the waterway, and, eventually, the health of humans.

Addition of organic wastes from various industries; food processing plants, tanneries, textile and dairies into near by water bodies result in proliferation of heterotrophic microbes, which in turn causes lowering of available oxygen for other aquatic life. The number and the type of microorganisms present in such water may indicate the nature of pollution and type of microorganisms present in such water may indicate the nature of pollution and hence called indicator organisms. e.g. Rising of bacterial population up to 10^6 to 10^7 /ml indicates the sign of organic pollution (Aneja, 1993). Faecal *Streptococci* are more numerous inhabitants of animal intestine while faecal coliforms are found in human intestine, thus when Fc / Fs ratios is greater than 4 indicates evidence of pollution with human wastes and Fc/Fs ratio less than 0.7 indicate pollution due to livestock and poultry wastes etc. (Bonde, 1977). According to Bruni et al (1997) faecal *Streptococci* are more suitable bacteria for investigation of the human impact on the water bodies. "Sewage fungus" is a characteristic and conspicuous feature of the water which is heavily polluted with organic matter. *Sphaerotilus natans* and zoogloeal bacteria found to be the dominant organisms in this fungus community (Curtis and Curds, 1971).

Pollution of water results from discharge of substances into water that cause unfavourable changes in its chemical nature or in the

microbial populations. It is important that the present level and the type pollution in Bolgoda Lake are determined in order to protect it from future pollution episodes. Total viable bacterial colony counts and species diversity of aquatic bacteria may be used as indicators of water pollution. Thus the objective of this study was to correlate the chemical parameters with bacterial densities and their type in order to understand the nature and level of pollution. Although many studies have been carried out on the fauna of inland water bodies of Sri Lanka, no detail study has been carried out on the microbial populations in relation to physico-chemical parameters, hence information is limited. The present investigation was therefore carried out to study the bacterial population in relation to selected physicochemical parameter of Bolgoda North Lake.

Materials and Methods

Study site

Bolgoda Lake is the largest natural fresh water body in the Western Province. This lake system is situated in the low country wet zone of Sri Lanka between longitudes E . 79 . 55'-79 . 58'and latitudes N . 6 . 40' – 6 . 48'. Bolgoda Lake has two major lakes, Southern and Northern connected by a narrow stream known as the Bolgoda Ganga (Fig. 1) Northern Lake has expanded up to Rathmalana and its extreme north is called Weras Ganga. The catchment area of the Northern Lake is about 243 Km² and its major fresh water inflow is called Maha Oya. The out flow of water from Bolgoda Lake is via Panadura estuary to the Indian Ocean. The South Lake is fed by Panape Ela and it connects to the sea via a narrow canal known as Thalapitiya canal, which is kept closed by a sand bar and open periodically when the water in the Bolgoda lake begins to flood (Wignarajah & Amarasiriwardena, 1983). Bolgoda Lake though essentially a freshwater body, its salinity varies between fresh and brackish near the sea mouth. Along the coastal boundary of the watershed, several densely populated townships are located. Few factories are

located on either side of the Weras Ganga from Kaudana to Katubeddea. The disposal of liquid waste, untreated sewage, industrial effluents and domestic and industrial solid waste, into Bolgoda Lake has created nutrient enrichment. From the available data on physicochemical and biological parameters for different locations of Bolgoda Lake, it is evident that there is high organic pollution (Dassanayake, 1991)

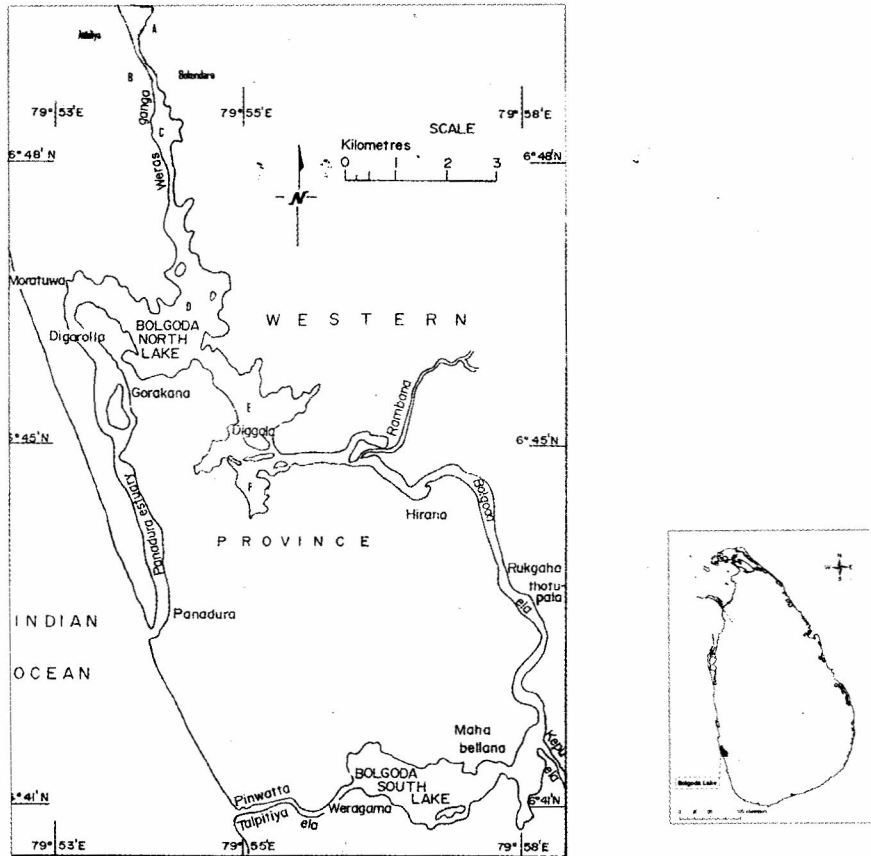


Figure 1. Map of the area showing the sampling sites A, B, C, D, E and F of the Lake and location of Bolgoda Lake

Sampling method

Study was carried out from January 2000 to June 2000 collecting water samples at monthly intervals. Six sampling stations (A, B, C, D, E & F) in Bolgoda North Lake were selected for this study (Fig.1). Time of sampling was between 9.00 a.m. to 11.30 a.m. at six stations in Bolgoda North Lake. Sampling stations were reached by boat and samples were taken from the front side of the boat without disturbing the water column.

Bacteriological analysis: Samples were taken from top 30 cm of the water body to 500ml sterile bottles from all six sampling stations. Samples were brought to the laboratory in an ice box and subjected to microbiological testing within 2 hours of collection. Total viable bacterial colony counts, which provide information with regard to aerobic and facultative bacteria were determined using standard spread plate technique. Density of bacterial population in each sample was calculated and expressed as number of colony forming units per milliliter (cfu /ml).

Multiple-tube technique was used to detect the both coliform bacteria and faecal coliforms in surface water samples. Lactose broth was used as the medium in the multiple tube technique and MPN of coliforms was found in terms of Index/100 ml by using standard MPN table. Densities of bacterial populations were compared by the confidence intervals to determine whether there is a significant difference among samples.

Physico-chemical parameters : Temperature, pH, conductivity, and salinity of the surface water samples were measured using thermometer, pH meter, conductivity meter and salinity meter respectively. Secchi disc transparency was determined as the average reading derived from lowering and raising the standard disc. Depth and rate of flow of water was determined at each place of collection.

Electrical Conductivity of water samples were determined using a conductivity meter (WTW-LF 92).

Acid washed bottles were used for collection water samples for chemical analyses.

Dissolved oxygen: For the determination of DO azide modification of Winkler method was used. (Trivedy et. al., 1992). First added, 2.0 ml manganese sulfate solution and 3.0 ml alkaline-iodide-azide solution were to water samples in 250 ml BOD bottles. Then the bottles were inverted several times to excluding air bubbles. After flock has formed added 2.0mL concentrated sulfuric acid down the neck of the bottle and mixed. Titrated with $\text{Na}_2\text{S}_2\text{O}_3$ to pale straw colour and added 1-2ml of starch indicator and titrated till the blue colour disappeared.

Biological Oxygen Demand (BOD): In this study, five day BOD at 20 °C was determined by using azide modification of Winkler method. In order to ensure that the nutrients and pH range of the incubated sample remain in the favorable range for bacterial growth, sample was diluted with oxygen saturated water. Two 250 ml bottles were used. Dissolved oxygen was immediately determined in one of the bottles and the other was incubated for 5 days at 20 °C in the dark. After five days the dissolved oxygen was determined. The results were expressed as mg /l.

Chemical Oxygen Demand (COD): COD was measured using potassium dichromate oxidation procedure (APHA, 1982).

Phosphate concentration ($\mu\text{g/L}$ of PO_4^{-3}) of surface water was measured using the ammonium molybdate spectrometric method at wave length of 650 nm.

Nitrate concentration ($\text{NO}_3^- \text{ N}$) of surface water samples were measured by using the sodium salicylate method.

Physico-chemical characteristics of the sampling stations were compared using ANOVA using “statistica” computer package to determine whether significant differences present among the sampling stations.

Densities of bacterial populations were compared using the t-test to determine whether significant differences exist among the sampling stations.

Pearson's correlations coefficient was used to see whether a correlation exist between the density of bacterial population and selected chemical pollution parameters.

Results

Temperature:

The surface water temperature varied between 28.5 and 32.5 ° C. The lowest temperature was recorded from the station A in March and the highest temperature valued was recorded from station A in April 2000. The mean temperature was not significantly different at six sampling stations (Table 1)

Transparency:

The transparency of the water column in terms of Secchi depth at the sampling station showed a monthly variation ranging from 58 cm to 180 cm. Lowest value was recorded from station A while highest was recorded at station D in the month of June 2000. However, the mean transparency values for five stations except for station F were not significantly different. The mean transparency at Stations F was significantly higher than other five stations. (Table 1)

Electrical Conductivity:

Conductivity of surface water of six sampling stations varied between 200 -7400 mv . High values were obtained in the month of March at stations D, E, and F and lowest values were recorded in all six stations in June 2000. The mean values of conductivity were not significantly different at stations A, B, C, E and F (Table 1).

pH :

The pH of surface water varied between 6.67 and 8.01. The highest value was recorded form station A in June 2000. The lowest value was recorded from station F on May. The mean pH values of stations A, B, C, D, E were above 7 but the mean pH value at station F was below 7. However e mean pH value at station A was significantly different from that of other stations (Table 1).

Table 1. Mean values of physico-chemical parameters of surface water at six sampling stations of Bolgoda North Lake (January 2000- June 2000)

Parameter	Sampling stations					
	A	B	C	D	E	F
Temperature (°C)	30.16 a (28.5-32.5)	30.25 a (29-32)	30.17 a (29-32.5)	30.2 a (29-32.5)	30.2 a (29-32)	30.2 a (28.5-32)
Depth (cm)	120 (115-120)	130 (100-169)	117 (108-12)	237 (230- 249)	260 (250-270)	354 (340-360)
Transparency (cm)	116.46	89	90.6	112.75	115.87	121.25
pH	7.4 (7.1- 8.01)	7.24 (6.89-7.59)	7.23 (6.9- 7.46)	7.23 (7.1-7.3)	7.06 (6.9- 7.35)	7.14 (6.67-7.22)
Conductivity Ms/cm	331.6 (300- 400)	346.6 (300-400)	323.3 (300-370)	2690 (200-7400)	1330 (100-3700)	822.5 (100-2100)
BOD (mg l ⁻¹)	5.3 (3.6-7.27)	5.48 (3.89-9.65)	6.4 (4.81-12.62)	2.44 (1.63- 3.87)	2.55 (1.83-3.65)	2.36 (1.42-3.78)
DO	6.08 (1.93-7.84)	1.8 (0.56- 2.97)	1.57 (0- 2.37)	6.57 (95.28-7.32)	5.92 (94.06- 6.66)	5.89 (4.77-6.47)
NO ₃ ⁻ (μg l ⁻¹)	127.33 (52-238)	151.66 (98-223)	175.33 (88-326)	111.20 (62-145)	97.00 (63-109)	73.75 (46.88)
PO ₄ ⁻³ (μg l ⁻¹)	90.8 (51.76- 209.3)	97.83 (58.31- 183.7)	113.6 (60.46- 284.2)	50.28 (27.91- 65.28)	39.88 (18.6-60.46)	33.47 (23.25-51)
Salinity(%)	0	0	0	1.5	0	0

*Upper values indicates the mean, lower values indicate the ranges of each parameter

*Mean values in bold typing are significantly different from others(p<0.05 ANOVA,

Salinity

High salinity values were recorded from station D in March while all the others showed zero salinity (Table 1).

Dissolved Oxygen (DO)

The dissolved oxygen content (DO) in surface water at six sampling stations showed a large variation during the study period ranging from 0.00 to 7.8 mg⁻¹ (Fig. 2). Lowest value was recorded from station C in June 2000. The highest DO content was recorded in April from station A. The mean value of dissolved oxygen at station B and C were significantly lower than that of other stations.

Biological Oxygen Demand (BOD₅)

The biochemical oxygen demand (BOD) of surface water at six stations showed a large variation ranging from 1.42 to 12.62 mg⁻¹ (Fig. 3). The lowest value was recorded in May 2000 from station F and the highest value was recorded in June 2000 from station C. Comparatively low values were recorded from station E and F. The mean values of BOD at station B and C were significantly different from those of other stations. Station A also showed high BOD values in April and May when compared to other months.

Phosphate Concentration (PO₄⁻³)

Phosphate levels at the six stations fluctuated between 18.6 and 284.2 µg l⁻¹. Lowest value was recorded from station E in June 2000 (Fig. 4). The highest value was recorded from station C in June 2000. The phosphate concentration in surface water at station A, B, D and E were not significantly different but the value obtained for station F was significantly lower than all other stations. The mean value for station C was significantly higher than all the other stations.

Nitrate concentration (NO₃⁻)

The nitrate concentration of the surface water fluctuated during the study period ranging from 46 to 326 µg l⁻¹. The lowest value was recorded from station F in March 2000 while the highest value was recorded from station C in April 2000 (Fig. 5). Mean

nitrate concentration at station F was significantly lower than those of all the other stations.

Chemical Oxygen Demand (COD)

Higher COD was recorded from station D during the study period and its highest value was recorded in March. The lowest value was noted at station F in February (Fig. 6).

Density of Bacterial populations

Total Viable Count

The density of bacterial population of the surface waters of six sampling stations showed a large variation ranging from 470 to 279,500 cfu ml⁻¹. The lowest and the highest values were recorded at station A and at station C respectively. The mean values of the total viable bacterial counts at stations A,D, E and F were not significantly different from each other. The mean values of total bacterial colony count at station B and C were significantly higher than that of other four stations throughout the study period (Fig 7).

Total Coliform Count

The maximum coliform counts were observed at stations B and C throughout the study period. The lowest coliform count was recorded at station A in January and highest values were recorded during the months of May and June at station A, B, C . Comparatively low counts were observed at stations D, E, and F (TableII).

Faecal Coliform Count

Highest cloiform counts >2400/ 100ml were observed at station A, B and C in the month of June. Low values for faecal coliform were recorded at all the sampling stations in March 2000 (Table III).

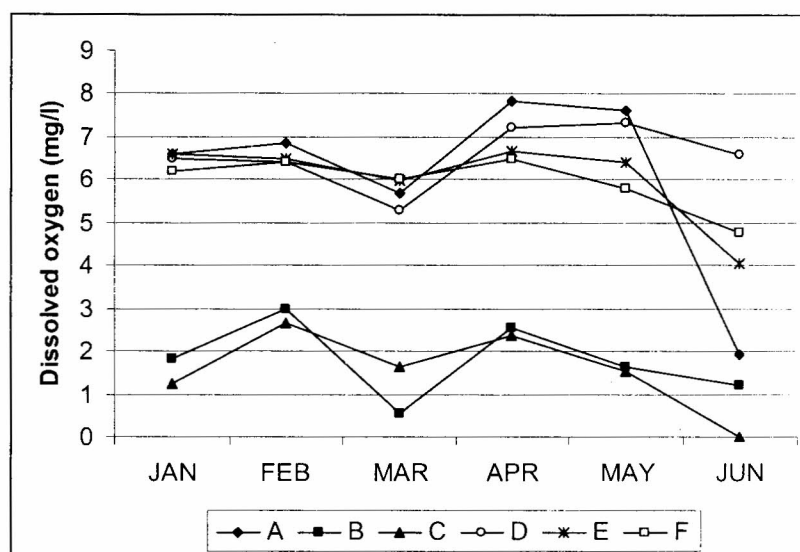


Figure 2. Monthly variation in dissolved oxygen content at different stations

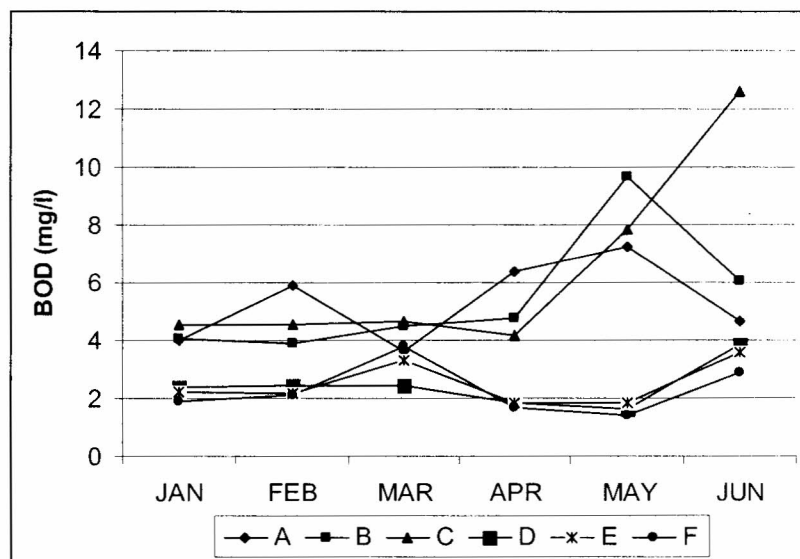


Figure 3. Monthly variation in Biochemical Oxygen Demand at different stations

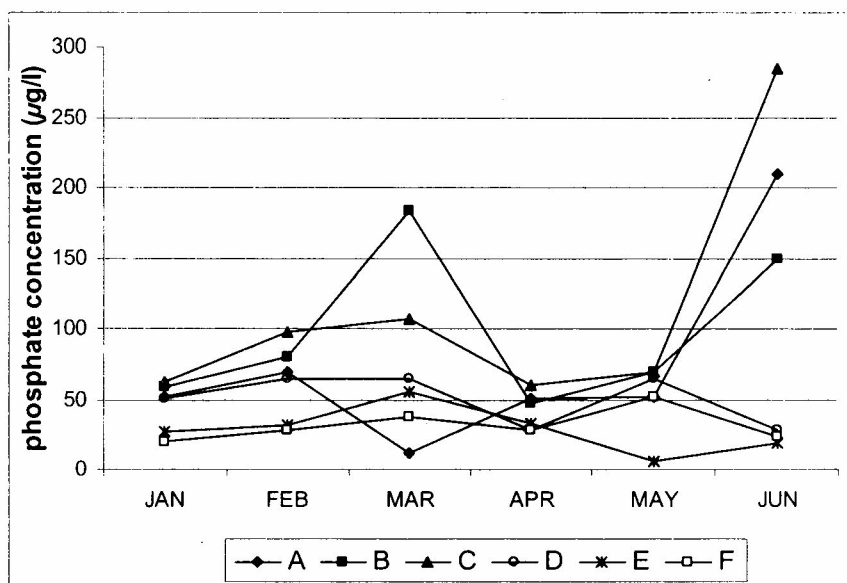


Figure 4. Monthly variation of phosphate concentration at different stations

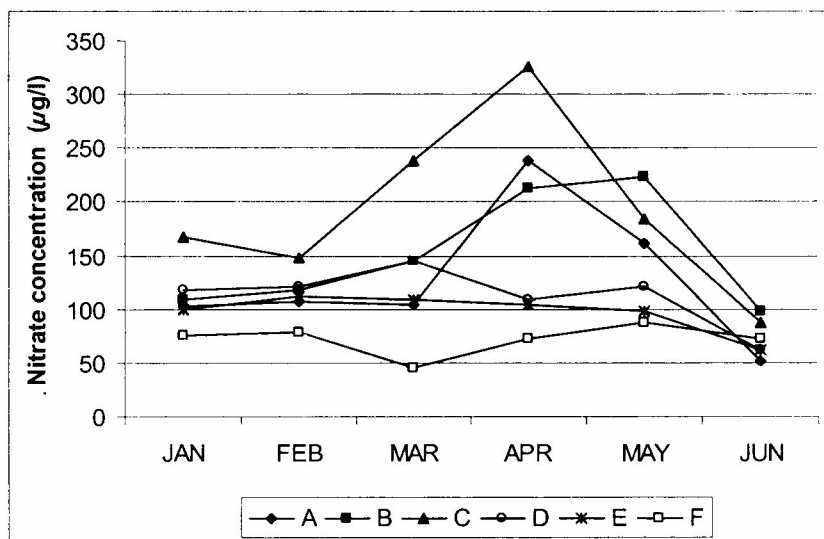


Figure 5. Monthly variation of nitrate concentration at different stations

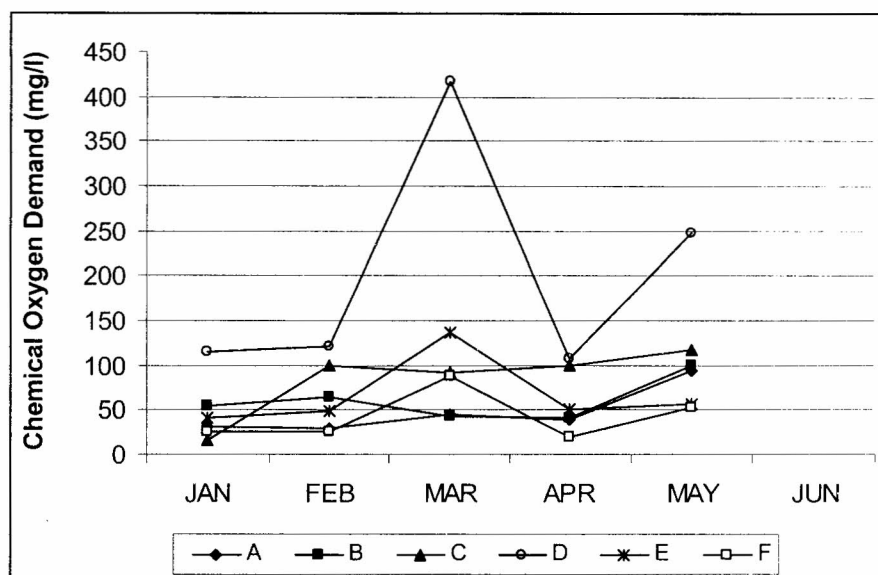


Figure 6. Monthly variation of Chemical Oxygen Demand at different stations

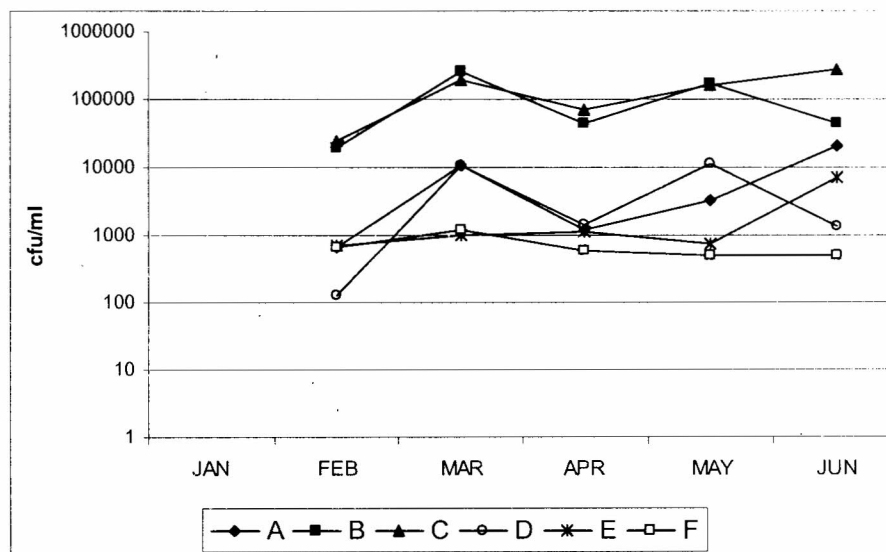


Figure 7. Monthly variation of colony forming units at different stations

Table 2. Total Coliform count at different stations in different months

Sampling Locations	January	February	March	April	May	June
A	43	NE	150	NE	2400	>2400
B	2400	NE	>2400	NE	>2400	>2400
C	2400	NE	>2400	NE	>2400	>2400
D	NE	NE	150	NE	210	460
E	NE	NE	210	NE	1100	150
F	NE	NE	93	NE	150	93

Table 3. Total faecal Coliform count (count per 100ml)

Sampling Locations	January	February	March	April	May	June
A	NE	NE	14	NE	1100	240
B	NE	NE	21	NE	112	2400
C	NE	NE	53	NE	1100	2400
D	NE	NE	21	NE	150	93
E	NE	NE	23	NE	210	43
F	NE	NE	15	NE	16	43

NE –Not examined

Table 4. The mean values for bacterial densities at different sampling stations in the Bolgod North Lake

Sampling stations	Mean Bacterial Density Cfu/mL
A	6143.33 (470-2,650)
B	95050 (29,800-2,60,000)
C	1,33,767 (23,600-2,79,500)
D	3643 (1300- 10,500)
E	2431 (710- 6900)
F	705 (490-1020)

Upper values indicate the mean, lower values indicate the ranges of each bacterial population. Means in bold typing are significantly different
 $p < 0.05$, t-test

Table 5. Values for correlation coefficient (r) between density of bacterial population (total viable bacterial colony forming units) and selected chemical parameters

Biological parameter		Chemical pollution parameter			
Total viable bacterial colony count		Dissolved oxygen (DO)	Biochemical oxygen Demand (BOD)	Phosphate concentration (PO_4^{-3})	Nitrate concentration (NO_3^-)
	r	-0.745	0.661	0.668	0.268
	p	0.000	0.000	0.000	0.152

Significantly correlated, $p < 0.05$

Discussion

Temperature is a significant parameter considered when studying the characters of a water body. However, absence of significant variability in temperature is usual feature in tropics although in an earlier study in the South Lake there had been a significant variability in temperature (Siriwardene and Tissa, 1996). In this study, there was no significant difference in temperature at different sampling sites and also in different months during the period reported in the North Lake.

Out of the other parameters tested for the water at different localities of Bolgoda North Lake, pH and transparency values showed significant difference. At the station A, pH showed a significant higher value than all the other localities. However, pH values were within the general standard value required for industrial wastewater discharged into inland surface water.

When compared to South Lake, which reported relatively high transparency (Wignarajah and Amarasiriwardene, 1983), North Lake showed relatively low transparency during this study. This could be due discharge of various waste materials such as saw dust by people living on the banks of Weras ganga. The high transparency value obtained at station F when compared to other places could be due to settling of some of the particles at locations down stream where the flow rate is slower.

Samples of water at Station B and C had significantly high BOD and lower dissolved oxygen values throughout the study period, while station A had high value in June. High BOD had also been reported for South Lake especially during high tide (Wignarajah and Amarasiriwardene, 1983). These result indicate high organic pollutants reach North Lake during high tide may be mainly due to surface run off.

However, in the North Lake, constantly high BOD and less DO was recorded at certain points. The sharp decline in the concentration of dissolved oxygen at station B and C indicate that at these sampling points, effluents containing high organic matter enter the water body. Poor oxygenation could be attributed to the growth of heterotrophic bacterial growth, which may occur at these sites due to high organic enrichment. This was well demonstrated by high densities of total bacteria at station B and C when compared to other stations. BOD values recorded at this location during this study period increased dramatically specially during the month of May and June. BOD is a good indicator of pollution due to organic matter. The density of bacterial population showed a highly significant negative correlation ($r = -$

0.745, $p = 0.00$) with dissolved oxygen content in the surface water indicating multiplication of heterotrophic bacteria at the expense of organic matter.

Also these locations recorded high phosphate and high nitrate contents. These results indicate that industrial effluents rich in nitrates and phosphates are discharged into Bolgoda North Lake at these points or at a point very close to these. Significantly high values at phosphate and nitrate concentrations obtained at both stations B and C (Weras Ganga site) indicate eutrophication of the Lake. Recent study also has shown that Weras Ganga site has high content of nitrate (Gunawardene et al, 2009). Also a significant positive correlation ($r = 0.668$, $p = 0.00$) was observed between total viable bacteria colony count and phosphate concentration of surface water in this lake. However, phosphate and nitrate concentrations decreased at locations down the stream, well below the permitted level as recommended in the proposed ambient water quality standard. This lowering of phosphate and nitrate levels could also be attributed to the luxuriant growth of aquatic weeds specially Water Hyacinth.

At station A, B, and C highest faecal coliform counts (MPN / 100 ml) were recorded in May and June. Indicating effluents entering the water way is contaminated with sewage. As station A is closer to the Air Force Base it could be suspected that there may be some leakage in the sewage system especially during the monsoon period.

High COD values recorded at station C and D indicate discharge of industrial effluents containing oxidizable organic compounds. Sudden decrease of total viable bacterial count at station D could be due to the presence of some toxic chemicals in the water in amounts intolerable for bacteria. The COD value recorded at this location during the month of March exceeded the level stipulated in the Standard for quality of effluents discharge into inland surface water after treatment. High COD level has been observed in Weras Ganga and North Lake in a recent study as well,

indicating that Bolgoda Lake is exposed to constant pollution (Gunawardane *et. al.*2009).

In the wake of the above findings, it is clear that Bolgoda North Lake is apparently a disposal site of various discharges of factories in addition to, poor drainage and sewage systems present in this area. Highly unplanned urbanization and absolutely lack of adequate waste disposal management facilities in industries close to Bolgoda North Lake have resulted in pollution of water in this picturesque Lake. Due to its vast area, there seems to be a certain amount of self-purification. Especially copious growth of fast growing water weeds seem to assist in reducing the amount of nitrate and phosphates in water. However, if the present trend of waste disposal and unplanned urbanization continue, they would create enormous environmental problems in future. If the relevant authorities fail to identify and mitigate the existing environmental issues, problems that may crop up in future would be more severe and would be nearly impossible solve them.

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