

Technical evaluation of sewage sludge pyrolysis: laboratory and pilot plant tests

E. Fersini¹, A. Giuliano¹, F. Todaro¹, C. Wieth², M. Notarnicola¹

¹Department of Civil, Environmental, Land, Building Engineering and Chemistry (DICATECh), Polytechnic University of Bari, Via E. Orabona n. 4, 70125 Bari, Italy

²AquaGreen ApS, Risø Huse 50DK-4000 Roskilde, Denmark

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Presenting author email: e.fersini@phd.poliba.it

Introduction

Energy valorization of sewage sludge is one of the most important issues in the wastewater treatment cycle in the European Union. In fact, the circular economy strategy promotes the research of new ways to recycle sewage sludge, including thermos-chemical treatments. In this context, among the emerging technologies aimed at recovering materials and energy from waste, pyrolysis is interesting (Paz-Ferreiro *et al*, 2018).

This work shows the main results of an experimental campaign aimed at the technological demonstration of the pyrolysis process developed by Aquagreen APS. In particular, the experimental activities involved the execution of pyrolysis tests both on a laboratory scale (to analyze different process temperatures in the range of 600-700°C) and on the pilot plant (with a treatment capacity of ca. 8-11 kg/h). The execution of the tests allowed the evaluation of the treatment efficiency (through mass and energy balances) and the characterization of the process products (i.e., biochar).

Materials and methods

The experimental activities were carried out on a composite sample, made by mixing dewatered sludge from six municipal wastewater treatment plants located in the Lecce Province (Apulia) in appropriate amounts.

Laboratory-scale pyrolysis tests were carried out on the composite sample at 600 °C, 650 °C, and 700 °C to evaluate the different energy yields and char production (Fig.1a).

As reported below, the pyrolysis process was also studied at a pilot scale in order to report the mass and energy balance (Fig.1b). In particular, chemical and physical analyses were carried out to assess the composition of the pilot-scale char produced. Regarding the energy balance, knowing the calorific value of the dried sludge (PC_e), the char produced (PC_{bc}) and its percentage of the total treated ($\%bc$), it was possible to calculate the energy of the pyrolysis gas produced by the process.

To study the effects of sludge type on process performance (energy consumption, mass and energy balances, efficiency and possible critical issues) a comparative analysis of experimental cycles was carried out with reference to the distribution and composition of pyrolysis treatment products (char).



Figure 1a - Laboratory-scale pyrolyzer



Figure 1b - Pilot plant pyrolyzer

Results

Laboratory-scale tests show that as the process temperature increases (within the range of 600-700 °C), the amount of char decreases, resulting in higher gas production. However, the energy content of the char produced decreases as the process temperature increases from 5,86 MJ/kg in the test conducted at 600 °C and decreases to 5,43 MJ/kg in the one conducted at 700 °C. The results are in line with Chen *et al* (2014) and Oladejo *et al* (2018).

The results of the pilot-scale process are consistent with what was verified at the laboratory scale (Fig. 2). In general, into the characterization of char generated from the different tests at the laboratory scale as well as in the pilot plant, an increase in ash is inferred as the process temperature increases. In addition, a higher ash content is inferred for char produced at pilot scale (Fig. 2).

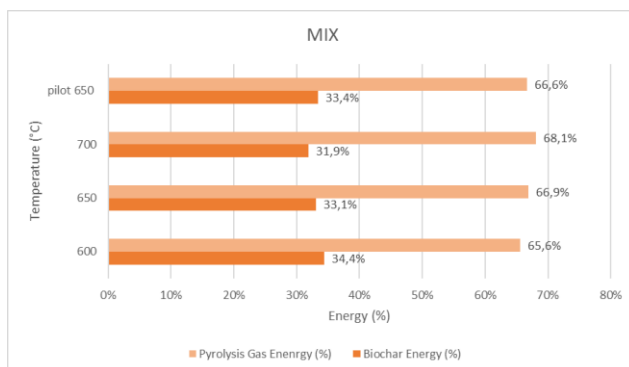


Figure 2a - Comparison of energy balances

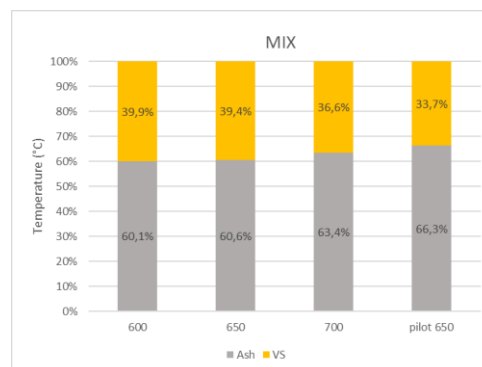


Figure 2b - Biochar characterization

The results of the pilot-scale experimentation are comparable with what was determined at the laboratory scale: i) the quantitative analysis of the products of the pyrolysis process shows that the sludge split about 56,5% into the volatile fraction and 43,5% into the solid residue; ii) in terms of energy, it is shown that the energy content of the char produced at the pilot scale (5,3 MJ/kg) is comparable with what was determined at the laboratory scale (5,6 MJ/kg).

Conclusions

Based on the results obtained, a good correspondence emerges between the results of the pyrolysis pilot test and the laboratory tests. Therefore, the experimental work lays the foundations for techno-economic evaluations for the scale-up of the technology.

To use char in agriculture further tests aimed at a more careful evaluation of the metal concentrations determined in the tested samples are needed to ensure compliance with the legal limits.

References

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