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ADVANCED TREATMENTS OF ORGANIC SOLID WASTE FOR ANAEROBIC DIGESTION

ABSTRACT

ING. ALESSANDRA CESARO

Relatore:
PROF. ING. VINCENZO BELGIORNO

Coordinatore:
PROF. ING. LEONARDO CASCINI

Correlatore:
PROF. ING. VINCENZO NADDEO

In the last years the increasing concern toward environmental protection and source exploitation has guided the legislative development of measures aiming to the sustainable management of municipal solid waste, which implies increasing material recovery and diminishing landfill disposal.

Biodegradable waste represents the prevailing fraction of municipal solid waste: in Europe, it can reach up to 40% of the total amount of waste produced. Therefore, its proper handling is fundamental.

In this context, anaerobic digestion has become one of the major developments in waste treatment facilities.

The interest in this technology is mainly due to the production of methane, which can be used as a renewable energy source in front of aerobic stabilization that requires energy consumption. Anaerobic digestion followed by an aerobic phase represents a recent treatment option, which allows not only biogas but also compost production.

Although anaerobic digestion is a well-established technology, extensive research proved that the methane yield of solid organic material is significantly affected by both the mass transfer in each biological step and substrate availability. It is recognized that the rate limiting step is the hydrolysis of the complex organic matter into soluble compounds.

Therefore, a proper treatment of the organic material before the digestion stage can promote substrate solubilisation and increase the amount of matter that is readily available to anaerobic microbial species.

To this end, several technologies can be applied, including ozonation and sonolysis, which have been widely investigated as sludge pretreatment for anaerobic digestion.

The use of ozone, which is well known as a strong oxidant, besides noticeable reduction of sludge production, was proved to modify sludge properties and characteristics and increase biogas production from pretreated substrates.

Sonolysis relies on the use of ultrasound to provide substrate disintegration by acoustic cavitational phenomena, which involves the formation and expansion of micro-bubbles and their consequent collapse. As a result, both chemical and physical reactions can occur resulting in solubilisation and digestibility enhancement.

The analysis of scientific literature highlighted that both ozone and sonolysis applications represent innovative pretreatment options for solid organic substrates to be treated by means of anaerobic digestion.

Furthermore, research development has recently pointed out that the enhancement of methane production after ultrasonic treatment is highly variable according to the different parameters affecting the combined US/anaerobic process.

Therefore, the research activity discussed in this work aimed to:

- the comparative evaluation of ozonation and sonolysis as pretreatment of the organic fraction of municipal solid waste (OFMSW) for anaerobic digestion;
- the assessment of the technical and economic feasibility of the optimal OFMSW pretreatment option.

To this end, experimental activity was structured in two main steps:

- the first one was focused on the assessment of both ozonation and sonolysis effectiveness in promoting solubilisation and anaerobic biodegradability of OFMSW;
- the second part, performed on the basis of the results of the previous phase, was focused on sonolysis effects. In particular, experimental activity was addressed towards the definition of main parameters, in order to assess the technical and economic feasibility of the full scale US pretreatment.

Moreover the relation between sonication pretreatment effects and organic matter composition was assessed.

The first part of the research, focused on the comparative assessment of ozonation and sonolysis, was performed at the Sanitary Environmental Engineering division (SEED) of Salerno University.

For both ozonation and sonolysis, different operating conditions were studied in order to highlight the relation between process extent and the induced solubilisation, which was estimated through soluble COD. The reduction in volatile solid content, which indicates the occurrence of mineralization phenomena, was also monitored for the investigated operating conditions.

Results show that both ozonation and sonolysis are effective in increasing solubilisation of the organic fraction of municipal solid waste. However, higher ozone doses resulted in the formation of by-products which are less biodegradable than the untreated substrate.

This aspect represents a limitation to the scale up of ozonation as pretreatment of OFMSW for anaerobic digestion, as the effectiveness of the process requires strict operating conditions in terms of ozone doses.

Moreover, this drawback was not reported to affect other chemical pretreatments, which can also be handled more easily.

Conversely, the ultrasound-induced disintegration determines an increase of the soluble compounds, which results in improved biodegradability of sonicated samples and, consequently, in higher biogas volumes from the anaerobic digestion of pretreated substrates.

The results of the comparative evaluation of ozonation and sonolysis addressed the research towards the in-depth analysis of sonolysis mechanisms on organic solid matter destined to anaerobic digestion.

In this second phase, the experimental activity was performed at the Technical University of Hamburg-Harburg (TUHH - Germany), in cooperation with Ultrawaves GmbH (Hamburg, Germany), acknowledged since 1995 for its valuable work on the development of new procedures for treating water, wastewater and sludge by means of ultrasound. This work led to the design of one of the most highly developed ultrasonic reactors, which is internationally commercialized. The cooperation allowed the acquisition of an over ten years experience accrued by prof. Uwe Neis and dr Klaus Nickel in the field of sonolysis as well as the use of the basic device of their ultrasonic reactor for the experimental activity.

The effects of the application of different operating conditions were assessed through the quantitative and qualitative characterization of the soluble fraction of sonicated samples as well as by means of anaerobic biodegradability tests.

Experimental results proved that, although the effects of sonolysis on organic substrates depend on the composition of the substrate itself, ultrasound is a valid technical option in anaerobic digestion facilities for OFMSW treatment, as it allowed relevant solubilisation enhancement as well as the improvement of methane production from pretreated substrates. Moreover, its proper application can imply several operating advantages and proved to be economically feasible.

The results of this research are of relevant interest, as they highlight advantages and limits of these innovative pretreatment technologies as well as the high operative potential of sonolysis as pretreatment of solid waste for anaerobic digestion.