Application of semi-continuous pilot-scale AD tests to assess biochemical methane potential and hydrolysis rate constant of raw and pre-treated sludge

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Primary (PS) and waste activated sludge (WAS) are the main by-products from conventional wastewater treatment plants (WWTPs). Although anaerobic digestion (AD) is the worldwide most used process for the stabilization of sewage sludge before final disposal, conventional AD of WAS shows some limitation. In fact, AD is not completely effective towards WAS, because the complexity of the sludge structure limits the efficiency of the biological process.

Over the last 30 years, researchers from both universities and private companies have developed different pre-treatment methods with the aim of increasing WAS biodegradability, hydrolysis rate, biogas/methane production, and of reducing the total amount of sludge that has to be disposed and the digester volume necessary for a correct AD stabilization. Some of these methods have been presented only in research papers and tested at a laboratory and pilot scales, others have been fully implemented into industrial plants.

Pre-treatment methods include mechanical, thermal, chemical, and biological processes. Hybrid pre-treatments are a combination of two or more of the lysis techniques previously mentioned. From the analysis of the published literature, it can be concluded that some pre-treatment techniques, such as thermal hydrolysis, thermal phased AD and ultra-wave hydrolysis, are effective ways to increase the methane production (Anjum et al., 2016; Carrère et al., 2010; Gonzales et al., 2018; Zhen et al., 2017).

However, these techniques require a high energy employment and both large capital expenditure (Capex) and operating expenditure (Opex). As a consequence, research on milder pre-treatment techniques is of capital importance.

In this work, an easily implementable technique, namely thermo-alkali treatment (4 g NaOH/100 g, 90 °C, 1.5 h), was tested. The effects of the proposed treatment were evaluated by using a semi-continuous anaerobic digestion test (mesophilic condition, 38 °C). Furthermore, the biodegradability of PS and raw WAS were evaluated.

All the employed PS and WAS samples were collected from the sludge line of Castiglione Torinese WWTP (2 M e.i). Semi-continuous AD tests were carried out on raw and treated WAS in a 240-L reactor. Conversely, the semi-continuous AD test on PS was carried out in a 10-L digester. The anaerobic biodegradability of raw WAS, treated WAS and PS was assessed in terms of increase of biomethane potential (B_0) and hydrolysis rate constant (k). The two parameters were estimated using a first order kinetics model. The synthetic results of the AD tests are reported in Table 1.

Table 1. Biochemical Methane Potential (Bo), hydrolysis rates (k) and biodegradability of raw WAS, thermo-alkali pre-treated WAS and PS.

Sludge	AD test	Bo [Nm3/kg VS]	k [1/d]	Biodegradability [%]
WAS	1	0.147	0.08	0.28
Treated WAS	2	0.250	0.46	0.48
Primary	3	0.300	0.52	0.50

Subsequently, an AD test of a substrate obtained by mixing PS and thermo-alkali treated WAS (named MIX) was carried out in the semi-continuous 240-L reactor. The MIX substrate was composed of 50% PS (by volume, b.v.) and 50 % (b.v.) treated WAS. The daily methane production returned from the test is shown in Figure 1. The previously estimated Bo and k parameters, relative to the treated WAS and raw PS, were used to predict the daily and cumulative methane production of the MIX substrate. The error between the experimental and modelled data of the cumulative methane production, at the end of the test, was only of 1.1% (see Figure 2).

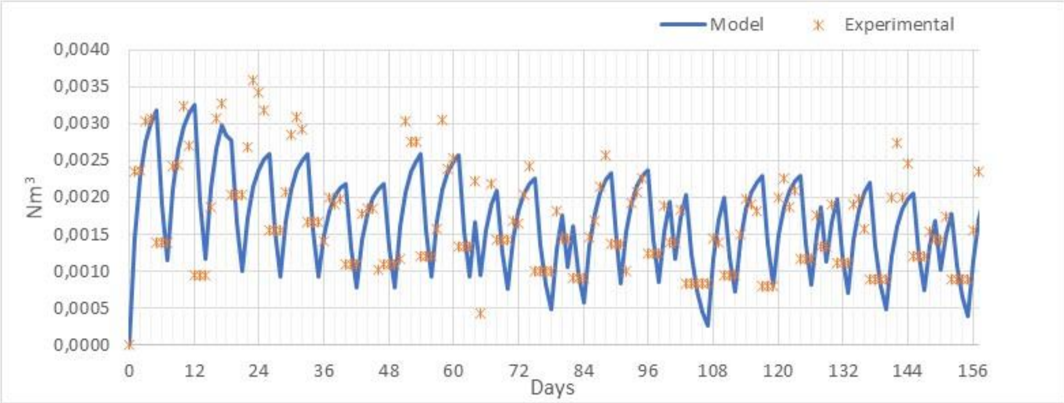

Figure 1. Experimental vs Model (first order kinetic) data of the daily methane production of MIX substrate

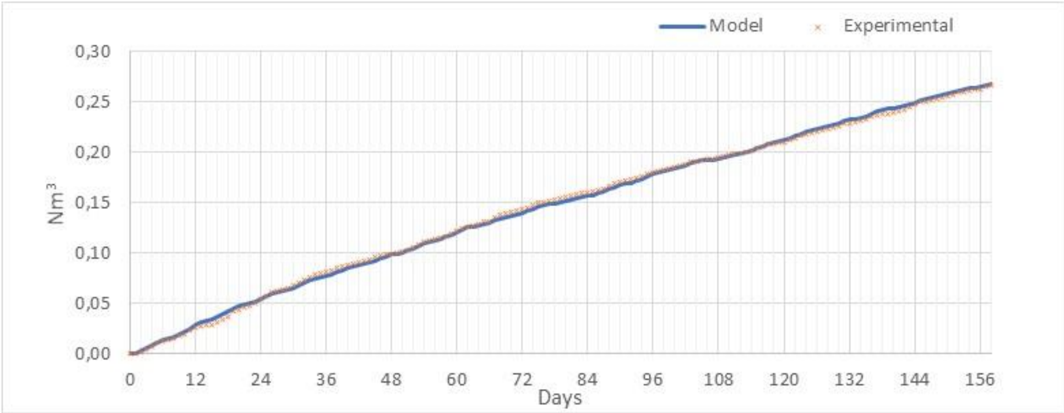

Figure 2. Experimental vs Model (first order kinetic) data of the cumulative methane production of MIX substrate

Conclusions

The following conclusions can be drawn from this study:

- The thermo-alkali treatment improved the biochemical methane potential by 70.1 %;
- The raw WAS was only slowly biodegradable (k =0.085 d^{-1}) but the thermo-alkali treatment increased the hydrolysis constant by 447%;
- Due to the thermo-alkali treatment; the WAS biodegradability rose from 28 to 48%, with an increase of 71.4 %;
- The improved efficiency of the AD of WAS, after the thermo-alkali treatment, was comparable with the performance of other treatments present into the market or reported in the scientific literature.

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