

Microalgae Potentials for Phycoremediation with Paint Effluent of Electroplating Industry

M. Muthukumaran*

PG and Research Department of Botany, Ramakrishna Mission Vivekananda College (Autonomous),
(Affiliated to the University of Madras), Chennai – 600 004, Tamil Nadu, India

*Corresponding author: muthukumaran.tni@gmail.com, mmuthukumaran@rkmcvc.ac.in

Received October 17, 2022; Revised November 22, 2022; Accepted December 04, 2022

Abstract Water pollution is a one of the major environmental issue that the world is facing nowadays. The untreated effluent as well as the chemically treated effluent both results in pollutions. These toxic contaminants directly and indirectly affect the flora and fauna of the ecosystem. The solution for such a drastic environmental issue lies within the cells of one such cosmopolitan plant group namely “Algae”. These are certain algal species which have the inhibit capacity to utilize some of the most threatening environmental contaminants such as nitrogenous compounds, ammonia, phosphates and some of the metal ions so on. Hence, treating the effluent with algae would be an eco-friendly method to reduce pollution. Phycoremediation of effluent using algae is a novel green-technique when applied to aqueous pollution. The present investigation included the preliminary screening of microalgae potentials for their tolerance and growth in paint effluent from an electroplating industry which include the native microalgae isolated from the effluent treatment plant (ETP). The microalgae, such as *Chlamydomonas pertusa*, *Dactylococcopsis raphioides* and *Chlorococcum humicola* were selected and employed in the treatment of electroplating paint effluent an individually and also as mixed algal group. The physico-chemical parameters were analyzed. The individual culture and the mixed algal culture both could effectively reduce TDS (Total Dissolved Solid), TSS (Total Suspended Solid), free ammonia, calcium, sodium, nitrate and phosphate. *Chlorococcum humicola* had a significant remedial level of Turbidity (20.51%), Calcium (95.76%), Sodium (8.33%), Free ammonia (62.96%), Phosphate (71.29%) and Total Kjeldhal Nitrogen (48.23%) treated with paint effluent of electroplating industry among the microalgae. Thus, *Chlorococcum humicola* could be selected for further field pilot scaling up study. Phycoremediation is a cost-effective, efficient and a sustainable technology for future clean earth.

Keywords: electroplating industry, green-technology, microalgae, paint effluent, Phycoremediation

Cite This Article: M. Muthukumaran, “Microalgae Potentials for Phycoremediation with Paint Effluent of Electroplating Industry.” *Applied Ecology and Environmental Sciences*, vol. 10, no. 12 (2022): 702-711. doi: 10.12691/aees-10-12-1.

1. Introduction

The environmental contamination is increasing day-by-day due to the various anthropogenic activities. The different kinds of toxic pollutants such as organic/inorganic chemicals, dyes, heavy metals, pesticides etc. enter in to the environment from different sources such as municipal, agricultural and industries [1]. Algae are a group of photosynthetic organisms which can thrive even in harsh environment. They have a high potential to eradicate pollutants from the effluents of industries and urban zones [2]. The prospective applications of phycoremediation have prompted laboratories to reinforce the improvement of algal based green technologies for healthier manipulation of their bioremediation potential and by-product generation capacity [3]. Microalgae based biorefinery together with effluent treatment method also enhances the economical biomass production [4]. The phycoremediation mechanism of heavy metals in

wastewater by using probable microalgae and their improved products was analyzed [5]. Algal cultivation during wastewater management uptakes nutrients and assimilates CO₂ their by increasing the production of algal biomass [6]. The effectiveness of phycoremediation using microalgae for eliminating nutrients and heavy metals from the wastewater have been proved [7]. The domestic sewage wastewater treatment and biogas produced with microalgae based technology is cost-effective and eco-friendly [8]. Microalgae are very effective at eliminating various nutrients from municipal wastewater [9]. It had proven effective in eliminating heavy metals from the tannery effluent with the highest level [10]. The effective elimination of diazinon from the aqueous segment by a freshwater microalga, *Chlorella vulgaris* was done [11]. The usage of microalgae to eliminate nutrient from the municipal wastewater treatment has shown recent enhancements in the considerate of removal mechanisms and progress of both the suspended and non-suspended methods. This nutrient directly and indirectly utilized is proportional to the rate growth and biomass

concentration [12]. Microalgae are representing an outstanding model organism and could be used for various heavy metals and metalloids removals [13]. The use of potential cyanobacteria for the removal of various heavy metals and nutrients from wastewater is the gaining curiosity due to its cost-effective process and being ecologically benevolent [14].

The efficient removal of organic micronutrients from the urban wastewater treatment was studied in two pilot high-rate algal ponds using microalgae. This efficient removal reached from negligible to more than 90% depending on the compound of pollutant [15]. The effectiveness for the bioremediation of municipal wastewater was assessed by determining the COD (Chemical Oxygen Demand), total phosphorous content and total nitrogen at the end of each batch cultivation [16]. Mixotrophic microalgae biofilm established an applicability of assimilating this innovative cultivation method with wastewater for maximum efficacy [17]. Microalgae cultivation as an alternate method for treatment of anaerobic digestion effluent was surveyed using two microalgae species, *Chlorella protothecoids* and *Chlorella vulgaris*. Both algal species have effectively removed ammonia and nitrate from the four digesters treated effluents under different operated conditions [18]. The exclusive pilot-scale photobioreactor structure are highly scalable and provided an abundant opportunity for the *Chlorella* sp. biomass production coupled with wastewater treatment [19]. The performance of two microalgae, *Chlorella vulgaris* and *Pseudochlorella pringsheimii* was assessed for the phycoremediation of combined sewage and tannery effluent under the different dilutions. The result showed significant reduction in contaminants such as ammonia, phosphate, chemical oxygen demand and total chromium in the effluent for both the algal species [20]. The proficiency of the native algal strains, *Chlorella* sp. and *Scenedesmus* sp. in the integrated management system to treat the effluent from palm oil mill industry and capture to CO₂ from the flue gas was analyzed [21]. The microalga, *Chlorella* sp. was cultivated in the batch photobioreactor (PBR) with various nitrogen sources to determine the biomass retention time (BRT) on nutrient uptake and biomass productivity showed that the algal biomass yield increase as the BRT reduced, leading to an increase in pollutant elimination rates very effectively [22]. The high rate algal pond (HRAP) methods have provided opportunities for low-cost wastewater treatment and energy retrieval from the wastewaters and waste solids, as well as biofuel production after harvesting algal biomass [23]. This method is beneficial perception to help future improvement of effluent and commercially feasible technology for microalgae based heavy metals and nutrients removal using bioremediation [24].

Each type of industry produces its own kind of chemical contaminants in its effluent. There are specific algal species which individually react with this toxic pollutant. This research basically concentrates finding the algal species which is more efficient in treating paint effluent from an electroplating industry. In this view, the present investigation comprises the preliminary screening of microalgal potentiality for their tolerance and growth in the paint effluent from an electroplating industry which

include the native microalgae isolated from the effluent treatment plant (ETP).

2. Materials and Methods

The experiment was studied in the PG and Research Department of Botany, Ramakrishna Mission Vivekananda College (Autonomous), Chennai – 600004, Tamil Nadu, India. The collected and isolated potentials microalgal species from effluent treatment plant (ETP) of electroplating industry were grown in the culture medium of Bold Basal Medium (1965), Central Food Technological Research Institute (1954) and raw effluent in the laboratory. The cultures were grown at $24 \pm 1^\circ\text{C}$ in a thermo-statically controlled environmental chamber illuminated with cool white fluorescent lamps (Philips 40w, cool daylight, 6500k) at an intensity of 2000 LUX in a 12/12 hours light/dark cycle. The feasibility study of microalgae potentials for their tolerance and growth in the paint effluent from an electroplating industry was investigated. The various parameters were analyzed after phycoremediation of paint effluent. Growth was measured by counting cells using a Hemacytometer (Neubauer, improved) and dry weight bases, pH was measured using digital pH meter (Elico LI 120), conductivity using digital conductivity meter (Equiptronics EQ - 660A) and estimation of physic-chemical parameters by American Public Health Association (2000) methods respectively.

3. Results and Discussion

The proliferation of industries to meet the basic needs of mankind increases the problem of pollution. The biological treatment is an important and vital part of any wastewater management plant that treats effluents from whichever municipality or industry having an organic, inorganic impurities and heavy metals [25]. The biotechnology of microalgae has expanded attractiveness due to the growing essential for novel environment green-technologies and the improvement of advanced mass production [26]. Microalgae based heavy metals bioremediation is reflected as a potential solution for determining present environmental glitches [27]. The algal based sewage treatment plant recycle 67.65 million liters per day of domestic wastewater and have recognize the role of algae in the treatment of sewage [28]. Phycoremediation using the native microalgae from the natural sources provided a capable process for bifenthrin elimination with the predominant algal species *Parachlorella kessleri* facilitating the biodegradation and biosorption process [29]. The best reduction was achieved by the microalga *Chlorella* sp. with municipal wastewater and triggered sludge treatment [16]. The influence of calcium peroxide pretreatment on sulfonamide antibiotic remediation by microalga, *Chlorella* sp. was done [30]. *Chlorella vulgaris* has an extraordinary potential to endure as well as uptake nutrients and heavy metals from tannery wastewater treatment [31]. The cyanobacteria, *Chroococcus turgidus* can be used in the mixed wastewater including domestic, textile and milk industrial bioremediation process which was very significant for

resource management and sustainable environment [32]. The outdoor cultivation of two microalgal species, *Chlorella* sp. and *Scenedesmus* sp. in the raw anaerobically digested abattoir effluent (ADAE) which were exposed to both continuous (24 hours) and daytime only (12 hours) paddle wheel mixing method was done. The microalga, *Scenedesmus* sp. established higher biomass productivity and nutrient elimination efficiency in the ADAE when compared to the *Chlorella* sp., with the continuously mixed cultures being most resourceful [33].

The potential application of microalga, *Chlorella vulgaris* for phycoremediation of textile wastewater (TW) treatment was examined using four batches of cultures in high-rate algal ponds (HRAP) containing dye effluent. The biomass achieved ranged from 0.17 to 2.26 mg chlorophyll a/L while colour removal range from 41.8% to 50%. There was also reduction of ammonia (44.4–45.1%), phosphate (33.1–33.3%) and chemical oxygen demand (38.3–62.3%) in the treated textile wastewater [34]. The acid-producing effluent was recycled three times utilization by heterotrophic potential microalga, *Chlorella sorokiniana*, the significant removal rates of chemical oxygen demand of 74.44%, total nitrogen of 88.05%, ammonia nitrogen of 79.08% and total phosphorus 82.69% was estimated [35]. The efficiency of *Scenedesmus* sp. to remediate heavy metals from the wet market wastewater highest level 93.06% of cadmium, 92.40% of iron, 92.40% of zinc and 91.50% of chromium respectively was analyzed [7]. The Zinc captivation by biomass of *Spirulina platensis* has been used to remove many pollutants by absorption in electroplating industrial effluent [36]. Potentially adverse effects of microalga, *Chlorella vulgaris* in the removal of sulfonamides and heavy metal of copper are frequently detected together in livestock wastewater treatment [37]. *Chlorella vulgaris* potentially remediated 98.63% of petroleum hydrocarbons and COD of 75% from crude oil exploration wastewater treatment for safe disposal [38]. An innovative system that associate centrate wastewater management and microalgae cultivation was established and tested under low light situations with different harvesting rates and CO₂ inoculation levels by using a nearby screened algal strain of *Chlorella* sp. The system can yield 34.6 g m⁻² day⁻¹ TSS (total suspended solids) and 17.7 ± 4.2 g m⁻² day⁻¹ VSS (volatile suspended solids) and removed 70% COD (chemical oxygen demand), 61% TKN (total Kjeldahl nitrogen), and 61% STP (soluble total phosphorus) compared to other methods [19]. The flagellate unicellular organism, *Euglena proxima* isolated from the tannery industrial effluent showed the tolerance against chromium (Cr⁶⁺) and lead (Pb²⁺). Chromium and lead treating abilities of *Euglena proxima* were operated for its potential usage as bioremediator of wastewater. *Euglena proxima* could also remove heavy metals such as Cr⁶⁺ of 88% and Pb²⁺ of 84% very effectively. The uptake ability of heavy metals by *Euglena proxima* can be demoralized for metal decontamination and environmental clean-up processes [39]. The feasibility of cultivated microalgae, *Chlorella* sp. and *Scenedesmus* sp. to succeed in the tannery effluent was analyzed. Both the algae could effectively remove heavy metals such as chromium, copper, lead and zinc with the highest rates [10]. The dairy effluent treatment by immobilized algae, *Euglena gracilis*

and *Chlorella pyrenoidosa* significantly removed ammonia and phosphate in both open and closed methods [40].

The potential of cyanobacteria, *Lyngbya majuscula* biomass to remove Cu(II) of 99.15% from simulated wastewater treatment was done [41]. The bioaccumulation and biosorption in the microalga, *Arthrospira platensis* were effective approaches for the removal of various heavy metals from Yamuna river water treatment [42]. Three microalgal species were investigated for their capability to accumulated metal ions. The microalgae, *Chlorella* sp., *Scenedesmus* sp., and *Selenastrum* sp. were found proficient in accruing metals such as copper, chromium and lead with 67% to 98% efficiency [43]. *Anabaena variabilis* cultivation in waste utilized medium have revealed its excellent phycoremediation ability [44]. The microalga *Scenedesmus obliquus* used in brewery wastewater treatment and biomass production showed, a higher reduction chemical oxygen demand of 57.5% and total nitrogen of 20.8% respectively [45]. *Synechocystis* sp., which grew fast and flourished in wastewater with phosphate and ammonium showed removal efficiencies of 97.5% and 99.4% [46]. The potentials of microalgae *Scenedesmus quadricauda* and *Chlorella vulgaris* were effectively involved for wastewater treatment and removal of heavy metals. The microalgae contaminants removal efficiency reached to BOD (92.7%), COD (87.5%) and 100% for TN and TP. The removal of heavy metals by microalgae reached to Cu (98.8%), Zn (90.4%), Cd (83.9%), Ni (75.7%), Co (99.8%), Fe (99.7%) and Pb (99.5%) in the similar way [47]. The significant removal of heavy metals, such as Zinc and Copper by green microalgae *Monoraphidium pusillum* and *Desmodesmus communis*, when applied to the wastewater treatment was proved [48]. The most effective treatment of municipal wastewater by alga, *Muriellopsis* sp., was pilot-scale phycoremediation investigation (800-L raceway pond), which removed 93% of phosphorus and 84% of nitrogen and other chemical compounds after 4 days of treatment of wastewater [49].

3.1. Paint Effluent from Electroplating Industry

The paint effluent was collected from electroplating industry situated at Chennai. The effluent is generated from coating of wheels, this effluent which is alkaline, contains various chemicals, especially high Total Dissolved Solids (TDS), calcium chloride and heavy metals.

3.2. Growth of Various Microalgae in Electroplating Industrial Paint Effluent

The feasibility study was deals with the preliminary screening of potentials microalgae for their tolerance and growth in the paint effluent from an electroplating industry which include the native microalgae isolated from the effluent treatment plant (ETP) as well as the culture collection of microalgal species from the Department of Botany, Ramakrishna Mission Vivekananda College, Chennai, Tamil Nadu, India. The algae employed for the study were as follows; The microalgae, *Chlamydomonas pertusa*, *Dactylococcopsis raphioides*, *Desmococcus olivaceus*, *Chlorococcum humicola*, *Chroococcus turgidus*, *Chlorella vulgaris*,

Scenedesmus dimorphus and *Scenedesmus incrassatulus* were inoculated in to raw effluent and effluent amended with CFTRI and BBM nutrients and incubated for 7 days. Growth rate was studied and the results were tabulated based on the difference between the initial and final cells during log phase of individual algae.

Chlamydomonas pertusa, *Dactylococcopsis raphioides*, *Chlorococcum humicola*, *Chlorella vulgaris*, *Desmococcus olivaceus* and *Scenedesmus dimorphus* showed growth rate of 0.3060, 0.5378, 0.4525, 0.3018, 0.2170 and 0.2300 divisions/day respectively. *Scenedesmus incrassatulus* and *Chroococcus turgidus* did not grow in the effluent. When the effluent was supplemented with BBM, *Chlorococcum humicola* showed maximum growth rate (0.4265) followed by *Chlamydomonas pertusa* (0.4087 divisions/day). *Dactylococcopsis raphioides* showed 0.3281 divisions/day. *Scenedesmus dimorphus* exhibited a poor growth rate (0.0093 divisions/day). *Scenedesmus incrassatulus* did not grow in the BBM supplemented effluent. In the effluent supplemented with CFTRI nutrients, *Chlorococcum humicola* showed maximum growth rate (0.1520 divisions/day). *Dactylococcopsis raphioides* showed growth rate of 0.0120, *Chlamydomonas pertusa* showed 0.0406 divisions/day. The results are given in Figure 1. Paint effluent supported the growth of micro algae very well. So further experiments were conducted with paint effluent.

3.3. Phycoremediation of Electroplating Industrial Paint Effluent

Actively grown cells of *Chlamydomonas pertusa*, *Dactylococcopsis raphioides*, *Chlorococcum humicola*

and a mixture of all these algae were centrifuged and the washed pellet was resuspended in 2 litres of the effluent in a conical flask bioreactor and incubated in the culture rack for 10 days. The algae survived well when inoculated individually, whereas in the case of algal mixture, *Chlorococcum humicola* was found to be dominating with the growth rate of 0.2943 divisions/day. The effluent sample was analyzed for physico-chemical parameters before and after treatment and the results are shown in Table 1 – Table 3 and Figure 2 – Figure 9.

Phycoremediation could effectively reduce TDS, TSS, free ammonia, nitrate and phosphate very effectively all the individual microalga including mixed algal culture. The microalgae, such as *Chlorococcum humicola* was maximum reduce the Turbidity (20.51%), Calcium (95.76%), Sodium (8.33%), Free ammonia (62.96%), Phosphate (71.29%) and Total Kjeldhal Nitrogen (48.23%); followed by the *Chlamydomonas pertusa* was reduce the Total Solids (10.68%), Total Suspended Solids (60%) and Nitrate (21.42%) and *Dactylococcopsis raphioides* was reduce the Potassium (25%) respectively to treated with paint effluent of electroplating industry. The significant reduction of Total Dissolved Solids (5.47%), Total Hardness (5.66%), Calcium (5.76%), Magnesium (5.26%), Potassium (25%), Nitrate (95.48%), Flouride (20.16%), Chloride (7.13%) and Silica (24.93%) respectively when applied to treated with electroplating industrial paint effluent. *Chlorococcum humicola* was remediated significant level among the other microalgae. The potential microalga, *Chlorococcum humicola* could be selected for further field pilot scaling up this technology to manage paint effluent of electroplating industry.

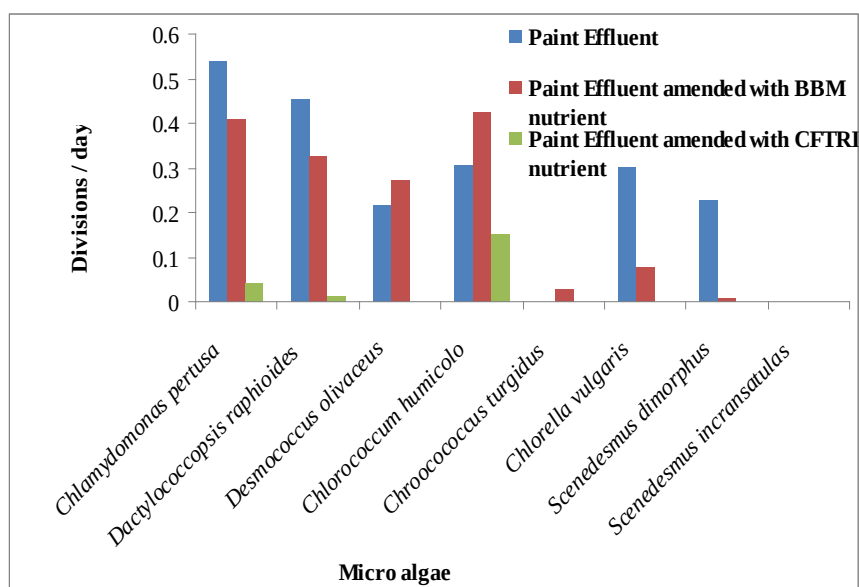


Figure 1. Growth rate comparison of various microalgae in electroplating industrial paint effluent amended with BBM and CFTRI nutrients

Table 1. Growth rate of mixed microalgae (10 days experiment) in electroplating industrial paint effluent

S.No	Micro algae	Growth Rate (Divisions/day)
1.	<i>Chlamydomonas pertusa</i>	0.2041
2.	<i>Dactylococcopsis raphioides</i>	0.1833
3.	<i>Chlorococcum humicola</i>	0.2943
4.	Mixed Algae	0.2827

Table 2. Comparison of parameters of raw and algae treated effluent in electroplating industrial paint effluent

Parameters	Raw effluent	Algae treated Effluent			
		A*	B*	C*	Mixed Algae
PHYSICAL EXAMINATION					
Turbidity NTU	85.8	72	83.8	68.2	71.4
Total solids mg/L	2921	2609	2812	2727	2711
Total Dissolved Solids (TDS) mg/L	2558	2464	2488	2476	2418
Total suspended solids (TSS) mg/L	363	145	324	251	293
Electrical conductivity (micro mho/cm)	3635	3505	3535	3515	3425
CHEMICAL EXAMINATION					
pH	8.55	9.55	9.45	9.97	9.61
Alkalinity pH (as Ca CO ₃) mg/L	28	84	128	180	124
Alkalinity total (as Ca CO ₃) mg/L	440	472	468	452	496
Total Hardness (as Ca CO ₃) mg/L	212	210	212	204	200
Calcium (as Ca) mg/L	55	54	53	52	52
Magnesium (as Mg) mg/L	18	18	19	18	17
Sodium (as Na) mg/L	720	690	670	660	680
Potassium (as K) mg/L	80	70	60	80	60
Iron (as Fe) mg/L	5.03	7.2	5.19	4.66	5.4
Manganese (as Mn) mg/L	Nil	Nil	Nil	Nil	Nil
Free ammonia (as NH ₃) mg/L	30.24	20.16	61.6	11.2	11.2
Nitrite (as NO ₂) mg/L	5.32	0.27	0.42	0.35	0.24
Nitrate (as NO ₃) mg/L	14	11	12	12	12
Chloride (as Cl) mg/L	75	733	743	752	703
Flouride (as F) mg/L	1.19	1.15	0.99	0.98	0.95
Sulphate (as SO ₄) mg/L	169	169	178	166	161
Phosphate (as PO ₄) mg/L	18.6	8.76	8.48	5.34	8.34
Tidy’s test (as O) mg/L	10.99	17.58	23.08	19.78	20.78
Silica (as SiO ₂) mg/L	24.66	24.05	31.01	19.39	18.51
BOD mg/L	35	60	72	90	66
COD mg/L	105	173	206	299	196
Total Kjeldhal Nitrogen mg/L	41.11	26.88	40.32	21.28	22.4
Copper (as Cu) mg/L	0.00556	0.00606	0.00625	0.00629	0.00606
Zinc (as Zn) mg/L	0.114	0.133	0.152	0.171	0.171
Chromium (as Cr) mg/L	0.00473	0.00472	0.00472	0.00629	0.00472

A*) *Chlamydomonas pertusa*B*) *Dactylococcopsis raphioides*C*) *Chlorococcum humicolo*

Table 3. Comparison of raw and algae treated effluent in electroplating industrial paint effluent under laboratory condition (% of reduction)

Parameters	Raw effluent	Algae treated Effluent			
		A*	B*	C*	Mixed Algae
PHYSICAL EXAMINATION					
Turbidity NTU	85.8	16.08	2.33	20.51	16.78
Total solids mg/L	2921	10.68	3.73	6.64	7.18
Total Dissolved Solids (TDS) mg/L	2558	3.67	2.73	3.20	5.47
Total suspended solids (TSS) mg/L	363	60	10.74	30.85	19.28
Electrical conductivity (micro mho/cm)	3635	3.63	2.75	3.30	5.77
CHEMICAL EXAMINATION					
pH	8.55	-	-	-	-
Alkalinity pH (as Ca CO ₃) mg/L	28	-	-	-	-
Alkalinity total (as Ca CO ₃) mg/L	440	-	-	-	-
Total Hardness (as Ca CO ₃) mg/L	212	0.95	0	3.77	5.66
Calcium (as Ca) mg/L	55	1.81	3.63	5.76	5.76
Magnesium (as Mg) mg/L	18	0	-	0	5.26
Sodium (as Na) mg/L	720	4.16	6.94	8.33	5.55
Potassium (as K) mg/L	80	12.5	25	0	25
Iron (as Fe) mg/L	5.03	-	-	-	-
Manganese (as Mn) mg/L	Nil	Nil	Nil	Nil	Nil
Free ammonia (as NH ₃) mg/L	30.24	33.33	-	62.96	62.16
Nitrite (as NO ₂) mg/L	5.32	94.92	92.10	93.42	95.48

Parameters	Raw effluent	Algae treated Effluent			
		A*	B*	C*	Mixed Algae
Nitrate (as NO ₃) mg/L	14	21.42	14.28	14.28	14.28
Chloride (as Cl) mg/L	757	3.17	1.84	0.66	7.13
Flouride (as F) mg/L	1.19	3.36	16.80	17.64	20.16
Sulphate (as SO ₄) mg/L	169	0	-	1.77	4.73
Phosphate (as PO ₄) mg/L	18.6	52.90	54.40	71.29	55.16
Tidy's test (as O) mg/L	10.99	-	-	-	-
Silica (as SiO ₂) mg/L	24.66	2.47	-	21.37	24.93
BOD mg/L	35	-	-	-	-
COD mg/L	105	-	-	-	-
Total Kjeldhal Nitrogen mg/L	41.11	34.61	1.92	48.23	45.51
Copper (as Cu) mg/L	0.00556	1.23	-	-	-
Zinc (as Zn) mg/L	0.114	-	-	-	-
Chromium (as Cr) mg/L	0.00473	-	-	-	-

A*) *Chlamydomonas pertusa*

B*) *Dactylococcopsis raphioides*

C*) *Chlorococcum humicola*

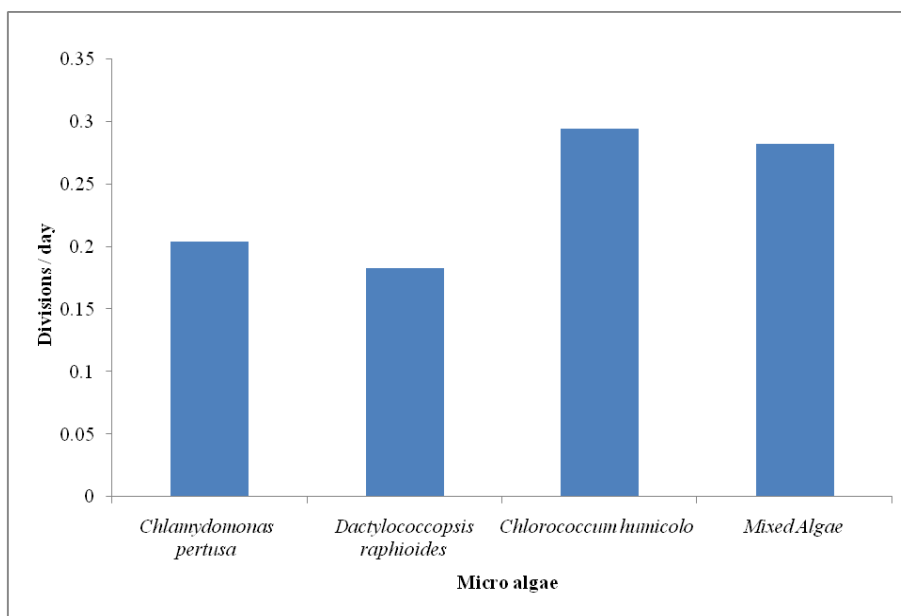


Figure 2. Growth rate of various micro algae in electroplating industrial paint effluent with aeration

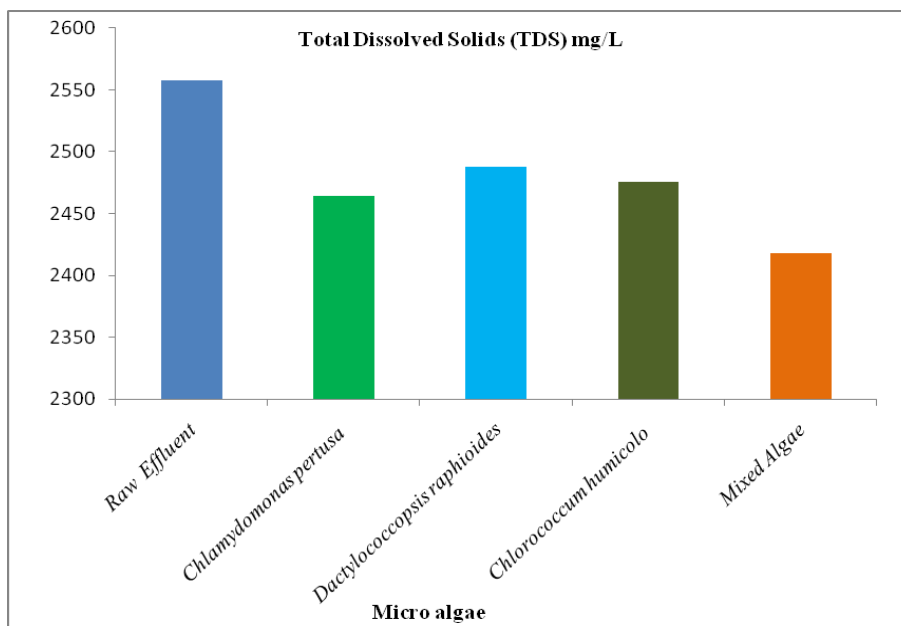


Figure 3. Phycoremediation effect on TDS of electroplating industrial paint effluent

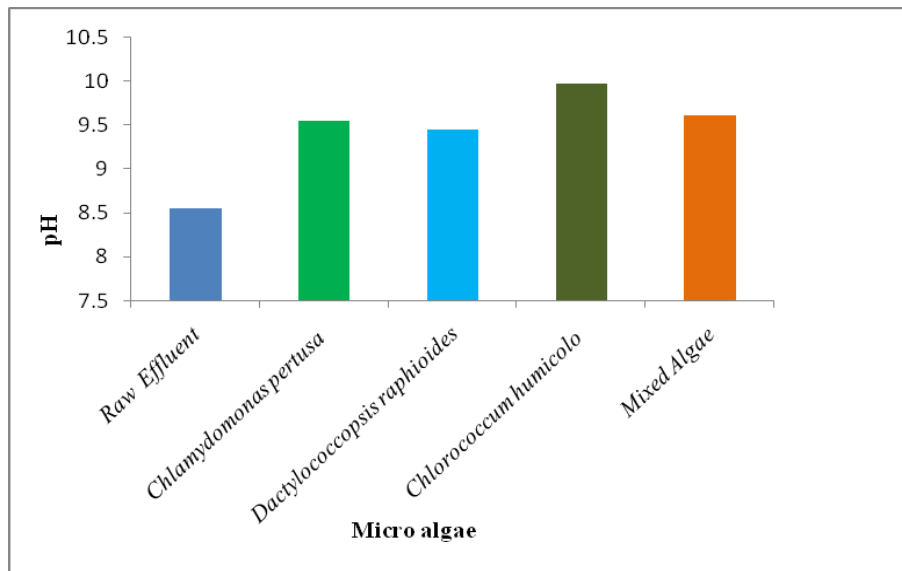


Figure 4. Phycoremediation effect on pH of electroplating industrial paint effluent

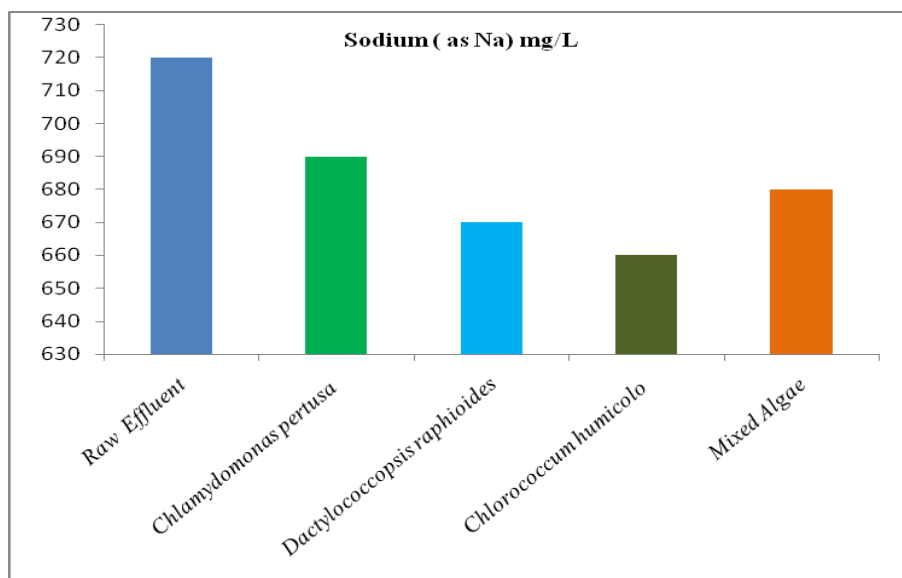


Figure 5. Phycoremediation effect on sodium of electroplating industrial paint effluent

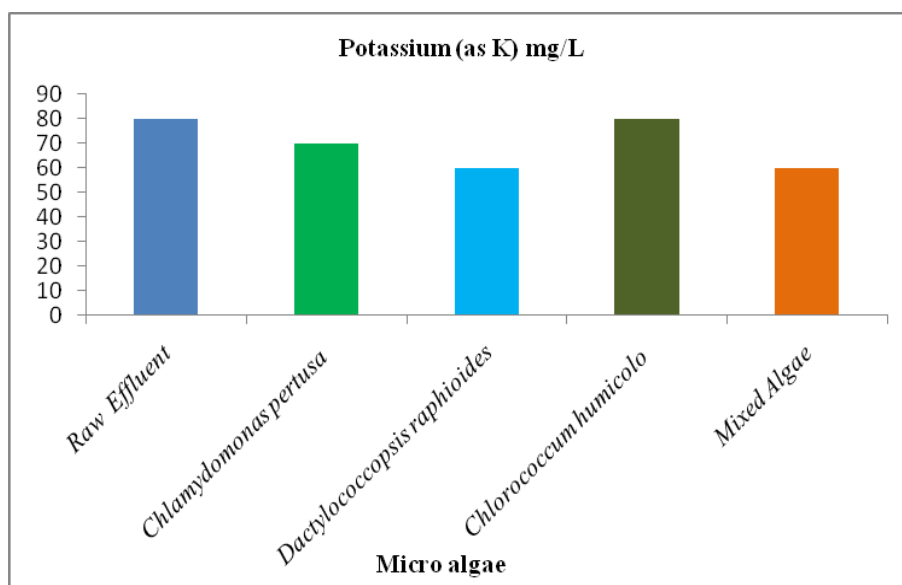


Figure 6. Phycoremediation effect on potassium in electroplating industrial paint effluent

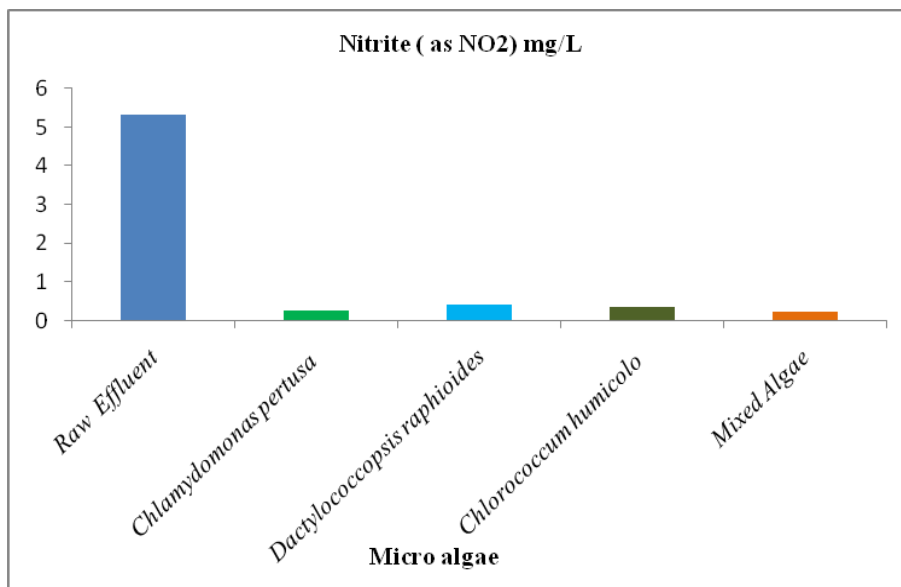


Figure 7. Phycoremediation effect on nitrate in electroplating industrial paint effluent

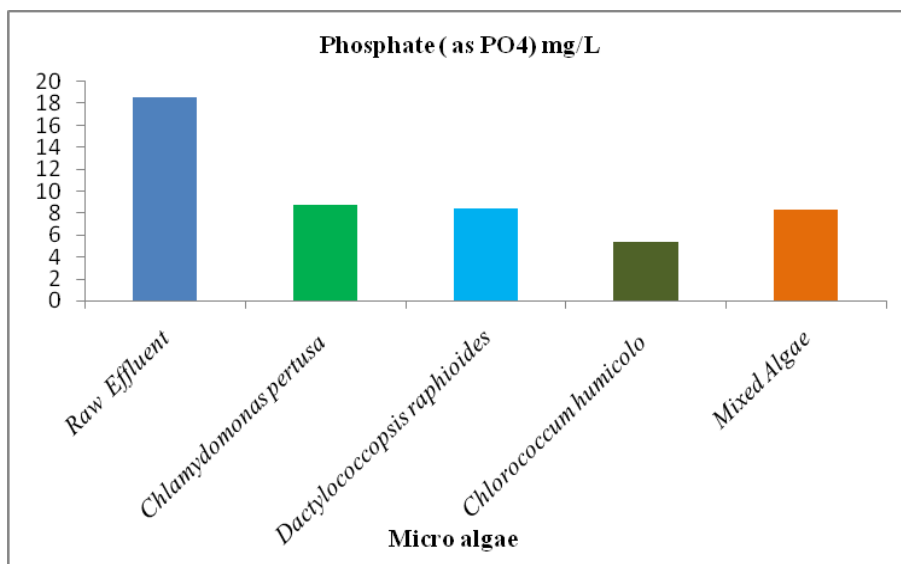


Figure 8. Phycoremediation effect on phosphate in electroplating industrial paint effluent

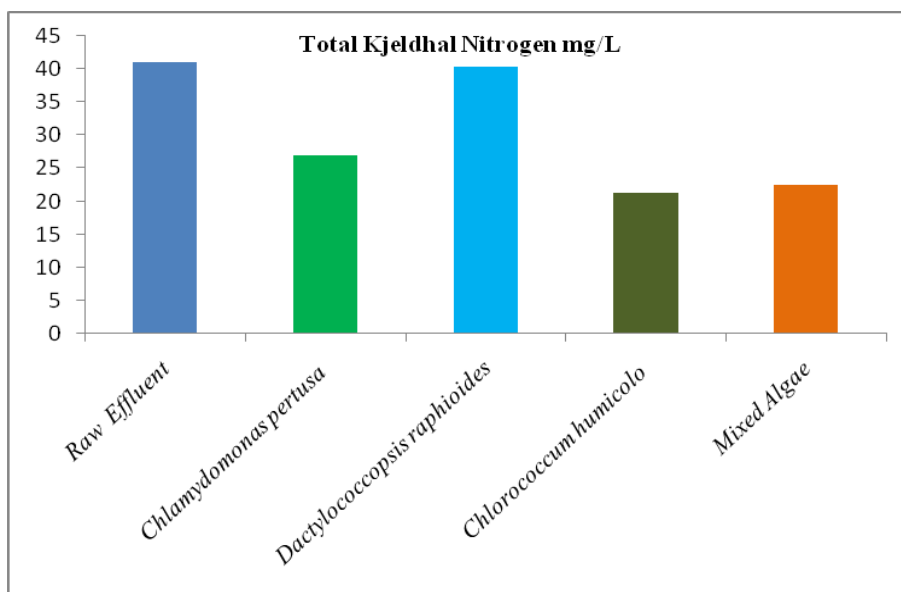


Figure 9. Phycoremediation effect on total kjeldhal nitrogen in electroplating industrial paint effluent

4. Conclusion

Phycoremediation of effluent using algae is a novel technique when applied to aqueous contamination. The present investigation dealt with the preliminary screening of microalgal species to analyses their potential to tolerate and grew in the paint effluent from an electroplating industry. The microalgae, *Chlamydomonas pertusa*, *Dactylococcopsis raphioides* and *Chlorococcum humicola* were selected and employed in the treatment of electroplating paint effluent. The physico-chemical parameters were analyzed. Phycoremediation could effectively reduce TDS, TSS, free ammonia, calcium, sodium, nitrate and phosphate in the algal treated paint effluent. Among the three microalgae, *Chlorococcum humicola* showed that significant level of remediation. The potential alga, *Chlorococcum humicola* could thus be selected for further field pilot scaling up technology to manage paint effluent of electroplating industry. Phycoremediation has them proved itself as a cost-effective and eco-friendly technology.

Acknowledgments

The author are very much thankful to the authorities of Electroplating Industry, Chennai to provide the effluent samples for academic research work, the HOD, PG and Research Department of Botany, the Principal and Secretary, Ramakrishna Mission Vivekananda College (Autonomous), Chennai, Tamil Nadu, India for providing laboratory facilities to complete the research work.

References

- [1] S. Mustafa, H. N. Bhatti, M. Maqbool, and M. Iqbal, "Microalgae biosorption, bioaccumulation and biodegradation efficiency for the remediation of wastewater and carbon dioxide mitigation: Prospects, challenges and opportunities," *J. Water Process Eng.*, vol. 41, p. 102009, Jun. 2021.
- [2] A. Abdelfattah *et al.*, "Microalgae-based wastewater treatment: Mechanisms, challenges, recent advances, and future prospects," *Environ. Sci. Ecotechnology*, vol. 13, p. 100205, 2022.
- [3] A. Bansal, O. Shinde, and S. Sarkar, "Industrial Wastewater Treatment Using Phycoremediation Technologies and Co-Production of Value-Added Products," *J. Bioremediation Biodegrad.*, vol. 09, no. 01, pp. 1-10, 2018.
- [4] L. C. Pessôa, K. M. Deamici, L. A. M. Pontes, J. I. Druzian, and D. de J. Assis, "Technological prospection of microalgae-based biorefinery approach for effluent treatment," *Algal Res.*, vol. 60, p. 102504, Dec. 2021.
- [5] C. Yan, Z. Qu, J. Wang, L. Cao, and Q. Han, "Microalgal bioremediation of heavy metal pollution in water: Recent advances, challenges, and prospects," *Chemosphere*, vol. 286, p. 131870, Jan. 2022.
- [6] L. N. Nguyen *et al.*, "Nutrient Removal by Algae-Based Wastewater Treatment," *Curr. Pollut. Reports*, Aug. 2022.
- [7] N. Apandi, R. M. S. Radin Mohamed, A. Al-Gheethi, A. Latiffi, S. N. Hidayah Arifin, and P. Gani, "Phycoremediation of Heavy Metals in Wet Market Wastewater," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 140, no. 1, pp. 1-6, 2018.
- [8] J. Xu, X. Wang, S. Sun, Y. Zhao, and C. Hu, "Effects of influent C/N ratios and treatment technologies on integral biogas upgrading and pollutants removal from synthetic domestic sewage," *Sci. Rep.*, vol. 7, no. 1, pp. 1-13, 2017.
- [9] K. E. Dickinson, C. G. Whitney, and P. J. McGinn, "Nutrient remediation rates in municipal wastewater and their effect on biochemical composition of the microalga *Scenedesmus* sp. AMDD," *Algal Res.*, vol. 2, no. 2, pp. 127-134, 2013.
- [10] K. V. Ajayan and M. Selvaraju, "Heavy Metal Induced Antioxidant Defense System of Green Microalgae and its Effective Role in Phycoremediation of Tannery Effluent," *Pakistan J. Biol. Sci.*, vol. 15, no. 22, pp. 1056-1062, Nov. 2012.
- [11] M. B. Kurade, J. R. Kim, S. P. Govindwar, and B. H. Jeon, "Insights into microalgae mediated biodegradation of diazinon by *Chlorella vulgaris*: Microalgal tolerance to xenobiotic pollutants and metabolism," *Algal Res.*, vol. 20, pp. 126-134, Dec. 2016.
- [12] R. Whitton, F. Ometto, M. Pidou, P. Jarvis, R. Villa, and B. Jefferson, "Microalgae for municipal wastewater nutrient remediation: mechanisms, reactors and outlook for tertiary treatment," *Environ. Technol. Rev.*, vol. 4, no. 1, pp. 133-148, 2015.
- [13] B. Pradhan *et al.*, "Microalgal Phycoremediation: A Glimpse into a Sustainable Environment," *Toxics*, vol. 10, no. 9, p. 525, Sep. 2022.
- [14] S. Sen, S. Dutta, S. Guhathakurata, J. Chakrabarty, S. Nandi, and A. Dutta, "Removal of Cr(VI) using a cyanobacterial consortium and assessment of biofuel production," *Int. Biodeterior. Biodegradation*, vol. 119, pp. 211-224, Apr. 2017.
- [15] V. Matamoros, R. Gutiérrez, I. Ferrer, J. García, and J. M. Bayona, "Capability of microalgae-based wastewater treatment systems to remove emerging organic contaminants: A pilot-scale study," *J. Hazard. Mater.*, vol. 288, pp. 34-42, May 2015.
- [16] S. Lima, A. Brucato, G. Caputo, F. Grisafi, and F. Scargiali, "Inoculum of indigenous microalgae/activated sludge for optimal treatment of municipal wastewaters and biochemical composition of residual biomass for potential applications," *J. Water Process Eng.*, vol. 49, p. 103142, Oct. 2022.
- [17] J. Roostaei, Y. Zhang, K. Gopalakrishnan, and A. J. Ochocki, "Mixotrophic Microalgae Biofilm: A Novel Algae Cultivation Strategy for Improved Productivity and Cost-efficiency of Biofuel Feedstock Production," *Sci. Rep.*, vol. 8, no. 1, pp. 1-10, 2018.
- [18] H. Yu, J. Kim, and C. Lee, "Nutrient removal and microalgal biomass production from different anaerobic digestion effluents with *Chlorella* species," *Sci. Rep.*, vol. 9, no. 1, pp. 1-13, 2019.
- [19] M. Min *et al.*, "Cultivating *Chlorella* sp. in a pilot-scale photobioreactor using centrate wastewater for microalgae biomass production and wastewater nutrient removal," *Appl. Biochem. Biotechnol.*, vol. 165, no. 1, pp. 123-137, 2011.
- [20] D. Saranya and S. Shanthakumar, "Green microalgae for combined sewage and tannery effluent treatment: Performance and lipid accumulation potential," *J. Environ. Manage.*, vol. 241, pp. 167-178, Jul. 2019.
- [21] H. B. Hariz, M. S. Takriff, N. H. Mohd Yasin, M. M. Ba-Abbad, and N. I. N. Mohd Hakimi, "Potential of the microalgae-based integrated wastewater treatment and CO₂ fixation system to treat Palm Oil Mill Effluent (POME) by indigenous microalgae; *Scenedesmus* sp. and *Chlorella* sp.," *J. Water Process Eng.*, vol. 32, p. 100907, Dec. 2019.
- [22] T. D. H. Vo *et al.*, "Influence of nitrogen species and biomass retention time on nutrient removal and biomass productivity in a microalgae-based bioreactor," *Environ. Technol. Innov.*, vol. 28, p. 102880, 2022.
- [23] R. Craggs, J. Park, S. Heubeck, and D. Sutherland, "High rate algal pond systems for low-energy wastewater treatment, nutrient recovery and energy production," *New Zeal. J. Bot.*, vol. 52, no. 1, pp. 60-73, 2014.
- [24] Y. K. Leong and J. S. Chang, "Bioremediation of heavy metals using microalgae: Recent advances and mechanisms," *Bioresour. Technol.*, vol. 303, p. 122886, May 2020.
- [25] P. Prabha Tripathi and V. Judia Harriet Sumathy, "A Comparative Study on the Application of Algae for Bioremediation of Cooum Water," *Int. J. Eng. Tech.*, vol. 4, no. 1, pp. 426-442, 2018, [Online]. Available: <http://www.ijetjournal.org>.
- [26] K. Suresh Kumar, H. U. Dahms, E. J. Won, J. S. Lee, and K. H. Shin, "Microalgae - A promising tool for heavy metal remediation," *Ecotoxicol. Environ. Saf.*, vol. 113, pp. 329-352, 2015.
- [27] R. K. Goswami, K. Agrawal, M. P. Shah, and P. Verma, "Bioremediation of heavy metals from wastewater: a current perspective on microalgae-based future," *Lett. Appl. Microbiol.*, vol. 75, no. 4, pp. 701-717, 2022.
- [28] D. M. Mahapatra, H. N. Chanakya, and T. V. Ramachandra, "Treatment efficacy of algae-based sewage treatment plants," *Environ. Monit. Assess.*, vol. 185, no. 9, pp. 7145-7164, 2013.

- [29] L. Weis, R. de Cassia de Souza Schneider, M. Hoeltz, A. Rieger, S. Tostes, and E. A. Lobo, "Potential for bifenthrin removal using microalgae from a natural source," *Water Sci. Technol.*, vol. 82, no. 6, pp. 1131-1141, 2020.
- [30] H. N. P. Vo *et al.*, "Effect of calcium peroxide pretreatment on the remediation of sulfonamide antibiotics (SMs) by *Chlorella* sp.," *Sci. Total Environ.*, vol. 793, p. 148598, Nov. 2021.
- [31] S. S. P. and R. P., "Chlorella vulgaris DPSF 01: A unique tool for removal of toxic chemicals from tannery wastewater," *African J. Biotechnol.*, vol. 17, no. 8, pp. 239-248, 2018.
- [32] K. Simsek and G. Sisman-Aydin, "Use of Mixed Wastewaters in Cyanobacteria *Chroococcus turgidus* (Kutzing, 1849) culture," *Int. J. Res. Innov. Earth Sci.*, vol. 5, no. 6, pp. 2394-1375, 2018.
- [33] A. Vadiveloo, H. Shayesteh, P. A. Bahri, and N. R. Moheimani, "Comparison between continuous and daytime mixing for the treatment of raw anaerobically digested abattoir effluent (ADAE) and microalgae production in open raceway ponds," *Bioresour. Technol. Reports*, vol. 17, no. February, p. 100981, 2022.
- [34] S. L. Lim, W. L. Chu, and S. M. Phang, "Use of *Chlorella vulgaris* for bioremediation of textile wastewater," *Bioresour. Technol.*, vol. 101, no. 19, pp. 7314-7322, 2010.
- [35] K. Su *et al.*, "Screening of the heterotrophic microalgae strain for the reclamation of acid producing wastewater," *Chemosphere*, vol. 307, p. 136047, Nov. 2022.
- [36] Palaniswamy R and Veluchamy C, "Biosorption of Heavy Metals by *Spirulina platensis* from Electroplating Industrial Effluent," *Env. Sci Ind J*, vol. 13, no. 4, p. 139, 2017, [Online]. Available: www.tsijournals.com.
- [37] S. Li *et al.*, "Evaluation of growth and biochemical responses of freshwater microalgae *Chlorella vulgaris* due to exposure and uptake of sulfonamides and copper," *Bioresour. Technol.*, vol. 342, p. 126064, Dec. 2021.
- [38] B. Das and S. Deka, "A cost-effective and environmentally sustainable process for phycoremediation of oil field formation water for its safe disposal and reuse," *Sci. Rep.*, vol. 9, no. 1, pp. 1-15, 2019.
- [39] A. Rehman, "Heavy metals uptake by *Euglena proxima* isolated from tannery effluents and its potential use in wastewater treatment," *Russ. J. Ecol.*, vol. 42, no. 1, pp. 44-49, 2011.
- [40] R. Yadavalli, C. S. Rao, R. S. Rao, and R. Potumarthi, "Dairy effluent treatment and lipids production by *Chlorella pyrenoidosa* and *Euglena gracilis*: Study on open and closed systems," *Asia-Pacific J. Chem. Eng.*, vol. 9, no. 3, pp. 368-373, 2014.
- [41] D. Kushwaha and S. Dutta, "Experiment, modeling and optimization of liquid phase adsorption of Cu(II) using dried and carbonized biomass of *Lyngbya majuscula*," *Appl. Water Sci.*, vol. 7, no. 2, pp. 935-949, 2017.
- [42] N. Kumar, S. Hans, R. Verma, and A. Srivastava, "Acclimatization of microalgae *Arthrospira platensis* for treatment of heavy metals in Yamuna River," *Water Sci. Eng.*, vol. 13, no. 3, pp. 214-222, 2020.
- [43] D. Brady, B. Letebele, J. R. Duncan, and P. D. Rose, "Bioaccumulation of metals by *Scenedesmus*, *Selenastrum* and *Chlorella* algae," *Water SA*, vol. 20, no. 3, pp. 213-218, 1994.
- [44] D. Deb, N. Mallick, and P. B. S. Bhadoria, "A waste-to-wealth initiative exploiting the potential of *Anabaena variabilis* for designing an integrated biorefinery," *Sci. Rep.*, vol. 12, no. 1, p. 9478, Dec. 2022.
- [45] T. M. Mata, A. C. Melo, M. Simões, and N. S. Caetano, "Parametric study of a brewery effluent treatment by microalgae *Scenedesmus obliquus*," *Bioresour. Technol.*, vol. 107, pp. 151-158, Mar. 2012.
- [46] S. Abedi *et al.*, "Decoupling a novel *Trichormus variabilis*-*Synechocystis* sp. interaction to boost phycoremediation," *Sci. Rep.*, vol. 9, no. 1, pp. 1-10, 2019.
- [47] Amany F. Hasaballah, "Phycoremediation of Metal Pollution of Wastewater," *Int. J. Eng. Res.*, vol. V8, no. 09, pp. 346-352, 2019.
- [48] Z. Novák, S. Harangi, E. Baranyai, S. Gonda, V. B-Béres, and I. Bácsi, "Effects of metal quantity and quality to the removal of zinc and copper by two common green microalgae (*Chlorophyceae*) species," *Phycol. Res.*, vol. 68, no. 3, pp. 227-235, 2020.
- [49] L. Cavieres *et al.*, "Pilot-scale phycoremediation using *Muriellopsis* sp. For wastewater reclamation in the Atacama Desert: Microalgae biomass production and pigment recovery," *Water Sci. Technol.*, vol. 83, no. 2, pp. 331-343, 2021.

