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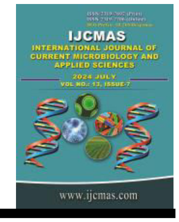

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Phycoremediation of Wastewater - An Approach Used Microalgae for Bioremediation

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ABSTRACT

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Over centuries, human industrial, mining and military activities as well as farming and waste practices have contaminated large areas of developed countries with high concentrations of heavy metals and organic pollutants. In addition to their negative effects on ecosystems and other natural resources, these sites pose a great danger to public health, because pollutants can enter food through agricultural products or leach into drinking water. A number of microalgae species or plant species are efficient in removing toxicants from wastewater. Phycoremediation is the technology that uses plants to remove pollutants from the environment. Phytoremediation uses wild or genetically modified plants (GMPs) to extract a wide range of heavy metals and organic pollutants from the water. Plants accumulate heavy metals from contaminated soil and water. These plants can be grown and harvested economically to clean up the environment, leaving only residual levels of pollutants. The various processes by which phytoremediation takes place are phytoextraction, rhizofiltration, phytostabilization and phytovolatilization. The expenditure of phytoextraction is moderately inexpensive and contaminants can be separated permanently.

Introduction

In developing countries like India, water scarcity is presenting serious issues, because of population explosion resulting in large quantities of sewage wastewater. Coupled with this, increasing industrialization, indiscriminate and excessive usage of fertilizers and pesticides is resulting in contamination/mixing of untreated wastewater with the available water resources (El-sheekh *et al.,* 2000; Ghosh *et al.,* 2012). In this regards the discharged of effluent is of great concern because it has a toxic or carcinogenic effect on human and living species. Bioremediation is emerging as most ideal alternative and ecologically sound technology for removing pollutants from the environment, restoring contaminated sites and preventing further pollution. Phycoremediation, a branch of bioremediation, the term ‘phycoremediation’ is in vogue for more than a decade, and of late the technology have begun to taste commercial success and it is a novel technique that uses algae to clean up contaminated soil and groundwater. It is a process similar to phytoremediation and applied to the removal of nutrients from animal wastewater and other high organic content wastewater with a great potential and demand considering that surface and underground water bodies in several regions of the world are suffering from eutrophication (Kari Dresback, 2001).

Phycoremediation is the use of micro or macroalgae for the removal or biotransformation of pollutants, including nutrients and toxic chemicals from wastewater. The term phycoremediation was introduced by John to refer to the remediation carried out by algae. Phycoremediation is comprised of several applications: (i) nutrient removal from municipal wastewater and effluents rich in organic matter; (ii) nutrient and xenobiotic compounds removal with the aid of algae-based biosorbents; (iii) treatment of acidic and metal wastewaters; (iv) CO^2 sequestration; (v) transformation and degradation of xenobiotics; and (vi) detection of toxic compounds with the aid of algae-based biosensors. These technologies should also be applicable at the small-scale level with potential of acceptance at commercial level in the future.

The methods applied in the treatment of effluents or contaminated water are broadly classified into three types—physical, chemical and biological (Fig. 1). These can be employed individually or in combination, depending upon the extent and type of pollution. In order to achieve the desired levels of contaminant removal, individual wastewater treatment procedures are grouped into a variety of systems, classified as primary, secondary and tertiary wastewater treatments. In general, both physical and chemical methods are costly. Also, most chemical methods increase the pH, conductivity and overall load of dissolved matter in the wastewater. In this respect, biological or biotreatment of wastewater is a better option. The most common biological wastewater treatment applied in the treatment of municipal and industrial wastewaters is the use of activated sludge alone (Nyholm *et al.,* 1996; Radjenovic *et al.,* 2009) or in combination with algae (Gonzalez *et al.,* 2008; Su *et al.,* 2012a). However, problems related to dewatering and disposal of sludge have made researchers look for other alternatives.

Phycoremediation is particularly attractive because it has the ability to deal with more than one problem on-site. The promising attributes of microalgae, such as (1) higher photosynthetic capabilities as compared to higher plants (Bhatnagar *et al.,* 2011), (2) ability to convert solar energy and CO2 emissions from power plants, hence, lower energy requirements (Razzak *et al.,* 2013), (3) capacity to incorporate excess nutrients such as nitrogen and phosphorus from sewage water for their growth, making disposal easy (Bhatnagar *et al.,* 2011; Mata *et al.,* 2012), (4) tolerance to extreme conditions (Makandar and Bhatnagar, 2010), (5) ability to reduce greenhouse gas emissions (Bhola *et al.,* 2014; Singh and Ahluwalia, 2013), (6) wide applications of harvested biomass (Gupta *et al.,* 2013). These useful features of microalgae have further strengthened their exploitation in wastewater treatment, as compared to the use of higher aquatic macrophytes (Table 1). Therefore, the cultivation of algae in wastewater offers the combined advantages of mitigation of greenhouse gases, treatment of the wastewaters, and simultaneously producing algal biomass. This review is, therefore, an attempt to summarize the reports available on use of microalgae in various wastewaters treatment.

Microalgal diversity in wastewater

The industrial and municipal release cause major environmental challenges to the receiving water bodies. The wastewater generally abundant in contaminant in the form of nutrients, heavy metals, hydrocarbons etc. The existence of nutrient mainly nitrogen (N) and phosphorus (P), in the form of nitrate, nitrite, ammonia/ammonium or phosphorus in wastewater leads to eutrophication. Microalgae serve as component of the microbial diversity that play important role in the self-purification of these wastewaters (Sen *et al.,* 2013). Microalgae constitute a broad category of organisms encompassing photoautotrophic eukaryotic microalgae and prokaryotic cyanobacteria, which are distributed both in fresh and marine environments, with a wide range of diversity in their thallus organization and habitat (Lee, 2008). The biodiversity of microalgae is enormous and estimated to be about 200,000–800,000 species, out of which about 50,000 species are only described (Starckx, 2012). This enormous diversity and propensity to adapt to extreme and inhospitable habitats has led the scientific community to screen, identify promising strains/species/ genera and develop promising microalgae-based technologies for wastewater treatment (Fouilland, 2012).

Hussein and Gharib (2012) analyzed the phytoplankton diversity in sewage water mixed with drain water and observed a total of 152 taxa, including Bacillariophyceae (60), Chlorophyceae (20), Cyanophyceae (20), Euglenophyceae (17) and Dinophyceae (9). Bacillariophyta was the dominant group, constituting

39.4 % of overall diversity in the drain. However, in an open sewage-contaminated channel, Renuka *et al.,* (2013) observed the dominance (58 %) of Cyanophycean members comprising species of Chroococcus (Fig. 2a, b), Lyngbya (Fig. 2c) Phormidium (Fig. 2d), Limnothrix (Fig. 2e), Oscillatoria (Fig. 2f), and Planktothrix (Fig. 2g), followed by members of Chlorophyta (25 %) and Bacillariophyta (17 %). Bernal *et al.,* (2008) studied the change in microalgal community in batch reactors of municipal wastewater treatment containing dairy sewage water and observed that microalgae from Cyanophyta, Chlorophyta and Euglenophyta groups were present during all the phases of the treatment process; *Arthrospira jenneri* (Cyanophyta) and Coccomonas sp. (Chlorophyta) were the most common members.

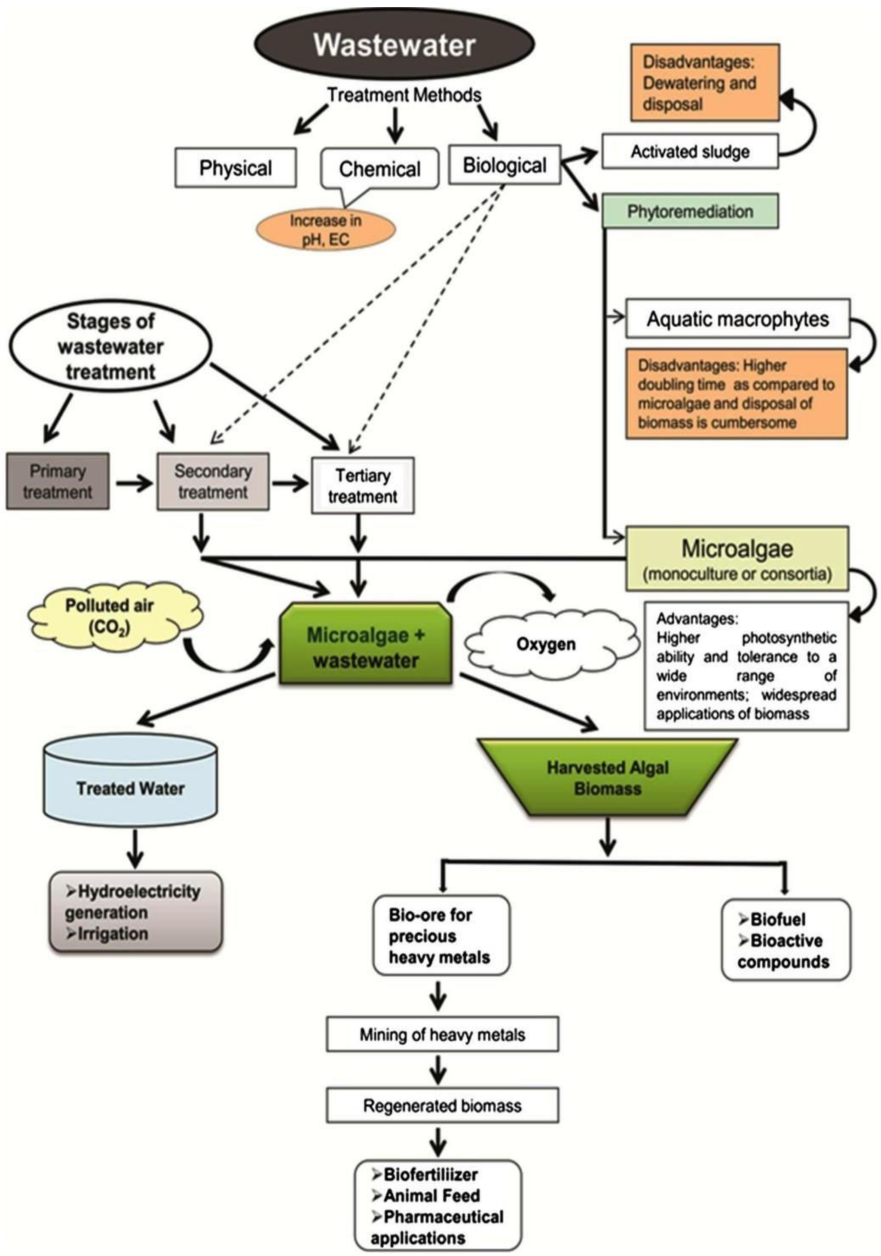
Bioremediation of Heavy Metal by Microalgae in Wastewater

Heavy metal is a pollutant that considered being a significant environmental problem related to human health. The contamination of water by toxic metals and organic pollutants recently increased due to anthropogenic activity. Thus, bioremediation technique to assimilate that toxic has a high potential to be applied in wastewater treatment. Bioremediation is a process of using specific microorganisms to transform hazardous contaminations in water to nonhazardous waste products (Dwivedi, 2012). In 2012, Dwivedi (2012) also described there are two steps involved in the assimilation of heavy metals. First, the metals are adsorbed over the cell very quickly called physical adsorption. Next, these metals are assimilated slowly into the cytoplasm in a process named chemisorptions. However, absorption of heavy metal depends on the other parameter such as pH. As highlighted by Dwivedi (2012), surface charge studies showed that the availability of free sites depended on pH. With increasing pH, the surface charged sites of calcium alginate became more negative, then the uptake of metal increased with increasing pH. Therefore, Table 2 shows the selection of microalgae in bio-remediate some of the heavy metals ions done by previous researchers. Worku & Sahu (2014) cultured *Synechocystis salina* in groundwater to reduce the heavy metals and total hardness within 15 days of treatment. At the end of the treatment day, *Synechocystis salina* be able to remove of Cr 60%, Fe 66%, Ni 70%, Hg 77%, Ca2+ 65%, Mg2+ and total hardness 78%. Meanwhile, Kumar *et al.,* (2013) had demonstrated to remove Zinc using immobilized and powder form from Chlorella marina. They found that the highest removal fall to the powder form of 97% compared to immobilized of 55.3%.

Table.1 Heavy Metals bioremediation by microalgae

Microalgae species	Heavy Metal Study	
	Metals	Removal (%)
Synechocystis salina	Cromium (Cr)	60
	Iron (Fe)	66
	Nickel (Ni)	70
	Mercury (Hg)	77
	Calcium (Ca^{2+})	65
	Magnesium (Mg^{2+})	63
	Total Hardness	78
Chlorella marina	Zinc, Zn (Powder)	97
	Zinc, Zn (Immobilized)	55.3
Porphyridium cruentum (S.F. Gray)	Copper (Cu)	92
Chlorella pyrenoidosa	Cromium (Cr)	52.8
	Copper (Cu)	77.1
	Lead (Pb)	43.8
	Zinc (Zn)	68.9
Scenedesmus sp	Cromium (Cr)	52
	Copper (Cu)	79.2
	Lead (Pb)	47.8
	Zinc (Zn)	66
Indigenous microalgae	Barium (Ba)	91.2
	Iron (Fe)	94.6

Figure.1 Schematic representation of waste water treatment using micro algae overview of advantages and applications



At the same time, the optimum pH for the heavy metal adsorption is at pH 8. In bioremediation of industrial wastewater, Soeprobowati & Hariyati (2013) used *Porphyridium cruentum* isolated from brackish water to assimilate the Pb, Cd, Cu and Cr. During the experimental, pH, temperature, salinity and light were maintained to be on 7-8, 28-32°C, 32-34 ppt and 4200 lux, respectively. Thus, this red microalga was able to reduce Cu of 92 % from the wastewater. In a different study, Ajayan & Selvaraju (2012) examined two strain of microalgae; *Chlorella pyrenoidosa* and Scenedesmus sp. in tannery effluent. As mentioned in Table 2, they analyzed that the highest removal using both microalgae were Copper, 77% and 79.2%, respectively.

Whereas Krustok *et al.,* (2012) were applying the Indigenous microalgae in wastewater collected from WWTP in Vasteras. Their finding was showing that this microalga very effective in removing of Barium 91.2 % and Iron 94.6 %. In summary, most of microalgae species, as listed in Table 2, have their advantages in bioremediation of heavy metal in water. Other than nutrient (Phosphorus and Nitrogen), microalgae also need a heavy metal element to build their cell, for example, iron and chromium (Dwivedi, 2012). Also, a major advantage using microalgae in bioremediation is that this process under the light condition and does not need oxygen. Instead they absorb CO2 and release O2. However, to the best author's knowledge, no report has been found so far using Botryococcus sp. in bioremediation of heavy metals in wastewater. To address this gap, the application of Botryococcus sp. in sewage treatment was the motivation behind the present project.

Human activities, including industrial, mining, and military activities, have contaminated areas of developed countries with heavy metals and organic pollutants, posing a threat to public health and ecosystems. Phycoremediation, a technology using plants to remove pollutants, uses wild or genetically modified plants to extract heavy metals and organic pollutants from water. This process, which involves phytoextraction, rhizofiltration, phytostabilization, and phytovolatilization, is economically viable and permanently separates contaminants. Because of the hazardous consequences and quick build-up in the environment, heavy metal pollution is a major problem for food safety and agricultural productivity.

Many strategies have been devised to minimize or lessen heavy metal contamination and revegetate the polluted soil. Comparing phytoremediation to other physicochemical procedures, it has been demonstrated to be a highly advantageous method for revegetating soil contaminated by heavy metals, with a high degree of public acceptance. Through a variety of processes, microalgae have the remarkable ability to remove a wide range of harmful compounds and pollutants from domestic agriculture runoff, effluents, textile, printing, pharmaceutical, and electroplating industries. Secondary contamination is not produced by microalgae bioremediation. Furthermore, the discarded microalgal biomass has substantial economic value as raw materials for the production of biofuel, pharmaceuticals, fertilizers, and nutrient-dense food.

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Author Contributions

Anuj Kumar: Investigation, formal analysis, writing—original draft. Sweety: Validation, methodology, writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

References

Ajayan, K. V., M. Selvaraju, 2012. Heavy metal induced antioxidant defense system of greem microalgae and its effective role in phytoremeduation of tannery effluent. *Pakistan journal of biological sciences*, 15(22): 1056–1062. https://doi.org/10.3923/pjbs.2012.1056.1062

Bernal CB, Vazquez G, Quintal IB, Bussy AN (2008) Microalgal dynamics in batch reactors for municipal wastewater treatment containing dairy sewage water. Water Air Soil Pollut 190:259–270.

Bhatnagar A, Chinnasamy S, Singh M, Das K C (2011) Renewable biomass production by mixotrophic algae in the presence of various carbon sources and wastewaters. Appl Energ 88:3425–3431 https://doi.org/10.1016/j.apenergy.2010.12.064

Bhola V, Swalaha F, Kumar R R, Singh M, Bux F (2014) Overview of the potential of microalgae for CO2 sequestration. Int J Environ Sci Technol 11:2103–2118 https://doi.org/10.1007/s13762-013-0487-6

Dwivedi, S., 2012. Bioremediation of Heavy Metal by

Algae : Current and Future Perspective. *Journal of Advanced Laboratory Research in Biology*, III(Iii), pp: 195–199. https://journals.sospublication.co.in/ab/article/view/88

El-Sheekh M M, El-Maggar A H, Osman M E H, Haieder A (2000) Comparative studies on the green algae *Chlorella homosphaera* and *Chlorella vulgaris* with respect to oil pollution in the river Nile. Water Air Soil Pollut 124:187–204 https://doi.org/10.1023/A:1005268615405

Fouilland E (2012) Biodiversity as a tool for waste phycoremediation and biomass production. Rev Environ Sci Biotechnol 11:1–4 https://doi.org/10.1007/s11157-012-9270-2

Ghosh S, Barinova S, Keshri J P (2012) Diversity and seasonal variation of phytoplankton community in the Santragachi lake, West Bengal, India. QSci Connect 3. https://doi.org/10.5339/connect.2012.3

Gonzalez C, Marciniak J, Villaverde S, Garcia-Encina P A, Munoz R (2008) Microalgae based processes for the biodegradation of pretreated piggery wastewaters. Appl Microbiol Biotechnol 80:891–898 https://doi.org/10.1007/s00253-008-1571-6.

Gupta V, Ratha S K, Sood A, Chaudhary V, Prasanna R (2013) New insights into the biodiversity and applications of cyanobacteria (blue–green algae)—prospects and challenges. Algal Res 2:79–97 https://doi.org/10.1016/j.algal.2013.01.006

Hussein N R, Gharib S M (2012) Studies on spatio-temporal dynamics of phytoplankton in El-Umum drain in west of Alexandria. Egypt J Environ Biol 33:101–105

Kari Dresback, 2001. Phycoremediation of trichloroethylene (TCE). Physiol.Mol. Biol. Plants,7(2):117-123

Krustok, I., E. Nehrenheim, M. Odlare, 2012. Cultivation of Microalgae for Potential Heavy Metal Reduction In A Wastewater Treatment Plant. International Conference on Applied Energy ICAE 2012, Jul 5-8, 2012, Suzhou, China Paper ID: ICAE2012-A10540.

Kumar, M., M. P. Sharma, G. Dwivedi, 2013. Algae Oil as Future Energy Source in Indian Perspective. *International Journal Of Renewable Energy Research,* 4(3): 913-921. https://doi.org/10.20508/ijrer.v3i4.921.g6223

Lee R E (2008) Phycology, 4th edn. Cambridge University Press, New York.

Makandar M B, Bhatnagar A (2010) Morphotypic diversity of microalgae in arid zones of Rajasthan. J Algal Biomass Utln 1:74–92

Mata T M, Melo A C, Simoes M, Caetano N S (2012) Parametric study of a brewery effluent treatment by microalgae *Scenedesmus obliquus*. Bioresour Technol 107:151–158. https://doi.org/10.1016/j.biortech.2011.12.109

Nyholm N, Ingerslev F, Berg U T, Pederson J P, Frimer-Larsen H (1996) Estimation of kinetic rate constants for biodegradation of chemicals in activated sludge wastewater treatment plants using short term batch experiments and microgram/L range spiked concentration. Chemosphere 33:851–864. https://doi.org/10.1016/0045-6535(96)00180-4

Radjenovic J, Petrovic M, Barcelo D (2009) Fate and distribution of pharmaceuticals in wastewater and sewage sludge of the conventional activated sludge (CAS) and advanced membrane bioreactor (MBR) treatment. Water Res 43:831–841 https://doi.org/10.1016/j.watres.2008.11.043

Razzak S A, Hossain M M, Lucky R A, Bassi A S, de Lasa H (2013) Integrated CO2 capture, wastewater treatment and biofuel production by microalgae culturing—a review. Renew Sust Energ Rev 27:622–653. https://doi.org/10.1016/j.rser.2013.05.063

Renuka N, Sood A, Ratha SK, Prasanna R, Ahluwalia AS (2013). Nutrient sequestration, biomass production by microalgae and phytoremediation of sewage water. Int J Phytoremed 15:789–800

Sen B, Alp M T, Sonmez F, Kocer M A T, Canpolat O (2013) Relationship of algae to water pollution and waste water treatment. In: Elshorbagy W (ed) Water treatment, ISBN: 978-953-51-0928-0, InTech.

Singh U B and Ahluwalia A S (2013) Microalgae: a promising tool for carbon sequestration. Mitig Adapt Strateg Glob Chang 18:73–95 https://doi.org/10.1007/s11027-012-9393-3

Soeprobiwati, T. R. and R. Hariyati, 2013. Bioaccumulation of Pb, Cd, Cu, and Cr by *Porphyridium cruentum* (S.F. Gray) NÃ¤geli. *International Journal of Marine Science*, 3(27): 212–218. https://doi.org/10.5376/ijms.2013.03.0027

Starckx S (2012) A place in the sun—algae is the crop of the future, according to researchers in Geel, Flanders Today.

Su Y, Mennerich A, Urbana B (2012a) Synergistic cooperation between wastewater-born algae and activated sludge for wastewater treatment: influence of algae and sludge inoculation ratios. Bioresour Technol 105:67–73 https://doi.org/10.1016/j.biortech.2011.11.113

Worku, A., O. Sahu, 2014. Reduction of Heavy Metal and Hardness from Ground Water by Algae. *Journal of Applied & Environmental Microbiology*, 2(3): 86–89. https://doi.org/10.12691/jaem-2-3-5

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