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# Nutrient loading and its consequences in a lake ecosystem

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Cultural eutrophication has emerged as one of the most relevant causes of fresh water quality deterioration. Excessive enrichment of inland waters, coupled with dramatic urbanization, has led to formidable algal blooms in many parts of the world. In order to save inland waters from extenuation, tremendous investigative activities have been observed all over the world (Elser & Kimmel 1985; Hezlar *et al.* 1993; Nedoma *et al.* 1993; Raschke 1993; Zutshi & Khan 1992) but biological response to nutrient enrichment has merely been appreciated (Garg & Garg 1999, 2001). In the aforecited backdrop, a pilot study was undertaken to assess the potential fertility of lentic waters and to ellucidate the ecology of aquatic flora. In addition, studies were performed at microcosmal level and the results, so obtained, were applied at field level, to forsee the impact of nutrients on natural waters. On this basis, limits have been suggested for each nutrient, the excess of which may cause eutrophication or considerable loss of lake biota.

Three major water resources of Bhopal, Upper lake (UL), Lower lake (LL) and Mansarovar reservoir (MR), have been selected for present investigation. Unfortunately, these beautiful water resorts are under great environmental stress owing to human influences, discharge of sewage, growth and deposition of organic matter, siltation and eventually eutrophication. Sampling stations were established near Vardaman park in Upper lake, opposite to fish aquarium in Lower lake and near Administrative Academy in Mansarovar reservoir. These transects were chosen after considering limnochemical representation, enutrint loading and input of sewage. Samples were drawn, from these lakes, on every 1st, 3rd, 5th, 10th, 15th and 30th day of the month and the parameters were simultaneously assayed for natural as well as microcosmal waters.

To facilitate replicate tests and standardization, microcosmal experiments were conducted in the laboratory. Four cubical glass aquaria, with 50 litres capacity, were housed with 35 litres of water, sediment and phytoplankton penned-off from natural lake waters. Three of them were administered with 5.0 mg $l^{-1}$, 10.0 mg $l^{-1}$ & 15.0 mg $l^{-1}$ of nutrients whereas the remaining one retained controlled condition. The experiments were conducted for 30 days and at a stretch only one nutrient was handled. Such experiments were performed in five replicates, one for each nutrient viz. calcium, magnesium, potassium, nitrogen and phosphorus. Thus, fifteen sets, five for each reservoir, with a total of sixty model ecosystems, were developed, over a spell of 15 months.

Phytoplankton were identified following the manual of Ward & Whipple (1968). Compound Quotient, also regarded as Nygaard's Coefficient, was computed for each lake as follows:

$$CQ = \frac{\text{Chlorococcales + Centrales + Cyanophytes + Euglenoids}}{\text{Desmids}}$$

Limnochemical features were analyzed according to APHA (1989) and NEERI (1988).

Water of all the three lakes were found to be hard with calcium contents ranging from 41.6 – 74.4 mg $l^{-1}$ in Upper lake, 30.0 – 78.0 mg $l^{-1}$ in Lower lake and 47.2 – 99.2 mg $l^{-1}$ in Mansarovar reservoir. The latter held high concentration of cal-

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cium since the lake water, apart from agricultural run-offs, also receives discharge from *Chunabhatti.*

Magnesium hardness was always lower than calcium hardness. Its range in water spreads fell between 5.0 – 14.1 mg $l^{-1}$ (UL), 6.3 – 14.7 mg $l^{-1}$ (LL) and 9.0 – 15.4 mg $l^{-1}$ (MR).

Another micronutrient, potassium showed expressive values in Bhopal waters fluctuating between 37.0 – 86.0 mg $l^{-1}$ (UL), 49.0 – 98.0 mg $l^{-1}$ (LL) and 43.0 – 74.0 mg $l^{-1}$ (MR). Nearly similar range was earlier determined (49.0 – 78.0 mg $l^{-1}$) by Adholia *et al.* (1992). These values invariably emphasize that Bhopal waters have high amount of potassium.

Total kjeldahl nitrogen in these experimental waters was found between 16.8 – 35.0 mg $l^{-1}$ (UL), 21.0 – 42.0 mg $l^{-1}$ (LL) and 14.0 – 35.0 mg $l^{-1}$ (MR). High concentration of TKN in Lower lake might be due to incursions of domestic sewage and decaying organic matter. In present study, nitrate values oscillated between 0.14 – 0.38 mg $l^{-1}$ (UL), 0.24 – 0.47 mg $l^{-1}$ (LL) and 0.08 – 0.48 mg $l^{-1}$ (MR).

During present discourse, very little variations were glimpsed in phosphorus concentration (4.2 – 6.8 mg $l^{-1}$ UL, 4.2 – 6.0 mg $l^{-1}$ LL and 4.4 – 8.0 mg $l^{-1}$ MR). On comparing with the range (0.0 – 18.3 mg $l^{-1}$) recorded by Sastry *et al.* (1970), in Upper lake, it becomes evident that the lake has assumed fairly high eutrophy during the last three decades. Further, increasing values were observed in Mansarovar reservoir – a more eutrophic water body than the other two.

The lakes were monitored extensively for recording phytoplankton population, composition and species diversity. Upper lake showed low eutrophy with CQ = 2.6 – 15.0. Major nutrient supply was from agricultural run-offs and channels dropping into it with ample amount of nutrients and eroded soil. In all, 27 species of phytoplankton were identified with total units falling between 9,200-19,480 org $l^{-1}$. The water body manifested luxuriant growth of *Crucigenia crucifera, Crucigenia quadricauda, Scenedesmus abundans, Scenedesmus dimorphus, Melosira granulate* and *Cosmarium granatum*.

Lower lake ranked second in the trophic continuum with Nygaard's value lying between 5.5 and 23.0. The lake harboured 32 species of phytoplankton distributed over 3 groups viz. Chlorophyceae (20), Bacillariophyceae (6) and Cyanophyceae (6). Total number of algal cells fluctuated between 11,660 – 19,400 org $l^{-1}$. The lake water was predominantly occupied by *Crucigenia crucifera, Crucigenia rectangularis, Scenedesmus abundans, Scenedesmus dimorphus, Anabaena ornaldii, Navicula cryptocephala, Merisopedia punctata* and *Microcystis aeruginosa.* Sensitive species like *Staurastrum orbiculare* and *Tetraedron gracile* displayed scarce representation.

Mansarovar reservoir experienced the highest eutrophy among Bhopal waters with CQ ranging from 20.0 to 31.0. The lake flourished well, depicting high abundance of microphytes (13, 120-27,020 org $l^{-1}$). Unlike the other two lakes, where chlorophytes were abundant, this reservoir sustained a large population of Cyanophyceae. Besides, it also promoted polluted water forms (euglenoids) which were conspicuously lacking in rest of the lakes. To this may be included water scums of *Microcystis aeruginosa* together with prominence of certain eutrophic forms like *Actinastrum hantzschii, Chlorella vulgaris, Eudorina elegans, Scenedesmus armatus, Melosira granulata, Navicula cuspidata, Anabaena ornaldii* and *Merismopedia punctata.* Data available in literature provided a clue to some rare forms, which dwelt in this lake a couple of years ago. These forms include *Botryodiopsis, Characium, Chlamydomonas, Dimorphococcus, Gontozygon, Pandorina* and *Shaerocystis* (Kulshrestha 1988). Absence of these genera during present study, dominance of few taxa and high concentration of nutrients not only rule out the possibilities of self-purification of this reservoir but also warn the hydrosystem to be on the verge of hypereutrophy.

When these waters were housed in artificial test-systems and were exposed to varying dosages of micro-nutrients viz. calcium, magnesium and potassium acetate, the system denoted a progressive state of eutrophy invariably in all lake waters. Under controlled condition, when no nutrient was added, the system did not show any significant change in species composition, except marginal reduction in the total density of phytoplankton. However, at high nutrient level, there appeared an increased competition among different algal taxa. Some cyanophytes mainly *Anabaena ornaldii, Merismopedia punctata, Microcystis aeruginosa* and a few others viz. *Crucigenia* sps., *Scenedesmus* sps. and *Melosira granulata* multiplied profusely, consuming available nutrients, thus, leaving aquaria nutrient –deficient for the less competent algal strains.

Similarly, when low dosage of urea and phosphoric acid were induced separately, an initial growth of algae, was observed, in almost all microcosms. But high dosage (10 mg $l^{-1}$ or 15 mg $l^{-1}$)

triggered inimical effect on algal community. As soon as nutrients were administered, cyanophytes availed competitive advantage, either by accumulation or by active proliferation and consumed greater fraction of nutrients. These nuisance creating microphytes overshadowed the other forms and rendered microcosms unsuitable for sensitive taxa. Thus, it can aptly be inferred that different species of phytoplankton can subsist upto a certain nutrient level (Table 1) beyond which competition between cyanophytes and other algae may enhance, eliminating the sensitive plankton flora.

**Table 1.** Range of tolerance (mg $l^{-1}$) for different species of phytoplankton.

| Name of species | Habitat | | | Calcium | Magnesium | Potassium | Nitrogen | Phosphorus |
|---|---|---|---|---|---|---|---|---|
| | UL | LL | SL | | | | | |
| *Actinastrum hantzschii* | | * | * | 57.6 – 101.6 | 10.5 – 31.0 | 57.0 – 95.0 | 25.0 – 49.4 | 4.5 – 9.2 |
| *Ankistrodesmus falcatus* | * | * | * | 56.8 – 101.6 | 10.5 – 31.0 | 49.0 – 91.0 | 19.6 – 49.4 | 4.5 – 9.9 |
| *Botryococcus braunii* | | * | | 57.6 – 97.6 | 10.5 – 24.3 | 00.0 – 83.0 | 26.4 – 43.4 | 4.5 – 8.9 |
| *Characiopsis longipes* | | | * | 76.0 – 83.2 | 10.8 – 24.3 | 61.0 – 75.0 | – | – |
| *Chlorella vulgaris* | | | * | 76.0 – 101.6 | 10.8 – 24.3 | 57.0 – 80.0 | 26.6 – 43.4 | 4.9 – 7.3 |
| *Coelastrum microporum* | | * | * | 57.6 – 83.2 | 10.5 – 22.6 | 57.0 – 75.0 | 19.6 – 43.4 | 5.8 – 7.5 |
| *Coelastrum proboscideum* | | * | | 57.6 – 83.2 | 10.5 – 31.0 | 48.0 – 75.0 | – | 00.0 – 7.3 |
| *Crucigenia crucifera* | * | * | | 31.2 – 97.6 | 10.4 – 31.0 | 48.0 – 95.0 | 19.6 – 49.4 | 4.5 – 10.0 |
| *Crucigenia quadrata* | * | | * | 31.2 – 101.6 | 10.4 – 25.4 | 48.0 – 80.0 | 19.6 – 43.4 | 4.9 – 9.9 |
| *Crucigenia rectangularis* | * | * | | 31.2 – 97.6 | 10.4 – 31.0 | 48.0 – 75.0 | 19.6 – 49.4 | 4.5 – 9.9 |
| *Eudorina elegans* | | * | * | 57.6 – 83.2 | 10.8 – 26.7 | 57.0 – 86.0 | 19.6 – 43.4 | 4.5 – 8.2 |
| *Kircheneriella contorta* | | | * | 80.2 – 83.2 | – | – | 25.2 – 35.0 | 5.0 – 7.3 |
| *Kircheneriella lunaris* | | * | | 60.8 – 97.6 | 10.5 – 31.0 | 48.0 – 61.0 | 26.4 – 49.4 | 4.5 – 9.2 |
| *Oocystis crassa* | | * | | 78.4 – 83.2 | 00.0 – 18.6 | – | – | 00.0 – 6.0 |
| *Oocystis irregularis* | | | * | 76.0 – 101.6 | – | 57.0 – 66.0 | 00.0 – 19.6 | 4.9 – 7.3 |
| *Pediastrum duplex* | * | * | * | 31.2 – 101.6 | 10.5 – 31.0 | 48.0 – 95.0 | 19.6 – 37.4 | 4.5 – 7.9 |
| *Pediastrum tetras* | | | * | 80.0 – 101.6 | 10.8 – 24.3 | 57.0 – 60.0 | 19.6 – 35.0 | 4.9 – 7.3 |
| *Phormidium bohneri* | | | * | – | – | – | 26.6 – 35.0 | 6.0 – 6.1 |
| *Scenedesmus adundans* | * | * | * | 31.2 – 97.6 | 10.4 – 31.0 | 48.0 – 95.0 | 19.6 – 49.4 | 4.5 – 10.0 |
| *Scenedesmus armatus* | | | * | 76.0 – 101.6 | 10.8 – 24.3 | 57.0 – 80.0 | 19.6 – 43.4 | 4.9 – 7.3 |
| *Scenedesmus bijugatus* | * | * | * | 31.2 – 101.6 | 10.4 – 31.0 | 49.0 – 95.0 | 19.6 – 49.4 | 4.5 – 9.9 |
| *Scenedesmus dimorphus* | * | * | * | 31.2 – 101.6 | 10.4 – 31.0 | 48.0 – 95.0 | 19.6 – 49.4 | 4.5 – 10.0 |
| *Scenedesmus obliques* | | * | | – | 11.9 – 31.0 | 61.0 – 75.0 | 35.0 – 49.4 | 4.5 – 7.3 |
| *Scenedesmus parisiensis* | * | | | 31.2 – 60.8 | 10.4 – 25.4 | 48.0 – 66.0 | 19.6 – 33.6 | 7.2 – 10.0 |
| *Scenedesmus quadricauda* | * | | | 31.2 – 63.2 | 11.8 – 25.4 | 48.0 – 66.0 | 19.6 – 33.6 | 7.2 – 9.9 |
| *Schroederia spiralis* | | * | | 63.2 – 83.2 | – | – | 00.0 – 35.0 | 00.0 – 6.0 |
| *Selanastrum gracile* | | | * | 89.6 – 91.6 | 12.5 – 22.6 | – | – | 6.0 – 7.3 |
| *Selanastrum granatum* | | * | | 63.2 – 97.6 | 00.0 – 18.6 | 83.0 – 92.0 | 35.0 – 49.4 | – |
| *Tetraedron gracile* | | | * | 76.0 – 83.2 | 10.8 – 24.3 | 57.0 – 66.0 | 19.6 – 35.0 | 5.8 – 7.3 |
| *Tetraedron minimum* | | * | * | – | 10.8 – 24.3 | 57.0 – 80.0 | 19.6 – 43.4 | 5.0 – 7.3 |
| *Closterium pronum* | * | | | 31.2 – 63.2 | 11.7 – 25.4 | 50.0 – 66.0 | 19.6 – 33.6 | 7.2 – 7.5 |
| *Cosmarium granatum* | * | * | * | 36.0 – 83.2 | 10.5 – 31.0 | 48.0 – 75.0 | 19.6 – 35.0 | 4.5 – 7.8 |
| *Staurastrum orbiculare* | * | * | | 36.0 – 78.4 | 11.8 – 25.4 | 49.0 – 66.0 | 19.6 – 35.0 | 4.5 – 7.3 |
| *Amphora acutiscula* | | | * | 76.0 – 83.2 | 10.8 – 24.3 | 57.0 – 66.0 | 20.8 – 33.6 | 4.9 – 7.3 |
| *Amphora cuspidata* | | | * | 76.0 – 101.6 | – | 57.0 – 80.0 | 19.6 – 43.4 | 4.9 – 7.3 |
| *Amphora ovalis* | * | | | 52.8 – 61.6 | 12.6 – 22.6 | 52.0 – 22.6 | 29.4 – 30.8 | 7.2 – 7.8 |
| *Cymbella affinis* | * | * | | 31.2 – 97.6 | 10.5 – 22.6 | 49.0 – 62.0 | 19.6 – 35.0 | 4.5 – 6.9 |

*contd…*

| Name of species | Habitat | | | Calcium | Magnesium | Potassium | Nitrogen | Phosphorus |
|---|---|---|---|---|---|---|---|---|
| | UL | LL | SL | | | | | |
| *Cyclotella meneghiniana* | | * | * | 57.6 – 83.2 | 10.5 – 22.6 | 57.0 – 95.0 | 19.6 – 49.4 | 4.5 – 8.2 |
| *Fragillaria* sp. | * | | * | 31.2 – 83.2 | 10.4 – 25.4 | 48.0 – 80.0 | 19.6 – 43.4 | 4.9 – 9.5 |
| *Melosira granulata* | * | * | * | 31.2 – 101.6 | 10.4 – 31.0 | 48.0 – 95.0 | 19.6 – 49.4 | 4.5 – 10.0 |
| *Navicula cryptocephala* | * | * | | 36.0 – 97.6 | 10.5 – 31.0 | 48.0 – 95.0 | 19.6 – 35.0 | 6.0 – 7.3 |
| *Navicula cuspidata* | | | * | – | 10.8 – 24.3 | 57.0 – 80.0 | 19.6 – 35.0 | 4.9 – 7.3 |
| *Nitzschia closterium* | * | * | * | 45.6 – 83.2 | 10.5 – 31.0 | 48.0 – 95.0 | 19.6 – 35.0 | 4.5 – 9.9 |
| *Synedra ulna* | * | * | * | 52.8 – 83.2 | 10.4 – 21.0 | 48.0 – 66.0 | 19.6 – 33.6 | 6.0 – 6.9 |
| *Tabellaria* sp. | * | | | 56.8 – 63.2 | 14.0 – 22.6 | 57.0 – 59.0 | 21.0 – 33.6 | – |
| *Anabaenopsis ornaldii* | | * | * | 57.6 – 101.6 | 10.5 – 31.0 | 57.0 – 95.0 | 19.6 – 49.4 | 4.5 – 9.2 |
| *Anabaena sphaerica* | * | | * | 00.0 – 36.0 | 10.4 – 25.4 | 52.0 – 80.0 | 19.6 – 43.4 | 6.0 – 10.0 |
| *Arthrospira massartis* | * | | * | 40.0 – 101.6 | 11.7 – 25.4 | 49.0 – 80.0 | 28.0 – 35.0 | 7.2 – 9.9 |
| *Merismopedia punctata* | | * | * | 57.6 – 101.6 | 10.5 – 31.0 | 57.0 – 95.0 | 19.6 – 49.4 | 4.5 – 9.2 |
| *Microcystis aeruginosa* | * | * | * | 31.2 – 101.6 | 10.4 – 31.0 | 48.0 – 95.0 | 19.6 – 49.4 | 4.5 – 10.0 |
| *Nostoc microscopicum* | * | * | * | 31.2 – 97.6 | 10.5 – 24.3 | 53.0 – 72.0 | 19.6 – 35.0 | 4.5 – 9.9 |
| *Oscillatoria amphigranulata* | * | * | * | 34.4 – 101.6 | 10.8 – 31.0 | 48.0 – 95.0 | 28.0 – 49.4 | 4.5 – 10.9 |
| *Oscillatoria jasorvensis* | | | * | 76.0 – 101.6 | 10.8 – 24.3 | 57.0 – 80.0 | 19.6 – 43.4 | 5.4 – 7.3 |
| *Oscillatoria subbrevis* | | | * | 76.0 – 101.6 | 10.8 – 24.3 | 57.0 – 80.0 | 19.6 – 43.4 | 4.9 – 7.3 |
| *Rhaphidiposis mediterranea* | * | | | 60.8 – 97.6 | 10.5 – 21.0 | 49.0 – 66.0 | – | 6.0 – 8.6 |
| *Phacus lammermannii* | | | * | – | – | 57.0 – 73.0 | 25.2 – 43.4 | 5.4 – 7.3 |
| *Trachelomonas playfairii* | | | * | 76.0 – 101.6 | – | – | 25.2 – 28.0 | 5.4 – 7.3 |
| *Trachelomonas robusta* | | | * | – | 10.8 – 24.3 | – | 26.6 – 40.6 | – |
| *Ceratium* sp. | * | | | – | 11.7 – 22.6 | 49.0 – 66.0 | – | – |

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