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Seasonal and Year Wise Variations of Water Quality Parameters in the Dhanmondi Lake, Dhaka, Bangladesh

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Abstract. The quality of the surface water through 16 physicochemical variables was monitored at three sites of Dharmondi Lake of Dhaka, Bangladesh, over 5 years during 2002-2007. The concentration of heavy metals (Pb, Cd, Cr, Co, Ni, Cu) was below detection limits with few exceptions. No clear seasonal variation trend for Fe, Mn, Zn, PO_4^{3-}, SO_4^{2}, Cl^- and F^- was observed which differed from year to year. Slight increasing tendency in case of sulphate, phosphate, chloride concentrations and electrical conductivity was observed but it was not clear in other parameters. The levels of all parameters were found well below the standards for drinking water.

Keywords: lake water, seasonal variability, pollution trend, water quality, heavy metals

Introduction

Over the past 25 years, the quality of water bodies around Dhaka city has deteriorated a lot due to unplanned discharge of untreated effluents from factories and sewage. Dhanmondi Lake is one of the biggest lake and a great recreation place for the people of Dhaka city. But, this Lake is being contaminated due to the increase in human activities during the last few years. Lot of construction work had also been done during 1980 to 2006 along the valley of this Lake, which had directly influenced the water quality of the Lake. In addition, frequent floods during recent years have also contributed in polluting the lake water. The number of tourists has also increased in recent years, directly affecting the quality of water. Fishing activities around the lake are another source of contamination. Thus, a constant and systematic monitoring is essential to study long term pollution in the Lake environment especially when it is impacted by the increasing tourist population which disturbs normal activities in the area. Some short-term research work had been carried out in the past on water quality parameters of the river, and lake water in our laboratory (Quraishi *et al.,* 2006; Azim 2005; Chowdhury *et al.*, 2005; Hossain, 2005; Hadi *et al.*, 1996; 1991; Maroof *et al.,* 1985). But long-term monitoring is necessary to evaluate the pollution sources and to get a clear trend of pollution. Therefore, a long-term monitoring program was initiated in 2002 spread over a period of 5 years during 2002-2007, for a wide range of water quality parameters. The main objectives of this work were (i) to establish background levels for Mn, Fe, Zn, Cr, Ni, Co, Cu, Cd, and Pb in the lake water of Dhaka City and (ii) to examine the seasonal and year-wise variability of trace metals in lake water on seasonal basis. Trace toxic metals and physicochemical parameters e.g., Pb, Cd, Cr, Ni, Co, Cu, Fe, Mn, Zn, EC, pH, Cl, F, SO_4, PO_4, CN, NO_3 concentrations were monitored three times at three different locations over a period of five years between March 2002 and September 2007; data for the year 2003 is not available.

Materials and Methods

Reagents. All chemicals were of analytical reagent grade. HNO_3, HCl and H_2SO_4 were of analar grade from BDH Laboratories. Certified reference material was obtained from the National Institute of Standards and Technology, USA. Commercially available 1000 mg/L (ICP grade) single element standard solutions (Merck or SPEX Certiprep, Metuchen, NJ, USA) were used in preparation of the working standards. Standard solutions were freshly prepared from 1000 ppm stock by dilution with deionized water (DI).

Sample collection, preparation and analysis. Water samples were collected from three locations thrice in a year between March 2002 and September 2007. Sampling was done in March (pre-monsoon), July (monsoon) and September (post-monsoon). The locations of the three sampling sites are shown in Fig. 1.

Each sample was divided into two portions, one for the analysis of metals ions and another for that of anion. pH of the portion for the analysis of metals was adjusted below 1 by addition of nitric acid to prevent adsorption to the bottle and the portion of anions was filtered, using Whatman filter #41 to remove suspended matter and stored at 4 °C. Water sample (250 mL) was quantitatively transferred to 250 mL beaker and then heated on a hot plate with 2 mL of HNO_3 until the total volume was reduced to approximately 5 mL. The concentrate

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obtained was transferred to a 10 mL volumetric flask and made up to volume.

Electrical Conductivity (EC) and pH were measured using Jenway Conductivity Meter, model No. 4070 and WTW Multiline P4 Universal Meter, respectively. Concentration of anions (Cl$^-$, F$^-$, NO$_3^-$) were determined by ion selective electrode (ISE). For fluoride determination, 1:1 (sample: TISAB) low level TISAB was used whereas for chloride and nitrate, 2% of 5M NaNO$_3$ and 2% of 2M (NH$_4$)$_2$SO$_4$ were used, respectively, as ionic strength adjuster (ISA) according to the users manuals (Quraishi *et al.*, 2006; Chowdhury *et al.*, 2005). The concentrations of chloride, fluoride and nitrate in samples were measured by the ISE method based on direct calibration. 50 mL of each of the calibration standard solutions (0.01, 0.10, 1.0, 10.0, 100 ppm) were taken in a 100 mL beaker and the required amount of ISA buffer was added to it. The electrode potentials (mV) of the standards were measured using the digital ion-selective electrode meter (Orion Ionalyzer/model 470 A). After measurement, a calibration curve was drawn by plotting electrode potentials of the standards against their respective concentrations. Then the target electrode was connected to the meter for determination of target anion in the real samples similarly treated as the standards. From the calibration curve constructed by the instrument as mentioned above, the slope was found to be -57±3 mV/decad. The computer code in the instrument provided the concentration of anion in the sample directly by carrying out the calculations based on the calibration factor (slope: -57±3 mV/decad) and the electrode potential value of the sample. SO$_4^{2-}$ and PO$_4^{3-}$ concentration were measured by Shimadzu 1201 uv-visible spectrophotometer. After digestion, CRM and samples were analyzed for metal content using a three point calibration by atomic absorption spectrophotometer (Perkin Elmer 3110 and 560, USA). Standard solutions were prepared from single element standards in acid media matching with sample solution. Calibration curve was constructed for all elements using at least three different concentrations. Very good R square value of 0.9995 was obtained for all the elements.

Quality assurance. Quality assurance measures included the calculation of method detection limit, recovery and analysis of standard reference materials. To determine the DL, a low concentration standard solution was analyzed several times and the standard deviation (δ) was calculated for the data. The detection limits of the method were calculated using $10\ \delta$, recommended by IUPAC, including preconcentration factors for the elements Pb, Cd, Cr, Ni, Co, Cu, Fe, Mn, Zn, as 10.0, 4.46, 5.07, 5.30, 1.50, 3.38, 3.0, 4.0 and 12.0 μg/L, respectively. The accuracy of the method was checked by recovery assays of known amounts of analyte added to the samples. The recovery values obtained for spiked samples were 95-102 % in case of all elements. Procedural blanks were used throughout the sample preparation and analysis to evaluate contamination from reagents, containers etc. and the procedures were validated by triplicate analysis of water samples, reference material and blanks.

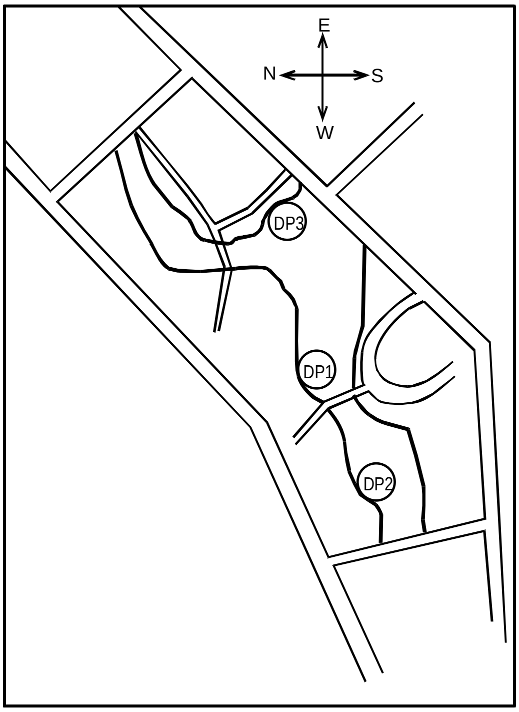

Fig. 1. Map of Dhanmondi lake

Results and Discussion

The baseline-monitoring programme was initiated in 2001 to monitor heavy metals in different lakes in Dhaka city by the

Table 1. Analytical results for analysis of NIST SRM 1643d and 1640

Elements	Method	NIST certified values for SRM 1643d, (μg/L)	Measured values (μg/L)	Trueness (%)
Fe	AAS	91.2 ± 3.9	91.5 ± 0.94	100
Mn	AAS	37.66 ± 0.83	35.55 ± 0.36	94.4
Zn	AAS	72.48 ± 0.65	69 ± 1.86	95.2
Cu	AAS	20.5 ± 3.8	21.77 ± 0.22	106
Cd	AAS	6.47 ± 0.37	7 ± 0.07	108
Cr	AAS	18.53 ± 0.20	18.75 ± 0.19	101
Ni	AAS	58.1 ± 2.7	54.54 ± 0.56	93.9
NIST SRM 1640, Trace elements in natural water (μg/L)				
Cu	AAS	85.2 ± 1.2	80.28 ± 0.81	94.2
Mn	AAS	121.5 ± 1.1	129.12 ± 1.31	106

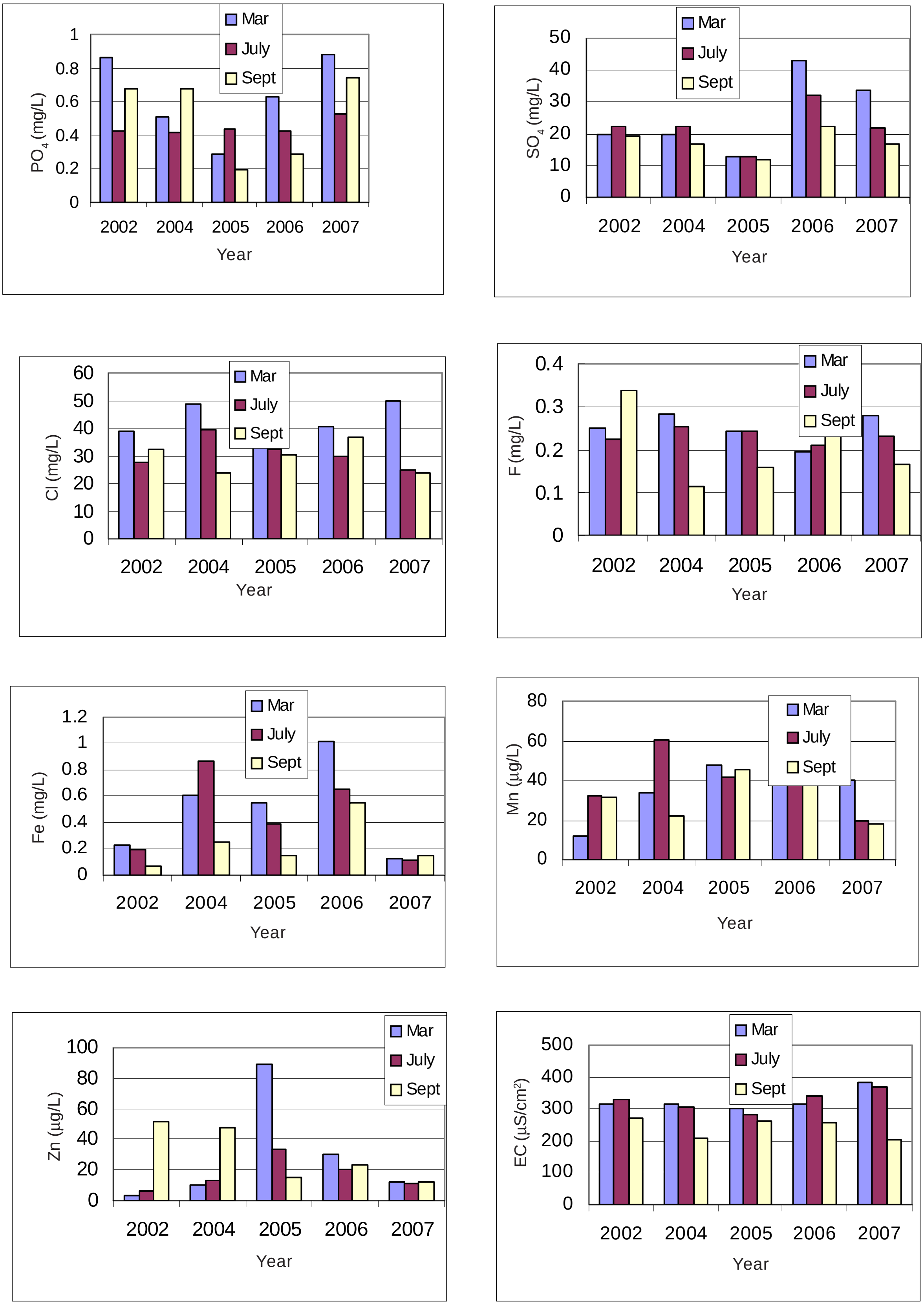

Fig. 2. Seasonal variations of different parameters of the Lake water during five years (2002-2007).

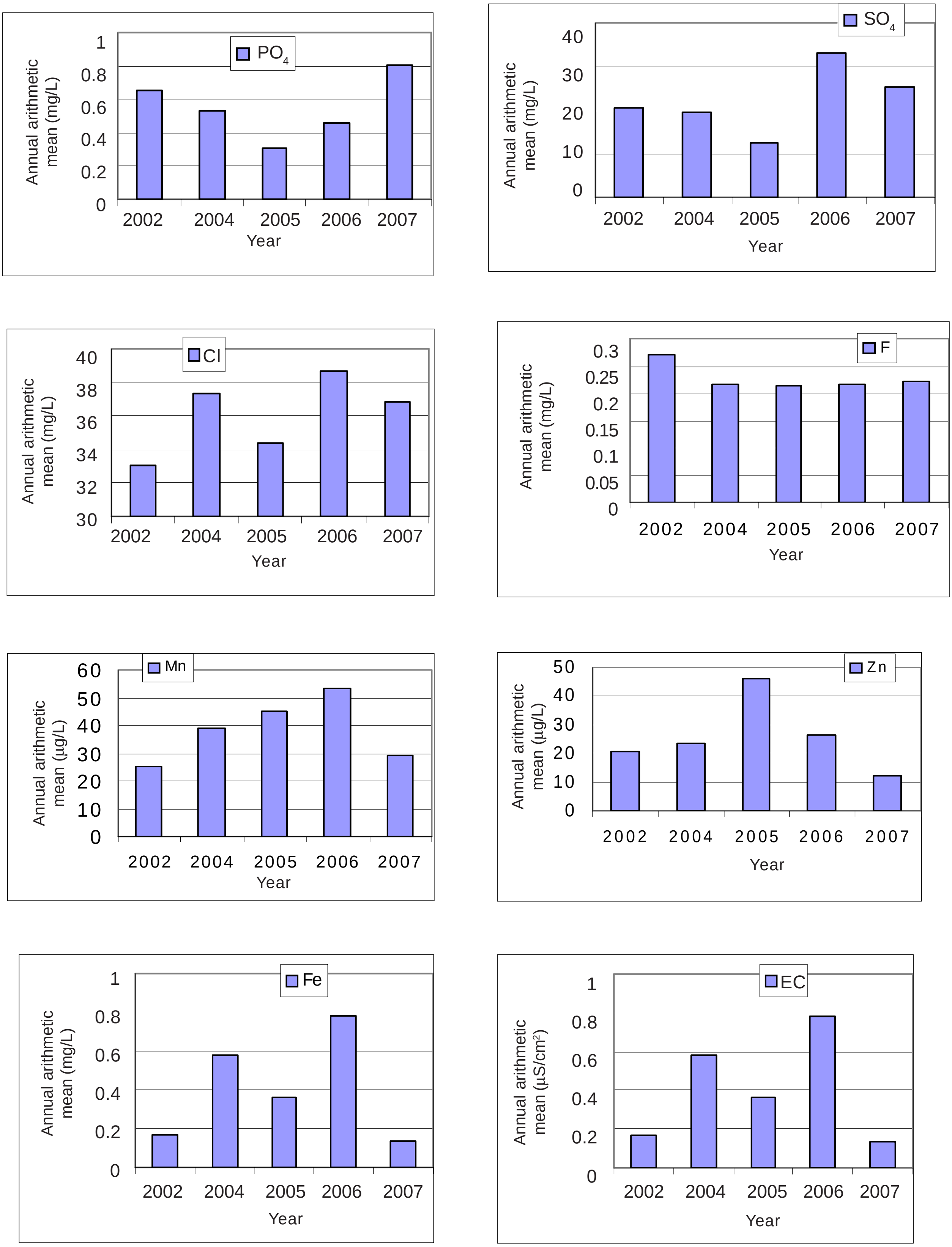

Fig. 3. Year wise variations of different parameters of Lake water during five years (2002, 2004-2007).

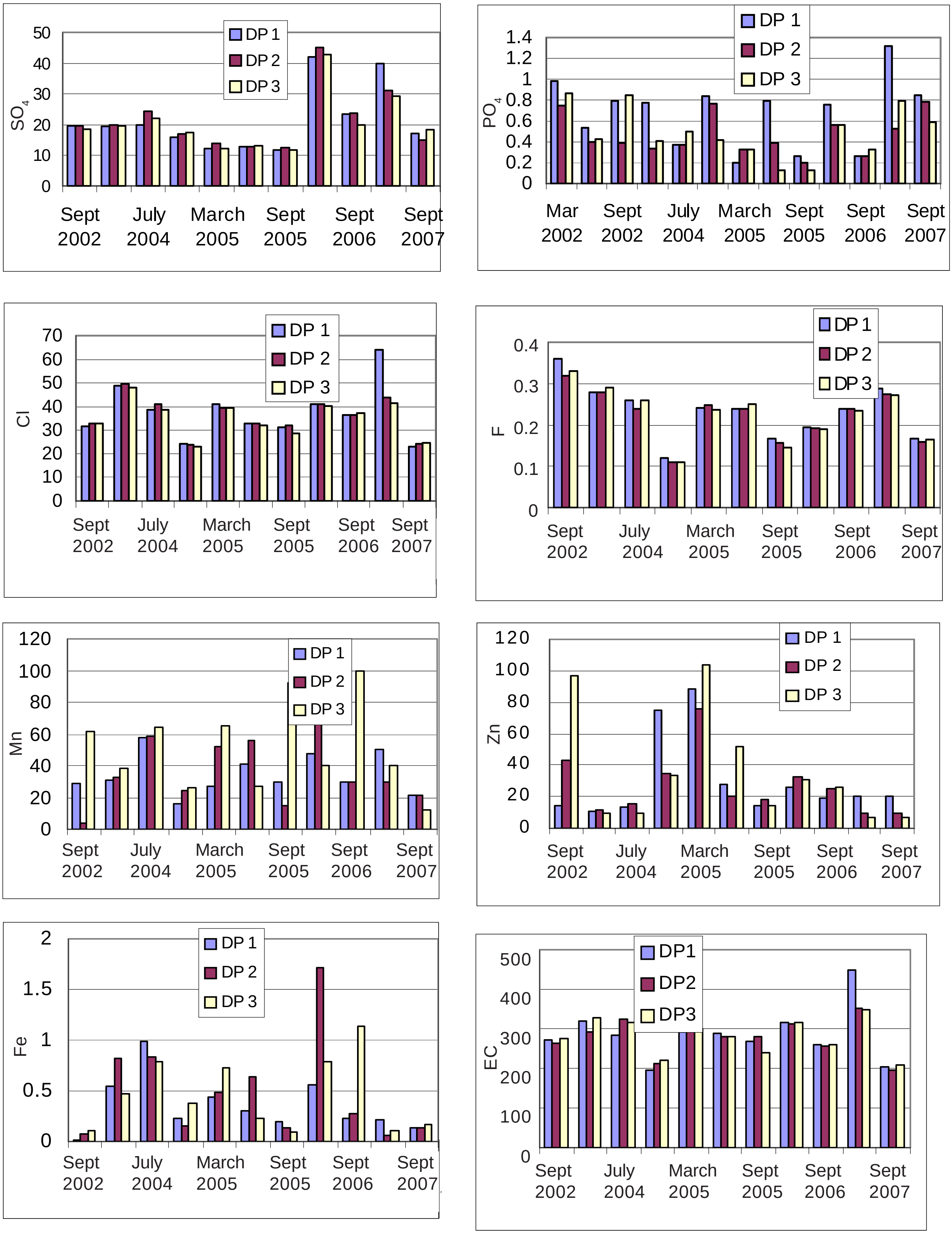

Fig. 4. Variations in different parameters of water between the sampling locations of the Lake (DP1, DP2 and DP3).

Chemistry Division of Atomic Energy Centre. Analytical results for analysis of NIST SRM 1643d and 1640 are summarized in Table 1. Good agreement was found between the measured and the certified values. The data of heavy metals and various physical parameter of water for 2002 and 2004-2007 (five years) are presented in Fig. 2-4. It was observed that during the study period (2002 and 2004-2007), the levels of various parameters including toxic metals were much lower than the drinking water standard of Bangladesh. Annual mean concentrations of phosphate in 2006 and 2007 were 0.45 and 0.81 mg/L, respectively, (Fig. 3) (MEF,1997) which were much lower than the standard set as 6 mg/L. The mean fluoride concentrations (0.20 mg/L) observed during the study period was also much lower than the standard, which is set at 1.0 mg/L. Mean sulphate concentration in Dhanmondi lake water was 17.5 mg/L which was much lower than the drinking water standard (400 mg/L). Concentrations of Pb, Cd, Cr, Co, Ni, known as toxic metals, were found to be below the method of detection limits. The levels of Fe, Mn and Zn, which are known to be the essential elements, were found to be in the range of 60-1000, 11.6-60 and 3.2-89 µg/L, respectively, the levels of Mn and Zn were much lower than the Bangladesh drinking water standards (Mn: 100 µg/L and Zn: 5000 µg/L) but were found much higher as compared to those of other lakes (Nojiri *et al.*, 1985).

Seasonal variations. Seasonal variations of phosphate, sulphate, chloride, fluoride, electrical conductivity, iron, manganese and zinc in the lake water are shown in Fig. 2 which were found to be inconsistent. Fluoride level in September 2002, was markedly high as compared to those in March and July. In the year 2004, a systematic decrease of fluoride was noticed during March to September. In case of phosphate, concentration was higher in March (pre-monsoon) than in the July (rainy season) in the year 2002. But in the year 2005, just reverse trend was observed and in the year 2006, the highest concentration was found in March and the lowest in September. Therefore, it could be concluded that seasonal variations of phosphate, sulphate, chloride, fluoride, electrical conductivity, iron, manganese and zinc were not consistent (Fig. 2). This inconsistency indicated that there is no particular or permanent source of contaminants but sudden contamination events appear which cannot be related to the local pollution events or other local anthropogenic origins but rather to the influence of tourism-related activities (Topalian *et al.*, 1999). Contamination by metals can be related to the metallic objects used in fishing activities, metallic containers and/or packing materials of food which are directly thrown into the lake by the tourists and thus contamination can increase with the increase in the number of tourists (Conde and Garcia - Montelongo, 2004).

Year wise variations. Time course changes in the concentrations of phosphate, sulphate, chloride, fluoride, electrical conductivity, iron, manganese and zinc in the lake water are shown in Fig. 3. Phosphate concentration decreased till 2005 and increased again in 2006 and 2007. Cl^- level increased from 2002 to 2004, decreased in 2005 and again increased in 2006 and fell in 2007. Sulphate concentration significantly decreased from 2002 to 2005 and again remarkably increased in 2006 and 2007. Fluoride concentration fell from 2002 to 2004 and remained almost constant until 2007. Zinc concentration increased from 2002 to 2005 and then sharply decreased in 2006 followed by 2007. On the other hand, iron concentration showed a zigzag pattern as shown in Fig. 3. In case of manganese, concentration increased till 2006 and then suddenly decreased in 2007. An increasing tendency was observed for EC from the year 2004 to 2007.

Variations between locations. The distribution of different parameters was not uniform in surface water of Dhanmondi Lake. Significant variations in iron, manganese, zinc and phosphate concentrations were observed with regard to sampling stations throughout the study period (Fig. 4).

Therefore, it was very difficult to find out a particular sampling station having the highest or the lowest contamination point in a particular season during the monitoring period. It also indicates that contamination sources are not fixed and these differences can be related to tourist activities. It can be also seen in this figure that no significant variations between the sampling stations were observed in case of sulphate, chloride, fluoride and electrical conductivity.

Conclusion

This study was focused on the evaluation of water quality of Lake and consequently on the determination of the pollution level of this aquatic environment. Seasonal variations did not show any clear pattern and were difficult to explain. A possible explanation might be made based on the fact that the lake is acceptor of both regular and non-regular pollution pulses. An increasing tendency was observed in case of electrical conductivity, phosphate, chloride and sulphate, whereas the level was unchanged in case of fluoride during the last four years of the study. Concentration of zinc, iron and manganese decreased in 2007 as compared to the previous year.

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