Table 1 reports the characteristics and the elemental analysis of pig manure.

Evaluate:

1. The dry ash free atomic composition
2. the dry higher heating value - DHHV ($kJ/kg_{dry\ manure}$) of pig manure assuming that the complete oxidation product of chlorine is HCl. Assume 2.500 MJ/kg for the evaporation latent heat of water
3. the higher heating value - HHV and the lower heating value - LHV of pig manure
4. the mass flow rate of stoichiometric air required by the combustion process ($kg_{air}/kg_{manure}$) assume the complete transformation of N into $N_2$
   $MW_{air}$ = 28.95 g/mol

Table 1: pig manure elemental composition, moisture, and DLHV (dry lower heating value).

<table>
<tr><td>C</td><td rowspan="7">dry basis</td><td>35.0%</td></tr>
<tr><td>H</td><td>4.5%</td></tr>
<tr><td>O</td><td>21.5%</td></tr>
<tr><td>N</td><td>3.0%</td></tr>
<tr><td>S</td><td>-</td></tr>
<tr><td>Cl</td><td>1%</td></tr>
<tr><td>ash</td><td>35.0%</td></tr>
<tr><td colspan="2">Moisture</td><td>66.0%</td></tr>
<tr><td colspan="2">DLHV</td><td>12,800 kJ/kg<sub>dry waste</sub></td></tr>
</table>

A dairy farm in Sacramento (CA) raises 1800 cows that produce 83.1 t/d of wet manure (Solid content = 14%, and 80% VS/TS). We suppose to co-digest this amount of manure with food waste (Solid content = 28% TS, and 86% VS/TS). The mixture contains 48% food waste and 52% of dairy manure, based on volatile solids (VS). Batch digestion tests at 35°C were performed on the same mixture: after 30 days the biogas yield resulted of 531 NL/kgVS, with a $CH_4$ content of 59%.

Calculate the biogas Qbiogas ($Nm^3_{biogas}/d$) and methane $QCH_4$ ($Nm^3_{CH4}/d$) production from the AD plant, by knowing that the conversion efficiency of the plant is 80%.

By assuming an hydraulic retention time of at least 40 d and an organic loading rate of no more than 2.5 kgVS/$m^3$/d, define the appropriate volume for the anaerobic digester.