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Anaerobic digestion as sustainable source of energy: A dynamic approach for improving the recovery of organic waste

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Abstract

Organic waste fraction disposed to landfill induce the release of greenhouse gas and leachate due to its degradation. The collection and treatment of such typology of waste is imperative in order to decrease environmental pollution and improve recycling rates. The aim of this study is to define a flexible and economically viable system to process all the RMSW and the OFMSW coming from SC, in a territory with low recycling rates. To that purpose, the survey provides a dynamic system which comply with future increases in the efficiency of SC systems. Dry anaerobic batch reactors are considered in order to treat RMSW and to operate the OFMSW, as long as SC improves. Four scenarios were considered, in particular for 10%, 25%, 50% and 75% SC rate. Biogas production has been estimated for evaluating the potentiality of each SC rate, since it can be exploited for generating electric energy and heating. Biogas generation is enhanced of the 21% by increasing from 10% to 75% SC, making the system more profitable under an energetic point of view. Moreover, the amount of electric energy which could be sold per year for each SC scenario was calculated, resulting as 631,293 kWh for the 10% SC and 442,527 kWh for 75% SC. Considerations on the exportability of the approach were also added in the paper, highlighting the affordability of the anaerobic digestion system in other countries.

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1. Introduction

MSW usually consists of more than 50% in putrescible matter and its management is a great issue worldwide, in particular for developing countries [1, 2]. MSW are commonly disposed to landfills or open dump sites affecting the environmental sustainability by the release of contaminants like leachates and GHG, generated by the high amounts of putrescible waste which increase the pollution potential of the sites [3, 4]. At the same time, the organic fraction can be considered as a source of energy and fertilizer since biological treatments, in particular composting and AD, are a viable way to treat and exploit the OFMWS and wastewater sludge for co-digesting procedures [5-8]. With respect to the aerobic process, which generates exhausted air mainly composed by CO_2 , NH_3 , H_2O , O_2 and N_2 , and a solid fraction (compost), the main advantage of AD is related to the energy recovery process [9]. Indeed, the anaerobic procedure generates methane which can be used for producing electric energy. One cubic meter of biogas can generate an electrical energy of 2.5 kWh [10], whereas putrescible waste can generate about $128 \text{ m}^3 \text{ t}^{-1}$ of biogas [11], resulting in the production of 150-300 kWh of electric energy per ton of waste treated [9]. The energy value can increase at 500-750 kWh t^{-1} if the biogas is generated from animal manures [12]. On the contrary, aerobic composting required 30-35 kWh of energy per ton input [13]. Although the investment cost for AD are 1.2-1.5 times higher than aerobic composting, the energy exploitation associated to the first process makes it more attractive [14].

In this frame, economic incentives on energy production play also an important role. Indeed, different companies working in the agricultural sector, food industry and livestock are moving toward the AD for energy production [15-21]. The same situation can be noticed regarding the OFMSW. In fact, within the EU, the interest on this waste stream keeps growing due to rising energy costs associated with the processing of wet waste, the prohibition of landfilling any putrescible refuse (EU Landfill directive 99/31/EC) and the need to comply with regulations for the disposal of animal by-products [22, 23]. AD is also a response to the increase of the global consumption of energy and to the limited availability of fossil fuels, together with the raise in waste production and the associated environmental and structural issues related to its treatment [24,25]. The topic concerning environmental sustainability, focused on the choice of the waste treatment process, becomes a paramount aspect during the decisional progression involving the technology that should be adopted [26]. The application of AD plants can meet the request of sustainable development, with benefits also in term of reduced odor impact around the plant, when compared with aerobic composting.

The design phase of a waste treatment facility is strictly bonded also into the EU regulations and the laws of the marketplace. Besides, only integrated solutions, that can transversally consider all the major issues, should be taken into account. Environmental problems, renewable energy request at national and international level, the quantity and quality of the waste produced and the economic requirements should be studied before the design phase of a plant [27, 28].

In the present work, the viability of an AD plant in a context with very low SC rates (and therefore it is not possible to operate only on the source separated streams) is analysed. Besides, the strong lack of waste treatment units was considered for all the refuse streams since it can be generally found in the developing countries. This work was meant to suggest a possible unique system capable of treating, through AD process, both the RMSW and the OFMSW, coming from a continuously evolving SC process, without having to operate substantial changes in the structure of the plant itself during the years. In this study, four progressive conditions of SC were considered: 10%, 25%, 50% and 75% referred to an area in the South of Italy. The solution proposed is based on the utilization of batch reactors. Most of them will be loaded with RMSW during the first period. Afterwards, they will be converted to the treatment of source separated putrescible waste as long as SC increases. Through this solution, there is no need of changing the total number of AD reactors. The two waste streams should be always kept and treated separately in order to avoid contamination of OFMSW coming from SC with RMSW, since only with OFMSW as input it is possible to produce high quality compost. From the unsorted waste, instead, a bio-stabilized matter is generated, which can be landfilled or used for capping activities. The digesters working temperature was chosen in order to always be able to process all the incoming waste in all the conditions. An estimation of the biogas produced was also performed, considering the transformation ratio of the VS into biogas which is exploited by a cogeneration unit. The approach was theoretically applied to the municipality of Agrigento, Sicily (Italy). This province, with a population of 474,493 inhabitants, presents a level of selective collection which remarks an underdeveloped condition in the SWM, as can be faced in the whole Sicily. The example and the assumptions of the study can help policy makers

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