Selecting liquid substrates for UASB process upgrade: Characterization and BMP tests

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Personal introduction

Background and education:

- Ph.D. student in «Environmental and Energy Engineering Science» at Udine University (Italy), XXXI cycle
- High education and research apprenticeship at Carniacque Spa company (society which holds integrated water cycle management in the northern area of Friuli-Venezia Giulia region)

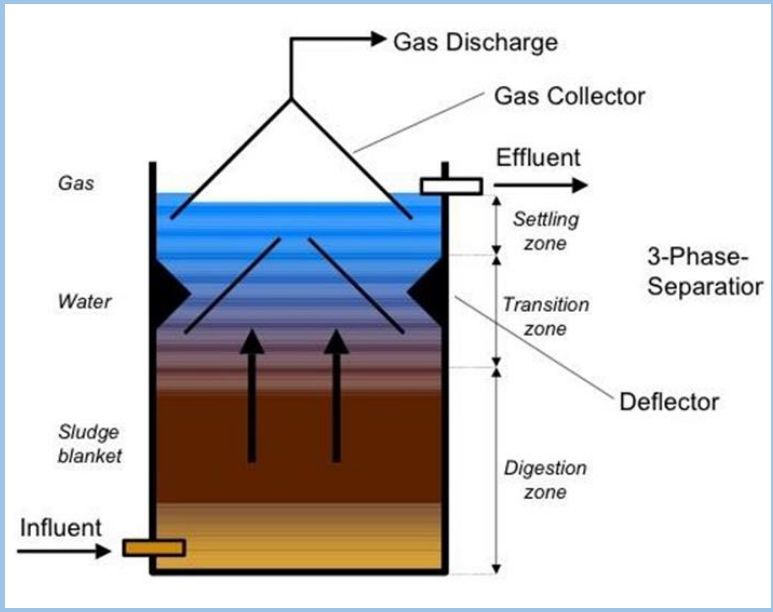
Field of expertise: Water and air pollution; High-velocity anaerobic UASB processes

Reasons for participating at Summer School: Great interest in anaerobic technology innovation and challenges

Introduction

UASB reactor

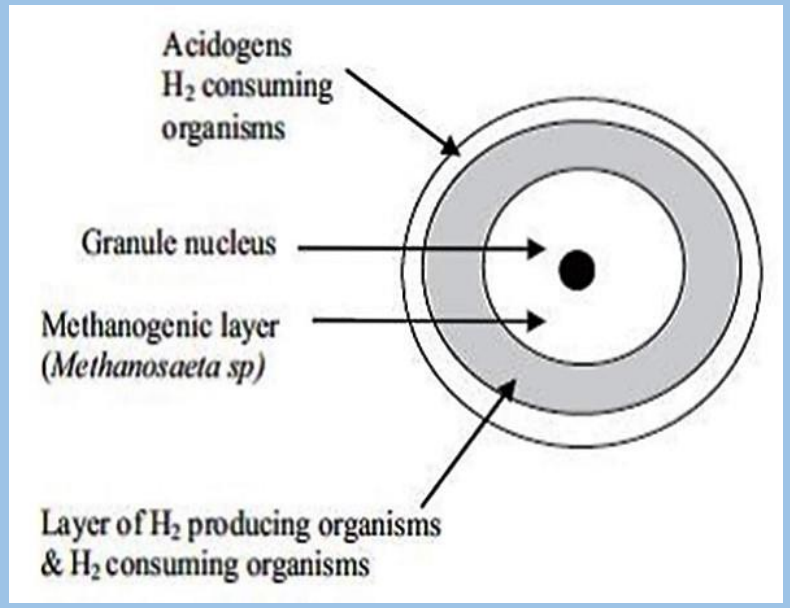
- UASB reactor, developed in the '70s, allowed to anaerobically treat liquid organic substrates, at a reduced HRT, if compared to traditional reactors
- It consists of an up-flow system, equipped with a three-phase (gas-solid-liquid) separator, to extract biogas
- Application: industrial wastewaters with COD in the range of 5-10 g/L



Introduction

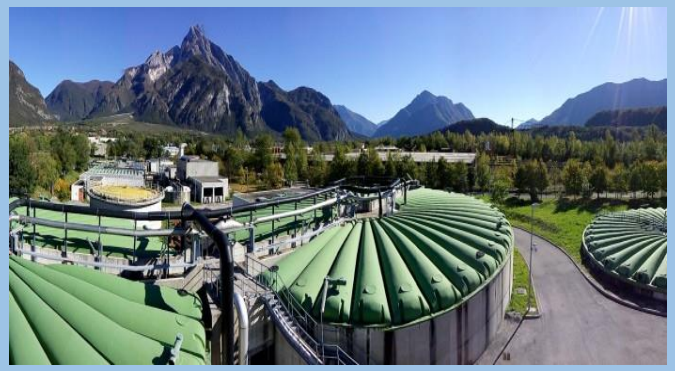
Granular sludge characteristics

- Biomass is characterized by excellent sedimentability, and very low SVI value (<20 mL/g)
- UASB configuration allows to efficiently retain biomass in the reactor (high SRT/HRT ratio); typical HRT<24 h
- Reduced excess sludge production



Research project: General framework

- **Objective:** upgrade of full-scale UASB reactor in Tolmezzo (Ud)
- **Proceeding:** Study of liquid organic substrates, suitable to be anaerobically treated, with the aim of maximizing energy yield and reducing, at the same time, smell nuisance



Materials and methods

Selected Substrates

- The selected substrates were:
  - Condensate water
  - Cheese whey
  - OFMSW leachate
  - Slaughterhouse liquid waste

- A complete physico-chemical characterization of the substrates was done, to underline the peculiar characteristics of each matrix and to evaluate the feasibility of high-rate anaerobic digestion
- Macromolecular and elemental analysis were also performed
- The substrates were withdrawn from local facilities

Materials and methods

OFMSW percolation bed

- The coupling of a solid-treating Leach Bed and a liquid-treating UASB reactor allows to extract a highly-biodegradable liquid substrate, able to produce consistent methane yields
- This system couples energy recovery (through anaerobic digestion of leachate) with material recovery (through composting of the residual solid waste)

Materials and methods

AMPTS tests

- Bio-methanization tests were performed with AMPTS (Bioprocess) equipment
- No nutrients were added to the substrates, to investigate biomass adaptation and possible operational problems
- I/S ratio (based on VS) was fixed at 2
- The thermostatic bath T was set at 35 °C
- Both 24-h and final methane production (BMP value) were analyzed

Results and discussion

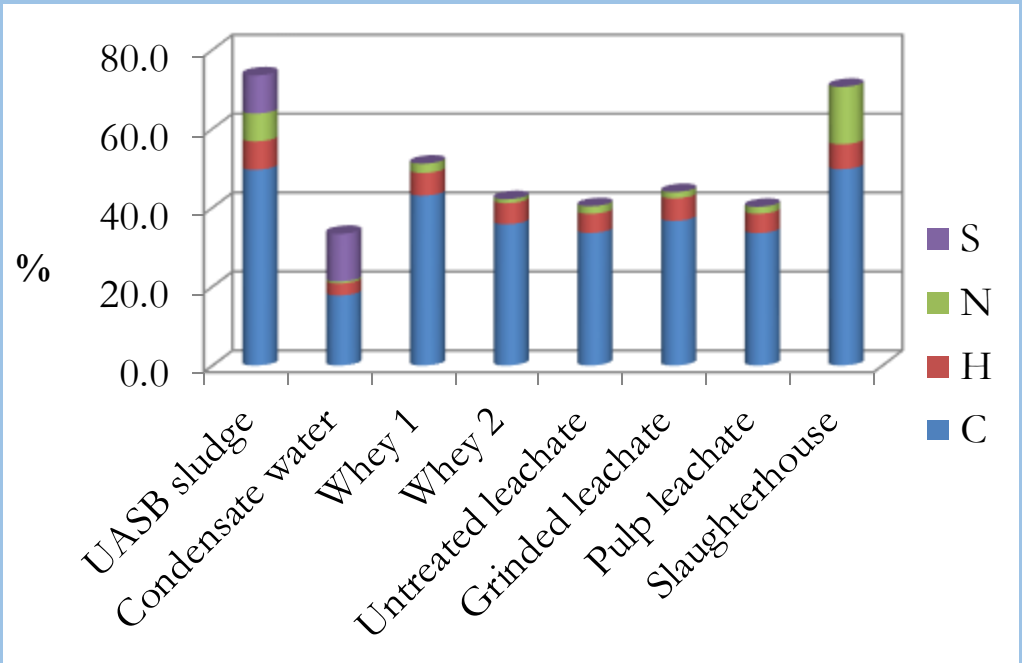
Substrates characterization

Parameter	*UASB sludge*	*Condensate*	*Whey 1*	*Whey 2*	*Untreated leachate*	*Grinded leachate*	*Pulp leachate*	*Slaughter*
tCOD (g/L)	n.d.	4.15	105.0	81.8	17.9	40.0	26.5	111.7
sCOD (g/L)	1.733	4.15	68.6	62.5	15.1	37.4	22.2	109.8
Alkalinity (mg $CaCO_3$/L)	1873	<5	1297	1153	490	443	538	11100
NH_3-N (mg N/L)	179	<1	44.1	3.19	24.8	36.5	41.6	19.6
PO_4^{3-} (mg P/L)	30.8	0.05	530	527	67	86	51	173
SO_4^{2-} (mg/L)	<2	17.3	<2	55.5	16.6	20.2	<2	<2
pH	6.91	3.5	5.5	5.8	5.2	4.6	4.9	7.2
TS (% w/w)	4.18	0.018	7.44	6.63	1.41	3.23	2.22	15.11
VS (% w/w)	3.79	n.d.	6.73	5.64	0.94	2.57	1.53	14.29
VS/TS (%)	90.59	n.d.	90.37	85.18	66.99	79.52	68.91	94.57
VFA (mg/L)	110	38	41	1	109	56	158	820
TKN (mg/L)	216	80	332	28	241	405	291	2160

Results and discussion

Elemental analysis

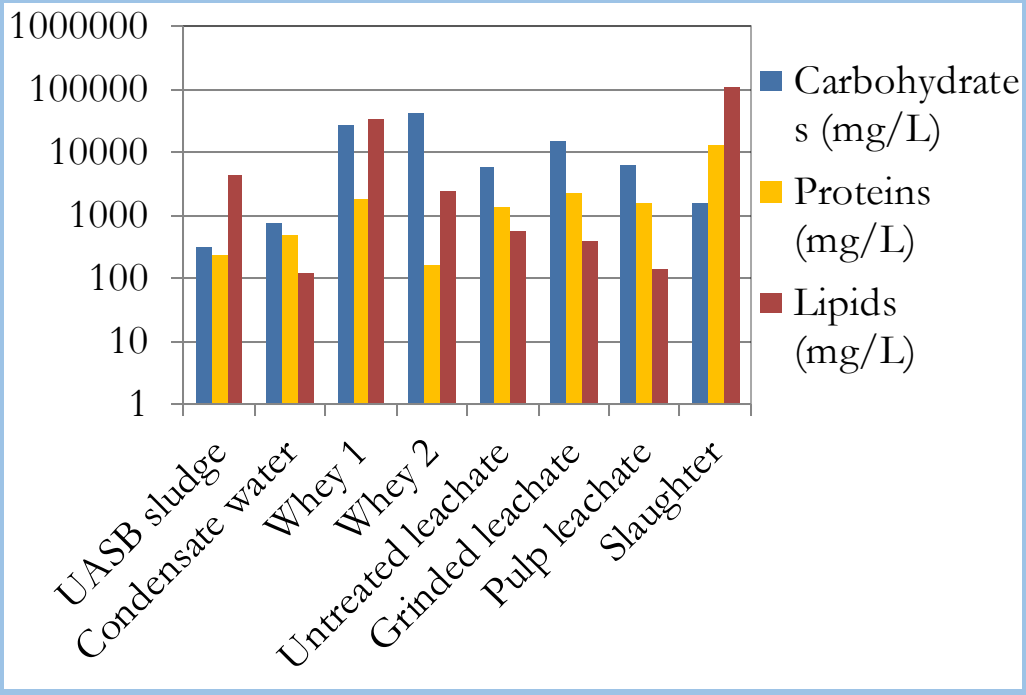
- Condensate water has consistent S levels (12.1%)
- Slaughterhouse waste is rich in N (14.6%)
- No substantial differences were observed between the three kinds of leachate



Results and discussion

Macromolecular analysis

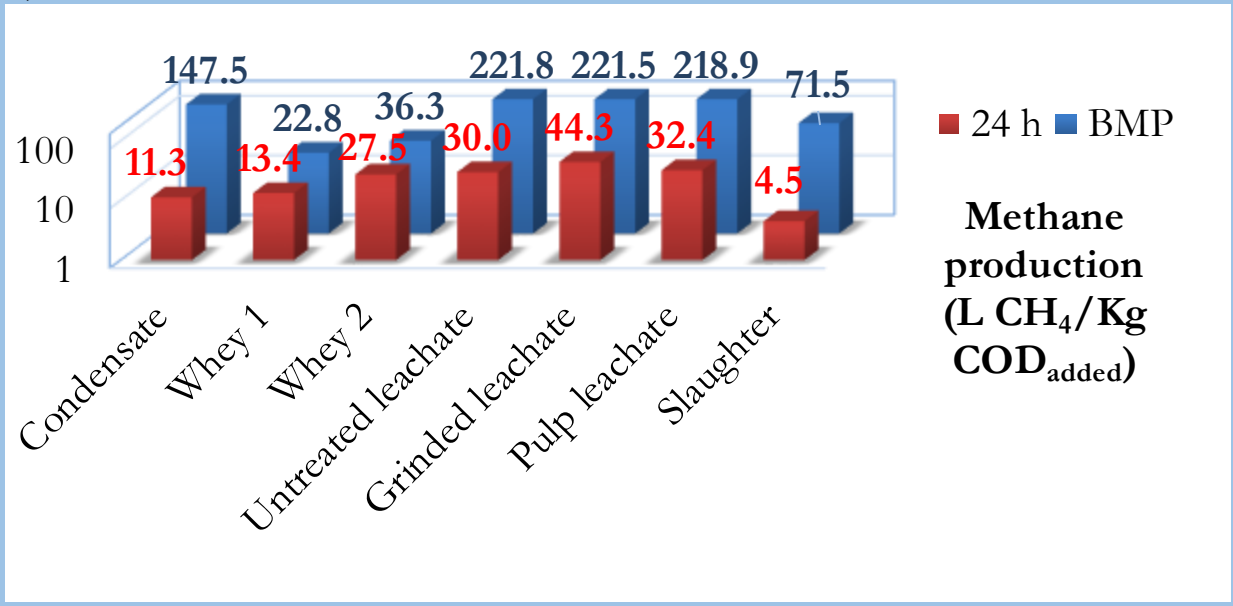
- Condensate water has low macromolecular concentration
- The main difference between first and second cheese whey is lipids concentration (32.96 g/L vs 2.39 g/L)
- OFMSW leachate is rich in carbohydrates (6.1-15.2 g/L)
- Slaughterhouse waste has the highest proteins (13.4 g/L) and lipids (110.3 g/L) concentration



Results and discussion

AMPTS tests

- Cheese whey mono-digestion stimulated acidification and overload of the reactor, so methane generation stopped just after 2 days
- An appropriate dilution of whey is required in continuous operations
- Condensate water requires nutrient addition, and also pH adjustment
- OFMSW leachate digestion, due to the high carbohydrates concentration, did not show operational problems, and final BMP was high (218.9-221.8 L CH_4/Kg COD_{added})



Results and discussion

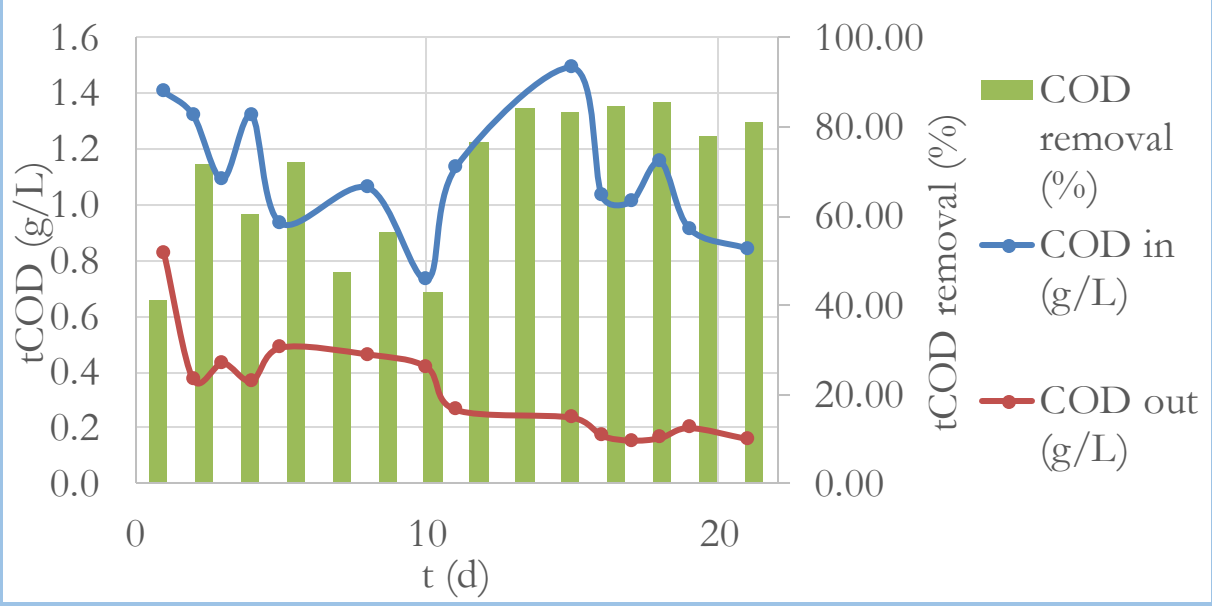
Continuous tests

- Lab-scale UASB reactor, with 11.5 L volume
- Q was fixed at 6.34 mL/min, to obtain a HRT of 30.1 h
- Tests were conducted with a mixture of 50% first whey and 50% second whey
- Whey was diluted with tap water in a proportion of 1 L of whey in 50 L of mixture
- Daily analysis on pH, COD_{in} and COD_{out} were performed, to evaluate the effectiveness of anaerobic pre-treatment

Results and discussion

Continuous tests

- Mean OLR was calculated as 0.96 Kg COD/m^3d
- Mean COD_{in} was 1.106 g/L
- Mean COD_{out} was 0.34 g/L (69% removal)
- After 16 days of operations, COD_{out} was always under 200 mg/L



Conclusions & Up-coming

- All selected substrates (condensate water, cheese whey, OFMSW leachate, slaughterhouse waste) demonstrated the potential to be anaerobically treated
- Physico-chemical analysis underlined an extreme variability in substrates characteristics
- OFMSW leachate, as a highly soluble substrate, produced high methane yields
- Cheese whey digestion stimulated acidification of the reactor, so an appropriate dilution (1:50 v/v) was used in continuous tests

Thank you for your attention