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Impact Of Cadmium Chloride On The Changes In Growth And 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 effluent mixed river water is used for irrigation into crop fields contained significant amount of cadmium. The cadmium metal is absorbed by both target and non-target live systems inhabiting in the crop fields. The cyanobacterium (BGA) selected is an inhabitant of the crop fields, which fixes atmospheric nitrogen and acts as a biofertilizer suffers the most. 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. The alga absorbed significant amount of cadmium from the crop fields. 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. 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, growth, pigment.

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. Pollution, the environmental contamination of air, water, soil and food have become a threat to the continued existence of many plant and animal communities of the ecosystem and may ultimately threaten the very survival of human race. Toxicology, the science of poisons, is developed because of extensive use of industrial chemicals, pesticides in urban and agricultural areas and increased awareness of the hazards of heavy metals to plants, wild life, domestic animals and people. The modern industrial society and present civilization discharge vast quantities of metals into the environment. Anthropogenic discharge of heavy metals pass up to the food chain becomes a major source of human exposure. Biosphere is that depth of

earths surface where incoming light energy from the sun is trapped by the functioning of the ecosystem involving in the interaction of the biotic components -producers, consumers and decomposers with non living abiotic components to produce cyclic interchange of materials between them. These materials are essential macro elements -H, O, C, N, Ca, Na, Mg, Cl, P and S and micro elements Fe, Cu, I, Mn, Mo, V, Zn, B, Co, F, Ni, Si and Sn. These elements are essential for the life processes. The other group of elements which are not essential for life processes are Cd, Hg, Pb, Be, Ba, Al, As ,Bi. These elements are considered to be toxic to life.

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 ± 2^0C and under 14 hours illumination at the intensity of 2400±200Lux 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. Growth was measured by recording the dry wt of the alga per 100 ml culture by taking the initial weight of the filter Whatman filter paper and filtering the culture solution through the filter paper. The filter paper along with the residue was dried and the final weight was taken after 24hours. The difference in weight indicates the dry weight of the alga. The optical density was measured by light scattering technique. The dry weight changes of control and cadmium chloride exposed alga was studied by measuring the dry weight by a

single pan balance. 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±1.2ºC; pH-8.1±0.6; Conductivity-687.9±11.7mho/cm; DO-4.2±0.5mg.L^{-1}; BOD-28.4±3.6mg.L^{-1}; COD-78.9±11.4mg.L^{-1}; TSS-219.6.8±15.4mg.L^{-1}; TDS-192.5±7.8 mg.L^{-1}; Chlorides-76.8±11.2mg.L^{-1}; Hardness-186.7±8.8mg.L^{-1}; Total Nitrogen-2.21±0.54 mg.L^{-1}; Total Phosphates- 1.95±0.66mg.L^{-1}; Total Sulphate-24.8±3.5mg.L^{-1}; Total Cadmium [Cd]- 0.06±0.02mg.L^{-1} and Total Lead (Pb)- 0.04±0.03mg.L^{-1} (Padhy & Panigrahi, 2018). Complete bleaching of the algal mass inside the test solution (C) was not observed from 3rd day of exposure period onwards. Gradually tiny blue-green particles started making their appearance in the white turbid mass as observed in the naked eye after 5 days of recovery period. The dry weight increased from 1.12±0.24mg to 14.86±0.18mg on 15th day of exposure in the control set. At concentration-A, the dry weight increased from 1.12±0.24mg to 2.8±0.28mg on 3rd day of exposure and the dry weight further increased to 4.9±0.35mg on 6th day of exposure. With the increase in exposure period the dry weight decreased and on 15th day of exposure the value decreased from 14.86±0.18mg to 13.51±0.24mg dry weight showing 9.1% decrease over the control value. At concentration-B, the dry weight increased from 1.12±0.24mg on 0day of exposure to 7.6±0.49mg on 15th day of exposure, showing 48.8% decrease over the respective control value and day of exposure. At conc.-C, the dry weight decreased from 1.12±0.24mg to 0.55±0.29mg on 15th day of exposure, showing 96.3% decrease in dry weight over the respective control value and respective day. At conc "A" the dry matter value was greater than the control value on 3rd and 6th day of exposure and decreased on 9th, 12th and 15th day of exposure. Highest increase in percentage of growth (10.2%) was marked on 6th day of exposure over the control value at conc. A. The "B" concentration showed a significant decreasing trend in growth when compared to control and conc."A", in which a maximum decrease of 48.8% was marked on 15th day of exposure. Whereas, an increasing trend was marked up to 15th day of exposure when compared to 0 day value and with the increase in exposure period the dry weight of the alga increased but when compared to 15th day exposure value, all the values were much less when compared to control and concentration-A. In case of conc-C, the dry weight value did not show any increase when compared to 0 day value on 3rd day of exposure. Rather the dry weight decreased with the increase in exposure period especially after 9th day of exposure and on 15th day of exposure 96.3% decrease was noted. All the exposed values were significantly less than the control, concentration-A and concentration-B values. A maximum of 96.3% decrease when compared to control value was noted indicating severe damage caused to the exposed system. An initial increase at conc. A and no increase in conc.B and conc.C indicated severe damage to the exposed system. A non-significant dual behavior of the toxicant on the exposed alga was clearly evident from the obtained data. The total chlorophyll content of the control and cadmium chloride exposed alga, at different days of exposure and recovery were presented in Fig. 1A. 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. 1A). 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 (Fig.-1B). 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 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.1B). 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.-1C). 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.- 1A,B,C).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. -4C). 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±0.001mg /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.-1C) in conc. C set. When the exposed alga was transferred to toxicant free medium the chlorophyll content further decreased from 0.003±0.001 mg /50 ml culture to 0.001± 0.0005 mg /50 ml culture after 15 days of recovery. Conc. A set showed an increase in total chlorophyll content at all exposure periods. In case of concentration 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 exp. in conc. C (1.22mg of cadmium as cadmium chloride/l) set.

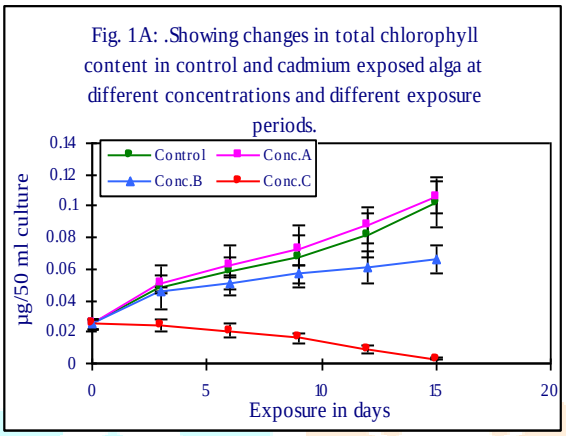

Fig. 1A: .Showing changes in total chlorophyll content in control and cadmium exposed alga at different concentrations and different exposure periods.

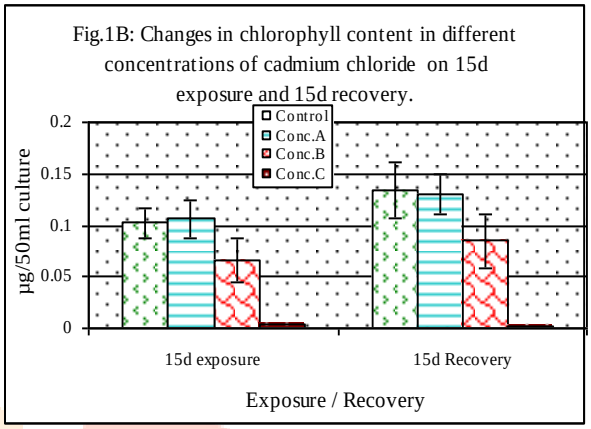

Fig.1B: Changes in chlorophyll content in different concentrations of cadmium chloride on 15d exposure and 15d recovery.

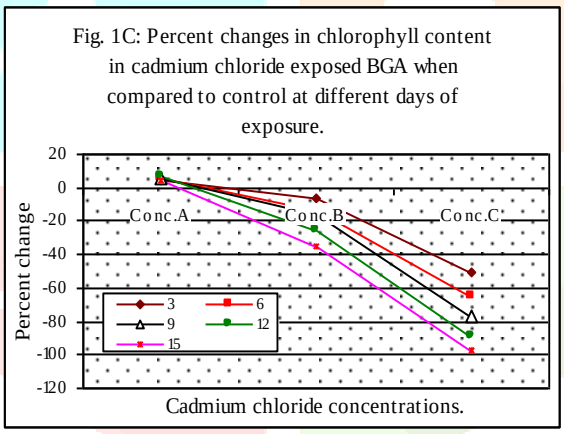

Fig. 1C: Percent changes in chlorophyll content in cadmium chloride exposed BGA when compared to control at different days of exposure.

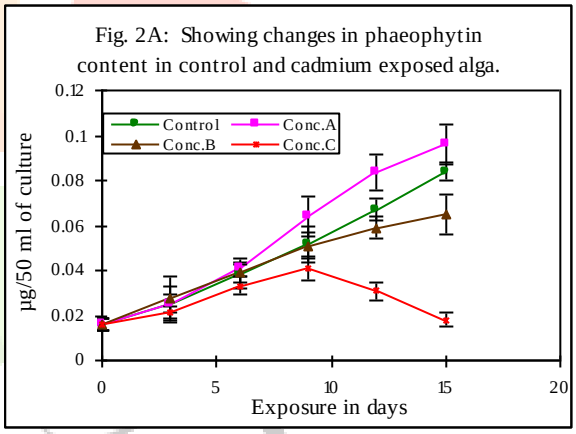

Fig. 2A: Showing changes in phaeophytin content in control and cadmium exposed alga.

In case of Conc. B, a positive correlation was marked between the chlorophyll content and days of exposure ($r = 0.901$, $p \geq 0.01$). A negative correlation ($r = -0.816$, $p \geq 0.05$) was marked in Conc. C. The two way analysis of variance ratio test based on the data, indicated the existence of significant difference between rows and significant difference between columns). The total chlorophyll present in control, exposed and recovered alga was clearly indicated in Fig.1A & B. The correlation coefficient value of total chlorophyll with days of exposure was significant at $p \geq 0.001$ level for control, and "A" concentration of the toxicant, i.e. the total chlorophyll amount increased significantly with the increase in days of exposure at control, and "A" concentration, whereas at "C" concentration it was not significant. With the increase in concentration, the total chlorophyll content decreased on all days of exposure but on 6th, 12th and 15th day the values were significant at $p \geq 0.05$ levels. The percent change value of total chlorophyll increased with the increase in days of exposure at "A" concentration but the values were not statistically significant, whereas this value decreased with days of exposure in "B" concentration and significantly decreased in "C" concentration. With the increase in cadmium chloride concentration, the percent change value of total chlorophyll showed gradual decrease on all days of exposure which was statistically significant levels except on 3rd day where it was significant. In recovery studies, it was clearly observed that no notable recovery was marked in conc. A & B but in conc. C set further depletion was noted without showing any recovery. The chlorophyll content was drastically affected in cadmium chloride exposed alga at higher concentrations and at higher exposure period.

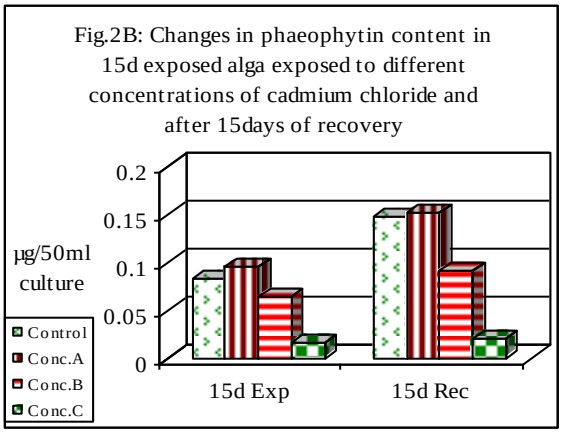

Fig.2B: Changes in phaeophytin content in 15d exposed alga exposed to different concentrations of cadmium chloride and after 15days of recovery

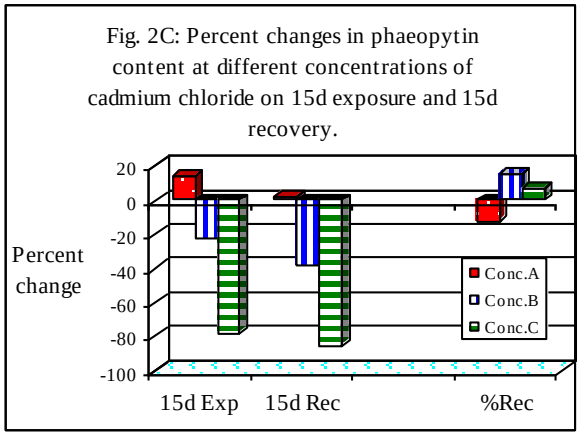

Fig. 2C: Percent changes in phaeopytin content at different concentrations of cadmium chloride on 15d exposure and 15d recovery.

Fig.2A shows the changes in total pheophytin content in control and cadmium chloride exposed blue-green alga at different exposure and recovery periods. The total pheophytin content increased from 0.016±0.0031 to 0.084±0.0038mg/50 ml culture within a period of 15 days. The pheophytin content further increased from 0.084±0.0038 to 0.148±0.014 mg /50 ml culture after 15 days of recovery. The pheophytin content increased in conc. A during exposure period and recovery period. The pheophytin content increased from 0.016±0.0031 to 0.096±0.0014mg/50 ml culture within a period of 15 days of exposure in conc. A. After 15days of exposure the cadmium chloride exposed alga was transferred to toxicant free medium for recovery studies. After 15days of recovery, the value increased from 0.096±0.0014mg/50 ml culture to 0.151±0.0024 mg/50 ml culture in conc. A. The pheophytin content interestingly declined from control value at all exposure and recovery periods in concentration-B. No doubt, the pheophytin content increased from 0.016±0.0031 to 0.065±0.0017mg /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 ($p \geq 0.01$), 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. 2A). In conc. B, the pheophytin content increased from 0.016±0.0031 to 0.028±0.008mg /50 ml culture on 3rd day of exposure showing more than the control and conc. A set and than the value significantly declined with the increase in exposure period compared to Conc. A set but no significant decrease or increase in pheophytin content was marked compared to the control set. The pheophytin value declined significantly on 15th day of exposure (Fig.2A). 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.2B). In conc. C, the pheophytin 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 than 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. 2A). 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.2B). Fig. 6C indicate the percent change in pheophytin content in the exposed alga at different exposure periods and recovery period and cadmium chloride concentration when compared to the control set. The pheophytin 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 pheophytin 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 pheophytin content decreased by 78.6% on 15th day of exposure compared to its control value. During recovery period, after 15days of recovery, the pheophytin 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.2C). In case of conc. C further depletion by 7.2% in pheophytin content was noted instead any recovery. From the data it is well evident that at lower concentration of cadmium chloride exposure increase in pheophytin content was noted and with the increase in cadmium chloride concentration, the pheophytin content probably got destroyed and deceased values were noted. The correlation coefficient analysis between pheophytin content and days of exposure indicated the existence of positive and significant ($p \geq 0.001$) correlation in control ($r = 0.984$); Conc. A ($r = 0.981$) and in conc. B ($r=0.891$). But in case of Conc. C a non-significant correlation was marked ($r = -0.827$, $p = NS$). The

ANOVA test indicated the existence of non-significant difference between rows and non-significant difference between columns

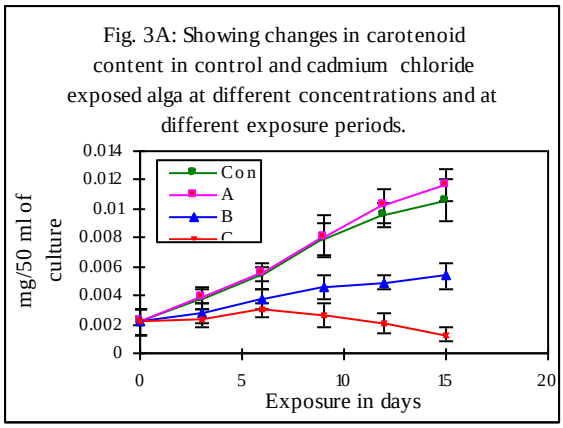

Fig. 3A: Showing changes in carotenoid content in control and cadmium chloride exposed alga at different concentrations and at different exposure periods.

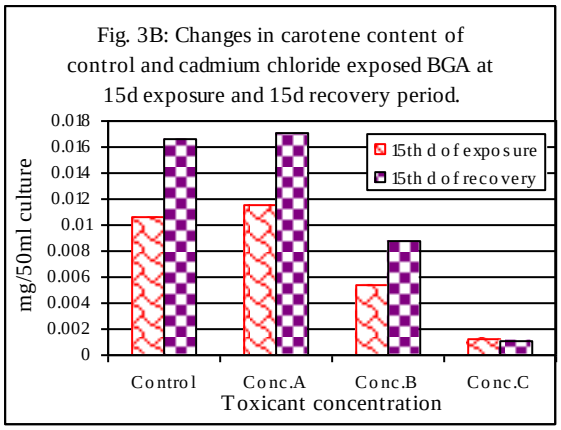

Fig. 3B: Changes in carotene content of control and cadmium chloride exposed BGA at 15d exposure and 15d recovery period.

Changes in carotenoid content of control and cadmium chloride exposed blue-green alga was shown in Fig.3A at different exposure periods. The carotenoid content of the control alga increased from 0.0022 ± 0.0007 to 0.0106±0.0011mg /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±0.0011mg /50 ml culture within 15 days of exposure and the value increased from 0.0116±0.0011 to 0.0171±0.0012mg /50 ml culture on 15th day of recovery, when the exposed alga was transferred to toxicant free medium (Fig. 9 A&B). 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. 3 A&B).

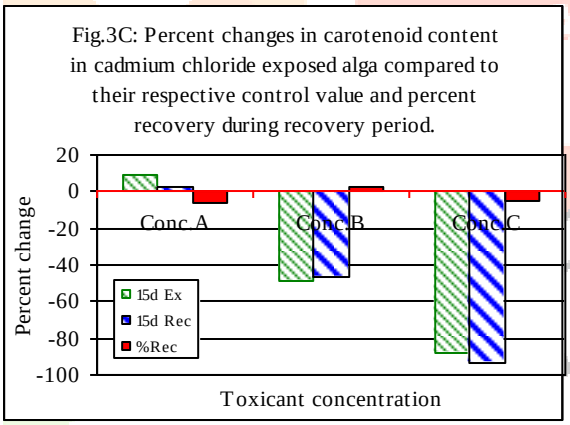

Fig.3C: Percent changes in carotenoid content in cadmium chloride exposed alga compared to their respective control value and percent recovery during recovery period.

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±0.0007mg /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. 3 B&C). Fig.9C 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. 3B). 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.3B & C).

Discussion

The discovery that Cadmium pollution from Pulp and Paper mills could cause series illness and possible death in a local community has led to widespread public anxiety (Tripathy *et al*, 2021). Although industrial operations are major sources of cadmium, many countries now show concern that disposal of metal contained sewage sludge and effluent on land flowing water body may adversely affect the fertility of the soil and water bodies; influence plant and animal life causing health hazards. Nevertheless, the increasing awareness of the potential hazards of cadmium contamination should not obscure the fact that cadmium is present in natural ecosystems and a ubiquitous element in all living organisms. For the environmental impact of cadmium to be assessed, major steps in the bio-geo-chemical pathway must be outlined and gaps in our knowledge identified for future research undertakings. Compounds vary tremendously in their toxicity. Usually at very low concentration the compound becomes harmless and even acts as an essential substance for growth and development. So, the primary objective of toxicological testing is to obtain data on the dose-response characteristics of a chemical. These studies provide the primary data base from which estimates of risk to an identified population of organisms may be determined in connection with specific uses or disposal practices for a specific chemical. Normally, the objective of toxicological testing is to identify the nature of possible adverse effects and to relate response (or injury) to dosage, dose-response expressions to a toxic agent and the spectrum of observed effects. The relationships imply a reasonable presumption that the observed effects are induced by a known toxic agent. Numerical and graphical expressions of the dose-response relationships are based on assumptions that (1) The response is a function of the concentration of a toxic agent at a site of action (2) Response and dose are causally related. That is, the probability of a test organism having some type of response is a function of the dose of the toxicant. In comparing the toxicity of different compounds it is convenient to have a standardized notation for describing the toxic level. The most common usage is the lethal concentration or lethal dose values, usually deduced from statistical interpretations, i.e. the dose-response relationship can be simply described by the LD_{50} or LC_{50} value, which is the dose determined from the line of best fit at the 50% mortality value (Misra, 2006). The review made by Whitton (1970), Gadd & Griffiths (1978) and Sorentino (1979) 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). Information's are available pertaining to the toxicity of mercury in the form of metal, mercury based pesticides, industrial wastes containing mercury etc. on fresh water blue-green algae (Rai *et al*., 1981 b and Sahu, 1987). Agarwal & Kumar (1978) showed decrease in growth of *Chlorella* sp when exposed to mercurial effluent and solid wastes indicating toxic nature of mercury on the organism. 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. Thus, an ideal explanation for stimulation of growth at lower concentrations of the toxicant is yet to be ascertained. Say *et al*., (1977) reported that the toxicity of zinc to green and blue-green algae could be reduced by supplementing the culture medium with phosphate, calcium and magnesium. Possible formation of complex of heavy metals with calcium and phosphate ions might be responsible for reduction in the toxicity, because of the complex formation they might not be getting an entry into the cell either through membrane transport or by surface adsorption which are the two known mechanisms for uptake of the substances (Rai *et al*., 1981, b). Further, different heavy meals interact among themselves either to reduce or to increase the toxicity of each other. In the present study, however, it was difficult to assign the definite role being played by cadmium in affecting the growth of the blue-green alga. Several authors have found that heavy metals cause prolongation of lag phase more or less in proportion to doses, followed by normal growth (Zingmark & Miller, 1975). In the present study, we observed inhibition at higher concentrations and stimulation at sub-lethal concentrations of cadmium chloride. This observation has potential implications, as we can use this alga for detoxification of cadmium or the alga can be used as an agent in phytoremediation protocols.

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