REVIEW ARTICLE

INTERNATIONAL JOURNAL OF RESEARCH IN PHARMACEUTICAL SCIENCES

Published by JK Welfare & Pharmascope Foundation Journal Home Page: https://ijrps.com

Impact of Leather Toxicity on People and Places: A Review

Satish Kumar Sharma*, Pankaj Bhatt

Department of Pharmacology, Glocal School of Pharmacy, Glocal University, Mirzapur Pole, Saharanpur-247121, Uttar Pradesh, India

Article History:

Received on: 20 Oct 2020
Revised on: 22 Nov 2020
Accepted on: 24 Nov 2020

Keywords:

Leather toxicity, Tannery effluents, Toxicity evaluation, Environmental sustainability

ABSTRACT

The production of the most luxurious form of textile, i.e. Leather, has always been associated with environmental toxicity. The royal texture and firm durability of leather demands animal as well as environmental sacrifices. The process of leather production not only introduces chemicals in the environment but also causes undeniable animal abuse. The leather manufacturing process involves beam house operations and tanning procedures involving toxic chemicals rich in heavy metals and carcinogens. The effluents from the leather tanneries expose these toxins into the environment, posing a threat to different life forms. The increased toxin load from tannery effluents has percolated the food chain, thus inducing toxicity in human beings. The effect of lather manufacturing has been mostly observed in occupational regions displaying evidence of severe respiratory diseases, gastrointestinal tract infections, skin infections, chromium toxicity in biological fluids and high risk of morbidity. Different studies have been performed on regions receiving tannery discharge indicating toxin exposure affecting agricultural land, water systems, plants and aquatic life forms. The present study reviews sources of toxicity in the leather manufacturing process and describes bioassays that can be utilized to study the effect of leather toxicity on the ecosystem. The study mentions examples of sustainable alternatives and waste management for tanneries that can be explored to provide an insight for better future of leather industries.

*Corresponding Author
Name: Satish Kumar Sharma
Phone:
Email: satishdipsar55@gmail.com

ISSN: 0975-7538
DOI: https://doi.org/10.26452/ijrps.v11i4.4073

Production and Hosted by
IJRPS | https://ijrps.com

INTRODUCTION

Leather manufacturing technology has been in existence since Stone Age when cavemen used animal skins for apparels, tents and tarpaulins. The royalty of texture and durability of transformed animal skin has made leather manufacturing as one of the largest industries of the world. Indian leather industry accounts for 12.9% of the world's total leather production by providing a broad range of consumer goods such as apparels, footwear, bags etc. (Dixit *et al.*, 2015). The transformation of animal skin into leather is achieved by a variety of processing steps which results in different forms of leather. Structurally, the raw animal hide is a natural polymer of collagen. In order to prevent natural decomposition of hide, water molecules are removed from collagen and flexibility is restored by using tanning chemicals (Harlan and Feairheller, 1977). Several tanning processes such as chrome tanning, vegetable tanning, aldehyde tanning, synthetic tanning and alum tanning determine the form and mechanical characteristics of finished leather material (Maina *et al.*, 2019). Leather tanning is a wet process that requires an enormous amount of water and mostly 90% of water is wasted as effluents. Tanning effluents contribute to the deposition of toxic tannins which damages land and water ecosystems.

Tannery effluents have been ranked as highly polluting agents among all other industrial wastes. The presence of metals in tannery waste is chronically toxic for organic life. The by-products of tanning industries cause significant environmental pollution unless pre-treated before discharge. Even treated effluents from leather industries are high in biochemical oxygen demand (BOD), chemical oxygen demand (COD) and heavy metal toxicity beyond permissible levels (Gupta *et al.*, 2012). Due to this, the tanning industry has affected the lives of workers as well as nearby residents in the area.

There have been reports of occupational cancer and severe DNA damage due to chromium toxicity among tannery workers in Kanpur, India (Kvitko *et al.*, 2012; Rastogi *et al.*, 2008). The leather industries are also responsible for heavy metal contamination in agricultural soil in nearby areas which affects the irrigation process. Soil pollution at phytotoxic concentration affects plants and causes the risk to human health (Liknaw and Tekalign, 2017). Similarly, tannery effluents in water have deleterious effects on aquatic ecosystems. Due to tannery effluents dispersal in soil, water and air, toxic chemicals have been incorporated in the food chain with rapid interactions with the environment. This review elaborately discusses specific toxicity sources in the leather manufacturing process, toxicity analysis bioassays and provides alternatives for sustainable leather industries.

Transformation process

Animal skin to Leather

In 2019-2020, there has been an export of 4.6 billion US dollars from leather industries in India (IBEF, 2020). The industry has transformed drastically from being a mere raw material supplier to exporter of value added leather products. Leather manufacturing process is technically a channeled process involving three sub processes – beam house operations, tanning and crusting (Figure 1).

Beam house operations are carried out on animal hide as pre-treatment required before tanning. Firstly, the hides undergo a curing process with salts and chemicals to prevent bacterial putrefaction and ensure preservation. Then, they are trimmed and soaked to restore moisture and get rid of salts in wastewater (Il *et al.*, 2010). The excess tissue, fats are removed to obtain uniform thickness and dehairing is performed by incubation in drums containing calcium hydroxide and sharpening agents. The flexibility is restored by hide bating and incubation in ammonium salts and proteolytic enzymes (U. N. I. D. O., 2000). Next step involves picking, which is required to adjust low pH to enhance the effects of tannins in the next process step.

The tanning process restores flexibility to make the material suitable for various applications. The two most common types of tanning methods include vegetable tanning and chrome tanning. Vegetable tanning is a three weeks long process which ensures complete penetration of dyes into the animal hide. Further, the hides are treated with sodium bicarbonate and sulphuric acid for bleaching and tannins removal. For flexibility, lingo-sulphate, oils or corn sugar are added as finishing steps. Chrome tanning is achieved when hide reacts with trivalent chromium salt. Subsequently, fat-liquoring is done by applying oil on the leather surface to provide the necessary moisture for flexibility (Heidemann, 1993). Chrome tanning is preferred over vegetable tanning due to better properties of finished leather in terms of softness, thermal ad water stability and less processing time.

Crusting is performed after tanning and lubrication of hiding and sometimes dye is incorporated at this step. Crusting ensures fixation of chemicals added in the entire process for leather softening. The final leather finish is provided by a surface coating that includes oiling, brushing, buffing, spray coating, embossing and glazing (Bienkiewicz, 1983). The environmental impact of leather tanning process involving toxic chemicals, tannins, resins, biocides along with negligent waste disposal and emissions are responsible for the fatalistic shape of the leather industry.

Impact of leather industry effluents on the environment

Wastewater effluents

The leather industry holds significant economic responsibilities, but its impact on the environment is undeniable. Almost 90% of leather tannery pollutants have been reported to be discharged during the pre-tanning and tanning process. According to Thanikaivelan et al., tanning process contributes to disturbed pH, increase in chemical oxygen demand (COD), sulphates and total dissolved solids (TDS) in wastewater (Thanikaivlaen *et al.*, 2001). The dehairing process of animal hides accounts for 84% BOD, 75% COD and 92% suspended solids (SS) in tannery effluents (Marsal *et al.*, 1999). Using sodium sulphide hinders the efficacy of waste treatment plants along with unusual consequences on the environment (Bailey *et al.*, 1982). The post tanning process has been reported to result in heavy metal leaching in water, causing ecological imbalance and increased river salinity. This has led to agricultural production loss and increased toxicity in drinking water.

Solid waste sludge and volatile effluents

Tanneries generate huge amounts of sludge which mostly comprise non-biodegradable tanned residues creating a clearance burden in terms of waste management. The tanned residues are generally resistant to chemical, microbial and thermal degradation due to perceived tanning chemicals (Han *et al.*, 2003). It is reported that tannery residues in water bodies affect aquatic life and agricultural activities. Different tannery chemicals, including hydrogen sulphide, hydrocarbons, amines, ammonia, and aldehydes are major effluents emitted into the atmosphere. During pH adjustments in the tanning process, hydrogen sulphide is generally leached in wastewater (Dixit *et al.*, 2015). Emissions of chromium can occur during chromate reduction reaction, leaching of chromium particulates from powder or during the buffing step. These volatile organic compounds released as effluents from tanning industries have been reported to be a major threat to the atmosphere.

Chemicals toxicity

Due to severe environmental threats posed by tanning chemicals, regulatory bodies have developed standards and control measures for chemicals used in leather industries. According to EU (2003 a), authorities have posed strict instructions on the labeling of products that contain more than 0.5% phthalates as di-butyl phthalate (DBP) and di-ethyl hexyl phthalate (DEHP) is used in the leather coating. Phthalates have been reported to induce reproductive toxicity and its low degradability result in their environmental persistence. Chemicals used in leather finishing such as o-phenyl phenol (OPP), formaldehyde and azo dye derivatives have been reported as carcinogens (Mohan *et al.*, 2008). Inorganic chemicals chromate, cadmium sulphate, are used for good leather color, but these impart heavy metals toxicity to the environment (Table 1). According to Srivastava and Nair, chromium (III) can lead to apoptosis and proteins structural changes (Shrivastava and Nair, 2001). A study conducted by Afaq et al. reported that leather dyes Bismarck brown and acid leather brown decrease RBC counts in marine life forms (Afaq and Rana, 2009). Thus for creating a balance of economic development and environmental repairment, leather processes need to be intricately studied to develop greener and sustainable solutions.

Evaluation of leather toxicity

Leather is a multipurpose product with a standard of texture, mechanical strength and durability properties. To achieve these characteristics, tannins' toxicity burden is increasing along with technology development. High concentration traces of tannins in effluents affect metabolic processes due to their ability to interact with organic compounds. Tanning chemicals have been responsible for leaching of heavy metals leading to lethal consequences of carcinogens, and mutagens exposure, causing genetic toxicity to flora and fauna (Siyanbola *et al.*, 2011). Hence it is essential to identify the toxicity potential of leather industry effluents.

In a study conducted by Roy et al., effluent samples were collected from a tannery discharge site in Tamil Nadu, India and several bioassays were performed to evaluate toxicity on different life forms (Table 2). According to physicochemical analysis, the effluent contained very high levels of Nickel, Chromium, Zinc and Iron with other heavy metals like Cobalt, Cadmium, and Manganese etc. at a relatively lower concentration. It was found that tannery effluent severely affected protein and chlorophyll synthesis in plant *Lemna minor.* .

Also, the effluent negatively affected human blood cells by inducing chromosome fragmentation, cellular damage and hemolytic activity (Roy *et al.*, 2015; Afaq and Rana, 2009). Overall the study suggested that tannery effluent was highly toxic for plants, microbes and human beings. The toxicity was majorly attributed to the presence of heavy metals. Hence it is extremely necessary to study the toxicity of leather industry effluents before discharging them to the natural environment.

Sustainable future of Leather

Environmental sustainability has become a burning issue all around the world. With the growing industrialization, it is necessary to reduce the negative impact on the ecosystem. There could be two concepts that can be implemented – using sustainable, eco-friendly technologies and vigilant treatment of waste (Dixit *et al.*, 2015). For cleaner processes, less toxic alternatives should be employed for animal hides treatments. The technology designing should support reuse and recycling processes specifically in tanning procedures. Vegetable tanning can be used in place of chromium tanning (Mahdi *et al.*, 2009).

Similarly, toxic effects of leather dyes can be reduced by incorporating natural dyes with non-toxic mordants in tanning procedures (Inayat *et al.*, 2010). Also, Sargassum seaweeds can be used to bioremediate chromium from tannery effluents, or

Table 1: Toxic chemicals used in leather industries affect human health. The tanning chemicals cause occupational cancer to workers and increase toxicity load in the ecosystem. These chemicals are exposed to the ecosystem through the unregulated discharge of tannery effluents

Toxic chemicals	Application in the leather industry	Human health effects
Anthracene	Tanning agent	Carcinogen, Kidney, Liver
Sodium dichromate	Chrome tanning salt	Carcinogen, Blood, Kidney, Heart, Eyes, Lungs
Cobalt dichloride	Leather dye	Lungs, Kidney, Heart, Liver, Skin
Methylisothiazolinone	Biocide (prevention of microbial putrefaction)	Carcinogen, Skin, Eye
Benzyl butyl phthalate	Artificial leather coating	Lungs, Eyes, Liver, Reproductive system
Chromium	dyeing	Kidney, Central Nervous System
Azo dyes	Leather dyeing	Carcinogen, Testes, Blood, Liver

Table 2: Bioassays for assessment of leather toxicity effect on different life forms. The assays involve a test organism representing a life form. Toxicity effect measured by evaluation of respective assessment factor. MIC- Minimum InhibitoryConcentration, RBC- Red Blood Cells.

Leather Toxicity Bioassays	Organism used	Assessment factor	Role of assessment
Microbiological Assay	Bacillus thuringiensis, Rhizobium etli, AspergillusTerreus	MIC of tannery effluents	To study the toxicity effect on agricultural soil microbes.
	Cyanobacteria	Chlorophyll and protein content of microbe	To study the impact of toxicity on microbes existing in a symbiotic relationship with plants.
Cultivation Assay	Allium cepa	Minimum Root Inhibition	To study the toxicity effect on plant growth.
	Lemma minor	Number of fronds	To study the toxicity effect on aquatic plant growth.
Genotoxicity Analysis	Homo sapiens	Chromosomal abnormality, Hemolytic activity, Micronuclei detection	To study the toxicity effect on human RBC.

chromium salt can be manufactured as reductant (Aravindhan *et al.*, 2004). It has been reported that using ammonia free de-liming and bating methods with acids and carboxylic acid esters, 97% of ammonia load can be reduced in effluents (Frendrup, 1995).

Enzymatic dehairing is an alternative to avoid chemicals involved in beam house operations (Valeika *et al.*, 2012). Additionally, the conventional methods of waste disposal have been ineffective in the case of leather industries.

The problem of chromium leaching from effluents to groundwater exposes several chemicals towards the ecological niche. Proper treatment of solid waste such as anaerobic digestion to produce biogas should be introduced in leather industry practices (Gnanamani and Bai, 1992; Dhayalan *et al.*, 2007).

Keratin hydrolysates can be employed in chrome tanning along with leather strength (Chakraborty and Sarkar, 1998). Flesh waste can be utilized for byproducts such as fat liquor, soap, biodiesel etc. Filtration technologies such as activated carbon filters, reverse osmosis, cross flow microfil-

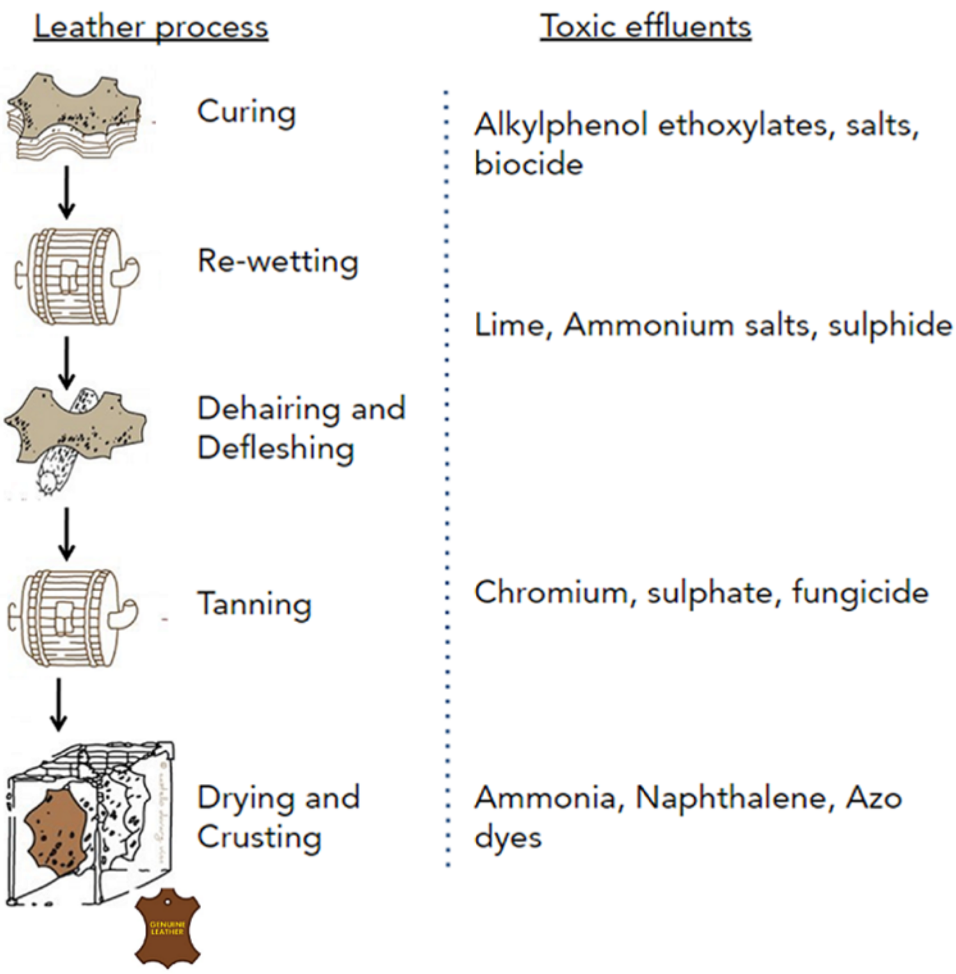

Figure 1: Different steps of the leather manufacturing process and toxic effluents associated with each processing step. The steps curing, rewetting and dehairing constitute the beam house process. Tanning and crusting account for most of the toxic leather tannery effluents

ters can be employed for tertiary wastewater treatment (Gallego-Molina *et al.*, 2013; Labanda *et al.*, 2009).

Membrane bioreactors can be used for treating tannery sludge waste and crystallization saline streams can be employed for salt bearing wastewater from tanneries (Keerthi *et al.*, 2013). Alternatively, sustainable leathers through biotechnology innovations have transformed the way of making leather material. Startups like Mycotech (Indonesia), Pinatex (London) and Malai (India) have developed leather alternatives maintaining similar properties and finish (Ladha, 2019). The upcoming new class of mushroom and plants based leathers has capabilities to reduce adverse environmental impact in terms of animal abuse, toxicity exposure and supply-demand paradigm of animal leather. Although the commercial acceptance of these leather similars remain unexplored, these innovations can reduce toxicity load on the environment and improve the image of the leather industry.

CONCLUSION

Leather industry has been famous for producing economically beneficial value added products along with undeniable ecological damage by toxicity exposure. The leather manufacturing process involves a series of technically essential steps which are responsible for producing toxic chemicals, heavy metals and carcinogens affecting environmental and occupational sustainability. The leather toxicity exposure affects agricultural practices, plants and aquatic life forms. The exposure to leather industry chemicals in the form of effluents has created toxicity load on the overall food chain, thus affecting human health. Hence there is a need to vigilantly evaluate the toxicity of leather industry effluents on different life forms. This study elaborately discuss specific toxicity source in the leather manufacturing process and toxicity evaluation assays concerned with biological life forms. The study describes alternatives to leather processes that can help in developing a sustainable future of leathers.

Funding Support

The authors declare that they have no funding support for this study.

Conflict of Interest

The authors declare that they have no conflict of interest for this study.

REFERENCES

Afaq, S., Rana, K. S. 2009. Toxicological effects of leather dyes on total leukocyte count of the freshwater teleost. *Cirrhinus mrigala*, 1(2):134–138.

Aravindhan, R., Madhan, B., Rao, J. R., Nair, B. U., Ramasami, T. 2004. Bioaccumulation of Chromium from Tannery Wastewater: An Approach for Chrome Recovery and Reuse. *Environmental Science and Technology*, 38(1):300–306.

Bailey, M. A., Tunick, D. G., Kuzma, M. K. 1982. Effect of sulfide, chromium and phosphate ions on methane production by an anaerobic sludge acclamatised of tannery beam house effluent. 14:202–211.

Bienkiewicz, K. 1983. Physical Chemistry of Leather Making. Krieger Publishing. ISBN: 9780898743043, 541 Pages.

Chakraborty, S. K., Sarkar, S. 1998. Enzyme hydrolysis of solid tannery wastes: solid estate enzyme production. *J. Soc. Leather Technol. Chem*, 82(2):56–58.

Dhayalan, K., Fathima, N. N., Gnanamani, A., Rao, J. R., Nair, B. U., Ramasami, T. 2007. Biodegradability of leathers through anaerobic pathway. *Waste Management*, 27(6):760–767.

Dixit, S., Yadav, A., Dwivedi, P. D., Das, M. 2015. Toxic hazards of leather industry and technologies to combat threat: a review. *Journal of Cleaner Production*, 87:39–49.

Frendrup, W. 1995. UNEP Cleaner Production Industrial Sector Guide. Leather Industry, Taastrup.

Gallego-Molina, A., Mendoza-Roca, J. A., Aguado, D., Galiana-Aleixandre, M. V. 2013. Reducing pollution from the deliming–bating operation in a tannery. Wastewater reuse by microfiltration membranes. *Chemical Engineering Research and Design*, 91(2):369–376.

Gnanamani, A., Bai, R. K. 1992. Influence of biodigested slurry on rice-gram cultivation. *Bioresource Technology*, 41(3):217–221.

Gupta, K., Gaumat, S., Mishra, K. 2012. Studies on phyto-genotoxic assessment of tannery effluent and chromium on Allium cepa. *J. Environ. Biol*, 33(3):557–563.

Han, B., Jaurequi, J., Tang, B. W., Nimni, M. E. 2003. Proanthocyanidin: A natural crosslinking reagent for stabilizing collagen matrices. *Journal of Biomedical Materials Research*, 65A(1):118–124.

Harlan, J. W., Feairheller, S. H. 1977. Chemistry of the Crosslinking of Collagen during Tanning. *Advances in experimental medicine and biology*, pages 425–440.

Heidemann, E. 1993. Fundamentals of Leather Manufacture. Darmstadt, Germany. ISBN: 9783792902066. 647 pages.

IBEF 2020. Leather Industry And Exports. India Brand and Equity Foundation, Ministry of Commerce and Industry, Government of India.

Il, Fs, Environment, IL. & FS. Environment 2010. Technical EIA Guidance Manual for Leather/skin/hide Processing Industry. *Minist. Environ. For. Gov. India*.

Inayat, A., Khan, S. R., Waheed, A., Deeba, F. 2010. Applications of eco friendly natural dyes on leather using different modrants. *Proc. Pakistan Acad. Sci*, 47(3):131–135.

Keerthi, Suganthi, V., Mahalakshmi, M., Balasubramanian, N. 2013. Development of hybrid membrane bioreactor for tannery effluent treatment. *Desalination*, 309:231–236.

Kvitko, K., Bandinelli, E., Henriques, J. A., Vanina D. Heuser, Rohr, P., da Silva, F. R., Schneider, N. B., Fernandes, S., Ancines, C., da Silva, J. 2012. Susceptibility to DNA damage in workers occupationally exposed to pesticides, to tannery chemicals and to coal dust during mining. *Genetics and Molecular Biology*, 35(4 suppl 1):1060–1068.

Labanda, J., Khaidar, M. S., Llorens, J. 2009. Feasibility study on the recovery of chromium (III) by polymer enhanced ultrafiltration. *Desalination*, 249(2):577–581.

Ladha, S. 2019. 6 vegan labels that create leather from unconventional resources.

Liknaw, G. T., Tekalign, K. G. 2017. Impacts of Tannery Effluent on Environments and Human Health. *Life Science and Technology*, 54:58–67.

Mahdi, H., Palmina, K., Gurshi, A., Covington, D. 2009. Potential of vegetable tanning materials and basic aluminium sulphate in Sudanese leather industry. *J. Eng. Sci. Technol*, 4(1):20–31.

Maina, P., Ollengo, M. A., Nthiga, E. W. 2019. Trends in leather processing: A Review. *International Journal of Scientific and Research Publications (IJSRP)*, 9(12):212–223.

Marsal, A., Cot, J., Boza, E. G., Celma, P. J., Manich, A. M. 1999. Oxidizing unhairing process with hair recovery. Part I. Experiments on the prior hair immunization. *J. Soc. Leather Technol. Chem*, pages 346–354.

Mohan, C. R., Saravanabhavan, S., Thanikaivelan, P., Rao, J. R., Nair, B. U. 2008. Development of formaldehyde-free leathers in the perspective of retanning: part II. Combination of formaldehyde-free retanning syntans. *Clean Technologies and Environmental Policy*, 10(3):287–294.

Rastogi, S., Pandey, A., Tripathi, S. 2008. Occupational health risks among the workers employed in leather tanneries at Kanpur. *Indian Journal of Occupational and Environmental Medicine*, 12(3):132–135.

Roy, S., Nagarchi, L., Das, I., Achuthananthan, J. M., Krishnamurthy, S. 2015. Cytotoxicity, Genotoxicity, and Phytotoxicity of Tannery Effluent Discharged into Palar River Basin, Tamil Nadu, India. *Journal of Toxicology*, 2015:1–9.

Shrivastava, H. Y., Nair, B. U. 2001. Chromium(III)-Mediated Structural Modification of Glycoprotein: Impact of the Ligand and the Oxidants. *Biochemical and Biophysical Research Communications*, 285(4):915–920.

Siyanbola, T. O., Ajanaku, K. O., James, O. O., Olugbuyiro, J. A. O., Adekoya, J. O. 2011. Physico-Chemical Characteristics of Industrial Effluents in Lagos State. *Glob. J. Pure Appl. Sci. Technol*, 1:49–54.

Thanikaivlaen, P., Rao, J. R., Nair, B. U. 2001. Development of leather processing method in narrow pH profile: Part 2. Standardisation of tanning process. *J. Soc. Leather Technol. Chem*, 85(3):106–115.

U. N. I. D. O. 2000. Regional programme for pollution control in the tanning industry in South-East Asia. United Nations Industrial Development Organization.

Valeika, V., Beleska, K., Sirvaityte, J. 2012. Alkali-free method of hide preparation for tanning. *Brazilian Journal of Chemical Engineering*, 29(2):315–323.