ENVIRONMENTAL IMPACT ASSESSMENT OF LEATHER PROCESS USING IMPACT 2002+ METHOD

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ABSTRACT

Life cycle assessment (LCA) is the commonly used decision support tool for quantifying and evaluating environmental impacts of any product, process or activity. This paper constructed inventory of rechroming process for both full-chrome (FCR) and retanned (RR) leather as a basis to analyze, compare and propose further improvement actions. The functional unit is 1 square meter leather and impact assessment conducted based on IMPACT 2002+methodology. In this method, data was inventoried and assembled according to life cycle assessment (LCA) methods principle and requirements of ISO-14040/44, 14067 standards. All procedure was carried out using leading LCA software SimaPro. Results indicated that, FCR process has more than 1.8 times higher impact on aquatic ecotoxicity and non-carcinogens but RR has 4.7 times higher on aquatic acidification and 1.45 times higher on Aquatic eutrophication. In addition, FCR has 1.8 times higher impact on damage category ecosystem quality and human health. Comparing all impact and damage categories, FCR process has higher environmental burden than RR process.

Keywords: IMPACT 2002+; impact assessment; SimaPro software and environmental impact

INTRODUCTION

The leather tanning process is composed of several batch stages associated with the consumption of large amounts of freshwater as well as the generation of liquid and solid wastes. The wastewaters are characterized by significant organic load and remarkably high concentrations of inorganic compounds such as chromium, chloride, ammonia, sulfide, and sulfate (Tünay, 1995, Ates et al., 1997). Among these, tanning agents from chromium metal poses a challenge to the future sustainability of the leather industry with a growing number and layers of non-tariff barriers, including environmental considerations and eco-criteria emanating from major export markets. Rechroming uses a significant amount of chrome tanning agent and subsequently a greater chance of releasing into environment. A common retannage for chrome tanned leather is more chrome tanning which is done usually to increase the shrinkage temperature and chromium content; to even up the color; to change the reactivity of leather and to modify the properties of leather (Covington, 2009). On the other hand, Leather which has been subjected to an additional tannage with similar or other tanning materials is called retanned leather (leather terminology, source: IULTCS). A useful tool to evaluate the environmental burdens associated with a product, process or activity is life cycle analysis or assessment (LCA). The objectives of this environmental management tool are the identification and quantification of the input and output flows of the process: energy and materials used and wastes released into the environment (Consoli et al., 1993). The application of LCA in process selection, design, and optimization is gaining wider acceptance and methodological development (Azapagic, 1999). The life cycle assessment framework consists of four phases. They are: goal definition and scoping, inventory analysis, impact assessment and improvement analysis. The definition of the scope of the LCA sets the borders of the assessment – what is included in the system and what detailed assessment methods are to be used (Azapagic, 1999). The second step (inventory analysis) includes inventory of the inputs such as raw materials and energy and the outputs such as wastes and emissions that occur during the life cycle. The third step (impact assessment) is integration of inventory elements into an assessment of environmental performance which requires the emissions and material used to be transformed into estimates of environmental impacts. The results of this stage of LCA are termed as 'ecoprofile'(Joseph & Nithya, 2009). The final step is interpretation of the results of impact assessment and suggestions for improvements(Azapagic, 1999). Earlier LCA of two representative leather articles of Bangladeshi tannery has been done from environmental perspective (Ahmed & Chowdhury, 2016). In addition, a similar study conducted for pretannage process using Chrome and Aluminium tanning agents (Chowdhury et al., 2015). The present study investigated the environmental impact of Rechroming process of both full-chrome and retanned leather. It will help to identify environmental burden and scope of improvement of the concern process.

METHODOLOGY

In this study, data was inventoried and assembled according to life cycle assessment (LCA) methods principle and requirements of ISO-14040/44, 14067 standards. All procedure were carried out using leading LCA software SimaPro (PRé, 2013). The impact assessment was conducted based on IMPACT 2002+ methodologies. As mentioned earlier, the life cycle assessment framework consists of four phases namely goal definition and scoping, inventory analysis, impact assessment and improvement analysis.

GOAL AND SCOPE DEFINITION

The goal of this study is to determine and compare the environmental burden of the most polluting leather process Rechroming of representative leather article full-chrome and retanned leather which will help to identify impact of different impact categories. Therefore, to find out where the environmental performance can be improved. Moreover it serves as a source of information for other tanneries or industries which may be interested to study the impact of their processes by applying the LCA methodology. Vegetable tanned leather is rechromed to increase the thermal stability and strength. Leather which has been tanned first with vegetable tannin and then re-tanned with chromium salts is called semi-chrome leather and the tannage is called semi-chrome tannage (leather terminology, source: IULTCS). Range of thickness of curst leather does not vary substantially from one article to the other. It was assumed based on in house observation. The functional unit chosen is 1 square meter leather. Therefore all the emissions are calculated in relation to the production of 1 square meter leather.

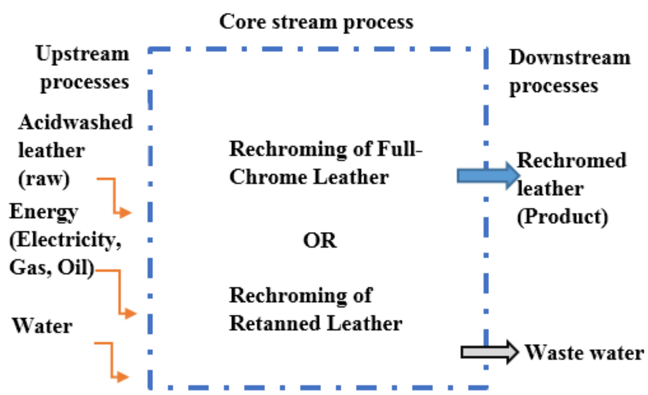

Figure 1: system boundary for both FCR and RR processes

According to the system boundaries illustrated in Fig. 1 and table 1, both differ in amount and types of tanning and other performance chemical agents. Preceding major upstream processes like slaughtering, preservation, presoaking, soaking, liming, deliming, bating and pickling are same for both leather except chrome tanning (FCL) and pretannage (RL). Data are based on Bangladeshi system that reasonably approximate this country's practices. All data used here are less than 10 years old to provide a reasonable approximation of current practices and energy systems. Data concerned to rechroming of both leather processes taken directly from production of stated articles in a representative tannery.

LIFE CYCLE INVENTORY

An analysis of the physical and chemical characterization of wastewater emissions of the leather processes was performed. The major tests conducted were chemical oxygen demand (COD), chloride, SO_4^{2-}, TS, TDS, pH, NH_3-N, NO_2-N, NO_3-N, PO_4^{3-}, total chromium. Data collection included annual wet-salted raw hides/skins consumption, input chemicals consumption, water and steam consumption, tannery solid waste generation, electricity, fuel oil consumption for generator and steam boiler but will not be showed in this study. Tests were conducted at Environmental Engineering laboratory, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology (BUET).

Table 1: Input chemicals consumption for both process FCR and RR (per meter square of leather)

Input as chemicals			
FCR	Quantity in kg/m^2	**RR**	Quantity in kg/m^2
Total water	2.691	Total water	1.943
Relugan RF (water-soluble Acrylic co-polymer tanning agent)	0.030	Derugan 3080 (Mixture with glutaraldehyde)	0.030
Formic acid	0.001	Provol BA (based on natural phospholipids with synthetic softeners)	0.006
Tankrom AB (Basic chromium sulfate)	0.090	Basic chromium sulfate	0.045
CP super (Chrome Syntan)	0.060	CRO chrome syntan	0.045
Sodium Formate	0.030	Sodium Formate	0.024
Atlasol 177C (based on bisulfited oil, fatty alcohols and synthetic lubricants)	0.012	Atlasol 177C	0.006
Sodium Bi carbonate	0.006	Sodium Bi carbonate	0.006
		Adusin (syntan)	0.030
		NH	0.012
		Basyntan AN (condensation products of aromatic sulphonic acids)	0.030

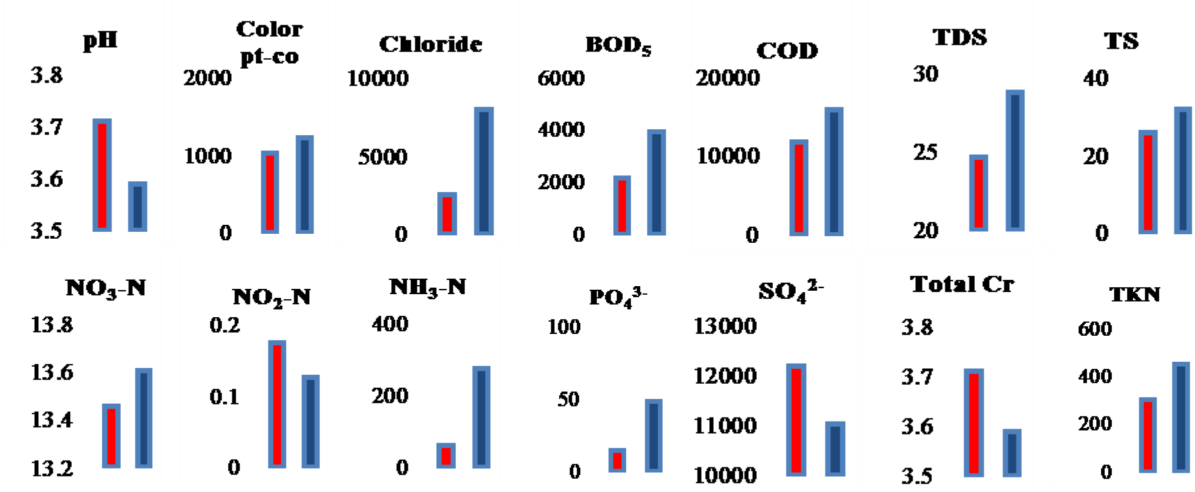

Fig. 2: comparative output results of both FCR and RR process

The samples being analyzed were waste liquors of presoaking, main soaking, liming, deliming and bating, pickling, pretannage (retanned) and chrome tanning (FC), acidwash (both) and rechroming (both) but has not been shown except FCR and RR process. Table 1 shows the input of both systems which in part represent the recipe for the studied processes but order of chemical addition, time etc. ignored.

According to the Fig. 2, RR contributed much in color, chloride, BOD_5, COD, TDS, TS, NO_3-N, NH_3-N, PO_4^{3-} and TKN. Among these, NH_3-N is about 4.7 times, PO_4^{3-} is 3.5 times, chloride is 3.2 times higher. In contrast, total chromium, SO_4^{2-} and NO_2-N of FCR are slightly higher than RR.

RESULTS AND DISCUSSIONS

The impact assessment of characterization and damage categories comprises the results and discussion. In addition, scope for improvement also belongs to this part.

IMPACT ASSESSMENT

The impact assessment was conducted based on IMPACT 2002+methodology. SimaPro has been used to analyze and compare these two processes. This method links all types of LCI results via several midpoint categories like carcinogens, non-carcinogens, respiratory inorganics, respiratory organics, ionizing radiation, ozone layer depletion, aquatic ecotoxicity, terrestrial ecotoxicity, aquatic acidification, aquatic eutrophication, terrestrial acidification/nitrification, land occupation, global warming, non-renewable energy consumption and mineral extraction to four damage categories (human health, ecosystem quality, climate change and resources). Linking to midpoint is associated with certain conversion factors for each pollutant and conversion to damage categories is also associated with damage factors (Humbert et al., 2011).

CHARACTERIZATION ASSESSMENT

Fig. 3 shows the relative contribution to the following impact and damage categories namely human health and ecosystem quality. According to Fig. 3, Kg equivalent of a reference substance expresses the amount of a reference substance that equals the impact of the considered pollutant (e.g. TEG-Triethylene glycol) in the midpoint categories. PDF.m^2.y (Potentially Disappeared Fraction of species disappeared on 1 m^2 of earth surface during one year) is the unit to measure the impacts on ecosystems. DALY (Disability-Adjusted Life Years) characterizes the disease severity, accounting for both mortality (years of life lost due to premature death) and morbidity (the time of life with lower quality due to an illness, e.g., at hospital)(Humbert et al., 2011).

Aquatic Ecotoxicity

This category is dominated mostly by FCR and this process contributes about 1.8 times higher. According to Fig. 3, both processes contributed 9384 and 5223 kg TEG water respectively. The ecotoxicity of these processes mentioned above is due to the associated heavy metal chromium emission into water.

Aquatic Acidification

This category is dominated mostly by RR process and this contributes about 4.7 times higher. According to Fig. 3, both processes contributed 6.26E-04 and 1.34E-04 kg SO_2 equivalent respectively. The aquatic acidification of these processes mentioned above is due to ammonia emission into air and water and ammonia as N.

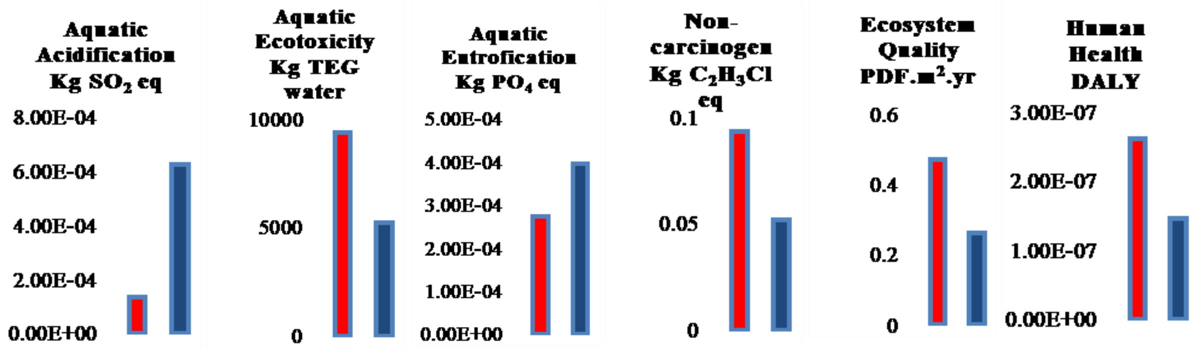

Fig. 3: characterization and damage assessment of both FCR and RR processes

Aquatic Eutrophication

According to Fig. 3, the amount of kg PO_4 emitted by FCR and RR are 3.97E-04 and 2.73E-04 respectively. Noticeably, RR process is 1.45 times greater than FCR process. The aquatic eutrophication of these processes mentioned above is due to higher COD and PO4 discharge into water.

Non-carcinogens

FCR process contributed about 1.80 higher compared to RR process which are 0.09 and 0.05 Kg C_2H_3Cl eq respectively. Non-carcinogens effect of these processes mentioned above is due to the associated heavy metal chromium emission into water.

DAMAGE ASSESSMENT

All midpoint categories except aquatic acidification and aquatic eutrophication have been grouped into four damage categories namely climate change, human health, ecosystem quality and resources. These two midpoint categories are represented separately from the four damage categories.

Ecosystem Quality

The damage category ecosystem quality is the sum of the midpoint categories aquatic ecotoxicity, terrestrial ecotoxicity, terrestrial acidification/nitrification and land occupation. According to Fig. 3, major contribution to this category comes from FCR followed by RR which are 0.47 and 0.26 PDF.m^2.yr. respectively. FCR contributes about 1.80 times higher.

HUMAN HEALTH

The human health category is the sum of the midpoint categories carcinogen and non-carcinogen, respiratory organics and inorganics, ionizing radiation, ozone layer depletion. This damage category followed the same trend as Ecosystem quality. According to Fig. 3, the contribution of both processes are 2.61E-07 and 1.45E-07 DALY respectively.

SCOPE FOR IMPROVEMENTS

It is clearly indicated in the characterized values the company has impact on aquatic ecotoxicity which results increased contribution to ecosystem quality damage category. Aquatic acidification, aquatic eutrophication and Non-carcinogen take the next position. Effluent treatment plant will significantly reduce environmental load of the following parameters. Chemical modification of chromium tanning salt can be one of the options for enhancing the uptake of chromium. Synthetic tanning material based on chromium improved significantly (90%) chromium uptake (Lofrano et al., 2013). Enhancement of chromium uptake in tanning using oxazolidine and a decreasing of the chromium load in wastewater can be achieved (Sundarapandiyan et al., 2011). Modification of process such as reduction of float is another tool for improving the chromium uptake. Carrying out chrome tanning without float and increasing the temperature at the end of the tanning process brought about 91% reduction in chromium discharged (Lofrano et al., 2013). Phosphate and ammonia as N mostly associated with increased use of syntans and fatliquors.

CONCLUSIONS

In this study, major emissions considered by IMPACT 2002+ method were heavy metal chromium discharge into water, high COD, PO_4^{3-} and ammonia as N wastes produced in rechroming process. These emissions are responsible for the contribution of the concern process to significant toxicological impacts namely aquatic ecotoxicity, aquatic acidification, aquatic eutrophication and non-carcinogens which eventually contributed to damage categories human health and ecosystem quality. The main impact categories associated with FCR leather are non-carcinogens, aquatic ecotoxicity and RR process is dominated by aquatic acidification and aquatic eutrophication.

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