



Integrated Environmental Impact Assessment of Tannery Effluent: Community Perception, Microalgal Bioremediation, And Phytotoxicity Evaluation

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KEYWORDS

Environmental Impact Assessment, Phycoremediation, Algal consortium, Plant growth analysis, tannery effluent.

ABSTRACT:

Introduction: Industrial activities such as leather processing generate large volumes of wastewater that pose serious environmental and public health concerns. Tannery effluents are particularly problematic due to their high concentrations of organic matter, suspended solids, and toxic heavy metals, especially chromium. In many industrial regions, untreated or partially treated effluents are discharged into nearby environments, negatively affecting soil quality, water resources, agricultural productivity, and surrounding communities. Phycoremediation, which utilizes microalgae to remove pollutants from wastewater, has emerged as a promising biological approach. Microalgae possess the ability to assimilate nutrients, absorb heavy metals, and reduce organic pollutants while simultaneously producing valuable biomass.

Objectives: The present study aimed to evaluate the environmental impact of tannery effluents in the industrial regions of Pammal and Nagalkeni, Tamil Nadu. It also sought to investigate the effectiveness of phycoremediation using mixed microalgal cultures in tannery wastewater. Additionally, the study aimed to assess the influence of treated and untreated effluents on the growth and biomass of selected vegetable crops.

Methods: An Environmental Impact Assessment (EIA) was conducted through field observations, community surveys, and evaluation of physical, ecological, and socioeconomic parameters to determine the overall environmental impact of tannery activities. Effluent samples were collected from tannery discharge points and analysed for key physico-chemical parameters including pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and heavy metals such as chromium. A mixed culture of microalgae was cultivated and applied for the treatment of tannery effluent under controlled conditions for 15 days. To evaluate phytotoxicity, growth experiments were conducted using two vegetable crops, *Solanum melongena* and *Capsicum annuum* under different irrigation conditions including untreated effluent, treated effluent, and diluted treated effluent.

Results: The Environmental Impact Assessment revealed a net Environmental Impact Value (EIV) of -19, indicating an overall negative environmental effect of tannery operations in the study area. Initial physico-chemical analysis showed that parameters such as BOD, COD, TSS, and chromium concentrations exceeded permissible environmental limits, confirming severe contamination. Following 15 days of treatment with mixed microalgae cultures, significant reductions in pollutant indicators were observed, accompanied by plant growth experiments using untreated and treated effluent in both crop species.

Conclusions: The findings of this study demonstrate that tannery effluents in the Pammal and Nagalkeni industrial zones exert a significant negative environmental impact. However, the application of mixed microalgae cultures for phycoremediation effectively reduced the pollutant load.

1. Introduction

Chennai is a hub for multiple sectors industry, mining, transportation, energy, agriculture, and construction generating significant waste. Among these, the tanning industry is notably polluting due to toxic chemicals used

in its processes [1]. Improper treatment of tannery effluents poses serious environmental and health threats. In the 1990s, environmental concerns began to be addressed [2]. However, treated wastewater released into rivers still leads to groundwater pollution [3], depleting water tables and raising dissolved solid levels [4]. Toxic



pollutants like chromium enter ecosystems, accumulating in food sources and damaging human health [5]. Water pollution caused by organic (e.g., bacteria, viruses) and chemical (e.g., pesticides, heavy metals) contaminants makes water toxic. Wastewater, generated from households, industries, and agriculture, varies in composition and is characterized physically (e.g., colour, odour, turbidity, temperature), chemically (e.g., BOD, COD, ammonia), and biologically (e.g., microorganisms) [6]. Conventional treatments involve physical, chemical, and biological processes, but their adoption is limited due to cost, feasibility, and other factors [7].

Bioremediation, using microorganisms to degrade or immobilize pollutants [8], is emerging as an effective solution. This includes Mycoremediation (fungi-based), Phytoremediation (plant-based), and Phycoremediation (algae-based), introduced by [9]. Algae have long been used to remove nutrients and metals, mitigating eutrophication [10, 11]. Their diversity—estimated between 200,000 and 800,000 species—offers great potential for wastewater treatment [12, 13]. Strains like *Spirulina*, *Phormidium bohneri*, *Chlorella*, and *Scenedesmus* are highly effective [14, 15, 16, 17]. Despite their benefits, industries remain a major pollution source, affecting soil, air, water, and health. The Environmental Impact Assessment (EIA) framework helps identify, evaluate, and mitigate these effects. Industrial growth, while serving societal needs, increases pollution especially in developing nations like India. Pollution types include air, water, soil, noise, thermal, and radioactive. Chemical (e.g., gases, metals), biological (e.g., pathogens), and physical (e.g., heat, sound) pollutants often persist post-treatment, affecting ecosystems and food safety. India's tanning industry, with around 2,500 tanneries (80% using chrome-tanning), generates vast effluents about 30 liters per kg of hide processed. Tamil Nadu, housing over 50% of tanneries, suffers severe environmental degradation. Chemicals like lime, sodium chloride, chromium salts, and pollutants like chlorine, sulfuric acid, chromium, lead, and zinc are major concerns. Solid waste adds to the crisis. These pollutants, many of which are carcinogenic, bioaccumulate and magnify in the food chain. Given these threats, this study examines how tannery effluent impacts the growth and biomass of two vegetable crops:

Solanum melongena (eggplant) and *Capsicum annuum* (bell pepper).

2. Objectives

The present study aimed to evaluate the environmental impact of tannery effluents in the industrial regions of Pammal and Nagalkeni, Tamil Nadu. It also sought to investigate the effectiveness of phycoremediation using mixed microalgal cultures in reducing the pollutant load of tannery wastewater. Additionally, the study aimed to assess the influence of treated and untreated effluents on the growth and biomass of selected vegetable crops.

3. Methods

Study area

The study was conducted in two different locations of Pammal and Nagalkeni in Chengalpattu District, Tamil Nadu, India. The groundwater of Nagalkeni is polluted by untreated sewage and waste water from tannery industry.

Environmental Impact Assessment

The study was performed by a series of following tasks: Visiting the tannery industries and nearby areas in person. On-site interviews and assessments with the relevant personnel including managers, workers, and the surrounding public. Formulating the EIA report based on the interviews conducted. To recommend some mitigation measures to control further pollution to the environment.

Collection of Tannery Effluent

Further study was carried using the tannery effluent taken from the Tannery dyeing unit, situated at Nagelkeni, Chennai. The effluent sample was collected from the disposal tank using a plastic can of 25-liter capacity for analysis.

Determination Of Physicochemical Parameters

The effluent samples were analysed for their physicochemical properties as appearance, odour, turbidity, such total suspended solids, total dissolved solids, electrical conductivity, pH, chemical oxygen demand (COD), biological oxygen demand (BOD), oil and grease. Heavy metals such as chromium were also analysed [18].



Microalgae Culture and Growth Conditions

The mixed culture of *Chlorella sp.*, *Nanochloropsis sp.*, *Spirulina sp.*, *Scenedesmus sp.*, *Chroococcus sp.*, *Ankistrodesmus sp.*, *Oscillatoria sp.*, *Lyngbya sp.* and *Nostoc sp.* are maintained in Algal laboratory, Madras Christian College were chosen. The identification of specific algal species was confirmed using monograph such as Desikachary (1959) [19], Philipose (1967) [20]. The mixed algal culture was mass cultivated in a 500 ml conical flask for further study using BBM (Bold's Basal Medium) [21] culture medium. These cultures were maintained at $24^{\circ}\text{C} \pm 1^{\circ}\text{C}$ in a thermo-statically controlled environmental chamber illuminated with white fluorescent lamps at an intensity of 2000 lux in a 12/12h light/dark cycle.

Separation of Algal Biomass and Experimental Setup

The mixed algae culture (*Scenedesmus sp.*, *Ankistrodesmus sp.*, *Chlorella sp.*, *Nanochloropsis sp.*, *Spirulina sp.*, *Chroococcus sp.*, *Oscillatoria sp.*, *Lyngbya sp.* and *Nostoc sp.*) of microalgae is harvested after 15 days of incubation from the growth media by allowing it to settle in the dark condition overnight. The algae settle at the bottom as a sediment layer was separated with aid of a tube. The culture media can also be further centrifuged at 3000 rpm for 15 minutes. The obtained biomass weighed about 18g and was used for the treatment of raw tannery effluent. The obtained biomass was divided into two equal halves and were introduced into 2 large 5L transparent containers which had 50% concentrated effluent and 100% concentrated effluent covered with a cotton plug lid. 50% concentrated effluent was prepared by diluting the 100% concentration effluent with borewell water. The set up was exposed to 12/12h of day/night respectively. External air pump was connected within the container supplying oxygen in to the tannery effluent facilitating the growth of microalgae. Proper light source and agitation at regular intervals was provided to speed up the algal growth.

Table 1: Bold's Basal Medium ([21]; also known as Bristol solution)

MEDIA COMPONENT	STOCK SOLUTION	CULTURE MEDIUM (1L)
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NaNO ₃	5g/200 ml	10 ml
MgSO ₄ .7H ₂ O	1.5g/200ml	10 ml
K ₂ HPO ₄	1.5g/200ml	10 ml
KH ₂ PO ₄	3.5g/200ml	10 ml
NaCl	0.5g/200ml	10 ml
CaCl ₂ .2H ₂ O	0.5g/200ml	10 ml
EDTA-KOH SOLUTION		1ml
EDTA STOCK	5g/100ml	-
KOH	3.1g/100ml	-
ACIDIFIED IRON SOLUTION		1 ml
FeSO ₄ .7H ₂ O	0.498g/100ml	-
H ₂ SO ₄	1 ml	-
BORON SOLUTION		-
H ₃ BO ₃	1.14g/100ml	1 ml
TRACE ELEMENTS SOLUTION		1ml
CuSO ₄ .5H ₂ O	1.57g/L	-
ZnSO ₄ .7H ₂ O	8.82g/L	-
MnCl ₂ .4H ₂ O	1.44g/L	-



Co(NO ₃) ₂ .6H ₂ O	0.49g/L	-
MoO ₃	0.71g/L	-

Plant Growth Analysis

To verify the toxicity of untreated tannery effluent plant growth analysis was done where healthy, uniform and viable seeds of *Solanum melongena* (L.) and *Capsicum annuum* (L.) was selected for the experimental study.

Experimental Setup and Determination of Plant Growth and Biomass

The experimental plant seeds were rinsed in distilled water after being washed in running tap water. In each pot, about 20 seeds were sowed and were grown for 45 days with the appropriate treatments (Control, 50% concentration of effluent and 100% raw effluent). The experimental plants were then harvested and analysed for their growth (Shoot length, root length, shoot diameter, root diameter and leaf area) and biomass (fresh weight and dry weight).

4. Results and discussion

The Environmental Impact Value (EIV) from the Table 2 is -19. The survey clearly states that some environmental qualities are not been affected by the tanneries hence no change in the value was noted, whereas the life values provided by tanneries is completely positive but other physical and human use-value made the total EIV negative.

Table 2: Environmental Impact Value (EIV) In Tannery Industry.

Parameter	Relative Importance Value	Degree of Impact	Relative Impact (positive)	Relative Impact (negative)	EIV
Physical					-22
Surface Water Quality	6	-1		-6	

Ground Water Quality	4	-3		-12	
Air Quality	3	-4		-12	
Noise Quality	2	-2		-4	
Soil Quality	3	+4	+12		
Ecological					+2
Fisheries	2	-2		-4	
Aquatic Biology	1	0	0		
Vegetative Cover	2	+3	+6		
Wildlife	1	0	0		
Human Use Value					-28
Water Supply	4	0	0		
Power	5	-3		-15	
Agriculture	1	0	0		
Housing	3	0	0		
Recreation	1	-1		-1	
Sewage	4	-3		-12	
Quality of Life Values					+29
Employment	7	+2	+14		
Aesthetics	3	+3	+9		



Public Health	3	+2	+6		
Safety	5	0	0		
Solid Waste	4	0	0		
Total EIV					-19

Based on the data obtained the human use values showed the highest negative value as -28 followed by physical values which is -22 (Fig.1). The relative change in the negative impact gradually increased from the surface water quality, noise quality, groundwater quality to air quality. The liquid wastes stored in the tanks caused a bad smell in the air and the continuous sound in the tanning process gave negative impacts in the quality of sound and air. The surface and groundwater quality showed colour change in some places but not in all the places, in some tannery industrial places, the water let out had some leakage that contaminated the water sources nearby causing damage to the surrounding ecosystem. The wildlife both aquatic and terrestrial seen where less in number hence no change in the environmental quality is observed. The aquatic water body around the industrial area had a negative impact by the tanneries. Tannery in the Pammal area had a huge land where they deposited the solid waste and gave some treatment for the sludges to use them as vermicompost. By this, the soil quality of the place had a high positive impact. Sometimes agriculture is even carried out inside the tannery land and showed great results. Employment opportunities earned the positive degree of impact, where some workers have experience of more than 25 years and the recruitment is also carried in the given period of time. Necessary gloves, special suits, shoes, and masks were provided to the workers, therefore, increasing the positive impact furthermore. Since there were no such specific guidelines to select the parameter and also for the relative importance value to conduct EIA. For this reason, judgement was introduced which will help develop the further study of EIA for similar industrial sectors and is an effective guideline to perform EIA [22].

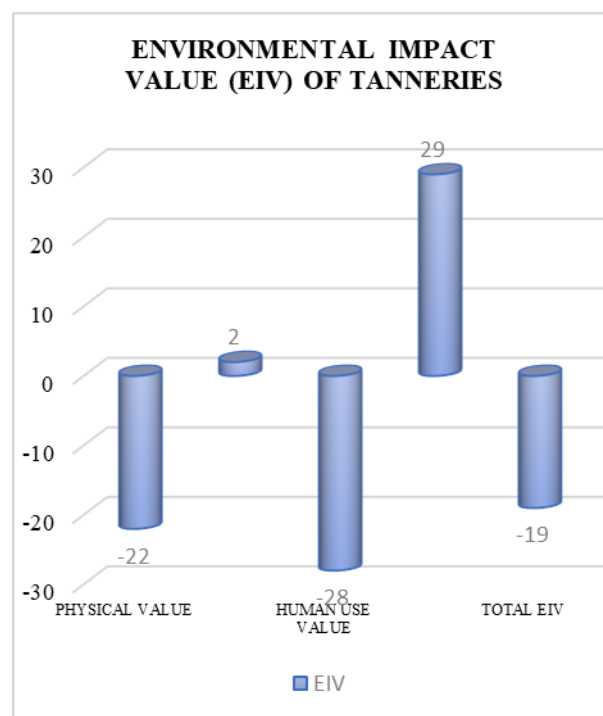


Fig. 1: Environmental Impact Value (EIV) in Tannery Industry.

The colour of the study effluent was golden yellow with unpleasant odour which turned into green colour and odourless for both 50% and 100% concentration of effluent after the treatment with microalgae mixture (Fig.2). From the table 3 we can interpret the oil and grease of the effluent was about 0.03mg/l respectively. After phycoremediation treatment the oil and grease were in negligible amount. The turbidity of the tannery effluent was found to be 28.9mg/l. At the time of collection, the temperature of the tannery effluent was about $36^{\circ} \text{C} \pm 2^{\circ} \text{C}$ which was also maintained throughout the treatment process also. The pH value of the effluent was 4.5 at the time of collection which was highly acidic that slowly reached to more or less neutral condition of 7.1 in 50% concentration of effluent and 6.8 in 100% concentration of effluent at the end of treatment. Similar results were observed in [23]. The EC was 9070 $\mu\text{mhos/cm}$. This value exceeded the permissible limit. After the treatment the values reduced to much lower rate of 560 $\mu\text{mhos/cm}$ and 880 $\mu\text{mhos/cm}$ for 50% concentration of effluent and 100% concentration of effluent respectively. Manoranjan *et al* 2016 [24], stated that ions present in treated effluent will be comparatively lesser than that of raw effluent. The



Total Dissolved Solids is comparatively higher (5150 mg/l) in the tannery effluent than the Total Suspended Solids which was about 1185mg/l, where as in 50% concentration of effluent after the treatment it showed significant reduction of 689 mg/l and in 100% concentration effluent it was about 920 mg/l. For Arif *et al* 2020 [25], there was a significant reduction in TDS and TSS in treated effluent. Dissolved Oxygen content was very low in the raw effluent which is not suitable for the aquatic life to survive the amount of Dissolved Oxygen was found to be 4.5mg/l. The BOD in the raw tannery effluent was found to be about 1450 mg/l. The COD was found to well about the recommended limits 4210 mg/l. Chromium concentration got significantly lesser in both the concentration proving that algae are capable of degrading 99% of chromium.



Fig. 2: Untreated effluent (left) – 50% concentrated (left) 100% concentrated (right), Treated effluent (right) – 50% concentrated (left) 100% concentrated (right).

The impact of the tannery effluent on the growth and biomass of the plants is discussed below. After 45 days of effluent treatment, the shoot length and root length of experimental plants (*Solanum melongena* L. and *Capsicum annuum* L.), were studied and the results were tabulated. There was a significance change in the shoot and root lengths in both the plants. From table 4 & 5 we can see that the shoot length and root length of *Solanum* treated with 50% treated of effluent (34.14cm and 9.02 cm) is found to be more or less equal to the control plants (36.38cm and 5.14cm). When compared to the two experimental plants, *Solanum melongena* showed 93% of shoot length whereas capsicum showed only 68% in 50% concentration of the effluent respectively. The shoot and root length of the vegetable plant *Daucus carota* L. showed decreased in height as the concentration of the effluent increases [26]. There was a significant change in the total length of *Solanum*

melongena plants which were grown in 100% concentrated effluent. The total length reduced to approx. 42% in the 100% effluent treated plants of *Capsicum annuum*. About 30% of reduction in total length was observed in 50% concentrated of effluent treated *Capsicum* to the control plants. Findings of Ali Imran Malhi *et al* 2020 [27] revealed that increasing concentration of effluent reduced the total plant height (shoot length and root length).

Table 3: PHYSIO-CHEMICAL PARAMETERS OF TANNERY EFFLUENT

Parameter s	Raw Effluent	50% Concentrat ion of Effluent	100% Concentr ation of Effluent
Color	Golden yellow	Green	Green
Odor	Unpleasa nt odor	Odorless	Odorless
Oil And grease	0.03mg/l	BDL(DL:0.01)	BDL(DL:0.01)
Turbidity	28.9 mg/l	9 mg/l	14 mg/l
Temperatu re	36°C ± 2°C	36° C ± 2 °C	36°C ± 2°C
pH	4.5	7.1	6.8
Electrical Conductivi ty	9070 1 micro mh0/cm	560	880
Total Dissolved Solids	5150 mg/l	689	920
Total Suspended Solids	1185mg/l	22 mg/l	37 mg/l
Dissolved Oxygen	4.5mg/l	7.2 mg/l	6mg/l
Biological Oxygen Demand	1450 mg/l	17 mg/l	33 mg/l
Chemical Oxygen Demand	4210 mg/l	66 mg/l	86 mg/l



Total Chromium	57 mg/l	BDL(DL:0.1)	0.6 mg/l
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The *Capsicum annuum* plant treated with water, 50% concentration and 100% concentration were about 0.42cm, 0.3cm and 0.28cm respectively and the root diameter was found to be 0.48, 0.34 and 0.28cm (Control, 50% concentration and 100% concentrated effluent). The root diameter and shoot diameter of *Solanum melongena* plants was found to be more or less 0.4 cm in Control and in effluent treated plants. The leaf area of the experimental plant decreases as the concentration of effluent increases it has been observed that there was 40% reduction of leaf area in 50 % when compared to Control in both the Experimental plants. The total no. of leaves is also decreasing when increase in the concentration of effluent in *Capsicum annuum* plant (24 - control plants, 14 and 12 in 50% Concentrated Effluent and 100% concentrated effluent respectively). In *Solanum melongena* plants the no. of leaves was more or less equal. *Capsicum annuum* showed almost 50% reduction in the Fresh and dry weight in Total plant weight, shoot weight and root weight. In *Capsicum annuum* the difference in the change in the fresh and dry weights are higher when compared to *Solanum*. The fresh and dry weight of Total plant, shoot and root of *Solanum melongena* showed about similar results with only slight changes in 100% of the effluent. The study on the effect of tannery effluent on the growth of *Allium cepa* L. and *Lycopersicon esculentum* L. showed reduction in growth when compared to the control plants [26]. In *Solanum melongena* both the fresh and dry weight of Control and 50% showed nearby results 9 (Fig.3). In *Capsicum* when compared to 100% concentrated effluent and control there was 70% reduction in 100% concentration of effluent (Fig.4).

Table 4: Effect Of Tannery Effluent on The Growth Parameters and Biomass of *Solanum melongena* L.

PARAMETERS	CONTROL (WATER)	50% CONC. OF EFFLUENT	100% EFFLUENT
Total Plant Height (cm)	48.92 ± 0.37 (100)	43.16 ± 1.01 (88)	36.5 ± 1.45 (11)

Shoot Length (cm)	36.38 ± 0.78 (100)	34.14 ± 0.46 (93)	29.84 ± 0.81 (82)
Shoot Diameter (cm)	0.48 ± 0.10 (100)	0.42 ± 0.01 (105)	0.4 ± 0.01 (100)
Root Length (cm)	12.54 ± 0.25 (100)	9.02 ± 0.62 (71)	6.86 ± 0.90 (54)
Root Diameter (cm)	0.42 ± 0.09 (100)	0.4 ± 0.14 (95)	0.38 ± 0.13 (90)
Leaf Area (cm ²)	114.05 ± 1.07 (100)	74.75 ± 0.78 (62)	61.15 ± 0.62 (53)
Total no. of Leaves	4 ± 0.1 (100)	3.98 ± 0.6 (99.8)	3.8 ± 0.97 (95)
Total Plant Weight (g)	8.58 ± 0.60 (100)	8.08 ± 0.14 (94)	7.84 ± 0.49 (91)
Shoot Fresh Weight (g)	7.16 ± 0.85 (100)	7.34 ± 0.74 (102)	6.92 ± 0.30 (96)
Shoot Dry Weight (g)	1.32 ± 0.85 (100)	1.25 ± 0.90 (94)	1.20 ± 0.79 (91)
Root Fresh Weight (g)	1.42 ± 0.75 (100)	0.92 ± 0.35 (64)	0.74 ± 0.49 (52)
Root Dry Weight (g)	0.2 ± 0.14 (100)	0.15 ± 0.08 (75)	0.12 ± 0.07 (63)
Leaf Fresh weight (g)	4.28 ± 0.97 (100)	4.18 ± 0.21 (107)	2.6 ± 0.39 (60)
Leaf Dry Weight (g)	0.68 ± 0.42 (100)	0.65 ± 0.50 (102)	0.62 ± 0.43 (91)

*Values in parenthesis () indicate percent activity
The values represent mean of the sample with their standard error (±)

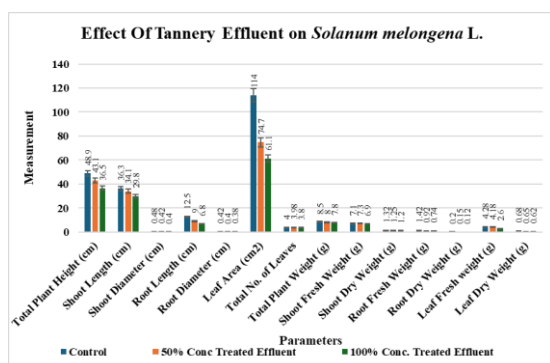


Fig. 3: Effect Of Tannery Effluent on *Solanum melongena* L.

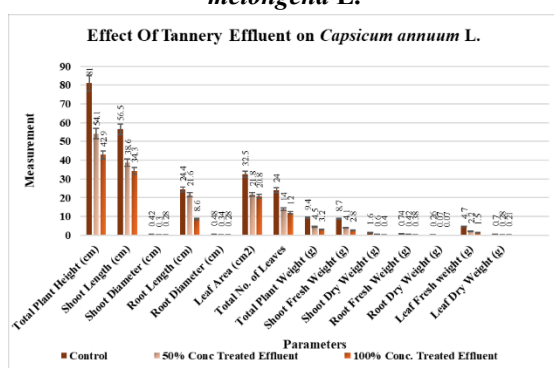


Fig. 4: Effect Of Tannery Effluent on *Capsicum annum* L.

Table 5: Effect Of Tannery Effluent on The Growth Parameters of *Capsicum annum* L.

PARAMETERS	CONTR OL (WATER)	50% CONC. OF EFFLUENT	100% EFFLUENT
Total Plant Height (cm)	81.04 ± 0.26 (100)	54.14 ± 0.08 (66)	42.92 ± 0.35 (52)
Shoot Length (cm)	56.56 ± 0.12 (100)	38.64 ± 0.74 (68)	34.3 ± 0.54 (60)
Shoot Diameter (cm)	0.42 ± 0.07 (100)	0.3 ± 0.01 (71)	0.28 ± 0.01 (66)
Root Length (cm)	24.48 ± 0.61 (100)	21.64 ± 1.01 (88)	8.62 ± 0.55 (35)

Root Diameter (cm)	0.48 ± 0.04 (100)	0.34 ± 0.08 (70)	0.28 ± 0.07 (58)
Leaf Area (cm ²)	32.55 ± 0.76 (100)	21.8 ± 0.93 (66)	20.85 ± 0.69 (64)
Total no. of Leaves	24.4 ± 0.60 (100)	14.6 ± 0.49 (59)	12 ± 0.41 (40)
Total Plant Weight (g)	9.46 ± 0.99 (100)	4.54 ± 0.19 (95)	3.22±1.01 (93)
Shoot Fresh Weight (g)	8.76 ± 0.92 (100)	4.16 ± 0.23 (85)	2.8±0.79 (51)
Shoot Dry weight (g)	1.62 ± 0.38 (100)	0.6 ± 0.17 (85)	0.48 ± 0.19 (64)
Root Fresh Weight (g)	0.74 ± 0.34 (100)	0.42 ± 0.11 (75)	0.38 ± 0.22 (52)
Root Dry Weight (g)	0.26 ± 0.08 (100)	0.07 ± 0.02 (63)	0.07 ± 0.04 (63)
Leaf Fresh Weight (g)	4.72 ± 0.98 (100)	2.24 ± 0.82 (97)	1.56 ± 0.55 (85)
Leaf Dry Weight (g)	0.71 ± 0.15 (100)	0.28 ± 0.09 (42)	0.21 ± 0.06 (17)

*Values in parenthesis () indicate percent activity

The values represent mean of the sample with their standard error (±)

5. Conclusion

The findings of this study demonstrate that tannery effluents in the Pammal and Nagalkeni industrial zones exert a significant negative environmental impact. However, the application of mixed microalgae cultures for phycoremediation effectively reduced the pollutant load and improved effluent quality. The improved plant growth observed with diluted treated effluent further indicates the potential of this approach in mitigating phytotoxic effects. Overall, microalgae-based remediation represents a sustainable, eco-friendly, and cost-effective strategy for treating tannery wastewater while supporting safer agricultural reuse.



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