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Potential of electrocoagulation technology for the treatment of tannery industrial effluents: A brief review

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In this new era, we are facing a major problem regarding wastewater in the environment, which has an adverse effect on human life. Wastewater from tanning industries is one of the major contributors to the pollution in aquatic systems. Tannery industries have always contributed to the world's economy and trade despite facing criticism due to environmental pollution. Tanning effluent consists of organic, inorganic (chromium, nitrogenous compounds), and a large amount of solid content like TDS, TSS, TVS. To overcome these significant challenges, there have been few advancements related to tannery wastewater treatment. This article aims to provide a brief review on electrocaogulation based treatment technologies for eliminating the impurities from tannery wastewater. This review consists of the background with characteristics of tannery wastewater, the alternatives for treating the tannery effluent over the years along. A detailed description of the advanced technologies based on electrocoagulations is implemented to overcome the drawbacks of the existing methods.

Keywords: tannery wastewater, alternative treatment methods, advanced electrocoagulation, hybrid/integrated approaches

1. INTRODUCTION

Tanning industry is found to be one of the oldest industries in the world. Tanning is the process of converting animal hide and skin to actual leather by eliminating water molecules from the skin's collagen (protein content) and replacing them with vegetable or chrome molecules, resulting in stable and imputrescible leather (Yusif et al., 2016). The vegetable tanning procedure generates leather by immersing it in natural tannin solutions several times over a period of 1–2 months to complete, and the product smells like a natural tone. Water molecules are eliminated from the collagen of the hide using Cr salts instead of tannins in the basic chrome tanning processes. Tanning can have major environmental consequences,

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as many chemical wastes are frequently released into waterways. Non-biodegradable organic substances such as polyphenolic, naphthalene sulfonic, and tannin are found in tannery wastewater. Proteins, blood, grease, hair, grit, and other biodegradable organic compounds are produced by a significant volume of soaking process effluent from tanneries. Chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS), total dissolved solids (TDS), and total volatile solids (TVS), as well as chromium and sulfides, are used to characterize the tannery effluent. In general, composite tannery effluent is alkaline in character with a pH above 7.5, high content of organic compounds, high suspended particles, a significant number of nitrates, and a significant proportion of total chromium. Tannery effluent also has a significant concentration of sulfide/sulfate, chlorides, and other metals. Therefore, the demand of environmental groups to adopt technologies that provide cleaner tannery effluent has grown due to the hazardous nature of the effluents. Electrocoagulation (EC) treatment processes are widely employed to remove the organic and inorganic contaminants from wastewater streams (Asfaha et al., 2021). In this article, an overview of recent EC based technologies has been briefed to evaluate the treatment efficiency of tannery wastewater.

2. METHODS FOR TREATMENT OF TANNERY WASTEWATER

Tannery effluent treatment methods are categorized into three main categories, physical, chemical and biological processes. Various treatments for the tannery wastewater like physico-chemical methods such as coagulation, sedimentation, filtration, adsorption, electro floatation, membrane filtration, precipitation and ion exchange, and biological methods such as aerobic, anaerobic, and wetlands and ponds are being used. The choice of wastewater treatment technique, on the other hand, is influenced by a number of criteria, including efficiency, cost, and environmental capabilities. Several researchers have already reviewed the various tannery wastewater treatment procedures (Asfaha et al., 2021; Garcia-Segura et al., 2017). Traditional primary methods for treating tannery effluent include sedimentation, filtration, and coagulation-flocculation with coagulants such as $Al_2(SO_4)_3$ or polyaluminum chloride. The chemical oxidation method is one of the novel technologies that use a chemical oxidant (H_2O_2, $KMnO_4$, O_3, K_2FeO_4, ClO_2, etc.) to convert the pollutants into less harmful & controllable forms in the physico-chemical treatment. Biological methods are applied as secondary treatment, post-primary treatment, in order to remove most of the soluble organics and nutrients from tannery effluent. The most prevalent kinds of biological processes that may be utilized at various phases of tannery wastewater treatments are aerobic, anaerobic, and mixed biological processes.

AOPs have emerged as potential techniques for the remediation of tannery wastewater containing refractory organic compounds due to their ability to exploit the high reactivity of hydroxyl radicals in accelerating oxidation (Karthikeyan et al., 2015; Korpe et al., 2019; Rekhate and Srivastava, 2020). Several methods are included in the AOPs, such as Fenton, ozonation, photo-Fenton, photocatalysis, wet oxidation, and so on, with the primary distinction being the source of radicals (Sivagami et al., 2018).

The integration of anaerobic and aerobic reactors has more efficacy in tannery wastewater treatments than independently anaerobic and aerobic reactors. The anaerobic process may alter the biochemical properties of the tannery effluent, improving the efficiency of the aerobic process that follows oxidation ditch, and man made wetland. Wetlands use an integration of physical, chemical, and biological processes to remove pollutants from tannery wastewater (Younas et al., 2022). To improve the adaptability and efficiency of this approach, efforts should be made in plant selection, numerous device combinations, and device structure modifications (Parde et al., 2021). Microbial Fuel Cells (MFCs), as one of the most promising biological therapies, have also emerged as a potential alternative for both removing COD and generating power (Chen et al., 2020; Kandasamy et al., 2020; Munoz-Cupa et al., 2021).

3. ELECTROCOAGULATION (EC) BASED TREATMENT METHODS FOR TANNERY EFFLUENTS

Electrocoagulation is an effective treatment process for the removal of organic and inorganic compounds from waste effluents. EC has proved as a versatile technology which has been applied for the treatment of various wastewater effluents (Hakizimana et al., 2017). It is based on electrochemical reaction, uses the in-situ generation of coagulants using electric current passed through a sacrificial metallic anode to de-stabilise the pollutants in an aqueous media. In order to improve the performance of EC process, it can be combined with other processes (Table 1 and Fig. 1).

Table 1. Advanced tannery wastewater treatment technologies and their limitations

Technologies	Advantages	Disadvantages	References
Photo-fenton-oxidation	• the high hydroxyl radical production, • high performance and simplicity	• required UV energy for a long time • the large production of ferric sludge	Manenti et al. (2014); Rekhate and Srivastava (2020); Mousset et al. (2021)
Sono electrocoagulation	• gives cavitation effect, • promote particle mixing, homogenization, dispersion, and emulsification	• the destruction of colloidal hydroxides and created adsorption layer • disorganizes migration process	Raschitor et al. (2014); Korpe et al. (2019)
Photo electrocoagulation	• simultaneous removal of microbiological content and turbidity, • complete disinfection of wastewater	• high energy consumption required	Moradi and Moussavi (2019); Jaafarzadeh et al. (2016)
Peroxi electrocoagulation	• decreases sludge content, • high removal efficiency of Cr, TDS, and turbidity	• formation of byproduct and nitrogen compound	Korpe et al. (2019); Vasudevan (2014)

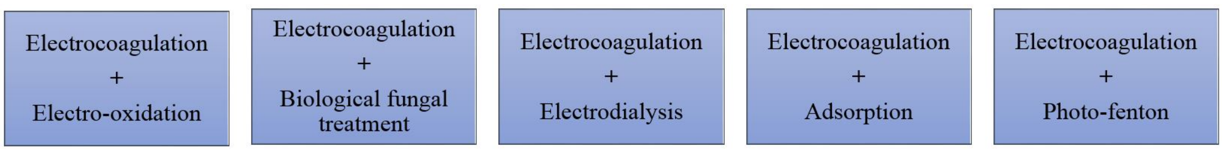

Fig. 1. Integration of EC unit with existing technologies

The sono-EC process is the combination of the electrocoagulation process associated with the ultrasound irradiation approach (Korpe et al., 2019; Moradi et al., 2021). Sound energy stirs up the sample, incubating particle mixing, homogenization, emulsification, and dispersion, including the cavitation effect. Korpe et al. (2019) reported degradation of organic pollutants from tannery wastewater effluent using an acoustic probe sonicator. UV irradiation is a commonly utilized and well-known water disinfection method. The disinfection method relies on the penetration of UV light through the cell wall, which affects the genetic material like RNA and DNA of microorganisms, preventing them from reproducing. Cotillas et al. (2013)

proposed integration of the EC process and UV irradiation, as a consequence, a synergistic impact on disinfection removal is achieved. Peroxi-coagulation or Peroxi-electrocoagulation is the simultaneous electroproduction of hydrogen peroxide by bielectronic cathodic reduction of oxygen by reaction and the anodic dissolution of iron as a sacrificial anode. This is most likely owing to the electro-generation of H_2O_2 and the subsequent creation of ·OH, as well as an increase in the amount of time pollutants are exposed to the oxidising agent (Borba et al., 2018). On the other hand, Peroxi-coagulation can be employed by simultaneous UV irradiation, normally termed as Photo-peroxi-coagulation or Peroxi-photo-electrocoagulation. In the photo-assisted electrochemical oxidation process, the current density of 25 mA/cm^2 efficiently eliminated 100% sulfide, 92% COD, and 70% total organic carbon (Selvaraj et al., 2020).

Several studies have been done using hybrid technologies or coupling of EC with other wastewater treatment technologies to improve effectiveness in an even better way (Moussa et al., 2017). In the past few years, EC pretreatment has been proposed as a feasible MF fouling reduction method (Garcia-segura et al., 2017). Several kinds of heavy metals were eliminated at a very significant and improved rate (> 98%) in hybrid iron-based EC and MF. Ben-Sasson et al. (2013) looked at the feasibility of using a hybrid EC and MF as a NOM removal strategy. This highlights the possibility of utilizing a hybrid EC-MF method as an alternative to UF for NOM. Chellam and Sari (2016) analysed new findings that use the EC pretreatment to improve the quality of microfiltered water significantly. Due to their extensive applicability and environmental compatibility, new electrochemical techniques, primarily electrocoagulation (EC), electrooxidation (EO), and hybrids of both EC and EO, have lately gained interest as a viable approach for treating wastewater (Asfaha et al., 2021). Deveci et al. (2019) used response surface methodology (RSM) to assess the impact of operating factors on the treatment performance of integrated EC and biological fungal treatment, BFT for tannery effluent. Deghles and Kurt (2016) looked at how well a hybrid electrocoagulation/electrodialysis method removed COD, NH_3–N, Cr, and colour from tannery effluent. The efficacy of coupling electrocoagulation (EC) and adsorption (AD) in terms of COD elimination, turbidity reduction, and residual chromium (VI) quantity is investigated by Ait Ouaissa et al. (2012). Módenes et al. (2012) investigated the treatment of tannery industrial effluent (TIE) by combining the commonly utilized photo-Fenton and electrocoagulation (EC) methods.

4. CONCLUSION AND FUTURE CHALLENGES

This review article looked at a large number of studies that incorporated the use of electrocoagulation (EC) with several other methods of pretreatment such as adsorption, ultrasonication, peroxi, electrodialysis, and membrane processes. It was concluded that depending upon the nature of the supplementary process for the EC, the sequencing of the integrated processes is differed. AOPs with EC have also emerged as a potential technique for the remediation of tannery wastewater containing refractory organic compounds due to their ability to exploit the high reactivity of hydroxyl radicals in accelerating oxidation. Finally, our study revealed that only a few studies have worked at kinetic models to forecast these coupled systems. However, the majority of EC processes rely on electricity supplied from non-renewable sources. As a result, renewable energy sources such as solar photovoltaic, biomass, and other types of renewable energy can be employed in future.

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