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Review

Eco-friendly waste management strategies for greener environment towards sustainable development in leather industry: a comprehensive review

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ABSTRACT

The leather industry deals with proteinous skin material for the conversion of leather and this generates huge amount of solid and liquid wastes giving rise to pollution that needs to be overcome by introducing sustainable cleaner technologies. This review describes various eco-friendly challenges and major achievements for abatement of pollution in leather processing. Different cleaner technological methods in preservation of raw hides/skins, unhairing, tanning and dyeing operations are discussed here. Cleaner-preservation techniques by using chemicals and biological agents have been developed to reduce pollution problems of salt up to a great extent in leather processing operations. Process intensified operations have helped to achieve better uptake and to manage pollution load. Enzymatic dehairing are implemented to reduce Bio-chemical-Oxygen-Demand (BOD) at the level of 40%, Chemical-Oxygen-Demand (COD) up to 50%. Improved biological methods for bio-degradation of dyes, azo-dyes and their mixtures and to reuse the liquors in the process to reduce the dye pollution load in the effluent streams are reviewed. Nano-Particle polymers and improved retanning materials have been synthesized for high exhaustion of dyeing and retanning properties. Mathematical models predicting kinetics and growth for the above processes are also reviewed. It could be concluded by utilization of these technologies, a possible reduction in pollution loads such as BOD & COD, upto levels of 50% & 40%, could be achieved in leather processing.

1. Introduction

Leather making is a very old traditional process that serves social needs, employs many skilled/unskilled persons while being one of the highest contributors of global economy. Leather is unique material and cannot be compromised with synthetic materials and can be obtained by the conversion of skin/hide into leather where the skin/hide undergoes various treatments. It provides a wide range of consumer goods such as shoes, garments, bags etc. In-spite of the incipit, leather industry has been categorized as one of the highly polluting industries having concerns that leather making activity can have adverse impact on the environment.

Global production of leather is approximately around 4.8 billion sqft. It is estimated that about 6.5 million tons of wet salted hides and skins are processed worldwide annually and 3.5 million tons of various chemicals are used in leather processing (Ramasami et al., 1999a). Chemicals that are used during the processing are not fully uptake by the leather leaving huge amount of pollution load through effluent streams (Fig. 1). The liquid effluent at the level of 45–50 m^3 per ton of raw hide is generated during the process. Nearly 70% of the emission loads of Bio-chemical-Oxygen-Demand (BOD), Chemical Oxygen Demand (COD), and Total Dissolve Solids (TDS) are generated in the process (Ludvik, 1996). The leather making process produces wastes comprising of COD, BOD, Suspended solids, Chromium, dyes, sulphur at the level of 1470 ppm, 619 ppm, 920 ppm, 30 ppm, 50 ppm and 60 ppm respectively

Abbreviations: ETP, effluent treatment plant; ppm, parts per million; TSS, total suspended solids; DNA, deoxyribonucleic acid nucleic acid; FT-IR, Fourier Transformation-Infrared; Lpm, litre per minute; Min, minute; h, hour; UV–vis, Ultra Violet visible; HPLC, High Pressure Liquid Chromatography; U/μl, Units/micro-litre; M-ESI, Mass-Electrospray Ionization; GC–MS, Gas Chromatography–Mass-Spectrometry.

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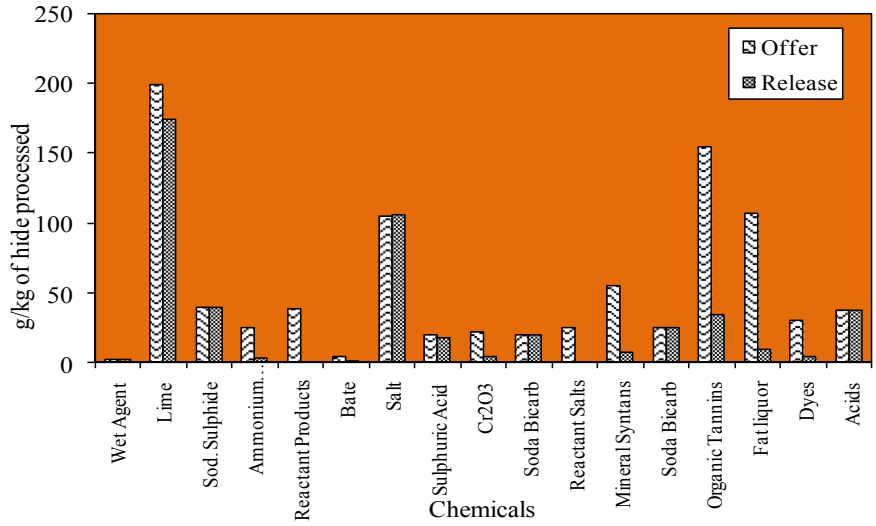

Fig. 1. Representation describing the various chemicals used in leather processing operation.

(Ludvik, 1996). In order to combat this pollution load suitable cleaner technologies are needed to create a green environment in the said industry.

Leather processing follows pretanning, tanning and post tanning operations. Prior to pretanning, the raw animal skin and hides are preserved by application of salt that restrains microbial attack. This process of preserving skins is called as "Curing". The pretanning processes consist of soaking, liming, deliming, bating, degreasing, and pickling unit operations. During soaking skins/hides are rehydrated to open up the contracted fibre structure. Similarly the main objective of liming is to remove hair, deliming is to remove lime, bating is to split the fibre into fibril, degreasing is to remove the fat and pickling is to reduce the pH of the skin from 8 to 2.8–5.0. Tanning renders permanent stability to the skin/hide. The post tanning operations are retanning, dyeing and fat liquoring mainly to give color and to enhance physic-chemical properties of leather. Pre-tanning and tanning operations contribute about 57% of the water consumption in leather processing and the washings about 35%. Rao et al. (2002) reported that pretanning and tanning need about 57% while washing needs about 35% of total water in leather processing. They provided viable solution (minimized amount of liquid effluent) to pollution problem by reducing amount of water through recycling and optimization in leather processing, particularly in pretanning and tanning (Gutterres et al., 2010).

Raw skins/hides, initial material for the leather industry, is subjected to a wide range of chemical, mechanical, biological and pH alterations requiring huge amount of water. The unspent quanta of chemicals as generated from the processes are discharged in the stream that causes problems to environment. There is an enormous pressure from the various pollution control bodies to regulate and minimize the amount of pollution generated from the leather processing (Ramasami et al., 1999). From a medium sized tannery, over 300 million cubic meters of waste liquor containing thousands of tons chemicals and solid waste are discharged daily by the leather industry. They are to be treated adequately and disposed scientifically complying with the statutory requirements (Mariappan, 1997). Besides liquid waste, leather industry is facing another problem from disposal of solid wastes. The reason being, skin itself is a proteinous material and part of which is loosened during different unit operations resulting huge solid wastes. The non-fibrous proteins such as albumin, globulin and mucoids and part of the fibrous proteins such as hair, fleshing wastes are also contributed to solid wastes. In addition to these wastes, i.e., raw hide/skin trimmings, chrome shavings, buffing dust, chrome trimmings, leather strips and cuttings, lime and chrome sludge, sludge from ETP (primary & secondary sludge) are also generated during manufacture of leather. The major amount of solid wastes emanate from beam house operation (80%), tanning operation (19%) and finishing operation (1%).

Literature reveals that per one thousand kg of raw skin/hide yield 150 kg of leather and remaining 850 kg contributes to solid wastes out of which 450 kg is collagen waste and 400 kg is fleshing wastes with 30 m^3 of effluent (Ludvik, 1996). The waste accumulation leads to sludge problem and chocking of treatment pipes which results in reduction of efficiency of treatment plant. Disposing of solid waste is an economic burden to tanners as many tanneries are closing down for above problem. Circular economy (CE) model has been tested as a new way of raw materials, water and energy consumption reduction in the leather industry. This model was suggested for reducing, reusing, recycling and recovering of the tannery effluents in leather processing to the different operation processes (Hu et al., 2010). The main aim of this review is to study liquid, solid waste that is generated through different processes to suggest suitable technology for cleaner production to overcome the problems in leather industry. The present paper reviews various cleaner technology options developed that include: Cleaner preservation skin/hide using various eco-friendly chemicals, bacteriocin solutions, sustainable method for dehairing of skin/hide, high exhaust chrome tanning using different synthesized additives, high exhaust vegetable tanning during tanning operations; and eco-friendly and improved dyeing process. Modeling of dye uptake rates in post tanning process has been developed and some of them are in practice. Merits and demerits of these above mentioned cleaner technologies will be discussed in this review.

2. Methods

The method of preparing silica gel is carried out by mixing sodium meta silicate and hydro chloric acid with pH of 5.5. Boric acid and SMB are used in powder form for the preservation of skins. Protease for dehairing was obtained from *Bacillus* sp. The FH and Biotannin were prepared from fleshing wastes by systematic hydrolysis followed by chemical treatment. The fibrin hydrolysate was