CHAPTER 7

SUMMARY AND CONCLUSION

7.1 SUMMARY

There are nearly 1500 tanneries in India processing 0.7 million tons of wet salted hides and skins per year. It was estimated that for every ton of hides or skins processed into leather, 30-50 m$^3$ of wastewater and 200-300 kg of limed fleshings were generated. Limed fleshings and tannery effluent samples from different clusters were collected and characterized. The average composition of volatile solids was found to be 0.67 ± 0.08 g/g dry wt. and COD was in the range of 0.79 ± 0.08 g/g dry wt which indicate high biomethanization potential of limed fleshings.

Preliminary investigations were carried out in order to study the effect of various pretreatment methods such as (i) Mechanical (ii) Thermo-chemical and (iii) Biological on liquefaction of limed fleshings. Liquefaction of limed fleshings was estimated in terms of particle size reduction, soluble organics (COD$_s$) and volatile fatty acids production. The effect of mechanical pretreatment on liquefaction of limed fleshings was studied by blending the limed fleshings samples in a commercial blender for a duration of 30, 60 and 90 seconds, after heating LF at 70°C for 15 minutes and blended samples were passed through 3.35 mm sieve.

The effect of thermo-chemical pretreatment using alkalis like sodium hydroxide (NaOH), potassium hydroxide (KOH), calcium hydroxide
(Ca(OH)$_2$) and sodium carbonate (Na$_2$CO$_3$) with varying concentrations of 1,2,3,4 and 5% solutions, was studied by subjecting the samples to a pressure of 1 kg/cm$^2$ at a temperature of 120ºC for 15 minutes.

Similarly, the experimental investigations were carried out to study the effect of biological pretreatment on liquefaction of limed fleshings using inoculums, (i) anaerobically treated tannery effluent (ii) aerobically treated tannery effluent and (iii) anaerobic sludge. Effect of biological pretreatment with inoculum from anaerobically treated tannery effluent on liquefaction of limed fleshings were studied with volatile solids percentage of 0.75, 1.12, 1.5, 1.8 and 2.25; inoculum from aerobically treated tannery effluent on liquefaction of limed fleshings with volatile solids percentage of 0.75, 1.12, 1.5, 1.8 and 2.25 and inoculum from anaerobic sludge on liquefaction of limed fleshings with volatile solids percentage of 6.6, 13.3 and 20. Liquefaction of limed fleshings was estimated in terms of particle size reduction, soluble organics (COD$_s$) and volatile fatty acids production.

Based on the outcome of the preliminary liquefaction studies, further laboratory scale investigations were carried out on biochemical methane potential of liquefied limed fleshings pretreated with NaOH, KOH and anaerobically treated tannery effluent (1.5% VS) as inoculum.

Based on the outcome of laboratory investigations on BMP, further long term bench scale studies on the effect of biomethanization on combined treatment of liquefied limed fleshings and tannery effluent were carried out for a period of 14 months using bench scale UASB reactors. The reactors were seeded with sludge from active pilot scale UASB reactor and experiments were carried out at constant temperature. Effect of organic loading rate and hydraulic retention time were investigated simultaneously on (i) combined treatment of tannery effluent and liquefied limed fleshings and (ii) tannery effluent alone.
Based on the outcome of the bench scale studies carried out, kinetic constants were arrived at for both the reactors treating tannery effluent with liquefied limed fleshings and tannery effluent alone by varying HRT, OLR and θc the same was used to the design of pilot scale reactor. Pilot scale studies were conducted using 12.5 m$^3$ capacity UASB reactor. 200 kg of limed fleshings after liquefaction was mixed with 30 m$^3$ tannery effluent and pumped into UASB reactor for combined treatment of liquefied limed fleshings and tannery effluent.

Based on the outcome of the above bench and pilot studies, techno economic analysis was carried out for a typical tannery cluster processing 150 tons of raw hides and skins per day, which would generate about 5000 m$^3$/day of tannery effluent and 30 tons/day of limed fleshings. Common effluent treatment plants with two process options were designed, (i) treating tannery effluent alone in open anaerobic lagoon for a design flow of 5000 m$^3$ per day; and (ii) combined treatment of tannery effluent along with liquefied limed fleshings in UASB reactor for design flow of 5090 m$^3$ per day. A full scale plant was designed for solid retention time of 25 days, HRT of 24 h, MLVSS concentration of 20 kg/m$^3$ and COD removal efficiency of 75 %. Cost estimation for civil, mechanical, electrical, instrumentation, operation and maintenance were done and the unit cost of treatment per ton of hides or skins processed was arrived at based on the annualized capital cost, operating cost and financial returns due to energy recovery and CER generated for combined treatment of tannery effluent and liquefied limed fleshings.

7.2 CONCLUSION

The following conclusions could be drawn from the studies:

1. Characterization of limed fleshings was carried out. The size of the fleshings was found to be in the range of 30-350 mm.
and the volatile solid content was in the range of 0.67 ± 0.08 g/g dry wt and COD was in the range of 0.79 ± 0.08 g/g dry wt indicating high biomethanization potential. It was found that mechanical pretreatment of limed fleshings was not very effective. Since, only 48% of limed fleshings was reduced to less than 3.35 mm and operational troubles such as frequent damage to the blades of blender were observed due to impurities such as grit prevalent in limed fleshings.

2. It could be seen from the thermo-chemical pretreatment studies carried out that the liquefaction of limed fleshings was feasible and could be achieved using NaOH, KOH, Ca(OH)$_2$ and Na$_2$CO$_3$. It was observed that maximum liquefaction in terms of soluble organics (COD$_s$) found to be in the following order: 91% (KOH) > 90% (NaOH) > 86% (Na$_2$CO$_3$) > 82% (Ca(OH)$_2$) and in terms of size reduction, (particles passing through 3.35 mm) was in the following order: 100% (KOH) > 100% (NaOH) > 90% (Na$_2$CO$_3$) > 85% (Ca(OH)$_2$). It was also observed that liquefaction of LF in terms of VFA production was in the order of 2.7% (KOH) > 2.4 % (NaOH) > 2.2% (Na$_2$CO$_3$) > 2% (Ca(OH)$_2$) for limed fleshings pretreated with 5% alkali. Hence, further studies were carried out on thermo-chemically pretreated limed fleshings using 5 % NaOH and KOH which were more effective.

3. It could be concluded from the biological pretreatment studies on liquefaction of limed fleshings that maximum liquefaction could be achieved in 8 days and liquefaction, in terms of soluble organics (COD$_s$), was in the following order: 93% (inoculum from anaerobically treated tannery effluent) > 62%
(inoculum from anaerobic sludge) > 29% (inoculum from aerobically treated tannery effluent). Similarly, VFA conversion in terms of acidification efficiency, was in the order of 48% (inoculum from anaerobically treated tannery effluent) > 12% (inoculum from anaerobic sludge) > 1% (inoculum aerobically treated tannery effluent). Hence, it could be concluded that inoculum from anaerobically treated effluent was more efficient than other inoculums. Though, size reduction, in terms of particles passing through ISS 3.35 mm was observed for all biological pretreatment methods, however, for samples pretreated with anaerobically treated tannery effluent as inoculum, the particle size of liquefied limed fleshings was found to be in the range of 2 µm to 200 µm.

4. Based on the laboratory scale studies carried out on biochemical methane potential of liquefied limed fleshings, it was found that biologically pretreated limed fleshings with inoculum from anaerobically treated tannery effluent with volatile solids of 1.5%, was more effective and could generate methane yield of 0.16 m$^3$ per kg COD added and the methane yield was found to be 2.7 and 1.5 times more than the yield for thermo-chemical pretreatment by NaOH and KOH respectively. Hence, it could be concluded that biological pretreatment of limed fleshings with inoculum from anaerobically treated tannery effluent could be an appropriate method to be adopted by the industry for enhancement of biomethenization.

5. It could be concluded from the long-term bench scale continuous studies conducted for a period of 14 months on
combined treatment of liquefied limed fleshings and tannery effluent that the additional methane yield upto 37.5% was found feasible compared to the methane yield from tannery effluent treatment alone. It was found that COD removal efficiency was 75% with methane yield of 0.29 m$^3$/kg of COD removed for an optimum OLR of 12 kg/m$^3$.day with an optimum HRT of one day. Based on the results from the experimental investigations, it could be concluded that methane yield could be enhanced upto 22 m$^3$/metric ton of hides or skins processed from combined treatment of liquefied limed fleshings and tannery effluent, whereas the methane yield was only in the order of 16 m$^3$/metric ton of hides or skins processed from tannery effluent treatment alone.

It was observed that only 53% gas was recovered i.e 0.29 m$^3$/kg of COD removed, against theoretical value of 0.388 m$^3$/kg of COD removed in treating TE and LLF. Balance COD were accounted towards dissolved methane (1%), untreated COD in effluent (25%), sulphate reduction (10%) and new cell formation (11%).

6. It could also be concluded from the bench scale studies that the kinetics and mathematical modeling were $Y$ and $k_d$, were 0.190 mg VSS/mg of COD and 0.007 d$^{-1}$ respectively for combined treatment of TE and LLF, whereas, $Y$ and $k_d$ were found to be 0.179 mg VSS/mg of COD and 0.006 d$^{-1}$ respectively for treating TE alone.

7. It could be concluded from the 12.5 m$^3$ capacity pilot scale reactor designed based on kinetics arrived from bench scale studies that combined treatment of liquefied limed fleshings
and tannery effluent with 200 kg of limed fleshings and 30 m$^3$ of tannery effluent, the methane yield of 0.29 m$^3$/kg of COD removed could be obtained with COD removal efficiency of 75% and HRT of 25 h.

8. It could be concluded from the techno economic analysis carried out for a typical cluster of tanneries processing 150 tons of hides or skins and generating 5000 m$^3$ per day of TE and 30 tons/day of LF, the capital cost for CETP for treating TE alone in anaerobic lagoon (option I) was estimated as `37.7 million/MLD. Similarly, for combined treatment of TE and LLF in UASB reactor (option II) unit capital cost was estimated as `39.2 million/MLD. The unit capital cost based on per ton of hides or skins processed works out to `1.26 million and `1.3 million respectively. It could be seen that the capital cost increased by `7.3 million due to additional cost towards liquefaction and UASB reactor system required for pretreatment of LF and treating along with TE, which is 3.8% higher.

9. Similarly, the total annualized unit cost for treatment of tannery effluent works out to `82.9 million for a design flow of 5 MLD and the same for combined treatment of tannery effluent and liquefied limed fleshings for a design flow of 5090 m$^3$/day works out to `79 million. The unit cost works out to `1842 and `1758 per ton of hides or skins processed for a typical tannery cluster processing 150 tons of raw hides and skins per day and generating about 5000 m$^3$/day of tannery effluent and 30 tons/day of limed fleshings for option I and II respectively.
10. Financial benefits considering electrical energy recovery, based on outcome of the present study, the unit cost for treatment comes down from `1842 to `1589 per ton of hides or skins processed, which indicates a reduction of 14%. Further, the unit cost considering the CDM benefits of 13036 CER generated based on methane capture at the rate of €15/CER and exchange rate of `65, treatment cost further comes down from `1589 to `1306 per ton of hides or skins processed, which indicates an overall reduction of 29% in the unit cost for a typical tannery cluster processing 150 tons of raw hides and skins per day and generating about 5000 m$^3$/day of tannery effluent and 30 tons/day of limed fleshings. The payback period works out to be 4 months only for combined treatment of tannery effluent and liquefied limed fleshings based on the findings of the present study. Hence, outcome of the investigation led to improvement in energy recovery and also eliminates the disposal problems of limed fleshings. In addition, it dispenses away with the necessity of a separate anaerobic digester for biomethanization of limed fleshings besides CDM benefits.

7.3 SCOPE FOR FURTHER STUDY

The scope for further work in this area of research is listed below:

1. Effect of sulphide recovery and recirculation of treated effluent on gas production shall be studied.

2. Liquefaction studies may be carried out for other animal organic wastes, for mitigation of global warming potential due to dumping of such wastes.