A CRITICAL REVIEW OF TANNERY INDUSTRY PROCESS, WASTE DISPOSAL AND ITS ENVIRONMENTAL IMPLICATIONS

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Abstract

Since ancient times leather used to be the basic need of humans to produce goods such as shoes, jackets, belts, caps etc. The effluent generated from tannery industry is extremely multiplex and distinguish among the elevated substances of inorganic and organic, chromium, sulphides, nitrogenous compounds, dissolved and suspended solids. The processing of leather includes an extensive use of water and synthetics. The tannery wastewater transmits dangerous hexavalent chromium. The discharge of tannery effluent in inappropriate manner causes grievous water and soil pollution. Heavy metals present in wastewater enter the food chain and impact on human health severely. In the current study, an overview of tanning industries along with the eco-friendly leather processing technologies and their ecological significance is briefly studied. The generation of various hazardous pollutants released in different processing steps, the environmental impact, health hazards and its disposal are studied. The studies also include the technological solutions available for reducing the pollution load at the leather processing stage. Wastewater treatment and solid waste disposal are also the scope of the studies.

Key words: tannery effluents; tannery processing; chromium, health hazards; contaminants

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DOI: 10.48047/ecb/2023.12.si10.00388

1. INTRODUCTION

India is having around 20 % of cattle and buffalos 11 % goat and sheep of the word total. Thus, India has abundant availability of the raw material to produce good leather[1].The leather sector might be recognized as non-polluting sector, as this operation waste material through meat manufacturing[2]**.** Although, the leather sector is generally related extremely environmental contamination because of foul-smelling, slaughterhouse waste and huge utilized water produce at the time of conventional production process[3].

The conversion of leather from animal hides/skins mainly comprises of six major stages in the manufacturing sequence; slaughtering, skinning, bringing to stop putrefaction; scrapping of flesh and hair (hair or skins not required for leather/leather articles), pursuant to leather end product, selected finishing using certain synthetic means**.** The ultimate goal is to make the unfinished matter rot-proof, communicate relief as well as increase its strength. This assumption emulates the morphological activity of hides as well as skins through the duration of the animal that is; to permit gas exchange, thermoregulation, safeguarding and cover. It is the identical properties that ultimately make leather unique compared to other manufactured substances either attire as well as footwear industries in terms of easement and comfort at the time of utilization.

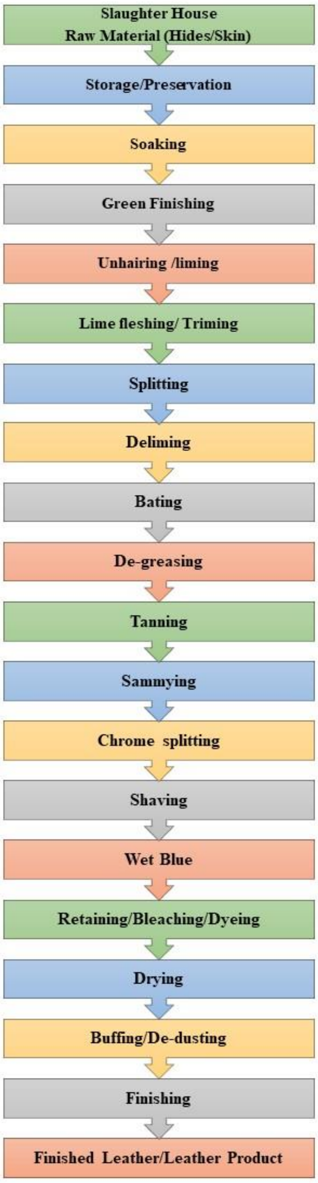
The principal process of tanning is to transform hide/skin through a firm substance known as leather. This action allows tannins to link for the conditioned skin, acting on and stabilizing collagen. In the process of tanning several tanning substances (substances able to form a strong bond for collagen) are used to make the leather a firm appearance and good thermal strength. Mineral tannins, vegetable tannins and syntans are the tanning agents, utilizes in tanning. Chromium, the mineral tanning agent frequently used in leather manufacturing as it has a distinctive property to enhance the leather quality. Vegetable tanning and aluminium agents are also extensively applied in leather manufacturing. Prior to treat the leather with other procedure the samming and setting-out procedure to be carried out. To get the appropriate thickness of leather hair removing is performed.

Tanneries produce considerable amount of coloured, cloudy, and foul malodorous wastewater around 30-35 L/kg refined hide/skin with fluctuating pH, COD, BOD tannins, and extremely concentrations of suspended solids, together with chrome[4-6]. Haphazard rise in industries and at the same time along with harmful pollution has intruding unexpectedly, approaching to villages as well as towns[7-10].

Various research data shows that 200kg of leather is produced from one tone of wet-salted skin/hides[2,3,11]. This amount accounts for about 20% of the weight of the rawhide. About 600 kg of solid waste generates by processing the rawhide into leather. That solid waste contains protein and fat and it is around 60% of the unprocessed hides/skin weight, is discarded into the habitat. Specifically, addition to the 30000-35000 litres of effluent that is discharged into the habitat through the processing of single tonne of unprocessed hide in the global leather sector. The figures shown by food and agriculture organization (FAO) that about 85 lakhs tonnes solid waste are released through the manufacturing of 110 lakhs tons unprocessed hide throughout the globe[12] and 20% of solid waste produced through re-tanning treatment[13].

2. Leather Manufacturing Process:

Main steps in leather manufacturing comprises of preserving, soaking, curing, liming, deliming, dehairing, holding, degreasing, tanning, staining, plucking and waste management. It can be classified in to pre-tanning, tanning, post-tanning, and leather finishing operations.



Flow chart for leather processing

Preserving Process

The raw skin/hides are preserved generally with salt (40 to 50% wt percentage of raw skin/hides) which increase the TDS and Cl- concentration in the tannery effluent. Alternative treatment methods like salt-less curing methods contain NaCl + EDTA, NaCl +silica gel, NaCl + sodium meta-bisulphite and NaCl + boric acid are of the interest of the research[14]. The criteria for consideration of best preservation should be non-polluting, lightweight, and compact for easy transportation and easy removal of curing agent without any damage to the skin/hides[15]

Soaking Process

Soaking is done mainly to desalt, dry skin to be rehydrated, and also detach undesirable substances such as soil, manure, blood etc. The time of soaking depends on the condition of the hides or skins[16]. The conserved untreated hides are processed with water and soft hides[17]**.** Soaking agents which are generally in use are salt, alkali, sodium sulphide and surfactants. Modern technologies suggest the use of multi enzyme system for the process of soaking of skin. However, process performance depends on species, enzyme ratio, concentration of salt, additives, pH[18]**.**

Liming

For the long-time lime and Sodium sulphide is used to remove hair and undesirable substances which do not move to the leather. Lime process is also used to detach the epidermis and separate dispersible skin proteins. 24This system generates higher amount BOD, COD and TDS along with hydrogen sulphide gas[19]**.**

Activity of enzyme can be stabilized by addition of Hydrogen sulphide and addition of peroxide provides activation effect[14] **α**-amylase enzyme is used fibre opening after enzymatic unhairing. This process completely eliminates the use of liming and deliming process and reduced COD by 45% and total solids load by 20%. The total dry sludge generated from the beam house operation is brought down to 94%[29]. Dehairing of goat skins using oxidising agent as well as enzyme is also tried using magnesium peroxide and protease has been attempted[20]**.**

Bating

Bating is the process to treat the skin/hides and make them smooth and maintain the flexibility and make the skin ready for tanning. Different types of enzymes are used to separate the undesirable proteins and enhance the stretching property[21]**.**

Degreasing

The procedure of degreasing utilizes to get rid of excess oils and fat, allowing the tannic to creep into skin smoothly. This act might be performed by synthesis of fats applying surface-active agent.

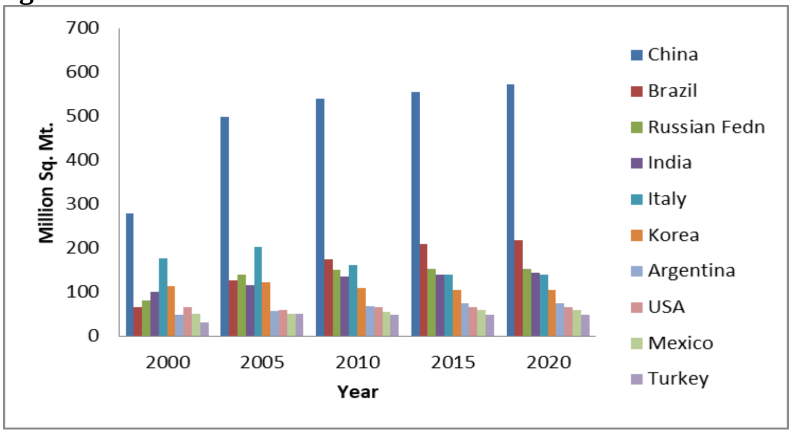
Tanning

The tanning process is an important stage of transforming hide/skin into firm leather stuff. Among all the tanning process available today vegetable tanning is the oldest tanning process. Vegetable tanning is useful environmentally-safe procedure resulting that to reduce the pollutants into the environment[22]**.** Vegetable tanning, uses tannins obtained from different section of the plant. Vegetable tanning was usually performed using tanning agents from the sources like wattle, quebracho, valonea chestnut, Trema Orientalist (L.), Xylocarpus granatum bark or mimosa trees[23-26]. The pH is the main and the significant feature influence the penetration as well as fixation of tannins. Temperature is one of the significant factors which effect the vegetable tanning. The content of salt and acid in the tanning liquor has a vital effect on the physical state of the leather**.** Today 90% of the all-leather goods are made using chrome or mineral tanning. When the hides arrive at the tannery, they are soaked in a water for 24 hours to remove salt that kept them preserve from the slaughter house. Then hides are dehaired and limed. The hides together with tannins are added in a drum for at least 3 to 7 weeks to tan whereas in case of chrome tanning the tanning time gets reduced to 1 day. Basic Chromium Sulphate (BCS) of 8-10% is added in the tanning process for chrome tanning. BCS, in the form of chromium (III) is used in tanning which gets converted into chromium (VI)[14]**.** During the process of chrome tanning, adequate amount of chromium is left in the effluent of tanneries, and fed in the tannery sewerage processing plant, finally assimilate surplus sludge through analyses procedure[27,28]**.** In an attempt to improve utilization of Chromium wattle extract was added to an effluent to form precipitate of chromate-flavonoid type of polymer. The separated supernatant is recycled in the process of tanning[14]**.** natural polymer material such as starch has been used by several researchers.

Post tanning:

Post Tanning operations involve operations like adding colour, strength and organoleptic to the leather. For providing suitable colour to the leather acidic, basic, direct and metal complex dyes are used. Not all the dye is utilized during the process of colouring, part of it gets discharged in to effluent which is very carcinogenic. Adding 2% of Copolymers as mentioned in tanning section in the dyeing process resulted in uptake of dye up to 99.1%[14]**.**

Top leather producing countries



References:[29,30]

Water Consumption in Tannery Industries

As per the estimates of earlier researchers in 2001 it was estimated that water consumption in tanneries can be reduced by 50 % by use of modern technologies as compared to convention tannery process. The maximum water is consumed by the washing and spillages which is around 11 to 13 L/Kg hide followed by soaking, liming, deliming and tanning processes. Other processes such as Picking, rechrome tanning, retanning, dyeing and fat liquoring need less amount of water[31]. The concept of zero liquid discharge as used for other industries is now more often used in the tannery industry. This can be achieved by the use of newer technological interventions during the processing of leather and the generation of wastewater[32,33]. The wastewater generation standards for tanneries in India is 28 m3/tonne of raw hide as per the THE ENVIRONMENT (PROTECTION) RULES, 1986 (Revised).

Water consumption in individual processing operations:

Operation	m^3 /t raw hide[34]		m^3/ ton of hides /skins (MOEF)[35]
	Conventional Technology	Advanced Technology	
Soaking	7-9	2.0	-
Liming	9-15	4.5	-
Deliming, Bating	7-11	2.0	-
Tanning	3-5	0.5	-
Post-tanning	7-13	3.0	20.0
Finishing	1-3	0	-
Raw to wet blue/white			20.0
Raw to finish			40.0
Total	34-56	12	

Sources:[34,35]

Waste water generation in leather industry

Water is most essential for the survival on earth various industries also utilises for various manufacturing procedure. The procedure of tanning required huge amounts of synthetics as well as water, make use of to process the unfinished hides/skins, The generation of effluent during the manufacturing of one tonne unfinished hides/skin nearly 30-35 cubic meter [36,37]. Though, effluent quantity is based on the kind of unfinished stuff, the refined output and the manufacturing production used[38,39]. The leather process in India ranges from 1.0-1.2 million tons/year with an average wastewater generation of 120 MLD [40].

The unfinished hide go through a various stages before becoming smooth leather[41] and discharges three principal categories of TWW: wastewater without chromium (from liming, deliming/

pickling, fleshing and splitting machine waters bearing elevated pH sulphides), wastewater holds elevated chromium (come out through tanyard and retaining, sammying (higher contents of Cr and acidic) , inadequate chromium soaking and more common wastewaters come out mostly through after tanning process (dyeing and fat liquoring)[6] discharge into habitat. The concentrates of COD, BOD_5, sulphide, ammoniacal nitrogen and suspended matter in the effluent from integrated tanning plants are elevated[42].

It has been found that chrome and chlorinated phenols are more likely related to tanning refuse as a substitute, chlorinated phenols such as 3,5-dichlorophenol, which behave as organic contaminants pertain to the tanning industry, and establish as extremely noxious and influence the cellular interconnection of organisms reveal to waste. Organic substances (protein and carbohydrate degradation) - reduction in dissolve oxygen (DO) content/quantity in running waters due to bacteriological putrefaction[43], $NaCl_2$ or brininess - slight decline in solvability of naphthalene, benzene, toluene (non-polar organic compounds[44].

Quantity of Pollution Load in TWW (Contributed by Individual Operations of Leather Tanning Process

Pollution load	Operation processing (load kg/ton of raw hide/skins)				Post tanning	finishing	Total load
	Soaking	Unhairing/ liming	Deliming / batting	Chrome tanning			
Waste water produced in (m^3)	9-12	4-6	1.5-2	1-2	1-1.5	1-2	17.5-25.5
BOD	7–11	28-45	5-9	2-4	8-15	0-2	50-86
Sulphides	–	3.9–8.7	0.1–0.3	-	-	-	49
TSS	11-17	53-97	8-12	5-10	6-11	0-2	83-149
COD	22-23	79-122	13-20	7-11	24-40	0-5	145-223
Cr	-	-	-	2-5	1-2	-	3-7
NH_3 -N	0.1–0.2	0.4–0.5	2.6–3.9	0.6–0.9	0.3–0.5	-	4-5.8
Chlorides	85–113	5–15	2–4	40–60	5–10	-	137-202
TKN	1-2	6-8	3-5	0.6-0.9	1-2	-	11.6-17.9
Sulphates	1-2	1-2	10-26	30-55	10-25	-	52-110

(Pollution Load (kg/T of raw hide/skins processed operations)
Source: [45,46,39]

Physico-Chemical Characteristics of tannery waste water (TWW)

pH	TDS	Total solids	Suspended solids	Volatile suspended solids	COD	BOD	TKN	Ammoniacal nitrogen	Chromium	Sulphide	Reference
-	15152	-	2004	1660	8000	930	-	-	11.2	228	Koeswari and Ramanibai (2003)
10.72	6810	-	-	-	11153.7	2906	-	162.15	32.87	507.5	Leta et.al(2004)
7.08 ± 0.28		10265±1460	2820±140	1505±90	4800±350			-	-		Ganesh et.al (2006)
10.5	17737	18884	1147	-	3114	1126	-	33	83	55	Ram et.al (1999)
7.4			2690	1260	3700	1470		180		440	Apaydinetal. (2009)
8.2-8.5	14750	19775	5025	-	5650	-	-	-	-	-	Thanigavel (2004)
7.7	36800	-	5300	1300	2200	-	270	-	-	-	Lefibvrev et al.(2005)
7.7	-	-	-	-	2426	-	370	335	29.3	286	Szpyrkowicz et al.(2005)
7.79	-	-	915	578	2155	-	228	268	50.9	35.8	Orhon et al. (2000)
7.0-8.7	13300-19700	-	600-955	-	4100-6700	630-975	144-170	-	11.5-14.3	-	Kongiao et.al (2008)

Sources:[47-56] (All values are in (mg/L) except pH)

Tannery sludge (TnS)

Leather industry produces solid waste mainly through untanned hides and skins waste (cuts, fleshing waste) and Tanned leather waste (polishing dust shaving waste). Research statistics reveal that 80% of solid waste is produced through pre-tanning treatment and 20% of solid waste produced through re-tanning treatment[57]. During the treatment of effluent discharge from tannery industry produces sludge. The amount and nature of sludge is determined by the effluent process mechanization. It is evaluated that refining 1 MG (millions of gallons) of unprocessed skin/hides produces 100 to 225 kg. of sludge over all during the **process**[58,59]. In India the yearly production of sludge varies considerably, small to a great extent 18,200 to 165,200 Mg[60]. Untanned hide/fur waste has harmful effect upon water and soil supplies of habitat in which it is spread, particularly on community flora and fauna, due to the bad odour generated through its decomposition, and its detrimental synthetic substances[61].

Various pollutants present such as colourants, retention agents, syntans, dyes as well as increased concentrate of heavy metals like cadmium (Cd), arsenic (As), copper (Cu), cobalt (Co), Zinc (Zn), chromium (Cr), Iron (Fe), and Nickel (Ni)[62]. It is estimated that 80 to 90% of tanneries through the world utilises chromium as the tanning agent which then gets concentrated in the sludge form.

Tannery Sludge Properties

(mg/kg)	Chand (2015)[63]	Kilic (2011)[64]	Patel (2014)[65]	Range
pH	7.5	7.3	9.2	7.3-9.2
Electrical Conductivity (ds/m)	3.7	2.5	8.3	3.7-8.3
Organic Carbon	17.8		9.2	9.2-17.8
Total Nitrogen	0.01	6.56	NA	0.01-6.56
Na		0.6	0.032	0.032-0.6
Ca		5.9	0.015	0.015-5.9
Cr	26910	8041	30512	8.41-30512
Cu	81	174	85	81-174
Zn	101		200	101-200
Fe	5125		1062	1062-5125
Mn	298			0-298
Ni	184	34.5	60	34.5-184
Cd	13	18.5	100	13-100
Pd	30	98.5	38	30-98.5

Sources:[63-65]

Tannery Wastewater and Chemicals- International Legislations Scenario

Tannery Wastewater Legislations for Discharge Limits

In process of leather a variety of synthetics are used, extremely noxious to living things and pollute the environment. Keeping in mind, many nations have also imposed ordinances on the manufacture, sale and import of leather goods that possess dangerous synthetics. The limits of discharge for tannery effluent may differ from nation to nation and rely on either the standard of the processed effluent and standard to draw the water[46]. The synthetics and their allowable limits in leather and leather goods that are permitted in various nations are categorise in Tabular form.

In developing nations as stated by the environmental protection regulations, compelled to establish the sewage treatment plants, ETP as separately or combined as CETP, and the processed effluent shall abide by standards of discharge. In India, many leather industries ordered to shut down their factories in the year1990s for failing to match the benchmark of discharge, in this duration several establishments paid large compensatory amount against the damages done by groundwater contamination[66].

Although, contamination difficulties are still widespread because of the elevated operational and administrative expenditure related with common effluent treatment plant (CETPs) and thus unlawful disposal of effluent[67].

Discharge standard of treated Tannery Waste Water in different countries

Parameters (mg/L)	India	Bangladesh	United States	China	Ethiopia	Italy	Vietnam	Pakistan	Brazil
COD	≤250	≤250	≤250	≤100	≤500	≤160	≤50	≤150	5.0-9.0
BOD	≤30	≤30	≤50	≤30	≤200	≤40	≤20	≤80	NA
TSS	≤100	≤100	≤50	≤50	-	≤80	≤50	-	60
NH_4^+ -N	–	–	≤10	≤25	≤30	≤15	≤60	≤40	NA
Total Cr	≤2	≤2	≤0.5	≤1.5	≤2	≤2	-	≤1	0.2
Sulphides	≤1	–	≤2	≤0.5	≤1	≤1	≤2	–	2.5
Chlorides	≤1000	-	≤1000	≤3000	≤1000	≤1200	-	≤1000	

Sources:[68-70].

Treatment Technologies for TWW:

The treatment of effluent has broadly into preliminary, primary, secondary, tertiary treatment, sludge handling and its disposal. Segregation of the waste streams would help reducing the overall load of water treatment[71].

The preliminary treatment consists of removal of large particles, grit and grease. Removal of large particles helps in avoiding blockage of pipes and pumps that transporting the effluent. This treatment also helps in significantly reducing the BOD/COD and eliminating sulphates which would be affecting the further treatment of effluent. Preliminary treatment involves use of bar screen, fine screen, equalization and sulphide oxidation, coagulation, flocculation, settling and finally sludge[6]. The equalization/hominization tank may have air diffuser through venturi, fixed or floating type. The coagulant such as alum, iron sulphate, lime, iron chloride are used for coagulation. Natural coagulant extracted from Moringa oleifera and Cicer aretinum seeds[72] and amphoteric polyacrylamide (AmPAM) emulsion, as an environmentally friendly flocculant for TWW are explored[73,74]. Recently, a lot of interest is generated in the use of electrocoagulation process as it is simple and cost effective wherein aluminium and iron electrodes are selected and can be arranged in parallel or in rotating cylinder electrode[75].

Membrane filtration, reverse osmosis, ultra-filtration and nono-filtration are the other techniques which are used in the treatment of TWW. Polyethersulfone[76]. Polyamide/ polysulfone membranes[77] layered double hydroxides (LDHs)/polyacrylonitrile (PAN) membranes[78]. and ceramic membranes such as Boehmite[79] natural clay[80]. Pozzolan[81]. natural moroccan perlite[82]. are effective in treatment of TWW.

High salt content makes the electrochemical oxidation the most suitable process for the treatment of TWW due to presence of anions and cations. The electrodes such as Ti/Pt, Ti/PbO2 and Ti/MnO2 anodes and Ti cathode are used in the treatment of wastewater. Graphite as low-cost electrode is used for the removal of organics in TWW. Change in electrode material and its design, applied voltage and pH of TWW can affect the performance of the process[83]. Another study suggested recovery of 99% Chromium in the form of $Cr(OH)_3$ and/or $Na_2Cr_2O_7$ at cathode and anode using Pb sheet as anode and Cu sheet as cathode[84].

Thermally-activated biochars produced at 600ºC derived from liming sludge were used for 99.8 % Cr adsorption from the TWW[85]. Several agriculture wastes are also tried as an adsorbents for the removal of Cr (III) such as coconut shell fibres, Syzygium cumini bark, waste rinds of Citrulus lanatus and waste peel of Citrus sinensis [86-88]. Real TWW when treated with Kaolin yielded Zeolite A resulted in 99.8 % removal of Chromium concentration[89].

Constructed wetlands (CW) as tertiary treatment is recommended by some researchers in tropical and subtropical climatic conditions. This treatment is effective in the removal of BOD, COD, TSS[90].

Environmental impacts:

Tannery Effluent impact on Human and Environment:

Leather mass production manufacturing experience an elevated effects on the environment, mainly due to the excess utilization of noxious synthetics in the tanning procedure. The biggest environmental problems of tanning industries are effluents and solid waste. The tanning industry is widespread in several segments of the globe and contaminate the groundwater as well as ecosystems.

The waste water from tanneries is huge in quantum, strongly coloured and hold large deposit fill, noxious metal amalgamation, synthetics, biologic oxidized substances and substantial amounts of decompose suspended substance. Solid waste from tanning industry is generally throw out inappropriate manner within and around industry premises[91]. Chromium is a major and noxious contaminant of major worry which exist in tannery effluent and familiar origin for perforation and bronchogenic carcinoma in constantly reveal humans. Sludge of tanning is the mixture of meat scraps, hair, skin trimmings, splits, shavings, leather trimmings, polishing, finish leather remainder, common herbs left over and sewage sludge[92] and acutely impairs the mitotic procedure and decreases the ripening in considerably developed leguminous plant [93].

The tanning industry uses more than 250 leather manufacturing synthetics and discharge a compound amalgamation of noxious hexavalent chromium with more noxious contaminants like magnesium, sulphides, sodium, potassium, phenolic compounds, cadmium compounds, azo dyes, antimony, lead, Cobalt, barium, copper, selenium, arsenic, zinc, nickel, formaldehyde resins, pesticide remains, solvents and mineral salts such as fats and pigments[91]. Main effluents noxious are hexavalent chromium and chlorinated phenols to biota and humans and other habitat or environs. Cr (VI) has various health issues and a source of severe virulence, mutagenicity, carcinogenicity, and hypertension for the communities utilizes untreated effluent carry huge quantity of hexavalent chromium releases through tanning process the germination of grains also effected in plants**.**

The salts of chromium not entirely established through skin/hides, residue amount (around 30% of the original) left over tanning liquor in the spent[94]. Heavily concentrated hexavalent chromium contain toxin, genotoxic with teratogenicity repercussions onto mankind, numerous herbs, bacteria, and animals living in water-bodies[95].

Chromium be a reason of transient impact like headache, dizziness, eye, skin or lung irritation, nervous system, liver poisoning, allergic reactions, and kidney breakdown because of oxygen deficit. All leather industries discharge large quantity of waste holds noxious chromium and phenolic solutions[96]. The workers who are exposed to Cr (VI) for a long period are at a great risk of cancer. Incessant risk to chrome hexavalent also harmful to airways and a source of nasal cancer[97,98,99]. Chromate direct contact with the eyes may permanently can harm the eyes and also cause irritation in eyes[100]. Long-time exposure also associates to skin allergies, skin cracking, dryness, swelling, and skin ulcers[101]. In some other way, employee can appear allergic hypersensitive when expose to a minute part creates acute skin rashes. Further repercussion of chromium is reproductive disorder, discoloration, dizziness, erosion of teeth and growth problems[99,100]. The concern of the environmental pollution can be resolved by adoption of cleaner technology at the processing of skin/hides and treating the waste before its disposal[46.] The article reviews the technological options available for sustainable production of leather.

Challenges and Future Prospects:

Currently tanneries are facing various severe threat caused by the people and authority mostly because of pollution and people objection to oppose the industry. Some of the biggest threat for tanneries comprises of:

(a) elevated manufacturing expenditure of leather/ unit area because of strict regulatory ordinances.

(b)high requirement of unprocessed stuff especially unprocessed skins/hides and unfinished leathers.

(c) Inadequacy to latest approach of process and effluent treatment approaches in emergent nations.

(d) Inadequacy of special industrial zones for the location of tanneries

(e)Substandard usage capacity trigger to higher financial implications and expenses.

(f)insufficient monetary help through government.

It is important to minimise all such type of threats and the government should provide sufficient monetary to modernize the tanneries, mainly micro scale manufacturing units[102]. Therefore, the process of leather should be reconsidered to ensure the workability of tanneries prospective as tanneries are the leading thrust of the economy for several nations

Conclusion

Historically tannery industry is seen as a water demanding industry. This industry also generates massive amount of hazardous waste water. TWW contain heavy metals, chemicals, inorganic salts, organic contaminants. The untreated TWW would cause severe water and soil pollution. The TWW adversely affects the human health and also the aquatic life.

The small and medium-capacity segments are not competent to set out and operate the costly effluents treatment plants. Therefore, society-based wastewater plants are required with in the community to control the pollution because of the tannery industries.

This review helps to understand that at each step of the processing of leather or its wastewater eco-friendly technological interventions are available. Water-efficient latest technologies can decrease the overall water demand of the tannery industries.

Chemicals used in the processing of leather can be reused. Wastewater streams if segregated can be recirculated or can be reused after its treatment. By-products from the tannery industry have become an alternative source of income for the tanners. As the researcher's interest is growing towards providing greener solutions the whole tannery industry is approaching towards achieving zero liquid discharge goal and thereby becoming sustainable.

References:

1. India Brand Equity Foundation (IBEF), Department of Commerce, Ministry of Commerce and Industry, Government of India. https://www.ibef.org/exports/leather-industry-india
2. Langmaier, F.; kolozmik, K.; Sukop, S.; Mladek, M.; *Journal of the Society of Leather Technologists and Chemists.*, **1999,** *83*(4), 187-95
3. Taylor, M. M.; Cabezal, F.; Dmalog, I,; Brown, E.M.; Marmer, W.N.; Carrio, R.; Ceima, P.J.; Cot, J.; *Journal of the American Leather Chemists Association.,* **1998,** *93* (3), 61-81.
4. Nandy,T; apasKaul, S.N.; Shastry; Sunita Manivel, U.; Deshpande, C. V.; *JSIR* ., **(1999),** *58*,(07), 475-516
5. Hayelom Dargo, and Adhena Ayalew, *International Journal of Emerging Trends in Science and Technology.*, **2014**, *1*(9), 1488-1494.
6. Buljan, J.; Kral, I.; Clonfero, G.; *UNIDO*, Vienna.**2011**,
7. Sreeram, K. J.; and Ramasami,T.; *Resources, Conservation and Recycling*.,**2003**, *38*(3),185-212.
8. Stoop, M. L. M.; *Technovation.*, **2003**,*23*, 265-278.
9. Kolomazník, K.; Adámek, M.; Andel, I.; Uhlirova, M.; *Journal of hazardous materials.*, **2008**, *160*(2-3), 514-520.
10. Hüffer, S.; Taeger, T.; *T Journal of the American Leather Chemists Association*., **2004**, *99*(10),424–428.
11. Veeger, L,; *Journal of the American Leather Chemists Association.,* **1993**, *88* (9), 326-329.
12. FAO. **2004,** Statistics. http://faostat.fao.org/faostat
13. Puntener, A.; *Journal of the American Leather Chemists Association.,* **1995**, *90* (7), 206-219.
14. Kanagaraj, J.; Senthilvelan, T.; Panda, R. C.; & Kavitha, S.; *Journal of Cleaner Production.*, **2015**, *89*, 1-17.
15. Wu, J.; Zhao, L.; Liu, X.; Chen, W.; & Gu, *Journal of Cleaner Production.*, **2017**,*148*, 158-173.
16. B.M.; Yapici, A.N.; Yapici, and E.C.; Kecici, *African Journal of Biotechnology*., **2008**, *7*, 3077-308.
17. Kite, M.; and Thomson, R.; (Eds.). *Routledge.*,**2006, 33**.
18. Ma, J.; Hou, X.; Gao, D.; Lv, B.; & Zhang, J.; *Journal of cleaner production.*, **2014**, *78*, 226-232
19. Jegannathan, K. R.; and Nielsen, P. H.; *Journal of cleaner production.*, **2013**, *42*, 228–240.
20. Kanagaraj, J.; Panda, R. C.; Prasanna, R.; & Tamilselvi, A.; *Environmental Science and Pollution Research.*, **2023**, 1-16.
21. Santos, L.M.; and Gutterres, M.; *Journal of Cleaner Production.,* **2006**, *15*(1), 12-16.
22. Jianzhong, M.A.; Yun, L.; Bin, L.; Dangge, G.; and Likun, W.; Synthesis and properties of tannin/ vinyl polymer tanning agents: Accessed 24 March 2011 http://www.aaqtic.org.ar/congresos/china2009/download/2-4/2-128.pdf.
23. Sukru, O. M. U.; R., and Mete, M. M.; DETERMINING LIGHTFASTNESS PROPERTIES OF VEGETABLE TANNINS AND CHEMICAL PROPERTIES OF THE LEATHERS TANNED WITH MODIFIED MIMOSA AND QUEBRACHO.
24. Chowdury, M. J.; Razzaq, M. A.; Biswas, M. I.; Quadery, A. H.; and Uddin, M. T.; *Journal of the American Leather Chemists Association.*, **2022**, *117*(1), 28-34.
25. Das, R. K.; Mizan, A.; Zohra, F. T.; Ahmed, S.; Ahmed, K. S.; and Hossain, H.; *Journal of Leather Science and Engineering.*, **2022**, *4*(1), 1-15.
26. Thorstensen, T.; *Krieger publisher company Malabar*., **1993**, 147-171.
27. Dhal, B.; Thatoi, H.N.; Das, N.N.; Pandey, B.D.; *Journal of hazardous materials.*,**2013**, *250*, 272-291.
28. Wang, Y.S.; Pan, Z.Y.; Lang, J.M.; Xu, J.M.; Zheng, Y.G.; *Journal of hazardous materials.*,**2007**, *147*(1-2), 319-324.
29. Global Leather Industry Fact Sheet, Accessed **2020** https://blog.bizvibe.com/blog/top-10-largest-leather-producing-countries
30. The Global Resource for the Leather Industry, Statistics and Sources of Information, Accessed **2020** https://leather-council.org/information/statistics-sources-of-information/
31. Sundar, V. J.; Ramesh, R.; Rao, P. S.; Saravanan, P.; Sridharnath, B.; and

Muralidharan, C.; *Journal of Scientific and Industrial Research.*, **2001**. *60*(6), 443-450.

32. Date, M.; Patyal, V.; Jaspal, D.; Malviya, A.; and Khare, K.; *Journal of Water Process Engineering.*, **2022**, *49*, 103129.
33. Ricky, R.; Shanthakumar, S.; Ganapathy, G. P.; and Chiampo, F.; *Recycling.*, **2022**, *7*(3),
34. Andrzej, B.; and Koltuniewic, Z.; *Environmental commission of International Union of Leather Technologists and Chemists Societies.*, (IULTCS); **1997**, *387*.
35. MINISTRY OF ENVIRONMENT, FOREST, AND CLIMATE CHANGE(MOEF) NOTIFICATION, **2021**,
36. Lofrano, G.; Aydin, E.; Russo, F.; Guida, M.; Belgiorno, V.; Meric, S.; *Water, Air, & Soil Pollution: Focus.*, **2008,** *8*, 529–542.
37. Islam, B.I.; Musa, A.E.; Ibrahim, E.H.; Sharafa, S.A.A.; Elfaki, B.M.; *Journal of Forest Products & Industries.*, **2014**, *3*(3), 141-150.
38. Tunay, O.; Kabdasli, I.; Orhon, D.; Ates, E.; *Water Science and Technology.*,**1995**, *32*(12), 1–9
39. Lofrano, G.; Meric, S.; Zengin, GE.; Orhon, D.; *Science of the Total Environment.*, **2013**, *461*, 265–281.
40. Rajamani, S. G.; *International Conference on Advanced Materials and Systems (ICAMS).*, **2016**, 513-518.
41. Durai, G.; Rajasimmam, M.; **2011**. Biological treatment of tannery wastewater: a review. J Environ Sci Technol *4*, 1–17
42. Gutterres, M.; Benvenuti, J.; Fontoura, J.T.; Ortiz-Monsalve, S.; *Journal of the Society of Leather Technologists and Chemists*, **2015,** *99*(6), 280-287.
43. Mwinyihija, M.; Strachan, N.J.C.; Dawson, J.; Meharg, A.; Killham, K.; *Archives of environmental contamination and toxicology.*, **2006,** *50*, 316-324.
44. Pepper, I.L.; Gerba, C.P.; Brussean, M.L.; *Pollution Science.*, **1996**, 387.
45. Sabumon. P.C.; *Advances in Recycling & Waste Management*, **2016**, *1*(1), 1-10.
46. Dixit, S.; Yadav, A.; Dwivedi, P. D.; and Das, M.; *Journal of Cleaner Production*, **2015**, *87*, 39-49.
47. Koteswari, Y. N.; and R.; Ramanibai, *Turkish Journal of Biology.*, **2003**, *27*(3), 163-170.
48. Leta, S.; Assefa, F.; Gumaelius, L.; and Dalhammar G.J.A.M.; *Applied microbiology and biotechnology.*, **2004**, *66*, 333-339.
49. Ganesh, R.; Balaji,G.; and Ramanujam, R.A.; *Bioresource Technology.*, **2006**,*97*(15), 1815-1821.
50. Ram, B.; Bajpai,P.K.; and Parwana, H.K.; *Process biochemistry*, **1999**, *35*(3-4), 255-265.
51. Apaydin, O.; Kurt, U.; and Gonullu,M.T.; *Global NEST Journal*, **2009**, *11*(4), 546-555..
52. Thanigavel, M.; Biodegradation of tannery effluent in fluidized bed bioreactor with low density biomass support. M.Tech. Thesis, Annamalai University, Tamilnadu, India. 2004.
53. Lefebvrev, O.; Vasudevan, N.; Torrijos, M.; Thanasekaran, K.; and Moletta, R.; *Water research.*, **2005,** *39*(8), 1471-1480.
54. Szpyrkowicz, L.; Kaul S.N.;, and Neti, R.N.; *Journal of Applied Electrochemistry*, **2005**, *35*, 381-390.
55. Orhon, D., Genceli, E. A.,; and Sozen, S.; *Water Sa.*, **2000**, 26.(1) 43-50.
56. Kongiao, S.; Damronglerd, S.; and Hunsom, M.; *Korean Journal of chemical engineering.*, **2008**. *25*, 703-709.
57. Bosnic, M.; Buljan, J.; and Daniels, R. P.; (2000). *United Nations Industrial Development Organization.*, 2000, *26*.
58. Bien, J.; Celary, P.; Wystalska, K.; *Journal of Ecological Engineering.*, **2017**, *18*(6), 13–20.
59. Kameswari, K.S.B.; Kalyanaraman, C.; Thanasekaran, K.; *Clean Technologies and Environmental Policy.*, **2011**, *13*, 517-525.
60. Kameswari, K.S.B.; Kalyanaraman, C.; Kumarasamy, T.; *Clean Technologies and Environmental Policy.*, **2015**, *17*, 693–706.
61. Verheijen, L.A.H.M.; Wiersema, D.; and Hulshoff Pol, L.W.; De Wit, J.; *International Agriculture Center., Wageningen., The Netherlands*.**1996**,
62. Juel, M.A.I.; Mizan, A.; Ahmed, T.; *Waste Management.*, **2017**, 60, 259-269.
63. Chand, S.; Yaseen, M.; Rajkumari, and Patra, D. D.; *International journal of phytoremediation*, **2015**, *17*(12), 1171-1176.
64. Kilic, E.; Font, J.,;Puig, R.; Çolak, S.; and Çelik, D.; *Journal of hazardous materials.*, **2011**, *185*(1), 456-462.
65. Patel, A.; and Patra, D. D.; *Chemosphere.*, **2014,** *112*, 323-332.
66. Money, C. A.; Ramasam, T.; Babu, C.; Muralidharan, J.; Ragava Rao, J.; and Saravanan, P.; *Final report on project AS1/2001/005. ACIAR, Canberra, ACT.* **2008.**
67. Beg, K.R.; Ali, S.; *American Journal of Environmental Sciences*, **2008**. *4*(4), 362.
68. Tran, T. K.; Leu, H. J.; Vu, T. Q.; Nguyen, M. T.; Pham, T. A.; and Kiefer, R.; *International Journal of Hydrogen Energy.*, **2020**, *45*(6), 3699-3711

69. Alemu, T.; Mekonnen, A,; Leta, S.; *Journal of Water Process Engineering.*, **2019**, *30*, 100514.
70. Ali, Z.; Malik, R.N.; Qadir, A.; *Chemistry and Ecology*, **2013,** *29*(8), 676-692.
71. cpcb, **2019,** Guidelines for environmental improvement in leather tannery sector.
72. Kazi, T.; Virupakshi, A.; and Scholar, M.; *Development*, **2013**, *2*(8).
73. Zhu, J.; Zhang, G.; & Li, J.; *Journal of applied polymer science*, **2011**, *120*(1), 518-523.
74. Mageshkumar, M.; and Karthikeyan, R.; *Desalination and Water Treatment*, **2016**, *57*(32), 14954-14964. Modelling the kinetics of coagulation process for tannery industry effluent treatment using Moringa oleifera seeds protein. *Desalination and Water Treatment*, *57*(32), 14954-14964
75. Ciner, F.; and Durmaz, U.; *Periodicals of Engineering and Natural Sciences*, **2017,** *5*(2).
76. Velu, S.; Muruganandam, L.; & Arthanaree-swaran, G.; *Brazilian Journal of Chemical Engineering*, **2015**, *32*, 179-189.
77. Religa, P.; Kowalik, A.;and Gierycz, P.; *Desalination*, **2011**, *274*(1-3), 164-170.
78. Gore, C. T.; Omwoma, S.,;Chen, W.; and Song, Y. F.; *Chemical Engineering Journal*, **2016**, *284*, 794-801.
79. Ray, M.; Bhattacharya, P.; Das, R.; Sondhi, K.; Ghosh, S.; and Sarkar, S.; *Journal of Porous Materials*, **2015**, *22*, 1043-1052.
80. Mouiya, M.; Abourriche, A.; Bouazizi, A.; Benhammou, A.;El Hafiane, Y.; Abouliatim, Y.; and Hannache, H; *Desalination*, **2018**, *427*, 42-50.
81. Beqqour, D.; Achiou, B.; Bouazizi, A.; Ouaddari, H.; Elomari, H.; Ouammou, M.; and Younssi, S. A.; *Journal of Environmental Chemical Engineering*, **2019**, *7*(2), 102981
82. Saja, S.; Bouazizi, A.; Achiou, B.; Ouammou, M.; Albizane, A.;Bennazha, J.; and Younssi, S. A.; *Journal of environmental chemical engineering*, **2018**, *6*(1), 451-458.
83. Sundarapandiyan, S.; Chandrasekar, R.; Ramanaiah, B.; Krishnan, S.; and Saravanan, P.; *Journal of hazardous materials*, **2010**, *180*(1-3), 197-203.
84. Kakakhel, L.; Lutfullah, G.; Bhanger, M. I.; Shah, A.; & Niaz, A.; *Journal of Hazardous Materials*, **2007**, *148*(3), 560-565.
85. Hashem, M. A.; Payel, S.; Mim, S.;Hasan, M. A.; Nur-A-Tomal, M. S.; Rahman, M. A.; & Sarker, M. I.; *Water Science and Engineering.*, **2022**, *15*(4), 328-336.
86. Mohan, D.; Singh, K. P.; & Singh, V. K.; *Journal of hazardous materials*, **2006**, *135*(1-3), 280-295
87. Hashem, M. A.; Momen, M. A.; Hasan, M.; and Sheikh, M. H.; *International Journal of Environmental Science and Technology*, **2019**, *16*, 1395-1404.
88. Ugya, A. Y.; Hua, X.; and Ma, J.; *Applied Ecology and Environmental Research*, **2019,** *17*(2), 1773-1787.
89. Ayele, L.; Pérez, E.; Mayoral, Á.; Chebude, Y.; and Díaz, I.; *Journal of Chemical Technology & Biotechnology*, **2018**, *93*(1), 146-154.
90. Ahmed, S.; Popov, V.; & Trevedi, R. C.; proceedings *of the institution of civil engineers-waste and resource manage-ment* **2008**, 161 (2), . 77-84.
91. Mahatma Gandhi, **2010**, 3-7. Effect of tannery effluent on water and soil profile, plant growth and human health, India; pp.
92. UNEP, I.; P.A.C.; **1994,** *4*, 151-155 *Tanneries and the Environment–A Technical Guide* Technical Report (2nd Print) Series.
93. Thangapandian, V.; Sophia, M; Swaminathan, K.; *J. Environ. Biol.*, **1995**, *16*, 67-70.
94. Alfredo, C.; Leondina, D.P.; Enrico, D.; **2007**, *Industrial & Engineering Chemistry Research.*, 46,6825,
95. Naik, S.J.K.; Pawer, A.C.; Vani, K.; Madhuri, K.; and Devi, V.V; *POLLUTION RESEARCH*, **2007**, *26*(2), 263.
96. Felsner, G.; *UNIDO***., 1995**, Status of the leather industry in eight African countries assisted by. In *47th annual convention of the Society of Leather< Technologists and Chemists. Halfway house*.
97. Gibb, H.J.; Lees, P.S.; Pinsky, P.F.; and Rooney, B.C.; *American Journal of Industrial Medicine.*, **2002**, 38(2), 115-126.
98. Lejri, R.; Younes, S. B.; Ellafi, A.; Bouallegue, A.; Moussaoui, Y.; Chaieb, M.; and Mekki, A.; *Journal of Water Process Engineering*, **2022**, *47*, 102686.
99. N.; Graham, *World Health Organisation, Geneva.*, *1.*, **1998**, 1-36.
100. Risco, T.A.; Auerkari,. E.I.; *Annual Research & Review in Biology.*, **2017**, *13*. 1-8.
101. Xu, X.; and Zhiping, W.; *Energy Procedia*, **2011**, *5*, 1341-1347.
102. Zhang, X. H.; Zhang, X.; Wang, X. C.; Jin, L. F.; Yang, Z. P.; Jiang, C. X.; ... and Zhu, Y. M; *BMC Public Health*, **2011**, *11*, 1-8.