Chapter 16
Environmental Impact and Treatment of Tannery Waste

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Abstract Tannery industry is considered to be one of the most important industry because of their economic, employment, and export potential. At the same time, because of the discharge of untreated effluents, these are treated as primary source of pollutants which has immense potential to pollute the soil and water. More than 200 chemicals are being used in this process, and further a mixture of complex toxic substances, such as polychlorinated biphenyl, chromium, sulphides, nitrates, etc., gets discharged as waste. Chromium is considered as the most toxic to humans and biota along with other environments. Various environmental agencies have enforced regulations related to the discharge of these toxic chemicals in to the water bodies. Thus, removal of toxic, such as hexavalent chromium, from the water becomes utmost important. Less work has been reported for the removal of chromium, sulphides, and toxic substances from tannery wastewater.

In this chapter, we have discussed (1) tanning process, which involves various processes through which leather is produced in the tannery industry; (2) characteristics of tannery waste, i.e. liquid waste, solid waste, and gaseous waste; (3) effect of waste on the environment that includes its effect on the soil, water, plant growth, and plant and animal health; (4) treatment technologies, that involve various treatment techniques through which these wastes can be treated or neutralized; and further (5) tannery waste management.

Keywords Tannery · Effluents · Environments · Untreated · Hexavalent chromium · Toxic substances · Waste management · Wastewater

16.1 Introduction

The basic need of one's life is water. Every organism, including human beings, plants, and animals, needs this essential resource for their survival. Apart from domestic purposes, such as drinking, cooking, washing, etc., water has many other essential usages, such as in agricultural purposes, industrial purposes, hydropower generation, and maintenance of healthy ecosystem (Bibi et al. 2016). While due to the continuous increase in the population, demand of water is rising at a rapid rate in order to satisfy their needs. Water is one of the main threats that the whole world is facing today in terms of quality and quantity. This problem further deteriorates in the case of developing countries, as most of them are not able to provide clean potable water to the majority of the population, resulting in severe health ailments or even death; approximately, 3.1% of the deaths are related to consumption of contaminated water (Pawari and Gawande 2015). Some health impacts are immediate, whereas some are noticed over time; these include illnesses related to the stomach and intestines, such as vomiting, diarrhea, cramps, and many other harmful effects (Montgomery and Elimelech 2007). The World Health Organization indicates that nearly 80% of diseases are somewhere and somehow related to water contamination, and a notable number of countries are not able to fulfil the standards laid by them for drinking water (Khan et al. 2013). There are a number of reasons associated with this issue; out of which, the most common is the enormous increase in the number of industries in the last few decades because of their contribution in economic growth. Rapid industrialization is associated with increase in level of environmental pollution in context of not only water but also to noise, air, and soil.

We all know that for any industrial process, water acts as a key raw material; in any form either volume or weight, it exceeds all other liquid or solid inputs used in manufacturing process. It also plays a key role in deciding the location of any industrial setup (Kollar and MacAuley 1980). As observed, most of them are located near banks of water bodies so that water is readily available. Apart from huge water requirement for different industrial purposes, the problem further rises, as only a small fraction of the water is converted in their required product, and only a small amount is lost by evaporation, and the rest makes its way into water bodies in form of waste. The waste generated from industrial units joins the municipalities which results in pollution of natural water bodies. These industrial wastes join water bodies either directly or emptied into municipal sewers carrying waste, which affect normal functioning of the water body. Now, a general perception of people has changed towards industries that only chemical industries cause pollution; apart from them, a number of industries are there which are degrading the natural environmental balance, and the extent of pollution varies from industry to industry. In general, no industry is pollution free in present scenario. Some of the industries related to cement, steel, petroleum, textile, pesticides, chemicals, transport vehicles, and leather are hugely polluting the nature. Waste originating from different industries can be divided into three main categories: biodegradable, nonbiodegradable, and radioactive or poisonous waste.

Tannery industry is one of the industries that is polluting the environment and its resources particularly water bodies (Leta et al. 2003). This ancient craft was initially practiced for over years at the village level of developed countries, and with the passage of time, this industry has shown a notable growth in developing countries as well due to strict norms of the former. Now, it has acquired status of a mature industry which plays an important role in the economy of producing country and lead to its development, as leather is an important foreign exchange earner due to its application in making a number of useful products (Joseph and Nithya 2009).

Tannery industry is basically associated with the manufacturing of leather and related products; more specifically, it is the place where a process termed as tanning takes place. Tanning is a process in which skin and hides of animals are processed through many stages to make leather (Dargo and Ayalew 2014). This process uses variety of chemicals, such as sodium sulfide, lime, ammonium sulfate, vegetable tannins, sodium chloride, chrome salts, and bactericides, and further high quantity of water is used for its processing (Cooman et al. 2003). Conventional tanning technology is adversely affecting the environment due to large amount of chemical and organic pollutant generation. These generated pollutants mostly present in effluent discharge and emerge as a serious threat to the environment.

16.2 Tannery Process

Manufacturing of leather during tanning process is a complex method which is performed into two parts: beam house operations and tanning process. Figure 16.1 shows various processes that are involved in the manufacturing of leather. In first step, i.e. beam house operations, blood and dirt from hides of animals are removed by washing which is followed by softening and salt removal from hides by soaking in water (Cassano et al. 2001). Fatty acids are also removed by fleshing. In order to provide better penetration of tanning agents and hair removal, swelling of hides is required which is done by liming. We use alkaline medium of sulphide and lime for chemical dissolution of the hair and epidermis. To facilitate de-hairing, sodium sulphide is added (O'Flaherty et al. 1965). In the process of liming, a high concentration of sodium sulphide, organic matter, and lime is produced which joins the effluent. To remove hair remnants and to degrade proteins, hides are neutralized by ammonium salts followed by treatment with enzymes. This leads to generation of high ammonium waste in the effluent.

After these stages, hides are prepared for tanning by a process known as pickling. Acids, mainly sulphuric acid, are added in order to adjust the pH value of hides (Cassano et al. 2001). In order to prevent hides from swelling, salts are added. In tanning process, reaction of collagen fibers present in hides takes place with chromium, tannins, alum, or other chemical agents. There are a number of compounds which are used as tanning agents; some of them are alum, formaldehyde, syntans, heavy oils, and glutaraldehyde. Nearly 300 kg of chemicals are used per ton of hides during the tanning process. Table 16.1 shows list of chemicals that are consumed for leather processing.

On the basis of tanning agent, tanning operations are further divided in chrome tanning and vegetable tanning. In vegetable tanning, natural organic substances are used which are derived from plants, and it is done in series of vats (Zywicki et al. 2002). In the case of chrome tanning, chromium salts are used, and it is performed at higher pH. Out of the total leather produced nearly 90% uses chromium salt for tanning (Stein and Schwedt 1994). When tanning is completed, tanned leather is piled down, wrung, and graded for required thickness and quality. Retaining, fat liquoring, and dyeing are the additional steps which are used in chrome tanning unlike vegetable tanning. During fat liquoring, oil gets introduced into the skin

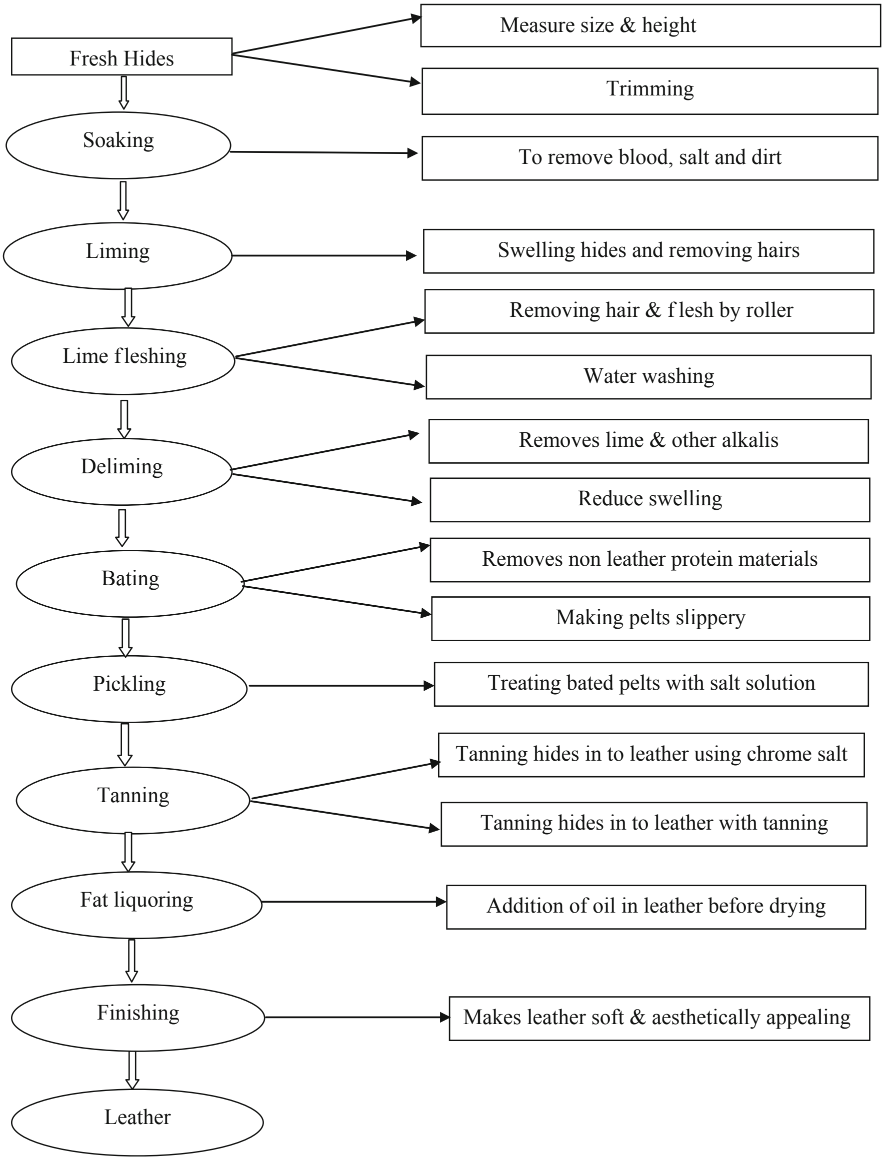

Fig. 16.1 Leather manufacturing process

before the leather is dried in order to replace the natural oil that had been lost in beam house and tan yard processes. Subsequent finishing operations are performed after drying, such as buffing, embossing, and plating, which are done to make leather soft and aesthetically appealing (Midha and Dey 2008). In the tanning industry

Table 16.1 Various chemicals consumed in leather processing (Murad et al. 2018)

Name of Chemical	In kg/ton of Hides or Skin Process
Soaking aids	1.0–2.5
Preservatives	2.5–5.0
Lime	80–200
Sodium sulphide	20–30
Sodium chloride	80–100
Ammonium salts	10–15
Sulphuric acid	12–20
Sodium formate	5–12.5
Basic chromium sulphate	60–120
A1uminium (A12O3)	1–20
Zirconium (ZrO2)	0–15
Vegetable tanning	10–220
Synthetic tanning a	20–60
Fatliquores	25–100
Dyes	2.5–20
Binders	20–45
Pigments	10–25
Top coats	20–45
Wax emulsions	2.5–5.0
Feel modifier	1.0–2.0

putrescible hides or skin is converted into leather; tanning agents provide permanent stabilization of skin against biodegradation.

16.3 Characteristics of Waste Generated

The waste generated from tannery industries consists of a mixture of organic and inorganic pollutants and is characterized by strong color, high biological oxygen demand (BOD), high dissolved salts, and high pH. Tanning agents are responsible for processing of hides into leather; during this process, effluent having turbidity, color, and foul smell generates (Dargo and Ayalew 2014), (Buljan and Kral 2011). Studies associated with tannery industries found that chlorinated phenols and chromium were found as a part of tannery effluents (Reemtsma and Jekel 1997). Chromium is an inorganic pollutant and found in oxidation state, having trivalent and hexavalent as most common form (Kotaś and Stasicka 2000). On the other hand, chlorinated phenols are organic pollutants associated with this industry and are proved to be toxic for cellular compounds of animals which may come under influence of this compound (Pasco et al. 2001).

Other notable concerned pollutants include cadmium compounds, azo dyes, copper, cobalt, antimony, lead, pesticide residues, barium, selenium, zinc, arsenic,

Table 16.2 Types of pollutants released at various leather processing

Leather Process	Liquid Pollutants	Solid Pollutants	Gaseous Pollutants
Fresh hides			
Socking	Salt, BOD, COD, DS, and organic nitrogen		
Liming/ unhairing		Hair, lime, and organic sludge	H_2S
Lime fleshing	BOD, COD, TDS, SS, alkanity, and sulphides	Fat containing lime	
Lime splitting		Lime split and organic matter	
Bating/ deliming	BOD, COD, TDS, and ammonia N		NH_3
Tanning	Acidity, vegetable tans, and syntans		
Chrome splitting		Organic matter containing Cr	
Shaving		Chrome containing organic matter	
Retaining	BOD, COD, DS, SS, fats, dyes, vegetable tans, and syntans		
Bating/ trimming		Formaldehyde and chrome trimming	
Leather product	All other finished agents, solvents, and formaldehyde		CH_2O and solvents

polychlorinated biphenyls, mercury, nickel, and formaldehyde resins (Mwinyihija 2010). Effluents are ranked top as the highest pollutants among the entire industrial wastewater tannery process (Shen 1995). Table 16.2 shows various wastes that arise because of tanning process.

Different wastes generated during tannery can be classified as:

16.3.1 *Liquid Waste*

Tanneries are one of the major water-consuming industries, and a large portion of water goes into waste. Approximately, 30–40 litres of water are required for the processing of 1 kg of raw hide into finished leather that is the reason why most of the tanneries are located near river banks. A study reveals that in India alone 1,75,000 cubic metre per day of liquid waste is generated by 3000 large, medium, and small scale tanneries (Kaul et al. 2005). Characteristics of liquid waste generated not only vary from tannery to tannery but also vary from time to time. Water generated from beam house after soaking, liming, and deliming is highly alkaline in nature and contains lime, hair, decomposed organic matter, organic nitrogen with high BOD, sulphide, and chemical oxygen demand (COD). Due to presence of organic matter in waste, reduction in dissolved oxygen takes place by microbial decomposition which adversely affects the life of aquatic animals (Balasubramanian and Pugalenthi 2000), (Song et al. 2000), (Mwinyihija et al. 2006).

Tanyard process viz. pickling, chrome tanning, leads to generation of acidic and colored wastes. During vegetable tanning, waste consists of organic matter, whereas high amounts of chromium are formed as waste in case of chrome tanning.

16.3.2 Solid Waste

As per European Commission, the amount of solid waste produced depends on different type of factors, such as type of leather produced, technique applied, and source of hides and skins (Basegio et al. 2002). Waste in solid form generated in tannery can be divided into following forms:

– Non-proteinous waste.
– Non-collagenous protein waste.
– Tanned collagen.
– Untanned collagen.

On average, only 20% weight of hide is transformed into leather, and the remaining goes as waste. Only 200 kg out of 1 ton of hides gets converted into finished leather, whereas the remaining gets discharged as waste in form of waste that contains blood, manure, protein, greases, and fat (Cooray 1999). A part of solid waste or byproducts fixed consumers in the gelatin, textile, glue, and artificial leather industry. Approximately, 35% of the original protein material comes out as effluent tannery sludge, flashings, showings, and brimming. Only a small fraction of solid waste produced in different tannery steps is utilized due to insufficient market (Cheda et al. 1984).

16.3.3 Gaseous Waste

Tanneries are well known to discharge dust, odorous gases, and smoke into the atmosphere (Shastri 1977). Nitrogen and sulfur are the main source of foul smell in the tannery industries. Decay of hides of animals starts immediately after its removal from animal body before its proper curing (Kiernan 1985). Hides which have given delayed curing may not smell bad in salted condition, but curing salt is removed during soaking, and it increases chances of protein putrefaction and possibility of bacterial growth (Mckinney 1969).

Chrome tanning or mineral tanning has an advantage of having no foul smell generation unlike vegetable tanning which suffers from bad smell as tanning agent comes from variety of plants and found in bark, twigs, nuts, and leaves which have their own peculiar smell.

16.4 Effect of Waste on Environment

Pollution due to tannery industries causes horrible ecological crisis to which we are subjected in the modern time. Due to improper management practices, tannery industry is polluting the environment day by day, and further condition becomes worsen as nearly 95% of tannery industries are built in unplanned way throughout the world (Kaul et al. 2005). Wastes generated from tanneries are the primary pollutant to the environment and has potential to pollute both soil and water because of its properties, such as discoloration, toxic chemical constituents, and high oxygen demand (Song et al. 2000).

Most of the tanneries throughout the world use chromium salts for tanning purpose in order to provide better leather water resistance, flexibility, and high shrinkage temperature, but chromium salts are not fixed completely by hides, and the remaining nearly 70% joins the spent tanning liquor (Cassano et al. 2007). High amount of chromium has mutagenic, carcinogenic, and teratogenic effects on animals, humans, and many plants along with bacteria inhabiting aquatic environments (Naik et al. 2007). This may lead to effects, such as headache; dizziness; irritation to skin, eyes, and lungs; poisoning of kidney, liver, or nervous system; or collapse due to insufficient oxygen (Lippmann 2000).

Chromium pollution is increasing in the world due to the increase in tannery industries and can be notably observed in countries, such as India, Pakistan, South Africa, Latin America, Burkina Faso, Ethiopia, and Sudan, where a large number of tannery industries are operating, and all of them are releasing waste containing toxic chromium and phenolics (Felsner and Kiruthu 1996). More specifically, adverse effect of tannery effluents can be studied in the following:

16.4.1 Soil Profiles

We all know the importance of soil in our ecosystem, as it is crucial for plant and animal life due to its vitality as a growth substrate for their development and continual growth. But this crucial resource of life is adversely affected by the presence organic and inorganic contaminants that are produced during tannery operation and discharge with effluent waste. The area of soil adjacent to tanneries are adversely affected by pollutants and lead to heavy metal contamination in the agricultural soil notably shown in areas of Kanpur, Jajmau in India. Continuous application of sludge for irrigation causes accumulation of heavy metals in soil, such as cadmium, zinc, lead, chromium, manganese, and many more, and it will lead to the release of heavy metal into groundwater or soil solution available for plant intake due to reduction in soil capacity to retain heavy metal. Soil contamination with heavy metal or micronutrients in phytotoxic concentrations affects adversely both human health as well as plants (Avudainayagam et al. 2003). As the land is irrigated with the wastewater rich in chromium sulphate, it leads to the increase in the amount of harmful chromium in the soil (Babyshakila and Usha 2009). At high level, chromium is mutagenic, noxious, carcinogenic, and teratogenic in nature and subsists as an extremely poisonous anion. Apart from chromium, chlorides and nitrates also released as the end product, when sodium chloride is used as a raw material (Mondal et al. 2005) in the tanning process. Increase in pH of the soil results due to alkalization caused by presence of sodium carbonate, sodium bicarbonate, sodium chloride, and calcium chloride produced during the tanning process (Tadesse and Guya 2017).

16.4.2 Water Profile

Effluents produced during tannery operations release color and diminish the quality of the water that is why they are of a large scale environmental concern (Pepper et al. 1996). Waste produced during the tannery process is consists of biodegradable organic matter, such as carbohydrates and proteins, which is responsible for the depletion of dissolved oxygen level of the water body, resulting from microbial decomposition of organic matter (Mwinyihija et al. 2006).

Due to reduction in oxygen level, anaerobic activity starts in the water system, and it will lead to the release of toxic gases into the water body which is harmful for the survival of aquatic species (Mwinyihija et al. 2006), (Barman and Lal 1994). Fishes and other aquatic animals are badly affected by the presence of sulphide released during the tannery process.

16.4.3 Vegetable and Plant Growth

Crop growth and yield gets highly affected when water from the tannery is used as source of irrigation (Camplin 2001). Further, it leads to the accumulation of different heavy toxic metals through the food chain at different tropical levels. Wastewater generated from tanneries, if used for irrigating crop, causes phytotoxicity in plants and results in salinity stress in plants. It affects various metabolic activities that lead to reduction of vegetative growth and also reproductive growth loss of plants in long term. Apart from this, it affects activities, such as photosynthesis, respiration, mitotic activities, and shortened germ sprouting and also leads to the increase in number of reactive oxygen species in the system (Camplin 2001). Accumulation of heavy metals depends upon number of factors, such as plant species, pH, redox, cation exchange capacity, dissolved oxygen, secretion of roots, temperature, and its bioavailability and element present in waste.

Studies suggest that all the parameters responsible for vegetative growth and biomass are reduced in sunflower due to the increase in effluent discharge from tanneries, and this adversely affects sunflower's root and shoot development (Rusan et al. 2007). Similarly, another study had also shown the same adverse growth effect of tannery wastewater on other crops, such as wheat plant, soybeans, and maize (Kılıçel and Dağ 2006, Hewitt and Keller 2003, Nath 2009). Due to high level of salts in tannery waste, such as chlorides and sulphates, the average growth of crop and development of maize were reduced (Hewitt and Keller 1999). Due to the excess amount of dissolved solids, chromium, sulphides, chlorides, high COD, and BOD in the effluents make it unsuitable for crop growth (Mishra and Bera 1995), and lower dilution of effluents inhibits seed germination and seeding growth (Khan and Ghouri 2011). More than 80% concentrations of effluent are harmful for both reproductive and vegetative stages of plants.

16.4.4 Atmospheric System

Air plays an important role in the life of everyone, as it is required for respiration, and no one can live without air. But disappointingly, the whole world is under the influence of air pollution, and the condition further deteriorates in developing countries. One or more hazardous substances are generally present in the polluted air which imparts problem to its belongings. Polluted air contains particulate matters, polycyclic aromatic hydrocarbons (PAHs), ground-level ozone, carbon monoxide, heavy metals, benzene, sulphur dioxide, nitrogen dioxide, ammonia, hydrogen sulphide which are readily present in the waste, originating from tannery industries during liming, deliming, unhearing, and bating processes and mix with the air and cause air problems (Classification of wastes 2009). Chromium is another harmful ingredient which is being released in the atmosphere. 60–70% of chromium in the atmosphere is mainly because of anthropogenic activities. Retention of chromium in the lungs leads to high health risks because of its carcinogenic nature. Till now, industries remains as major source of environmental pollution.

16.4.5 Human and Animal Health

Microorganisms are generally sensitive to chromium (VI) toxicity; tannery worker's exposure to chromium for a period of five months to fourteen years represents a relevant risk factor for the development of disease associated with the genetic damage. Initial exposure to toxic effluents, such as chromium, lead, zinc, hydrogen sulphide, formaldehyde, and cadmium, leads to headache, dizziness, damage in skin or lungs, irritation of eyes as temporary symptoms. Further exposure leads to poisoning of the liver and collapse of the kidney or nervous system due to limited availability of oxygen and in long term leads to illness, such as ulcers, occupational asthma, genetic defects, bronchitis, and dermatitis, in human as well as animal health (Tare et al. 2003).

16.5 Tannery Waste Treatment Technologies

Generally, various physico-chemical and biological methods or combination of both are used for treatment of tannery waste effluent. Tannery waste can be treated by various methods. In general practice, individual tannery applies only to pre-treatment or a part pre-treatment, and sometimes there is no treatment, and they simply send the effluent to a centralist treatment plant, but a treatment is necessary due to toxicity of the effluent at each and every level (Midha and Dey 2008). Generally, for treatment of tannery effluent, physical and chemical methods are generally employed, but they often are unable to remove the contaminants, and they are found to be costly in comparison to biological methods. That is why biological methods are more favorable and cost-effective for treatment of tannery effluents. A group of organisms work together in the presence or absence of oxygen to carry out decomposition of pollutants, as they utilize them as a source of energy or nutrients (Buljan and Kral 2011). Many research works have reported that tannery effluent can be treated by using activated sludge process (Ahmad 2002, Srivastava and Thakur 2006). By using activated sludge process, BOD_5 removal of tannery effluent can be attained to 90–97% as suggested by these studies, which indicate that this process of treatment is highly efficient. We have already discussed the necessity of removal of chromium and other heavy metals from industrial waste effluent not only due to its toxicity to human beings but also its adverse effect on soil fertility. For carrying out removal of heavy metals, a number of physico-chemical methods have been employed, such as precipitation by hydrolysis, use of ion-exchange resins, carbonates and sulphides, membrane separation, adsorption on activated carbon, and bioremediation, despite that effluents emerging out of leather industries (Spiegel et al. 2012).

In recent times, low-cost industrial proven advanced methods have been applied which includes hair-save liming, salt-free preserved raw hides and skins, advanced chrome management system, ammonia free or low ammonia bating, deliming methods and many more. By using above mentioned methods, it is possible to reduce pollution load significantly as BOD5 and COD by more than 30%, ammonia nitrogen by 80%, sulphides by 80–90%, total kjeldahl nitrogen (TKN) by 50%, sulphates by 65%, chlorides by 70%, and chromium by up to 90%.

Generally, in the following different phases, treatment of tannery effluents takes place:

16.5.1 Preliminary Treatment

It is often used in developing countries where common effluent treatment plants is used for examining the tannery clusters and for removal of not only sand/grit, grease, and large particles but also helps in the reduction of sulphides and chromium before the effluent gets discharged into the collection tank.

16.5.2 Primary Treatment

Primary treatment is associated with physico-chemical processes where sedimentation and skimming are used for the removal of settleable organic and inorganic solids. Moreover, the extra advantage of this method includes satisfaction of 25–50% of BOD_5, 65% of oil and grease, and 50–70% of total suspended solids (TSS). The sludge generated from primary sedimentation is known as primary effluent or sludge.

16.5.3 Secondary Treatment

Secondary treatment is related with the biological treatment of the waste, which is carried out in the presence or absence of oxygen by aerobic and anaerobic microorganisms, respectively, or in some cases by facultative microorganisms.

16.5.4 Tertiary Treatment

Tertiary method is employed for the removal of waste constituents that cannot be removed by using primary and secondary treatment methods. This method gets associated with the advanced treatment methods for reduction of residual COD.

Choice of treatment method depends upon a number of factors, such as location of plant in respect to neighboring use of land; if a number of tanneries exist together then cooperative treatment will prove to be more economical as compared with the individual tannery waste treatment. It also depends on the final tannery and discharge standard specified by the law (Dixit et al. 2015).

16.6 Tannery Waste Management Process

After discussing all the harmful impact of tannery industry on the environment, it is the need at present hour to work together in order to find a suitable solution that will help to satisfy our needs of leather and causing minimal/zero effect on the environment. For this, we have to adopt following waste management practices.

16.6.1 Waste Management

Fundamental control practices have to be adopted in order to reduce the harmful impact of tannery industry; the general waste management hierarchy must include prevention and reduction of waste, recycle and reuse along with treatment, and disposal of waste (Tare et al. 2003).

16.6.2 Cleaner Technology for Leather Manufacturing

It will reduce the cost of environmental compliance due to reduction in effluent loadings and saving in chemical cost used in manufacture of leather. The need to adopt cleaner technology emerges environmental imperatives, such as reduction in treatment cost, need to meet specific discharge needs, and to provide occupational safety and health standards (Germann 1999). It is good to see that now a days every tannery industry has developed some wastewater management systems and use several on site cleaning equipments (Mizan et al. 2016).

16.6.3 Management and Disposal of Sludge

The main purpose of sludge management or disposal is not only limited to reduction of material by the weight or volume that has to be transported but also to attain the dry matter content. Sludge coming from primary clarification, secondary clarification, and tertiary clarification is transferred to the sludge thickener by the help of a pumping system. After that, water is removed by sludge drying beds, or in some cases, mechanical dewatering is done by centrifuge. And finally, solid is obtained which can be processed more easily (Dixit et al. 2015).

16.6.4 Utilization of Sludge

Sludge generated from tanneries consists of greater heavy metal content, and greater inorganic matter content especially compound content of chromium and sulfur. A number of methods for disposal or utilization of safe tannery sludge have been proposed, practiced, tested, and applied at industrial scale that consists of vitrification, land filling, composting, stabilization, and anaerobic digestion. But none of the abovementioned methods have been founded to be satisfactory enough, and no effective universal solution has been provided for sludge utilization, till now. So, detailed investigation has to be done in order to provide a solution for sludge utilization.

16.6.5 Some Developed Techniques for Treatment of Tannery Effluents

In recent time, some techniques have been proposed for effective treatment of tannery effluent. Some of them are as follows:

- Application of low-cost absorbent for mitigation of pollution caused by tannery effluents in water (Mottalib et al. 2014).
- Treatment of tannery effluents must be simple and effective (Alvarez et al. 2004).
- Characterization of tannery effluents (beam house) and study of chromium recovery by water hyacinth (Panov et al. 2003).
- Exhausted chrome tanning solution regeneration method (Usha et al. 2017).
- Application of gamma radiation for treatment of wastewater from leather industry (Fettig et al. 2017).
- Use of membrane bioreactor for treatment of wastewater from leather industry (Yusuf 2018).
- Nonconventional application of basic chromium sulphate for wet blue production (Muralidhara et al. 1982).

16.6.6 Tannery Byproduct

Apart from principal product, if we are able to produce some product which has utility to us, it is known as byproduct. In case of tannery some solid waste are produced during processing of skins, as well as in trimming and fleshing process are termed as tannery byproducts.

16.7 Conclusion

Tannery operation is growing rapidly due to its application in the leather manufacturing which acts as a source of foreign exchange. But at the same time, it is imparting a huge burden on environmental agencies to treat them due to its potential to pollute the environment and its belongings. Complex characteristics, such as COD, BOD, chromium, sulphide, suspended matters, and heavy metals, are the main reasons because of which there is difficulty in treating waste associated with tanneries. A series of different methods have been used worldwide, but only few of them have given fruitful results. Efficiency of these methods can be improved by using them in combination of one another, as compared with the application of individual method.

To stop tannery operation for the sake of our environment is not the solution. As it is possible to reduce the pollution potential of the waste effluent below a level so that it can't create a disastrous situation for its inhabitants and provide a safe environment. So active work has to be done by the government agencies to strict the norms and regulations on the permissible level of effluent discharge into the environment. Furthermore, systematic approaches have to be made in order to not only reduce the pollutant but also to recover useful things from it which leads to sustainable development.

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