Chapter 4
Sustainable Aviation of the Leather Industry: Life Cycle Assessment of Raw Materials, Energy Consumption and Discharge of Pollutants, and Recovery of Some Economical Merit Substances

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4.1 Introduction

Nowadays, the main pollutants in the leather industry wastes are liquid wastewaters, particulate wastes, sludge generation, and gases emitted to the atmosphere (Zhao and Chen 2019). These pollutants mainly include organics, toxic heavy metals such as chromium, sodium ammonium salts, chlorides, and sulphonated inorganics (Kanchinadham and Kalyanaraman 2017). The recent studies showed that the composition of wastewaters emitted to the receiving media varies between 140 and 160 million tons per year (Tasca and Puccini 2019). Meanwhile, 800–900 kg of solid effluents and 60–70 tons of outputs originated from different types of organic and inorganic chemicals produce 1.9 ton of raw effluents into leather effluents. This corresponds to a huge pollutant load, and it should be treated. Therefore, the solid and liquid emissions of the leather industry should be treated effectively by considering the innovative treatment processes. However, first the wastewater characterization and the pollutant yields should be calculated, and the pollution level of the wastewater should be performed (Cabeza et al. 1998). At the beginning, the leather production process should be environmentally friendly and sustainable, and the output pollutants should be minimized by eco-friendly treatment processes. A sustainable mass and balance inventory should be performed. In this work, a life cycle assessment was performed for the leather industry by considering the raw materials, discharging of pollutants, energy consumption, and recoveries of gelatine, collagen, and chromium from a reverse osmosis (RO) plant.

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4.2 Method

Based on ISO 14040 environmental management system, to investigate the life cycle assessment of 1 kg of chrome tanned leather, the case studies were conducted in four steps namely life cycle inventory analysis, life cycle impact assessment, results, and interpretation of the results (Proske and Finkbeiner 2019). In this study, tanned leather industry was chosen since it has a big emission originated from the chromium. Footprint software (USA 2018) was utilized for the modelling process. For the modelling of this matrix, suitable data were collected, a database matrix was designed, a life cycle assessment model was generated (SimaPro LCA, 2023). The analysis results obtained from the laboratory scale analysis and the removal yield distribution data were placed to the studied method program. In the first step, environmental impact from raw materials to finished leather was determined using chrome tanning technology. Then, the major contributing factors were identified. In this model, the data taken by the beamhouse, tanning, and finishing steps were evaluated. The beamhouse process includes e.g., soaking, liming, deliming, bating, several mechanical operations and pickling. Tanning can be defined as the process of treating skins and hides of animals. Animal skins are processed in a place called tannery. During tanning, an acidic chemical called tannin penetrate the leather, the protein structure of the skin is permanently altered, becoming durable and less susceptible to decomposition, and provide colour. Prior to tanning, the skins are dehaired, desalted, degreased, and soaked into water from 6 h to 2 days. In finishing, appearance of the leather is improved. It includes mechanical processes that give shape and smoothness to the leather, and chemical treatments that provide colour, lubrication, softening and application of surface finish to the leather (Roy Choudhury 2017).

4.3 Results and Discussion

The pollutant parameters considered in the life cycle assessments of the leather industry studied is shown in Table 4.1.

4.3.1 Impacts to the Model Used

Life cycle impact assessment method includes all the numerical data and characteristic properties of the leather emissions to the environment known as environmental impact of all input and output in the chromium leather industry. To determine the environmental impact inventory, four impacts were embedded to our targeted model in suspension. These items were: main energy requirement (PED, MJ), effect of temperature increase on the CO_2 production potential (GWP, kg CO_2 eq), water

Table 4.1 The characterization of pollutants in the studied leather industry for evaluation of life cycle assessment

Process flow	Raw materials	Dosage (%)
Pre-soaking	Water	400.0
	Soaking bactericide KF	0.8
	Wetting agent WT-H	0.5
Soaking	Water	400.0
	Bactericide KL	0.4
	Degreasing agent DFH	0.4
	Wetting agent WT-H	0.5
	Sodium carbonate	0.3
	Sodium sulfide	0.4
Liming and unhairing	Water	380.0
	Degreasing agent DN	0.4
	Wetting agent WT-H	0.5
	Liming additives	1.9
	Lime	5.3
	Sodium sulfide	2.95
	Liming additives SP	2.0
Pre-deliming	Water	180.0
	Ammonium sulfate	2.0
Deliming	Water	130.0
	Ammonium sulfate	4.0
Bating	Water	120.0
	Bating enzyme U2	2.0
Pickling	Water	90.0
	Salt	7.0
	Formic acid	0.9
	Sulfuric acid	0.9
Chrome tanning	Cationic oil	2.0
	Chrome tanning agent (Cr2O3 29%, basicity 38%)	10.0
	Sodium formate	1.8
	Sodium bicarbonate	1.9
	Water	200.0
Retanning	Water	190.0
	Formic acid (85%)	0.9
	Glutaraldehyde (30%)	3.0
	Acrylic retanning agent	3.0
	Chromium powder (Cr2O3 29%, basicity 38%)	6.0
	Sodium bicarbonate	0.9

(continued)

Table 4.1 (continued)

Process flow	Raw materials	Dosage (%)
Neutralizing	Water	160.0
	PAK-N	1.6
	Sodium acetate	1.8
	Sodium bicarbonate	0.9
Filling	Water	180.0
	Tanning extract	9.0
	Protein filling agent	4.0
	Formic acid (80%)	2.0
Fatliquoring and dyeing	Water	150.0
	Dyestuff	2.0
	Fatliquoring agents	9.0
	Formic acid (85%)	2.0
Base coating	Water	320.0
	Pigment paste 3	12.0
	Filler resin	2.9
Model leather top coating	Water	780.0
	Pigment paste 3.	0 11
	Casein solution	1.9
	Urethane resin	4.9
	Filling agent	0.9

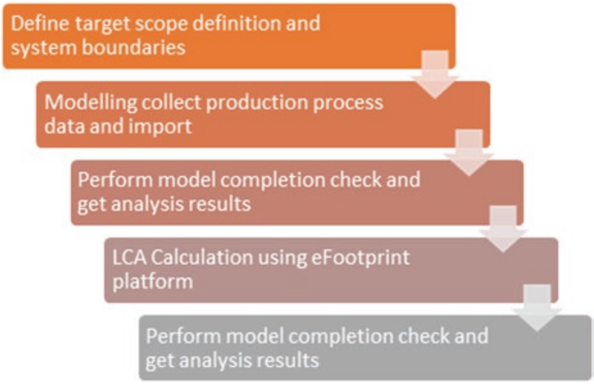

Fig. 4.1 Steps used in the modelling of tanned cowhide leather containing chromium

volume consumed (WU, kg), and acid production data from the leather industry process (AP, kg SO_2 eq). Figure 4.1 showed the steps designed during the modelling intervals.

In the first step, the toxic and no-toxic organic, inorganic, and emergency materials released during the main and co-product productions. Meanwhile, the recovery of energy used during energy losses and utilization of the recycled compounds

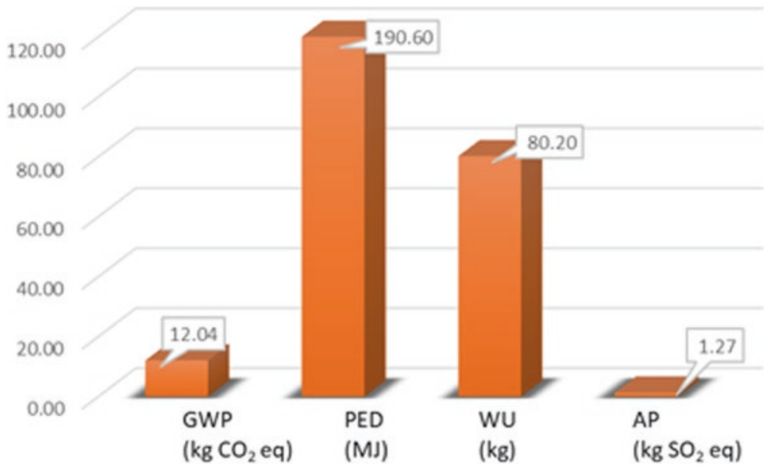

Fig. 4.2 Variation of temperature increase, energy, water, and acid production values during production of 1 kg of cowhide leather via chrome-based tanning

during wastewater treatment were not considered. The limit for the utilization of the raw compounds should be lower than the 1% of the produced leather masses. This assumption was incorporated to the life cycle assessment process in the studied model.

As shown in Fig. 4.2, the effect of temperature increase (GWP), energy requirement (PED), consumed water (WU), and acid production rate (AP) of 1 kg of cowmass leather produced during tanning process with chromium were 12.040 kg CO_2 eq, 190.60 MJ, 80.20 kg and 1.27 kg SO_2 eq, respectively. Generally, the acid production and increase of weather temperature limited the life cycle assessment process, whereas energy requirement and water consumption significantly affected the life cycle assessment process. Water was extremely used in the beamhouse and tanning processes. Under these conditions a big value of water was consumed during this step.

4.3.2 Energy Utilization

In the tanning step of leather, a huge amount of power was used as high as 90% of the total power used in the leather industry (Fig. 4.3). Majority of the machines utilized high power and electricity and a high energy consumption occurred during this leather processing step. To minimize the energy utilization, some green ultrasound and low frequency microwave devices should be utilized. This will shorten the tanning duration, and will improve the exhaustion of some toxic, refractory chemicals during tanning process. In the absence of chromium, a green leather processing will be safe to the environment during tanning process. This should also minimize the chemical cost.

Fig. 4.3 Variation of energy requirements in the tanning section of the leather industry

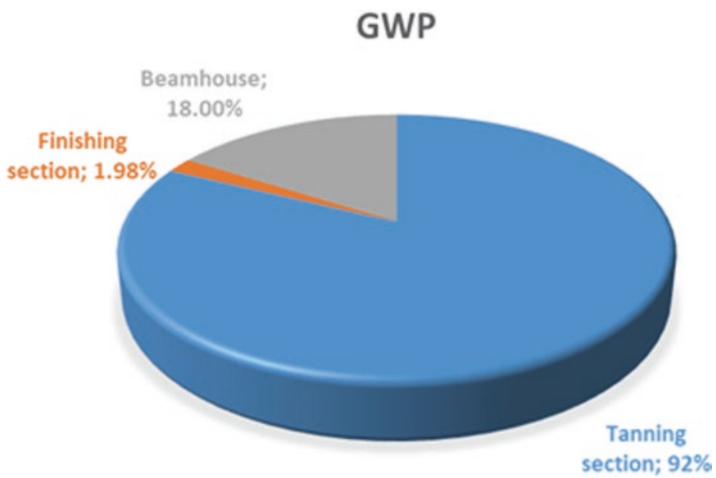

Fig. 4.4 Variables in the global warming versus increase of temperature in the tanning leather industry

4.3.3 CO_2 Production

As shown in Fig. 4.4, the CO_2 emissions were 92% in the tanning section, whereas the beamhouse and finishing sections emitted low CO_2 percentages such as 18% and 1.98%, respectively. During the tanning and retanning processes, chromium powder was extremely used. The amount of the chromium powder utilized in these two processes were approximately 49% of the total global warming effect mentioned in full leather process. Some other green chemicals instead of chromium powder should be utilized to minimize the carbon dioxide emissions releasing to the atmosphere during leather processing. By decreasing the amounts of sodium sulphide and lime utilized during the unhairing and liming steps, the carbon dioxide emissions to the atmosphere should be decreased. By the utilization of enzymes during unhairing process and collagen fiber instead of lime should be utilized. Recovery of floating tanning materials reduces the utilization of toxic sodium sulphide. Re-used tanning compounds will decrease the lime and chromium percentages during the end of leather tanning and un-hairing steps.

4.3.4 Consumed Water

In the beamhouse process, it was used a hug amount of water. In this process, the consumed water percentage was 78% of total water utilized during total leather production. The water percentage used during tanning process was 26.4% of the total water consumption. Figure 4.5 illustrated the water consumption during washing and beamhouse processes. In the beamhouse step the utilized water ratio was 16% of the total water consumption of the whole leather processing. To minimize

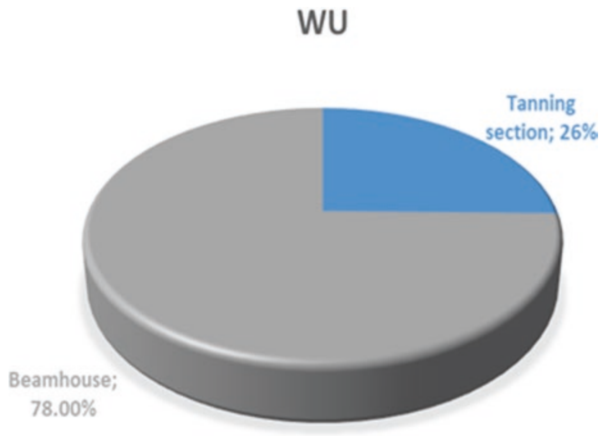

Fig. 4.5 Variation of water consumption in the entire tanning process

the water used in this process the washing devices could be improved and the excess dirty, polluted wastewater should be treated and re-used. In other words, the treated water should be re-used after the tanning process and should be used again in the next processes such tanning and pickling processes. This should reduce the cost of water utilized in the leather processes.

4.3.5 Acid Production

During tanning processing, the acid production percentage was 93% of the total acid formation during leather processing. The produced acid percentage from the beamhouse step was only 8.9% of the total acid production from whole leather process (Fig. 4.6). Furthermore, acid production was detected during deliming and retanning steps. The utilization of chromium during tanning of the leathers and the sulphide productions in deliming processes decrease the pH of the liquids to 2.0. Furthermore, acidification occurred during dissolving of chromium powder. This phenomenon affects the environment negatively. Instead of chromium powder and sulphides, some enzymes should be used. Enzymes can be used effectively during the unhairing process. This should decrease the sodium sulphide amount utilized during process and should decrease the hydrogen sulphide emissions resulting with very low pH levels in the deliming process. Some new green chemicals without ammonia and chromium should decrease the pH lowering via the acidification (Cabeza et al. 1998; Zhang and Chen 2019).

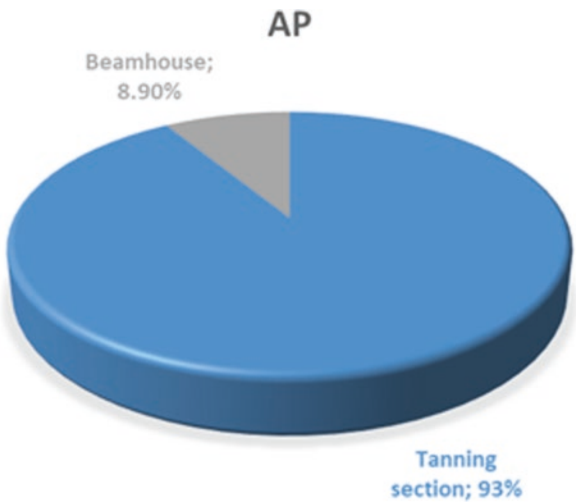

Fig. 4.6 Variation of acid production variables in the tanning leather industry

4.3.6 Recovery of the Leather Industry Compounds

Chrome recoveries from the RO retentates are chemically studied and it is found to complex with collagen. Hydrolysis of this waste involves the breakdown of bonds responsible for its stability. The bonds are responsible for collagen stability as the collagen-chromium bond. Other covalent bonds have linkage between the complex chromium ion and the ionized carboxyl groups on collagen. The concentrate of the RO was subjected with an alkali for denaturation and degrading the protein fraction. These studies were performed at 70 °C temperature and at a pH of 10 according to procedure by Sponza (2021). The alkaline condition was achieved by the utilization of sodium carbonate. The collagen was broken down to large molecular weight peptides into aqueous solution while the chromium was converted to an insoluble condition under alkaline conditions. The chemical characteristics of the hydrolysate was as follows: The peptides passed into the aqueous solution as collagen hydrolysates whose concentration is expressed as % total nitrogen. The hydrolysis yield was 87% for total nitrogen. The production of low molecular weight degradation products showed the reduction in the dry matter content of the collagen hydrolysate. The composition of hydrolysate was inorganic ash (2%), TKN (49%), chromium (28%), collagen (28%), and gelatine (19%) according to a dried compound.

4.4 Conclusion

As a result of tanning process, when chromium was used, 1 kg of chrome tanned cow hide leather waste affect the aquatic and soil ecosystem negatively. On the other hand, utilization of chromium powder in tanning and retanning process; sodium sulphide and lime in the liming and unhairing processes affect the environment negatively resulting in toxicities and non-biodegradable accumulations in the environment. Toxic discharges containing beamhouse, tanning, and retanning wastes should be detoxified. By the utilization of some non-toxic, non-refractory, non-accumulative, and bio-compounds, the sustainability of the leather industry wastes should be maintained with processes revealing low acid production and low CO_2 emissions in this industry, and by recovering and reusing the water and the energy.

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