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Biochemical responses of some freshwater algal species to selenium : A laboratory study

Mane P. C.[1], Kadam D. D.[2] and Chaudhari R. D.[*3]

[1] School of Earth Sciences, Swami Ramanand Teerth Marathwada University, Nanded, (M.S.) India.
*[2 & *3] Zoology Research Centre, Shri Shiv Chhatrapati College of Arts, Commerce and Science, Junnar, University of Pune, (M.S.) India.*

ABSTRACT

The disturbance of aquatic ecosystems due to metal pollution from various sources such as industrial and domestic, cause loss of biodiversity as well as increases the bioaccumulation and magnification of toxicants in the food chain. The objective of the present investigation was to evaluate the effect of selenium on several physiological activities of Anabaena ambigua, Anabaena subcylindrica, Nostoc commune, Nostoc muscorum, Spirogyra sp, Spirulina sp. To carry out this research work, the algal strains were obtained from various sources. A standard initial inoculum of the isolated algal species were inoculated to culture flasks. The culture flasks were supplied with various concentrations (0.1, 0.5, 1.0, 2.0, 3.0, 4.0 and 5.0 mg/L) of selenium. At the end of the incubation period 10 ml of sample was taken and centrifuged at 6000 rpm for 15 minutes and the pellets were used for measurement of the various experimental parameters. The results show that, the lower doses of selenium had stimulatory effects on total chlorophyll, total protein, total carbohydrate, total starch and total free amino acids of all the tested algal species. All the biochemical parameters of the tested algal strains were gradually decreased in a manner dependent on the metal concentration in the culture medium. The inhibitory and stimulatory effects of either of the used heavy metals depends on concentration. Different organisms, however, have different sensitivities to the same metal and the same organisms may be more or less damaged by different metals.

Key words: Metal pollution, biochemical parameters, algae, inhibitory effects, stimulatory effects.

INTRODUCTION

Without liquid water we would not exist. Water is the (nearly) universal solvent that carries nutrients and wastes to and from our cells. It participates in many organic functions and reactions that allow life as we know it to exist. The earth we is the only place that know of where water exists in liquid form in any appreciable quantity. Liquid water covers nearly three-fourths of the earth's surface, and during the winter, snow and ice cover a good deal of the rest. Not only is essential for cell structure and metabolism, but water's unique physical and chemical properties directly affect the earth's surface temperatures, its atmospheres, and the interactions of life-forms with their environments.

Any physical, biological, or chemical change in water quality that adversely affects living organisms of makes water unsuitable for desired uses can be considered pollution. There are natural sources of water contamination, such as poison springs, oil seeps, and sedimentation from erosion, but here we will focus primarily on human-caused

changes that affect water quality or usability. Water pollution occurs due to the presence of dissolved inorganic, organic materials and other substances [12].

Metal contamination of the environment arises not only from natural sources, but from industrial activity [9, 20]. Combustion of fossil fuels releases about 20 toxicologically important metals into the environment including arsenic, beryllium, cadmium, lead and nickel. Industrial products and used industrial material may contain high concentrations of toxic metals. For example, mercury is used by the chlor-alkali industry to produce chlorine and caustic soda in the pulp and paper industry and in the production of battery cells, fluorescent bulbs, electrical switches, paints, agricultural products, dental preparations and pharmaceuticals. Cadmium, a by-product of zinc and lead mining, is an important environmental pollutant. It has many industrial uses in paints, pigments, batteries and plastics. Another use is as an anticorrosive agent for steel, iron, copper, brass and other alloys.

The levels of trace metals are usually higher in rivers than in oceans because metals from point and non-point sources are discharged into the rivers. Changes in concentrations of metals in river are easily detected because of their rapid rate of transport [18].

The pollution of aquatic environments by metals is well documented worldwide. Metal contamination in several rivers in Wales has been documented from the early 19^{th} century, with some rivers having only invertebrate communities and showing no sign of fish life by the early 20^{th} century [13].

Heavy metal ions have become an ecotoxicological hazard of prime interest and increasing significance, because of their accumulation in living organisms. The effects of metals on aquatic organisms is difficult to determine as many physical and chemical properties such as flow rate contribute to the outcome. Also the size and the nature of particulates to which the metals are attached affect the toxicity of the metals. Various factors influence the metabolism and effects of metals. Those factors that include particular characteristics of the organisms exposed are known as host factors. Host factors includes age, diet, immune status, sex, species and interphyletic and circadian biorhythms [7, 14].

In the present research work, the effects of selenium on the physiological activities of six freshwater algal species was observed.

MATERIALS AND METHODS

Cultivation of algae -
The starting culture of *Anabaena ambigua*, *Anabaena subcylindrica*, *Nostoc muscorum*, and *Spirulina sp.* was obtained from National Chemical Laboratory, Pune. The culture of *Nostoc commune* was brought from the School of Life Sciences, Swami Ramanand Teerth Marathawada University, Nanded while *Spirogyra sp.* was isolated form the water body present in the campus of Swami Ramanand Teerth Marathawada University, Nanded. The strains of *Anabaena ambigua*, *Nostoc muscorum*, *Nostoc commune*, *Anabaena subcylindrica* were inoculated and grown in the Fog's medium at p^H 7.5 while the *Spirogyra sp.*was inoculated and grown in the modified Bold's basal medium and the *Spirulina sp.* was inoculated and grown in the Spirulina medium. All these medium were sterilized by autoclaving at 121^oC for 15 minutes. All these medium were stored at 4^oC until inoculated. Culture was grown in the respective liquid media in 2 liter glass Erlenmeyer flasks and incubated at 25^oC in a growth chamber with a light and dark cycle of 8 hours and 16 hours and 3000 – 3500 lux, light intensity provided by cool white day light fluorescent tube lamps.

Experimental setup -
Stock solutions (1000 mg/L) of selenium was prepared in double distilled water. Three different sets of flasks (250 ml) along with one control were prepared each containing 100 ml of nutrient medium and sterilized by autoclaving at 121^0C and 15 lb pressure for 15 minutes. Cooled at room temperature and metal solution was mixed aseptically in flasks for preparation of different concentrations. One ml of algae culture (one month old) was inoculated in each flask and incubated for 15 days under white fluorescent light of 2000 lux with 16/8 hours light and dark photoperiod at 28 ± 2^0C in temperature controlled culture chamber.

Estimation of chlorophyll -
Chlorophyll content was estimated by Arnon's method. 10 ml of sample was taken and centrifuged at 6000 rpm for 15 minutes. Supernatants were discarded, while pellets extracted with 5 ml of 80% aqueous acetone for at least 6 hours at 4^0C temperature. The tubes were wraped with aluminum foil and kept in dark. The samples were centrifuged again and the supernatants were used for measuring the optical density at 663 nm and 645 nm against 80% acetone as a blank by spectrophotometer. Total chlorophyll was calculated for each sample using the Arnon's formula [1].

Estimation of protein -
Protein contents were estimated by the Lowry method using Bovine Serum Albumin (BSA) as standard. The pellets remaining after chlorophyll extractions were dissolved in 0.1 N NaOH, centrifuged at 6000 rpm for 15 minutes. 0.2 ml of supernatant was mixed with 2.1 ml of working solution – I (1% $CuSO_4$ + 1% Na-K-Tartrate + 2% Na_2CO_3 in 0.1 N (NaOH). After 10 minutes, 0.2 ml of 50% diluted Folin – Ciocalteu's reagent was added. Absorbance was recorded after 30 minutes at 750 nm by spectrophotometer against a blank having no protein [11].

Estimation of total carbohydrate -
The total carbohydrate contents were estimated by the Anthrone reagent method. 10 ml samples were centrifuged at 6000 rpm for 15 minutes. Pellets were separated and extracted with 80% ethanol. On further centrifugation, the supernatants were used for total carbohydrate estimation. 0.5 ml of supernatants was added to 2.5 ml anthrone reagent in ice bath. Then the tubes were boiled in water bath at 100^0C for 10 minutes. After cooling, the absorbance were recorded at 620 nm using spectrophotometer, against a blank having no carbohydrate [4].

Estimation of starch -
The starch contents were estimated by the Anthrone reagent method. The pellets remained during total carbohydrate estimation, were used for starch estimation. The pellets were extracted with 52% perchloric acid for 30 minutes at 0^0C centrifuged and supernatants were diluted upto 15 times. 1 ml of diluted sample was mixed with 2 ml cold anthrone reagent in ice bath. Boiled for 10 minutes at 100^0C in water bath, cooled and recorded the absorbance at 630 nm by using spectrophotometer against a blank having no starch. Calculated the starch content by multiplying with 0.9 to the values obtained from standard curve.

Estimation of free amino acids -
The total free amino acids were estimated by the Ninhydrin method. 10 ml of samples taken and centrifuged at 6000 rpm for 15 miutes. Supernatants were discarded while pellets extracted with 5 ml of 80% ethanol. 0.1 ml of extract was mixed with 1 ml of ninhydrin solution and 0.9 ml of distilled water. The tubes were boiled in water bath for 20 minutes. 5 ml of diluent was mixed and after 15 minutes recorded the absorbance at 570 nm by spectrophotometer against a blank by taking 0.1 ml of 80% ethanol instead of the extract [15].

RESULTS AND DISCUSSION

Table 1 : Effect of selenium concentrations on chlorophyll content of selected algae (mg/ml).

Conc. (mg/L)	Algae					
	Anabaena ambigua	***Anabaena subcylindrica***	***Nostoc commune***	***Nostoc muscorum***	***Spirogyra sp.***	***Spirulina sp.***
Control	0.0283± 0.00020	0.0914± 0.00024	0.7765± 0.00034	0.1813± 0.00016	1.7765± 0.00028	0.3706± 0.00024
0.1	0.0574± 0.00024	0.1235± 0.00020	0.9284± 0.00020	0.2314± 0.00028	1.9805± 0.00024	0.4035± 0.00024
0.5	0.0716± 0.00020	0.0994± 0.00028	0.8714± 0.00029	0.1835± 0.00028	1.7015± 0.00016	0.3544± 0.00024
1.0	0.0515± 0.00020	0.0854± 0.00020	0.6535± 0.00029	0.1466± 0.00020	1.4523± 0.00024	0.2984± 0.00028
2.0	0.0494± 0.00028	0.0753± 0.00020	0.5015± 0.00029	0.1024± 0.00024	1.1256± 0.00020	0.2752± 0.00012
3.0	0.0473± 0.00016	0.0686± 0.00024	0.3873± 0.00016	0.0897± 0.00016	0.9834± 0.00021	0.2314± 0.00028
4.0	0.0253± 0.00024	0.0453± 0.00016	0.1387± 0.00017	0.0614± 0.00020	0.8537± 0.00016	0.2035± 0.00016
5.0	0.0144± 0.00029	0.0165± 0.00021	0.0844± 0.00020	0.0364± 0.00024	0.3543± 0.00024	0.1854± 0.00024

Data are mean ±S.D. of three replicates per treatment.

Changes in the total chlorophyll contents of *Anabaena ambigua*, *Anabaena subcylindrica, Nostoc commune*, *Nostoc muscorum*, *Spirogyra sp, .Spirulina sp.*, in presence of different concentrations of selenium after seven days of incubation period were investigated.

The effects of different selenium concentrations are depicted in table 1 on total chlorophyll contents of algae. The data expresses that the total chlorophyll was inhibited 50% (IC_{50}) for *Anabaena ambigua* at 5.0 mg/L, *Anabaena subcylindrica* at 4.0 mg/L, *Nostoc commune* at 3.0 mg/L *Nostoc muscorum* at 3.0 mg/L, *Spirogyra sp.* at 4.0 mg/L *a*nd *Spirulina sp.* at 3.0 mg/L of selenium concentrations. In this work it was cleared that at higher concentrations of selenium showed inhibitory effects. Several researchers done a work on the effects of some metals iron [21], copper [5], silver, copper and zinc [8] on chlorophyll content of algae and supported our results.

However, the selenium exhibited stimulatory effects on chlorophyll content of *Anabaena ambigua* upto 3.0 mg/L, *Anabaena subcylindrica* upto 0.5 mg/L, *Nostoc commune* upto 0.5 mg/L *Nostoc muscorum* upto 0.5 mg/L, *Spirogyra sp*. upto 0.1 mg/L *a*nd *Spirulina sp.* upto 0.1 mg/L.

Table 2 : Effect of selenium concentrations on protein content of selected algae (mg/ml).

Conc. (mg/L)	Algae					
	Anabaena ambigua	***Anabaena subcylindrica***	***Nostoc commune***	***Nostoc muscorum***	***Spirogyra sp.***	***Spirulina sp.***
Control	0.4126± 0.00024	0.0625± 0.00034	0.9194± 0.00012	0.4234± 0.00029	0.6195± 0.00021	1.1465± 0.00028
0.1	0.5284± 0.00024	0.0842± 0.00012	1.2544± 0.00028	0.4830± 0.00079	0.7544± 0.00033	1.2375± 0.00012
0.5	0.6315± 0.00024	0.0604± 0.00024	0.9436± 0.00024	0.4124± 0.00028	0.6014± 0.00020	1.0655± 0.00024
1.0	0.4852± 0.00017	0.0513± 0.00024	0.7855± 0.00032	0.3716± 0.00021	0.5783± 0.00016	0.8744± 0.00028
2.0	0.2785± 0.00020	0.0425± 0.00034	0.5544± 0.00028	0.2974± 0.00028	0.5035± 0.00024	0.7933± 0.00021
3.0	0.2175± 0.00024	0.0354± 0.00020	0.4605± 0.00028	0.2114± 0.00021	0.4534± 0.00029	0.6944± 0.00024
4.0	0.0684± 0.00024	0.0128± 0.00010	0.2024± 0.00024	0.0954± 0.00024	0.3155± 0.00028	0.4125± 0.00026
5.0	0.0076± 0.00020	0.0084± 0.00024	0.0984± 0.00021	0.0634± 0.00029	0.1544± 0.00020	0.0956± 0.00021

Data are mean ±S.D. of three replicates per treatment.

Proteins are biochemical compounds consisting of one or more polypeptides typically folded into a globular or fibrous form, facilitating a biological function. A polypeptide is a single linear polymer chain of amino acids bonded together by peptide bonds between the carboxyl and amino groups of adjacent amino acid residues. The sequence of amino acids in a protein is defined by the sequence of a gene, which is encoded in the genetic code. The data given in (table 2) showed the effects of different selenium concentrations on total protein contents of algae. The data expresses that the total protein was inhibited 50% (IC_{50}) for *Anabaena ambigua* at 3.0 mg/L, *Anabaena subcylindrica* at 3.0 mg/L, *Nostoc commune* at 3.0 mg/L *Nostoc muscorum* at 3.0 mg/L, *Spirogyra sp.* at 4.0 mg/L *a*nd *Spirulina sp.* at 3.0 mg/L of selenium concentrations. The stimulation of protein synthesis at lower concentration of selenium may be attributed to the synthesis of stress proteins but at higher concentration of selenium the total protein content was inhibited [16, 19, 22].

However, the selenium exhibited stimulatory effects on protein content of *Anabaena ambigua* upto 1.0 mg/L, *Anabaena subcylindrica* upto 0.1 mg/L, *Nostoc commune* upto 0.5 mg/L *Nostoc muscorum* upto 0.1 mg/L, *Spirogyra sp.* upto 0.1 mg/L *a*nd *Spirulina sp.* upto 0.1 mg/L. After fifteen days of incubation period, the total protein content of all the algal strains was significantly decreased. In this study it was cleared that the total protein content tested algal species increases marginally at 0.1 mg/L.

Table 3 : Effect of selenium concentrations on carbohydrate content of selected algae (mg/ml).

Conc. (mg/L)	Algae					
	Anabaena ambigua	***Anabaena subcylindrica***	***Nostoc commune***	***Nostoc muscorum***	***Spirogyra sp.***	***Spirulina sp.***
Control	0.0563± 0.00024	0.0574± 0.00033	0.2575± 0.00020	0.0575± 0.00032	0.1576± 0.00024	0.0665± 0.00024
0.1	0.0765± 0.00024	0.0658± 0.00026	0.3214± 0.00033	0.0784± 0.00029	0.2315± 0.00020	0.0954± 0.00020
0.5	0.0624± 0.00029	0.0615± 0.00024	0.2054± 0.00024	0.0704± 0.00020	0.1755± 0.00029	0.0603± 0.00020
1.0	0.0415± 0.00024	0.0426± 0.00024	0.1724± 0.00033	0.0534± 0.00024	0.1094± 0.00020	0.0576± 0.00029
2.0	0.0324± 0.00024	0.0393± 0.00020	0.1543± 0.00024	0.0473± 0.00020	0.0956± 0.00021	0.0445± 0.00024
3.0	0.0265± 0.00028	0.0325± 0.00026	0.1425± 0.00020	0.0405± 0.00024	0.0895± 0.00028	0.0395± 0.00024
4.0	0.0495± 0.00024	0.0294± 0.00029	0.1305± 0.00020	0.0265± 0.00028	0.0863± 0.00020	0.0344± 0.00016
5.0	0.0465± 0.00021	0.0095± 0.00034	0.0854± 0.00020	0.0093± 0.00024	0.0434± 0.00033	0.0105± 0.00016

Data are mean ±S.D. of three replicates per treatment.

Table 3 exhibited the effects of different selenium concentrations on carbohydrate contents of algae. The data expresses that the carbohydrate was inhibited 50% (IC_{50}) for *Anabaena ambigua* at 3.0 mg/L, *Anabaena subcylindrica* at 4.0 mg/L, *Nostoc commune* at 4.0 mg/L *Nostoc muscorum* at 4.0 mg/L, *Spirogyra sp.* at 4.0 mg/L *a*nd *Spirulina sp.* at 4.0 mg/L of selenium concentrations. However, the selenium showed stimulatory effects on carbohydrate content of *Anabaena ambigua* upto 0.5 mg/L, *Anabaena subcylindrica* upto 0.5 mg/L, *Nostoc commune* upto 0.1 mg/L *Nostoc muscorum* upto 0.5 mg/L, *Spirogyra sp*. upto 0.5 mg/L *a*nd *Spirulina sp.* upto 0.1 mg/L. The present results demonstrated a concentration dependent effects of selenium on carbohydrate formation, being stimulated by lower concentrations and inhibited at higher concentrations [3]. The toxicity of heavy metals with *Nostoc muscorum*, observed the effects of copper (I) oxide on biochemical compositions of two marine microalgae, *Tetraselmis suecica and Dunaliella tetriolecta* [10].

Table 4 : Effect of selenium concentrations on starch content of selected algae (mg/ml).

Conc. (mg/L)	Algae					
	Anabaena ambigua	***Anabaena subcylindrica***	***Nostoc commune***	***Nostoc muscorum***	***Spirogyra sp.***	***Spirulina sp.***
Control	0.3314± 0.00028	0.8324± 0.00024	1.3286± 0.00016	0.3127± 0.00012	1.6435± 0.00024	0.6534± 0.00028
0.1	0.3424± 0.00020	0.9716± 0.00020	1.3854± 0.00024	0.3724± 0.00033	1.8224± 0.00028	0.7613± 0.00024
0.5	0.3167± 0.00017	0.8165± 0.00020	0.9985± 0.00024	0.2915± 0.00024	1.5254± 0.00028	0.6127± 0.00014
1.0	0.2814± 0.00024	0.3284± 0.00024	0.8545± 0.00024	0.2414± 0.00029	1.2744± 0.00028	0.5933± 0.00030
2.0	0.2155± 0.00024	0.2294± 0.00029	0.7601± 0.00455	0.1886± 0.00020	1.0545± 0.00016	0.5014± 0.00029
3.0	0.1645± 0.00024	0.0424± 0.00028	0.5115± 0.00028	0.1536± 0.00020	0.8894± 0.00033	0.4784± 0.00029
4.0	0.0714± 0.00028	0.0115± 0.00024	0.3275± 0.00020	0.0853± 0.00016	0.7994± 0.00028	0.3994± 0.00024
5.0	0.0184± 0.00024	0.0085± 0.00032	0.0984± 0.00020	0.0416± 0.00029	0.4535± 0.00020	0.3216± 0.00024

Data are mean ±S.D. of three replicates per treatment.

Table 4 shows the effects of different selenium concentrations on starch contents of algae. The data expresses that the starch was inhibited 50% (IC_{50}) for *Anabaena ambigua* at 3.0 mg/L, *Anabaena subcylindrica* at 3.0 mg/L, *Nostoc commune* at 2.0 mg/L *Nostoc muscorum* at 3.0 mg/L, *Spirogyra sp.* at 4.0 mg/L *a*nd *Spirulina sp.* at 5.0 mg/L of selenium concentrations. However, the selenium showed stimulatory effects on starch content of *Anabaena ambigua* upto 0.1 mg/L, *Anabaena subcylindrica* upto 0.1 mg/L, *Nostoc commune* upto 0.1 mg/L *Nostoc muscorum* upto 0.1 mg/L, *Spirogyra sp.* upto 0.1 mg/L *a*nd *Spirulina sp.* upto 0.1 mg/L. The increase in the starch content of all the six algal species at lower concentrations mainly at 0.1 mg/L after fifteen days of exposure period was determined. After this concentration the starch content was decreased with increase in the metal concentrations.

The research work by other researcher supported our results they evaluated the effect of enhanced lead and cadmium concentration on biochemical attributes of *Phaseolus vulgaris*. In this research work they found that, the starch content of leaves decreases 7.09%, 27.90%, 34.98% and 50.22% at 2, 4, 6 and 8 g/kg of lead concentration and 41.93%, 46.48% and 50.85% at 1.5, 2.0 and 2.5 g/kg of cadmium concentration [2]. The effects of eight heavy metals on some proximate compositin of *Eichhornia crassipes*. In this experiment, after three weeks of exposure to 0.3 mM of silver, cadmium, chromium, copper, mercury, nickel, lead and zinc, 73.71, 73.69, 74.01, 73.67, 70.09, 72.16, 73.68 and 74.62 mg/g of dry weight starch was observed respectively. While the starch content in control set was around 78 mg/g of dry weight [17].

Table 5 : Effect of selenium concentrations on free amino acid content of selected algae (mg/ml).

Conc. (mg/L)	Algae					
	Anabaena ambigua	***Anabaena subcylindrica***	***Nostoc commune***	***Nostoc muscorum***	***Spirogyra sp.***	***Spirulina sp.***
Control	0.3603± 0.00020	0.0695± 0.00029	1.1223± 0.00017	0.3693± 0.00020	1.5425± 0.00032	0.9845± 0.00024
0.1	0.3914± 0.00028	0.0865± 0.00024	1.2925± 0.00024	0.3943± 0.00024	1.7885± 0.00024	1.1934± 0.00020
0.5	0.3785± 0.00028	0.0615± 0.00032	1.2165± 0.00028	0.3115± 0.00024	1.3325± 0.00024	0.9125± 0.00028
1.0	0.2964± 0.00028	0.0525± 0.00024	0.5994± 0.00028	0.2485± 0.00033	1.1054± 0.00034	0.5483± 0.00024
2.0	0.2176± 0.00024	0.0446± 0.00029	0.3675± 0.00028	0.1834± 0.00028	0.7095± 0.00020	0.4855± 0.00024
3.0	0.1794± 0.00024	0.0344± 0.00024	0.0874± 0.00028	0.1155± 0.00028	0.3215± 0.00024	0.1315± 0.00032
4.0	0.0715± 0.00024	0.0094± 0.00020	0.0585± 0.00028	0.0874± 0.00020	0.0854± 0.00033	0.0874± 0.00024
5.0	0.0025± 0.00024	0.0044± 0.00033	0.0165± 0.00024	0.0314± 0.00020	0.0325± 0.00024	0.0324± 0.00020

Data are mean ±S.D. of three replicates per treatment.

Table 5 depicted the effects of different selenium concentrations on free amino acid contents of algae. The data expresses that the free amino acid was inhibited 50% (IC_{50}) for *Anabaena ambigua* at 3.0 mg/L, *Anabaena subcylindrica* at 3.0 mg/L, *Nostoc commune* at 1.0 mg/L *Nostoc muscorum* at 2.0 mg/L, *Spirogyra sp.* at 2.0 mg/L *a*nd *Spirulina sp.* at 2.0 mg/L of selenium concentrations. However, the selenium showed stimulatory effects on free amino acid content of *Anabaena ambigua* upto 0.5 mg/L, *Anabaena subcylindrica* upto 0.1 mg/L, *Nostoc commune* upto 0.5 mg/L *Nostoc muscorum* upto 0.1 mg/L, *Spirogyra sp.* upto 0.1 mg/L *a*nd *Spirulina sp.* upto 0.1 mg/L. Total free amino acid at the increasing concentration of selenium decreased in all the six tested algal species. However, at lower concentration of selenium the total amino acid content was increased. These findings were supported by [6, 23].

CONCLUSION

The metals plays very important role in the growth and photosynthetic rate of the algae. But at higher concentrations of the metals the algae shows toxic effects. In the present study the toxic effects of the selenium concentrations on some biochemical parameters of the six algal species was shown.

It is therefore clear that exposure of algae to selenium can cause long-term and non-reversible effects. Because metals in the environment may have a profound impact on the physiology and general health of the exposed organism, this present work will focus on the impact of well-known and frequently occurring selenium on the metabolic parameters mainly the photosynthetic parameters of some selected algal species.

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