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Response of an Algal Community to Chromium

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Abstract

The paper deals with the study conducted for evaluation of the effects of chromium on the algal population by laboratory bioassay test. The results show that the algal species are affected differentially by the chromium concentrations ranging from 0.5 to 10 ppm.In general, the sensitive species to chromium include *Closterium acutum, Closterium cambricum, Closterium venus, Crusigenia fenestrata, Kirchneriella contorta, Monoraphidium capricornutum, Monoraphidium contortum ,Scenedesmus acuminatus, Tetraedron trigonum, Anabaena incrassata, Chroococcus turgidus, Merismopedia tenuissima, Spirulina laxissima, Cylindrotheca gracils* and *Melosir agranulata.* However, a few species like *Navicula viridula, Cosmarium depressum,* Kirchneriella *microscopica* and *Microcystis* aeruginosa were found to be tolerant to chromium, which could be exploited for their indicator value along with other species found tolerant by other workers.

Key Word: Algae, response, chromium, bioassay test

Introduction

Algae being autotrophic in nature have an important niche in aquatic systems. They are important link in the food chains and any change in their composition due to contamination of water can modify the biotic relationships thus changing the whole ecosystem. Many environmental contaminants like pesticides, heavy metals, variety of organic toxicants, organic matter and even nutrients can greatly influence the algal populations. The presences of pollutants have beçome a pervasive threat to many natural aquatic ecosystems. The pollutants can have toxic effects on almost all kinds of organisms and the biological process at the cellular, population, community and ecosystem level of organisations. The pollutants act on a number of cellular and biochemical processes critical to growth and production of algae. These processes include photosynthesis, nucleic acid production, protein and lipid biosynthesis, nitrogen fixation and uptake of nutrients.

Toxic effects on algae are difficult to generalize owing to interactions of toxicities with other physico-chemical factors, and the difference in the tolerance level of different algal species. Secondary effects of pollutants on algae may also exist due to stress on zooplankton community declining the grazing pressure. Due to this it becomes difficult to extrapolate the laboratory studies to natural field conditions (Trainor 1984)

It has been reported that the limits of safe concentrations of various pollutants to fish and aquatic biota may well be in the toxic range of several algal and zooplankton species. It becomes increasingly important, therefore, to understand the effects of pollutants on all kind of aquatic life to manage and keep the aquatic systems healthy, as well as to maintain the algal based waste water treatment and recycling systems (Patrick *et al.* 1968).

Though, a vast information has been generated on the effects of various pollutants on different aquatic life forms (Cairns *et al.* 1978, Gohash and Konar 1980, Welch 1980 and Goel *et al.* 1987) relatively little is known about the effeéts of heavy metals on algae (Statton and Corke 1979, Rai *et al.*1981, Goel and Shete 1977). The present paper deals with the effect of chromium on a natural algal community in laboratory conditions.

Experimental Set Up

The experiment was conducted in glass jars of 500 ml capacity having a wide mouth with surface area of 40.7cm^2. Chromium solutions of various strengths, i.e. 0.5, 1, 2, 5, and 10 ppm were made from potassium dichromate using algal water after killing and removing algae by boiling and filtration. The algal water was collected from two different ponds of which one was comparatively more polluted than the other Both the ponds were having a well developed algal community represented by a large number of genera. For running the experiment the algal waters

from these two ponds were mixed in 1:1 ratio. The mixed algal water was acclimatized to the laboratory condition for few days in a glass aquarium tank.

For experiment, the mixtures of variously diluted chromium solutions and the algal water were taken in the ratio of 3:1(300 ml of chromium solution plus 100 ml of algal water). In each set of various dilution, two replicates were taken thus employing total 12 jars with 400 ml of the above mixtures in each. The harvesting schedule of the experiment was kept as to collect 50 ml sample from each jar on first, third and sixth day from the start of the experiment. Some quantity of the original mixture was also kept to take the reading for the zero day. The collected samples were concentrated 10 – fold by centrifugation, and were preserved with 4%formalin for further study.

Results

The results of the experiment with regard to the change in the density of algal taxa in various concentrations of chromium are presented in Fig. 1, Table 1 and 2. The data indicated that a large number of species were declined in density, while a few showed a complete elimination during the six days of the experiment. However, a few concentrations of chromium were favorable to certain species that has reflected an increase of their density during the experimental period.

Effect of Chromium on Individual Algal Species

Chlorophyceae: The species *Closterium acutum* showed an adverse effect of chromium where it was decreased in the range of 50.0 – 76.56% in various concentration of the metal. However the decrease in density did not show a correlation with concentration of chromium. *Closterium venus* also showed an adverse effect with the decrease in density to the magnitude of 47.91 – 62.66% in various concentrations of chromium. On the other hand, the control showed a decrease of only 37.5%. *Closterium cambricum* was also the species that registered a quite significant decline up to 89.83% in 5 ppm of chromium. The control for this species, however, showed an increase in the density by 23.0%. *Cosmarium depressum* showed a mixed trend having a decline in density with 0.5 and 2 ppm chromium, and an increase in density with 5 and 10 ppm. Its density remained unchanged in 1 ppm. The increase in density was much higher than the magnitude of decline. Control also showed an increase in the density. The algal species *Crucigenia fenestrata* was found to get decreased in numbers in all the concentrations of chromium with maximum decline of 69.04% in 1and 2 ppm concentrations. The control for this showed a much lower decline of 28.57%. *Crucigeniella rectangular* is also showed a decline in all the dilution with the maximum decline of 89.43% in 2 ppm chromium concentration. *Kirchneriella contorta* registered a significant decline with total elimination in 10 ppm of chromium concentration. However, the control for this alga showed a marginal increase. Another species of this genus, *Kirchneriella microscopica,* on the other hand, showed a mixed trend with a slight decrease in density with 5 and 10 ppm chromium, but showing an increase in density in the lower concentrations. As the increase in the density was much higher in control with the value of 66.66%, it can be infer, therefore, that this species is adversely affected by chromium to a great extent.

The species *Monoraphidium capricornutum* also showed adverse effect of chromium having a decline in density in all the concentrations with highest fall of 56.21% in 0.5 ppm and lowest of 8.64% in 10ppm.The data indicate that the species is affected more in the lower concentrations of chromium. The second species of this genus, *M. contortum,* however, was much more affected than the former with the highest value of decline by 74.36% in 10ppm chromium. On the contrary, the control for this species showed a tremendous increase of more than 98.0%. There were three species of *Scenedesmus,* all of them getting adversely affected by chromium. *S. acuminatus* was completely eliminated in 2 ppm and registered a decrease of 66.66% in 1 ppm. The control for this showed a decline of only 27.77%. *S. arcuatus* was not much affected as compared to the previous one with the maximum fall in density to be 64.86% in 1 ppm followed by 37.84% in 2 ppm. This species showed, however a slight increase in 5 ppm as well in control. *S. quadricauda* has fallen in density to the tune of 84.04% in 2 ppm followed by 85% in 10 ppm. This species also showed a marginal increase in 1 ppm of chromium. The control for this species showed a greater decline of 69.15%.

Tetraedron trigonum showed a tremendous decline in density by chromium with even total elimination in 2and 5 ppm concentrations. The algal species *Tetrastrum triangulare* also suffered a decline in density with chromium

concentrations from 1 to 10 ppm. However, this species showed a very slight increase (1.04%) in 0.5 ppm concentration of chromium.

Cyanophyceae: Anabaena incrassata showed a decline from 69.90% to 88.67% in various dilutions of chromium. However, the control also showed a substantial decline of 70.55% in density. Still, the data indicate that the species is adversely affected by chromium. *Chroococcus limneticus* while showing a slight increase of 3.84% in 10 ppm,showed a substantial decline in the remaining dilution. The control for this, however, registered an almost 200% rise in density, thus indicating that the species is greatly suppressed by chromium. Another species of this genus *C. turgidus* also showed a substantial decrease in density with all the dilutions, whereas in control it was marginally higher.

Merismopedia tenuissima was also the species that got drastically affected by chromium with a highest decline of 99.25% in 10 ppm. The control for this species showed only 35.19% fall.

Microcystis aeruginosa, except for 1 ppm of chromium, showed an increase in all the dilutions with maximum value of 170.0% in 10ppm chromium concentration. As the control for this also showed a higher increase of 164.44%, it can be included that the species remains almost unaffected by chromium.

Oscillatoria limnetica showed a mixed trend with an increase in the density in 0.5 and 5 ppm chromium and a decrease in density in the remaining. The maximum decline was obtained (43.75%) in 1ppm while the maximum increase was 25% in 0.5 ppm chromium. The control for this showed a decline in density by 25%. *Spirulina laxissima* was drastically affected by chromium and showed complete elimination in all the dilutions.

Bacillariophyceae: *Cyclotella catenata* showed a decrease in density in 1, 2 and 5 ppm of chromium with the maximum value of decline by 51.24% in 2 ppm. In 0.5 and 10 ppm of chromium, however there was a marginal increase. The control for this also showed an increase but it was not high (15.30%). The overall results indicate that the species is only slightly affected. *Cylindrotheca gracills* suffered in all concentrations of chromium with a fall in density, which was maximum in 05 ppm concentrations of chromium with a magnitude of decrease by 77.41%. In control, on the other hand, this species showed an increase by 145.16%. *Melosira granulata* also declined in density in all the concentrations of chromium with total elimination in 2 ppm followed by 74.07% fall in 0.5 ppm. In control, the species showed a substantial increase of 166.66%.

Nitzschia closterium was found to be destroyed completely by all the concentrations of chromium as well as in control. *Navicula viridula* showed an increase in all the chromium dilutions together with control. The maximum increase was observed to be 806.25% in 0.5 ppm chromium. The increase in control was also of high magnitude (304.6%). The data indicate that the low concentration of chromium might be promoting the growth of this species.

Species adversely affected by chromium

The results of the experiments reveal that all most all the species except a few showed a distinct trend of getting adversely affected by different concentrations of the chromium. Table 3 gives the name of the species which were totally eliminated in either of dilutions or control. It was found that there were three species eliminated in each 5 and 10 ppm of chromium , 4 species in 2 ppm chromium and 2 species each in 0.5 and 1 ppm of chromium.

Some of the important species which showed an adverse effect of chromium were *Closterium acutum*, *Closterium venus*, *Coelastrum cambricum*, *Scenedesmus acuminatus*, *Tetraedron trigonum*, *Anabaena incrassata*, *Chroococcus turgidus*, *Merismopedia tenuissima*, *Spirulina laxissima*, *Cylindrotheca gracilis* and *Melosira granulata*.

The species *Nitzschia closterium* showed a total decline of the population in all the concentrations of chromium as well as the control, hence, it is difficult to make any inference whether the metal has any adverse effect on this species or there are some other enviromental conditions common to all the sets including control which are responsible for decline in density.

Table 1. Algae showing decrease (%) over the control on 6th day in different sets of various concentrations of chromium.

Name of the species	10 ppm	5 ppm	2 ppm	1ppm	0.5 pp	Control
Class: Chlorophyceae						
Closterium acutum	71.87	75.00	73.44	76.56	50.00	35.94
Cloterium venus	66.66	64.58	66.66	64.58	47.91	37.50
Coelastrum cambricum	86.44	89.83	85.59	86.44	70.34	-
Cosmarium depressum	-	-	37.50	00.00	31.25	-
Crucigenia fenestrata	38.09	61.90	69.04	69.04	40.47	28.57
Crucigeniella rectangularis	19.67	75.40	89.34	78.68	79.50	65.57
Kirchneriella contorta	100.00	76.47	87.50	80.88	72.05	-
Kirchneriella microscopica	25.12	6.37	-	-	-	-
Monoraphidium capricornutum	8.64	40.90	52.42	55.15	56.21	26.36
Monoraphidium contortum	74.36	67.94	62.82	69.23	46.15	-
Scenedesmus acuminatus	55.55	36.11	100.00	66.66	33.33	27.77
Scenedesmus arcuatus	12.16	-	37.84	64.86	3.97	-
Scenedesmus quadricauda	80.85	55.32	84.04	-	13.83	69.15
Tetraedron trigonum	68.00	100.00	100.00	66.00	62.00	11.50
Tetrastrum triangulare	78.12	48.96	88.54	75.00	-	61.46
Class: Cyanophyceae						
Anabaena incrassata	69.90	88.67	81.07	88.02	81.07	70.55
Chroococcus limneticus	-	40.38	15.38	46.15	0.64	-
Chroococcus turgidus	80.85	55.31	74.47	56.38	65.95	-
Merismopedia tenuissima	90.25	66.79	79.60	86.46	90.79	35.19
Microcystis aeruginosa	-	-	-	57.77	-	-
Oscillatoria limnetica	20.83	-	29.16	43.75	-	25.00
Spirulina laxissima	100.00	100.00	100.00	100.00	100.00	48.27
Class: Bacillariophyceae						
Cyclotella catenata	-	4.27	51.24	36.65	-	-
Cylindrotheca gracilis	58.06	64.51	61.29	69.35	77.41	-
Melosira granulata	48.15	62.96	100.00	66.66	74.07	-
Nitzschia closterium	100.00	100.00	100.00	100.00	100.00	100.00

Table 2: Algae showing increase (%) over the control on 6th day in different sets of various concentrations of chromium.

Name of the species	10 ppm	5 ppm	2 ppm	1ppm	0.5 pp	Control
Class: Chlorophyceae						
Coelastrum cambricum	-	-	-	-	-	23.73
Cosmarium depressum	85.41	133.33	-	0.0	-	135.42
Kirchneriella contorta	-	-	-	-	-	16.54
Kirchneriella microscopica	-	-	43.14	23.04	9.91	66.66
Monoraphidium contortum	-	-	-	-	-	98.72
Scenedesmus arcuatus	-	15.54	-	-	-	40.54
Scenedesmus quadricauda	-	-	-	18.08	-	-
Tetrastrum triangulare	-	-	-	-	1.0	-
Class: Cyanophyceae						
Chroococcus limneticus	3.84	-	-	-	-	195.51
Chroococcus turgidus	-	-	-	-	-	10.64
Microcystis aeruginosa	170.00	138.88	48.88	-	13.33	164.44
Oscillatoria limnetica	-	6.25	-	-	25.00	-
Class: Bacillariophyceae						
Cyclotella catenata	6.04	-	-	-	7.83	15.30
Cylindrotheca gracilis	-	-	-	-	-	145.16
Melosira granulata	-	-	-	-	-	166.66
Navicula viridula	216.66	229.16	16.66	91.66	806.25	304.16

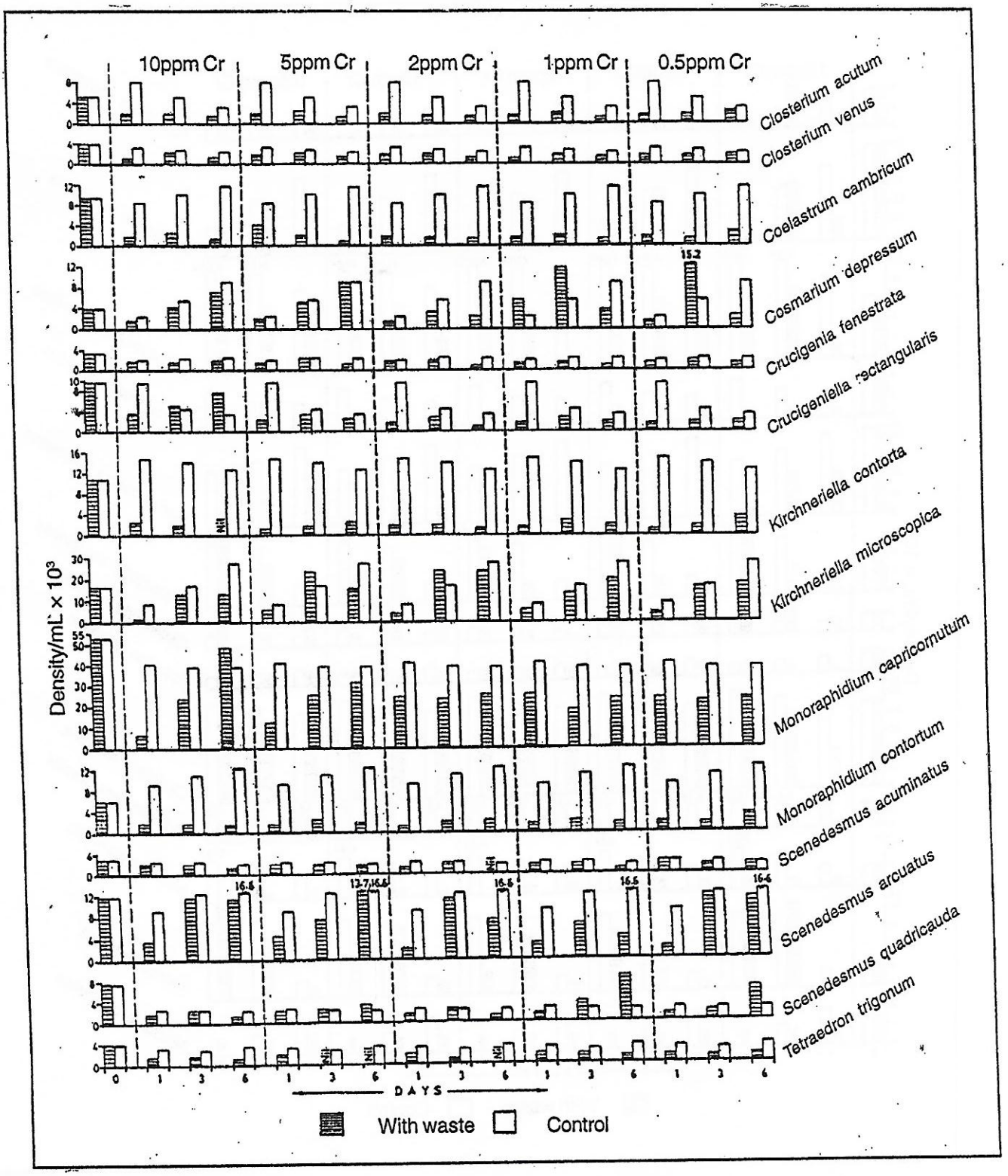

Fig.1 (A): Variation in Density of Phytoplankton Species in the Various Concentrations of Chromium

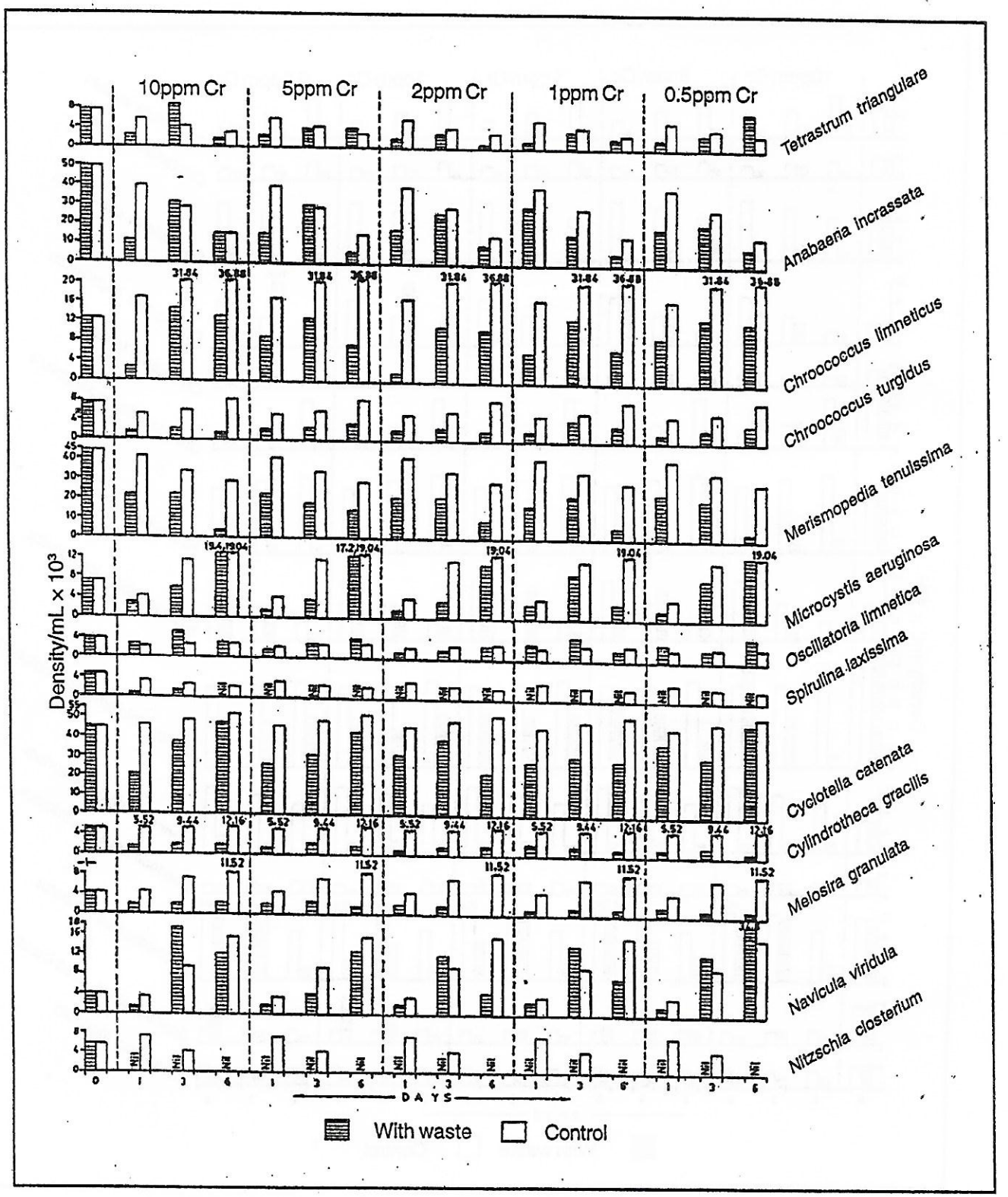

Fig.1 (B): Variation in Density of Phytoplankton Species in the Various Concentrations of Chromium

Table 3. Algal species showing different responses to chromium.

Species totally eliminated	Species adversely affected	Species promoted	Species with no clear trend
Kirchneriella contorta	*Closterium acutum*	*Navicula viridula*	*Oscillatoria limnetica*
Scenedesmus acuminatus	*Closterium venus*	*Cosmarium depressum*	
Tetraedron trigonum	*Coelastrum cambricum*	*Kirchneriella microscopica*	
Spirulina laxissima	*Crucigenia fenestrata*	*Microcystis aeruginosa*	
Nitzschia closterium	*Crucigeniella rectangularis*		
	Kirchneriella contorta		
	Monoraphidium capricornutum		
	Monoraphidium contortum		
	Scenedesmus acuminatus		
	Scenedesmus arcuatus		
	Scenedesmus quadricauda		
	Tetraedron trigonum		
	Tetrastrum triangulare		
	Anabaena incrassata		
	Chroococcus limneticus		
	Chroococcus turgidus		
	Merismopedia tenuissima		
	Oscillatoria limnetica		
	Spirulina laxissima		
	Cyclotella catenata		
	Cylindrotheca gracilis		
	Melosira granulata		

Species promoted by chromium

The species *Navicula viridula* showed a favourable response to the lower concentrations of Chromium while *Cosmarium depressum* was promoted at 5 and 10 ppm chromium and *Kirchneriella microscopica* was promoted at 0.5 and 2 ppm chromium. *Microcystis aeruginosa* also showed an increase in growth at 5 and 10 ppm of chromium.

DISCUSSION

Most heavy metals are toxic to algae with a varying degree depending upon the tolerance of the algal species (Kant 1989).While a few metals in small concentrations may be essential micronutrienuts to algae like copper, molybdenum and zinc etc., others such as cadmium, chromium, lead and mercury are toxic at almost all concentrations.The growth of algae in low concentration of essential metals remain normal but their increased concentration, as a rule, becomes toxic or lethal.

Whatever information on effects of heavy metals is available, comes from the laboratory studies, which according to Kant 1989 may not be fitted or extrapolated to natural habitats with large number of interacting factors. To overcome these limitations upto certain extent in the present study, the natural water enriched with chromium was used to grow the mixed population of algae rather than using single species cultures.

The studies so far conducted clearly indicate that the heavy metals pose a severe threat to the organisms in water including algae (Rai *et al.* 1981, Patric 1978, Whitton 1970, 1980, 1984, Welch 1980, Strokes 1983, Goel and Shete 1997). It is revealed from the studies that the algae exhibit different responses to different concentrations of heavy metals. The present experiment shows that while a large number of species (22) are sensitive to chromium, a few (four) show tolerance. Some of the extremely sensitive species to chromium include *Closterium acutum, C. venus, Kirchneriella contorta, Monoraphidium contortum, Scenedesmus acuminatus, Tetraedron trigonum, spirulina laxissima, Cyclotella catenata and Melosira granulata.*

The species showed tolerance to chromium include *Navicula viridula, Cosmarium depressum, Kirchneriella microscopica* and *Microcystis aeruginosa.* Palmer 1980 gave a list of 12 indicator algal species for chromium , i.e. *Closterium acerosum , Euglena acus , E. oxyceris, E. sociabilis, E. stellata, E. viridis, Navicula atomus, N. cuspidata, Nitzschia linearis, N. palea, Stigeoclonium lenue, and Tetraspora species.* It seems that the species of *Euglena* , in general , are quite tolerant to chromium.Our study adds some more species to the list of indicator species of chromium.

The reduction in the growth of *Scenedesmus*, by chromium in the present study is in confirmity to the observations made by Patrick 1978 who found that 5 ppm concentration of the metal is extremely toxic to this species. Many species of *Scenedesmus* have also been reported to be inhabited by other metals like cadmium (Goel and Shete 1997). According to Patrick 1978 many diatoms can flourish in lower concentrations of chromium, but can be replaced by blue greens at increased concetrations. It was also found in the present study that *Microcystis aeruginosa* increases substantially at 10 ppm of chromium, while *Navicula viridula* increases to several folds only at 0.5 ppm concentration.

The oxidation state of chromium is an important factor which may influence the toxicity as indicated by Patrick *et al.* 1968 who found that TLm (killing of 50% organisms) for diatoms was quite low (0.59 ppm) in case of Cr^{+6} as compared to the TLm value for Cr^{+3} revealing that the former is much more toxic than the latter.

Many studies showed that several species of algae bioaccumulate different heavy metals and, thus, may be used as indicators of metal pollution (Palmer 1980, Whitton 1984). While the impact of metals in isolation on a single species is worth studying, there is a need to study the toxicity of metals in relation to the presence of other influencing factors common to most natural situations. For example, a decrease in oxygen level in water can lead to the rise in toxicity of chromium (Cr^{+3}) to a great extent (Goel 1997). Considering the important status of algae, in aquatic systems, it is increasingly felt for an emphasis to understand the responses of algae to diverse pollutants specially in the natural habitats having complex interacting factors.

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