ABSTRACT

There are nearly 1500 tanneries in India processing 0.7 million tons of wet salted hides and skins per year. It has been estimated that for every ton of hides or skins processed into leather, 30-50 m$^3$ of tannery effluent (TE) and 200-300 kg of limed fleshings (LF) is generated. LF could not be disposed off in landfills due to high volatile solids content, which has high potential for bio-energy generation. Further the enormous global warming potential (GWP) of methane generation during dumping of LF has created a lot of concern and there is a need to address the issue considering the Clean Development Mechanism (CDM) benefits. If LF could be liquefied by adopting appropriate pretreatment methods, the liquefied LF could be mixed with TE and treated in a biomethanization reactor treating TE. This approach not only improves energy recovery but also eliminates the disposal problems of LF and dispense with the necessity of a separate anaerobic digester for biomethanization of LF besides CDM benefits.

Experimental investigations were carried out initially to study the effect of various pretreatment methods such as mechanical, thermo-chemical and biological on liquefaction of LF. The extent of liquefaction of LF was estimated in terms of soluble organic content (COD$_s$), particle size reduction, and volatile fatty acids production. Mechanical pretreatment of LF was not found to be very effective. The effect of thermo-chemical pretreatment on
liquefaction of LF was studied using alkalis like NaOH, KOH, Ca(OH)$_2$ and Na$_2$CO$_3$ with varying concentrations of 1,2,3,4 and 5% solutions. Similarly, the experimental investigations were carried out to study the effect of biological pretreatment on liquefaction of LF using inoculums, anaerobically treated TE, aerobically treated TE and anaerobic sludge. From biological pretreatment studies on liquefaction of LF, it was found that the maximum liquefaction could be achieved in 8 days. From the results, it could be concluded that inoculum from anaerobically treated effluent was more efficient than the other two inoculums on liquefaction of LF.

Based on the outcome of the preliminary liquefaction studies, further laboratory scale investigations were carried out on Biochemical Methane Potential (BMP) of liquefied LF pretreated with NaOH, KOH and anaerobically treated TE (1.5% VS) as inoculum. From the BMP studies, it was observed that biologically pretreated LF with inoculum, anaerobically treated TE with volatile solids of 1.5% was 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 with LF pretreated with NaOH and KOH respectively.

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 LF and TE were carried out using Upflow Anaerobic Sludge Blanket (UASB) reactors for a period of 14 months. It was also found that COD removal efficiency was 75% and methane yield was 0.29 m$^3$/kg of COD removed for the optimum Organic Loading Rate (OLR) of 12 kg/m$^3$.day
and optimum Hydraulic Retention Time (HRT) of one day. From the bench scale studies conducted on combined treatment of TE and liquefied LF, it could be concluded that the methane yield could be enhanced up to 37.5% over and above the methane yield from treatment of TE alone. Pilot scale studies were then conducted on combined treatment of liquefied LF and TE using a 12.5 m$^3$ capacity UASB reactor. Based on the outcome of the bench and pilot scale 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 TE and 30 tons/day of LF. Common effluent treatment plants (CETPs) with two process options were considered: (i) treating TE alone using open anaerobic lagoon for a design flow of 5000 m$^3$ per day (option I); and (ii) combined treatment of TE along with liquefied LF using UASB reactor for design flow of 5090 m$^3$ per day (option II). Cost estimation for civil, mechanical, electrical, instrumentation and operation and maintenance were done to arrive at the unit cost of treatment per ton of hides or skins processed based on the annualized capital cost, operating cost and financial returns due to energy recovery and CER generated for combined treatment of TE and liquefied LF.

Based on the techno-economic analysis carried out, the unit capital cost for CETP, treating TE alone, using anaerobic lagoon was estimated as `37.7 million / MLD. Similarly, for combined treatment of TE and liquefied LF in UASB reactor, the 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 was
estimated that the total annualized unit cost for treatment works out to `82.9 million and `79 million for treatment of TE alone for a design flow of 5000 m³/day and combined treatment of TE and liquefied LF for a design flow of 5090 m³/day respectively. The unit treatment cost works out to `1,842 and `1,758 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 m³/day of TE and 30 tons/day of LF excluding electrical energy recovered. Considering financial benefits expected through electrical energy recovery based on outcome of the present study, the unit cost for treatment comes down from `1,842 to `1,589 per ton of raw hides or skins processed, which indicates a cost reduction of 14%. Considering the CDM benefits of 13036 CER generated based on methane capture at the rate of €15/CER and exchange rate of `65, the unit cost comes down from `1589 to `1306 per ton of hides or skins processed, which indicates overall reduction of 29% in the unit cost. The payback period works out to be 4 months only for combined treatment of TE and liquefied LF based on the outcome of the present study.