Nutrient Overloading of a Freshwater Lake in Bhopal, India

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One of the most important crises of the 21st century is the scarcity of drinking water. Most freshwater bodies the world over are becoming polluted, thus decreasing the potability of the water. Today, eutrophication of natural waters is one of the most significant causes of a decline in water quality. It is accompanied by a large quantity of plant material in the water. It is fair to state that nitrates and phosphates are probably the key nutrients in controlling aquatic plant growth. The study area selected was the Shahpura Lake of Bhopal, the state capital of Madhya Pradesh, India. The lake was found to be highly eutrophic. The phosphate content of the lake water studied was found in the range of 6.05 to 9.21 ppm. The nitrate content of the water was found to be in the range 2.02 to 15.22 ppm.

Introduction

A lake is a large body of water surrounded by land and inhabited by various aquatic life forms. Lakes are subjected to various natural processes taking place in the environment, such as the hydrological cycle. As a consequence of unprecedented development, human beings are responsible for choking several lakes to death. Storm water runoff and discharge of sewage into the lakes are two common ways that various nutrients enter the aquatic ecosystems resulting in the death of those systems (Sudhira & Kumar, 2000). The washing of large amounts of clothes by *dhobis*, laundry workers, and the continued entry of domestic sewage in some areas are posing pollution problems (Benjamin, Chakrapani, Devashish, Nagarathna & Ramachandra, 1996). Of all the water quality issues regarding lakes everywhere, eutrophication is of great concern. Eutrophication of a water body signifies the aging of a lake. It is caused by the accumulation of nutrients, sediments, silt and organic matter in the lake from the surrounding watershed. Eutrophication describes the variations in aquatic systems due to nutrient enrichment; the eventual consequence of that enrichment is the growth of primary production to nuisance proportions (Marsden, 1989). The main cause is excessive loading into the system of

phosphorus and nitrogen, resulting in high algal biomass, dominance by cyanobacteria, and loss of macrophytes (Jana & Das, 1995). Although eutrophication is a natural process of aging of lakes and water bodies, human activities can greatly accelerate eutrophication by increasing the rate at which nutrients and organic substances enter aquatic ecosystems from their surrounding watersheds.

According to Vollenweider (1976), the concept of nutrient overloading has a great impact on all subsequent eutrophication research and lake management. Eutrophication is accelerated as a result of human activities near or in a body of water that generate residential wastes, untreated or partially treated sewage, agricultural runoff, urban pollutants, and so forth. Sewage or residential waste, consisting largely of phosphate-containing detergents, is a major source of nutrients in bodies of water. The flow of nutrients in the water may over-stimulate the growth of algae. This creates conditions that interfere with the recreational use of lakes and adversely affect the diversity of indigenous fish, plant and animal populations. International studies on the nitrates and phosphates in the surface waters of various bodies of water has drawn the attention of scientists around the globe.

Experimental Work

The study area selected was Shahpura Lake situated in the center of Bhopal city, the state capital of Madhya Pradesh, India (latitude 23° 12’ 00” E and longitude 77° 25’ 30” N).

This area has a sub-tropical climate with pronounced summer, winter and rainy seasons. The lake is a shallow aquatic ecosystem, mostly muddy due to the accumulation of silt. The main inlet, the Nalla, joins the lake at its northern end. The catchment area stretches over to 8.29 square kilometers, which includes the area of agricultural land on its western side, the barren rocky land mass on its northern side, and hillocks and residential area on its eastern side.

Need for Study

The lake suffers from the deterioration of the water quality, accumulation of toxic chemicals and sediments, shrinkage of lake area, and above all, a loss of the aesthetic value. The local residents generally complain of bad odors around the lake. Research work has been carried out to understand the status of lake. There is a need for continuous evaluation of the pollution level in order to promote better living conditions around the lake. Shahpura Lake is subjected to enormous anthropogenic stress and receives heavy

inputs of domestic waste and sewage. The lake water is used for aquaculture, irrigation, and drinking water for cattle, and the lake is used for fishing and recreational activities. Garg and Garg (2001) carried out a similar type of study on different lakes of Bhopal, attempting to formulate measures to restore those lakes that are already spoilt and to check further eutrophication in the watersheds.

Sampling

With consideration of the sources of inflow to the lake, four different sampling sites were selected. The water samples were collected in glass-stoppered sterile bottles. These samples were transported to the laboratory in an ice box to avoid unpredictable changes in physico-chemical characteristics. Physico-chemical parameters like nitrates and phosphates in the surface water were studied monthly for a period of one year. Sampling and physico-chemical investigation was carried out according to the standard method (American Public Health Association, 1985, pp. 391-448). Phosphates in the water were determined by the Vanado-molybdo phosphoric acid method, and nitrate was determined by the spectrophotometric and the Phenol disulphonic acid methods.

Results and Discussion

Nitrates

The nitrate content of the water was in the range of 2.02 to15.22 ppm. The highest concentration of nitrates in water was recorded in May 2004, while the minimum was recorded in June 2003 and July 2003, as shown in the Table 1. There is a sharp rise in nitrate content of water from 2003 to 2004 showing the increasing anthropogenic influence on the lake. The raw sewage is the source of nitrates and phosphates in the water (Aggarwal, Singh & Gupta, 2000). The standard drinking water quality guideline for nitrates is 40 ppm (American Public Health Association, 1985).

Table 1

Monthly Variation in Nitrate Content in ppm During the Period 2003-2004

Months	Station 1	Station 2	Station 3	Station 4
May 2003	2.03	4.62	2.03	2.62
June 2003	2.02	4.61	4.52	3.12
July 2003	2.02	4.52	4.62	2.63
August 2003	2.13	2.03	2.03	2.12

September 2003	2.62	3.01	4.68	3.12
October 2003	3.13	3.03	4.92	3.14
November 2003	3.12	6.41	5.01	4.22
December 2003	4.11	6.80	5.11	4.13
January 2004	4.62	7.22	5.32	4.19
February 2004	5.15	8.61	5.36	4.95
March 2004	7.24	10.93	5.41	5.12
April 2004	8.41	11.40	5.48	5.73
May 2004	9.32	15.22	5.60	5.87

Phosphates

The phosphate content of the water was in the range of 6.05 to 9.21 ppm. The highest value of 9.2 ppm was recorded in May 2003, while the minimum value 6.05 ppm was recorded in May 2004, as shown in the Table 2. The United States Public Health Standards limit for phosphates in drinking water is 0.1 ppm (De, 2002, pp. 231-232).

The phosphate content in the lake water is alarming. The values are comparatively lower in the year 2004 and, in general, the concentration decreased in the monsoon months due to the accumulation of rain water. The values at Station 4 are slightly higher in all months. This is due to the fact that Station 4 is located at one of the lake's feeding sources where a high concentration of phosphates from the manure and chemical fertilizers used in an adjacent garden drains into the lake. For phosphates, the U.S. Environmental Protection Agency (1976) suggested that 0.08 ppm was the critical level for the occurrence of eutrophication in lakes and reservoirs.

There are various sources of phosphate to the lake water, such as firm rock deposit, runoff from surface catchments, and interaction between the water and sediment from dead plant and animal remains at the bottom of the lake. Phosphate is considered to be the most significant among the nutrients responsible for eutrophication of lakes, as it is the primary initiating factor. Phosphate enters the lakes in domestic wastewater, accounting for the condition of eutrophication. Atmospheric input, as well, may account for a significant proportion of the influx of nutrients to the lake.

Table 2

Monthly Variation in Phosphate Content in ppm During the Period 2003-2004

Months	Station 1	Station 2	Station 3	Station 4
May 2003	8.41	8.03	8.33	9.21

June 2003	8.52	8.08	8.54	8.56
July 2003	8.33	8.21	9.03	9.02
August 2003	7.88	7.92	8.01	8.52
September 2003	7.83	7.42	8.32	8.43
October 2003	7.82	7.13	8.11	8.23
November 2003	7.71	7.10	8.09	8.15
December 2003	7.63	7.03	7.94	8.02
January 2004	7.62	7.08	7.82	8.14
February 2004	7.62	7.06	7.98	8.12
March 2004	6.82	6.14	6.12	6.62
April 2004	6.08	6.11	6.24	6.72
May 2004	6.05	6.21	6.64	6.82

Conclusion

Seasonal variations are evident in all the physico-chemical parameters examined. Temperature is one of the most important ecological features that is a limiting factor for the growth and distribution of flora and fauna in any aquatic ecosystem. High phosphate content in the Shahpura Lake water reveals that nutrient load in the lake is very high and hypereutrophic conditions are prevailing. The results obtained after study were quite surprising. The phosphate concentration in the water body was very high as compared to the standard guidelines. This condition is accompanied by a gradual filling up of the water body, which becomes shallower from the accumulation of plants and sediments on the bottom and also becomes smaller due to the invasion of shore vegetation. The extinction of the lake can result because of enrichment, productivity, decay and sedimentation.

The concentration of nitrates in the water was within the acceptable limits although it tends to increase considerably in one year's time. The deterioration in the quality of lake water has contributed to the decline in the biological diversity of the flora, fauna and productivity of the wetland systems (Ramachandra, 2001). The deterioration in the quality of Shahpura Lake water and rise in the nutrient level is alarming, and periodic monitoring and preventative measures are required to save the lake from eutrophication.

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