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CULTIVATION AND UTILIZATION OF BLUE GREEN ALGAE FOR TREATMENT OF TEXTILE INDUSTRY EFFLUENT AS A SUSTAINABLE AND ECO-FRIENDLY APPROACH

NUDRAT GHULAM RASOOL
Department of Environmental Science, Lahore College for Women University, Lahore Pakistan.

MONEEZA ABBAS
Department of Environmental Science, Lahore College for Women University, Lahore Pakistan.

SHABNUM SHAHEEN
Department of Botany, Lahore College for Women University, Lahore Pakistan.

FAKHRA ASLAM
Department of Environmental Science, Lahore College for Women University, Lahore Pakistan.

SAIMA ATIF
Department of Environmental Science, Lahore College for Women University, Lahore Pakistan.

SUMAIRA AMEEN
Department of Environmental Science, Lahore College for Women University, Lahore Pakistan.

Abstract

In current times Water pollution is considered to be dangerous because it is indirectly disturbing the ecosystem by polluting water bodies. Hence it is necessary to resolve this issue by controlling it on source or by treating it through treatment processes such as chemical treatment and biological treatment. Industries are of various categories from which some are major polluting industries such as textile. A valuable work done on laboratory level by growing algal species (blue green algae) on textile effluent after characterization of effluent samples. For this characterization of effluents was done for various physiochemical parameters and isolation of algal species was done and algal species was introduced in experimentation through adsorption method and biomass was produced by remediating the textile effluent samples. Blue green algae was considered to be good absorbent of pollutants such as trace metals by analyzing under Fourier Transform Infrared Spectroscopy (FTIR) and X-Ray Diffraction (XRD). Results of the study revealed that BGA can be a good absorbent of trace metals for industrial effluent treatment on large scale and considered to be a cost-effective and sustainable bioremediation technique.

Keywords: Effluent Treatment; Physiochemical Parameters; X-Ray Diffraction; Fourier Transform Infrared; Eco-Friendly.

1. INTRODUCTION

Algae ponds at large scale are being utilized as cost-effective and valuable source of sewage treatment. The bulk of algae biomass manufactured in the ponds can be collected and used in pollutant elimination. As pollution is a current problem either pollution of water, soil or air. Algae had been studied as pollutant eliminator in effluent, soil and in air. Algae have capacity to uptake heavy metals as well as greenhouse gas (carbon dioxide gas) and oxides of Nitrogen and Sulphur and ammonia. Blue-green

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algae show special benefits in large scale production; Its filamentous nature allow mechanical harvest, their capability for nitrogen fixation made them attractive for production of fertilizer, or their vesicles can lesser pond mixing need.

Algae is photoautotrophic and are the most primitive existing on our earth surface and it is considered to be of Proterozoic and Archaean period which were 2.7 billion years ago, at that time these were accountable to create our oxygen containing atmosphere by their activities like photosynthesis. Blue green algae were first to use two photosystems I and II and to break down water instead of Hydrogen sulfide like other bacteria. Blue green algae capture light from sun by using chlorophyll a and different pigments particularly c-phycocyanin and carry out photosynthesis as plants and algae. Although blue green algae carry out oxygen producing photosynthesis like higher plants and eukaryotic green algae, but they cannot store food as starch in their body. Cyanophycean starch and Glycogen collectively with specific intracellular storage components like protein consisting cyanophycean granules, lipids and polyphosphate bodies are its main storage products Kulasooriya (2011).

Algae are amongst the most primitive of inhabitants on Earth surface and considered as extremely diverse member in the existing worldwide biodiversity and play a major role in the Nitrogen and Carbon bio-geochemical cycles, mainlyin deep oceans. Blue green algae in latest years gained importance due to their probable use in different fields of research. This varied group has applications into diverse fields as agriculture, biotechnology and pharmacology etc. Because of presence of broad range of biologically active compounds blue green algae possesses anticancer, antibacterial, antiviral and antifungal activities. A number of strain of blue green algae also rich into food supplements.

Additionally, nitrogen fixation capability of blue green algae has attracted researchers and agriculturists as they use blue green algae as a constituent of bio-fertilizers to make better both the growth of plants and as 5 5 well as soil fertility. Current studies have shown that blue green algae have ability to decompose environmental contaminants and are being utilized as a capable source of substitute energy. Despite of all the research and analysis more work should be done in search of additional strains of algae and genetically modified strains to get highest production of desired yield. Blue green algae are amongst the organisms that can change atmospheric nitrogen into organic compounds like ammonia or nitrates and consequently they serve as economical biofertiliser in agriculture and as biofuel. Ananya and Ahmad, (2014).

Natural farming has developed as a significant area worldwide concerned with increasing demand for healthy and safe food. And concerns for sustainability and environmental pollution linked with random use of agrochemicals. Although use of chemical input in farming is expected to meet up the rising demand for food production on the earth, there are opportunities in chosen crops and fields where natural production could be enhanced to increase the export market at domestic level. Biofertilizers as being necessary components of natural farming are compounds containing latent or live cells of effective strains of phosphate solubilizing, cellulolytic and nitrogen fixing micro-organisms used for applying to soil, seed and composting areas with the purpose of increasing such micro-organisms and speed up those microbial processes that increases the accessibility of nutrients which could be easily used by plants. Biofertilizers play an important role to improve soil fertility by atmospheric nitrogen fixation both in relationship with plant roots or without it, and solubilise the insoluble phosphates and produces growth substances of plants in the soil.In fact they are being developed to get naturally accessible biological system of mineral mobilization (Venkatashwarlu, 2008).

The importance and role of biofertilizers in sustainabily production of crops has reviewed by authors. While the advancement in the area of biofertilizer production technology always remained under less satisfaction in the Asia due to different constraints (Mishra et al., 2013).

2. MATERIALS AND METHODS

2.1 Effluent sample collection

Textile effluent samples were collected from diverse Textile Industries of Lahore in November, 2021 and February, 2022. These were collected in amber glass bottles, closed properly to avoid any impurity and were labeled as E1, E2, E3 and E4. And were transferred in laboratory for various parameters such as pH, temperature, BOD, COD, TDS, TSS, DO, electrical conductivity and trace metals.

1) Collection and preservation of Algae

Algal samples were collected in plastic bottles and cans and labeled with number and were transferred to be kept in refrigerator at about 4oC.

2) Algal species identification

Algal species were identified under light microscop by following standard procedure of (Coltli et al., 2014).

3) Algal species isolation

Algae species were isolated by following standard procedures of streak plate and serial dilution method.

4) Desired species cultivation on synthetice media

For the growth of desired algae, BG-11 media was used by following standard method of university of texas (2009).

5) Effluent treatment by desired algal species

Adsorption experiment was utilized for effluent treatment. 0.5g of Algal biomass was taken in flask containing 300 ml wastewater and were placed in aeration through aeration pump and under fluorescent light.

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Estimation of algal biomass production during effluent treatment:

Algal biomass was calculated through optical density method by using UV Visible Spectrophotometer under 680nm wavelength.

6) Characterization of Algal biomass

XRD analysis of algal biomass:

Algal samples were oven dried and ground into fine powder form for XRD analysis.

FTIR analysis of algal biomass:

Samples were prepared by freeze drying method for FTIR analysis.

Statistical Analysis:

Statistical analysis was done through Origin Lab and Microsoft Excel.

3. RESULTS

All the results of characterization of textile industry effluents were compared with National Environment Quality Standards for Industrial effluents and data was interpreted in Table 1.

Table 1: Observed values of physio-chemical parameters of each industry compared with the standard values of NEQS

Characterization Parameters	Effluent analysis values (Mean±SE)				NEQS limits
	(E1) Industry 1	**(E2)**Industry 2	**(E3)** Industry 3	**(E4)** Industry 4	
pH	6.5±0.25	12.6±0.61	8.2±0.43	8.2±0.523	6-10
Temp(°C)	31.17±0.256	34.2±1.6	38.7±2.91	37.7±1.38	40°C
TDS(mg/L)	1280.5±16.885	3323.1±37.17	1785.3±147.9	2927.5±9.872	3500 mg/L
TSS(mg/L)	143±16.274	2808±178.40	2794.4±164.34	2075±216.88	150 mg/L
DO(mg/L)	6.2±0.284	6.62±0.161	6.34±0.444	7.25±0.412	6 mg/L
BOD(mg/L)	51.43±9.056	408.7±3.941	472.5±46.347	610.3±15.027	80 mg/L
COD(mg/L)	72.51±6.555	803.4±16.985	126.4±6.364	210±4.647	150 mg/L
EC (µs/cm)	2026±25.823	3754±16.157	2521.6±25.842	4036±37.301	750 µs/cm
Cd(mg/L)	0.001±0.006	0.082±0.004	0.065±0.005	0.96±0.052	0.1 mg/L
Zn(mg/L)	1.107±0.239	2.62±0.191	1.614±0.136	2.27±0.113	5.0 mg/L
Pb(mg/L)	0.018±0.002	0.32±0.0351	0.324±0.157	1.262±0.126	0.5 mg/L
Cu(mg/L)	0.084±0.025	4.1±0.208	8.38±0.466	4.066±0.202	1.0 mg/L
Cr(mg/L)	1.123±0.055	2.24±0.143	2.55±0.078	3.14±0.255	1.0 mg/L
As(mg/L)	0.75±0.036	7.1±0.082	2.18±0.056	3.34±0.232	1.0g/L

1) Comparison of Average values with the Standard values:

The Mean values of pH of industry 1, 3 and 4 were in standard range of NEQS standards, which is 6-10. However, a high pH 12.75 was observed in the effluent of E2. Hence, the effluent was basic in nature. The mean values of temperature of all samples were below the permissible limit which was 40oC. The effluent samples were in range of 31-38oC. The total dissolved solids were also found below the standard value which is 3500 mg/L

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in all samples of effluent. These were within permissible range. The mean values of total suspended solids of the effluent of industry 1 were within the standard value i.e 150mg/L. However, the average values recorded for E2, E3 and E4 were very high.

The biological oxygen demand of effluent of E1 was under standard range but the values of other industrial effluent samples were very high. The value recorded was between 400 to 600mg/L of range. The dissolved oxygen was extremely low. The average value of chemical oxygen demand of effluent of industry 1 and 3 were under the normal range of standard value. The COD of E4 was slightly higher than the standard limits. And the COD value of E2 was very high i.e almost 804 mg/L. The dissolved oxygen of samples of industries was near the limit of standard described by WHO. The temperatures of samples were under the limit of NEQS therefore, the dissolved oxygen was also present in adequate concentration.

The standard value of electrical conductivity described by WHO is 750 µs/cm. The electrical conductivity values recorded from samples of all industrial effluent were very high. They were in range of 2000 to 4000 µs/cm.

For heavy metals, cadmium was within the normal range of standards for E1, E2 and E3 but was slightly higher in the effluent of E4. The zinc concentration was noted in the normal range of standard for all samples. The lead concentration was slightly higher in water of E4 as compared to other three industries which showed normal values. Copper concentration was only normal in effluent of E1 and was many folds high in other three industrial effluents i-e up to 8mg/L. The average value noted for chromium was higher in effluent samples of E2, E3 and E4. The value of E1 was within the range of standard limits. Arsenic was also present in the effluent samples. The range of arsenic in effluent of E2 and E4 was many folds high. The concentration in E1 was normal and that of E3 was also high but somehow near to the standard value.

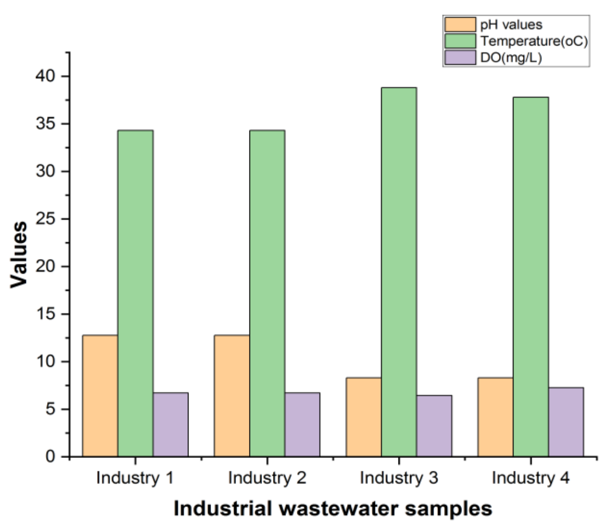

Fig 1: Observed Average values for pH, Temperature and DO of four industries

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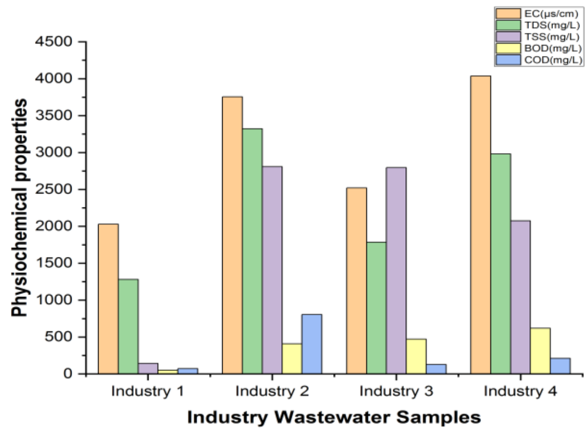

Fig 2: Observed/Average value for EC, TDS, TSS, BOD and COD of four industries

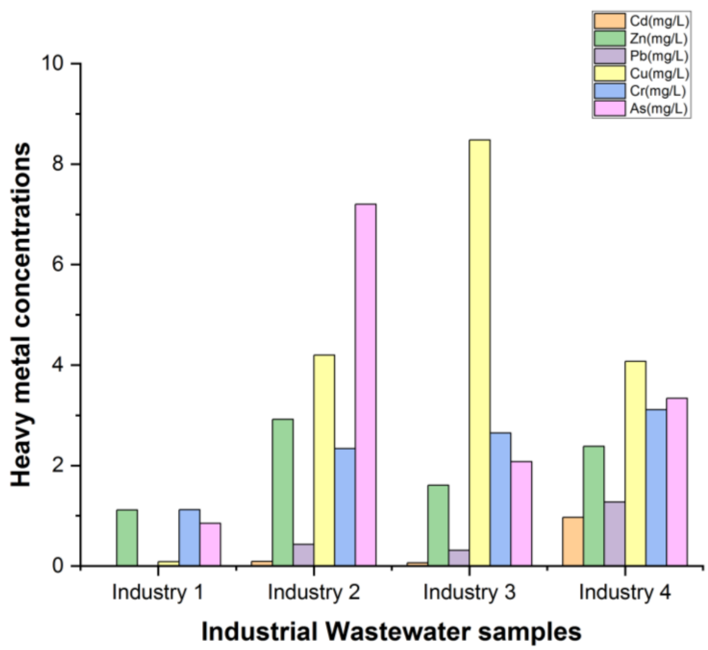

Fig 3: Observed/Average concentration for Cd, Zn, Pb, Cu, Cr and As. of four industries

2) Identification of algae through Light Microscope and SEM:

The BGA specie were identified under light microscope According to appearance under Light Microscope blue green algae present in sample were bead-like strings as shown in the figure 4, and belongs to nostoc genus. These are freshwater photosynthetic specie. These contain an outer layer and an inner matrix.

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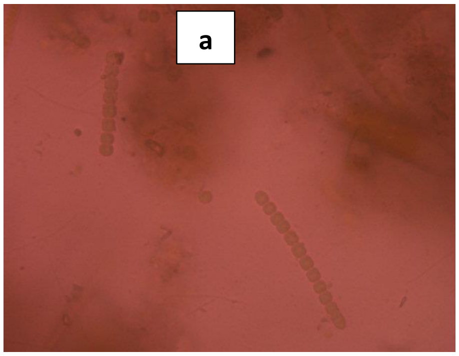

Fig 4 (a): Blue green algae detected under light microscope

1. XRD analysis:

The X-ray diffraction results of blue green algae was observed and recorded as graph. The sharp peaks of graph showing high intensity sample and hence resulting in crystalline material and broad peaks showing the low intensity revealing an amorphous nature of sample material. The following graph shows that the peaks are not sharp enough. According to results, the sample was 25% crystalline. Hence, it is semi-crystallized polymeric substance (amorphous). Results reveals that algae of amorphous nature can act as a good absorbent because they have high strength, good porosity and high chemical stability.

FTIR results:

The Fourier-transform Infrared spectroscopy results of blue green algae sample are plotted below as a graph. According to it, seven regionswere taken for interpretation according to which various functional groups were present there. These wave numbers were in range of 1022 to 3658cm-1. Results were interpreted by following literature of Coates, 2000.

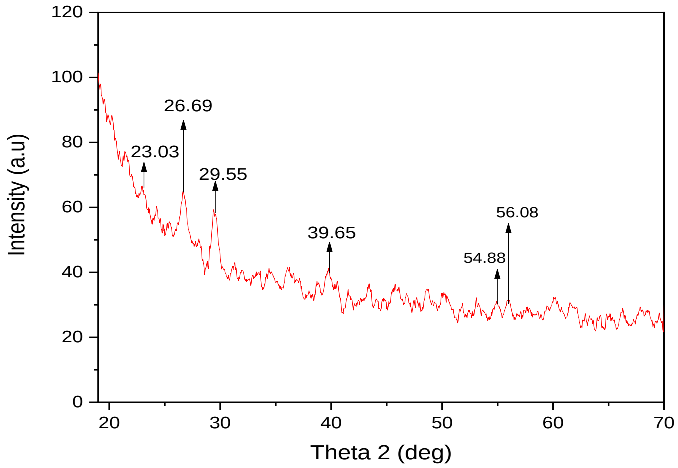

Fig 5: XRD graph of sample (25% crystallinity)

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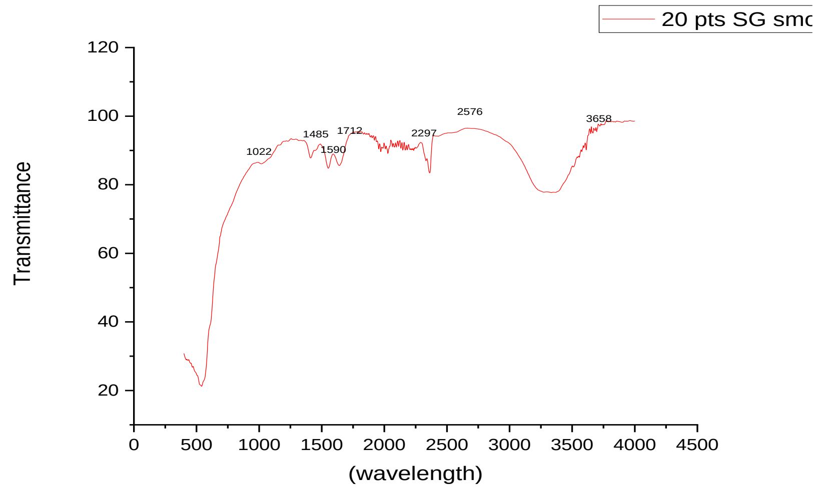

Fig 6: FTIR graph of sample

Functional group Interpretation:

In the region of first wavenumber i-e 1022cm-1, here lies the possibility of in the region of 1485cm-1 wavenumber shows that methylene C-H bond, aromatic nitro compounds and carbonate ion were present. At 1590cm-1, various combinations of functional groups were expected to be present. These include primary and secondary amine aromatic ring (aryl), NH bond, carboxylate, open chain amino and azo. At the fifth wavenumber i-e 2297cm-1, aliphatic nitrile/cyanide was present. At about 2578cm-1 wavenumber, thiols (S-H stretch) were detected. Further At about 1712cm-1, ketone and carboxylic acid was present. Lastly, at the wavenumber 3658cm-1, non-bonded hydroxyl group (OH stretch) was detected.

Because the functional groups found in the sample i-e, methanethiols, carbonyl, amino, carboxylic acid, and hydroxyl group (OH stretch) possess good absorbent properties and hence show that it can remove metals successfully so After analyzing the functional groups in the sample, it was concluded that the sample algae is a good absorbent of metals..

2. Biomass determination through spectrophotometer

A flask containing syntheic media was used to determine the biomass of blue green algae at 680nm upon regular time intervals under Uv visible Spectrophotometer. Growth pattern was recorded for 12 days. Maximum growth of algae was recorded at 6 and 7 day under observation. After seven days the growth started to be declined slowly. Optical density was calculated by the following formula:

DOPT = αxl Where;

DOPT = Optical Density, A(α) = absorbance coefficient = 2.303x A/l, l = thickness = 1cm

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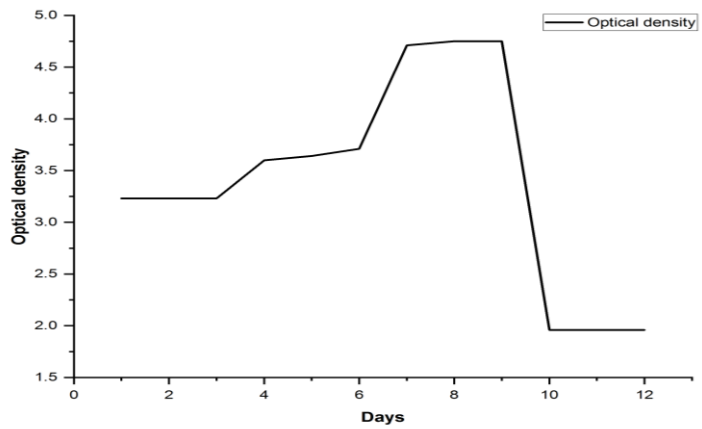

Fig 7: Graph curve showing growth pattern of blue-green algae

The artificial (BG11) medium shows the highest rate in the growth of many species of the cyanobacteria genus (University of Texas, 2009). Some other researchers also used cyanophycean agar, basal broth media or combination of BG11 media with some other media and salts. Such as species including Synechococus elongtus, Leptolyngbya, Anabaena, Synechocystis and Oscillatoria were grown in BG11 medium (Khan,2018). Microcystis was grown in BG11 medium (BG11 without combined nitrogen) supplemented with sodium nitrate and sodium bicarbonate. In a work conducted by Haande, 2008 explained that high values of Cod, Nirates, BOD and Phosphate with low Dissolved Oxygen favored the development of Blue Green Agae than any other algae. Their outcomes were reinforced by the observations of Jacob et al., 2018 and Darda et al., 2019, in diverse industry effluents respectively. Growth and biodegradation abilities were affected by microbial species, their natural environment, contaminants concentration, contact time and use as individual or mixed cultures.

Heavy metals analysis:

The effluents of various textile industries were analyzed for trace metals concentrations and also for the remediation abilities of algal biomass. The data of heavy metal concentrations, before and after remediation processes is gathered below for every metal. The remediation ability of blue green algae was determined through the following formula:

Adsorption (%) = $(C_i - C_f) \times 100/C_i$ where;

C_i – initial concentration and C_f – final concentration

Being an environmental friendly method, phycoremediation possess many benefits such as algal biomass may be utilized for various purposes over a period of years (Salama et al., 2017), algae possesses the ability to remove diverse pollutants (e.g., pesticides, heavy metals, organic and inorganic toxins); in diluted effluents, these are reletively effective because of their high surface area to volume ratio, these are appropriate even in effluent containing higher heavy metal concentrations, algae are suitable for anaerobic

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and aerobic effluent treatment units and cultures of algae may be grown on large-scale, and also in the laboratory and open ponds (Acuner and Dilek 2004).

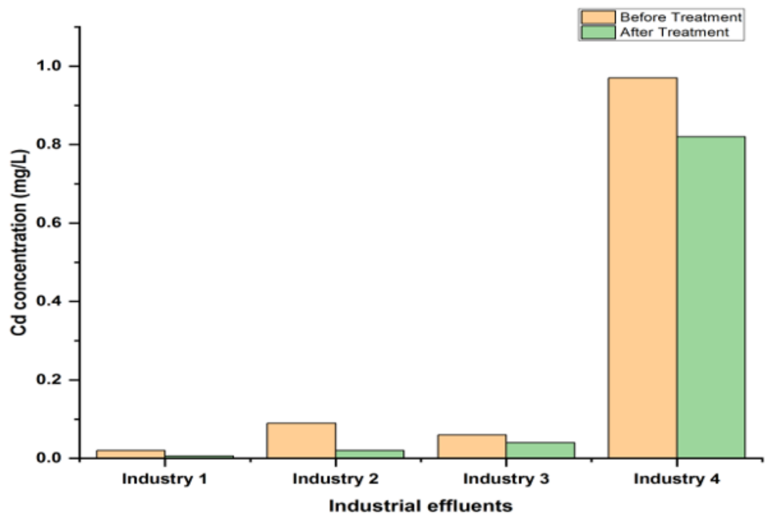

Fig 8: Cadmium concentration (mg/L) before and after treatment of effluent

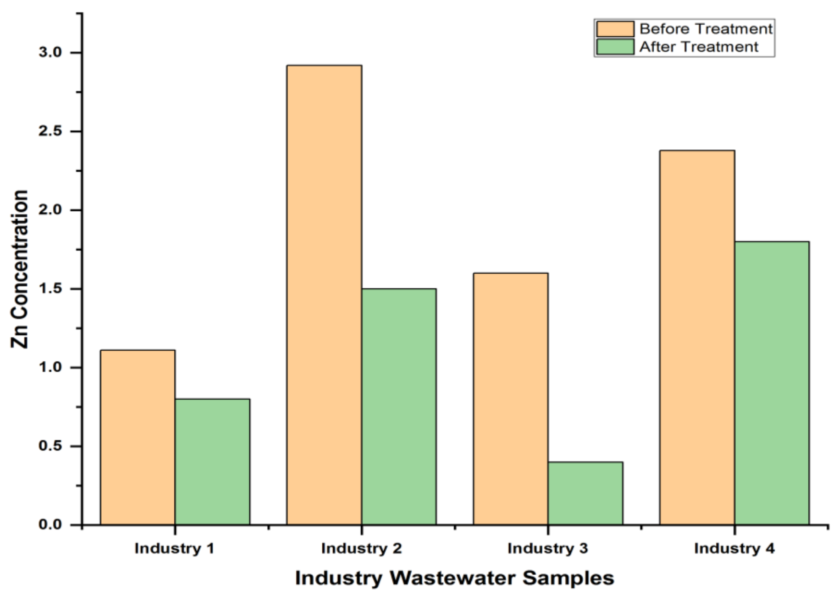

Fig 9: Zinc concentration before and after treatment of effluent

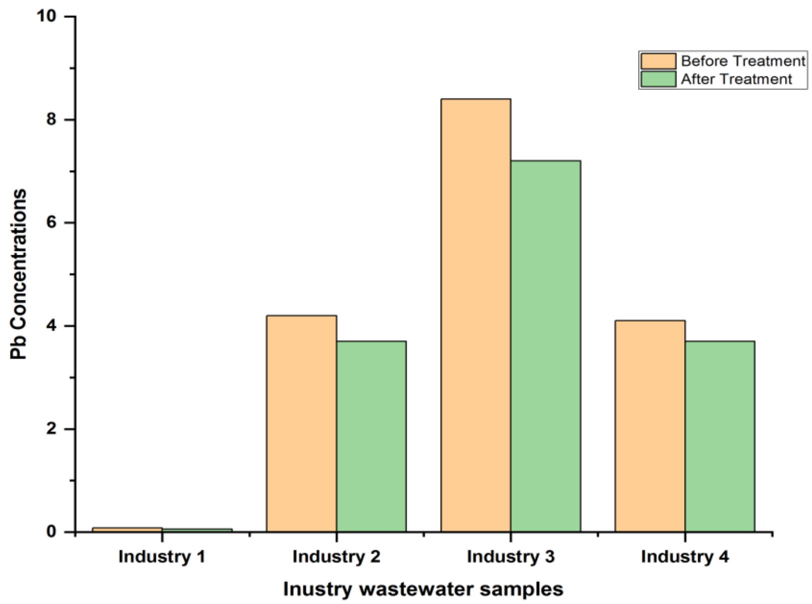

Fig 10: Lead concentration before and after treatment of effluent

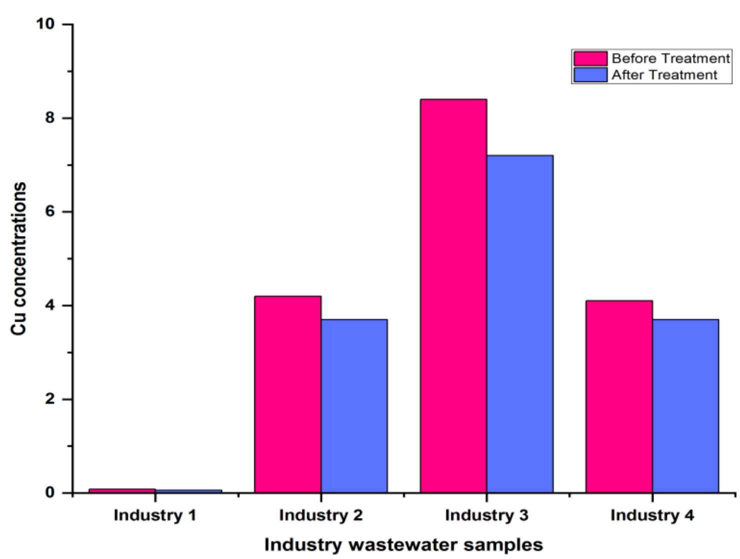

Fig 11: Copper concentration before and after treatment of effluent

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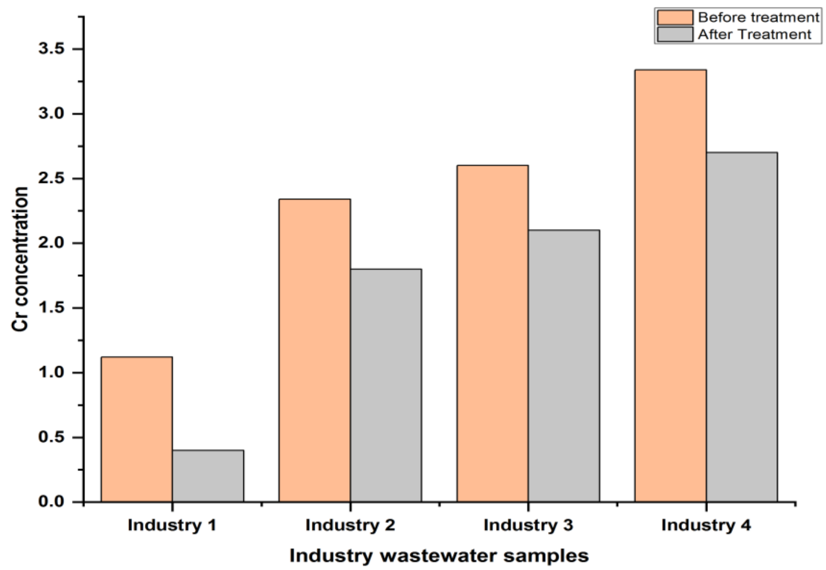

Fig 12: Chromium concentration before and after treatment of effluent

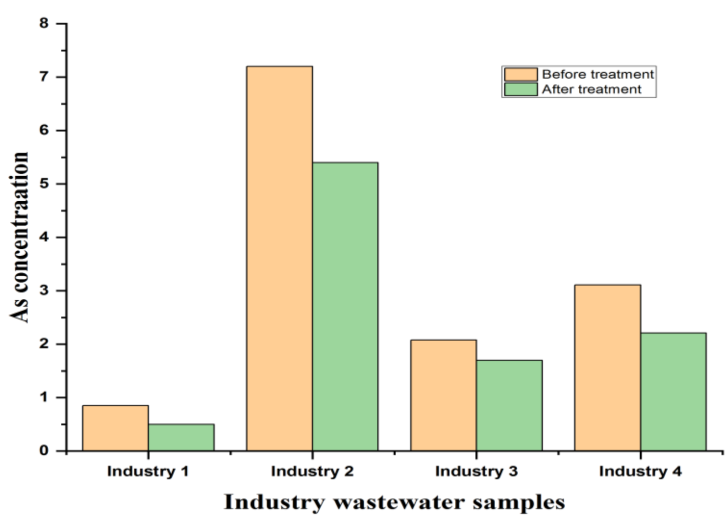

Fig 13: Arsenic concentration before and after treatment of effluent

Metal removal efficacy of Algae:

Blue green algae removed the 28.1% of Arsenic, 30.1% of Chromium, 15.1% of Copper, 37.6% of Lead, 43.6% of zinc and 48.6% of Cadmium. Among various processes of heavy metal removal biosorption method shows high potential for heavy metal removal. To eliminate pollutants, various processes including aerobic/anaerobic biological treatment,

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chemical oxidation and photolytic analysis are being utilized (Verma and Kumar, 2023). Freshly, a research work by Shen et al., 2018 described the high efficacy of Cadmium removal utilizing Chlorella sp. A greater bioaccumulation volume of 13.71 mg/g of the complex of water hyacinth biochar immobilized with algal cells was achieved. The study also revealed that intracellularly sorbed Cadmium accounted for 34.7% of the total heavy metal ions adsorbed. Recovery tests showed that both the biochar pellets and algal cells could be reused and recycled. Metal removal by common physico-chemical techniques is expensive and not environment friendly hence, biotechnological methods have received a larger deal of consideration as an alternative source in current years. The use of microbial cells (microalgae, fungi and bacteria etc.) for the determination of heavy metal elimination has been extravagantly studied by Malik, 2004. In adding to cells, seaweeds are also known to have the capacity to remove trace metals from the nearby seawater (Davis, 2000).

4. CONCLUSION

With increasing population worldwide high consumption of resources are resulting in high pollution and environment degradation and climate change. For control of pollution in environment various cost effective and sustainable stratagies are being introduced. In our concerned water pollution is sourced from domestic and industrial outputs. It is need of time to introduce some ecofriendly techniques to remediate this polluted water, Hense under our study it is concluded from all experimentation that algal species can be a better option to treat contaminated industrial effluents for chemical parameters such as high BOD, COD and trace metals. Algae have many benefits as it is less costly, gives high growth and can prevail rapidly in contaminated water and are considered to be the good absorbant. Other recommendations can be taken from the results of this study that various other algal species can be utilized for the treatment of textile effluents as well as for other industries relevant to dealing with high organic load such as industries relevant to food and food products.

References

1) Darley, WM. Algal biology. A physiological approach. Blackwell Scientifi c, Oxford. 1982.

2) Bhaskar US, Gopalswamy G, Raghu R.,. A simple method for differential extraction and purifi cation of C-phycocyanin from Spirulina platensis Geitler. Indian J Exp Biol. B. 2005, 43:277–279.

3) Subhashini J, Mahipal SV, Reddy MC.. Molecular mechanism in C-phycocyanin induced apoptosis in human chronic myeloid leukaemia cell line K562. Biochem Pharmacol. 2014, 68:435–462.

4) Kushak R, VanCott E, Drapeau C, Winter H.,. Effect of algae Aphanizomenon fl os - aquae on digestive enzyme activity and polyunsaturated fatty acids level in blood plasma. Gastroenterology 1999, 116:A559.

5) Valencia A, Walker J. Amulti-axial treatment paradigm for mild traumatic brain injury to achieve reparative functional metaplasticity. 3rd World Congress on Brain Injury, IBIA, Quebec City. 1999.

6) Mohan, M.,. Effi cacy of Spirulina fusiformis in a case of rheumatoid arthritis. In: Seshadri CV, Jeeji Bai N (eds) Spirulina ETTA national symposium MCRC, Madras. 1992, p 140.

7) Bilal M, Rasheed T, Sosa-Hernandez JE, Raza A, Nabeel F, Iqbal HMN.. Biosorption: an interplay between marine algae and potentially toxic elements- a review. Mar Drugs. 2018, 16:65.

8) Vikrant K, Giri BS, Raza N, Roy K, Kim KH, Rai BN, Singh RS.. Recent advancements in bioremediation of dye: current status and challenges. Bioresour Technol. 2018, 253:355–67.

9) Azimi A, Azari A, Rezakazemi M, Ansarpour M.. Removal of heavy metals from industrial effluents: a review. ChemBioEng Rev. 2017, 4:37–59.

10) Ghosh A, Ghosh Dastidar M, Sreekrishnan TR.. Recent advances in bioremediation of heavy metals and metal complex dyes: review. J Environ Eng. 2016, 142(9):C4015003.

11) Francis O., O. Biosorption of selected heavy metals using green algae Spirogyra Species. J Nat Sci Res. 2016, 6:22–34.

12) Surisetty VR, Kozinski J, Rao Nageswara L.,. Biosorption of lead ions from aqueous solution using Ficus benghalensis L. J Eng. 2013, 2013:1–8.

13) Forutan R, Ehsandoost E, Hadipour S, Mobaraki Z, Saleki M, Mohebbi G.. Kinetic and equilibrium studies on the adsorption of lead by the chitin of pink shrimp (Solenocera melantho). Entomol Appl Sci Lett 2017, 3:20–26.

14) Ecer U, Tekin S.. A response surface approach for optimization of Pb(II) biosorption conditions from aqueous environment with Polyporus squamosus fungi as a new biosorbent and kinetic, equilibrium and thermodynamic studies. Desalination Water Treat. 2018, 102:229–240.

15) Chu WL.. Strategies to enhance production of microalgal biomass and lipids for biofuel feedstock. Eur J Phycol. 2017, 52:419–37.

16) Chakraborty N, Banerjee A, Lahiri S, Panda A, Ghosh AN, Pal R. Biorecovery of gold using cyanobacteria and an eukaryotic alga with special reference to nanogold formation – a novel phenomenon. J Appl Phycol 2009, 21:145–152.

17) Coates, J.. Interpretation of infrared spectra, a practical approach. Encyclopedia of analytical chemistry, 2000, 12, 10815-10837.

18) Kumar, K.S.; Dahms, H.U.; Won, E.J.; Lee, J.S.;. Shin, K.H. Microalgae—A promising tool for heavy metal remediation. Ecotoxicol. Environ. Saf., 2015, 113, 329–352.

19) Park, D.M.. Bioadsorption of rare earth elements through cell surface display of lanthanide binding tags. Environ. Sci. Technol., 2016, 50, 2735–2742.

20) Coltelli, P., Barsanti, L., Evangelista, V., Frassanito, A. M., & Gualtieri, P. (2014). Water monitoring: automated and real time identification and classification of algae using digital microscopy. Environmental Science: Processes & Impacts, 16(11), 2656-2665.

21) Anastopoulos, I.; Kyzas, G.Z.. Progress in batch biosorption of heavy metals onto algae. J. Mol. Liq. 2015, 209, 77–86.

22) Zeraatkar, A.K.; Ahmadzadeh, H.; Talebi, A.F.; Moheimani, N.R.; McHenry, M.P. Potential use of algae for heavy metal bioremediation, a critical review. J. Environ. Manag., 2016, 181, 817–831.

23) Zahra, N.; Kalim, I.. Perilous effects of heavy metals contamination on human health. Pak. J. Anal. Environ. Chem., 2017, 18, 1–17.

24) Dhaouefi Z, Toledo-Cervantes A, García D, Bedoui A, Ghedira K, Chekir-Ghedira L, Muñoz R.. Assessing textile effluent treatment in an anoxic-aerobic photobioreactor and the potential of the treated water for irrigation. Algal Res. 2018, 29:170–8.

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25) El-Sheekh, M. M., El Shafay, S. M., El-Shanshoury, A. E. R. R., Hamouda, R., Gharieb, D. Y., & Abou-El-Souod, G. W.. Impact of immobilized algae and its consortium in biodegradation of the textile dyes. International Journal of Phytoremediation, 2022, 1-10.

26) Van Baalen, C. . : Quantitative surface plating of coccoid blue green algae. – J. Phycol. 1967, 3: 154-157.

27) Stanier, R. Y., Kunisawa, R., Mandel, M., and Cohen-Bazire, G.. Purification and properties of unicellular blue-green algae (order chroococcales). Bacteriol. Rev. 1971, 35, 171-205.

28) Venkateshwarlu, V.. Taxonomy and ecology of algae in the river Moosi. Hyderabad (India). Nova Hedwigia, 1976, 27: 661-676.

29) Khan MM, Cho M.H. Positively charged gold nanoparticles for hydrogen peroxide detection. BioNanoScience. 2018, 8(2):537–543.

30) Haande, S.,. On the ecology, toxicology, and phylogeny of cyanobacteria in Murchison Bay of Lake Victoria, Uganda. Ph.D. Thesis, University of Bergen, Norway. 2008.

31) Jacob, J.M.; Karthik, C.; Saratale, R.G.; Kumar, S.S.; Prabakar, D.; Kadirvelu, K.. Biological approaches to tackle heavy metal pollution: A survey of literature. J. Environ. Manag.,2018, 217, 56–70.

32) Darda, S.; Papalas, T.; Zabaniotou, A.. Biofuels journey in Europe: Currently the way to low carbon economy sustainability is still a challenge. J. Clean. Prod., 2019, 208, 575–588.

33) Salama, E.S.; Kurade, M.B.; Abou-Shanab, R.A.; El-Dalatony, M.M.; Yang, I.-S.; Min, B.; Jeon, B.-H.. Recent progress in microalgal biomass production coupled with effluent treatment for biofuel generation. Renew. Sustain. Energy Rev., 2017, 79, 1189–1211.

34) Acuner, E., & Dilek, F.. Treatment of tectilon yellow 2G by Chlorella vulgaris. Process Biochemistry, 2004, 39(5), 623–631.

35) Verma, G., & Kumar, A.. Recent Advances in Downstream Processing Deployed in the Treatment of Pharmaceutical Effluents. Biomanufacturing for Sustainable Production of Biomolecules, 2023, 45-66.

36) Shen Y, Zhu W, Li H, Ho SH, Chen J, Xie Y, Shi X.. Enhancing cadmium bioremediation by a complex of water-hyacinth derived pellets immobilized with Chlorella sp. Bioresour Technol. 2018, 257:157–63.

37) Malik A.. Metal bioremediation through growing cells. **Environ. International**, 2004, 30: 261–78.

38) Davis T.A., Volesky B., and Vieira R.H.S.F.. Sargassum seaweed as biosorbent for heavy metals. **Water Res.**, 2000, 34: 4270–8.

39) Wu, J., & Wang, T.. Ozonation of aqueous azo dye in a semi-batch reactor. Water Research, 2001, 35(4), 1093–1099.

40) Abdoul, H. J., Yi, M., Prieto, M., Yue, H., Ellis, G. J., Clark, J. H., & Shuttleworth, P. S.. Efficient adsorption of bulky reactive dyes from water using sustainably-derived mesoporous carbons. Environmental Research, 2023, 115254.

41) Safi, C., Zebib, B., Merah, O., Pontalier, P.-Y., & Vaca-Garcia, C.. Morphology, composition, production, processing, and applications of Chlorella vulgaris: A review. Renewable and Sustainable Energy Reviews, 2014, 35, 265–278.

42) Rao, P. H. R., R. Kumar, B. G. Raghavan, V. V. Subramanian, V. Sivasubramanian.. Application of phycoremediation technology in the treatment of effluent from a leather-processing chemical manufacturing facility. Water SA 2011, 37(1):07–14.

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DOI: 10.5281/zenodo.12204762

43) Chinnasamy, S., A. Bhatnagar, R. W. Hunt and K.C. Das.. Microalgae cultivation in a effluent dominated by carpet mill effluents for biofuel applications. Biores. Technol. 2010, 101:3097–3105.

44) Tarlan, E., U. Yetis and F.B. Dilek.. Algal treatment of pulp and paper industry effluents in SBR systems. Water Science and Technology. 2002, 45: 151-158.

45) Mulbry, W., S. Kondrad, C. Pizarro and E. Kebede-Westhead... Treatment of dairy manure effluent using freshwater algae: Algal productivity and recovery of manure nutrients using pilot-scale algal turf scrubbers. Bioresourc. Tech. 2008, 99:8137–8142.

46) Arora, A. and S. Saxena.. Cultivation of Azolla microphylla biomass on secondary-treated Delhi municipal effluents. Biomass Bioenergy. 2005, 29: 60–64.

47) Ananya, A. K., & Ahmad, I. Z. (2014). Cyanobacteria" the blue green algae" and its novel applications: A brief review. International Journal of Innovation and Applied Studies, 7(1), 251.

48) Mishra, D., Rajvir, S., Mishra, U., & Kumar, S. S. (2013). Role of biofertilizer in organic agriculture: a review. Research Journal of Recent Sciences ISSN, 2277, 2502.