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Microalgal Remediation Of Electroplating Wastewater And Biomass Production -An Ecofriendly Approach

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Abstract: *Electroplating industrial(EPI)effluents are the major source of heavy and toxic metals discharged into the waste water lines. Sustainable technology through the greener path using microalgae helps to recycle the EPI effluent. In our research the removal of heavy metals in light and dark cycles using Westiellopsis was assessed and recorded the results as follows:Cr-91%,Cu-90% ,Ni-84%,Zn-86% .Response of Westiellopsis to recover the heavy metals in EPI effluent was recorded in the descending order:Cr > Cu > Zn>Ni. The cell growth of the Westiellopsis was increased upto 95% in raw EPI effluent(T4). Cell recovery was achieved upto 100%.Among all treatments,in T4 maximum yield of biomass and protein was recorded upto 97% and 95% respectively. Thus the current research on cultivating Westiellopsis in EPI effluent was an ecofriendly approach with dual advantage of reduction in heavy metal load and high yield of dry biomass .*

Keywords: *Electroplating effluent, microalgal growth, Westiellopsis,biomass yield, protein yield.*

INTRODUCTION

Increasing population and industrialization had caused new and increasing menace to the ground water system. By 2050 the availability of surface and ground water would decline to less than 80 cubic kilometers from about 500 cubic kilometers. (Cabanelas et al.,2013; Sun et al.,2016;Acién fernández et al.,2018; Ali et al.,2021). Heavy metals such as nickel, chromium, cadmium, zinc etc are toxic and non degradable discharged through industrial effluents pose a serious threat on potable water to become unfit for consumption(Rangsayatorn et al.,2004; Romera et al.,2007).The dissolved heavy metal constituents primarily affected ground water recharge operations are targeted for the recovery through biosorption technologies.

Recently a large number of small scale industries have been established throughout India.The industries discharge a large amount of waste water into the rivers and lakes mainly through increased pollutants from the industrial wastes and green house emissions at higher rate affected the environment that leads to global warming and climate change.Hence there is a great responsibility for the researchers and industrialists to involve in curtailing pollution through immediate steps to implement the green technologies, life cycle assessment and circular economy approaches (El-Bestawy, 2008;Colica et al.,2010).

Microalgae are also known as cyanobacteria or blue green algae have unique photosynthetic efficiency which offers a greener path to produce biomass from the waste waters. Use of various microalgal biomass for the detoxification of different industrial effluents for environmental protection and recovery of valuable metals provides a potential alternative to the existing expensive treatment technologies(Kocberber and Donmez 2007; Hodaifa et al.,2008; Indu sharma et al.,2023). *Westiellopsis sp* is an oxygenic phoyosynthetic filamentous microalga.It has special structure called heterocyst able to fix atmospheric nitrogen and it is intercalary in nature.The branched thallus consists of vegetative cells with blue green pigments known as trichomes.

Here we mainly concentrate on the conservation of ground water which is affected by the heavy metal pollution from electroplating industrial effluents.Hence in the present study analysis of pollutants present in the various processing units of electro plating industrial effluent and its influence on growth and yield of selected microalga in terms of dry biomass and protein had been experimented. For heavy metal recovery, biosorption technology was effected on the selected microalga *Westiellopsis*.

MATERIALS AND METHODS

Electroplating industries are characterized based on its infrastructure, production and quality of raw materials used. Source of water in each unit varies that influences the growth and yield of *Westiellopsis sp*.

Physico chemical Profiling of Electroplating industrial Effluent

Various physico chemical parameters were analysed before and after microalgal remediation of EPI effluent. Estimation of physicochemical parameters viz., pH,dissolved oxygen, Total dissolved solids, Total suspended solids, Chemical Oxygen Demand, Biological Oxygen Demand, Sulphate, Chloride, Nickel, Chromium, Zinc and Copper by American Public Health Association (APHA,2017) methods.

Lab-scale Study on Microalgal Cultivation

A microalgal cultivation studies on the growth efficiency of *Westiellopsis* in light and dark cycle was conducted. *Westiellopsis* sp cultures were grown in BG11 medium at pH 7.2 and 24±1°C at bioprocess laboratory of Madha Engineering College.A 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 (Parks, 2004). The colonies of *Westiellopsis* were grown on liquid BG11(control) ,EPI effluent of undiluted (raw effluent-T4) and diluted solutions(T1,T2andT3) for 24 days under standard conditions (Desikachary, 1959; Rippka et al., 1979).

The cell growth of *Westiellopsis sp* was monitored by measuring the wavelength at 436 nm by a spectrophotometer (Priyanka et al.,2021). Treatments of the experiments in triplicates are as follows:Control(BG-11medium) was kept without any dilutions.25% ,50%,75% (v/v) dilutions were made with EPI effluent and water in T1,T2,T3 respectively.In T4 (100%) raw EPI effluent was taken. For cell recovery membrane filtration technology was used.The dry biomass yield (mg/ml) and protein yield (mg/g) of *Westiellopsis* were assessed at week 1,2 and 3. The amount of microalgal protein was determined according to Lowry's method (1951). Profiling of aminoacids in *Westiellopsis* was performed by HPLC as per methodology given by Rao et al.,2010.

Statistical Analysis

Triplicates were maintained in all experiments and IBM SPSS Version 18 was used for statistical analysis. Comparison of data was performed by one way ANOVA test and t-test with 95% confidential intervals.

RESULTS AND DISCUSSION

Physico Chemical Profiling of EPI Effluent

The physico chemical experiments for the four processing units of EPI effluent resulted with various micro and macro nutrients viz., pH 3.2 -4.5; DO 6.0-7.4 (mg/l) ;TDS-1175.5(mg/l) ; SO4 131.4-138 (mg/l) ;Cl2-275.9 - 293(mg/l);Cr 37.5 (mg/l) ; Cu-32.5(mg/l) ; Zn -25 (mg/l); Ni 82.5 (mg/l).Details of the four processing units (Table-1)are discussed below.

Table 1: Characteristics of Electroplating industrial effluent at Processing Units 1,2,3 and 4

S.No	Parameters	Unit 1	Unit 2	Unit 3	Unit 4
1	pH	3.2±0.02	3.6±0.05	4.2±0.05	4.5±0.09
2	dissolved oxygen(mg/l)	7.4±0.09	7.1±0.03	6.12±0.05	6.0±0.07
3	Total dissolved solids (mg/l)	1175±9.02	1206±11.7	1277.6±9.70	1215.1±10.2
4	Total suspended solids (mg/l)	740±5.51	793±12.28	755 ±8.55	801±14.01
5	Chemical Oxygen Demand (mg/l)	218.4±2.62	225.5±1.33	268.4 ±3.35	265.0±1.51
6	Biological Oxygen Demand (mg/l)	390±5.10	395±7.01	490 ±6.11	470±4.02
7	Sulphate(mg/l)	138±2.09	145.2±1.01	149.4±1.02	137.1 ±1.37

8	Chloride (mg/l)	250.9±11.05	262.1±14.02	274.9±10.07	276 ±10.09
9	Nickel (mg/l)	-	-	81.5 ±0.86	83.05±0.75
10	Chromium (mg/l)	-	-	37.5±0.61	38.5±0.42
11	Copper (mg/l)	-	-	35.3±0.55	34.7±0.72
12	Zinc (mg/l)	22±0.02	25 ±0.01	27.5±0.04	26.1±0.11

* Data represented as mean values ± standard derivation, Significance level at $p<0.05$

Processing unit -1: Highly acidic effluent with pH 3.2 because of cleansing the raw materials was found.TDS 1175.5mg/l and TSS 805mg/l were made the effluent turbid . Chloride level was found moderate. Concentration of Zn(II) was 21 mg/l.BOD,COD ratio was 4.94.

Processing unit -2 (pre plating section):pH of the effluent in this unit was highly acidic with 3.6.Total suspended and dissolved solids.Chlorides, BOD,COD ratio was 7.1. There was no contents of Ni,Cr and Cu.

Processing unit -3 (plating):The nature of EPI effluent due to plating process resulted as follows:pH is 4.2 ;DO 6.12 (ppm) ; SO4 149.4 (mg/l) ;Cl2-274.9 (mg/l);Cr 37.1 (mg/l) ; Cu 35.3(mg/l) ; Zn 27.8 (mg/l); Ni 81.5(mg/l). Heavy metal contents of rinsing unit is higher compared to the other 3 units.

Processing unit-4(rinsing): Rinsing process effected the EPI effluent with the following results:The pH was slightly lesser than other units.Sulphates contents were lesser .But the chlorides were more.TDS & TSS were found in high quantity.The BOD,COD values were higher in this unit compared to other units.

The electroplating industrial (EPI) effluents are the major source of heavy and toxic metals discharged into the waste water lines. Units 3 and 4 of the EP industries use distilled water as source for chrome plating and zinc plating.The other two units of EP industries use tap water or ground water based on their availability.Because of this nature of EPI effluent , the fresh water microalga *Westiellopsis*, was able to enhance its metabolic activity very faster in light and dark cycles(Table-2).

Table 2: Light and dark uptake of heavy metals of electroplating industrial effluent by *Westiellopsis* sp *

Heavy Metals	**Uptake Rate by *Westiellopsis* sp (mg / 10 min) in Raw EPI effluent under Light and dark cycles**	
	Light Uptake	**Dark Uptake**
Cr	0.633±0.02	0.525±0.02
Zn	0.811±0.04	0.609 ±0.01
Cu	0.753±0.03	0.566 ±0.02
Ni	0.540 ±0.02	0.371±0.01

* Data represented as mean values ± standard derivation, Significance level at $p<0.05$

In T1 biomass yield was insignificant due to the maximum dilution.The heavy metal removal efficiency of *Westiellopsis* sp was found to be 12.-15% in a retention time of 10 minutes. In T2 and T3 increasing the retention time increased the removal percentage for Cu and Zn.There was no significant removal Cr and Ni after 20 minutes.This might be due to the growth reached to stationery phase which affected the uptake of heavy metals.In T4 the removal percentage for Ni and Zn was ranging from 84 % to 86% within 15 minutes of retention time.Removal percentage upto 90%-91% of Cu and Cr respectively by *Westiellopsis* was recorded in raw effluent(Table-3).

Table 3: Percentage of Removal of heavy metals by *Westiellopsis* sp in electroplating industrial effluent

% of Removal of heavy metals in Raw Effluent by *Westiellopsis*	**Retention Time (minutes)**			
	5	**10**	**15**	**20**

Cr	46.5 ±0.12	90.5±1.09	93.5±1.04	92.8±1.04
Zn	35.2±0.12	86.4±0.14	87.3±1.00	80.1±0.42
Cu	42.7±0.09	90.3±1.12	90.1±0.75	86.4±1.06
Ni	38.1±0.15	84±1.08	87.1±1.01	87±0.33

*Data represented as mean values ± standard derivation, Significance level at $p<0.05$

The nutrients in the EPI effluent influenced the growth of *Westiellopsis sp* in a positive trend in all the treatments(Figure-1) except T1 which was insignificant compared to other treatments .The enhancement of dry biomass was ranging from 26.4% to 49.9% in T2 and T3 respectively and 39 to 97% in T4 for *Westiellopsis* . Furthermore the dual advantage of cultivating *Westiellopsis* in EPI effluent was potentially reduced the heavy metal load after biosorption experiments and high yield of dry biomass ranging from 82-95%.The effect of pH, agitation time, adsorbant dosage and eluting agents were the parameters (standardized by various trials in our previous study) demonstrated the efficiency of microalga *Westiellopsis* for the recovery of heavy metals (Table-3). Microalgal heavy metal removal from various waste waters was experimented by Whitton et al.,2015; Prabha Tripathi and Judia harriet sumathy,2018; Leong and chang,2020; Yan et al.,2021.

Furthermore the uptake/removal efficiency of heavy metals within 5 to 15 minutes as follows:Cr 47% to 94%; Ni 38-92%; Cu 48-90%; Zn 35-87% (Table-4). Microalgal treatment leads to the improvement in the quality of the recycled waste water(Table-4) by decreasing COD, phosphates and specifically heavy metals (Michalak and Chojnacka ,2010; He et al.,2020;Al-jabri et al.,2021).

Hence from our research it had been prominently proved that the culture of microalgal biomass in EPI effluent facilitated triple advantages as its role in conserving natural resources especially the ground water , recycling of waste water and dense growth of microalgal biomass in the effluent.

Study on Growth , Biomass and Protein Yield of *Westiellopsis*

Microalgal cultivation study and heavy metal removal efficiency of *Westiellopsis* in light and dark cycle and the growth profile had shown the potentiality of *Westiellopsis* to utilize the nutrients in electroplating effluent(Table-3 and 4). The pollutants were metabolized for the growth and decontaminated the EPI effluent to reuse in the industry. This effect has been recorded as a part of lifecycle assessment and bioeconomy approach in the electroplating industries. Similar trend of research was observed in the earlier work of Lim et al., 2010 ; Udom et al.,2013; Palaniswamy and Veluchamy 2017;Silambarasan et al.,2021).

Biomass yield represents the efficacy of *Westiellopsis* in raw EPI effluent effected 48% which was comparable with the control in which 49% yield obtained. Dilutions of 25% -75% influenced only 19-43%.Yield with reference to the dry biomass in the EPI effluent was ranging from 38.7% to 97% for *Westiellopsis*. The growth of microalga *Westiellopsis sp* in electroplating industrial effluent with reference to the vegetative cells , heterocysts and its frequency (Figure-1& 2) brings about oxygenation and mineralization which accounts for the increase in biomass and protein yield .

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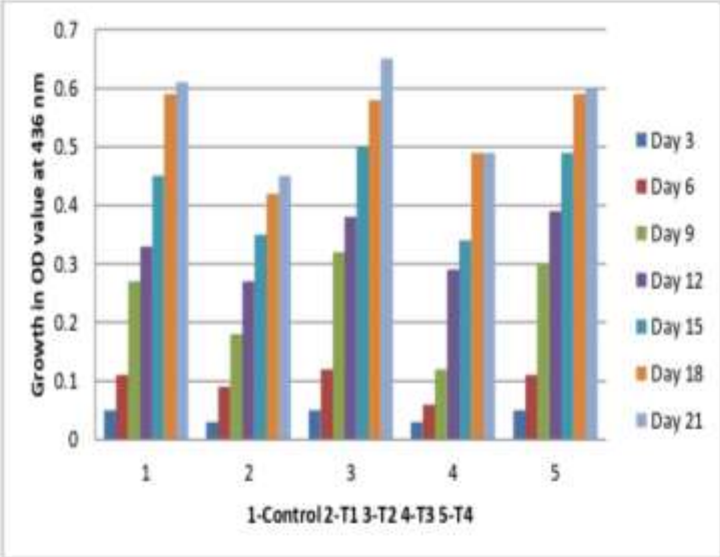


Fig. 1- Growth Profile *of Westiellopsis* in electroplating industrial effluent (Mean of triplicates)

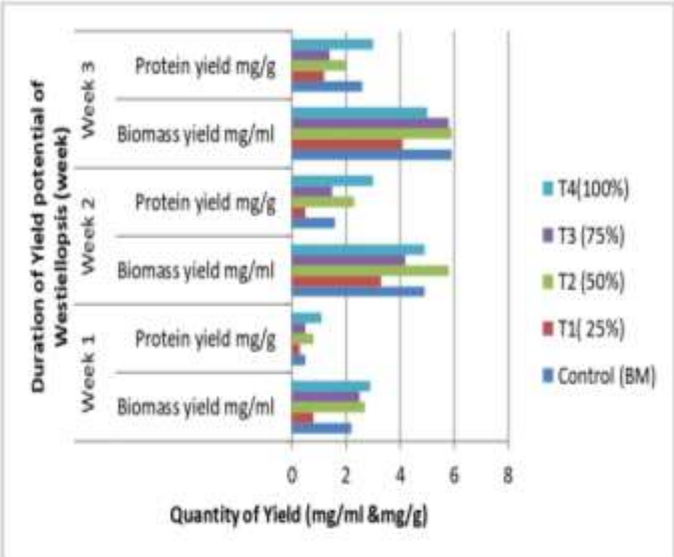
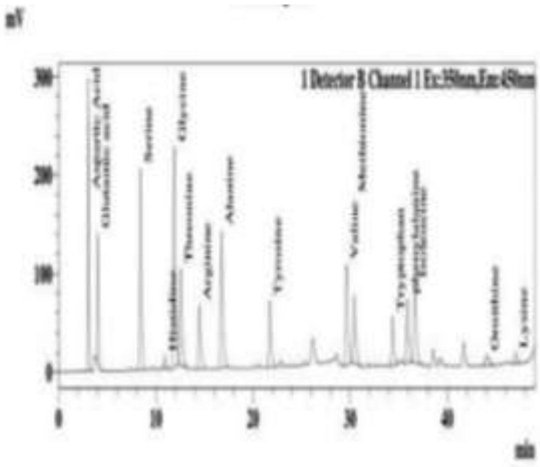


Fig-2 Dry Biomass and Protein Yield of *Westiellopsis* in Electroplating industrial Effluent (Mean of triplicates)

Protein yield of *Westiellopsis* in all the treatments were ranging from 25% to 37% and in basal medium it was 46%.The raw EPI effluent was effectively influencing the microalga *Westiellopsis* to yield protein upto 43% which was confirmed by the aminoacid profile performed by HPLC(Figure-3).



Peak Table

Detector B Channel 1 Ex:350nm,Em:450nm

Peak#	Name	Ret. Time	Area	Conc.	Unit
1	Aspartic Acid	3.837	1510943	0.000	mg/L
2	Glutamic acid	4.019	93242	0.000	mg/L
3	Serine	8.405	2611548	0.000	mg/L
4	Histidine	10.922	150091	0.000	mg/L
5	Glycine	11.882	3197539	0.000	mg/L
6	Threonine	12.558	1407156	0.000	mg/L
7	Arginine	14.468	972323	0.000	mg/L
8	Alanine	16.758	2239455	0.000	mg/L
9	Tyrosine	21.717	1009635	0.000	mg/L
10	Valine	29.628	1804718	0.000	mg/L
11	Methionine	30.421	1212910	0.000	mg/L
12	Tryptophan	34.343	855456	0.000	mg/L
13	phenylalanine	35.806	1085780	0.000	mg/L
14	Isoleucine	36.644	1469962	0.000	mg/L
15	Ornithine	44.063	252325	0.000	mg/L
16	Lysine	47.828	193131	0.000	mg/L

Fig-3. Aminoacid profile of *Westiellopsis* Performed by HPLC

Microalgal proteins contain all the essential amino acids and possess balanced total amino acid profiles Lucakova *et al.* 2022.Because of these specific essential aminoacids *Westiellopsis* thalli were divide faster in light and dark cycles. Light uptake of 0.592- 0.723 mg /10 min and dark uptake of 0.470-0.542 for copper by the cyanobacterial biomass were recorded . For zinc the light uptake of 0.604- 0.781 mg /10 min and dark uptake of 0.515- 0.535 mg /10 min by the cyanobacterial biomass were recorded which showed the potentiality of *Westiellopsis* sp to uptake the nutrients and heavy metals. Light: Dark cycle exposure of *Westiellopsis* to illumination for 12:12 hrs influenced protein yield in all the treatments from 25% upto 37% during the exponential phase of growth (Wong,2016; Sui *et al.* 2019).

Exposure to EPI effluent at various dilutions by the trichomes of *Westiellopsis* proved that the microalgal protein yield in which specific essential aminoacids are the backbone to withstand harsh environmental condition. Ursu et al.,2014 discussed the functional role and the properties of proteins with the aminoacid contents of *Chlorella vulgaris.*Few research on various microalgal aminoacids are in accordance with the current study on aminoacid profile by HPLC (Lourenço *et al.*2004;Kolmakova and Kolmakov,2019). Amino acid contents of microalga used to indicate the direct impact on growth status and it is directly proportional to the dry biomass yield.These results are in accordance with the earlier experiments of Seyfabadi *et al.* 2011; Biancarosa *et al.* 2017; Gorissen *et al.* 2018.

Microalgal proteins have technofunctional properties provide uniqueness for its physiology that can withstand diverse and harsh challenging environments.Thus it is suggested that the EPI effluent could be used as an ambient medium to cultivate the microalga *Westiellopsis* with a potential of yielding protein as a valuable product.

From these findings it is recommended that the raw EPI effluent could be treated effectively in a faster manner as the heavy metal load was reduced by biosorption technology. Future research scope pertaining to extraction of valuable products from *Westiellopsis* and its role as multipurpose raw material to the industries will be experimented.

CONCLUSION

From the lab scale experiments it is demonstrated that *Westiellopsis* sp utilised EPI effluent as an ambient medium for the cell growth in all the treatments (T1- T4).Furthermore the 50% dilution is highly effective in enhancing the growth of *Westiellopsis* sp which could be compared with its growth pattern in the basal medium. The raw EPI effluent was effectively influencing the microalga *Westiellopsis* to yield protein upto 43% which was confirmed by the aminoacid profile performed by HPLC .

The scope of future research enlighted towards the effects of heavy metals on the microalgal physiology and gene expression involved in decontamination of various pollutants. Furthermore, it is essential to assess the consequences of heavy metal pollution and the biotechnological exploitation of the resistant strains for the treatment of industrial effluents. The microalgal (*Westiellopsis*) biomass could be used as a potential resource for the production of biofuel and other valuable products. Thus it would be an added advantage to account for bioeconomy and sustainable technology for the electro plating industries.

CONFLICT OF INTEREST

Author declares that there is no conflict of interest.

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