CHAPTER 4

 METHODOLOGY FOR CLEAN DEVELOPMENT MECHANISM AND TECHNO-ECONOMIC ANALYSIS

4.1 METHODOLOGY FOR CLEAN DEVELOPMENT MECHANISM (CDM)

Certified emission reduction (CER) arrived as per the guideline of UNFCCC by replacing of anaerobic lagoon by UASB reactor for treatment of TE and replacement of open dumping of fleshings by liquefaction and treatment of LLF in UASB for tannery cluster. Baseline emission was calculated based on equation 4.1, project emission was calculated based on equation 4.4 and emission reduction was calculated based on equation 4.5.

Baseline Emissions are estimated as follows:

\[
BE_y = BE_{CH_4,y} + BE_{EL,y} + BE_{HG,y} \tag{4.1}
\]

where

\[
BE_y = \text{Baseline emission in year } y \ [\text{tCO}_2\text{e/yr}]
\]

\[
BE_{CH_4} = \text{CH}_4 \text{ emissions from anaerobic treatment of the wastewater in open lagoons } [\text{tCO}_2\text{e/yr}]
\]

\[
BE_{EL,y} = \text{CO}_2 \text{ emission from electricity consumption in the absence of the project activity in year } y \ [\text{tCO}_2\text{e/yr}]
\]

\[
BE_{HG,y} = \text{CO}_2 \text{ emission from fossil fuel combustion for heating equipment that is displaced by the project in year } [\text{tCO}_2\text{e/yr}]
\]
Calculation of Baseline Emissions from Anaerobic Treatment of the Wastewater

Step 1: Methane conversion factor method

\[
BE_{CH_4,y} = GWP_{CH_4} \times MCF_{BL,y} \times B_O \times COD_{BL,y}
\]  
(4.2)

\[
BE_{CH_4,y} = \text{Methane emission from anaerobic treatment of the wastewater in open lagoon in a year } y \ [tCO_2e/yr]
\]

\[
GWP_{CH_4} = \text{Global warming potential of methane } [tCO_2e/yr]
\]

\[
B_O = \text{Maximum methane producing capacity, expressing the maximum amount of methane that can be produced from a given quantity of chemical oxygen demand } [tCH_4/tCOD]
\]

\[
MCF = \text{Average baseline Methane conversion factor (fraction) in year } y
\]

\[
COD_{BL,y} = \text{Quantity of COD that would be treated in open lagoons in the absence of UASB } [tCO_2e/yr].
\]

Step 2: Baseline Emissions from generation and / or consumption of electricity

\[
BE_{EL,y} = (EC_{BL,y} + EG_{PJ,y}) \times EF_{BL,EL,y}
\]  
(4.3)

where \( BE_{EL,y} = \text{CO}_2 \text{ emissions associated with electricity generation that is displaced by the project activity } / [tCO_2e/yr] \)

\[
EC_{BL,Y} = \text{Annual quantity of electricity that would be consumed in the absence of the project activity for the treatment of the wastewater } [tCO_2e/yr]
\]
$\text{EG}_{\text{PJ},y} = $ Net quantity of electricity generation from new anaerobic digester [MWh/yr]

$\text{EF}_{\text{BL,EL},y} = $ Baseline emission factor for electricity generated / consumed in the absence of the project activity in year [tCO$_2$/MWh]

Project emissions are estimated as follows:

$$\text{PE}_y = \text{PE}_{\text{CH}_4,\text{effluent},y} + \text{PE}_{\text{CH}_4,\text{digest},y} + \text{PE}_{\text{flare},y} + \text{PE}_{\text{Sludge, LA},y} + \text{PE}_{\text{EC},y} + \text{PE}_{\text{FC},y} \quad (4.4)$$

where

- $\text{PE}_y = $ Project emissions in year $y$ [tCO$_2$/yr]
- $\text{PE}_{\text{CH}_4,\text{effluent},y} = $ Project Methane Emissions from Effluent from the Reactor [tCO$_2$/yr]
- $\text{PE}_{\text{CH}_4,\text{digest},y} = $ Project Emissions Related to Physical Leakage from the Reactor [tCO$_2$/yr] (2% leakage is considered)
- $\text{PE}_{\text{flare},y} = $ Project Emissions From Land Application of Sludge [tCO$_2$/yr]
- $\text{PE}_{\text{Sludge, LA},y} = $ Project Emissions From Land Application of Sludge [tCO$_2$/yr]
- $\text{PE}_{\text{EC},y} = $ Project Emissions from Electricity Consumption [tCO$_2$/yr]
- $\text{PE}_{\text{FC},y} = $ Project Emissions from Fossil Fuel Combustion [tCO$_2$/yr]

$$\text{ER}_y = \text{BE}_y - \text{PE}_y \quad (4.5)$$

where

- $\text{ER}_y = $ Emissions reductions of the project activity in year $y$ [tCO$_2$/yr]
- $\text{BE}_y = $ Baseline emissions in year $y$ [tCO$_2$/yr]
- $\text{PE}_y = $ Project emissions in year $y$ [tCO$_2$/yr]
4.1.1 CER from Treatment of TE Alone (Anaerobic Lagoon Vs UASB)

Presently, for the treatment of TE, physicochemical followed by two stage biological treatment are provided to meet the standards. Generally, first stage biological treatment is provided using anaerobic lagoon which is an economical treatment method but it requires considerable amount of land and also leads to emissions of methane (GHG) and hydrogen sulphide (odorous gas) into the atmosphere. Based on the present study it is possible to replace the anaerobic lagoon by UASB and reduce the land requirement and also emission of GHG into atmosphere. A typical tannery cluster processing 150 tons of leather, generating 5000 m$^3$ of TE and 30 tons of fleshings has been considered for arriving at CER generated for calculating financial benefit through CDM (carbon trading) for techno-economic studies. The COD of TE at the inlet and outlet of the anaerobic lagoon were 4000 mg/L and 1600 mg/L respectively with a flow rate of 5000 m$^3$/day. Similarly for UASB reactor the COD concentration at the inlet and outlet were 4000 mg/L and 1200 mg/L respectively with the flow rate 5090 m$^3$/day.

4.1.2 CER from Treatment of LF (Open Dumping Vs UASB)

Currently fleshings are disposed off in open dumping leading to ground water contamination, odor nuisance and emission of methane (GHG). Based on the present investigation it is possible to liquefy the fleshings and treat in UASB reactor which results in reduction of pollution load and GHG emission, avoiding odor nuisance and ground water pollution.

The details of the parameter considered and estimation of CER for a typical cluster generating 5000 m$^3$/day of TE are given below.
Fleshings generated (for equivalent flow of 5000 m$^3$/day) = 30 tons/day (a flow of 30 m$^3$ and 200 kg of LF generation/ton of leather processed).

Fleshings generated on dry wt basis (85.5% moisture) = 4.35 tons/day

VS dry wt basis (85.5% moisture) = 2.91 tons/day (67% VS)

(i) Composting in dump sites (Baseline)

COD g/g of fleshings on dry wt basis = 0.79 g/g

Total COD/day from fleshings = 3.42 tons/day

COD removed (90%) = 3.1 tons/day

Total methane produced at the rate 0.3 m$^3$/kg of COD removed = 927.8 m$^3$CH$_4$/day

(ii) UASB (Project Activity)

Total COD/day from fleshings = 3.43 tons/day

COD removed (70%) = 2.41 tons/day

Total methane produced at the rate 0.3 m$^3$/kg of COD removed = 721.6 m$^3$CH$_4$/day

4.2 TECHNO-ECONOMIC ANALYSIS

For techno-economic analysis, a tannery cluster processing 150 tons of raw hides and skins per day was considered which would generate about 5000 m$^3$/day of TE and 30 tons/day of LF and liquefaction of 30 tons of LF would generate LLF of 90 m$^3$ per day. CETP with two process design options namely, option I for treating TE alone in open anaerobic system for a design flow of 5000 m$^3$ per day and option II, for combined treatment of TE and LLF in closed anaerobic system for a design flow of 5090 m$^3$ per day were considered and process flow charts for option I and II are shown in...
Figures 4.1- 4.2. Cost of effluent treatment plant was arrived at by adding up the cost of individual treatment units. For comparison of economics, cost estimates were made for options I and II consisting of the physio-chemical treatment followed biological system. For option II liquefaction tanks were considered.

4.2.1 Characteristics Adopted for Design of Treatment Units

Volume of LLF generated after liquefaction of 30 tons of LF is 90m$^3$/day. Typical characteristics of TE considered based on the research findings for design of CETP are as follows: pH – 8.5; COD – 3500 mg/L, BOD – 1700 and SS – 2500 mg/L. Characteristics considered for combined treatment of TE and LLF are as follows: pH – 7.5; COD – 4000 mg/L, BOD – 2000 and SS – 3000mg/L.

4.2.2 Design Criteria Adopted for Sizing of Treatment Units

CETP has been designed for baseline activity, TE alone with anaerobic lagoon (Option I) and also for project activity, combined treatment of TE and LLF using UASB reactor (Option II). The process flow diagrams of baseline activity and project activity are depicted in Figures 4.1 and 4.2. All the treatment units in CETP were designed for both options, TE alone and combined TE and LLF as per design criteria recommended by Metcalf and Eddy (2003) and UNIDO report (1997). Design criteria considered for the design of units for both options are given below in Table 4.1. For secure landfill 5 yrs storage capacity has been considered.
Figure 4.1 Process flow Diagram for Baseline Activity for Typical Treatment of Tannery Effluent Alone (Option I)
Figure 4.2 Process flow Diagram for Project Activity for Typical Treatment of TE and LLF (Option II)
## Table 4.1 Design Criteria for Treatment Units

<table>
<thead>
<tr>
<th>S. No</th>
<th>Treatment units</th>
<th>Design criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Screen</td>
<td>Approach velocity - 0.5 m/s</td>
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<tr>
<td></td>
<td></td>
<td>Angle of screen - 60°</td>
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<tr>
<td>2</td>
<td>Equalization Tank</td>
<td>Detention time - 24 h</td>
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<td>3</td>
<td>Lime</td>
<td>Solution strength (Lime)-5%, Dosage - 200 mg/L;</td>
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<td></td>
<td></td>
<td>Solution strength(Alum)- 10% Dosage - 400 mg/L;</td>
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<tr>
<td></td>
<td></td>
<td>Solution strength (PE)- 0.001% Dosage - 2 mg/L for flocculation and 4.5 kg/ton of dry solids for sludge conditioning.</td>
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<tr>
<td>4</td>
<td>Flash Mixer</td>
<td>Detention time - 90 sec</td>
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<tr>
<td>5</td>
<td>Flocculation tank</td>
<td>Detention time - 30 min</td>
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<tr>
<td>6</td>
<td>Primary Clarifier</td>
<td>Over flow rate -25 m$^3$/m$^2$.h</td>
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<tr>
<td></td>
<td></td>
<td>Side water depth - 2.5m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weir loading &lt; 300 m$^3$/m.d</td>
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<tr>
<td>7</td>
<td>Anaerobic Lagoon</td>
<td>OLR- 0.54 kg BOD/ m$^3$.d</td>
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<tr>
<td></td>
<td></td>
<td>BOD removal- 60%</td>
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<tr>
<td>8</td>
<td>Pre-aeration tank</td>
<td>Detention time – 30 min</td>
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<td>9</td>
<td>Liquefaction tank</td>
<td>Retention time - 8 days</td>
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<td>10</td>
<td>UASB</td>
<td>OLR- 5 Kg COD/ m$^3$.d</td>
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<tr>
<td></td>
<td></td>
<td>Aperture velocity-3m/h</td>
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<tr>
<td></td>
<td></td>
<td>Up-flow velocity -0.5m/h</td>
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<td>11</td>
<td>Extended Aeration system</td>
<td>MLSS - 4000 mg/L</td>
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<td></td>
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<td>F/M ratio - 0.15 to 0.18</td>
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<td>12</td>
<td>Secondary Clarifier</td>
<td>Over flow rate - 15 m$^3$/m$^2$/h</td>
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<td></td>
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<td>Side water depth - 2.5 m</td>
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<tr>
<td></td>
<td></td>
<td>Weir loading&lt; 300 m$^3$/m.d</td>
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<td>13</td>
<td>Sludge Drying Bed</td>
<td>Dewatering, drying and recycling cycle - 7 days;</td>
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<td>Sludge depth - 0.3 m</td>
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<td>14</td>
<td>Secure landfill</td>
<td>Storage capacity : 5 years</td>
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<td></td>
<td></td>
<td>Depth - 4.5 m (Effective)</td>
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</table>
4.2.3 Cost Estimation

Abstract cost estimate for capital cost for treatment of TE (option I) and combined treatment of TE and LLF (option II) was arrived at for individual units. Capital cost of civil works was estimated from the unit sizes arrived at by determining the quantities like earthwork excavation, sand filling, plain cement concrete, reinforced cement concrete, reinforcement, shuttering, plastering, brick work and labour charges based on Central Public Work Department schedule of rates (2007). Cost of mechanical, electrical, equipment and specifications including piping and valves were obtained from manufacturers and adopted to arrive at the cost.

4.2.4 Operation and Maintenance Cost

Operation and maintenance cost of CETP for both options were estimated considering chemical, energy, sludge management, oil & grease and manpower. The sludge management cost has been arrived at considering secure landfill with single HDPE liner system for a storage capacity of 5 yrs.

4.2.5 Annualized Cost

For the purpose of comparison the annualized cost for the investment made (capital cost) for both options were calculated using the following formula

\[
\text{Annualized cost} = P \left[ \frac{i(1+i)N}{(1+i)-1} \right] 
\]

(4.6)

\[\text{P} = \text{Capital cost; } I = \text{Rate of interest; } N = \text{Life in years}\]

The rate of interest, life in years for civil and mechanical items considered were 14%, 20 yrs and 10 yrs respectively.
4.2.6 Economics Consideration with Electrical energy Recovery and CDM

The methane production based on the findings of the present study was considered during treatment of 30 tons per day of LF with 5000 m$^3$ per day TE in UASB reactor for bio-energy generation and estimation of financial benefit. For electrical energy generation of 2.14 kw per m$^3$ methane and electricity unit rate of € 4 based on prevailing rates were considered for arriving at the economic benefit of bio-energy.

The CER was estimated for the following options based on the methodology given in Section 3.5.14 for option II i.e. combined treatment of LLF and TE with UASB reactor along with bio-energy generation in the place of anaerobic lagoon and open dumping as baseline data. CDM benefits were arrived at the rate of € 15 per CER and conversion rate of € 65 per euro.