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# Potential of Algae in Bioremediation of Wastewater: Current Research

**Yati Prabha*, S.K. Soni, Sharmita Gupta and Sonal**

Spirulina Lab, Department of Botany, Faculty of Science, D.E.I., Dayalbagh University, Agra, India
**Corresponding author*

**A B S T R A C T**

Despite the algal diversity and relatively inexpensive algal biomass, there has been little commercial exploitation of these plants for treatment of wastewater. Bioremediation is a cheap and efficient method of decontamination that has become increasingly popular now a days to reduce environmental pollution. In urban and semi urban colonies sewage disposal has become an ecological problem. The effluent discharge from residences and industries constitute a major source of water pollution. A number of methods has been developed for removal of such polluted substances like precipitation, evaporation, ion-exchange etc. Algae are important bioremediation agents, and are already being used in wastewater treatment. The potential for algae in wastewater remediation is however much wider in scope than its current role. This paper identifies the area where research gives to the world an "Algal Based Bioremediation" for cleaning the water bodies. In this review paper we observed the effectiveness of alga for bioremediation of wastewater.

**Keywords**

Bioremediation, Biosorption, Heavy Metals, Microalgae, Toxicity.

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## Introduction

As the nations growing urban major problem is the removal of wastes so humans exposed these wastes directly into rivers, these water than directly consumed by Aquatic life and so indirectly it affects the human health when human consume it with lots of disease such as Chlorella, Typhoid, Diarrhea as these disease are commonly generate through contaminated water. The availability of good quality water is necessary for preventing such disease and improving the quality of life (Oluduro and Adewoye, 2007). So some new technologies are being proposed to access the treatment of waste water.

Heavy metals such as Lead, cadmium, mercury, nickel, zinc, aluminum, arsenic, copper and iron are mentioned as environmental pollutants which cause severe poisoning conditions (Derek, 1999; Dias *et al*, 2002; Ballantyne *et al*, 1999). Bioremediation is a pollution control technology that uses biological system to catalyze the degradation or transformation of various chemicals to less harmful forms. Developing of biological based treatment system considered as economically cheaper and more environment friendly (Valderrama, 2002). Algal bioremediation are being used in waste water treatment as its potential in waste water remediation is much wider in scope then its current role (Volesky, 1990; Wase and Foster, 1997) so this review paper gives overall picture to use by microalgae for bioremediation of water bodies.

## Reports of Some Algae in Heavy Metal Uptake

Bioaccumulation process is known as an active mode of metal accumulation by living cells which depend on the metabolic activity of the cells (Volesky 1990; Wase and Foster, 1997). The idea that microalgae help in bioaccumulation of heavy metals was firstly proposed by Oswald and Gootas in 1957 but this topic gained attention recently by Oswald 1988 and Doshi *et al*, 2007. It has been observed that microalgae are so efficient in uptake of heavy metals from effluent water (Kajan *et al*, 1992). Heavy metal contamination of agricultural soils has become a serious issue in crop production and human health in many developed countries of the world. Techniques presently in existence for removal of heavy metals from contaminated water include reverse osmosis, electro dialysis, ultra filtration, ion-exchange, chemical precipitation, phytoremediation etc. Table 1 indicates the ability of algae to absorb different organic and inorganic pollutants from water (Industrial effluents, sewage water, pond water, oil effluents, heavy metals etc) which has been recognized from many years.

**Table.1** Algae Involve in the Bioremediation of Different Pollutants Present in Wastewater

| Pollutant | Algal genera used to bioremediate it | Summary of Result | References |
|---|---|---|---|
| Copper(Cu) and Iron(Fe) | *Anabena doliolum* | Immobilized cyanobacteria is very potential in metal removal than free living cell as immobilized algae show increase in uptake of Copper and Iron upto 45% and 23% higher than free living cells | Rai and Mallic, 1992 |
| Lead(Pb), Cadmium(Cd), Copper(Cu), Nickel(Ni) and Zinc(Zn) | *Sargassum fluitans* | Studies of *S.fluitans* regarding adsorption of heavy metals uptake was depend upon the size of particle. Lead is found to be the best sorbed metal followed by others in decreasing order. Adsorption capacity of glutaraldehde cross linked *S. fluitans* is Pd>Cd>Cu>Ni>Zn | Leusch *et al*, 1995 |
| Ammonia($NH_3$) and Phosphorous | *Chlorella vulgaris* and *Scenedesmus dimorphus* | *C. vulgaris* and *S. dimorphus* is also an efficient microalgae in the removal of $NH_3$ and phosphorous during biotreatment of agroindustrial waste water of dairy industry. Both theses algae remove phosphorous from wastewater in cylindrical bioreactor. *C. vulgaris* is superior for removal of ammonia in triangular bioreactor while the cylindrical bioreactor was superior in removal of phosphorous. | Gonzalez *et al*, 1997 |
| Copper(II) | *Padina sps.* | Pre treatment biomass of *Padina* sps. could be used as an efficient biosorbent for the treatment of Copper (II) containing wastewater stream. biosorption capacities | Kaewsarn, 2002 |

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| | | were solution dependent and the maximum capacity obtained was 0.08m mol/g at a solution pH of about 5. Biosorption kinetics was found to be fast with 90% adsorption in 15min. | |
| Lead(Pb) | *Spirulina* | In the initial stage (0-12min) the adsorption rate of *Spirulina* is so high that it adsorbs 74% metal biologically and its biosorption capacity was estimated to be 0.62mg Lead per $10^5$ alga cells. | Hong and Shan-Shan, 2005 |
| Copper(II) | *Cladophora fascicularis* | Biosorption is an effective means of removal of heavy metals from waste water. In this the biosorption behavior of *C.fascularis* has been investigated as a function of pH, amount of biosorbent, initial copper ions concentration, temperature and co-existing. | Deng *et al*,2007 |
| Lead(II) | *Spirogyra* | *Spirogyra* found to be an effective alga in Lead removal. It was observed that maximum adsorption capacity of Pb(II) ion was around 140 mg metal/g of biomass at pH 5.0 in 100 min with 200 mg/L of initial concentration | Gupta and Rastogi, 2008 |
| Copper(Cu), Cadmium(Cd) and Lead(Pb) | *Chlorella vulgaris* | Dried dead *C.vulgaris* was studied in terms of its performance in binding divalent Cu, Cd and Pb ions from their aqueous solutions. Percentage uptake of cadmium ions exhibited general decrease with decrease in dielectric constant values while that of copper, Lead ions shows decrease with increase in donor numbers | Al- Qunaibit, 2009 |
| Oil effluents | *Scenedesmus obliques* | Biological oxygen demand (BOD) and Chemical Oxygen Demand (COD) level was reduced up to 16.66% and 82.80% by *S.obliques*. Reduction of BOD and COD levels might occur due to the removal of the Dissolved Organic compounds and derivatives by some extent from the effluents during treatment process. Treatment of refinery effluents with *S.obliques* is an effective technology in the reduction of pollutants. | Rajasulochana *et al*, 2009 |
| Cadmium(Cd) cations | *Scenedesmus obliquus* | Viable biomass removed metal to a maximum extent of 11.4 $mg_{Cd}$/g at 1 $mg_{Cd}$/l, with most $Cd^{2+}$ being adsorbed onto the cell surface. A commercially available strain (ACOI 598) of the same microalga species was also exposed to the same Cd concentrations, and similar results were obtained for the maximum extent of metal removal. Heat-inactivated cells removed a maximum of 6.04 $mg_{Cd}$/g at 0.5 $mg_{Cd}$/l. The highest extent of metal | Monteiro *et al*, 2009 |

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| | | removal, analyzed at various pH values, was 0.09 $mg_{Cd}$/g at pH 7.0. | |
| Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) | *Oscillatoria* | The effectiveness of Cyanobacteria treatment system for bioremediation of textile effluents has been investigated by the use of *Oscillatoria*.Results revealed that there was the 57.6% and 39.82% decrease in COD and BOD | Abraham and Nanda, 2010 |
| Cadmium(Cd) and Copper(Cu) | *Sargassum sinicola* | Non-living biomass of *S.sinicola* showed a significant result on the biosorption of Cd and Cu ions. By batch experiments ability to remove Cd is significantly slows down from 81.8% to 5.8% while of Cu remains high from 89 to 80% at a range of salinity from 0-40psu. Maximum capacity of biosorption was 3.44mg/g for Cd and 116mg/g for Cu at 35psu. | Prado *et al*, 2010 |
| Mercury(Hg), Cadmium(Cd) and Lead(Pb) | *Dunaliella* | *Dunaliella* alga tolerates high concentration of heavy metals and it has a great ability to absorb metals from aquatic environments. It is concluded that the amount of Cd, Pb and Hg ions adsorption was not increase in aqueous solution with increase in time. Amount adsorbed remained fairly constant with time during competitive sorption | Imani *et al*, 2011 |
| Biological Oxygen Demand (BOD) , Chemical Oxygen Demand (COD) , Dissolved Oxygen (DO), $NH_3$, Nitrate, Magnesium, Organic and Inorganic Phosphates | *Oscillatoria, Synechococcus, Nodularia, Nostoc* and *Cyanothece* | Contaminants Removal Efficiency(RE) percentage of cyanobacterial species *(Oscillatoria, Synechococcus, Nodularia, Nostoc and Cyanothece)* ranged between 69.5% and 99.6% at 5ppm, 83.9% and 99.7% at 10ppm and maximum between 95.5% and 99.7%. mixed culture removal efficiency percentage range is between 91.6 and 100% while at 10ppm. Result indicates the potential of natural resources as efficient agents for pollution control | Dubey *et al*, 2011 |
| Phosphorous, Ammonia nitrogen, Nitrite Nitrogen and Nitrate Nitrogen | *Isochrysis zhanjiangenesis* | *Isochrysis zhanjiangenesis* from the culture of *Cyanoglossus semilaevis* in pH 7, 5000Lux illumination and original inoculation density 0.01mg/l. microalgae could eliminate 78%active phosphorous, 100% ammonia nitrogen, 62.3% nitrite nitrogen and 84.7% nitrate nitrogen in waste water within 11 days. | Zheng *et al*, 2011 |
| Cadmium(Cd) | *Spirogyra* sps. and *Oscillatoria* sps. | Different concentration of Cd has been examined in cultures of *Spirogyra* sps. and *Oscillatoria sps.* Photosynthetic pigments of chlorophyll, sugar, protein and proline contents shows decreasing trends with increase of Cd ions from waste water | Brahmbhatt *et al*, 2012 |

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| Chemical Oxygen Demand(COD) and Phenolic Compounds | *Chlorella vulgaris, Spirulina platensis* and *Dunaliella saline* | *C. vulgaris, S.platensis* and *D.saline* were found to be an efficient algae in decreasing the amount of COD and phenolic compounds from olive mill waste water | Ismael *et al*, 2012 |
| Cadmium(Cd), Mercury(Hg), Lead(Pb), Arsenic(Ar) and Cobalt(Co) | *Spirogyra hyaline* | Dried biomass of *S. hyaline* used for removal of these heavy metals. Highest amount of Cd, Hg and Ar was absorbed when initial heavy metal concentration was 40mg/l whereas Lead and Cobalt exhibited greatest removal at 80mg/l. metal uptake for dried biomass was found in the ordered Hg> Pb> Cd> Ar> Co | Kumar and Oommen, 2012 |
| Crude Oil | *Aphanocapsa* sps., *Chlorella autotrophica, Coccochloris elabens, Dunaliella tertiolecta, Oscillatoria* sps., *Scenedesmus obliques, Synechococcus elongates* and *Volvox* | These algae were helpful in the degradation of 35% of the crude and they remain alive also in high crude condition abilities that are necessary for bioremediation. Results demonstrate that properly controlled algae are feasible agents for crude oil bioremediation. | Cao *et al*, 2013 |
| Phosphate, Nitrate, COD and BOD | *Chlorella vulgaris* and *Scenedesmus quadricauda* | Removal efficiencies of COD, BOD, Nitrate and Phosphate of waste water were 80.64%, 70.91%, 78.08% and 62.73% respectively using *C. vulgaris* up to 15 days while using *S. quadricauda* the removal efficiencies of COD, BOD, Nitrate and Phosphate of waste water were 70.96%, 89.21%, 70.32% and 81.34% respectively up to 15$^{th}$ days | Kshirsagar, 2013 |
| Phosphorous and Nitrate | *Chlorella minutissima* | The amount of Phosphorous in water sample treated with *C. minutissima* reduced from 4.47ppm to 1.15ppm while reduction of Nitrate is from 3.6ppm to 0.3ppm. removal effeciencies of *C. minutissima* was very high. | Sharma and Khan, 2013 |
| Lead | *Enteromorpha* algae and its silicates bonded material | Lead adsorption capacity was 83.8mg/g at pH 3 with algae and 1433.5mg/g for silicates modified algae. Thomas and Yoon Nelson Column Model were best for adsorbent (E) and Algae after reflux (ER) and Yan model for (EM) with capacity 76.2, 71.1 and 982.5mg/g respectively. EM and ER show less swelling and better flow rate control than E | Hammud *et al*, 2014 |
| Copper(Cu) ions | *Spirulina platensis* | Adsorption of Cu ions was found to increase gradually along with decrease in biomass concentration. Biosorption was found to be maximum (90.6%) in a solution containing 100mg Cu/l at ph 7 with 0.050 dried biomass of algae at 37°C with 90min contact time. | Homaidan, 2014 |

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| Copper(Cu) and Zinc(Zn) | *Chlorella vulgaris, Spirulina maxima* and *Synechocystis sps.* | Microalgae removed up to 81.7% Cu reaching lowest final concentration of 7.8ppb after 10 days. Zn reduced up to 94.1% reaching 0.6ppb after 10 days. Inoculated samples show decreased heavy metal concentration within 6 hrs of initial inoculation as microalgae don't require long period | Chan *et al*, 2014 |
| Textile waste effluents(Color and COD) | *Chlorella vulgaris* | Cultivation of *C. vulgaris* present maximum cellular concentration $C_{max}$ and maximum in specific growth rates $\mu_{max}$ in waste water concentration of 5% and 17.5%. Highest COD and color removal occurred with 17.5% of textile water effluents. *C.vulgaris* culture in textile waste effluent demonstrated the possibility of using this microalga for COD and Color removal. | Kassas and Mohamed, 2014 |
| Chromium(Cr) and Lead(Pb) | *Chlorella marina* (Butcher) | Seven days incubation of *C.marina* in waste water increased from $3x10^6$ to $1.5x10^7$ cell/ml and it reduced 88%Nitrate, 64% Ammonia, 75% Nitrate and 51% Phosphorous overall. Heavy metals such as Chromium and Lead largely remove the % of these metals upto 89% and 87% respectively | Kumar *et al*, 2015 |

In conclusion, these reviews indicate the potential of Algae for the removal of different pollutants such as industrial waste , oil effluents, organic and inorganic pollutants etc from wastewater. With the advantages of low cost raw material and no secondary pollution, algae is promising for purification of waste water containing heavy metals.

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## References

Abraham Jayathi and Sonil Nanda.2010. Evaluation of Textile Effluents before and After Treatment with Cyanobacteria. *J of Industrial Pollution Control* 26(2) pp 149-152.

Al-Homaidan A. Ali, Hadel J. Al-Houri, Amal A. Al-Hazzani, Gehan Elgaaly, Nadine M.S.Moubayed. 2014.*Arabian Journal of Chemistry*. Vol 7(1):57-62.

Al-Qunaibit M. H.2009. Divalent Cu, Cd, and Pb Biosorption in Mixed Solvents. Bioinorganic Chemistry and Applications.

Ayodhya D Kshirsagar. 2013.Bioremediation of waste water by using microalgae: An experimental Study. *Int. J. LifeSci. Bt. & Pharma Res.* Vol. 2, No. 3.

Ballantyne B, Timothy CM, Tore S. 1999.*General and Applied Toxicology*, Second Edition. Vol. 3, Macmillan Publishers. pp. 2052-2062, 2145-2155.

Brahmbhatt N.H., Patel V. Rinku and Jasrai R.T.2012. Bioremediation Potential of *Spirogyra* sps. and *Oscillatoria* sps. for Cadmium. *Asian Journal of Biochemical and Pharmaceutical Research*.Vol 2. Issue 2.

Cao Xiuqi, Ying Xiong and Janelle Lund.2013. The effects of micro-algae characteristics on the bioremediation rate of Deepwater Horizon Crude Oil. Journal of Emerging Investigators.

Chan Alison, Hamidreza Salsali and Ed McBean.2014. Heavy Metal Removal (Copper and Zinc) in secondary effluents from waste water treatment plants by Microalgae.ACS Sustainable Chemistry and Engineering, Vol. 2: issue 2 pp 130-137.

Chen H. and Pan Shan Shan.2005. Bioremediation potential of *Spirulina* Toxicity and Biosorption Studies of Lead. J. Zhejiang Univ. Sci. 6B (3):171-174.

Deng Liping, Xiaobin Zhu, Xinting Wang, Yingying Su and Hua su.2007. Biosorption of copper (II) from aqueous solutions by green alga *Cladophora fascicularis*. *Biodegradation* 18:393-402.

Derek WJ.1999. Exposure or Absorption and the Crucial Question of Limit for Mercury, J. *Can. Dent. Assoc*., 65: 42-46.

Dias MA.2002. Removal of heavy metals by an *Aspergillus terreus* strain immobilized in polyurethane matrix. *Lett. Appl.Microbiol*.34 (1): 46-50.

Doshi H., Ray A., Kothari IL. 2007.Bioremediation potential of dead and live *Spirulina*: Spectroscopic, Kinetics and SEM studies. *Biotechnol Bioeng* 96(6):1051-1063.

Dubey Sanjay Kumar, Jaishree Dubey, Sandeep Mehra, Pradeep Tiwari and A.J. Bishwas.2011.Potential Use Of Cyanobacterial Species in Bioremediation Of industrial Effluents. *American Journal of Biotechnology*.Vol10 (7). Pp.1125-1132.

Gonzalez Luz Estela, Rosa Olivia Canizares and Sandra Baena, 1997. Efficiency of ammonia and phosphorous removal from a Colombian agro industrial wastewater by the microalgae *Chlorella vulgaris* and *Scenedesmus dimorphus. Bioresource Technology* Vol. 60: 259-262.

Gulshan Kumar Sharma and Shakeel Ahmad Khan.. Bioremediation of Sewage Wastewater using Selective Algae for Manure Production. 2013. *International Journal of Environmental Engineering and Management*. ISSN 2231-1319, Vol. 4, No. 6, pp 573-580

Hala Yassin El- Kassas and Laila Abdelfattah Mohamed .2014.The *Egyptian Journal of Aquatic Research*.Vol. 40(3):301-308.

Hammud H. Hasan, Ali El-Shaar, Essam Khamis and El- Sayed Mansour. 2014. Adsorption Studies of Lead by *Enteromorpha* Algae and its silicates Bonded Material. *Advances in Chemistry*. Vol. Article ID 205459, 11pages.

Imani Saber, Rezaei-Zarchi Saeed, Hashemi Mehrdad, Borna Hojjat, Javid Amaneh, Ali mohamad Z and Hossein Bari Abarghouei. 2011. Hg, Cd and Pb heavy metal bioremediation by Dunaliella alga. *Journal of Medicinal Plants Research* Vol. 5(13), pp. 2775-2780, 4 July.

Ismail., Azza A.M. Abd EL-All and Hanan A.M. 2013. Hassanein. Biological influence of some microorganisms on Olive Mill Waste Water. *Egypt J. Agric. Res.*, 91(1) .

J. Zheng, J.M. Hao, B. Wang and C. Shui. 2011. Bioremediation of Agriculture Wastewater by Microalgae *Isochrysis zhanjiangensis* and production of the Biomass Material. Key Engineering Material, Vols 460-461, pp. 491-495.

Kaewsarn Pairat. 2002. Biosorption of Copper (II) from aqueous solutions by pre-treated biomass of marine algae *Padina* sp. *Chemosphere* 47:1081-1085.

Kajan M., Livansky K. and Binova J. 1992. Archiv fur Hydrobiologie. Supplement 93:93.

Kumar Dinesh, S.P. Santhanam, T. Jayalakshmi, R. Nandakumar, S. Ananth, A. Shenbaga Devi and B. Balaji Prasath. 2015. Excessive nutrients and heavy metals removal from diverse waste waters using marine microalga *Chlorella marina* (Butcher).*Indian Journal of Geo- Marine Sciences*. Vol.44 (1) .

Kumar JI and Oammen C. 2012. Removal of Heavy Metals by Biosorption using freshwater alga *Spirogyra* hyaline. *J. Environ Biol*. Vol. 33(1):27-31.

Leush A., Holan ZR, Volesky B. 1995. Biosorption of Heavy Metals (Cd, Cu, Ni, Pb, Zn) by chemically reinforced biomass of marine algae. *J. Chem Technol. Biotechnol* 62:279-28.

Monteiro Cristina M., Paula M. L. Castro and F. Xavier Malcata (2009). Solutions. WORLD. Volume 1573-1578

Oluduro AO and Adewoye BI. 2007.Efficiency of moringa Oleifera Sead extract on the microflora of surface and ground water *J. plant Sci.* 6:453-438.

Oswald W and Gootas HB.1957. Photosynthesis in sewage treatment. Trans Am Soc Civ Eng 122:73-105.

Oswald WJ. 1988. Microalgae and Waste water treatment. In: Borowizka, MA and L.J. Borowitzka. Editors. *Microalgal Biotechnology*. Cambridge University Press. P. 305-328.

Prado Monica Patron-, Baudilio Acosta-Vargas, Elisa Serviere- Zaragoza and Lia C. Mendez- Rudriguez. 2010. Copper and Cadmium Biosorption By dried Seaweed *Sargassum sinicola* in saline wastewater. *Water Air Soil Pollut* 210: 197-202.

Prado Monica Patron-, Margarita Casa-Valdez, Tania Zenteno- Savin, Daniel B.Lluch-Cota, Elisa Serviere- Zaragoza and Lia C. Mendez- Rudriguez. 2011. Biosorption Capacity for Cadmium Of Brown Seaweed *Sargassum sinicola* and *Sargassum lapazeanum* in the Gulf of California. *Water, Air and Pollution*. Vol 221, No.1-4, pp 137-144.

Rai LC and Mallich N 1992. Removal and assessment of toxicity of Cu and Fe to *Anabena doliolum* and *Chlorella vulgaris* using free and immobilized cells. *World J. Microbiol. Technol* 8:110-114.

Rajasulochana, P., Dhamotharan, R., Murgesan, S. and Rama Chandra Murthy A. 2009. *Journal of American Science;* 5(4): 17-22.

V.K. Gupta, A. Rastogi .2008.Biosorption of Lead from aqueous solutions by green algae *Spirogyra* species: Kinetics and equilibrium studies. *Journal of Hazardous Materials*. Volume 152, Issue 1, Pages 407–414

Valderrama, L. T., C. M. Del Campo, C. M. Rodriguez, L. E. De Bashan and Y. Bashan. 2002. Treatment of recalcitrant wastewater from ethanol and citric acid production using the microalga *Chlorella vulgaris* and the macrophyte *Lemna minuscula*. Water Research, 36 (17): 4185-4192.

Volesky B.1990. Biosorption of heavy metals, Boca Raton, Flo.: Press CRC, Florida. pp 3-6().

Wase J. and Forster C.F.1997., Biosorbents for metals ions: *Taylor& Francis.* Lo.

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