

Impact of Cadmium Chloride on the Changes in Pigment Content of a Cyanobacterium under Laboratory Controlled Conditions.

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Abstract

The Pulp and paper mill effluent waste contained significant amount of cadmium, mercury and lead much more than prescribed limit by Pollution Control Board is deadly toxic. The effluent of this industry is discharged into River Nagavali without any biological treatment. The present study aims at understanding the impact of cadmium on the growth and pigment content of the blue-green alga under laboratory controlled conditions. Complete bleaching of the algal mass was observed from 3rd day of exposure period onwards and at higher concentration of the toxicant in the exposed set when compared to control algal cells. Gradually tiny blue-green particles started making their appearance in the white turbid mass as observed in the naked eye after 15-20 days of recovery period. The maximum allowable concentration (MAC) recorded for this alga for 15 days exposure was 0.33 mg l⁻¹. The LC₁₀ value was 0.51 mg l⁻¹, the LC₅₀ value was 0.76 mg l⁻¹, LC₉₀ value was 1.14 mg l⁻¹ and LC₁₀₀ value was 1.26 mg l⁻¹, for this particular alga, *Anabaena cylindrica*. The control set showed 100% survival through out the experimental periods. The alga absorbed significant amount of cadmium. The growth of the alga significantly reduced at lethal concentrations. However at maximum allowable concentration, no impact was noticed. The pigments like total chlorophyll, total pheophytin content and carotenoid content significantly depleted at higher concentrations of cadmium chloride except at sub-lethal concentration where either no impact or little stimulation was noticed. No significant recovery was noted in the tested parameters. The study indicated dual impact of cadmium chloride indicating no harm at sub-lethal concentration and inhibition at higher concentration.

Keywords: Pulp & Paper mill, effluent, cadmium, cyanobacterium, BGA, pigments.

Introduction

Environmental contamination generally occurs mostly because of man's actions & man's wastes either deliberately or accidentally causing serious concern and pollution. Pollution is considered to be a creation of man or man's actions and related to direct or indirect human activity. The entry of the pollutant at primary producer level and gradually its translocation and transport to other higher trophic levels in the food chain, i.e. with the increase in the trophic levels, cause biomagnification. As a result of biomagnification, the organisms placed at higher trophic levels usually accumulate a persistent pollutant in its tissues to a concentration much greater than those present in the surrounding habitat. These

chemicals / pollutants are now, an inevitable part of the process of industrialization & modernization and mostly they are produced and used by the industry to deliver finished goods. Some of these chemicals, the by-products and the waste discharges of the industry are released inadvertently or accidentally into the environment to such an extent that they really threaten the ecosystem in global scale.

Sources and uses of cadmium in the Environment: Smelters and incinerators discharge huge amount of airborne cadmium in to the atmosphere, burning of fossil fuels like coal or oil, incineration of municipal waste such as plastics, nickel-cadmium batteries, Significant amount of cadmium is found in the effluent of Pulp and paper mills, cadmium is found in zinc ores (sphalerite [ZnS]), in lead and copper ores, cadmium is also found in the environment due to volcanoes and weathering of rocks, fossil fuel combustion discharges significant amount of cadmium into the environment. Cadmium is used to produce nickel-cadmium rechargeable batteries particularly for mobile phones and cordless equipments. Cadmium is also used as a sacrificial corrosion-protection coating for iron and steel, industrial use of cadmium alloys. Cadmium is used as coating (electroplating) of steel, iron, copper, brass and other alloys to prevent corrosion. Cadmium is used in solar cells, plastic stabilizers; cadmium is used in preparation of pigments which are used in fabrics, textiles and paints etc. Cadmium is used in industries like paint industry, plastic manufacture industry, pulp and paper mills, fertilizer and pesticide industries, luminescent dials, X-ray screens etc and cadmium in good quantity is also found in cigarette smoke. Significant amount of heavy metals like cadmium, lead and mercury was found in the effluent waste of JK Pulp and paper mills located at Jaykaypur, Rayagada as reported by Tripathy *et al*, (2021). The present study was planned to study the impact of cadmium in the form of cadmium chloride on the growth and pigment content of a cyanobacterium under laboratory controlled conditions.

Materials & Methods

Analysis of select physico-chemical parameters were carried out following the procedure of APHA (1985) and EC (1979). In addition the field analysis kit (Systronics, India), portable instruments were used to measure pH, conductivity & temperature of water and effluent samples. Dissolved oxygen was measured by modified Winkler's method (APHA, 1985). Mercury in digested samples were estimated following the process described in Analytical Method for estimation of mercury with Mercury Analyser MA 5800A issued and marketed by ECIL (1981). Known amount of sample was taken in a Klein's apparatus (digester) with acid digestion mixture and digested till the whole sample was fully digested (Wantorp and Dyfverman, 1955). After completion of digestion, the digested extract was cooled to room temperature. After cooling, the cadmium and lead content of the digested extract was estimated following the procedure of Yoshida *et al*. (1976).

Anabaena cylindrica, Lemm. is photo-autotrophic, unbranched, filamentous, heterocystous, blue-green alga belonging to the family Nostocaceae. Sahu (1987) found that Allen and Arnon's (1955) nitrogen free medium with trace elements of Fogg (1949) as modified by Pattnaik (1964) was most suitable for the organism. It was used as the basic culture solution in all the experiments in the present study. Test Chemical: Cadmium chloride (Analytical grade). For toxicity study of the pollutant, cadmium chloride solution was prepared by taking analytical grade cadmium chloride and dissolved in distilled water. A graded series of concentrations of cadmium chloride ranging from 0.1mg l⁻¹ to 2.0mg l⁻¹ (V/V) was prepared in different experimental conical flasks. The dilutions were made up with the nutrient medium. One ml of unialgal, axenic, homogenized culture was inoculated in each 150 ml flask containing 100 ml of normal nutrient solution (Control) and cadmium chloride exposed cultures, inside the Laminar air

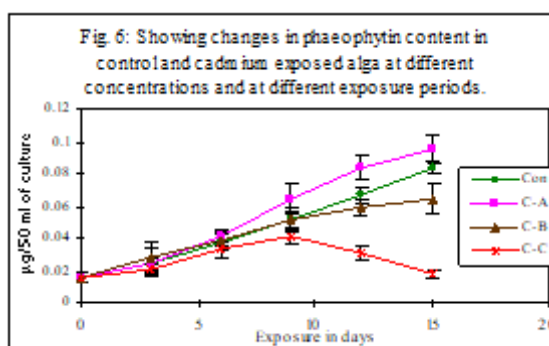
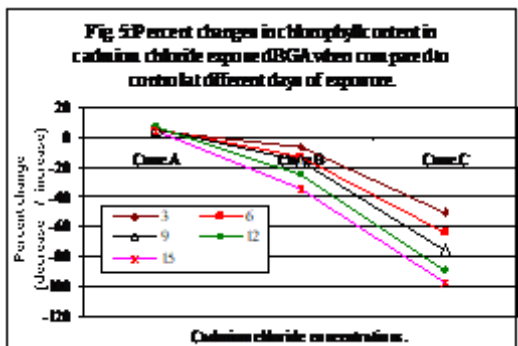
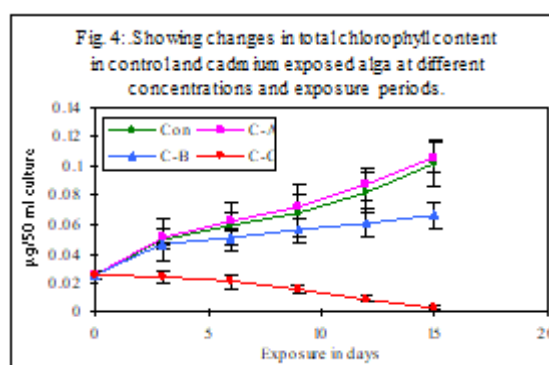
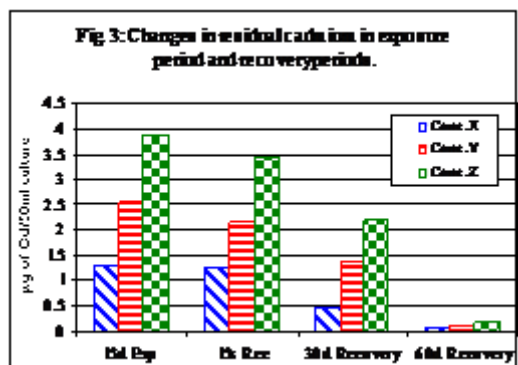
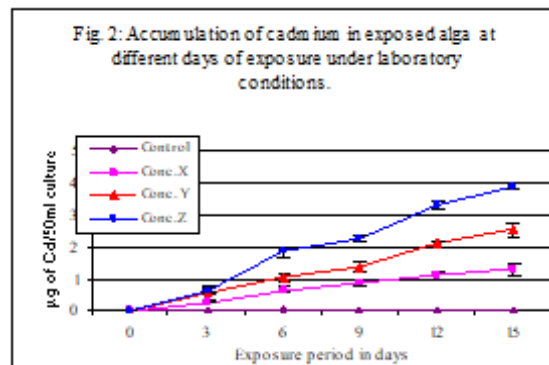
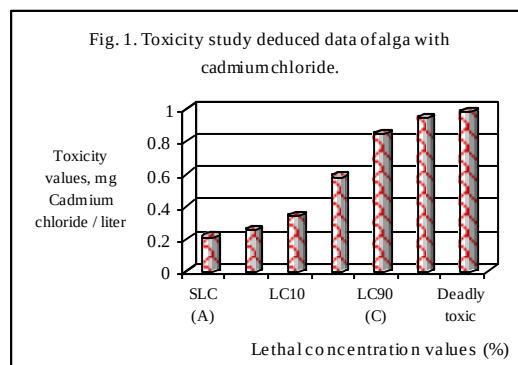
flow chamber under aseptic conditions. The inoculated flasks were kept inside the culture room at $28\pm 2^{\circ}\text{C}$ and under 14 hours illumination at the intensity of $2400\pm 200\text{Lux}$ and were hand shaken twice daily to avoid clumping of cells. The test algae were exposed for a period of 15 days in different test medium after which their survival and mortality percentage were calculated by counting the number of cells present in one ml of the test solution after micro-tissue homogenization. From this, different survival percentage and mortality percentage, the lethal concentration (MAC) value were determined. The pigment contents were measured by following the methods of Vernon (1960) and Davies (1976). Obtained data was statistically analyzed.

Results

The analysis of the physico-chemical parameters of the effluent mixed river water collected from the crop fields at Jaykaypur, Chandilli village revealed to be toxic as detailed: Color- Light yellow; Odour- Filthy smell; Temperature- $23.5\pm 1.2^{\circ}\text{C}$; pH- 8.1 ± 0.6 ; Conductivity- $687.9\pm 11.7\text{mho/cm}$; DO- $4.2\pm 0.5\text{mg.L}^{-1}$; BOD- $28.4\pm 3.6\text{mg.L}^{-1}$; COD- $78.9\pm 11.4\text{mg.L}^{-1}$; TSS- $219.6\pm 15.4\text{mg.L}^{-1}$; TDS- $192.5\pm 7.8\text{mg.L}^{-1}$; Chlorides- $76.8\pm 11.2\text{mg.L}^{-1}$; Hardness- $186.7\pm 8.8\text{mg.L}^{-1}$; Total Nitrogen- $2.21\pm 0.54\text{mg.L}^{-1}$; Total Phosphates- $1.95\pm 0.66\text{mg.L}^{-1}$; Total Sulphate- $24.8\pm 3.5\text{mg.L}^{-1}$; Total Cadmium [Cd]- $0.06\pm 0.02\text{mg.L}^{-1}$ and Total Lead (Pb)- $0.04\pm 0.03\text{mg.L}^{-1}$ (Padhy & Panigrahi, 2018).

In the present investigation, a graded series of concentrations of the cadmium chloride was prepared ranging from 0.1 to 1.0mg l^{-1} (micro-range), and from 1.0 to 10.0mg l^{-1} (middle range) to evaluate the toxic effects of cadmium chloride on the blue-green alga and to find out maximum allowable concentration of cadmium chloride for the experimental purposes. Below mentioned data explains the toxicity of the cadmium chloride to the blue-green alga, *Anabaena cylindrica*. With the increase in the concentration of the cadmium chloride the percent survival decreased and hundred percent deaths were noticed at 0.94mg/L of cadmium chloride with in a period of 15 days. With the increase in exposure period the concentration of cadmium decreases at a particular lethal dose / concentration value. The maximum allowable concentration (MAC) recorded for this alga for 15 days exposure was 0.21mg l^{-1} . The lethal concentration values for 15 days of exposure periods have been outlined below. The LC_{10} value was 0.34mg l^{-1} . The LC_{50} value was 0.58mg of cadmium chloride l^{-1} . LC_{90} value was 0.84mg l^{-1} and LC_{100} value was 0.94mg l^{-1} , for this particular alga, *Anabaena cylindrica*. The control set showed 100% survival through out the experimental periods. The same data can also be interpreted as 90% survival at 0.34mg l^{-1} , 50% survival at 0.58mg l^{-1} , 10% survival at 0.84mg l^{-1} , and 100% survival at 0.25mg l^{-1} was marked. Out of the above concentrations, safe MAC value of 0.21mg l^{-1} was selected as 'A'; LC_{50} or PS_{50} of 0.58mg.l^{-1} was selected as 'B' and LC_{90} or PS_{10} value of 0.94mg l^{-1} was selected as 'C' for conducting future experiments (Fig.1). From the toxicity testing, the above marked A, B and C concentrations of cadmium chloride were selected for future experiments. No residual cadmium accumulation was observed indicating the non contamination of the control set. In case of conc. A, the residual accumulation of cadmium increased with the increase in exposure period. The amount of cadmium accumulated in the conc. A exposed alga was $0.28\pm 0.06\mu\text{g}/50\text{ml}$ culture after 3rd day of exposure, $0.65\pm 0.09\mu\text{g}/50\text{ml}$ culture after 6th day of exposure, $0.88\pm 0.11\mu\text{g}/50\text{ml}$ culture after 9th day of exposure, $1.14\pm 0.12\mu\text{g}/50\text{ml}$ culture after 12th day of exposure and $1.31\pm 0.18\mu\text{g}/50\text{ml}$ culture after 15th day of exposure. In case of conc. B, the residual accumulation of cadmium increased with the increase in exposure period showing a significant positive correlation ($r=0.988$; $P\geq 0.01$). The amount of cadmium accumulated in the conc. B exposed alga was $0.58\pm 0.08\mu\text{g}/50\text{ml}$ culture after 3rd day of exposure,

1.05±0.15µg/50ml culture after 6th day of exposure, 1.39±0.16µg/50ml culture after 9th day of exposure, 2.11±0.08µg/50ml culture after 12th day of exposure and 2.54± 0.21µg/50ml culture after 15th day of exposure (Fig.2). In case of conc. C, the residual accumulation of cadmium increased with the increase in exposure period showing a significant positive correlation ($r=0.993$; $P\geq0.001$). The amount of cadmium accumulated in the conc. C exposed alga was 0.65±0.11µg/50ml culture after 3rd day of exposure, 1.85±0.14µg/50ml culture after 6th day of exposure, 2.28±0.08µg/50ml culture after 9th day of exposure, 3.32± 0.0.13µg/50ml culture after 12th day of exposure and 3.88±0.09µg/50ml culture after 15th day of exposure (Fig.3).



The total chlorophyll content of the control and cadmium chloride exposed alga, at different days of exposure and recovery were presented in Fig. 4A. The total chlorophyll content increased from 0.025±0.004 to 0.103±0.011 mg /50 ml culture within 15 days of exposure in the control set and the value increased to 0.134±0.012 mg /50 ml culture on 15th day of recovery (Fig. 4). The total chlorophyll content increased significantly ($p \geq 0.01$) in the exposed set (Conc-A), the value increased from 0.025±0.004 to 0.106±0.01mg /50 ml culture on 15th day of exposure. In concentration-A, the chlorophyll content increased insignificantly at all exposure periods and significantly decreased when compared to

their respective control values. The values increased by 4.08%, 5.08%, 5.88%, 7.32% and 3.92% on 3rd, 6th, 9th, 12th and 15th day of exposure respectively. Maximum of 7.3% increase was recorded on 12th day of exposure and on 15th day 3.9% increase over the control value was marked (Fig. 5) in conc. A set. When the exposed alga was transferred, to toxicant free medium the chlorophyll content increased from 0.106 ± 0.01 mg /50 ml culture to 0.130 ± 0.008 mg /50 ml culture after 15 days of recovery in concentration-A set (Fig.4). The total chlorophyll content increased from 0.025 ± 0.003 to 0.102 ± 0.016 mg /50 ml culture within 15 days of exposure in the control set and the value increased to 0.134 ± 0.011 mg /50 ml culture on 15th day of recovery (Fig.-5). The total chlorophyll content increased significantly ($p \geq 0.05$) in the exposed set (Conc.-B), the value increased from 0.025 ± 0.003 to 0.066 ± 0.009 mg /50 ml culture on 15th day of exposure. A maximum of 25.6% decrease was recorded on 12th day and on 15th day 35.3% decrease over the control value was marked in conc. C set. When the exposed alga was transferred to toxicant free medium the chlorophyll content increased from 0.066 ± 0.009 mg /50 ml culture to 0.085 ± 0.005 mg /50 ml culture after 15 days of recovery (Fig.5). The chlorophyll content decreased by 6.1%, 13.6%, 16.2%, 25.6% and 35.3% on 3rd, 6th, 9th, 12th, and 15th day of exposure showing a positive correlation (Fig.4). The total chlorophyll content decreased significantly ($p \geq 0.05$) in the exposed set (Conc.-C), the value decreased from 0.025 ± 0.003 to 0.003 ± 0.001 mg /50 ml culture on 15th day of exposure. A maximum of 89.02% decrease was recorded on 12th day and on 15th day 97.06% decrease over the control value was marked (Fig.5) in conc. C set. In case of conc. B, the total chlorophyll content though increased on 3rd day onwards, when compared to 0 day value but the chlorophyll amount was far less than control and conc. A and a maximum of 35.3% decrease was recorded, when compared to the control value. The percent decrease increased with the increase in exposure period, where a positive correlation was marked. A maximum of 97.06% decrease was recorded on 15th day of exposure in conc. C set. The correlation coefficient analysis between days of exposure verses total chlorophyll indicated the existence of significant positive correlation in control ($r = 0.993$, $p \geq 0.01$) and Conc. A ($r = 0.989$, $p \geq 0.01$).

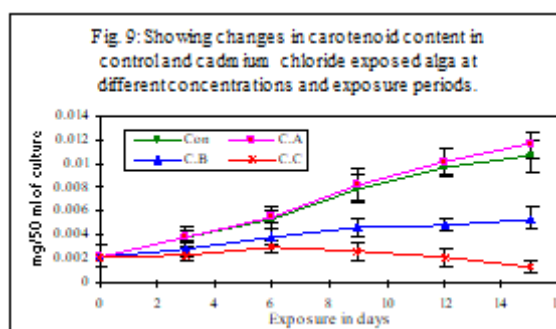
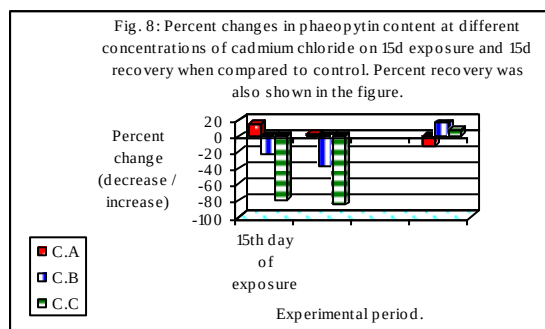
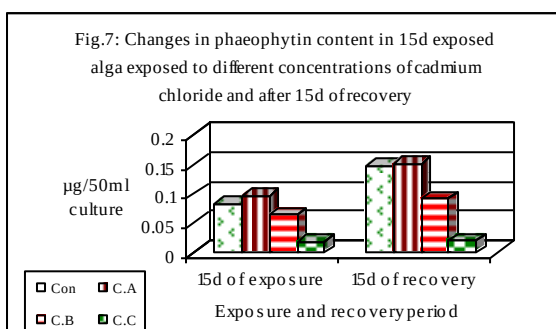


Fig.6 shows the changes in total phaeophytin content in control and cadmium chloride exposed blue-green alga at different exposure and recovery periods. The total phaeophytin content increased from 0.016 ± 0.0031 to 0.084 ± 0.0038 mg/50 ml culture within a period of 15 days. The phaeophytin content further increased from 0.084 ± 0.0038 to 0.148 ± 0.014 mg /50 ml culture after 15 days of recovery. The phaeophytin content increased from 0.016 ± 0.0031 to 0.096 ± 0.0014 mg/50 ml culture within a period of 15 days of exposure in conc. A. After 15 days of exposure the cadmium chloride exposed alga was transferred to toxicant free medium for recovery studies. After 15 days of recovery, the value increased from 0.096 ± 0.0014 mg/50 ml culture to 0.151 ± 0.0024 mg/50 ml culture in conc. A. The phaeophytin content interestingly declined from control value at all exposure and recovery periods in conc-B. No doubt, the phaeophytin content increased from 0.016 ± 0.0031 to 0.065 ± 0.0017 mg /50 ml culture on 15th day of exposure and the same value increased to 0.065 ± 0.0009 mg /50 ml culture, showing a positive correlation after 15 days of recovery, with the increase in recovery period, like the control set but the values were interestingly much less than the respective control values for each exposure and recovery period (Fig.6). In conc. B, the phaeophytin content increased from 0.016 ± 0.0031 to 0.028 ± 0.008 mg/50 ml culture on 3rd day of exposure showing more than the control and conc. A set and then the value significantly declined with the increase in exposure period compared to Conc. A set but no significant decrease or increase in phaeophytin content was marked compared to the control set. The phaeophytin value declined significantly on 15th day of exposure (Fig.6). When the exposed alga of concentration 'Y' was transferred to toxicant free nutrient medium, no recovery was marked. Rather the values further depleted to 0.092 ± 0.014 mg/50 ml culture, on 15th day of recovery, indicating total damage and destruction of the pigment (Fig.7). In conc. C, the phaeophytin content increased from 0.016 ± 0.0031 to 0.041 ± 0.0046 mg/50 ml culture on 9th day of exposure showing less than the control and conc. A & B sets and then the value significantly decreased with the increase in exposure period. The value declined from 0.041 ± 0.0046 to 0.018 ± 0.0028 mg /50 ml culture on 15th day of exposure. When the exposed alga of concentration 'C' was transferred to toxicant free nutrient medium, partial insignificant recovery was marked (Fig. 6. The values increased from 0.018 ± 0.0028 mg /50 ml culture to 0.021 ± 0.0012 , on 15th day of recovery, indicating total damage and destruction of the pigment (Fig.7). Fig. 6C indicate the percent change in phaeophytin content in the exposed alga at different exposure periods and recovery period and cadmium chloride concentration when compared to the control set. The phaeophytin content increased by 14.3% in concentration-A when compared to control value in the exposure set. On 15th day of recovery still an increase by 2.03% was noted. The value was more but the recovery was only -12.3% when compared to the control value. In case of conc.B, the depletion of phaeophytin content was 22.6% on 15th day of exposure and on 15th day of recovery the depletion was by 37.8%. Here, the recovery was around by 15.2% when compared to 15th day exposure value. In case of concentration-C, the phaeophytin content decreased by 78.6% on 15th day of exposure compared to its control value. During recovery period, after 15 days of recovery, the phaeophytin content instead of showing any increase rather showed a decreased value and the decrease value was 85.8% compared to its respective control value (Fig.7). In case of conc. C further depletion by 7.2% in phaeophytin content was noted instead any recovery. From the data it is well evident that at lower concentration of cadmium chloride exposure increase in phaeophytin content was noted and with the increase in cadmium chloride concentration, the phaeophytin content probably got destroyed and decreased values were noted.

Changes in carotenoid content of control and cadmium chloride exposed blue-green alga was shown in Fig.8 at different exposure periods. The carotenoid content of the control alga increased from $0.0022 \pm$

0.0007 to 0.0106 ± 0.0011 mg/50 ml culture within a period of 15 days and the value further increased to 0.0116 ± 0.0013 mg /50 ml culture at 15 days of recovery. The carotenoid content significantly increased at conc. A dose at all exposure and recovery periods. The carotenoid content increased from 0.0022 ± 0.0007 to 0.0116 ± 0.0011 mg /50 ml culture within 15 days of exposure and the value increased from 0.0116 ± 0.0011 to 0.0171 ± 0.0012 mg /50 ml culture on 15th day of recovery, when the exposed alga was transferred to toxicant free medium (Fig. 8&9). The carotenoid content significantly increased at conc. B dose at all exposure and recovery periods but the values were less than the control and concA values. The carotenoid content increased from 0.0022 ± 0.0007 to 0.0054 ± 0.0019 mg /50 ml culture within 15 days of exposure and the value increased from 0.0054 ± 0.0019 to 0.0088 ± 0.0009 mg /50 ml culture on 15th day of recovery, when the exposed alga was transferred to toxicant free medium (Fig. 8). Where as, in conc.-C, the carotenoid content decreased significantly up to 3rd day of exposure and then decreased linearly with the increase in exposure period, showing a significant negative correlation. The carotenoid content depleted from 0.0022 ± 0.0007 to 0.0013 ± 0.0007 mg /50 ml culture on 15th day of exposure. When the exposed alga was transferred to cadmium free medium, instead of showing any recovery, the value further depleted to 0.0011 ± 0.0003 mg /50 ml culture on 15th day of recovery (Fig. 8). Fig.9 shows the percent change and percent recovery in carotenoid content, where, dichotomous behaviour of the toxicant was clearly seen. At concentration A, the carotenoid content increased at all exposure periods, when compared to the control value. A maximum of 9.4% increase over the control value was marked on 15th day of exposure. In contrast, at concentration B, the percent change significantly & linearly decreased showing a maximum of 49% decrease on 15th day of exposure and 46.9% decrease on 15th day of recovery (Fig. 9). Insignificant partial recovery was recorded in conc.-‘A’ and no recovery was marked in conc.-‘B’, when the exposed alga was transferred to toxicant free, nutrient medium. In case of conc.- C, highly significant decrease in the carotenoid level was noted. A maximum of 87.7% decrease was noted on 15th day of exposure and when the exposed alga was transferred to toxicant free medium, 93.4% decrease when compared to control was marked showing the highest damage caused to the exposed system (Fig.9). The correlation coefficient analysis between carotenoid content of control and exposed alga versus days of exposure indicated the existence of a positive correlation in the control set ($r = 0.993$, $p \geq 0.01$) and the value was significant. In Conc.-A positive correlation ($r = 0.995$, $p \geq 0.001$) was marked. In conc.-B, positive correlation ($r = 0.886$, $p \geq 0.05$) was noted and in conc.-C, a non-significant correlation was marked. The two way of analysis of variance ratio test indicated the existence of significant difference between rows and columns.

Discussion

Toxicity tests were designed to find out safe level of toxicants and different lethal concentration values for a particular organism or for different types of organisms. The toxic effects of cadmium on plants have been described (Boddi *et al.*, 1995) and characterized in many physiological processes. Among these, the chlorosis of leaves (Bishoni *et al.*, 1993; Ferretti *et al.*, 1993 and Siedlecka and Bazynski, 1993) and the inhibition of various reactions of photosynthesis (Bazynski *et al.*, 1980) have been described. Boddi *et al.*, (1995) raised the question, whether the Cd^{2+} inhibits directly the chlorophyll biosynthesis and several reactions of photosynthesis or if it interacts with other metabolic processes and acts indirectly. Cadmium²⁺ might induce iron deficiency which later causes the above mentioned symptoms (Siedlecka & Bazynski, 1993). A further possibility is that the cadmium²⁺ stimulates decomposition processes in the plants, resulting in the decrease of the chlorophyll contents and changes

of the photosynthetic apparatus. Specific inhibitory effects of the Cd^{2+} have been observed by Boddi *et al.*, (1995), on the synthesis of 5-aminolevulinic acid and on the Pchlide photo reduction into chl_a. Boddi *et al.*, (1995) opined based on his observations that the reaction of Cd^{2+} was concluded to interact with essential thiol groups of enzymes involved in those reactions. Cadmium may be the more toxic heavy metal for plants at concentrations lower than for other metals, inhibiting the synthesis of chlorophyll in barley and beans, the growth of sugar beet plant and the photosynthetic activity of tomato. The concern over the public health implications of cadmium pollution has resulted in a considerable amount of research being carried out by regional and national laboratories and field stations throughout the world. The most notable aspects of the geo-chemistry of cadmium with regard to its rock soil plant animal relationships are its low concentrations in the Earth's crust. Plants and animals are unlikely to have evolved mechanisms to cope with relatively high concentrations of cadmium, since these rarely occur in nature. However, with the increasing production of cadmium, pollution will assume a greater significance for soil plant animal pathways. "Cadmium has an estimated crustal abundance of between $0.15\mu\text{g. g}^{-1}$ " and " $0.2\mu\text{g g}^{-1}$ " & "thus occurs in sixty seventh position in an order of relative abundance". "The estimated mean cadmium concentration in igneous rocks was $0.2\mu\text{g g}^{-1}$ with a range of $0.01 - 1.6\mu\text{g g}^{-1}$ Cadmium but very few values of over $0.5\mu\text{g g}^{-1}$ was found". These low contents of cadmium in igneous rocks accounts for its low crustal abundance. Kamp-Nielson (1971) demonstrated a time dependent effect of HgCl_2 (added to $30\mu\text{g/liter}$) on the photosynthesis of *Chlorella pyrenoidosa*. Sahu (1987) reported that the algae *Westiellopsis prolifica*, Janet, could tolerate only 40% concentration of the supernatant effluent of a chlor-alkali industry. There was little effect in the first hour of incubation. An overall rate production of about 50% occurred after 5 hours with a cell density of 6.5×10^7 cells / liter. There was greater effect on photosynthesis at lower cell densities. The review made by Whitton (1970), Gadd & Griffiths (1978) and Sorentino (1989) on impact and effect of heavy metals on algae added a lot of information to the literature of algal toxicology. Algae have been shown to concentrate heavy metals to a larger extent (Hong *et al.*, 1994; Trollope & Evans, 1976; and Say *et al.*, I & II, 1977). A liquid industrial waste may affect the algal growth in any of three ways: stimulation, inhibition and stimulation at lower concentrations but inhibition at higher concentrations (Walsh & Alexander, 1980; Sahu, 1987 and Misra, 2006). The present investigation did not agree with the above conclusions. But such stimulation in the growth cannot be easily explained at this stage of the study. Prasad & Prasad (1982) observed stimulation in the algal growth at low concentrations of Cd, Pb and Ni. Neither Cd, Pb and Ni has been reported to be essential micronutrients for algae (O'Kelley, 1974) nor the pure solution of these heavy metals are expected to contain any growth regulator. Rai *et al.* (1981a&b) exposed *Chlorella vulgaris* to HgCl_2 , concentrations between 100 and $1000\mu\text{g/l}$, for 3 weeks, and monitored survival and growth of the alga. LC_{50} for survival was at $400\mu\text{g/l}$ of HgCl_2 and the growth rate was 92% of the control value at $100\mu\text{g/l}$, the growth rate was 31% at $800\mu\text{g/l}$ and there was no growth at $1000\mu\text{g / lt}$. There was a protective effect of calcium and phosphate in the medium and to a lesser extent of magnesium. Cadmium concentration in the soil solution plays an important role and increase in cadmium concentration in plants was facilitated because of ease of transport from root to shoot solution which influences dry matter production and management practices (Singh, 1994). Addition of ammonium and phosphatic fertilizers tend to increase plant cadmium concentration (Choudhury *et al.*, 1994). Phytochelatins (Pcs) are low molecular weight peptides enzymatically produced by the plants, under the action of a specific phytochelatin synthase, in response to excessive uptake of heavy metals.(Grill *et al.*,1989,Scheller *et al.*,1987). They are cystein rich peptides with general structure (γ -

Glu-cys)_n Gly(n=2 to 11) capable of binding metal ions via thiolate coordination. This reaction leads to the formation of an intracellular complex between a metal ion and Pcs (Grill *et al.*, 1985 & Grill *et al.*, 1987). These inducible metal binding complexes act as an effective heavy metal detoxifying mechanism, because they sequester metal ions in a form, which limits damage to metabolic processes (Gekeler *et al.*, 1988). Among the metal ions capable of inducing phytochelatin synthesis in plant cells, cadmium represents the best activator of the enzyme (Grill *et al.*, 1985 & 1987). The technology for removing cadmium from industrial wastewater or from flue dust is well-established. In waste water, dissolved cadmium can be precipitated with sodium sulphide, cemented by the addition of zinc separated out by ion exchange. If the cadmium is incorporated into particulates, the cadmium can be dissolved by the addition of acid and then separated by one of the above techniques or the solids can be settled out the cadmium removed with the sludge. Cadmium released to the atmosphere via smoke stacks is primarily in the form of fine particulate materials, which can be separated from the stack gases by wet scrubbers, fabric filters or electrostatic precipitators (OECD, 1975). Removal of cadmium by any of the above technique may lead to solids disposal problem if cadmium is not to be recovered or recycled. Dumping of cadmium or cadmium containing compounds at sea or in fresh water is prohibited. Land disposal is the obvious solution but only in areas where the soil is neutral or basic so that the cadmium is not mobilized by percolating groundwater. Environmental safety should be the priority for good management of the environment.

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