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A New Approach To Biosorption Of Heavy Metal Contaminants (Chromium, Lead) Using Spirulina (*Arthrospira Platensis*)

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Abstract:
Spirulina (Arthrospira platensis), a cyanobacterium of considerable economic importance is studied for the adsorption capacity to Lead and Chromium. The cyanobacterium is very responsive to low metal concentration. The Biosorption studies showed that the algae had a great potential for adsorbing the heavy metal on to the cell. The study focuses on feasibility of the algae to be a good biosorbent. Culturing the algae in low metal concentrations can be utilized as potential tertiary treatment for metal containing effluent. The ability of Spirulina biomass to remove lead and chromium from aqueous solution was studied in batch process with respect to contact time and initial metal ions concentration at constant pH level and Biomass dosage at room temperature. The batch experiment yielded encouraging results on the potentiality of the algae to be a possible agent for removal of heavy metals from aqueous solutions

Keywords **—**Spirulina (Arthrospira platensis), Heavy Metal, Contaminants (Cr, Ld), Biosorption---------------------

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I. INTRODUCTION

Contamination of heavy metals in the environment is a major global concern, because of toxicity and threat to the human life and ecosystem [1]. The levels of metals in all environments, including air, water and soil are increasing in some cases beyond toxic levels, with contributions from wide variety of industrial and domestic activities. Metal contaminated environments pose serious threat to health and ecosystems [2]. Metals like arsenic, cadmium, lead, mercury, silver etc cause conditions including heart disease and liver damage, cancer and neurological and cardiovascular diseases, central nervous system damage and sensory disturbances [3]. Unlike organics, metals are persistent in the environment and cannot be completely degraded through biological, chemical or physical means to an innocuous by-product. The chemical nature and bioavailability of a metal can be changed through oxidation or reduction[5]; however, the elemental nature remains the same because the metals are thermally decomposable[4]

II.MATERIALS AND METHODS

A. MATERIALS-CHEMICALS

The metal salts used in this work are Basic Lead acetate and Potassium Dichromate as respective source of metal ions lead and zinc. Hydrochloric acid (HCl) and Sodium hydroxide (NaOH) were used for adjusting pH. The pH levels of the metal solutions were maintained constant[7].

B. ALGAE AND ITS GROWTH CONDITION (BIOSORBENT MATERIAL)

Spirulina for the study were purchased from OfER (an NGO cultivating Spirulina on commercial scale). Commercial synthetic medium for low-cost mass production of *Spirulina, in* a larger scale with constant aeration at room temperature was used[8]. The algae were harvested from medium solution byplankton cloth mesh, 20 diameters [6]. The collected algal were completely dried in sunlight for 3 weeks and then in oven at 60 °C for1 week. The dried algae were ground using a domestic mixer. The sieved algae were treated by 0.1 M HCl for 4 h. After washing in distilled water the algal was dried at 70º C for 8 h. Medium used for microorganism and all the glassware were properly sterilized autoclaved at 15 lb/in^2 pressure and at 121˚C for 30 minutes[10].

C. PREPARATION OF METAL SOLUTIONS

The stock solution of 100ppm was prepared and various concentrations of test solutions were prepared by appropriate dilution of stock solution in distilled water. The heavy metal at various concentrations is prepared synthetically at various concentrations (10ppm, 20ppm, 30ppm) [9]. The lead solution presents following concentration: (10ppm, 20ppm, 30ppm) and chromium solution presents following concentration: (10ppm, 20ppm, 30ppm) [13]. These are prepared and kept at respective conical flasks at room temperature. This conical flask containing synthetic effluents of various concentrations are taken as our experimental sample. The pH level of these initial metal ion solutions is adjusted as required to a constant level of acidic medium [12].

D.BATCH EXPERIMENTS

Batch experiments were conducted with solutions prepared from metal salts [11]. The working volume of metal solution is 100ml taken in 250ml conical flask. Biosorbent dosage is kept constant which is 0.1g/100ml and the said dosage value of dry biomass was added to the several flasks. All the flasks were sealed to minimize the evaporation. The flasks were stirred at constant speed of 150 rpm at room temperature (28 ± 2 ˚ C) in a rotary shaker.

Test samples were collected at regular interval of time (30mins, 60mins, 90mins, and 120mins). Experiments were carried out over a wide range of operating conditions and the percentage of metal removal [14].

E. ANALYSIS OF BIOSORPTION

Batch mode adsorption studies for individual metal compounds were carried out to investigate the effect of different parameters such as adsorbate concentration, adsorbent dose, agitation time, pH and temperature [17]. Here, the pH (acidic medium pH=5), temperature (room temperature 28 ± 2˚C) and adsorbent dosage (0.1g/100ml) is kept at constant. Therefore, mainly effect of the initial metal ion concentration and effect of contact time is studied. The adsorbate is separated from the adsorbent by filtration [16]. The lead ion and chromium ion concentration in the test samples were analyzed by UV-Vis spectrophotometer. Lead and chromium concentrations were expressed in mg/L in liquid and the difference between the initial and the residual concentrations was assumed to be adsorbed by *A. platensis* (Spirulina) cells[15].

III.RESULTS AND DICUSSION

A. BIOSORPTION STUDIES USING SPIRULINA PLATENSIS – LEAD

In the studies carried out so far, *Arthrospira platensis* (Spirulina) was used for the biosorption of lead [19].

A.1.EFFECT OF INITIAL CONCENTRATION

The concentration of lead (10ppm, 20ppm, 30ppm) was taken and 0.1g/100ml of biomass were added to each metal concentration. The effect of the initial metal ion concentration for the same dosage was studied at contact time of 120 minutes [18]. The reduction percentage in the lower metal concentrations is greater than that of higher metal concentrations (as shown in figure 7) . The lead removal percentage at 30 minutes for 10ppm metal concentration is 30.24%, for 20ppm metal concentration is 28.66% and for 30ppm metal concentration is 25.89%. At 120 minutes the removal percentage is at 61.55%, 51.36% and 44.25% for 10ppm, 20ppm, 30ppm respectively [20][21]. There is a notable decrease in the adsorption as the initial concentration of the heavy metal increases and the adsorption slows down due to the low activity of biomass. With increase of the initial concentration of heavy metal (Pb) percentage of biosorption is decreased and metal ion uptake capacity is increased [22].

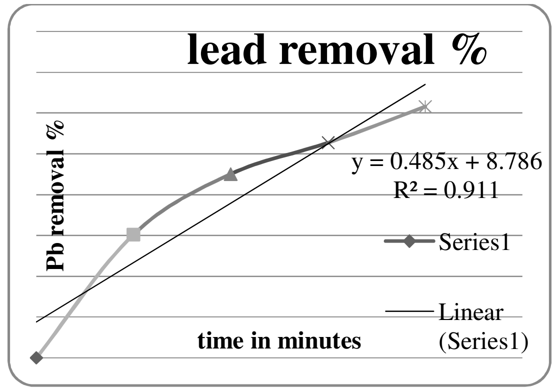


FIGURE.A.1- Effect of initial concentration on lead biosorption, 0.1g/100ml biomass dosage at room temperature (28 ± 2˚C), pH 5 (constant), contact time (120 mins) and 10ppm initial metal concentration for spirulina[25].

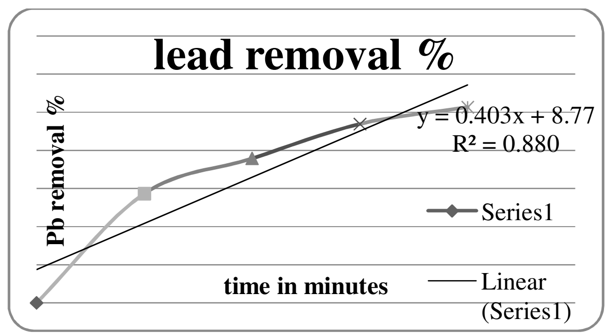


FIGURE.A.2:- Effect of initial concentration on lead biosorption, 0.1g/100ml biomass dosage at room temperature (28 ± 2˚C), pH 5 (constant), contact time (120 mins) and 20ppm initial metal concentration for spirulina[23].

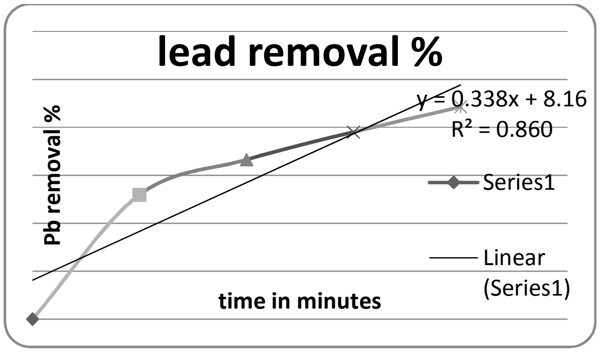
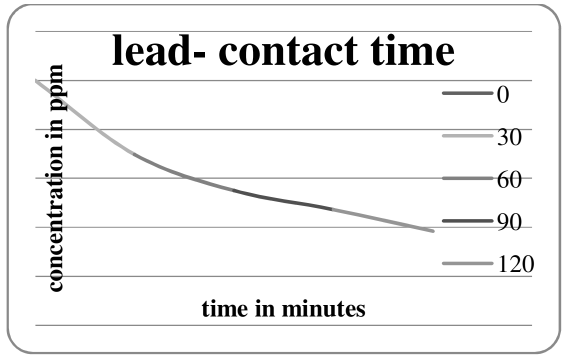


FIGURE.A.3:- Effect of initial concentration on lead biosorption, 0.1g/100ml biomass dosage at room temperature (28 ± 2˚C), pH 5 (constant), contact time (120 mins) and 30ppm initial metal concentration for spirulina[24].

A.2.EFFECT OF CONTACT TIME

Biosorption experiment of lead using spirulina were carried out for different contact time (30, 60, 90, 120 minutes) at fixed pH, initial concentration, biomass dosage and temperature. The concentration of the heavy metal decreases with time (as shown in figure 8) as the adsorption percentage of the metal increases with time. The concentration of heavy metal at 120 minutes is 3.845ppm, 9.728ppm and 16.725ppm for 10ppm, 20ppm and 30ppm initial concentrations respectively[26][27]. The sorption of metal was rapid at the initial stages of contact timeand gradually drcreases with lapse of time until saturation. It can inferred from the graph that thetime taken for adsorption by spirulina is dependant on initial metal ion concentration and increased with the increase in concentration of lead.



FIGUR.A.(a):- Effect of time on lead biosorption, 0.1g/100ml biomass dosage at room temperature (28 ± 2˚C), pH 5 (constant), contact time (120 mins) and 10ppm initial metal concentration for spirulina[29].

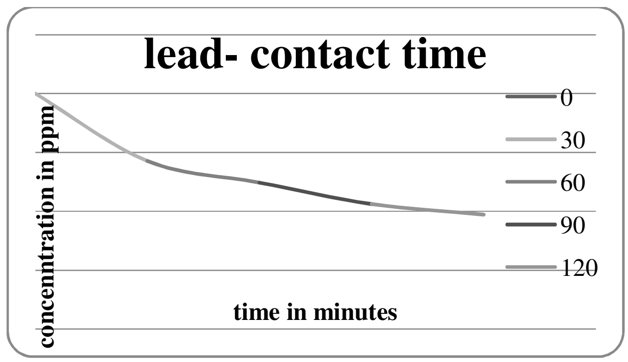


FIGURE.A.(b):- Effect of time on lead biosorption, 0.1g/100ml biomass dosage at room temperature (28 ± 2˚C), pH 5 (constant), contact time (120 mins) and 20ppm initial metal concentration for spirulina.

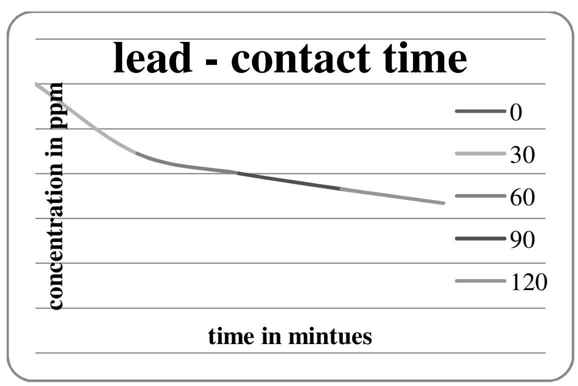


FIGURE.A.(c):- Effect of time on lead biosorption, 0.1g/100ml biomass dosage at room temperature (28 ± 2˚C), pH 5 (constant), contact time (120 mins) and 30ppm initial metal concentration for spirulina.

B.BIOSORPTION STUDIES USING SPIRULINA PLATENSIS – CHROMIUM

In the studies carried out so far, *Arthrospira platensis* (Spirulina) was used for the biosorption of chromium [28].

B.1.EFFECT OF INITIAL CONCENTRATION

The concentration of chromium (10ppm, 20ppm, 30ppm) was taken and 0.1g/100ml of biomass were added to each metal concentration. The effect of the initial metal ion concentration for the same dosage was studied at contact time of 120 minutes.

The reduction percentage in the lower metal concentrations is greater than that of higher metal concentrations (as shown in figure 9). The chromium removal percentage at 30 minutes for 10ppm metal concentration is 64.6%, for 20ppm metal concentration is 49.25% and for 30ppm metal concentration is 34.7%. At 120 minutes the removal percentage is at 83.8%, 73.75% and 59.57% for 10ppm, 20ppm, 30ppm respectively. There is a notable decrease in the adsorption as the initial concentration of the heavy metal increases and the adsorption slows down due to the low activity of biomass [30]. With increase of the initial concentration of heavy metal (Cr) percentage of biosorption is decreased and metal ion uptake capacity is increased.

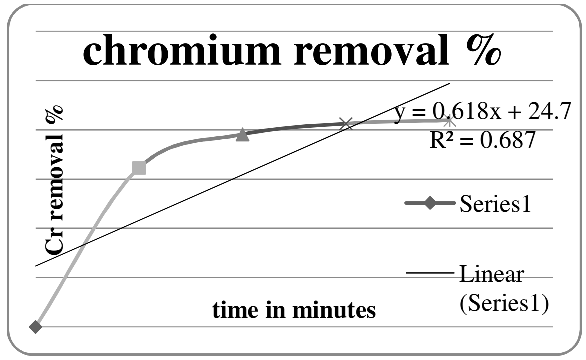


FIGURE.B.(a):- Effect of initial concentration on chromium biosorption, 0.1g/100ml biomass dosage at room temperature (28 ± 2˚C), pH 5 (constant), contact time (120 mins) and 10ppm initial metal concentration for spirulina.

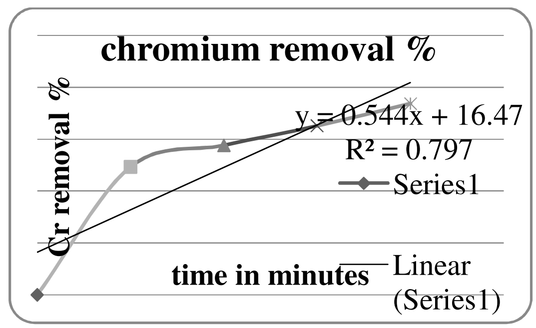


FIGURE.B.(b):- Effect of initial concentration on chromiumbiosorption, 0.1g/100ml biomass dosage at room temperature (28 ± 2˚C), pH 5 (constant), contact time (120 mins) and 20ppm initial metal concentration.

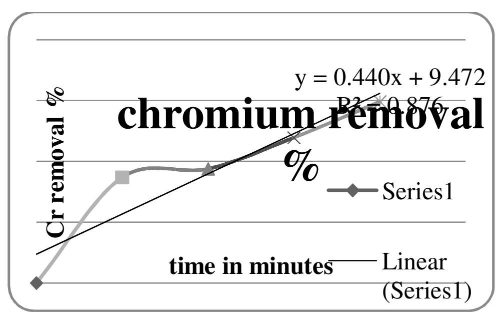


FIGURE.B.(c):- Effect of initial concentration on chromium biosorption, 0.1g/100ml biomass dosage at room temperature (28 ± 2˚C), pH 5 (constant), contact time (120 mins) and 30ppm initial metal concentration for spirulina.

C.**EFFECT OF CONTACT TIME**

Biosorption experiment of chromium using spirulina were carried out for different contact time (30, 60, 90, 120 minutes) at fixed pH, initial concentration, biomass dosage and temperature[31]. The concentration of the heavy metal decreases with time (as shown in figure 10) as the adsorption percentage of the metal increases with time. The concentration of heavy metal at 120 minutes is 1.62ppm, 5.25ppm and 12.13ppm for 10ppm, 20ppm and 30ppm initial concentrations respectively. The sorption of metal was rapid at the initial stages of contact timeand gradually drcreases with lapse of time until saturation[32]. It can inferred from the graph that thetime taken for adsorption by spirulina is dependant on initial metal ion concentration and increased with the increase in concentration of chromium.

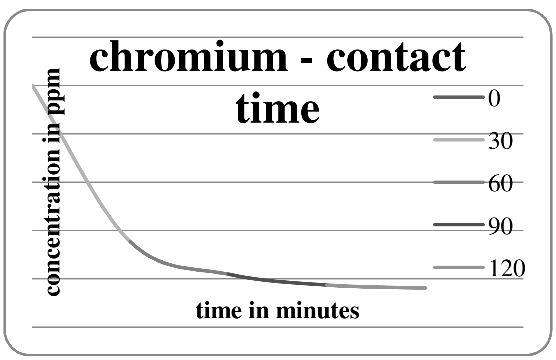


FIGURE.C.(a):- Effect of time on chromium biosorption, 0.1g/100ml biomass dosage at room temperature (28 ± 2˚C), pH 5 (constant), contact time (120 mins) and 10ppm initial metal concentration for spirulina.

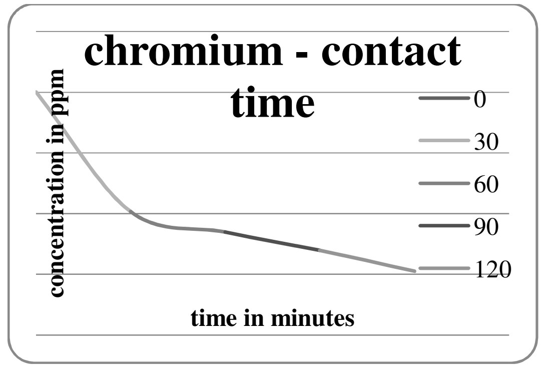


FIGURE.C.(b):- Effect of time on chromium biosorption, 0.1g/100ml biomass dosage at room temperature (28 ± 2˚C), pH 5 (constant), contact time (120 mins) and 20ppm initial metal concentration for spirulina.

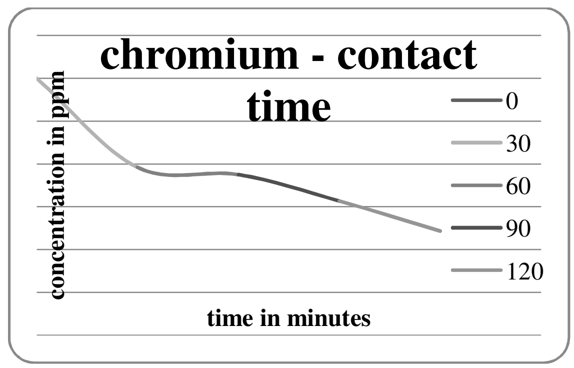


FIGURE.C.(c):- Effect of time on chromium biosorption, 0.1g/100ml biomass dosage at room temperature (28 ± 2˚C), pH 5 (constant), contact time (120 mins) and 30ppm initial metal concentration for spirulina.

IV.CONCLUSIONS

The biosorption capacity of *Arthrospira platensis* (Spirulina) biomass was investigated for the removal of lead and chromium ions from aqueous solutions. The biosorption capacity of dry Spirulina biomass was obviously affected by the operation conditions such as solution pH, contact time, biomass dosage and initial metal concentration. The lead removal percentage at the end of 120 minutes for the initial metal concentrations 10ppm, 20ppm and 30ppm are 61.55%, 51.36% and 44.25% respectively. The chromium removal percentage at the end of 120 minutes for the initial metal concentrations 10ppm, 20ppm and 30ppm are 83.8%, 73.75% and 59.57%. The optimum conditions for lead and chromium biosorption were pH 5 and contact time 120 minutes at room temperature (28 ± 2˚C). Furthermore, the biosorption capacity of Spirulina is greater for chromium ions in comparison to lead ions. The overall result showed the dry Spirulina biomass is an effective adsorbent that can be used for the removal of heavy metals lead and chromium from waste water.

REFERENCES

1. Elhaddad and Tantawy, (2015) Equilibrium and kinetic studies of biosorption of Cr (III) and Cd (II) by activated carbon prepared from Spirulina algae p. 132 140
2. R. L. Babu , E. Vijayalakshmi , M. Naveen Kumar , Rajeshwari H. Patil , K. S. Devaraju&S. Chidananda Sharma (2013) Biosorption of Chromium(VI) and Lead(II): Role of Spirulina platensis in the Treatment of Industrial Effluent, Bioremediation Journal, 17:4, 231-239
3. Zinicovscaia, Duca, Rudic, Cepoi, Chiriac, Frontasyeva, Pavlov, Gundorina*(2013) Spirulina platensis* AS BIOSORBENT OF ZINC IN WATER *1079-1084*
4. C.Solisio, A. Lodi, D.Soletto, A.Converti (2017) Cadmium biosorption on Spirulina platensis biomassDepartment of Chemical and Process Engineering ''G.B. Bonino'', Genoa University, via Opera Pia 15, I-16145
5. Inga Zinicovscaia, Liliana Cepoi, Tatiana Chiriac, Otilia Ana Culicov, Marina Frontasyeva, Sergey Pavlov, Elena Kirkesali, Artem Akshintsev& Elena Rodlovskaya (2016) Spirulina platensis as biosorbent of chromium and nickel from industrial effluents,
6. Shubha M. Hegde, R.L. Babu, E. Vijayalakshmi†, Rajeshwari H. Patil,
7. M. Naveen Kumar, K.M. Kiran Kumar, Rashmi Nagesh, K. Kavya, S. Chidananda Sharma (2015) Biosorption of hexavalent chromium from aqueous solution using chemically modified Spirulina platensis algal biomass: an ecofriendly approach Desalination and Water Treatment, 57:24, 11103-11110 1–10
8. Ravindra Kumar Gautam, Mahesh Chandra Chattopadhyaya, and Sanjay K. Sharma S.K. Sharma and R. Sanghi (eds.), (2013) Biosorption of Heavy Metals: Recent Trends and Challenges Wastewater Reuse and Management, DOI 10.1007/978-94-007-4942-9_10, # Springer Science
9. Inga Zinicovscaia, Nikita Yushin, Margarita Shvetsova& Marina Frontasyeva (2018) Zinc removal from model solution and wastewater by *Arthrospira (Spirulina) Platensis* biomass, International Journal of Phytoremediation, 20:9, 901-908
10. Hiren Doshi, Arabinda Ray, I. L. Kothari CURRENT MICROBIOLOGY Vol. 54 (2007), Biosorption of Cadmium by Live and Dead

Spirulina: IR Spectroscopic, Kinetics, and SEM Studies pp. 213–218

11. Agnieszka Dmytryk, Agnieszka Saeid, and Katarzyna Chojnacka (2014) Biosorption of Microelements by *Spirulina*: Towards Technology of Mineral Feed Supplements Institute of Inorganic Technology and Mineral Fertilizers,Wrocław University of Technology, Smoluchowskiego 25, 50-372Wrocław, Poland , Article ID 356328
12. Ays¸eg¨ulS¸eker a, Talal Shahwan a, Ahmet E. Ero˘glu a, Sinan Yılmaz a, ZelihaDemirel b, Meltem Conk Dalay Equilibrium, thermodynamic and kinetic studies for the biosorption of aqueous lead(II), cadmium(II) and nickel(II) ions on *Spirulina platensis* Journal of Hazardous Materials 154 (2008) 973–980
13. E. Hernández & E. J. Olguín (2002) Biosorption of Heavy Metals Influenced by the Chemical Composition of Spirulina sp. (Arthrospira) Biomass, Environmental Technology, 23:12, 1369-1377
14. HazminMansor, Jamaludin Mat, Wan Puteri Aishah Wan Mohd Tahir (2011) TREATMENT OF LEACHATE USING CULTURED SPIRULINA PLATENSIS International Journal of Engineering and Technology, Vol. 8, No.2, 2011, pp. 57-60
15. Adity Biswas (2017) BIOSORPTION OF LEAD AND COPPER FROM CONTAMINATED SOLUTIONS BY THE CYANOBACTERIA – *SPIRULINA MAXIMA*
16. Amber Cain, RaveenderVannela, L. Keith Woo Cyanobacteria as a biosorbent for mercuric ion, Department of Chemistry, Iowa State University, Ames, IA 50011-3111, USA Bioresource Technology 99 6578–6586
17. Lodi , D. Soletto, C. Solisio, A. Converti (2008) Chromium(III) removal by *Spirulina platensis* biomass Chemical Engineering Journal 136 151–155
18. "G.B. Bonino",(2013) Department of Chemical and Process Engineering Genoa University, via Opera Pia 15, Article ID 325636
19. Abdulmumin A. Nuhu *Spirulina (Arthrospira)*: An Important Source of Nutritional and Medicinal Compounds Department of Chemistry, Ahmadu Bello University, P.M.B. 1069, Zaria, Kaduna, Nigeria
20. RaveenderVannela* and Sanjay Kumar Verma (2006) Co2+, Cu2+, and Zn2+ Accumulation by Cyanobacterium *Spirulina platensis* Centre for Biotechnology, Birla Institute of Technology & Science, Pilani-333031, India Biotechnol., 22, 1282□1293
21. Rezaei, H. (2013) Biosorption of chromium by using Spirulina sp. Arabian Journal of Chemistry
22. Ali A. Al-Homaidan , Hadeel J. Al-Houri, Amal A. Al-Hazzani, GehanElgaaly, Nadine M.S. Moubayed (2014) Biosorption of copper ions from aqueous solutions by Spirulina platensis biomass Arabian Journal of Chemistry 7, 57–62

23. Ekmekyapar, F., Aslan, A., Bayhan, Y. K.andCakici, A (2012) Biosorption of Pb(II) by Nonliving Lichen Biomass of *Cladoniarangiformis*Hoffm*Int. J. Environ. Res., 6(2):417-424*
24. Murugesan, A.G., Maheswari, S. and Bagirath, G. (2008) Biosorption of Cadmium by Live and Immobilized Cells of Spirulina Platensis *Int. J. Environ. Res., 2(3): 307-312*
25. Singanan, M., Singanan, V.andAbebaw, A (2008) Biosorption of Cr (III) from aqueous solutions using indigenous biomaterials *Int. J. Environ. Res., 2(2): 177-182*
26. Sahmoune, M.N., Louhab, K. and Boukhiar, A. (2009) Biosorption of Cr (III) from Aqueous Solutions Using Bacterium Biomass *Streptomyces rimosus*Int. J. Environ. Res., 3(2):229-238
27. A Review: Spirulina a source of bioactive compounds and nutrition **Journal of Chemical and Pharmaceutical Sciences** 10(3):1317 · July 2017
28. Environmental Sustainability using Green Technologies, (2016) Chapter: Algal biosorption of heavy metals, Publisher: CRC publishers.
29. Vahid Javanbakht, Seyed Amir Alavi and Hamid Zilouei (2014) Mechanisms of heavy metal removal using microorganisms as biosorbentWater Science & Technology 69(9):1775-1787
30. P. Nagaraj ·N. Aradhana (2008) Spectrophotometric method for the determination of chromium (VI) in water samples Environmental Monitoring and Assessment 157(1-4):575-82 ·
31. AnantharamanShivakumar ·Ashwinee Kumar Shrestha ·Avinash k Gowda Mustapha MU, Halimoon N (2015) Microorganisms and Biosorption of Heavy Metals in the Environment: A Review Paper. J MicrobBiochem Technol 7: 253-256

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