

PRECEPT 3: ANAEROBIC DIGESTION

#1 Anaerobic digestion of cheese whey

A cheese factory is producing 250 t/d of cheese whey that is sold at a price of 13 €/t.

- Calculate whether the option of producing renewable electrical energy by anaerobic digestion may be economically interesting.
- Calculate the volume of a UASB reactor for the conversion of whey into biogas.

Data:

- Whey characteristics:
 - Composition:
 - proteins 13.5 g/100 g_{TS}
 - carbohydrates 75.2 g/100 g_{TS}
 - lipids 0.813 g/100 g_{TS}
 - Solid content: 6.7 g_{TS}/100g
 - Specific weight: 1 t/m³
 - Ultimate biochemical methane potential (BMP): 0.35 m³_{@ 0°C, 1 atm} / kg_{COD}
- UASB operational parameters for whey treatment:
 - typical organic loading rate (OLR) values: from 1 to 29 kg_{COD}/m³/d
 - acceptable hydraulic retention time (HRT): from 2 to 12 d
 - expected actual/ultimate BMP (η_{BMP}): 0.97
 - typical volume of each UASB unit: 80 m³
- CHP performance → Electrical efficiency (η_{el}): 40%
- Other data:
 - Lower heating value of methane: 9.96 kWh/m³_{@ 0°C, 1 atm}
 - Revenue of renewable energy production for installations of less than 1 MW: 0.28 €/kWh

#2 Computing operational parameters of an existing biogas installation

An anaerobic digester is fed with a mixture of activated sludge (primary and secondary sludge) from a wastewater treatment plant and the organic fraction of municipal solid waste (organic fraction). The volume and operational temperature are known as well as relevant characteristics of the inlet and outlet flows.

From available data, calculate:

- the organic loading rate;
- the hydraulic retention time;
- the specific biogas production rate;
- the ratio between the actual and ultimate BMP;
- the efficiency of VS degradation.

Finally, compute and verify the COD mass balance.

Data:

- Inlet flow rates:
 - Primary sludge: 57 t/d
 - Secondary sludge: 125 t/d
 - Organic fraction: 90 t/d

- Substrates characteristics:

| | VS/TS (%) | Moisture (%) | COD/VS | ultimate BMP ($\text{m}^3_{@0^\circ\text{C}, 1 \text{ atm}}/\text{kg}_{\text{VS}}$) |
|------------------|-----------|--------------|--------|---|
| Primary sludge | 65 | 96 | 1.55 | 0.352 |
| Secondary sludge | 75 | 98 | 1.42 | 0.150 |
| Organic fraction | 85 | 80 | 1.5 | 0.367 |

- Outlet flows:
 - Digestate flow rate: $250 \text{ m}^3/\text{d}$
 - Digestate VS content: 3.26%
 - COD/VS of digestate: 1.626
 - Biogas flow rate: $9343 \text{ m}^3_{@35^\circ\text{C}, 1 \text{ atm}}/\text{d}$
 - CH_4 in biogas: 62%
- Digesters data:
 - Total anaerobic digesters volume: 7400 m^3
 - Operational temperature: 35°C