SUMMARY

Cyanobacteria are nature’s unique gift to mankind, as they possess several innate properties that make them ideal organisms with potential for multifaceted biotechnological applications. The basic and fundamental requirement for initiating cyanobacterial biotechnology is to first enumerate the available natural cyanobacterial wealth and to understand their ecophysiological properties. So far, there has been no systematic survey of the blue-green algae (in particular) and algae (in general) of fresh water or terrestrial habitats of Kurukshetra. This work is the first of its kind, surveying a continuous stretch of the religious ponds of Kurukshetra.

Studies on cyanobacterial and algal flora of the religious ponds of Kurukshetra is expected to provide a wealth of information that is not only academically rewarding, but also very useful in planning mass cultivation strategies oriented towards the biotechnological exploitation of these organisms.

The present study provides an insight into the ecological characteristics of the religious ponds of Kurukshetra, as well as the physiological studies of *Anabaena variabilis*, a cyanobacterium, locally isolated from Study Site-I (*Brahma Sarowar*) during the study.

The study was achieved by fulfilling the following specific objectives:

1. Physico-chemical analysis of water samples of some religious ponds of Kurukshetra
2. Mercury contamination in different parts/ components of study sites
3. Cyanobacterial and algal biodiversity of study sites
4. Impacts of intracellular accumulation of mercury on physiology of *Anabaena variabilis*.

The results of various experiments conducted are summarized as follows.

- The frequent and time to time monitoring of the physico-chemical analysis of fresh water ponds of human importance is an essential requirement for the maintenance of the quality of these ponds.

- From different religious ponds, the three big ones i.e. *Brahma Sarowar*, *Sannihit sarowar* and *Jyotisar Sarowar* were selected as Study Site-I, Study Site-II and Study Site-III respectively.

- Regarding the measurements of different ecophysiological parameters for different study sites, a lot of variations have been recorded.

- The various physico-chemical properties like surface water temperature, transparency, turbidity, pH value, dissolved oxygen content, free CO$_2$ content, electrical conductance, nitrate, sulphate, chloride and ammonium ion content etc. of the selected religious ponds i.e. Study Site-I (*Brahma Sarowar*), Study Site-II (*Sannihit Sarowar*) and Study Site-III (*Jyotisar Sarowar*) not only varied from season to season, but also year wise.

- In almost two-third cases, the seasonality had a significant effect (p<0.01) on the distribution of these parameters.

- While checking for the heavy metal mercury content in different study sites, it was quite strange to observe such high concentrations of this toxic metal in such religious ponds.
The distribution of mercury content in the water-sediment system is controlled by many physico-chemical interactions and equilibria, largely governed by pH, concentration, type of ligands and chelating agents, oxidation state of the mineral components and the redox conditions of the ecosystem.

The most probable source of mercury contamination to these religious fresh water ponds is the introduction of flowers, fruits, leaves, garlands, twigs etc. (different plantlets) by the people for many rituals and other occasions. It could be possible that these plantlets might be earlier treated with the pesticides or the insecticides containing mercury as one of their constituents. These plants had bioaccumulated that mercury and introduced it into the clean water of such religious ponds.

The Hg$^{2+}$ content of water samples of different study sites was found maximum during the winter seasons, followed by the rainy seasons and minimum during the summer months of the three studied years respectively.

The crude algal biomass sample of Sannihit Sarowar showed maximum Hg$^{2+}$ content as compared to that of Jyotisar Sarowar and Brahma Sarowar respectively.

Regarding the algal biodiversity of different study sites, I have observed mainly the three groups of algae i.e. Cyanophyta, Chlorophyta and Bacillariophyta in different ponds of Kurukshetra.

The cyanobacterial genera observed during the study are: *Chroococcus, Aphanocapsa, Aphanathece, Microcystis aeroginosa, Merismopedia, Gloeoeche, Gloeocapsa, Synechocystis, Nostoc*
muscorum, Anabaena variabilis, Oscillatoria, Lyngbya, Aulosira, Nodularia, Phormidium, Cylindrospermum, Rivularia, Gloeotrichia and Microcoleus etc.

- In case of chlorophycean algae, the genera observed during the study are: Eudorina, Closterium, Cosmarium, Chlorella, Cladophora, Spirogyra, Scenedesmus and Ulothrix etc.

- The diatoms identified are: Navicula, Pinnularia, Synedra, Fragillaria, Melosira, Nitzschia and Amphora etc.

- The cyanobacterium, Anabaena variabilis has been proposed as the bio-indicator organism of mercury pollution.

- The laboratory experiments, exploring the impacts of bioaccumulation of toxic heavy metal mercury on the algal physiology were conducted with the cyanobacterium, Anabaena variabilis, in combination with other heavy metals like zinc, copper and cadmium.

- The cyanobacterium, Anabaena variabilis demonstrated a maximum efficiency of 96 % metal extraction in the cultures treated with 0.1 µM Hg²⁺/ml culture. The cultures treated with maximum concentration of 1.0 µM Hg²⁺/ml culture showed the metal extraction efficiency of 53.1 % only.

- Mercury was inhibitory to general growth of the cyanobacterium at extremely low concentrations.

- The metal toxicity effects were regulated by the various biotic and abiotic factors.
The natural chelators were more effective in sequestering metal toxicity as compared to synthetic ones.

The blue green alga, *Anabaena variabilis* may be used as a bioindicator of Hg$^{2+}$-pollution in aquatic ecosystems, exploring its various physiological parameters.

Mercury inhibited synthesis of photosynthetic pigments and macromolecules.

Phycocyanin was more respondent to heavy metals than chlorophyll a and carotenoids.

The differential toxicity of Cd$^{2+}$, Cu$^{2+}$ and Zn$^{2+}$ (in combination with Hg$^{2+}$) was attributed to their varied adsorption site affinities.

Mercury non-competitively inhibited the active uptake of nutrients like nitrate and ammonium ions.

The non-competitive inhibition of nitrate and ammonium ion uptakes showed the possibility of a common site of entry of essential ions and Hg$^{2+}$, and argues in favour of the metal induced depletion of ATP and reductants.

The synergism shown by Hg$^{2+}$ and Cd$^{2+}$ is the result of indirect competition between cations for metal binding sites intracellularly.

Mercury also inhibited the *in vivo* activity of enzyme Nitrate Reductase (NR) as a result of binding of metal ions on the regulatory sites of the enzyme or indirectly through the decrease in energy, reductant and carbon skeleton of the organism.

It has also been suggested that the sensitivity/tolerance of enzyme, Nitrate Reductase depends not only upon its intrinsic responding
behavior or chemical composition, but also on mode of action and its location at the cell interior.

- Therefore, it is concluded that various metabolic inhibitions in *Anabaena variabilis* exposed to mercury (alone or in combination with other heavy metals like Cd$^{2+}$, Cu$^{2+}$ and Zn$^{2+}$) also occurred through inhibition of photosynthesis.

- Being a tolerant species, *Anabaena variabilis* can also be explored as a tool for bioremediation of mercury.