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UASB anaerobic treatment and OFMSW reutilization: Tolmezzo case potentiality

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Abstract. More and more interest is being dedicated to anaerobic processes in the scientific literature; in particular, high velocity reactors, such as the Up-flow Anaerobic Sludge Blanket reactor, are able to reduce the required HRT and to optimize biogas production. This kind of reactors is particularly indicated for high concentrated wastewaters, in which the soluble fraction is prevalent over the suspended one. In this cases, the anaerobic process can achieve high efficiencies, in terms of COD removal, with low energy requirements, if compared to a traditional activated sludge process. This work is focused on Tolmezzo wastewater treatment plant, because it contains a UASB reactor, that is inactive since 2007, and so it is, potentially, a source of clean energy. It is supposed to feed the reactor with the liquid fraction of Organic Fraction of Municipal Solid Waste (OFMSW), separately segregated in the local geographic area, while the solid fraction, residual from the separation process, is suitable to be sent to a composting plant.

Key-words. Anaerobic digestion, UASB, OFMSW, biogas, renewable energy.

1. UASB anaerobic treatment. In general, it is known that the anaerobic treatment converts the organic matter, present in a given substrate, into biogas, which is mainly composed of methane and carbon dioxide. The sequence of reactions proceeds from the hydrolytic step, through the acidogenic step, to the acetogenesis and, finally, to the methanogenesis. Differently from aerobic processes, the main problem to face is the optimization of each step, because the product of one particular reaction is the substrate of

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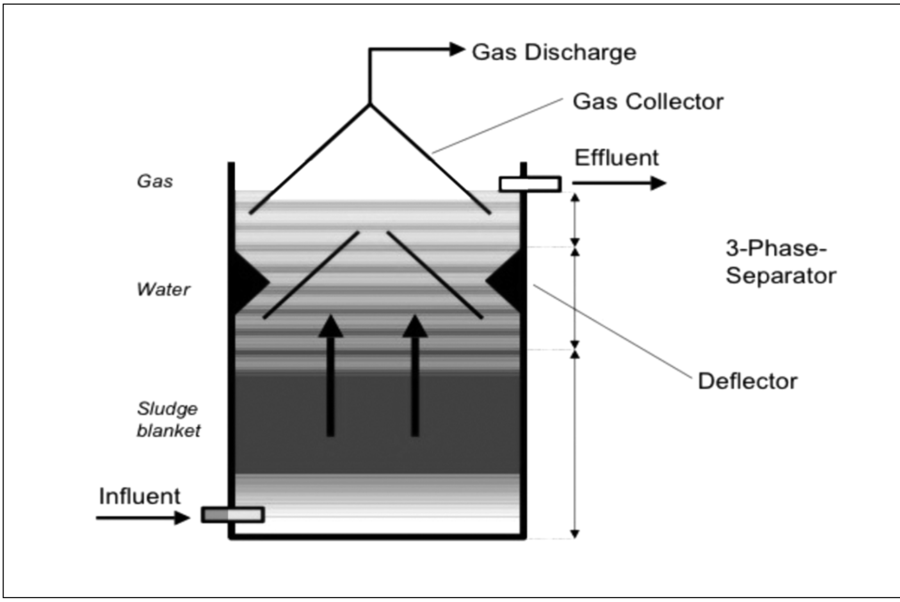

Figure 1. UASB reactor scheme.

the successive one; in fact, we identify a real trophic chain (Bonomo 2008). The anaerobic processes typically operate in mesophilic conditions (in which temperature is in the range of 35-40 °C), in order to favor biomass activity, without experiencing excessive endogenous reactions, that prevail in thermophilic conditions. Other important working parameters are pH, which must be controlled at values of 6.3-7.8 (to avoid methanogenic biomass inhibition), nutrient request (that is quite restricted) and the concentration of inhibitory compounds, which are mainly ammonia, hydrogen sulfide and metals (Chen, Cheng, Creamer 2008).

High strength wastewaters, that is substrates having a COD concentration of 2-20 g/L, are particularly indicated to be treated anaerobically; high rate systems, such as the UASB reactor, can accelerate the process, if compared with traditional digesters, and they require less volume, because they reduce the HRT by an order of magnitude.

The UASB reactor is an up-flow reactor, in which the influent enters at the bottom and flows towards the upper part of the reactor. Firstly, it passes through the sludge bed, in which anaerobic degradation happens, and then it moves to the transition zone, where the granular sludge particles (that settle down) are separated from the biogas (which rises to the gas col-

Table 1. Main operational parameters for UASB anaerobic digestion.

Parameters	*Value*
Influent concentration (g COD/l)	5-10
Operating temperature (°C)	32-36
Organic Loading Rate (kg COD/m^{3}d)	12-20
Up-flow velocity (m/h)	< 1.2
Hydraulic ritention time (h)	> 6
COD removal (%)	75-90

lector area). The triangular dome represents the three phase collector, which is able to separate biogas, that is piped to the gasometer (and then sent to the cogenerative motor), from the effluent, that spills in the upper part of the reactor, and from the residual sludge particles (Bonomo 2008).

The peculiarity of this kind of reactor is the formation of granules of biomass, having a diameter of 0.1-5 mm and a high density; they are maintained in suspension in the reactor. This configuration greatly increases the SRT value; it is possible, indeed, to reduce HRT, at values of 8-10 h. The up-flow velocity is very slow, in the range of 0.5-1.5 m/h (Latif et al. 2011). The excess granular sludge production is limited, and, however, its disposal is quite simple. It must be pointed out, anyway, that the start-up phase is critical, because the anaerobic sludge has to adapt to the particular substrate, and inhibitory phenomena (due, for example, to the accumulation of Volatile Fatty Acids, if the wastewater is not sufficiently alkaline) may occur (Lim, Kim 2014). The main applications of UASB reactor are easily hydrolysable substrates, with a COD concentration of 5-10 g/L; for example, a high rate anaerobic process is an appropriate solution for the treatment of wastewaters from breweries, pulp and paper factories, distilleries, sugar factories, cheese factories. However, substrates rich in lipids, such as those coming from cheese factories, favor foam formation in the reactor (with successive problems of sludge flotation), because greases are removed with a low kinetics and amass at the surface of the granules (Latif et al. 2011).

2. Tolmezzo WWTP. Tolmezzo WWTP has a potentiality of 143,000 E.I. and it mainly treats pulp and paper wastewaters, coming from the near Burgo factory. Industrial wastewater, in fact, forms approximately 90% of the total flow rate coming into the plant, while the residual 10% represents wastewater of the drainage system of Tolmezzo and the near villages of Amaro and Villa Santina. Moreover,

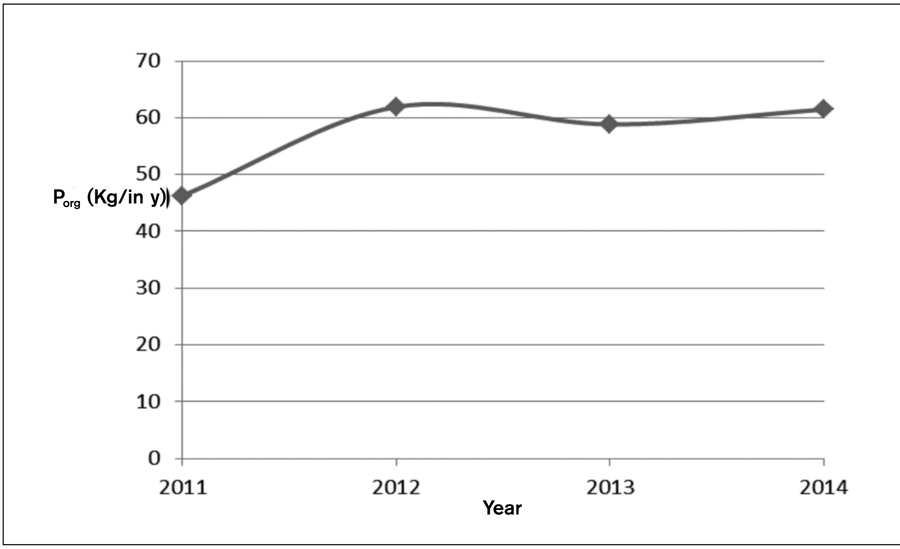

Figure 2. Specific organic waste production (expressed in kg/ab y) in the mountain area of Friuli-Venezia Giulia region.

three different flows of industrial wastewaters, having different pollution values, are identified: condensate water, whitening water and process water.

While civil wastewater is treated in a conventional activated sludge process, an anaerobic UASB pre-treatment of the most polluted stream, coming from the Burgo factory (that is, condensate water) was planned, even if, actually, it is not active, and so all the streams are channeled together to the aerobic treatment.

From the technical point of view, the anaerobic section is composed of a pre-acidification basin, having a volume of 250 m^3, followed by a UASB reactor (having a height of 4.5 m) with a modular construction: globally, there are 20 modules of 50 m^3 each, for a total volume of 1000 m^3. Biogas is then sent to the gasometer; it is desulphuryzed from hydrogen sulfide, using a FeO bed, and the condensation water is removed; finally, biogas is burned in the cogenerative motor, to produce electrical and thermal energy (Passavant Impianti, Achille Fadalti Costruzioni).

3. The case study. This work proposes a possible solution for the recovery and reutilization of the UASB reactor; it is supposed to feed the reactor with a high concentrated liquid substrate, coming from a solid-liquid separation of the OFMSW. In particular, OFMSW production in the mountain zone surrounding the plant

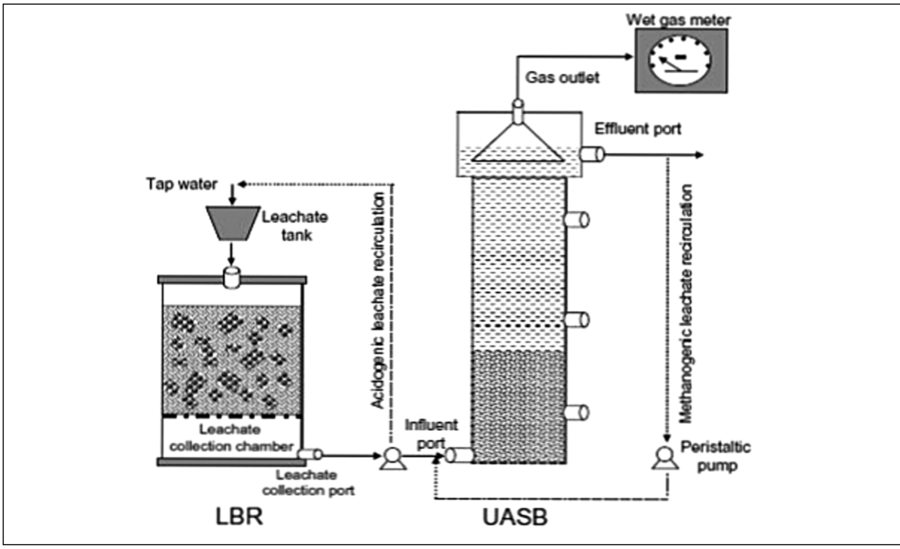

Figure 3. HASL scheme, consisting in a LBR and a UASB reactor.

was analyzed, and the specific production was calculated: for the 2013 year, 4158 ton/y of OFMSW were produced, corresponding to 58.8 kg/in y. Thus, the evolution in OFMSW production in the zone comprising Mountain Community of Carnia and Canal del Ferro was analyzed.

Talking about the lay-out of the system, a hangar needs to be constructed, to receive the waste, and also a machine is essential, to open the containment bag of the waste. Also, all undesired materials must be removed from the organic waste: a screen, an iron remover and an eddy current separator are needed.

The solid-liquid separation step can be carried out with a Leach Bed, which consists of a metallic reactor, in which the waste is grinded and arranged over a perforated plate (Xu et al. 2011). Tap water is introduced from the top of the reactor, and percolates through the waste, extracting soluble substances. Then, it crosses a sand bed, which has the function of removing solid particles, and the leachate is collected in the lower part of the reactor. Normally, part of this leachate is recirculated over the LBR, to facilitate the liquid collection, while the other fraction is directly sent to the methanogenic UASB reactor (Browne, Murphy 2014). In literature, this typology of systems, which combines two different reactors, is called HASL (Hybrid Anaerobic Solid-Liquid) system, and can be classified as a two-step anaerobic digestion. In this particular situation, the leachate, before entering the UASB

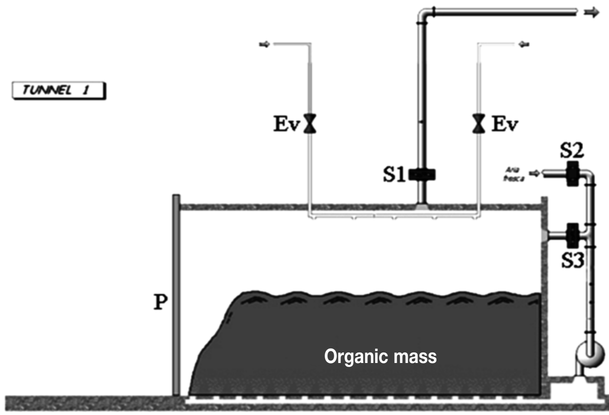

Figure 4. Example of a bio-container for OFMSW composting.

reactor, needs to be heated to the UASB operating temperature, which is 35 °C: so, a heat exchanger is needed. A shell & tube exchanger is introduced, and the heat content of the condensation water, which has a temperature of nearly 40 °C, is used as hot fluid.
Starting from the expected flow rate of the leachate, some technical considerations have been made. Firstly, the flow rate is not sufficient to feed all the modules of the UASB reactor, and so it is recommended to reduce the operating volume to 50 m^3, corresponding to the activation of only 1 module of the existing reactor. Secondly, because of the extremely high COD concentration of this wastewater, the influent is mixed with a fraction of the plant effluent; finally, a total flow rate of 146 m^3/d is obtained, with a COD concentration of 5 g/L. The HRT of the UASB reactor is calculated as 8.2 h, and the OLR is 14.6 kg COD/m^3d. In this conditions, the daily methane production is calculated as 197 m^3/d, corresponding to an available theoretical energy of 655 MWh/y.
The solid fraction, residual from the separation step, is suitable to undergo a composting process; in particular, given the total mass rate of the waste (2495 t/y), the quantity of bulking agent (wood chips), which is used to control C/N ratio and to increase the porosity, is calculated as 832 t/y. So, globally the composting plant has to treat 19.3 m^3/d of material. The Active Composting Time (ACT) phase can be completed using bio-containers, which are modular closed reactors that permit to control the most important operating variables of the process (moisture, temperature, pH)

(Rada et al. 2014). In particular, to obtain a residence time of the waste of 23.1 d, it is required to use 16 reactors with volume of 25 m^3 each, for a total volume of 400 m^3.
The process is then completed in the curing phase, disposing the waste in open piles; the final product is refined and screened, to obtain a quantity of compost of 4.9 t/d.
Finally, some considerations are made from the economical point of view: in particular, the payback time is calculated for the scenario involving UASB reutilization with OFMSW leachate, considering the investment costs, the operating costs and the incomes. Two different hypothesis are made: the first considers to build a new composting facility, while the second supposes to reutilize the composting plant located in Villa Santina. This plant had the potentiality to treat 25,000 ton/year of mixed municipal waste; it produced compost from the wet fraction and RDF (Refuse Derived Fuel) from the dry fraction. In particular, composting was realized with aerated static piles, covered with a cloth. This scenario is particularly interesting from the economic and environmental point of view, because it permits to reduce the payback time of the investment from 10 to 6 years and, moreover, it contributes to complete the whole cycle of the organic waste, from its creation, through energy generation (in the UASB reactor), to obtain compost, in the same area where it is produced.

4. Conclusions. The results obtained in this work show that it is possible to plan an integrated cycle of the organic wastes, which consists not only in material recovery (through composting), but also in energy recovery (extracting soluble substances from the waste, and coupling the Leach Bed Reactor to the UASB). However, the scarce production of waste, due to the insufficient population present in this geographical area, limits the volume of the UASB that can be effectively used. In this sense, it is desirable to seek for alternative substrates, presents in this territory, with the characteristics of high biodegradability and good potential for biogas production. For example, it is possible to treat anaerobically also cheese whey, that is actually considered as a waste, but has a great energetic potential, slaughterhouse waste (in particular, blood) and breweries wastewater, that are characterized by substantial biodegradability. This substrates may (or may not) be coupled to the condensation water stream, in order to create an appropriate mixture, with a high energetic potential and low inhibitory effects.

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