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Environmental Assessment of Tannery Wastes from Chittagong, Bangladesh

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Abstract: The present paper deals with the study of different physico-chemical parameters as well as metal concentration in the effluents discharged by a leather processing industry, Madina Tannery, Chittagong, Bangladesh. Industrial effluents were collected from every section of the leather-processing unit (viz., preliminary soaking, soaking, dehairing, re-liming, bating, pickling, chrome tanning, neutralization, colouring and fat liquoring). The pH value and concentrations ($mg.l^{-1}$) of TDS, TSS, Cl^-, BOD, COD and Cr were found in the range of 3.4–12.8, 570–85,340, 68–2384, 69–23,125, 1148–8875, 2068–16,231 and 26–6853 respectively. Levels ($mg.l^{-1}$) of BOD, COD, Chloride (Cl^-), Electric Conductivity (EC), Total Alkalinity (TA), Total Dissolved Solid (TDS) and Total Suspended Solid (TSS) were found in the range of 4768–5798, 6636–7859, 1978–2215, 2900–5600, 745–1358, 7068–9068 and 1003–2307 respectively. Metal concentrations ($mg.l^{-1}$) of Cr, Mn, Fe and Cd were found in the range of 69–74, 0.07–0.09, 2.5412–2.8796 and 0.0257–0.0325 respectively. The study reveals that tannery effluents play a key role in environmental contamination.

Introduction

Leather and fur making are the oldest trades of mankind. In the early days, the animals' skins were made first to putrefaction by kneading them with grease, which also made them supple and soft. In addition, the skins were smoked over an open fire to prevent them from rotting. The skins treated in this way were mainly used as fur garments to protect the wearer against the adversities of weather. Over the centuries, newer methods were developed, often as a result of chance discoveries. It was found that the hair could be loosened by wood ash and burnt limestone rocks, which made the manufacture of leather possible. A further discovery was that the skins could be made more resistant if they were treated with leaves and barks containing tannin. Vegetable dyestuffs were even used in the ancient history of colouring purposes. Through the migration of people, the art of leather and fur making gradually spread and by the Middle Ages it had developed into a highly sophisticated craft. Now-a-days, leather production is largely based on the utilization of raw hides and skins, which occur as a waste product in the slaughtering of domestic animals that are kept for meat. From an ecological point of view, the tanner is, therefore, an "important utilizer" of putrescible matters, which would otherwise contribute to an immediate increase in the release of CO_2 into the atmosphere and the much discussed heating up of the earth's climate.

The leather industry in Asian countries is characterized by a number of distinctive features. Many of the countries in the region attach particular importance to the sector in view of enormous potential it offers for fostering employment, nurturing economic growth and increasing exports. At the same time, failure to appreciate the environmental impact and to enforce appropriate

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regulations for waste treatment and management in the leather manufacturing industries has led to land and water degradation. The generations of single characteristic hazardous waste streams of three countries (viz. Estonia, Latvia and Lithuania) are shown in Table 1.

Table 1: Generation of Single Characteristic Hazardous Waste Streams (Tonnes per Year)

	Waste category	*1993*	*1994*	*1995*	*1996*
Estonia	Waste oil	24,710	20,615	15,755	11,863
	Solvents, paints, etc.	1370	920	1794	4186
	Tannery waste	723	652	443	454
	Sludge containing heavy metals	100	54	45	44
Latvia	Waste oil	–	8062	1466	8390
	Solvents, paints, etc.	–	4858	4312	4245
	Tannery waste	–	1400	1470	1400
	Sludge containing heavy metals	–	1200	3520	290
Lithuania	Waste oil	109,906	64,555	73,817	60,945
	Solvents, paints, etc.	222	181	767	1854
	Tannery waste	14,864	13,426	12,506	9136
	Sludge containing heavy metals	2400	1525	2331	605

Bangladesh has 30,000 industrial units, out of which 24,000 are small and cottage industries and the remaining 6000 are large and medium scale industries. In Bangladesh, industrialization was started in the early fifties. That Bangladesh does not have open-handed industrial pollution because of lacking enough industrial growth is not true. Instead, due to mismanagement, inferior technology, lack of facilities for treating wastes, wrong approach towards industrialization and so forth, environmental problems in the industrial sector are acute to varying degrees (World Bank, 1993).

Leather industry is one of the most important export sectors in our economy. Bangladesh, being principally an agricultural country with a sizeable livestock population, has been producing hides and skin since time immemorial. Leather industry is based on locally available hides and skins, which play an important role in the economy of the country. The annual supply of hides and skins in Bangladesh is estimated to be about 18 million square metre. Hardly 18 per cent of the total supply is required to meet the local demand. The rest 82% is exported mainly in the form of crust leather and to some extent finished leather and leather products, thus earning a sizeable amount of foreign exchange for the country. The export earning from the leather sector in 1996-97 was US$222.06 million (EPB of Bangladesh, 97–98). The leather industry in Bangladesh causes horrendous environmental pollution. There are 270 tanneries in the whole country out of which 90% are located in Hazaribagh, a densely populated residential area of Dhaka, the capital city of Bangladesh. Among them, 4.07% are big size units with annual production capacity of more than five million square feet each; 9.62% are medium size with annual production capacity of 1 to 3 million square feet each; 8.5% are light-medium size with annual production capacity of 0.5 to 1 million square feet each and 40.47% are small size with annual production capacity of about 0.5 million square feet each. The rest 37.03% are cottage based with annual production capacity of about 0.5 million square feet each. The pollution caused by the tannery industry results in phenomenal environmental pollution to the soil, ecology and human body. All these tanneries process 240 MT of leather everyday. The tannery units all over the country generate 8.47 million litre liquid waste and 98 MT solid wastes (World Bank, 1993) daily.

Although tannery is one of the most polluting industries in Bangladesh, it is one of the major foreign exchange earners to strengthen the national economy. Leather processing involves a series of chemical operations (e.g., preservation, soaking, liming, reliming, bating, pickling, tanning, retanning, dyeing, fat liquoring, finishing). Most of the operations discharge wastewater consisting of hides scraps, soluble and colloidal proteins, blood, emulsified fatty matters, preservative, bleaching, stuffing, fat liquoring and colouring agent. The wastewater is usually characterized by high levels of pH, suspended and dissolved solids, BOD, COD and strong colour. Moreover, leather processing also involves a series of mechanical and manual operations, which produces solid wastes (e.g., fleshing, scrap leather, shaving dust, buffing dust, etc).

In the area of working environment, an individual has got direct effects on health. All the environmental factors like contaminated air, heat, humidity, ventilation, etc. have got direct influence on the state of health that a person may possess. Substances like chemicals, dyes, metals, gases, fumes, dusts of various substances, etc. may adversely affect health of the people at work. The present works were conducted in the Madina Tannery (Unit I), the largest tannery in Chittagong, which lies at 22º24.168′ N, 91º49.087′ E. The objectives of the present study were to assess Significant Environmental Impacts (SEI), wastewater quality of the tannery effluents of each section of processing and to suggest abatement plan to comply with the sustainable Environmental Quality Standard of Bangladesh (Bangladesh Gazette, 1997).

Materials and Methods

The present study was carried out from February 2000 to January 2001. According to production process, section-wise samples were collected for analytical purposes.

Collection of Tannery Effluent

The effluents were collected from different processing sections. Besides this, a total of five effluent samples were also collected from inlet (sample no. 1), outlet (sample no. 2) and inside of screening tanks (sample nos. 3, 4 and 5).

Analysis of Effluents

The effluents were divided into two portions, one used for the analysis of physico-chemical parameters and the other for the analysis of metals. The different parameters were measured in the laboratory following the standard methodologies.

Physico-Chemical Parameters

pH was measured in the laboratory by microprocessor pH meter (Model No. HI 9321). BOD was determined by incubation method involving the measurement of dissolved oxygen content of the samples before and after five days of incubation at 20°C. BOD was determined by Winkler's method (APHA, 1981). COD was determined by the open reflux method (ibid). Mohr Method was followed for the determination of chloride concentration (ibid). Alkalinity was measured volumetrically by titration method (ibid). Total Dissolved Solids and Total Suspended Solids were determined following standard method (ibid). Electric Conductivity (EC) was measured by EC meter (Model No. 1033).

Heavy Metals Analysis

Preservation of Samples: Samples were collected in pre-cleaned pyrex glass beaker of 500 ml. To avoid bacterial degradation, 2.5 ml of conc. HNO_3 was added to each beaker and shaken homogeneously. The beakers were then carefully preserved in the refrigerator at 4ºC until laboratory analysis.

Digestion and Preparation of Samples: Acidified samples (250 ml) were taken in a pyrex glass beaker followed by the addition of 5 ml. conc. HNO_3. The sample was then evaporated to about dryness on a water bath at 100°C, placing watch glass on the beaker. A blank digestion was also performed to quantify possible contamination. After completion of the digestion, 5 ml de-ionized water was added in the beaker and warmed on the water bath at 100°C for ten minutes. The beaker was then set aside to cool the solution. Then the digested sample and the blank were filtered into separate volumetric flasks (25 ml) by using filter paper (Quantitative Whitman 541) and made the filtrates upto the mark with de-ionized water. To make the volume up to the mark few drops of conc. HNO_3 were added in each flask. The same procedure was followed for each of the sample.

Preparation of Standard Solutions: The standard solutions of Cr, Mn, Fe, Cr, Pb and Cd were prepared by pipetting the required amount of the specific solution from the stock solution (Fisher Scientific Company, Chemical Manufacturing, U.S.A.). The standard solution was prepared before every determination of the analysis of the present work.

Preparation of Calibration Curves: Calibration curves were prepared by plotting the absorption against concentration of the standard solution for each element. Metal concentrations in the samples were measured with the help of those calibration curves. For the calibration curve, the standard solutions were prepared with the concentrations covering the optimum linear absorbance range. In all the absorbance measurements, the reading was taken after the instrumental zero was adjusted. By measuring the absorbance of the standard solutions for respective element, a calibration curve was automatically constructed by the Atomic Absorption Spectrophotometer (AAS) and displayed in the monitor. For preparation of calibration curve of every element, the correlation co-efficient, r was 0.97 to 0.99. The calibration curve was checked occasionally by making measurements with the standard solutions and, if necessary, a new calibration curve was prepared.

Atomic Absorption Spectrophotometric Measurements: After preparing the calibration curves and adjusting all instrumental conditions for respective element, the digested samples were aspirated into Atomic Absorption Spectrophotometer (Hitachi A-1800) by an automatic sampler and the absorbance and concentration data were automatically printed out and displayed. Flame atomization was adapted for the detection of Cr, Mn, Fe, Cu, Pb and Cd with an air acetylene flame in combination with Hollow Cathode Lamp.

Results and Discussion

The effluent qualities of different sections of leather processing unit have been represented in Table 2. Besides this, effluent qualities of five samples have been represented in the Tables 3 and 4. Five effluent samples were collected from the inlet, outlet and inside the screening tank of Madina Tannery. The sample no. 1 was found to contain high concentrations of BOD and COD as 5798 and 7859 $mg.l^{-1}$ respectively. The values of the BOD and COD were found higher than the Bangladesh Standard (BG, 1997). The pH value was found as 7.84, which was within the standard. The concentrations of Cl^{-}, EC and TA were found higher than the values of Sakthival & Sampath (1990). Besides these, TDS and TSS were also found very high (9068 and 2307 $mg.l^{-1}$ respectively), which was also much higher than Bangladesh Standard (BG, 1997). The concentration of Cr was recorded as 74 $mg.l^{-1}$. This value was lesser than the value of Sakthival & Sampath but higher than Bangladesh Standard. The concentrations of Mn, Cu and Cd were found within the limit. On the other hand, Fe and Pb were recorded as 2.8796 and 0.2156 $mg.l^{-1}$ respectively, which were higher than Bangladesh Standard.

Table 2: Physico-chemical Parameters of Effluents from Different Sections of Processing (Per Ton of Hide)

Parameters	*Steps*									
	Preliminary soaking	*Soaking*	*Liming*	*Re-liming*	*Bating*	*Pickling*	*Chrome tanning*	*Neutrali-zation*	*Colouring*	*Fat liquoring*
pH	6.7	7.1	11.8	12.8	8.5	3.7	3.4	6.2	3.7	4.1
TDS ($mg.l^{-1}$)	44,410	9427	21,068	3253	3500	49,071	85,340	4094	2543	570
TSS ($mg.l^{-1}$)	1103	208	2384	1325	68	185	286	231	92	156
Cl^{-} ($mg.l^{-1}$)	23,125	5623	2659	130	688	135	9635	1263	248	72
COD ($mg.l^{-1}$)	7958	3975	16,231	4958	2468	2048	4654	ND	4987	4865
BOD ($mg.l^{-1}$)	2865	1653	8875	3335	1148	1465	2562	ND	2631	2863
Chromium ($mg.l^{-1}$)	ND	ND	ND	ND	ND	ND	6853	26	56	48

ND = Not Detected

Table 3: Physico-Chemical Parameters of Five Samples of Different Sampling Points

Sample No.	*pH*	*BOD ($mg.l^{-1}$)*	*COD ($mg.l^{-1}$)*	*Chloride ($mg.l^{-1}$)*	*EC ($Mmho.cm^{-1}$)*	*TA ($mg.l^{-1}$)*	*TDS ($mg.l^{-1}$)*	*TSS ($mg.l^{-1}$)*
1	7.84	5798	7859	2215	5600	1358	9068	2307
2	7.82	5700	7458	2165	5250	1286	8456	2133
3	8.25	5683	7385	2123	4780	1089	7456	2107
4	8.20	4986	6895	2089	3500	856	7425	2055
5	8.13	4768	6636	1978	2900	745	7064	1003

Table 4: Metal Concentrations of the Five Samples of Different Sampling Points

Sample No.	*Cr ($mg.l^{-1}$)*	*Mn ($mg.l^{-1}$)*	*Fe ($mg.l^{-1}$)*	*Cu ($mg.l^{-1}$)*	*Pb ($mg.l^{-1}$)*	*Cd ($mg.l^{-1}$)*
1	74	0.08	2.8796	0.2289	0.2156	0.0325
2	71	0.07	2.6532	0.2286	0.2036	0.0312
3	70	0.08	2.6321	0.2287	0.2316	0.0309
4	69	0.09	2.6256	0.2358	0.2158	0.0298
5	69	0.08	2.5412	0.2145	0.2245	0.0257

The sample no. 2 was collected just after the first screening. It is desirable to pass the tannery wastes through screens to remove flesh, hair and other large solids. It was found that a considerable reduction in the suspended solids of the tannery could be achieved by sedimentation. The pH value of the sample no. 2 was found within the standard level. The concentrations of BOD and COD were 5700 and 7458 $mg.l^{-1}$ respectively. The values of the BOD and COD were found higher than the Bangladesh Standard. The concentrations of TDS and TSS were recorded as 8456 and 2133 $mg.l^{-1}$ respectively, which were higher than the standard levels (BG, 1997). Beside these, the concentrations of Cl^- and EC were also found lesser than the sample no 1. But those values were higher than the values of Sakthival & Sampath (1990). The concentration of TA was found as 1286 $mg.l^{-1}$, which was lesser than that of the sample no. 1, but higher than the value set by Chakraborty (1985). The concentrations of Cr, Mn, Fe, Cd, Cu and Pb were recorded as 71, 0.07, 2.6532, 0.0312, 0.2286 and 0.2036 $mg.l^{-1}$ respectively. Out of these, only Mn and Cd were found within the levels of Bangladesh Standard (BG, 1997).

In the sample no. 3, it was observed that the concentrations of the maximum parameters were lesser than those of the sample no. 2. The value of pH was found 8.25, which was within the standard (ibid). The concentrations of BOD and COD were found as 5683 and 7385 $mg.l^{-1}$ respectively, which were higher than the values of Sakthival & Sampath (1990). The concentrations of TDS and TSS were found as 7456 and 2107 $mg.l^{-1}$ respectively, which were much higher than the standard for Bangladesh (BG, 1997). The concentration of TA was found as 1089 $mg.l^{-1}$. The concentrations of Cl^- and EC were found higher than the values of Sakthival & Sampath (1990). The Cr concentration (70 $mg.l^{-1}$) was lesser than the standard (Dhanapal et al., 1990). Other metals such as Fe, Cu and Pb were recorded higher (2.6321, 0.2287 and 0.2316 $mg.l^{-1}$ respectively) than the acceptable limit while concentrations of Mn and Cd (0.08 and 0.0309 $mg.l^{-1}$ respectively) were found within the Bangladesh Standard (BG, 1997). Increasing level of Cr (VI) decreases the grain and straw yield. The grain yield reduction over control is 14% at 200 mg Cr (VI)/kg soil due to the transformation of this toxic form to non-toxic $Cr(OH)_3$ (Cary et al., 1977; Kamada & Doki, 1977). Ferric oxide and hydroxide coating in the alluvial particles absorb Cr (VI) and this might eventually react with Fe^{2+} and form relatively insoluble $Cr(OH)_3$. The presence of high level of Fe^{2+} may transform the added toxic form of Cr (VI) to non-toxic Cr (III) (Stollenwerk & Grove, 1985).

In the sample no. 4, the value of pH was found 8.20, which was within the standard (BG, 1997). The concentrations of BOD, COD, TDS and TSS that were recorded from the sample no. 4 (4986, 6895, 7425 and 2055 $mg.l^{-1}$ respectively) were higher than the standard limit (ibid). The concentrations of Cl^-, EC and TA were found higher than the standard levels (ibid). The concentration of Cr was found as 69 $mg.l^{-1}$, which was lesser than the values set by Stollenwerk and Grove (1985). The concentrations of Mn, Fe, Cu, Pb and Cd were found as 0.09, 2.6256, 0.2358, 0.2158 and 0.0298 $mg.l^{-1}$ respectively. Out of these, Mn and Cd were found within the standard levels of Bangladesh (BG, 1997).

In the sample no. 5, the value of pH was found 8.13, which was within the standard (BG, 1997). The concentrations of BOD, COD, TDS, TSS, TA and Cl^- were found as 4768, 6636, 7064, 1003, 745 and 1978 $mg.l^{-1}$ respectively, which were higher than the values of Bangladesh Standard (ibid). The concentration of EC was also found higher than the standard (ibid). The concentrations of Cr, Mn, Fe, Cu, Pb and Cd were recorded as 69, 0.08, 2.5412, 0.2145, 0.2245 and 0.0257 $mg.l^{-1}$ respectively. Among them, only Cd concentration was found within the standard level of Bangladesh (ibid).

Leather is a fibrous protein, called collagen, with minor amounts of lipids, albumins, globulins and carbohydrates. For preparing tanned leather, the processes involved are removal of undesired non-fibrous protein constituents of the hide followed by tanning of the collagen with different tans (e.g., vegetable tan, chrome tan or synthetic tans, etc.) and finishing operations. For the removal of undesirable constituents, the processes involved are curing, fleshing, washing, soaking, dehairing, lime splitting, bating and degreasing. The finishing operation includes bleaching, stuffing, fat liquoring and colouring. In Bangladesh, tanning is mainly done either through vegetable tans (oak or *Quebracho* bark extracts) or chromes tan (basic chrome sulphate).

In the preliminary soaking section, due to the presence of salt, blood, hair and other fatty substances, the concentration of TDS, TSS and chloride were found too high (44,410, 1103 and 23,125 $mg.l^{-1}$ respectively). The concentrations of BOD and COD were found in abundance as 2865 and 7958 $mg.l^{-1}$ respectively. Those values were higher than the standard values (Chakrabarty, 1985) and the Bangladesh Standard (BG, 1997). The concentration of pH was found to be slightly acidic (6.7).

In the soaking section, the concentration of TDS, TSS and Cl^- were also high (9427, 208 and 5623 $mg.l^{-1}$ respectively). Those values were much higher than the standard values (Chakrabarty, 1985). The concentrations

of BOD and COD were also found in abundance as 1653 and 3975 mg.l^{-1} respectively, which were higher than the Bangladesh Standard (BG, 1997). The concentration of pH was found to be alkaline (7.1). Virtually, chemicals both in number and quantity used in the tannery were enormous. Wetting agents, sharpening agents (i.e., catalysts to intensify chemical reactions), alkalis and bactericides were also used for soaking purpose. A little quantity of these chemicals was found to remain unused. Besides, by-products like proteoglycans, blood, hair, etc. would lead to increased pollution. Carbon dioxide, produced from sodium carbonate, would increase the level of carbon dioxide in the air, which through inhalation might cause senselessness to the workers and damage to their lungs. In fact, the tannery labourers were directly exposed to carbon dioxide and other health hazardous substances including disgusting smell produced from the rotten wastes. Due to the presence of many chemicals, the concentrations of BOD and COD in liquid waste were found in abundance (1653 and 3975 mg.l^{-1} respectively), which were lesser than previous section, but higher than the Bangladesh Standard (ibid).

In the liming section, sodium sulfide, sodium bisulfide, calcium oxide and molasses were mainly used, which resulted in the fully alkaline effluents. The concentrations of TDS and TSS were found as 21,068 and 2384 mg.l^{-1} respectively, which were higher than the standard values (Chakrabarty, 1985; Dhanapal et al., 1980). Chloride ion was found as 2659 mg.l^{-1}, which was lesser than the soaking section. The concentration of BOD and COD were found as 8875 and 16,231 mg.l^{-1} respectively, which were higher than the set values (Chakrabarty, 1985) and Bangladesh Standard (BG, 1997). The concentration of pH was found to be alkaline (11.8). It was evident that maximum level of environmental pollution occurs at the liming stage because most of the tannery wastes are produced at this stage.

Ammonium sulfate and sodium meta-bisulfite were mainly used in the re-liming section. The effluents of this section were found fully alkaline and the pH value was found as 12.8. The concentrations of BOD and COD were found as 3335 and 4958 mg.l^{-1} respectively, which were higher than the standard values (Dhanapal et al., 1980) and Bangladesh Standard (BG, 1997), but lower than the values suggested by Khan (1996–97). Furthermore, the Cl^- concentration was found as 130 mg.l^{-1}, which was lesser than the suggested values (ibid). The concentrations of TDS and TSS were found 3253 and 1325 mg.l^{-1} respectively, which were lesser than the previous section but almost equal to the standard values (Chakrabarty, 1985).

In the bating section, alkaline bating agent (i.e., Pancreol EG-98) and degreasing agent (i.e., Mollescal FA 607) were used. Pancreol EG-98 was used for bating and Mollescal FA 607 was used for removing fat. The pH value was found as 8.5, which was lesser than the re-liming section. The concentrations of TDS and TSS were found as 3500 and 68 mg.l^{-1} respectively. The concentration of TDS was found higher than the value of Dhanapal et al. (1980) and Bangladesh Standard (BG, 1997). The concentrations of BOD and COD were found as 1148 and 2468 mg.l^{-1} respectively, which were higher than Bangladesh Standard (ibid). The Cl^- concentration was found as 688 mg.l^{-1}, which was higher than the value suggested (Khan, 1996–97).

NaCl, sulfuric acid and different bleaching agents were used in the pickling section. Due to the use of sulfuric acid, the effluents of this stage were found fully acidic and the pH value was found as 3.7. The concentration of Cl^- was found as 135 mg.l^{-1}, which was lesser than the suggested value (ibid). The concentration of TDS and TSS were found as 49,071 and 185 mg.l^{-1} respectively, which were higher than the values of Chakrabarty (1985) and Bangladesh Standard (BG, 1997). The concentrations of BOD and COD were found as 1465 and 2048 mg.l^{-1} respectively, which were higher than Bangladesh Standard (ibid) and almost similar to the results of Dhanapal et al. (1985).

It was found that during chrome tanning, only 68-74% of tan (i.e., chrome sulphate) was utilized by the skins. Consequently, a large amount of chrome sulphate was drained out as effluent, making the effluent colour green. The pH was found as 3.4. The concentration of TDS was found to be the highest (85,340 mg.l^{-1}) for the present study and higher than the values of Chakrabarty (1985) and Dhanapal et al. (1990). The concentration of TSS, BOD and COD were found as 286, 2562 and 4654 mg.l^{-1} respectively, which were higher than the values for Bangladesh Standard (BG, 1997) and Chakrabarty and Dhanapal et al. (op cit). Those values were higher than that of the pickling section due to the use of alkaline chrome sulfate in large quantity and other chemicals. The concentration of Cl^- was found as 9635 mg.l^{-1}, which was higher than the value suggested by Khan (1996–97). The concentration of Cr was found as 6853 mg.l^{-1}, which was higher than the standard value (Agarwal & Arumugan, 1975) and Bangladesh Standard (BG, 1997). This effluent containing the highest concentration of Cr absorbed in the soil for a long time might reach even the deep underground water layer and thus polluting the underground water severely.

In the Madina Tannery, sodium carbonate, sodium bicarbonate, sodium formate, sodium thiosulfate, borax, syntan, etc. were used in neutralization section. In the effluents of this section, the pH was found as 6.2. The concentrations of TDS and TSS were found as 4094 and 231 mg.l^{-1} respectively, which were higher than normal (Dhanapal et al., 1990). The concentration of Cl^- was found as 1263 mg.l^{-1}, which was higher than the value suggested (Khan, 1996–97). The concentration of Cr was found as 26 mg.l^{-1}, which was higher than the value of Bangladesh Standard (BG, 1997). The colouring or dyeing was done during re-tanning process. Usually, dyeing was done in the liquor obtained after neutralization of the solution in which rechroming had been carried out. Since rechroming and dyeing were done in the same solution, the concentrations of BOD and COD of the effluents were found to increase after dyeing. During dyeing, leveling agent, fixing agent, vegetable extract, tanning agent and syntan were used for bringing varied effects. These chemicals might increase environmental pollution. However, the value of pH was found 3.7 in the effluent of this section. The concentrations of BOD, COD, TDS and TSS were found as 2631, 4987, 2543 and 92 mg.l^{-1} respectively. The concentrations of BOD, COD and TDS were found higher than the standard values (Chakrabarty, 1985; Dhanapal et al., 1990) and Bangladesh Standard (BG, 1997). The concentration of Cr was found as 56 mg.l^{-1}, which was higher than the value of Bangladesh Standard (ibid). These levels indicate that a severe pollution occurs at dyeing stage in the tannery.

In the fat liquoring section, fish oil, SLP (i.e., fat solution containing negative ions), formic acid, etc. were used. The steps at this stage were decided on the quality of the leather and the targeted standard for leather. The pH value was found as 4.1. The concentrations of TDS and TSS were found as 570 and 156 mg.l^{-1} respectively, which were lesser than that of the colouring section. The value of TDS was found lower and that of TSS was higher than Bangladesh Standard (ibid). The concentrations of BOD and COD were found as 2863 and 4865 mg.l^{-1} respectively, which were higher than the standard values (Chakrabarthy, 1985; Dhanapal et al., 1990) and Bangladesh Standard (BG, 1997). The concentration of Cl^- was found as 72 mg.l^{-1}, which was lesser than the value of Khan (1997). The concentration of chromium was found as 48 mg.l^{-1}, which was lesser than the value of Agarwal & Arumugan (1975).

Wastewater from tanneries contains a high proportion of biologically oxidizable materials in solution and also large quantities of putrescible suspended matter, which might form the bulk of sludge on the bed of a river and, particularly in hot weather, might deoxygenate the water emitting foul-smelling gases. Vegetable tanning liquors are dark in colour and might discolour river water for a long distance from the point of discharge. This discolouration is accentuated when the water contains iron, with which tanning liquors interact to form black compounds. Lime, when present in high concentrations, might block sewers by forming loose deposits or adherent calcium carbonate scale. The presence of toxic substances and solvents might inhibit biological processes. Tanning wastes, when discharged untreated, might adversely affect aquatic life, particularly fish and algae, apart from becoming unfit for irrigation and human consumption. Thus, the composite waste from a tannery might cause severe pollution.

Organic pollutants like proteins and vegetable tanning, and the presence of sulphate in the waste, might give rise to nuisance odour, when allowed to stagnate. The persistent colour of the waste might give an unsightly appearance. Similar to other countries, the Government of Bangladesh also limits for the disposal of tannery effluents in order to protect the natural water resources (Table 5).

Table 5: Bangladesh Standard for the Effluents of Tannery Industry

Parameters	*Bangladesh standard*
pH	6–9
TSS (mg.l^{-1})	150
TDS (mg.l^{-1})	2100
BOD (mg.l^{-1})	100
COD (mg.l^{-1})	200
Cl^- (mg.l^{-1})	600
EC (Mmho.cm^{-1})	1200
Cr (mg.l^{-1})	2
Fe (mg.l^{-1})	2
Pb (mg.l^{-1})	0.1
Mn (mg.l^{-1})	5
Cd (mg.l^{-1})	0.05
Cu (mg.l^{-1})	0.5

(*Source:* Bangladesh Gazette, 1997)

From the present study, it was revealed that tannery wastes contain large amount of toxic substances as well as heavy metals, which are threatening our environment. For the sake of our environment, proper waste management and environmental rules should be followed strictly. Otherwise, the nation has to pay much for this dreadful menace.

Conclusion and Recommendations

In general, the leather and leather goods producing industries are highly concerned in term of their effects resulting in environmental pollution. So, their management practices should undergo a sustainable and environment friendly manner. In each step of work in the leather industry, some precautionary measures should be followed strictly so as to minimize the load of environmental contaminants as well as hygienic conditions of the workers. From the present study, it was revealed that some of the following recommendations might hold well in order to have a safer and environment friendly sustainable management system:

- Correct amount of chemicals should be used to help reduce the pollution.
- Solid wastes should be buried under soil at a distant place from residential area.
- The labourers must wear masks, gloves and apron to avoid physical contact with poisonous gases and other corrosive chemicals.
- Dehairing should be followed with the process of enzymatic dehairing (with bacteria) rather than using sodium sulphite.
- The sulfur dioxide gas should be neutralized by using lime or lime stone solution.
- Re-liming should be followed preferably with CO_2 rather than ammonia salts.
- Chromium should be recycled and its reuse must be ensured.
- The consumers must be cautious about using leather goods. If possible they should test the level of unused chromium in the leather goods before using it.
- The operator must be very careful while operating the shaving machine, which has fine and sharp blade.
- Benziding free dyes should be used.
- The finishing should be applied in padding (made of cloth), roller coating or carton padding methods to reduce the air pollution.

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References

Agarwall, G. D. and V. Arumugan (1975). Economic Analysis of the recovery of Chromium from chrome tanning industrial wastes. Proceedings of National Symposium on Planning Desert and Conservation of India, Tircuchirapalli, India, 1975, Series 2, 5-9.

APHA (American Public Health Association) 1981. Standard Methods for the Examination of Water and Wastewater, 15th edition, American Public Health Association, American Water Works Association and Water Pollution Control Federation, Washington DC; pp. 1134.

BG (Bangladesh Gazette) (1997). Bangladesh Environmental Preservation Rules, Dept of Environment and Forest, Govt. of the Peoples Republic of Bangladesh, Dhaka, 3103 –3146.

Cary, E. E., Allaway, W. H. and O. E. Olsen (1977). Control of chromium concentration in food plants. Chemistry of chromium in soils and its availability to plants. *Journal of Agricultural and Food Chemistry*, **25:** 305-309.

Chakrabarty, R.N. (1985). An industrial waste survey report. Part I: Tanneries of Uttar Pradesh. *Indian Journal of Environmental Health*, **7:** 235-247.

Dhanapal, S., Sivakumar, A. A., Logankumar, K. and M. Aruchami (1990). Toxicity of tannery effluent on the fish, *Sarotherodon mossambicus*. *Indian Journal of Environmental Health*, **32:** 153-156.

EPB (Export Promotion Bureau of Bangladesh), Bangladesh Export Statistics 1997-98, Government of the Peoples Republic of Bangladesh, Dhaka.

Kamada, K. and R. Doki (1977). Movement of Cr in submerged soil and growth of rice plant (ii). Influence of two different kinds of soil and addition of Fe(I) on injury of rice plant by Cr (VI). *Journal of Soil Science*, **48:** 457-465.

Khan, M.H. Pollution Control Strategies for Industrial Areas: The Case of Hazaribagh Tanneries, Dhaka. MSc Program in Urban Environmental Management, September 1996-December 1997, 73-89.

Sakthivel, M. and K. Sampath (1990). Respiration, blood cells and food conversion efficiency in *Cyprinus carpio* exposed to sublethal concentrations of tannery effluents. *In:* Environment and Experimental Toxicology. P.B. Deshmukh, A.T. Mathai, R.C. Dalela and K.S. Pillai (eds.) Jai Research Foundation, Valvada. 139-150.

Stollenwerk, K.G. and D.B. Grove (1985). Absorption and description of hexavalent chromium in an alluvial aquifer near Telluride, Colorado. *Journal of Environmental Quality*, **14:** 150-155.

WB (World Bank) (1993). Exports Prospects for Leather and Leather Products: Industrial Strategy Study of Bangladesh. Paper no. 12, 128-130.