CHAPTER VI
SUMMARY AND CONCLUSION

This study is concerned with the toxicity and accumulation of four heavy metals, viz. Cu, Cd, Ni and Cr on two species of cyanobacterium, *Anacystis nidulans* and *Spirulina platensis*. For toxicity studies, the following parameters were used: Biomass productivity, growth rate, EC50, Chlorophyll a content, carbon assimilation, and protein content. The metals were added to the culture medium independently and also in combinations.

*Anacystis*, the unicellular species showed faster growth rate than *Spirulina*, the filamentous species. *Anacystis* contained higher chlorophyll a (~0.74% by dwt) and also exhibited higher assimilation efficiency (carbon assimilation to Chl a ratio) than *Spirulina* (~0.42% by dwt Chl a). *Spirulina* contains more protein than *Anacystis*.

With sublethal concentrations of heavy metals an enhancement in biological activity was observed. This enhancement was more prominent in the case of carbon assimilation and was negligible in case of Chl a and protein content.

In case of both the species the growth rates altered with even slight change in growth conditions. The growth rate is also very sensitive to the presence of heavy metals. For short term studies (<24 hrs) carbon assimilation was found to be a very sensitive parameter, while protein content was the least
sensitive. With low concentrations of heavy metals the alterations in protein content were negligible.

The order of toxicity of the metals used in the present study varied for the two species. Based on EC50 estimated from the survival ratio the order was Ni > Cd > Cu > Cr for *Anacystis* sp. and Cu > Ni > Cd > Cr for *Spirulina* sp. Considering all the parameters used in the study Cr was found to be the least toxic. In most of the cases the filamentous species *Spirulina* sp. exhibited higher tolerance to metals than unicellular species *Anacystis* sp. With increase in exposure time the toxicity curve (EC50 vs exposure time) became asymptotic indicating an "incipient lethal level".

Changes in pH modified the toxicity of metals. Algae altered the pH of the medium if it was suboptimal (<8) possibly by release of organic exudates. With decrease in pH (to 7.2) the toxicity of Cu and Cd was enhanced while that of other metals got lesser affected. In case of other metals (Cd, Ni and Cr) an antagonistic response to the deleterious effect of pH decrease to 6.4 on algae were clearly observed.

Addition of EDTA reduced the toxicity of Cu, Cd, Ni and Cr on algae.

Algae exposed to illumination contain higher Chl a content than those kept under darkness. Under illumination the inhibitory effect of heavy metals on Chl a content was higher
than under darkness. Carbon assimilation and Chl. a content under heavy metal stress followed the relation \( CA\text{ (Chl a)} = K + n \ln C \) where \( CA\text{ (Chl a)} = \) carbon assimilated \( 10^{-3}\ \text{gm/gm/hr} \) or Chl. a \( 10^{-3}\ \text{gm/gm} \); \( C \) = concentration of metal in ppm. \( K \) and \( n \) = constants.

When the algae were exposed to combinations of two metals in different concentrations the toxicity of each component was altered. The modifications manifested were dependent on the concentrations of the components added and the ratio of components decided the interaction. It was also observed that the exposure time also modified the net toxicity of the toxicant combination.

Both *Anacystis* and *Spirulina* showed high capacity to accumulate the metals used in the present study. The concentration factors observed were in the range of \( 10^3 \) to \( 10^4 \). In general Cu and Ni were accumulated more than Cd or Cr. The concentration factors showed an inverse in relation with metal concentration in the medicine. This indicates a saturation effect. Metal uptake followed a relation \( m = KC^n \) where \( m = M 10^{-4}/\text{gm algae} \); \( C = \text{concentration of the metal in the medium} \ 10^{-6} \ \text{M/l}; \ K \) and \( n \) constants. In all the cases, the exponential constant \( n \) was lower than 1 indicating a non-Langmuir type of absorption. When the metals were added in combinations of twos, the accumulation of each got altered.