CURRENT SCENARIO OF MANAGEMENT AND UTILIZATION OF TANNERY SOLID WASTES CONCERNING THEIR USE IN LIVESTOCK FEED

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JUNE, 2021

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REGISTRATION NO.: 19-10083

A Thesis

Submitted to the Department of Animal Production & Management,

Faculty of Animal Science and Veterinary Medicine,

Sher-e-Bangla Agricultural University, Dhaka-1207,

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE (MS) IN ANIMAL SCIENCE

SEMESTER: JANUARY- JUNE, 2021

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CERTIFICATE

*This is to certify that the thesis entitled "**CURRENT SCENARIO OF MANAGEMENT AND UTILIZATION OF TANNERY SOLID WASTES CONCERNING THEIR USE IN LIVESTOCK FEED**" submitted to the Department of Animal Production & Management, Faculty of Animal Science and Veterinary Medicine, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS) in ANIMAL SCIENCE,*** *embodies the results of a piece of bona fide research work carried out by* ***ANKUR SARKER PROTIK,*** *bearing Registration No.* ***19-10083,*** *under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution. I further certify that any help or sources of information received during this study has duly been acknowledged.*

Dated:

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Supervisor

Dedicated To

My

Beloved Parents

LIST OF SYMBOLS & ABBREVIATIONS

Full Word	Abbreviation
Bangladesh Bureau of Statistics	BBS
Integrated Waste Management	IWM
Waste-To-Energy Technological Aspects	WTETA
Anaerobic Digestion	AD
Selective Non-Catalytic Reduction	SNCR
Common Effluent Treatment Plant	CEPT
Sludge Power Generation System	SPGS
Mega watt	MW
Department of Livestock Services	DLS
For example	e.g.,
And others	*et al.*
Etcetera	etc.
Food and Agriculture Organization	FAO
Feet	Ft
Gram	G
Hours	Hrs.
That is	i,e,
International Unit	IU
Journal	J.
Kilo calorie	K. cal.
Kilogram	Kg
Kilometer	Km
Milligram	Mg
Minute	Min
Metric Ton	MT
Sher-e-Bangla Agricultural University	SAU
Transglutaminase	TGase

Total Suspended Solids	TSS
United States Department of Agriculture	USDA
Organic Solid Waste	OSW
Volatile Oxygenated Carbons	VOC
Tannery Laborer Union	TLU
Bangladesh Agricultural University	BAU
Intergovernmental Panel on Climate Change	IPCC

ACKNOWLEDGEMENTS

All praises are due to the Almighty creator, the great, the gracious, merciful, and supreme ruler of the universe to complete the research work and thesis successfully for the degree of Master of Science (MS) in Animal Science.

The author expresses the deepest sense of gratitude, and heartfelt indebtedness to his reverend research supervisor, ***Dr. Md. Saiful Islam*** *Associate Professor, Department of Animal Production & Management, Sher-e-Bangla Agricultural University, Dhaka for his scholastic guidance, innovative suggestion, constant supervision and inspiration, valuable advice, and helpful criticism in carrying out the research work and preparation of this thesis.*

The author deems it a proud privilege to acknowledge his gratefulness and best regards to his respectable Assistant Professor ***Md. Enayet Kabir****, co-supervisor, Department of Animal Production and Management, Sher-e-Bangla Agricultural University, Dhaka for his valuable advice, suggestion, constructive criticism and factual comments in upgrading the research work and the documents, during the entire study period.*

The author would like to express his deepest respect and boundless gratitude to ***Falguni Dadok****, Assistant Professor and respected teachers of the Department of Animal Production and Management, Sher-e-Bangla Agricultural University, Dhaka for their valuable teaching, sympathetic co-operation, and inspirations throughout the course of this study Thanks are also extended to the butchers who co-operated well during the collection of data.*

I'd also like to convey my gratefulness to the ***Ministry of Science and Technology*** *for sponsoring the research, which enabled me to do it efficiently.*

I express my supreme gratitude to my beloved ***parents****,* ***sister****, and* ***brother*** *who-were constant source of inspiration and source to achieve this cherished goal and research work.*

The author likes to thank his entire batchmates and his friends to help him in his research work.

The Author

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CURRENT SCENARIO OF MANAGEMENT AND UTILIZATION OF TANNERY SOLID WASTES CONCERNING THEIR USE IN LIVESTOCK FEED

ABSTRACT

All sectors of our society generate waste: industry, agriculture, mining, transportation, construction etc. There is a belief existing in our society that tannery industry is the large contributor of chromium pollution. A field survey was conducted regarding the management and utilization of tannery solid waste in response to its use in livestock feed at Hemayetpur, Dhaka, Bangladesh, the mostly tannery dense area of the country. 20 different respondents (manager) from 20 different types of tanneries were interviewed to attain the exact picture of tannery waste management and utilization. According to the study, the generation rate of solid waste is 28.88% of total raw hides and skin. On the other hand, the percentage of generation of finished leather which was referred as the final product by the author was 22.72%. Among all the different types of tannery solid wastes chrome shaving was generated at 31.8% based on total amount of solid waste. After this the rate was 28.85% in case of Chrome splitting generation. The main type of solid waste which has raised concern for the use as poultry feed is Wet blue trimmings which was generated at 3.84%. The study also unearthed that 55% of the tanneries dispose their tannery solid by landfilling and 30% sell their solid waste for poultry feed preparation. Besides, the study showed that only 0.019% of the total poultry feed produced a year in this country could be consisted of tannery solid wastes which is trivial in number and negligible. It is the food for thought for the researchers whether the safety level of heavy metals is ensured in poultry feed and for the food safety for human consumption.

CHAPTER- 01

INTRODUCTION

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INTRODUCTION

Tannery industry plays an important role in the economy of Bangladesh due to its large potential for employment, growth, and export. At the same time, it poses serious environmental threats by discharging liquid effluents as well as solid wastes directly into surrounding low-lying areas without proper treatment. Solid wastes generated in leather industries pose great risks both to the environment and public health (Kanagaraj *et al.,* 2006). Industrial wastes are major sources of pollution in all environments which require onsite treatment before discharge into sewage system (Emongor *et al.,* 2005). In Bangladesh, there is a progressive increase in industrial wastes and due to rapid industrialization, such waste products have been causing severe contamination to the air, water and soils thus pollutes the environment (Islam *et al.,* 2000). The DoE (The Department of Environment) recently identified 900 large polluting industries, which have no treatment facilities for effluent and wastes (DoE, 2001). These heavily toxic effluents were discharging directly to adjacent soils and rivers (Khan, 2006). Among all the industrial wastes tannery effluents are ranked as the highest pollutants (Azom *et al.,* 2012). The industries expanded after the independence of Bangladesh in 1971 (Azom *et al.,* 2012). The Savar area in Dhaka was selected because of its history of widely known untreated discharge of chromium based tanning effluents (Gain, 2002). About 200 tons of solid waste is generated per day during peak season and 75 tons during off-peak season from the tanneries of Dhaka (Huq, 2015). Around 20,000 peoples are presently living in the slums in the study area, under extremely densely populated and unhygienic conditions (Zahir and Ahmeduzzaman, 2012). Dhaka city is situated mainly in the Buriganga river and secondly the Turag River. The rivers are very much polluted by the tannery wastes. During last decade, the livestock production and fish culture are seriously affected by the industrial waste specially tannery waste (BBS, 2019). For this reason, a survey work is to be done aiming at investigating actual picture of tannery waste disposal on water, soil, and agricultural productivity.

Livestock industry plays a vital role in our national economy as it mitigates the protein demand in human body as well as provides employment to the unemployed people. In Bangladesh, 51.87% of protein people consume in their daily life comes from livestock (WHO, 2019). Among this amount about 19.01% protein comes from the edible livestock by product (FAO, 1995). So, it is very important to take care of our livestock resource. To fulfill the increasing protein demand livestock should be properly taken care of. They need proper management practice, appropriate medication, and hygienic feed. A group of unscrupulous people are betaking cheap and unhealthy ways to fulfill the need ideal livestock feed and protein supplement.

There is a myth that a group of dishonest folks are preparing livestock feed specially the poultry feed by mixing tannery solid wastes and give them to the livestock. Some greedy livestock feed making industries are also involved with this heinous work. The businessmen are unconsciously causing a great predicament for the food chain. This is not only affecting the health of livestock but also on humane health which is a great concern. Recently, it was showed that the amount of chromium in poultry meat, egg is above the optimum level which is a food for thought. As we consume these poultry meat and egg the chromium and other hazardous metal components are in taken unconsciously by us. Unfortunately, chromium is one of the major components for causing cancer, gastrointestinal ulcer, meningitis, bronchitis, hepatitis-C, sexual complexities etc. (WHO, 2019). All the diseases are lethal but due to lack of knowledge and unconsciousness these are becoming common phenomenon in our daily life (Makrigiannis, 2009).

We are optimistic. So, we are expecting that the probability of the myth of mixing the chromium containing tannery solid waste were very low. If, though they use tannery waste for making the livestock feed, the level of chromium concentration is low and tolerable for human consumption. The study was carefully designed to achieve the controversial information mentioned above. It is a national concern, and we should be very careful about it. Therefore, this research was designed with a view to targeting some objectives.

The present study was undertaken with the following objectives

- **i.** To know the types of different solid tannery waste generated with their percentage of generation in different tanneries.
- **ii.** To detect the utilization of different types of tannery solid wastes found during the process of leather manufacturing.
- **iii.** To detect the level of inclusion of tannery wastes in livestock feed.

CHAPTER- 02

REVIEW OF LITERATURE

CHAPTER 02

REVIEW OF LITERATURE

2.1 Tanneries of Bangladesh

The leather making operation conducted in a tannery that consists of converting the raw skin or hide which is a highly putrescible material into leather, a stable material that can be used in the manufacture of a wide range of products. The whole process consists in a sequence of complex chemical and mechanical processes. Amongst them, the fundamental stage is tanning. During this process the leather acquires stability and its essential character. By following all the steps, the initial raw hides and skins evolved into a final product with specific properties: stability, temperature resistance, elasticity and permeability for perspiration and air, appearance, water resistance, etc.

Leather tanning industry is recognized as one of the major sectors to produce industrial pollution throughout the world and the processes of leather tanning are completely wet processes. Due to the existence of excessive extremely colorful compounds, NaCl and Na_2SO_4, different types of organic and inorganic compounds, hazardous metallic compounds with various biologically oxidizable tanning materials, and a huge quantity of decomposing suspended materials, tannery effluents hold severe (Kabir *et al.,* 2011) pollution loads (Akan *et al.,* 2007). As tanning processes are completed, a tiny proportion of the large amounts of chemicals are immersed by leather with the rest being discharged as wastewater that deteriorates the usual functioning of life of recipient aquatic bodies and ground surfaces (Cooman *et al.,* 2003). At present there are about 100 tanneries in Bangladesh in total, most of which are established in Hemayetpur, Savar, a heavily populated suburban area of Dhaka. This particular area is popularly known for its tannery industries, listed fifth in the list of top 10 polluted places of the world (Bernhardt & Gysi, 2013). During the off season the tanneries, located in Hemayetpur area, usually process 60,000 tons of raw hides and skins on an annual basis, which release nearly 95,000 litres effluents without treatment along with 115 tons of solid wastes daily into the open environment (Rusal *et al.*, 2006). Various industrial applications of chromium and its compounds, e.g. pigments, dyes, leather tanning, and refractory materials, result in extensive environmental pollution. Trivalent chromium is considered a significant nutritive trace element. On the contrary, soluble hexavalent chromium is severely toxic, with mutagenic and carcinogenic impacts on living organisms (Horitsu *et al.*, 1978). Traditional methods for removing trace metals from wastewater include chemical precipitation, chemical oxidation or reduction, ion exchange, filtration, electrochemical treatment, reverse osmosis, membrane technologies, and evaporation recovery (Ahluwalia & Goyal, 2007). It is very unfortunate that it is not possible for developing countries to achieve economic viability through these methods, a few of which might even produce huge amounts of waste as secondary pollution (Ahluwalia & Goyal, 2007).

2.2 Tannery Process

Tannery process is a process of converting animal skin and hides into non putrescible a stable commercial product called leather. The technologies used by all tanneries are not the same but there are some common operations in leather making activities. Before leather processing the cured skins and hide arriving the tannery are trimmed to remove unwanted materials and long shanks. Leather making processes are classified in to four main categories. The four main leather processing categories are Beam house operation, Tanning, post tanning and finishing (Covington, 2009).

2.3 Beam House Process

The beam house processes are the process where the skin and hide are soaked, washed, limed, unhaired, fleshed, delimed and their preparation for tanning. It includes soaking, liming, unhairing, fleshing, splitting, deliming, bating and pickling operations (IPPC, 2013). Soaking is a process of rehydrating the skin/hide to remove the salt used for the preservation, soluble protein, dirt, blood and dung. Sodium hydroxide and soda ash chemicals are used for quick and uniform soaking. Liming is the second chemical-based operation. Unhairing and liming are used to remove hair, epidermis residues, and some degrees of the inter fibrillary protein and to prepare the skin/hide for the removal of adhering flesh and fat by the fleshing process. The chemicals used for liming and unhairing process are sodium sulphide (Na_2S) and sodium hydrogen sulphide (NaHS) and lime (IPPC, 2013). After liming/ unhairing the excessive organic material (flesh, fat and connective tissue attached) which must be attached prior to further processing are removed by mechanical process called fleshing process by using fleshing machine. After fleshing process splitting is applied to produce hides of set thickness. Splitting is applied to a grain layer if the hide is thick enough. Splitting can also be done at the tanning condition. Splitting is carried out by splitting machine fitted with a band knife (Covington, 2009). The limed pelt is adjusted to lower pH by using some mild acids and salts such as ammonium chloride, sulphate or boric acid; this process is known as delimming. During delimming process the skin/hide become flaccid and is treated with proteolytic bating enzymes to clean the grain and make the pelt smooth and silky. The removal of hair roots and pigments are achieved by bating process. The bated pelts are finally treated with sulphuric acid, formic acid, and salt to obtain the desired pH for the optimal penetration of the tanning agent and used for preservation at pickled stage.

2.4 Tanning Process

The second operation in leather processing is the tanning process. Tanning is applied to the leather by using two different methods called vegetable tanning and chrome tanning (IULTCS, 2013). Chrome tanning by using chromium sulphate chemical which is very popular. Nearly 90% of all leather produced is tanned using chromium salts (Nashy *et al*, 2011). Vegetable tanning is a tanning process that uses natural tannin materials, available in liquid or powder form which are obtained from different part of plants including woods, barks, fruits, fruit pods and leaves (Covington, 2009). These tanning materials blend with the collagenous protein to convert the hide/skin into non putrescible material called leather.

2.5 Post Tanning

After tanning process post tanning is applied to the leather which involves neutralization and washing, followed by retanning, dyeing and fat liquoring. Post tanning also called wet finishing. To add certain properties such as water repellence, gas permeability, flame retarding, abrasion and antielectrostatics properties to leather specialized operations also be carried out at this stage. The different processes that have applied at this stage like retanning, dyeing and fat liquoring chemicals are allowed to penetrate and distribute with the collagen fibers before the pH is lowered. The astringency causes the chemicals to be fixed to the tanned materials. Finally, binding of chemicals is encouraged by drying process. Batches of leather are toggle dried on frame by using heated tunnel for four to six hours or vacuum dried separately. Drying is followed by buffing, conditioning and staking. The product got after post tanning process are crust leather, ready for finishing which is resistant to microbial attack and have desired leathering property of finished leather (Ozgunay *et al.,* 2007).

2.6 Finished Leather

The objective of finishing is to enhance the appearance of leather and to provide the performance characteristics expected of finished with respect to color, gloss, handle, flex, adhesion, rub fastness as well as other properties as required as the end use including extensibility, light and perspiration fastness, water vapor permeability and water resistance. Finishing is also required to hide defects and contributed to the leather beauty, property and to provide fashion effects.

Finally, after the leather manufacturing process is completed the product sent to product manufacturers to be turned to shoes, clothing or upholstery (Covington, 2009).

2.7 Types of waste generated in leather processing

Three different categories of waste types are generated during tanning process such as solid, liquid and gaseous. Only 20-25% of the raw hide is converted into finished leather, about 75-80% of the raw hide converted

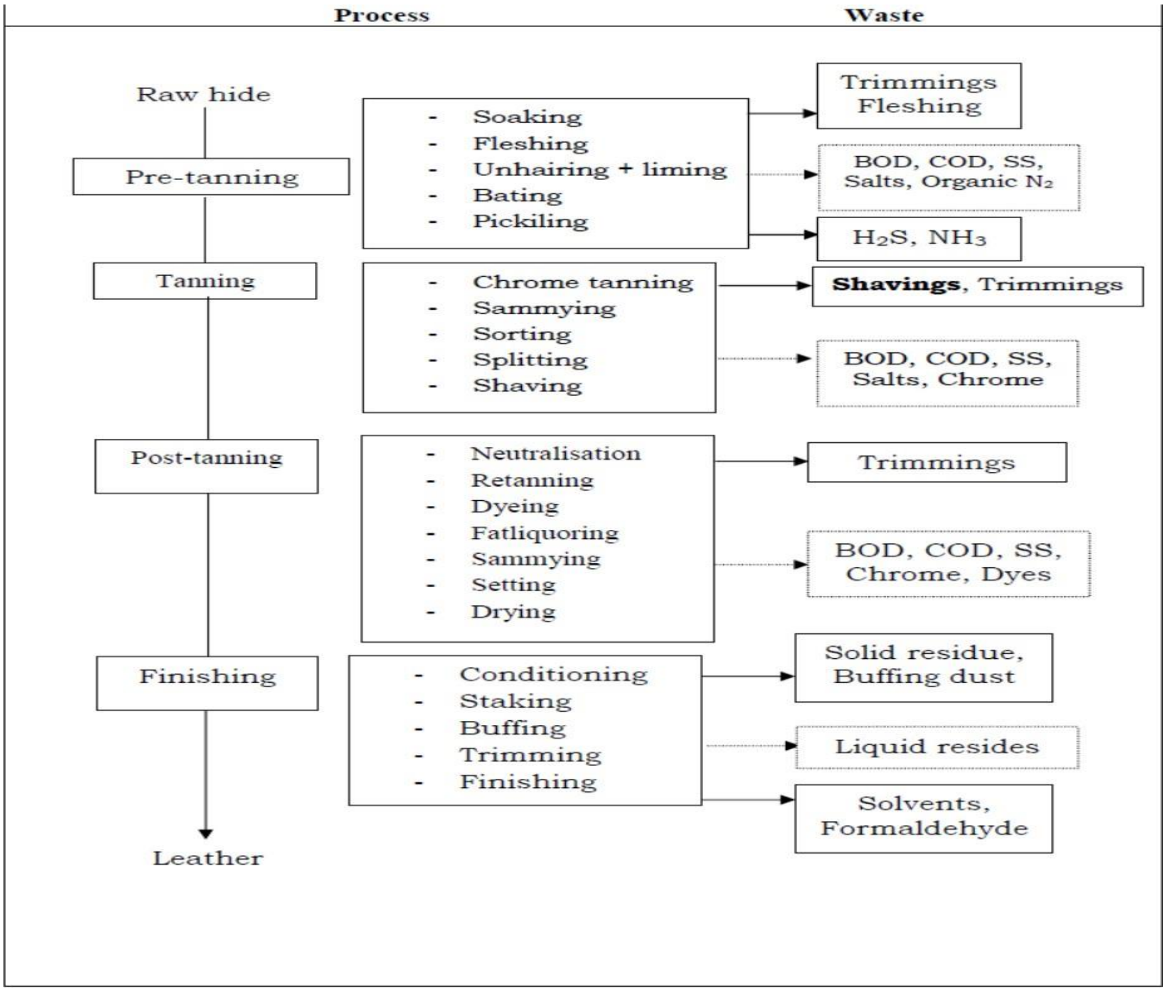

Figure 1: Leather processing flow diagram and Types of solid wastes generated (Amal, 2014)

into solid and liquid waste (Kanagaraj *et al,* 2006). Different types of chemicals have been used in leather processing (Huq *et al,* 1998). The chemicals that have used in leather processing have an impact on the environment. High amount of water is used for leather processing. Considerable parts of the chemicals are not absorbed in the production process, and they will discharge to the environments together with the water used in leather processing (Suresh *et al,* 2001). The major pollution load comes from beam house operation. The organic pollution load in terms of BOD comes from beam house operation due to degradation of hides/skins and hair. On the other hand, the chemicals and dusts released to air due to dry finishing. Different types of solid wastes are generated at different stages of leather processing. The major solid wastes consist of raw trimming, fleshing, splitting, chrome shaving, crust trimming, finished trimming and wastewater treatment sludge (Abajidah, 2012). The data from FAO revealed that approximately 8.5 million tons of solid waste is generated during the production of 11 million tons of raw hide processed in the world (Amal, 2014).

2.7.1 Solid wastes generated in tannery process

Different types of solid wastes are generated at different stages of leather processing. These solid wastes classified as untanned solid waste (before tanning process) and chromium containing solid waste (after tanning process) based on the tannery process. The untanned solid wastes are trimmings, fleshing and pelt splitting. Wastes from tanned leather which contains chromium sulphate chemical is chrome shaving waste, wet blue trimming, buffing dust, crust trimming and finished trimming (Harshita *et al.,* 2015).

Table-1: Tannery solid waste generation (Kanagaraj *et al.,* 2006)

Type of waste	Amount (%)
Fleshing	50-60
Chrome shaving, chrome splits and buffing dust	35-40
Skin trimming	5-7
Hair	2-5

2.7.2 Untanned solid waste

i. Fleshing and Trimming Waste: Fleshing are a solid waste generated during a mechanical process called fleshing that aims to remove the flesh or fats from the inner part of the hide or skin. Trimming is cutting unwanted parts of processed hides/skin just after fleshing operation is completed (Abajidah, 2012). The amount of fleshing and fleshed trimming waste generates 50-60% of the total 10 tannery solid waste (Knagaraj *et al.,* 2006).

ii. Splitting Waste: Hides at the pelt stage which have already fleshed and trimmed are usually subjected to mechanical operation called splitting to remove some unwanted layers of the hides. Splitting operation can also be applied at wet blue stage which is called wet blue splitting. Splitting operation is applied when it is required to divide the hide into two layers. Most of the time the split is utilized, and this way make the split not considered as waste. The splitting that has been considered as a waste is the splitting at the liming stage which is also called pelt splitting (Abajidah, 2012).

2.7.3 Chromium containing solid wastes

All the tannery solid waste are not chromium containing, only the solid wastes that generates after tanning processes is chromium containing solid waste because of these chromium sulfate salt (Harshita *et al.,* 2015). The solid wastes that contain chromium in tanning process are wet blue shaving (chrome shaving), wet blue trimming, buffing dusts, finished leather trimmings and wastewater treatment sludge:

i. **Wet blue (chrome) shaving:** It is one of the tannery solid wastes that generate after tanning process. The chrome shaving waste is generated during the thickness adjustment process of wet blue leather based on the required thickness. It mainly contains the scraps from the reverse side of wet blue. This solid waste consists of wet blue leather cuttings originated from un-usable parts of wet blue leather and rags created during shaving operation (Sharphouse, 1983). The chromium content present on wet blue stage of chrome shaving and wet blue trimming are chromium trivalent (Fatima *et al.,* 2012).

Table 2 Physical and chemical characteristics of chrome shaving waste (Harshita *et al.,* 2015).

S/no	Parameters	Unit	Amount
1	Moisture content	%	35.1
2	Cr_2O_3	%	3.12
3	Inorganic ash	%	5.21
4	Nitrogen	%	16.4
5	Oil and fat	%	1.5
6	Ph	-	3.4

ii. **Crust trimming:** After the wet stage tannery process is followed by the dry stage tannery. In hide processing, wet vacuum drying is applied at crust stage just after setting out operation to reduce the moisture content of the crust leather. Before this drying process the crust leather must be trimmed to avoid some unwanted parts which are considered as crust trimmings waste. The crust leathers are buffed on the flesh side and sometimes on the grain side. Buffing is done on the flesh side to produce specialty leathers such as nubuck generates leather looking soft and light which is called buffing dust (Fathima *et al.,* 2012).

iii. **Finished leather trimmings: -**is solid waste that generates during trimming of finished leather to remove some unwanted parts of the leather, to maintain the shape of finished leather, aesthetic value and for easy measurement of the leather (Fathima *et al.,* 2012).

iv. **Wastewater treatment sludge:** Sludge is produced during wastewater treatment process. Wastewater contains chromium because the chromium sulphate chemical used during tanning and retaining will not completely fix to the leather. More than 40% of the chrome sulphate used in leather making process joins the wastewater treatment. After the wastewater is treated the wastewater contains high amount of sludge. The sludge contains chromium that comes from tanning and retanning process (Jones, 1979).

2.8 Particulates

Most particulate emissions arise from dry processes, such as milling, buffing and spray finishing operations. These emissions can be abated by using filters, down flow booths, chemical dosing equipment and/or dust free chemicals (dust free bates, liquid dyes and liquid re-tanning agents) (Harshita *et al.,* 2015).

2.9 Organic solvents

The principal source of organic solvent emissions in tanneries is from finishing operations. Abatement techniques, such as scrubber units, are used and are effective in capturing a large part of the organic solvent emissions. Tanneries employing solvent-based degreasing processes (mainly sheepskins) have also organic solvent emissions requiring special abatement (Harshita *et al.,* 2015).

2.10 Odor

Odor emissions from raw hides can be controlled by ensuring correct curing procedures, improving storage conditions, and ensuring adequate stock rotation (Jones, 1979). Cool and dry conditions should be maintained in storage facilities and doors should remain closed. Odors may arise from degradation of organic matter or from chemical substances that are also toxic. Odors can arise from storing hides and skins, from beamhouse operations (sulphides, ammonium), from ammonia releases in dyeing, from VOC released in finishing processes and from the wastewater treatment. Odor is one of the main reasons for complaints from neighbors. Sulphur dioxide emissions might occur during bleaching.

2.11 Impact of tannery solid waste on health and the environment

According to Huq (1998) different types of chemicals have been used during leather processing including sodium sulphide and basic chromium sulphate for tanning process. It has been reported that only about 20% of the large number of chemicals used in the leather processing is absorbed by the leather, the rest is released in the form of waste. Wastes are characterized by their source, generation rate and by the type produced, improper handling of solid waste have potential risk to health and the environment. According to Mu *et al.*, (2003) about 25% of tannery solid waste end up with chromium containing solid waste which are more dangerous than other tannery solid wastes. Tanneries in Bangladesh have been disposed their solid waste with other municipal solid wastes. Mixing up of industrial waste with municipal solid waste has potential effect on health (Alam and Ahmade, 2013). Tannery solid waste has chromium in the form of chromium trivalent, the main environmental impact of tannery solid waste is the oxidation of chromium trivalent into chromium six which is highly toxic and has carcinogenic and mutagenic effect. Chromium containing solid waste percolates to the ground and cause ground water pollution and soil contamination. Water pollution affects aquatic animals which are common sources of food and contamination of soil poses health effect through food chain also poses a health hazard through inhalation of toxic dust which can be inhaled by both people and livestock (Harris and Cartor, 2011).

2.12 Solid Waste Management

Solid waste management is the collection, transportation, storage, recycling or disposal of solid waste, or the subsequent use of a disposal site that is no longer operational. It is a complex process because it involves many technologies and disciplines. These include technologies associated with the generation (including source reduction), on-site handling and storage, collection, transfer and transportation, processing, and disposal of solid wastes. All these processes must be carried out within existing legal, social, and environmental guidelines that protect the public health and the environment and are aesthetically and economically acceptable (Harris and Cartor, 2011). The objective of solid waste management is to reduce the quantity of solid waste disposed off on land by recovery of materials and energy from solid waste.

2.12.1 Integrated Waste Management

Integrated waste management (IWM) can be defined as the selection and application of suitable techniques, technologies, and management programs to achieve specific waste management objectives and goals.

To be responsive to public attitudes, the disciplines that must be considered in integrated solid waste management include administrative, financial, legal, architectural, planning, environmental, and engineering functions. For a successful integrated solid waste management plan, it is necessary that all these disciplines communicate and interact with each other in a positive interdisciplinary relationship. The four basic waste management options (strategies) for IWM are: (1) source reduction, (2) recycling and composting, (3) combustion (waste-to-energy facilities), and (4) landfills. Figure 2 below shows waste management hierarchy (Harris and Cartor, 2011).

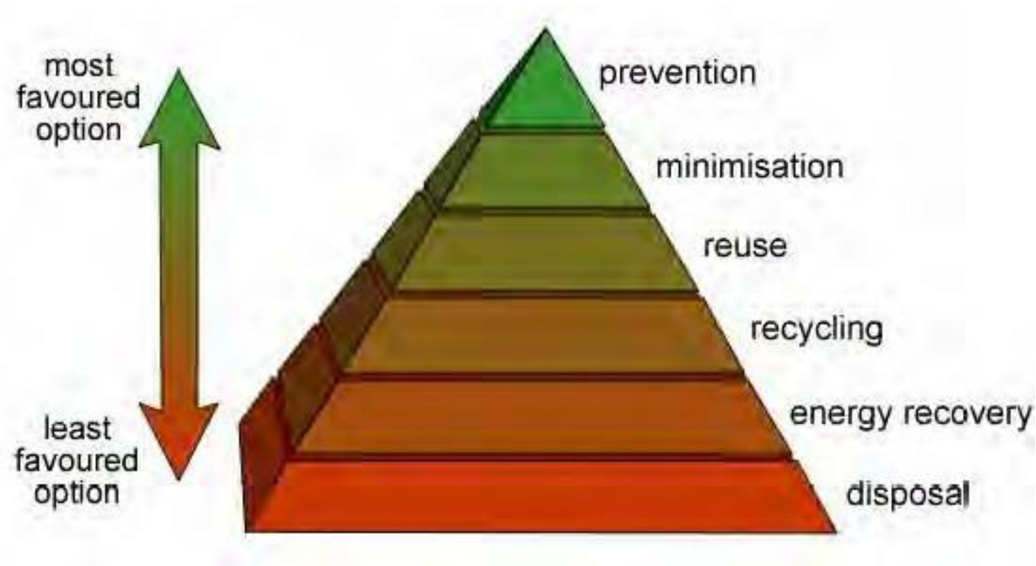

Figure 2: Waste Management Hierarchy (Harris and Cartor, 2011)

In this literature survey the energy recovery and reuse methods of waste management strategies are reviewed as below so that they can be applied to manage tannery solid wastes.

2.12.2 Waste-To-Energy (WTE) Technological Aspects

Waste to energy technology offers a way to manage solid municipal waste while at the same time generating the energy needed to stop the dependence on foreign oil and other fossil fuels (Harris and Cartor, 2011). There are several different processes and technologies that can be used to change waste into energy. Energy can be recovered from the organic fraction of waste (biodegradable as well as non-biodegradable) basically through two methods (Thermo-chemical Conversion and Bio-chemical conversion).

2.12.3 Incineration

Incineration is the process of direct burning of wastes in the presence of excess air (oxygen) at temperatures of about 800 ◦C and above, liberating heat energy, inert gases and ash (Jones, 1979). It is a waste treatment process that involves the combustion of organic substances contained in waste materials. The ash is mostly formed by the inorganic constituents of the waste and may take the form of solid lumps or particulates carried by the flue gas. The flue gases must be cleaned of gaseous and particulate pollutants before they are dispersed into the atmosphere. Net energy yield depends upon the density and composition of the waste; relative percentage of moisture and inert materials, which add to the heat loss, ignition temperature, size and shape of the constituents, design of the combustion system (fixed bed/ fluidised bed), etc. In practice, about 65 to 80 % of the energy content of the organic matter can be recovered as heat energy, which can be utilised either for direct thermal applications or for producing power via steam turbine generators (with typical conversion efficiency of about 30%) (Jones, 1979).

The combustion temperatures of conventional incinerators fuelled only by wastes are about 760◦C in the furnace and in excess of 870◦C in the secondary combustion chamber (Harshita *et al.,* 2015). These 20 temperatures are needed to avoid odour from incomplete combustion but are insufficient to burn or even melt glass. To avoid the deficiencies of conventional incinerators, some modern incinerators utilise higher temperatures of up to 16500C using supplementary fuel (Harshita *et al.,* 2015). These reduce waste volume by 97% and convert metal and glass to ash. Ash is the weight of residue after combustion in an open crucible. By resource recovery facilities, several solid residuals are produced including bottom ash and fly ash. Bottom ash is the unburned and non-burnable portion. It can contain considerable amounts of metals and glass as well as unburned organics. Fly ash is composed of the micron and submicron particulates that have been collected by the air pollution control system, it must be handled very carefully to avoid fugitive dust emissions, which may be harmful to workers and the surrounding environment. Wastes burned solely for volume reduction may not need any auxiliary fuel except for start- up. When the objective is steam production, supplementary fuel may have to be used with the pulverized refuse, because of the variable energy content of the waste or in the event that the quantity of waste available is insufficient. While incineration is extensively used as an important method of waste disposal, it is associated with some polluting discharges which are of environmental concern, although in varying degrees of severity. These can fortunately be effectively controlled by installing suitable pollution control devices and by suitable furnace construction and control of the combustion process. One of the most attractive features of the incineration process is that it can be used to reduce the original volume of combustibles by 80 to 95 %. Air pollution control remains a major problem in the implementation of incineration of solid waste disposal. In the United States, the cost of best available technology for the incineration facility may be as high as 35 % of the project cost. The cost of control equipment will, however, depend upon the air pollution regulations existing in each lesser developing country. Waste incineration may be advantageous when a landfill cannot be sited because of a lack of suitable sites or long haulage distances, which result in high costs. Incineration plants can be located close to the center of gravity of waste generation, thus reducing the cost of waste transportation. Incineration provides the best way to eliminate methane gas emissions from waste management processes. Furthermore, energy from waste projects provides a substitute for fossil fuel combustion.

2.12.4 Applicability of Incineration

Incineration projects are immediately applicable only if the following overall criteria are fulfilled.

- ❖ A mature and well-functioning waste management system has been in place for several years.
- ❖ Solid waste is disposed of at controlled and well operated landfills.
- ❖ The supply of combustible waste will be stable and amount to at least 50,000 metric tons/year (Haque, 2017).
- ❖ The community is willing to absorb the increased treatment cost through management charges, tipping fees, and tax-based subsidies.
- ❖ Skilled staff can be recruited and maintained.

2.12.5 Bio-Chemical Conversion

Bio-chemical conversion process is based on enzymatic decomposition of organic matter by microbial action to produce methane gas or alcohol. The bio-chemical conversion processes, on the other hand, are preferred for wastes having high percentage of organic bio-degradable matter and high level of moisture/water content, which aids microbial activity. The main 23 technological options under this category are Anaerobic Digestion (Bio-methanation) and fermentation process which can take biomass and create ethanol, using cellulosic waste or organic material. In the fermentation process, the sugar in the waste is changed to carbon dioxide and alcohol. Normally fermentation occurs with no air present. In addition to the above two methods to convert solid waste to energy, a chemical process called esterification can also be used to produce biodiesel from the solid wastes (Harshita *et al.*, 2015).

2.12.6 Anaerobic Digestion (Bio-Methanation)

In anaerobic digestion (AD) process the organic fraction of waste is segregated and fed to a closed container (biogas digester) where, under anaerobic conditions, the organic wastes undergo biodegradation producing methane-rich biogas and effluent/sludge. The biogas production ranges from 50- 150 m3 /tons of wastes, depending upon the composition of waste (McMillan and George, 2015). The biogas can be utilized either for cooking/heating applications, or through dual fuel or gas engines or gas/steam turbines for generating motive power or electricity. The sludge from anaerobic digestion, after stabilization, can be used as a soil conditioner, or even sold as manure depending upon its composition, which is determined mainly by the composition of the input waste.

Fundamentally, the anaerobic digestion process can be divided into three stages with three distinct physiological groups of micro-organisms:

Stage I: It involves the fermentative bacteria, which include anaerobic and facultative micro-organisms. Complex organic materials, carbohydrates, proteins and lipids are hydrolyzed and fermented into fatty acids, alcohol, carbon dioxide, hydrogen, ammonia and sulphides (McMillan and George, 2015).

Stage II: In this stage the acetogenic bacteria consume these primary products and produce hydrogen, carbon dioxide and acetic acid.

2.12.7 Composting

Composting is a controlled biological process that uses natural aerobic processes to increase the rate of biological decomposition of organic materials. It is carried out by successive microbial populations that break down organic materials into carbon dioxide, water, minerals and stabilized organic matter. Carbon dioxide and water are released into the atmosphere, while minerals and organic matter are converted into a potentially reusable soil-like material called compost. The loss of water and carbon dioxide typically reduces the volume of remaining material by 25–60% (Jones, 1979). Compost can be used as a soil amendment in a variety of agricultural, horticultural or landscaping applications, as long as appropriate measures are taken to eliminate contaminants and impurities from the finished product. The release of organic acids may decrease the pH and production of ammonia from nitrogenous compounds may raise the pH. At higher pH levels, more ammonia gas is generated and may be lost to the atmosphere. A pH value between 6.5 and 8.5 is optimal for compost microorganisms. As bacteria and fungi digest organic matter, they release organic acids. The standard physicochemical parameters required for composting is give in Table as below.

Table3: Standard Values of Physicochemical Parameters for Composting (Harris and Cartor, 2011).

S. N	Physicochemical parameters	Standard values suitable for composting
1	Ph	5.5 - 8.0
2	Moisture (% dry basis)	< 50
3	Organic matter (% dry basis)	> 20
4	Nitrogen (% dry basis)	> 0.6
5	Carbon (% dry basis)	30 - 40
6	C:N ratio (total dry basis)	25 - 50:1

The important physical parameters requiring consideration include size of constituents, density, and moisture content. Smaller size of the constituents' aids in faster decomposition of the waste. Wastes of high density reflect a high proportion of biodegradable organic matter and moisture. Low density wastes, on the other hand, indicate a high proportion of paper, plastics and other combustibles. Moisture content indicates water contents of the waste, which is the percentage of the wet weight material to dry material. Microorganisms can only use organic molecules if they are dissolved in water, so the compost pile should have a moisture content of 60-80% of water holding capacity. If the moisture content falls below 40% of water holding capacity the microbial activity will slow down or become dormant. If the moisture content exceeds 80% of water holding capacity, aeration is hindered, nutrients are leached out, decomposition slows, and the odor from anaerobic decomposition is emitted (Jones, 1979).

High moisture content causes biodegradable waste fractions to decompose more rapidly than in dry conditions.

2.13 Environmental, Social and Political Aspects of Waste to Energy Technologies

Waste-to-energy is renewable because its fuel source, garbage, is sustainable and non- depletable. Waste-to-energy facilities produce electricity with “less environmental impact than almost any other source of electricity,” according to (The U.S. Environmental Protection Agency, 2018). Waste-to-energy facilities today meet some of the most stringent environmental standards and employ the most advanced emissions control equipment. In addition to combustion controls, waste-to-energy facilities employ sophisticated air quality control equipment as stated below.

A “Selective Non-Catalytic Reduction” or “SNCR” converts nitrogen oxides – a cause of urban smog – to harmless nitrogen by spraying ammonia or urea into the hot furnace (IPCC Global Report, 2013).

A “scrubber” sprays a mixture of lime and water into the hot exhaust gases. The lime neutralizes acid gases, just as a gardener uses lime to neutralize acidic soil. Scrubbing also can improve the capture of heavy metals such as mercury in the exhaust gases.

A “carbon Injection” system blows powdered carbon into the exhaust gas to absorb mercury. Carbon injection also reduces emissions of trace organics such as dioxins (IPCC, 2000). A “bag house” works like a giant vacuum cleaner with hundreds of fabric filter bags that clean the air of soot, smoke, and metals. As a result of the controls employed at these plants, dramatic reductions in emissions have been achieved. When a ton of trash is delivered to a waste-to-energy plant, several things happen: the energy content of the waste is retrieved, metals are recovered and recycled, and electricity is generated. For every megawatt of electricity generated through the combustion of solid waste, a megawatt of electricity from conventional, e.g., coal or oil-fired, power plants are avoided, creating a net savings of emissions of greenhouse gases, i.e., carbon dioxide (IPCC Report, 2013). A modern municipal waste-to-energy facility separates ferrous and/or nonferrous metals for recycling. This is more energy efficient than mining virgin materials to produce new metals such as steel. As a result, there is a significant energy savings and additional avoidance of greenhouse gas emissions. When a ton of solid waste is delivered to a waste-to-energy facility, the methane that would have been generated if it were sent to a landfill is avoided. While some of this methane could be collected and used to generate electricity, some would not be captured and would be emitted to the atmosphere. Methane is a potent greenhouse gas twenty-three times more potent than carbon dioxide (WEF, 2012) and (UNFCCC, 2012). Modern waste-to-energy facilities are subject to comprehensive health risk assessments that repeatedly show that waste-to-energy is safe and effective. Waste-to-energy facilities destroy pathogens, organics, and other disease-bearing material in trash. Trash coming into a waste to-energy facility is handled in enclosed tipping halls that are maintained under negative pressure to pull air directly into the boilers and destroy any odors.

2.14 Cost Effectiveness of Waste-To-Energy Technologies

There are many waste-to-energy technologies, but how many of these are cost effective? As stated above, the waste to energy technology includes incineration, gasification/pyrolysis, anaerobic digestion, fermentation, and esterification. Some of these technologies are very cost effective, while others may not be as much so. Some use thermal processing, others use chemical processing, and still others use biochemical processing.

Gasification and pyrolysis are some of the most effective wastes to energy technologies available currently (WEF, 2012). These two technologies can be performed together to maximize the cost effectiveness. Pyrolysis needs an outside heat source, and this is supplied by the gasification process, making both processes together self-sustaining. This reduces the cost of the process, making them both more cost effective. The cost effectiveness of esterification will depend on the feedstock being used, and all the other relevant factors such as transportation distance, amount of oil present in the feedstock, and others.

All waste to energy technology can be developed to be cost effective. This is crucial because most of the people will not pay a lot more just to use a green energy source. This means that any methods used must be cost effective or it will not succeed. All the factors involved need to be examined and it is important to set up any waste to energy plant in a location that meets all the needs. The waste must be available, although this would not be a problem in any area usually, plus the labor, resources, and infrastructure must be present as well. Otherwise, the cost of creating the energy from waste is too high and will not be used. Using cost cutting measures and placing the waste to energy plant in the right location, can bring down the energy cost significantly. Waste to energy technology can be extremely cost effective and efficient when implemented correctly.

2.15 Solid Tannery Wastes Used in Livestock Feed

In a bid to save the river Buriganga from severe pollution, tanneries were relocated to Savar from Hazaribagh amidst huge public outcry and growing protests from the green campaigners. The consequences of such relocation had been ironic as the waste generated in Savar Tannery Estate has been contaminating the Dhaleshwari and polluting Savar and adjacent areas since its inception. What is more alarming is that tannery waste collected from the relocated Savar Tannery Estate is being used for producing poultry and fish-feed (Islam *et al.*, 2000). Moreover, the production of poultry and fish feed from tannery waste contaminated with toxic chemicals such as chromium and cadmium is causing serious air pollution in Savar's Bhakurta and adjacent areas (Zahir and Ahmeduzzaman, 2012). Hence, immediate steps should be taken to stop use of poisonous tannery waste in poultry feed and in this regard relevant authorities must pull down all feed firms that use toxic tannery wastes as the raw material. The opinion that consumption of tannery waste through eating fish and poultry might lead to liver and kidney diseases. People eating such fish, chicken or eggs may be subjected to cancer or liver and kidney-related diseases (WHO, 2019). If chromium and lead remain in the chicken and fish feed, it can be transferred to people consuming these items. Poultry chicken and fish are the best resource of protein for the masses and is consumed by people of every class. But because of using tannery waste in poultry feed harmful chemicals are making way into the masses through such food and bringing about public health crisis. Therefore, necessary steps should be taken to compel the poultry traders to refrain from using tannery waste as animal feed that may cause public health crisis.

CHAPTER- 03

MATERIALS & METHODS

CHAPTER 03

MATERIALS & METHODS

The study was conducted under the Dept. of Animal Production & Management using the laboratory facilities provided by the mentioned grand Department of Sher-e-Bangla Agricultural University, Dhaka 1207. In this research, the data were collected from respondents (manager/ project manager) of different tannery at Hemayetpur, Savar, Dhaka by face-to-face interview using a structured questionnaire. The detail procedure is given below:

3.1 Selection of Study Site

The experiment was carried out at some randomly selected tanneries at Hemayetpur, Savar, Dhaka (Fig:3). Almost all the tanneries of our country are situated at Hemayetpur, Savar, Dhaka. So, to attain all the objectives of this study it was the best location for this operation.

3.2 Survey Design

The study was based on field survey where primary data were collected from different tanneries at Hemayetpur, Savar, Dhaka. A total of 20 respondents were selected adopting PPRS (Proportional Probability Random Sampling) techniques of Lahiri (Snedecor and Cochrane, 1989). The design of the survey for the present study involved some necessary steps which were outlined in this section. Primary data were collected considering the nature of the study and its objectives.

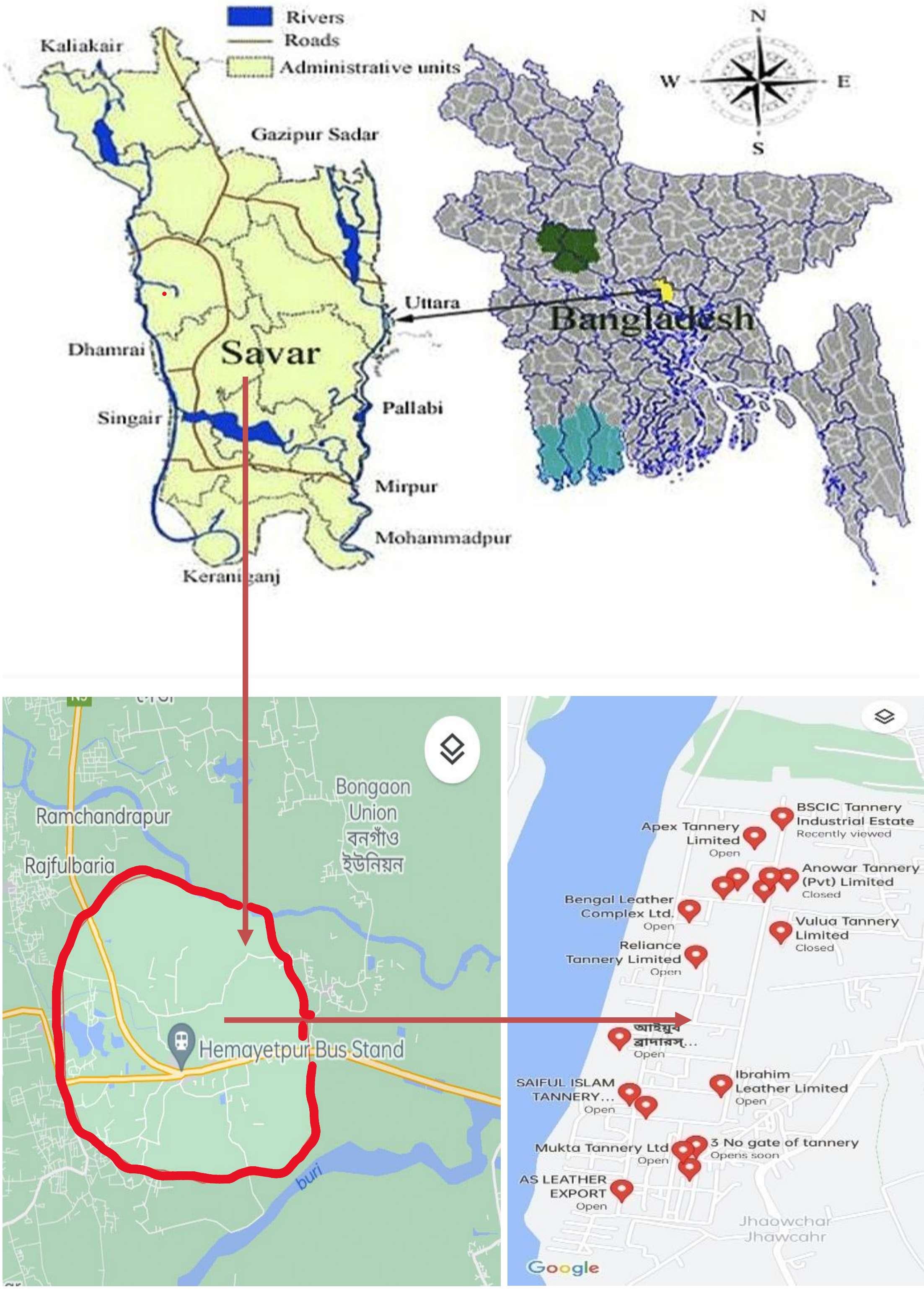

Fig- 3: Map of the study area of this survey (google map)

3.3 Study Works for Survey

The study works were selected to target the tanneries, solid wastes, its management practices, and utilization. All the 20 study tanneries were classified into 3 types – small, medium, and large according to their raw hides and skin processing capacities. The capacity of raw hides and skin processing of small, medium, and large are less than 800 kg/ day, (800-1100) kg/day and more than 1100 kg/day respectively. From this study the percentage of waste generation based on total raw material was calculated. It was found that the percentage of different types of tannery solid wastes generation varies from one tannery to another. The percentage of final product (finished leather) based on total amount of raw materials was to determine. After that it was clarified the mode or process of waste disposal and if there was any use of the wastes by observation, interview, and investigation.

Finally, the survey focused on the challenges or problems that are faced by the tannery authorities for the betterment of this industry in our country.

3.4 Sample Size of Survey

This experiment is related to the field survey at Hemayetpur, Savar, Dhaka and data was collected from the direct interview with tannery manager or project manager. For this experiment **20** interviews were taken from **20** different tanneries. After each interview inspection and general observation was done. In some specific cases like to know if the tannery wastes were used as animal feed, investigation was performed at the local market and some tannery personnel. These **20** respondents (manager) of 20 tanneries were selected randomly from the study area.

3.5 Questionnaire Development

For this survey, at first a questionnaire was developed for tannery respondent (manager) interview. An interview schedule was carefully prepared that contained both open and closed for structured questions keeping in mind the objectives of the study. These questions were set chronologically so that the respondents can provide data in a systematic manner. Then appropriate tanneries were randomly selected from the study area.

3.6 Pre-survey Trial

After developing questionnaire, a pre-survey trial was performed with some tannery authorities and personnel. The draft interview schedule was pre-tested and necessary correction, additions and rearrangements were made before being used it for final data collection. Then visit the tannery industrial area carefully to ensure the questionnaire is appropriate for target data collection properly.

3.7 Data Collection

The experiment was carried out by collecting data using questionnaires, direct observation, investigation, and face-to-face interview during the time period from March to October, 2020. Desired rapport was established to each respondent, so any respondent failing to understand any question, care was taken by the researcher to explain the situation.

3.8 Variables and Its Measurements

The selection of variables and their measurements constitute an important task in research work. Some characteristics of tannery waste management, disposal, and utilization were selected by the researcher for this study. The characteristics are as follows: types of raw material (hides, skin or both), condition of raw material received (cured, non-cured, cured as well as not cured), raw material sources (from Dhaka only, all across

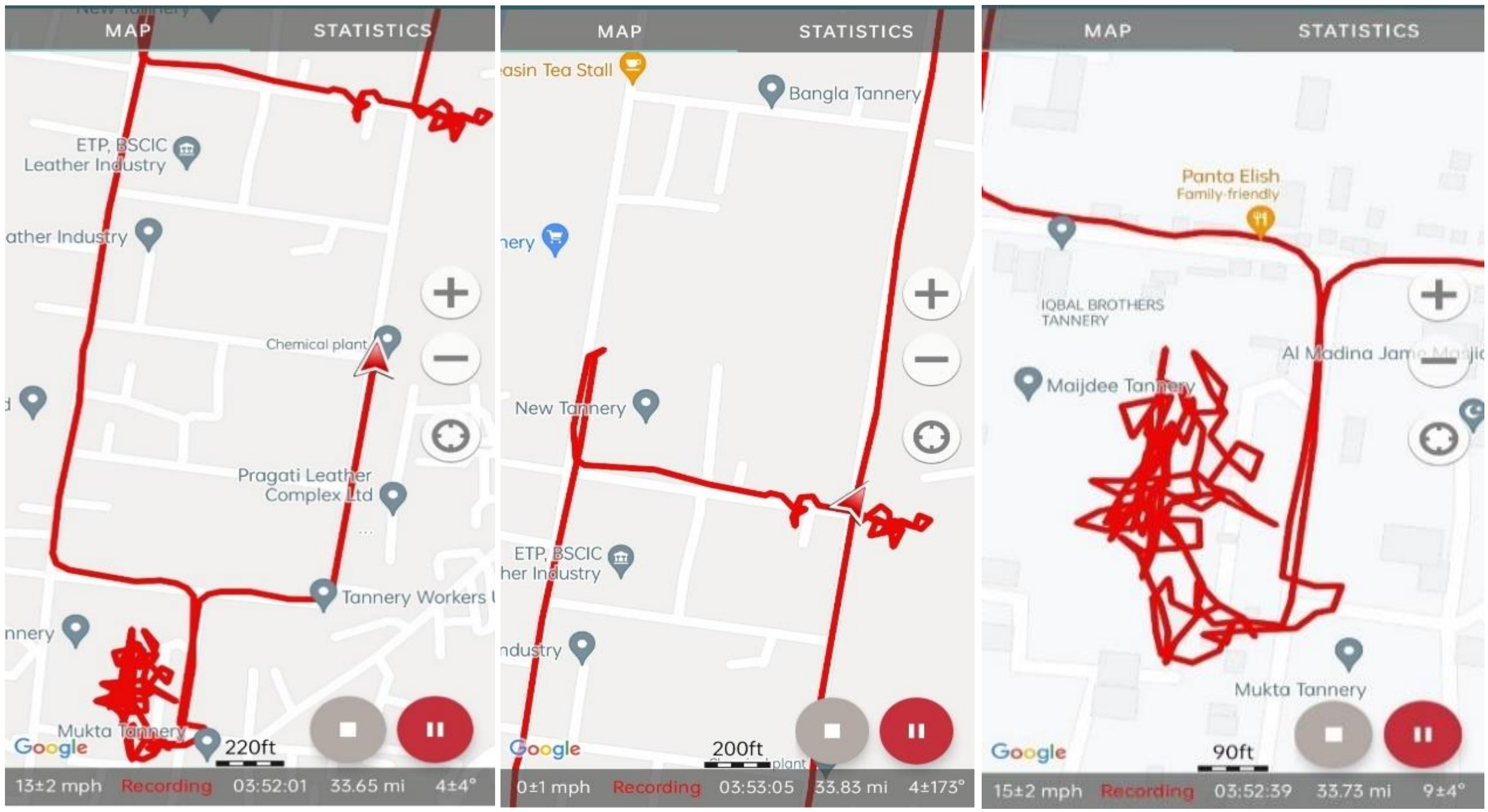

Fig12: Screenshots on mobile phone while moving throughout the Tannery industrial area for the survey (Geotracker software).

the country), raw material receiving channels (directly from owner, from middlemen, both), modern facility for solid waste storage, recycling device, different waste disposal mode, protocol the tannery maintain and challenges the tannery authority faces for the betterment of the industry.

3.9 Lab Analysis

The collected tannery waste samples which were collected directly from the study tanneries were examined physically (color, odor, texture, coarseness etc.).

3.9.1 Dry Matter (DM)

Dry matter was determined in the collected tannery waste samples according to the methods of AOAC (1984) and Makkar (2000). Dry matter was estimated in separate tannery waste samples which was weighed and dried under sunlight till the constant weight was attained.

3.9.2 Nitrogen

CP percentage (Nitrogen) of all the samples was determined by Kjeldahl digestion of 1 g sample with concentrated sulfuric acid and 1 g mixed catalyst, distilled into 2 percent boric acid solution and titrated with 0.1 N HCl.

3.10 Data Analysis

The survey on different qualitative and quantitative parameters of this study were exploratory descriptive. Therefore, data were collected, tabulated and analyzed with simple statistical method to fulfill objectives of the study. Tabular technique of relative frequency distributions is applied for the analyses of data using descriptive statistical method (Aviva and Paul, 2013), by using IBM® SPSS-v-16™, MS® Excel™ Software. The formula of relative frequency calculation is given below-

$$\boldsymbol{RF} = \frac{\boldsymbol{f}}{\sum \boldsymbol{f}} \times \mathbf{100}$$

Here,

$\boldsymbol{RF}$	=	Relative Frequency (or Percentage)
$\boldsymbol{f}$	=	Frequency
$\sum \boldsymbol{f}$	=	Total Frequency

CHAPTER- 04

RESULTS & DISCUSSION

CHAPTER 04

RESULTS & DISCUSSION

4.1 Respondent's information

The current research revealed that most of the respondents were above 36 years old (70%). After that, 20% of the respondents were between the age ranged from 26 to 35, the rest (10%) were below 25 years old (Table-4).

Table: 4 Respondent's information

Variables	Category	Frequency	Percentage (%)
Age	< 25 years	2	10
	26-35 years	4	20
	>36 years	14	70
Qualification	Undergraduate	1	5
	Graduate	14	65
	Postgraduate	5	25
Experience	< 1 year	2	10
	2-5 Years	7	35
	>5 years	11	55

Among all the respondents, 65% were graduate, 25% of them had their post-graduation degree and rest (5%) were undergraduate. The present study also showed the working experience of the respondents. Among 20 respondents, 55% had working experience over 5 years, 35% of the respondents had working experience between 2-5 years and 10% had working experience of below 1 year (Table:4).

4.2 Tannery features

The current research revealed some important features of the studied tanneries. Among all the studied tanneries, 18 (90%) were private tanneries and the rest 2 (10%) were merger (Table:5).

Table: 5 Features of studied Tannery (n=20)

Variables	Category	Frequency	Percentage (%)
Establishment history	Tanneries moved from Hazaribagh to Hemayetpur	18	90
	Tanneries established in Hemayetpur recently	2	10
	Tanneries established in Hemayetpur previously	0	0
Tannery type	Government	0	0
	Private	18	90
	Merger	2	10
Waste management Protocol	Yes	19	95
	No	1	5
Storage facility	Yes	5	25
	No	15	75
Recycling facility	Yes	3	15
	No	17	85
Size of the tannery	Small (raw materials<500kg/day)	5	25
	Medium(500-1000kg/day)	12	60
	Large (>1000kg/day)	3	15

According to the result found by Bethelhem (2018), the percentage of private tannery was 87%, cooperative tannery was 8% and govt. tannery was 5% which was quite relevant to the current study due to the similarity in the socio-economic perspective of Ethiopia with that of Bangladesh. This study showed the establishment history of the studied tanneries.

Among all the studied tanneries, most tanneries (90%) were moved from Hazaribagh to Hemayetpur tannery industrial area. Only 2 (10%) tanneries had been established in hemayetpur recently. And there was no such tannery which was established in Hemayetpur from the very first time (Table:5). The present study clearly showed the status of the studied tanneries whether they had any protocol for the waste management or not. This investigation expressed that 95% of the studied tanneries had well-defined tannery waste management protocol and only 5% of the studied tannery had no such protocol for the waste management. This study was similar to the study by Christina (2018) because, Christina (2018) showed that 91% of the study tannery had standard protocol for tannery waste management which was performed in Ethiopia. On the other hand, according to this experiment, 75% of the studied tannery had no storage facility and 85% had no recycling device for the tannery solid waste. A research conducted by Cooman (2018), 69% of the studied tannery had recycling device. A study performed by Mwanzia *et al.,* (2018) showed that 79% of the studied tannery had followed standard protocol for tannery waste management and 25% of the studied tannery had tannery waste storage facility. According to Islam (2014), about 81% of his studied tannery had standard protocol for tannery waste management to follow, 19% had tannery solid waste storage facility and 22% of the studied tannery had tannery waste recycling device.

4.3 Raw materials used in tannery

The study provided the information about which type of raw materials were processed in different tanneries. In all tannery raw materials were categorized into three type such as Hides, skins and both mentioning that the larger tanneries process both hides & skins (Plate:1). But the small sized tanneries processed with only hides (Plate:2). From this research it

(A) **(B)**

Plate 1: Cured raw hides (A) & cured raw skins (B)

(A) **(B)**

Plate 2: Hides after unhairing and soaking (A & B).

was clearly showed that 55% of the studied tanneries processed both hides and skin, 45% of the tanneries processed only hides. But there was no such tannery which processed only skins (Table:6). According to an experiment conducted by Bethelhem (2018), the percentage of processing of hides was 83.32% and the percentage of processing of skin was 12.59% because in that case the availability of large animal was greater than that of the small animals. But the small sized tanneries dealt with only hides or skin. This result was quite similar to that of Okalebo *et al.*, (2014) which showed the percentage of hides and skin processing was 59.76% and the percentage of processing of only raw hides was 41.83%. This investigation showed the comparative scenario about the sources/origin from where the raw materials were collected and conveyed to the study tanneries. 70% of the study tanneries collected raw materials from only Dhaka division. There were 30% of the tanneries which collected raw materials across the country. This result was similar to the experiment conducted by Islam (2017) which showed that about 60% of

Table:6 Raw materials characteristics and their acceptance rate in studied tanneries

Variables	Category	Frequency	Percentage (%)
Types	Hides	9	45
	Skin	0	0
	Both	11	55
Source	Dhaka only	14	70
	Across the country	6	30
Receiving channel	Directly from the owner	0	0
	From middleman	17	85
	Both	3	15
Condition	Cured	17	85
	Non cured	0	0
	Both	3	15

the studied tanneries raw materials from only Dhaka division. The current experiment provided the overall picture how the studied tanneries received raw materials which indicated raw materials receiving channel. From this study, it was viewed that 85% of the study tannery collected their raw materials from middlemen and rest 15% of the studied tanneries collected raw materials from both middleman and owner. But no such tannery that collect raw material only from the owner (Table:6). This research provided information about how the studied tanneries usually dealt with which conditioned raw materials, as we know raw materials could be received in cured or not cured condition. This study revealed that 85% of the study tanneries received raw (hides & skin) materials which were cured in condition and 15% of the study Tanneries were dealing with both cured and not cured conditioned raw materials. No such tannery was there which had delt with only not cured raw materials. This study was similar to that of Bethelhem (2018). According to the study 85% of the study tanneries collected their raw materials from middlemen (Table:6). A research conducted by Islam (2017) revealed that 87% of the study tannery collect their raw materials from middlemen and 13% collect their raw materials from both owner and middlemen and this agreed with the current study.

4.4 Generation of solid waste and finished leather

The current study unearthed that the average percentage of solid waste generation was 28.88% and the tannery solid waste generation rate in small, medium, and large tanneries were 27.94%, 30.01% and 28.69% respectively. According to the study by Bethelhem (2018), which was conducted on the tannery solid waste showed that the solid waste generation rate was 25%. The current study provided the idea of the

(A) **(B)**

Plate 3: Newly generated wet blue trimmings (A) and finished leather trimmings (B).

percentage of different types of tannery solid wastes based on the total amount of solid tannery waste. Present study revealed that, the highest among of tannery solid waste was chrome shaving which was generated at 31.8% of total solid waste. The second highest solid waste was chrome splitting which was generated at 28.85% of total solid wastes and the rest were vegetable splits and trimmings, vegetable shaving, wet blue trimmings, buffing dust, finished trimmings (Plate:3) which were generated at 11.08%, 5.95%, 3.84%, 4.37%, 2.98% respectively (Table:7). According to Zulfikar (2012), the obtained result was quite similar because the chrome shaving generation rate was 30.65% of total solid waste and the generation rate of chrome splitting was 27% which was nearly the same.

Table:7 Different types of tannery solid wastes generated in the studied tanneries per day (n=20)

Types of solid tannery wastes	Processing stages	Percentage (%)
Wet blue trimmings	Post-tanning	3.84
Chrome splitting	Post-tanning	28.85
Dyed trimmings	Tanning	4.53
Buffing dust	Tanning	4.37
Chrome shaving	Tanning	31.8
Vegetable splits and trimmings	Beam House Operation	11.08
Vegetables shavings	Beam House Operation	5.95
Finished shavings	Finishing	2.98
Other	Multiple stage	6.32
Total	-	100

On the other hand, the average percentage of finished leather which was final product (Plate:4) generation in small, medium, and large tanneries are 21.69%, 22.62% and 23.85% resulting in average of 22.72% (Table:8). This study agreed with the result found by Bethelhem (2018) because the result was 21% by Bethelhem (2018). According to the study by Islam *et al*., (2000), chrome shaving was generated at largest rate and that was 35.81% and the second highest generation rate was 31.52% which was of chrome splitting. This study also agreed with the current study. This experiment revealed that, wet blue trimmings and chrome splittings were found in the post-tanning process. Buffing dust, chrome shavings and dyed trimmings were found in the tanning process. Vegetables shavings and vegetable splits were found during Beam House operation. Lastly, finished trimmings were found during finishing process. The cause why the result had been quite similar to the current

(A) (B)

Plate 4: Finished leather: white **(A)** & brown **(B)**

study was that was also conducted in Bangladesh under the supervision of BAU teachers but in different period of time. Then the tanneries were situated at Hazaribagh, Dhaka.

Table:8 Generation rate of total amount of solid tannery wastes and final products in study tanneries

Variables	Type of the tannery	Percentage (%)	
		Percentage %	Overall average percentage
Waste generation	Small	27.94	28.88
	Medium	30.01	
	Large	28.69	
Final product (finished leather) generation	Small	21.69	22.72
	Medium	22.62	
	Large	23.85	

The present study showed that the generation rate of final product which was finished leather (Plate:4) of the tanneries was 21.69 % of the raw hides and skin in case of small tanneries and 22.62 % and 23.85 % of the raw hides and skin in case of medium and large sized tanneries respectively (Table:8). And the overall average percentage of the finished leather generation was 22.27 % (Table: 8). The current study agreed with the study by Okalebo *et al.*, (2014) because this study showed that the percentage of finished leather generation was 24% which was very close to the current study.

4.5 Solid tannery waste utilization and disposal mode

The ongoing research provided the overall concept of utilization mode of tannery solid wastes which revealed that in 60% studied tannery, solid waste were often used as source of fuel, 20% studied tanneries used solid wastes as fertilizer, 30% respondents disclosed the information about tannery solid wastes being used as poultry feed. And 55% of the studied tanneries had no use of the solid wastes. The respondents were allowed to provide multiple choices of the given options. This result agreed with the results found by Christina (2018). The current investigation disclosed that there were some uses (30%) of tannery solid waste as poultry waste but there was no such use of tannery solid waste as cattle feed (Table:9). The ongoing study provided concepts about disposal mode of tannery solid waste (Table:9). The respondents were allowed to provide their multiple concepts of disposal mode of tannery solid waste. This experiment revealed that 55% of the studied tannery dispose the solid waste by land filling, 35% of the studied tanneries were used to do this by open dumping, 45% of the studied tanneries disposed the wastes by incineration.

Table:9 Utilization and disposal mode of solid tannery wastes

Utilization of solid waste		
Variables	**Frequency**	**Percentage (%)**
Source of fuel	12	60
Source of fertilizer	4	20
Source of poultry feed	6	30
No use	11	55
Disposal mode of solid waste		
Variables	**Frequency**	**Percentage (%)**
Land filling	11	55
Open dumping	7	35
Incineration	9	45
No specific / documented method	13	65

And 65% of the studied tannery had no specific/documented method of waste disposal (Table:9). According to the findings by Islam (2017), 49% of the tannery used to dispose their tannery solid waste by land filling and 45 % dispose by open dumping which was fairly similar to the current study.

4.6 Tannery solid waste (wet blue Trimmings) used in poultry feed

The current investigation showed that 30% of the respondents expressed their experience that some tannery solid wastes were used as poultry feed. Among all these types of solid waste only wet blue trimmings (Plate:5) are sold and used in the poultry feed.

Table:10 Physical parameters of tannery solid waste (wet blue trimmings) samples

Parameters	Sample-1	Sample-2	Sample-3	Sample-4
Color	Bluish	Bluish	Bluish	Bluish
Odor	Normal	Normal	Normal	Normal
Insect infestation	No	No	No	No

So, these wet blue trimmings were the concern. Four fresh samples of wet blue trimmings were collected from four randomly selected studied tannery and then physical and chemical parameters were examined. Physical and chemical parameters were variable from tannery to tannery.

Table:11 Chemical parameters of solid waste samples

Parameters	Sample-1	Sample-2	Sample-3	Sample-4	Average
Dry matter (DM)	52.86 %	52.71 %	53.18 %	52.83 %	52.9 %
Crude protein (CP) **(on DM basis)**	95.21 %	93.90 %	94.21 %	95.62 %	94.74 %

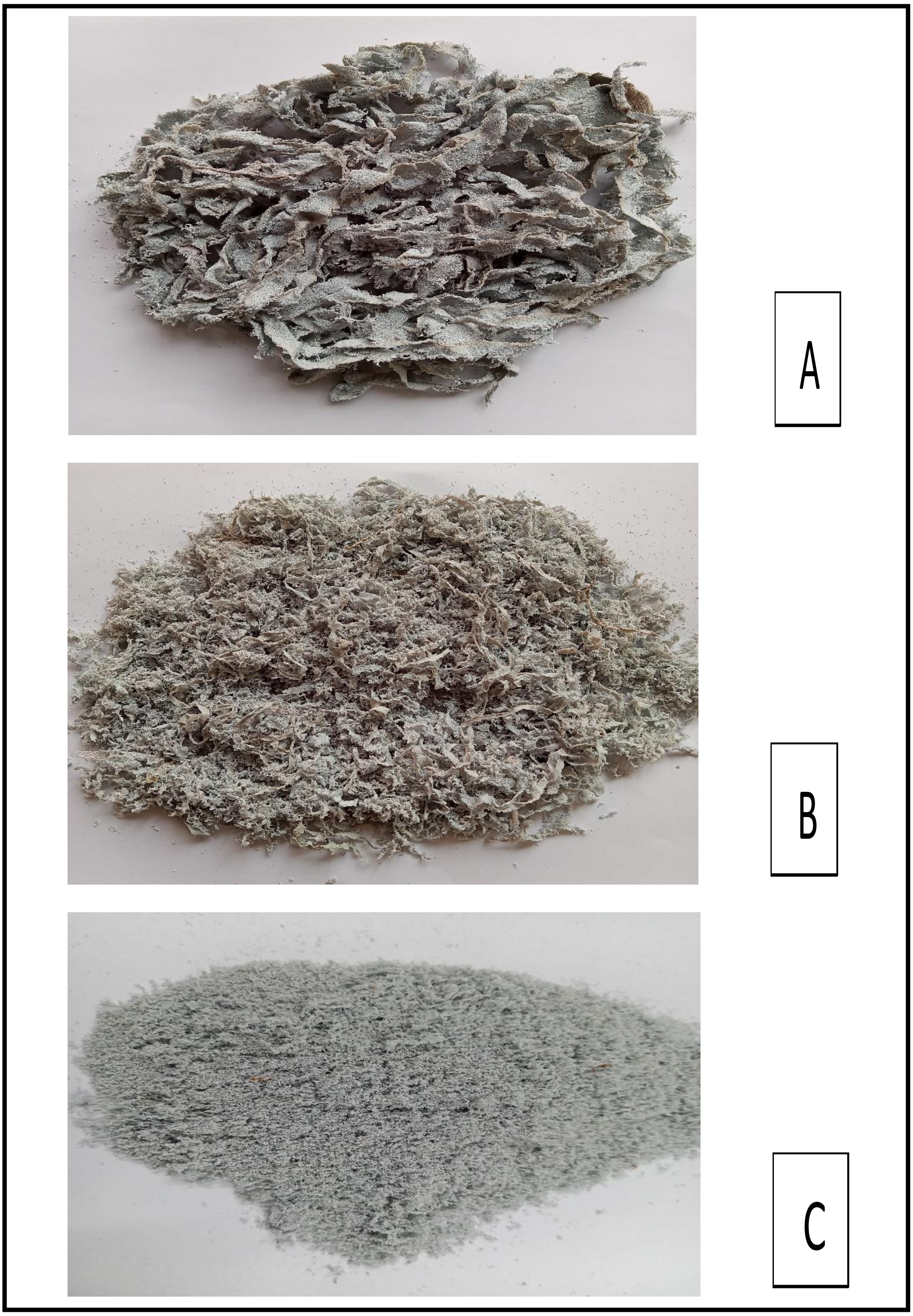

Plate 5: Pictures of wet blue trimming samples (**A**, **B** & **C)**

From the lab test results, it was evident that all the four samples were bluish in color, their odor were normal and there was no insect infestation (Table:10). On the other hand, the research revealed that among the chemical parameters, the average moisture content for those four samples was 47.1% and dry matter was 52.9%. The average Crude protein of that samples was 94.74% on DM basis (Table:11).

4.7 Contribution of tannery solid waste (wet blue trimmings) in livestock feed production

The current study divulged that among all the tannery solid waste, only wet blue trimmings were used as poultry feed or as a portion of the poultry feed (Table:9). So, only the amount of wet blue trimmings and the amount of poultry feed production per year were considered in this experiment. It was found that the total amount of tannery solid waste production per day was 6.104 MT (Metric Ton) and total wet blue trimmings production per day was 0.234 MT. The wet blue trimmings production per year was 85.545 MT. If the businessmen who produced tannery solid waste mixed poultry feed, mix wet blue trimmings at 10 % of the total volume of poultry feed. Then the probable maximum amount of tannery solid waste mixed poultry feed per year would be 855.451 MT. On the other hand, according to the report published by BBS, (2021) and The Business Standard (19 Feb, 2021), total poultry feed production per year was 4450000 Metric ton. So, it was not so hard task to determine the percentage of using tannery solid waste which were mixed in poultry feed production per year in Bangladesh. The percentage was 0.019 % (Table-12). This percentage was so trivial to consider. But some blatant results

Table: 12 Contribution of tannery solid waste in livestock feed

Parameter	Quantity
Total tannery solid waste production per day	6.104 MT
Total Wet blue trimmings waste production per day	0.235 MT
Total Wet blue trimmings waste production per year	85.545 MT
Probable amount of tannery solid waste (wet blue trimmings) mixed poultry feed per year [maximum 10% inclusion level]	855.451 MT
Total poultry feed production per year	4450000 MT [**source:** BBS, 2021 and The Business Standard (19 Feb, 2021)]
Percentage of tannery solid waste mixed feed per year	$\frac{855.451}{4450000} \times 100\% = 0.019\ \%$

were found by some researchers such as Islam (2017) and Okalebo *et al.*,(2014) etc. few years back. According to those reports, the percentage was so high for both animal and public health. The difference between the results of current study and those reports must have occurred due to the difference in sample collection and overall calculation process. Because it was obvious to observe the high percentage if all the samples were collected only from the tannery dense area and if the calculation was not performed on the basis of total annual livestock feed generation.

4.8 Common Challenges

This research provided the problems or challenges which were faced by the tannery authorities for the betterment of this industry. The respondents were allowed to express multiple problems/challenges. The current experiment identified that the unrest political situation in tannery laborer union as the top-notch challenge (90%). Eighty five percent of the respondents indicated the high labor cost as one of the major problems, 70% of the respondents highlighted high transportation cost, 35% respondents were mentioned lack of skilled manpower as their challenges.

Table:13 Challenges of tannery industry in BD

Challenges	Frequency	Percentage (%)
Lack of skilled manpower	7	35
Difficulty in assessing buffer zone/dumping site	13	65
Lack of sufficient land for tannery expansion	9	45
High transportation cost	14	70
High labor cost	17	85
Unrest political situation in Tannery Worker Union	18	90
Unstable leather market	6	30
Fluctuation of raw hides & skin supply	4	20
High availability of synthetic goods in the market	9	45
Lack of Govt. support	8	40

Forty percent said about lack of Govt. support. And 20% respondents indicated fluctuation of raw hides and skin supply as a challenge for the betterment of this industry (Table:13). Because of being an undeveloped country in Africa, the result found by Mwanzia *et al.*, (2013) was highest for the lack of skilled manpower. Though this study found that 90% of the total respondents expressed unrest political situation as their problem, according to the result found by Christina (2018), undeveloped transportation system was identified as major problem. As these research were conducted two different countries, socio-economic perspective were different. So, the results were also different.

4.9 Respondent's Opinion

After completing the regular questionnaire survey, the opinions of the respondents were taken to know their point of views for the betterment of the industry. All the 20 (100%) respondents were allowed to provide multiple opinions. The present study revealed the respondents' points of views for the betterment of this industry. They were however allowed to opine multiple opinions. The current study divulged that, total 17 respondents (85%) provided their opinion to the Govt. to provide soft loan to the tannery owners, 11 respondents (55%) opined to grant demesne for the expansion of the industry, 13 respondents (65%) provided their opinion to lessen the VAT% for the imported instrument, tools and machinery, 45% respondents provided their opinion for the establishment of institutions for advanced training for the tannery worker, 50% of the respondents provided their opinions for the control of the country leather market, 18 respondents (90%) provided their opinion to resist the import of the foreign synthetic leather goods and 8 respondents

Table:14 Opinions of the respondents for the betterment of the industry

Opinion	Frequency	Percentage (%)
Provision of soft loan from the Govt.	17	85
Allowance of demesne/ land for the expansion of tannery industry	11	55
Lessen the VAT% for the imported instrument, tools, and machinery	13	65
Establishment of institutions for the training of the laborer	9	45
Control the country leather market	10	50
Resist the import of foreign synthetic leather goods	18	90
Development of the transportation system	8	40

(40%) of the total respondents provided their opinion for the development of the transportation system (Table:14). opinions for the control of the country leather market, 18 respondents (90%) provided their opinion to resist the import of the foreign synthetic leather goods and 8 respondents (40%) of the total respondents provided their opinion for the development of the transportation system (Table:14).

CHAPTER- 05

SUMMARY & CONCLUSION

CHAPTER 05

SUMMARY & CONCLUSION

From the current study on tannery solid waste management and utilization the following conclusions were drawn-

The physical composition of the solid waste generated from the tannery are found to be wet blue trimming, chrome splits and trimmings, vegetables shaving, vegetable trimmings, buffing dust, dyed trimmings, finished trimming etc. But some other wastes are found like de-dusted salt, raw skin trimmings, hair waste, flashings, splitting waste, crust trimmings and sludge from the wastewater treatment plant. The assessment on the existing solid waste management of the studied Tannery indicates that the solid wastes generated from the tannery is being disposed to open dumping area in most cases some tanneries claimed to dispose by city administration for municipal solid waste disposal. Therefore, as industrial solid waste contains hazardous components, it should be managed separately. In this industry, about 21134 kg of cattle hide and sheep, goat skins are processed daily, the tannery area a total of 6103.5 kg of solid waste from beamhouse, tanning, re-tanning, and finishing processes are generated and this is found to be 28.88% of the raw hide and skin processed. According to this study averagely 4818.6 kg of finished leather are produced daily which is about 22.72% of the total raw material processed. Among the different types of tannery solid wastes chrome shaving contributes to 31.8% of the total solid wastes. Secondly chrome splitting at 28.85% of the total solid wastes generated. The chromium content of chrome shaving, and chrome splitting is much higher than the other tannery solid wastes. This chromium concentration is beyond the safe limit of the metal in soil. Therefore, as chromium metal is highly toxic, the solid waste must be segregated, collected separately, and disposed to secured landfill. Though this study shows that 95% of the studied tanneries claimed to have and maintain a specific protocol for the tannery solid waste management, 65% of the tanneries dispose their solid waste by undocumented way and 55% of the tanneries dispose their wastes by land filling. 35% dispose their waste by open dumping which is quite significant. This study provided the proof that only 25% of the tanneries have their modern solid waste storage facility and only 15% of them have waste recycling device. According to this study, for the betterment of this industry 90% of the tanneries faces problems related to lack of skilled manpower. Eighty percent of them expressed their challenges related to lack of adequate space and modern facility, 70% expressed their concern about lack of sufficient land for tannery expansion, 65% of them admitted problems with high transportation cost and unrest political situation of the tannery laborer union. In general, the results of this study have revealed that the tanning industry generates solid waste with different characteristics according to the process steps from which it is generated. Therefore, to determine the most appropriate solid waste management strategies, it is highly important to acquire the information concerning the process steps from which these solid wastes are generated, the target product desired to be produced through these processes, and the characteristics of the wastes.

Though the wastes are the global problem, it cannot be avoided totally. But for sure, by the application of proper managemental system, the nefarious effects of harmful tannery wastes could be mitigated. The Govt. should encourage the tannery owners to adopt ecofriendly tanning process. Recycling device can reduce the detrimental effects of the tannery wastes to the environment. Mobile court law should be enforced for monitoring the misusage of the tannery wastes.

CHAPTER- 06

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CHAPTER- 07

APPENDICES

APPENDIX-(I)

QUESTIONNAIRE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

Sher-e-Bangla Nagar, Dhaka-1207

Department of Animal Production &Management

EXPERIMENT TITLE

CURRENT SCENARIO OF MANAGEMENT AND UTILIZATION OF TANNERY SOLID WASTES CONCERNING THEIR USE IN LIVESTOCK FEED

[THIS SURVEY DATA WILL BE USED FOR ONLY MS RESEARCH PURPOSE]

QUESTIONNAIRE

SAMPLE NO: DATE:

1. **NAME OF THE TANNERY:**

2. **Respondent's (in charge during interview) details:**

<table>
<tr><td>NAME</td><td colspan="6"></td></tr>
<tr><td>AGE</td><td colspan="6"></td></tr>
<tr><td>SEX</td><td colspan="2">□ MALE</td><td colspan="2">□ FEMALE</td><td colspan="2">□ OTHER</td></tr>
<tr><td>DESIGNATION</td><td colspan="6"></td></tr>
<tr><td>WORKING EXPERIENCE</td><td colspan="2">□ < 1 year</td><td colspan="2">□ 1-5 year</td><td colspan="2">□ > 5 years</td></tr>
<tr><td>CONTACT NO. (IF POSSIBLE)</td><td colspan="6"></td></tr>
<tr><td>EDUCATION</td><td>□
UNEDUCATED</td><td>□
PRIMARY</td><td>□
SECONDARY</td><td>□
INTERMEDIATE</td><td>□
DRADUATE</td><td>□
POST GRAD</td></tr>
</table>

3. TANNERY RELATED INFORMATION:

OWNERSHIP	□ GOVT	□ PRIVATE	□ MERGER
SIZE	□ SMALL	□ MEDIUM	□ LARGE
WORKING DAYS (PER WEEK)			
WORKING HOUR			
RAW MATERIALS	□ HIDES ○ CATTLE ○ BUFFALO	□ SKIN ○ GOAT ○ SHEEP ○ PIG	□ BOTH ○ CATTLE ○ BUFFALO ○ GOAT ○ SHEEP ○ PIG
CONDITION OF RAW MATERIALS	□ CURED ○ WET SALTING ○ BRINE-CURING ○ BOTH	□ NOT CURED	
RAW MATERIALS RECEIVES FROM	□ DHAKA DIVISION ONLY	□ ALL OVER THE COUNTRY	
RAW MATERIALS RECEIVING CHANNEL	□ FROM OWNER	□ FROM MIDDLEMAN	□ BOTH
AMOUNTS OF RAW MATERIALS RECEIVES PER DAY(APPRX.)	□ HIDES	□ SKIN	
FINAL PRODUCTS	NAME	TOTAL AMOUNT	
TIME REQUIREMENT FOR FINAL PRODUCT			

4. WASTE RELATED INFORMATION:

a. NAME OF THE WASTES FOUND IN YOUR TANNERY

□ Chrome shaving	□ Vegetable splits & trimmings	□ Buffing dust (including shaving bovine after dust)
□ Fleshing	□ Vegetable shavings	□ Other (if any):
□ Wet blue trimming (grain split)	□ Finished trimmings	
□ Chrome splitting & trimmings (bovine)	□ Dyed trimmings / crust trimmings	

b. AMOUNT OF WASTE GENERATED A DAY: -

NAME OF THE WASTE	AMOUNT (KG or TON)
Wet blue trimming	
Chrome splitting & trimmings (bovine)	
Dyed trimmings / crust trimmings	
Buffing dust (including shaving bovine after dust)	
Chrome shaving	
Vegetable splits & trimmings	
Vegetable shavings	
Finished trimmings	
Other (if any):	

c. DO YOU THINK TANNERY SOLID WASTE HAS ANY DETRIMENTAL EFFECT UPON ENVIRONMENT?

□ YES, IT CAUSES…	□ NO
▫ Air pollution	
▫ Water pollution	
▫ Soil pollution	
▫ All	

d. ANY PROTOCOL THAT THIS TANNERY FOLLOW?

□ YES	□ NO

e. IS THERE ANY STORAGE FACILITY FOR WASTES?

□ YES		□ NO
▫ DURATION OF STORAGE	▫ CAPACITY	

f. IS THERE ANY RECYCLING DEVICE OR FACILITY?

□ YES		□ NO
▫ CAPACITY	▫ USABLE FORM PRODUCED	

g. HOW ARE THE WASTES DISPOSED?

□ Landfilling method of disposal	
□ Dried flashings and trimmings are disposed by	▫ Open dumping
	▫ Incineration
□ No documented method of recycling or reusing of leather waste	
□ Other method (if any): -	

h. ANY VALUE OR DEMAND FOR THE TANNERY WASTES (MODE OF UTILIZATION)?

□ YES	□ NO
▫ Being used as a source of fuel	
▫ Being used as a source of poultry/cattle feed	
▫ Being used as a source of fertilizer	
▫ Other (if any): -	

i. CHALLENGES IN THE MANAGEMENT OF TANNERY WASTES FOR THE GROWTH OF THIS SECTOR: -

□ High transportation cost of the waste to landfills
□ Bad smell
□ High cost of energy
□ Marketing constraints (fluctuation of prices)
□ High costs of machinery and spare parts, equipment and leather manufacturing and recycling chemicals
□ Lack of skilled manpower
□ Lack of sufficient land for tannery expansion and waste disposal
□ Difficulty in assessing the buffer zone area/ dumping site (especially during rainy season)

□ Pollution due to solid waste decomposition/ degradation
□ Soil water contamination due to leaching
□ Environmental pollution due to lack of proper disposal and treatment mechanisms for both tannery solid waste and effluents
□ Stiff competition in the global market
□ Influx of cheap synthetic shoes from China
□ Influx of secondhand leather goods and footwear into the country
□ Low govt. support for value addition in the tannery sector
□ Other (if any):

5. ANY OPINION YOU CAN PROVIDE THAT THE GOVT. SHOULD TAKE FOR THE BETTERMENT OF THIS INDUSTRY:

____

____

____

____

THANKS

SIGNATURE OF THE SURVEYOR SIGNATURE OF THE SUPERVISOR

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APPENDIX-(II)

The percentage of different tannery solid wastes from raw skins and hides

Tanneries	Wet blue trimming (%)	Chrome splitting (%)	Dyed trimming (%)	Buffing dust (%)	Chrome shaving (%)	Vegetable splits & trimming (%)	Vegetable shaving (%)	Finished trimming (%)	Other (%)	Total (%)
T-1	0.3	8.63	2.03	1.37	7.88	3.52	2.18	0.6	1.19	27.7
T-2	1.2	9.36	1.2	0.64	9	4.04	2.2	0.56	2.32	3.05
T-3	1.14	7.69	0.06	0.66	9.7	3.76	1.98	0.51	2.01	27.51
T-4	0.86	8.11	1.18	1.07	8.61	3.28	2.27	0.92	2.04	28.8
T-5	0.64	7.22	1.33	1.13	10	3.57	2	0.99	2.18	29
T-6	0.85	8.27	0.96	1.15	8.8	3.52	1.46	0.53	1.96	27.5
T-7	0.65	7.9	1	0.89	7.1	2.89	1.37	0.69	1.64	24.13
T-8	1	8.1	1.28	1.22	10	3.17	1.33	0.59	1.68	28.37
T-9	0.91	7.32	1.5	1.95	8.15	3.18	2.15	0.96	2.24	28.3
T-10	1.05	10.1	1.44	1.18	9.5	3.86	2	0.57	2.3	31.9
T-11	0.75	9.16	1.02	1.07	9.22	3.52	2	0.87	2.21	29.85
T-12	0.1	9.86	1.43	1.18	9	3.57	2.02	0.65	2.26	30.07
T-13	1.09	8.65	1.37	1	8.17	3.25	1.87	0.53	2	27.93
T-14	0.75	8.19	0.91	1.02	7.39	3.1	1.97	0.78	1.92	26
T-15	1.02	9.3	1.41	1.2	9.4	3.7	2.31	1.14	0.66	30.14
T-16	1.28	10.2	1.32	`1.42	8.89	3.85	2.73	0.82	2.4	32.91
T-17	1.94	8.74	1.27	1.25	8.2	2.69	1.88	1.3	1.67	28.94
T-18	1.22	8.7	1.87	0	8.29	3.49	2.47	1.05	2.01	29.07
T-19	1.93	7.55	1.51	1.17	8.14	2.44	2.15	1.65	1.42	27.96
T-20	1.77	9	1.52	1.77	9.93	3.69	1.71	0.71	0.93	31.03
Avg.	1.02	8.6	1.44	1.06	8.77	3.4	2	0.77	1.85	28.88

APPENDIX-(III)

The percentage of different tannery solid wastes from total amount of tannery solid Wastes

Tanneries	Wet blue trimming (%)	Chrome splitting (%)	Dyed trimming (%)	Buffing dust (%)	Chrome shaving (%)	Vegetable splits & trimming (%)	Vegetable shaving (%)	Finished trimming (%)	Other (%)	Total (%)
T-1	4.2	31.7	6	5	29	12.9	8	1.1	2.1	100
T-2	3.88	30.6	4.1	2.05	29.53	13.25	7.17	1.84	7.66	100
T-3	4	27	3.6	23	34.1	13.2	6.9	1.8	7.1	100
T-4	3	29.8	4.1	3.7	29.9	11.4	7.9	3.2	7.1	100
T-5	2.2	24.9	4.6	3.9	34.5	12.1	6.9	3.4	7.5	100
T-6	3.1	30.09	3.5	4.2	32	12.8	5.3	1.9	7.1	100
T-7	2.7	32.87	4.2	3.7	29.1	12.03	5.7	2.9	6.8	100
T-8	3.7	29.9	4.7	4.5	36.9	11.7	4.9	2.2	6.2	100
T-9	3.2	25.9	5.1	6.9	28.8	11.2	7.6	3.4	7.9	100
T-10	3.3	31.3	4.5	3.7	29.8	12.1	6.3	1.8	7.2	100
T-11	2.5	30.7	3.4	3.6	30.9	11.8	6.8	2.9	7.4	100
T-12	3.4	31.8	4.6	3.8	29	11.5	6.5	2.1	7.3	100
T-13	3.9	30.9	4.9	3.6	29.2	11.6	6.7	1.9	7.3	100
T-14	2.9	31.5	3.5	3.9	28.4	11.8	7.6	3	7.4	100
T-15	3.4	30.9	4.7	4	31.2	12.3	7.7	3.8	2.2	100
T-16	3.9	31	4	4.3	27	11.7	8.3	2.5	7.3	100
T-17	6.7	30.2	4.4	4.3	28.3	9.3	6.5	4.5	5.8	100
T-18	4.2	30	6.3	0	28.5	12	8.5	3.6	6.9	100
T-19	6.9	27	5.4	4.2	29.1	8.7	7.7	5.9	5.1	100
T-20	5.7	29	4.9	5.7	32	11.9	5.5	2.3	3	100
Avg.	3.84	29.85	4.53	4.37	31.8	11.08	6.95	2.88	6.32	

APPENDIX-(IV)

Percentage of finished leather found from raw materials

Tannery	Amount of raw materials (kg)	Amount of finished leather (kg)	Percentage (%)
T-1	838	191.1	22.8
T-2	1250	261.38	20.91
T-3	1690	369.77	21.88
T-4	1469	367.4	25.01
T-5	1214.5	282.37	23.25
T-6	1390	277.31	19.95
T-7	822	177.6	21.6
T-8	1180	284.38	24.1
T-9	759	171.53	22.6
T-10	1340	253.26	18.9
T-11	928	213.44	23
T-12	750	171.75	22.9
T-13	749	157.59	21.04
T-14	1190	285.72	24.01
T-15	1088	290.9	26.74
T-16	1507	358.67	23.8
T-17	577	136.17	23.6
T-18	768	146.84	19.12
T-19	947.5	205.61	21.7
T-20	677	186.2	27.5
Average	1056.7	239.45	22.72