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Research Article

Treatment of Tanning Effluent Using Seaweeds and Reduction of Environmental Contamination

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One of the main sources of dangerous chemicals that are dumped untreated into land and water bodies and have a negative influence on the ecosystem are industrial effluents. Seaweeds are currently used for treating industrial effluent effectively. The technology is at a maturing stage. This paper reviews the characterization and cultivation of seaweeds for wastewater treatment. In this present study, different extracts of four seaweeds such as *Gracilaria edulis*, *Sargassum wightii*, *Turbinaria ornata*, and *Kappaphycus alvarezii*, from the Mandapam coastal regions were analyzed. The seaweeds are used to treat the leather industry effluents collected from EKM leather processing company, Erode, Tamil Nadu, India. Among all, extracts of *Gracilaria edulis* survived at different concentrations of TDS: 15,000, 25000, and 35000 mg/l. Out of these different ranges, TDS of about 25000 mg/l seaweed named *Gracilaria edulis* reduced more amounts of chemicals present in the effluent like TDS (93.90%), phosphates (72.71%), nitrate (75.08%), nitrite (76.92%), and turbidity (99.01%) content. Additionally, we produce the quality and strength of agar gel from the cultivation of *Gracilaria edulis* by the Nikansui method. Finally, we got the extraction procedure to obtain a higher yield of about 10.26% and a maximum gel strength of 92.06 $g \cdot cm^{-2}$ while maintaining the melting point at 78°C.

1. Introduction

Waste is produced by every area of our society, including consumers, manufacturing, farming, mines, energy, transport, and construction. Pollutants in waste include chemicals, process byproducts, and waste materials [1]. When these contaminants are released in excess of what the ecosystem can absorb, pollution may occur. Industrial wastes are produced by a variety of industrial processes, and each production method has a unique impact on the quantity and severity of the pollution discharged [2]. The biggest contaminant of all industrial wastes is tannery effluent. The leather industry plays a significant role in the Indian economy, supplying 2 billion US dollars in exports and 2% of global trade. Nearly, 2.5 million people are currently in the leather sector, and the bulk of the leather industries is classified as small- and medium-sized businesses [3]. The country's enormous animal population is a significant factor in the development and expansion of the leather industry. Nearly, 10% of the world's supply of raw hides and skins, the essential raw resources for leather industry, are available in India. In India, the states of Tamil Nadu, Andhra Pradesh, Karnataka, Punjab, West Bengal, and Uttar Pradesh are home to the majority of tanning salons.

The quantity of chemicals used in tanning processes is almost in the same range as that in all the regions in India. Depending on the availability of water, the wash water volume usage varies, and wash water contains chemicals in various concentrations in the sectional and composite wastewater [4, 5]. The concentration of the pollutants present in the wastewater also depends on the clean technology adopted in the tanneries like dusting of salt, recovery and reuse of chromium, and the quality of the chemicals used. In Tamil Nadu, it is mandatory for tannery processing, raw to semifinish (chrome tanning process), to have a chrome recovery system [6, 7]. Due to scarcity of water, the quantity of water used for washing is less in Tamil Nadu when compared with that of other parts of the country. Due to this, the concentrations of chemical oxygen demand (COD) and biochemical oxygen demand (BOD) are comparatively high in wastewater [8, 9]. However, in the case of tanneries in Uttar Pradesh, Punjab, and West Bengal, the volume of water used for washing is high and this results in dilution of the pollutants [10, 11]. In Andhra Pradesh and Tamil Nadu, soak and pickle liquor are segregated and conveyed to solar evaporation pans. However, in other parts of the country, no segregation of the soak and pickle is done and they are combined with the remaining sectional streams [12–14].

Seaweed is the common name for countless species of marine plants and algae that grow in the ocean as well as in rivers, lakes, and other bodies of water [15]. Seaweeds are used for a variety of things, including integrated aquaculture, fertilizers, animal feed, and nourishment for humans and animals. Presently, soak effluent is treated by solar evaporation pan. In this process, a coagulant is added to reduce the odor and turbidity of soak effluent and to increase the evaporation rate of effluent [16]. To provide a solution, this study focuses on the treatment of soak effluent by phytoremediation technique. This technique not only treats the effluent but also uses it to produce useful byproducts like agar gel by the Nikansui method. In the soak effluent having basic parameters like TDS, turbidity was found to be in a high range [17, 18]. For treating this effluent, the conventional methods are suitable but not an economical one. To overcome this, an ecofriendly method called phytoremediation technique (It is a method of "bio remediation" where different kinds of plants are used to transfer, remove, and stabilize toxins from the soil and ground water.) is adopted instead of the phytoaccumulation (The contaminants, along with other nutrients and water, are absorbed by plant roots during this process) process.

2. Materials and Methods

2.1. Collection of Seaweeds. The seaweeds (Figure 1 and Figure 2) were collected from the Mandapam coastal regions (latitude 9° 16′ 32.56″ N and longitude 79° 07′ 25.03″ E), India's southeast coast. A sample of seaweed was manually collected, and any extraneous materials, sand particles, and epiphytes were quickly rinsed away with seawater [19]. It was immediately brought to the laboratory and extensively cleansed, utilizing normal water to remove the salt from the sample's surface while being maintained in an icebox filled with slush ice [20].

2.2. Collection of the Soak Effluent. The effluent was collected from E. K. M. Leather Processing Company at Erode (Figure 3). Many industries were using normal water in the soak process, but this industry was using reverse osmosis (RO) reject wastewater, which has more organic and inorganic constituents and other trace compounds. Therefore, the soaking effluent contains more organic and inorganic constituents [21]. These effluents were analyzed the raw and diluted effluent for physical and chemical characteristics such as pH, turbidity, BOD, COD, and phosphate by using APHA (33) methods. Physical and chemical characteristics of raw soak effluent are pH is 7.0–8.5, turbidity is > 1000 NTU, TDS is 30000–40000 mg/L, BOD is 1560 mg/L, COD is 3000 mg/L, TSS is 9800 mg/L, phosphate is 18 mg/L, NO_3 is 9.80 mg/L, and NO_2 is 0.08 mg/L, and biochemical parameters are total protein is 1800 μg/l, lipid is 12 mg/l, and carbohydrate is nil.

2.3. Aqua Culturing Technique. Marine or freshwater species may be raised by aquaculture, sometimes known as "fish farming," in the marine or on shore. The farming technique employed heavily influences how environmentally friendly farmed seafood is [22].

2.3.1. Floating Raft Method. Floating rafts for hydroponically produced plants. The rafts can be used to improve water quality by filtering, consuming, or decomposing contaminants (such as nutrients, silt, and metals) from the wastewater [23]. They float on a wet pond top.

FRM might be a viable and reasonably affordable engineered the best management practice (BMP) for lowering wastewater pollution (Figure 4).

2.3.2. Determination of Growth of Seaweeds from the Soak Effluent. I have chosen 4 types of seaweeds like *Gracilaria edulis*, *Turbianria ornata*, *Kappaphycus alwarezii*, and *Sargassum wightii* that were cultivated by the low tide method. In this method, for 1 liter of the soak effluent, 10 g of seaweeds was used for each species. Furthermore, aeration is provided [24]. After a period of 20 days, only the species called *Gracilaria edulis* alone has shown growth. It is found by measuring the final weight of that species [25].

Growth Rate = (Initial weight − Final weight)/(Final weight).

2.3.3. Determination of Optimum TDS for the Growth of Gracilaria edulis. An optimum dosage for the growth of *Gracilaria edulis* was identified by diluting the soak effluent with water to make different concentrations like 15,000,

Figure 1: Brown algae.

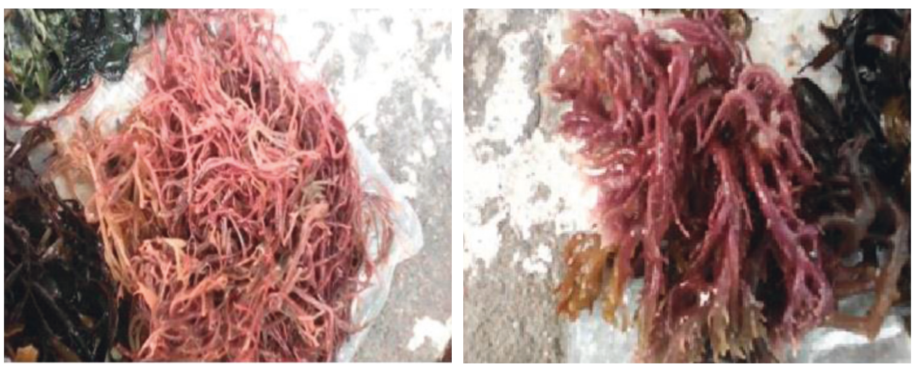


Figure 2: Red algae.

Figure 3: Collection of the soak effluent from E.K.M. Leather Processing Company.

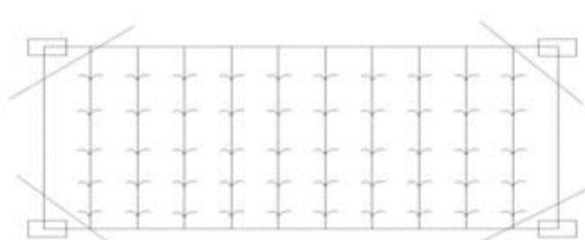


Figure 4: Floating raft method.

25,000, and 35,000 mg/l. Finally, that seaweed survived at a TDS range of 25,000 mg/l. Then, the plant was cultivated using the diluted soak effluent to determine the optimum TDS for the growth of the plant [26].

2.3.4. Aqua Culture Study for Gracilaria edulis. This study was conducted on three different samples (Figure 5).

(1) Tannery soaking effluent of 15,000 TDS
(2) Tannery soaking effluent of 25,000 TDS
(3) Tannery soaking effluent of 35,000 TDS

2.4. Treatment of Wastewater Using Gracilaria edulis

2.4.1. Determination of the Soak Effluent after Treatment at 5 Days Retention Time. An optimum dosage for the growth of *Gracilaria edulis* was identified by diluting the soak effluent with water to make different concentrations of 15,000, 25,000, and 35,000 mg/l of TDS. Finally, it was determined that this plant can survive at 25,000 mg/l TDS [27]. Then, the plant was cultivated using the diluted soak effluent to determine the treated soak effluent. The initial weight of the seaweeds is tested for its soak effluent parameters for 5 days' retention time. We take the final weight of seaweeds after 15 days. These 25,000 mg/lit of TDS of the soak effluent has high removal efficiency of physical-chemical parameters by using *Gracilaria edulis*.

2.4.2. Analysis of the Soak Effluent at 5 Days Retention Time. The tannery effluent was collected through the soaking process and tested for its physical-chemical parameters by the AHPA method. Then, the cultivation of seaweed is weighted after 15 days by a weighing machine (Figure 6).

2.5. Removal of BOD and COD from Treated Wastewater. It was found that the treated soak effluent had high COD and BOD content. It will be removed by adding a large amount (2pinch) of coagulant dose like alum and polyelectrolyte [28].

2.6. Production of Agar Gel from Gracilaria edulis. The best combinations of alkali/acid and thermal processing were found to improve the yield and quality of agar from the red seaweed *Gracilaria edulis* [29].

2.6.1. Soaking. To study the effect of the soaking period, 20 g of dried *Gracilaria edulis* were soaked in 400 ml of potable water. Time units such as 4 h, 8 h, and 12 h were selected [30].

2.6.2. Acid Pretreatment. To determine the effect of acid soaking, the seaweeds were soaked in a dilute solution of HCL/NaOH at a concentration of 0.5 N for 1 hr. Presoaked samples in potable water for 11 h were transferred to a concentration of NaOH/HCL (0.5 N–3.0 N) for 1 h in a water bath at 82°C. To this mixture, 10 ml of $CaCl_2.2H_2O$ was added to reduce the loss of agar while processing [31].

2.6.3. Agar Extraction. The treated plant was washed with running tap water to remove traces of NaOH/HCL. The dry sample of about 20 g was boiled in a 1 liter beaker after adding 400 ml of distilled water and maintaining pH in the range of 6.0–6.5 in an autoclave for 2 h. The hot extract was recovered after filtration through a muslin cloth. The residue was re-extracted with 100 ml of hot (80–85°C) distilled water. The filtrated samples were maintained at room temperature at −20°C for 12 h. The frozen gel was allowed for thawing. Alternatively, change the freezer and thaw the filtrated samples two times. The thawed gels were kept in the sun to dry for 3 days. Agar samples after complete drying were weighted accurately to calculate the percentage yield of agar [32].

2.6.4. Agar Gel Strength Measurement. The agar gel strength is measured by the FMC gel tester or by the Nickansui Method [33]

We calculate the gel strength formula according to the following equation:

$$G = X\left(\frac{W}{200}\right), \quad (1)$$

where $G = X$ gel strength in grams. W = millimetre of water necessary to break the gel. X = weight of gel in grams.

3. Results and Discussion

3.1. Analysis of Sea Water. The nutrient status of seawater for the selection of seaweed should be surveyed for basic physicochemical parameters like TDS, pH, NO_2, DO, NO_3, and phosphate by APHA (33) methods. From Table 1, it can be observed the TDS has a maximum value of 37,000 mg/l and the minimum value was NO_2 as 0.06 mg/Lit.

3.2. Analysis of the Lime Effluent. The lime effluent should be analyzed by the AHPA method. The lime effluent comes from the tannery process. It is also one of the tannery effluents [34]. It was analyzed for the physicochemical parameters like BOD, COD, TDS, pH, nitrate, nitrite, phosphate, and hardness of the lime effluent. From Table 2, it can be seen that NO_2, NO_3, and phosphate values fall to less than 0.01 mg/lit. Selection of seaweeds survived at 7.2–8.5 of pH, 30,000–37,000 of TDS, 0.3–1.74 mg/lit of nitrate, 0.17–0.98 mg/lit of nitrite, and 0.65–4.23 mg/lit of phosphate. However, the lime effluent has the minimum amount of nutrients. Therefore, the seaweeds are not able to survive in lime effluent. However, the lime effluent should not be taken for treating purposes because the effluent has nutrients of less than 0.001 mg/lit.

3.3. Analysis of Soak Effluent. The first nutrient content of soak effluent was found. The selection of seaweed should be based on physicochemical parameters like TDS, pH, NO_2, DO, NO_3, and phosphate by APHA (33) methods. The soak effluent is from the tannery process [35].

Two water samples, like fresh water and RO rejected water, are used for the soaking process. Here, we have chosen

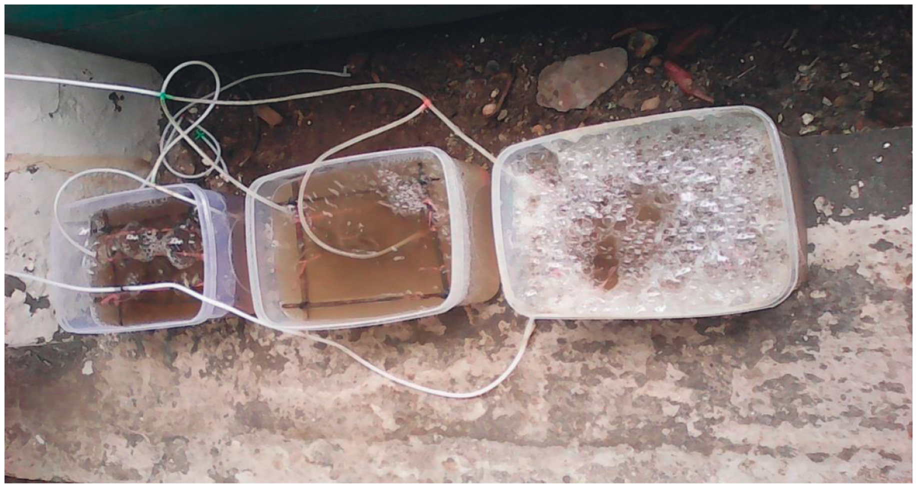
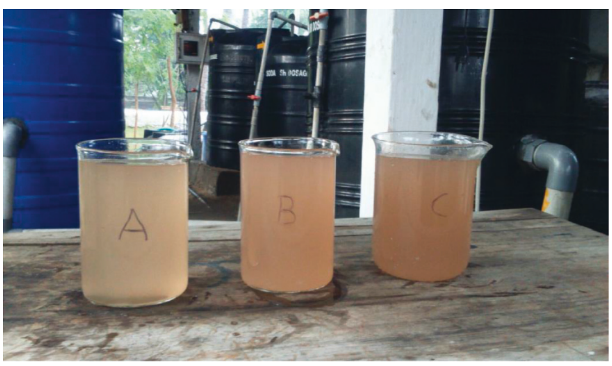


Figure 5: Growth of *Gracilaria edulis* constructed in Aquaculture.



Diluted Soak Effluent at 15,000 TDS | Diluted Soak Effluent at 25,000 TDS | Raw Soak Effluent at 35,000 TDS

Figure 6: Initial soak Effluent for treating wastewater by seaweeds.

Table 1: Characteristics of sea water.

S.NO	Parameters	Range
1	TDS	37,000 mg/lit
2	DO	1.2 mg/lit
3	pH	7.2–8.5*
4	Temperature	25°C–35°C
5	NO_2	0.06 mg/lit
6	NO_3	20.0 mg/lit
7	Phosphate	4.80 mg/lit

*value on the pH scale.

the fresh water only, because the fresh has 33,000 mg/lit of TDS. The RO rejects wastewaters having 40,000–50,000 mg/lit (Table 3).

3.4. Aqua Culturing Study for *Gracilaria edulis*

3.4.1. Method for the Growth of Seaweeds from the Soak Effluent. *Gracilaria edulis* was cultivated by the low tide method. In this method, for 1 liter of soak effluent, 10 g of

Table 2: Characteristic of lime effluent.

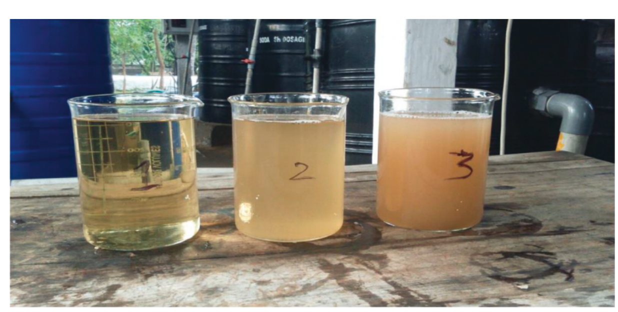
S.NO	Parameters	Range
1	TDS	22,000 mg/lit
2	BOD	3000 mg/lit
3	COD	11,000 mg/lit
4	pH	12–14*
5	Hardness	2250 mg/lit
6	NO_2	<0.01 mg/lit
7	NO_3	<0.01 mg/lit
8	Phosphate	<0.01 mg/lit

*value on the pH scale.

Table 3: Characteristics of the soak effluent.

S.NO	Parameters	Range
1	TDS	33800 mg/lit
2	pH	7.5*
3	COD	2960 mg/lit
3	Total protein	1800 μg/lit
5	NO_2	0.06 mg/lit
6	NO_3	20.00 mg/lit
7	Phosphate	4.80 mg/lit
8	Temperature	28°C

*value on the pH scale.



(1) Treated Soak Effluent | (2) Diluted Soak Effluent | (3) Raw Soak Effluent

Figure 7: Treated soak effluents at 5 days retention time.

Table 4: Physical and chemical characteristics of feed and treated effluent—5 days retention time.

S.NO	Parameters	Feed effluent	After treatment	Removed from waste water	Removal percentage
1	pH	8.30*	8.22*	0.08*	—
2	TDS	12150 mg/lit	11410 mg/lit	740 mg/lit	93.90%
3	BOD	845 mg/lit	720 mg/lit	125 mg/lit	85.06%
4	COD	3400 mg/lit	2920 mg/lit	480 mg/lit	85.35%
5	NO_2	0.013 mg/lit	0.010 mg/lit	0.003 mg/lit	76.92%
6	NO_3	2.878 mg/lit	2.161 mg/lit	0.717 mg/lit	75.08%
7	Phosphate	52.38 mg/lit	38.09 mg/lit	14.29 mg/lit	72.71%
8	Turbidity	0.5 NTU	0.3 NTU	0.2 NTU	90.73%

*value on the pH scale.

Table 5: Characteristic of BOD and COD.

S.NO	Parameters	Initial BOD	Final BOD
1	BOD	845 mg/lit	338 mg/lit
2	COD	3400 mg/lit	1360 mg/lit

Table 6: Quality of agar gel from *Gracilaria edulis*.

S.NO	Treatment	Agar yield (%)	Gel strength (g.cm^{-2})	Melting point (°C)
1	Control	12.132	52.36	66
2	2 hrs	11.440	68.80	73
3	4 hrs	10.812	69.06	81
4	8 hrs	10.275	82.26	82
5	11 hrs	10.361	95.05	78

seaweed was used for each species. Further aeration is provided. After a period of 20 days, only the species called *Gracilaria edulis* showed growth. It is found by measuring the final weight of that species [5].

Number of plant: 1.

Initial weight of plant: 20 g.

Final weight of plant: 26 g.

3.4.2. Analysis of Soak Effluent Characteristics after Phytoremediation. During the growth, different parameters of effluent were analyzed like pH, TDS, turbidity, BOD (biological oxygen demand), COD (chemical oxygen demand), and TSS (total suspended solids).

In this study, the best removal efficiency and retention time of 5 days were taken for *Gracilaria edulis*, such as 5 days [36, 37]. Effluent characteristics was analyzed for phytoremediated water after the retention time of 5 days (Figure 7). Plant feed is the soak effluent for growth. During growth plant parameters and characteristics of effluent from aquaculture was monitored and analyzed (Table 4).

3.5. Removal of BOD and COD in the Treated Soak Effluent. The effluent should have high COD and BOD content, if it is not treated. It will be removed by adding a large amount (2 pinch) of coagulant dose like alum and polyelectrolyte (Table 5).

3.6. Quality of Agar Gel from Gracilaria edulis. The FMC Gel tester measures the agar gel. This method is done by following procedures such as the soaking process, alkali/acid Pre-treatment process, and agar extraction process (Table 6). Finally, we find out the agar gel strength [38, 39].

From the above table, the maximum ager gel strength (95.05 g cm^{-2}) was achieved 11 hours treatment at 78°C and the minimum ager gel strength (52.36 g·cm-2) was achieved at 66°C.

4. Conclusion

Results from this study show that soak effluent has a higher concentration of TDS and odor. Seaweeds like *Gracilaria edulis* were found to be effective compared to the other three species for treating soak effluent. The maximum removal efficiency of (physicochemical characteristics) soak effluent is given with retention time. The turbidity of treated soak effluent is reduced to 90.73% in 5 days of retention time. The phosphate of treated soak effluent is reduced to 72.71% in 5 days of retention time. The nitrate of treated soak effluent is reduced to 76.92% in 5 days of retention time. The nitrite of treated soak effluent is reduced to 75.08% in 5 days of retention time. The TDS of treated soak effluent is reduced to 93.90% in 5 days' retention time. The pH of the soak effluent is reduced to 99.03% in 5 days' retention time. Then, the extraction procedure to obtain a higher yield is 10.361% and the maximum gel strength is 95.05 g·cm^{-2} while maintaining the melting point at 78°C.

Data Availability

All data are included in the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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