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Treatment of tannery effluent using sono catalytic reactor

Kannan Kandasamy [a,*], Kalaithanagm Tharmalingam [a], Sangeetha Velusamy [b]

[a] Department of Chemical Engineering, Kongu Engineering College, Perundurai 638052, Tamil Nadu, India
[b] Department of Food Technology, Kongu Engineering College, Perundurai 638 052, Tamil Nadu, India

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ABSTRACT

The effluent released from the leather process industries contain high amount of chemical oxygen demand (COD), biologicaloxygen demand (BOD), suspended solid (SS), ammonia nitrogen, Total Kejeldahl Nitrogen, nitrate, nitrogen, hexavalent and trivalent chromium, chloride, sulphates, etc. In the present study the lime pre-treated effluent is exposed to a sonocatalytic reactor, in which the TiO_2 catalyst was used. The parameters such as BOD, COD and total dissolved solids (TDS) were studied by varying the concentration of effluent, time and catalyst load. The results reveal that the efficiency of sono catalytic reactor on percentage removal of COD, BOD and TDS were 89.53, 87.35 and 92.63 respectively. The response surface methodology (RSM) was used to optimize the variables such as catalyst loading and time. Statistical results were assessed with various descriptive such as p value, lack of fit (F-test), coefficient of R^2 determination. The predicted and adjusted R^2 values were found to be 0.9956, 0.9673 for% COD removal, 0.9484, 0.9926 for% BOD removal and 0.9980, 0.9954 for% TDS removal respectively.

1. Introduction

Leather industry belongs to one of the most polluting industrial sector. There is an increasing environmental concern regarding tanneries since they produce large amounts of potentially toxic wastewaters containing both organic and inorganic compounds. The characteristics of tannery wastewater vary widely depending on: the nature of the adopted tanning process, the amount of water used, the process of leather preservation, the leather processing capacity and the in-plant measures followed to reduce pollution. Some pollutants present in tannery wastewater are soluble, other exists in suspension and few are colloids. The organic compounds present in tannery wastewater are tannins which are highly toxic polyphenolic contaminants that are difficult to degrade [1,14,17]. Therefore, they must be removed from the waste water before discharging into the environment. The uncontrolled release of tannery effluents in water hike the environmental pollution and peril the health of living organisms [2,15].

The treatment methods which are commonly employed for tannery wastewater are physical, chemical and biological processes. Distinct treatment methods like physicochemical methods such as sedimentation, electro floatation, filtration, membrane filtration, precipitation, coagulation, adsorption, ion exchange and biological methods may exposes the chemicals into the environment after processes being carried out [3]. The sludge clearance of this treatment process is also convoluted, with limited efficiency, high expenditure and environmental means estimation. Therefore, cost-effective alternative technologies are needed for treatment of tannery wastewater [16,18]. Sonoreactor is the application of ultrasonic sound waves, having a frequency of 20,000 Hz and above [13]. The chemical outcome of ultrasound is concerned with understanding the effect of sonic waves on chemical systems; this is called sono chemical system or sonochemistry [4]. Sonoreaction enhances chemical reaction kinetics, chemical yields, pathway, breaking and formation of chemical bonds, protein purification, the removal of suspended particles from solids or liquids, extraction, heart transestrification, focused, cleaning, degassing, emulsification, automotive, aerospace, 3D module cleaning, medical devices etc. Sonocatalytic has more efficiency and there is no need of adding chemicals and it is an eco-friendly process. Sonocatalytic process is a simple working process with high efficiency compared to any other process [6,7]. The high frequency acoustical, electrically energy is transformed into ultrasound waves by means of ultrasonic transducer, which is bounded to the base of a stainless steel water tank. These high frequency sound waves is created in the liquid countless, microscopic vacuum bubbles, which rapidly expand, collapse and forms cavitation [5]. The cavitation produce eminent mechanical and chemical effects like intense agitation, dispersion, emulsification, degreasing, micro-jetting, and free rad-

* Corresponding author.
E-mail addresses: kannank@kongu.ac.in, kannankongu@gmail.com (K. Kandasamy).

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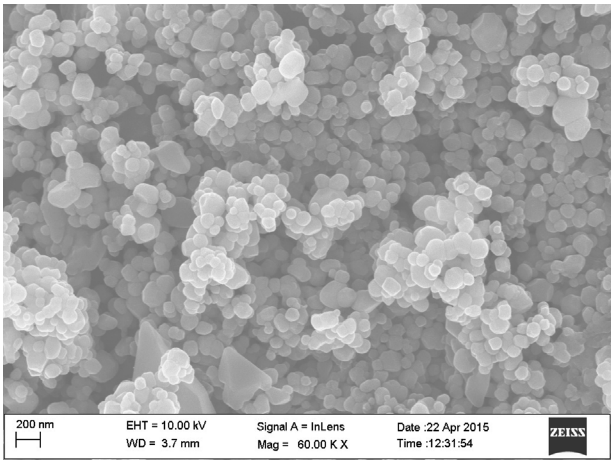

Fig. 1. Characterization of TiO_2 nano catalyst by FESEM at 200 nm.

ical production. Sonication in leather processing has been reached for more than 50 years. This shows that sonication process could help in steps like soaking, degreasing, un-haring, liming, fat liquoring, dyeing, and also in effluent treatment process [10]. The water streams which contain volatile and non- volatile compounds at high temperature and pressure using high frequency may produce reactive hydroxyl and hydrogen radical [9]. Hence, organic compounds are partitions into the cavitation bubbles by undergoing thermolysis due to high bubble collapse conditions [8] whereas non-volatile and surfactants are not undergoing bubble collapse conditions [11]. During the liquid opening, these bubbles act as a miniature high speed brushes and reduces the organic and suspended solids in the effluent very effectively at less time.

The objective of the present work was to characterize and to treat the tannery effluent using sonocatalytic process. Various loading of TiO_2 catalyst were used to study the responses such as COD, BOD and TDS removal. The study also investigated to optimize the process variables using RSM design software for the sustainability of the effluent treatment process. RSM is statistical tool used to evaluate, analyze and optimize the process parameters. RSM is done by using the statistical software tool MINITAB 14 (PA, USA). The advantage of using RSM is to study the effect of the independent variables alone or in combination and also to generate a mathematical model which describes the processes interaction. It also helps in designing and minimizing the experimental runs. To optimize the process parameters the Box- Behnken design approach was applied with three factors at three levels [20,21].

2. Materials and methods

2.1. Sonocatalytic reactor

The experiments were conducted in a batch mode sonocatalytic reactor of 2500 ml volume and 42 kHz frequency, the make is Equitron, India of 230 V, 50 Hz AC supply with 170 W capacity. The characterized tannery effluent was introduced into the sono reactor with sound waves emitted from the bottom of the reactor. For the present experimental study, waste water samples were collected from a tannery in Erode –state of Tamil Nadu in India. The chemicals used for the analysis were Lab grade reagents. Various range of operating conditions such as a time of reaction 5–180 min, temperature of 39 °C, different effluent concentration, TiO_2 nanocatalyst loading of 0.1 g and 0.05 g with an intensity of 1.5 ml vial (W) and 0.5 W/m^2. The percentage removal of COD, BOD and TDS were analyzed as per APHA standards [22].

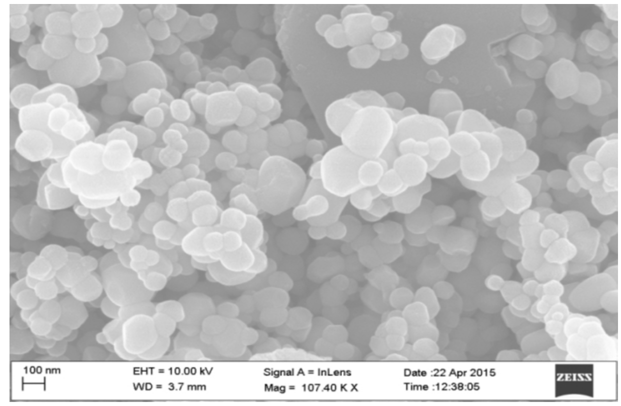

Fig. 2. Characterization of TiO_2 nano catalyst by FESEM at 100 nm.

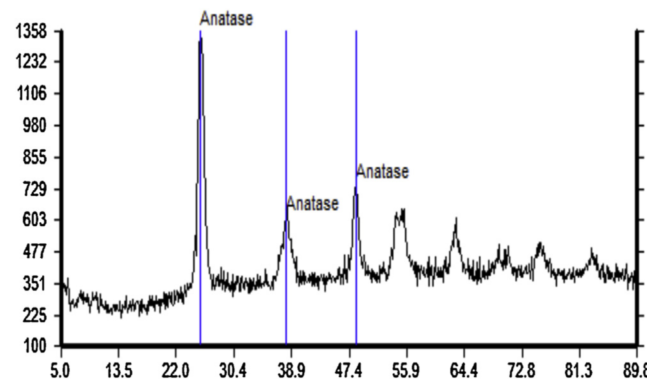

Fig. 3. Characterization of TiO_2 nano catalyst by XRD –By XRDCALC V5.5.

2.2. Preparation of TiO_2 nano catalyst

The TiO_2 nano catalyst was prepared using sol-gel process [12]. 30 ml of $TiCl_4$ was added drop wise into 100 ml of absolute ethanol in reaction vessel. This reaction was performed under a fume hood with continuous stirring in ambient conditions. Due to exothermic reaction $TiCl_4$ was highly volatile and also hydrogen chloride is released as soon as the addition of ethanol. Then the above solution was converted into a colorless and forms a yellow precipitate which produced TiO_2 nano powder by drying at 85 °C in an oven for 15 h. Finally, TiO_2 nano catalyst was obtained. The calcinations temperature ranges between 200 and 800 °C for 2 h.

2.3. Characterization of TiO_2 nano catalyst by SEM

Figs. 1 and 2 show the FESEM image of TiO_2 at 100 nm and 200 nm and the morphology of the catalyst is seems with greater porous inside with good aggregation of the sample. The field emission scanning electron microscope made of ZEISS- India customer core and SIGMA- 0403 was used for this study. The size of the particle is around 18–27 nm. The formed TiO_2 nano particles are clearly visible, and also the shape of the particle was observed almost sphere like morphology with different size.

2.4. Characterization of TiO_2 nano catalyst by XRD

The XRD analysis of the synthesized TiO_2 nanoparticle was done using a Bruker make, X Flash detector 410-m with product ID 1103-0000:400 diffractometer, and the results confirmed that the nano sized powder was TiO_2. X-ray diffraction pattern of the synthesized TiO_2 nano particles is shown in Fig. 3 and the peak details are given in Table. 1. The 2θ at peak 25.4 °confirms the TiO_2 (Anatase) struc-