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Assessment of biogas production in Argentina from co-digestion of sludge and municipal solid waste

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ABSTRACT

In Argentina, there is an important potential to utilize organic waste to generate bioenergy. This work analyzes the environmental impacts and the energetic and economic requirements of the biogas produced by digesting the sewage sludge (SS) produced in a wastewater treatment plant in a medium city in Argentina. The SS is co-digested with the organic fraction of municipal solid waste (OFMSW), and the basis of this study is the life cycle assessment (LCA). The LCA is performed according to ISO 14040-44 using the SimaPro simulator. First, the transport of the raw materials to the biogas plant was defined. Then, the co-digestion and the biogas treatment for final use were evaluated. The co-digestion was improved with glycerol, and the generation of biogas was estimated using the GPS-X software. Two alternatives for the end use of biogas were considered: combined heat and power (CHP) and biomethane generation. For the first, H_2S and water vapor were removed from the raw biogas stream, and for the second, also CO_2 was removed. The H_2S removal process was simulated in the SuperPro software by anaerobic biofiltration. The same software was used to simulate the removal of CO_2 absorption-desorption with water as solvent. Finally, the environmental impacts related to the end use of biogas (CHP and biomethane) were evaluated. The environmental, energetic and economic analyses showed that the co-digestion of SS and OFMSW has great potential for reducing the environmental impacts and increasing the economic and energetic value of the substances via the production of biomethane, electricity and, potentially, fertilizer.

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1. Introduction

Biogas is a renewable energy that is produced from different types of biomass, including energy crops, municipal solid waste, sewage and waste from agriculture, livestock and some industrial activities. A complete discussion on production, conditioning and utilization of biogas can be found in Budzianowski (2016). That work presents many potential process innovations from most recent patent and academic literature. Currently, considering the great potential that exists in Argentina, there is growing interest in the use of biomass for energy purposes to diversify its energy matrix. Municipal solid waste and sewage are the main organic wastes generated in urban centers, and treatment in Argentina is beginning to be required by local laws. The use of organic waste to generate energy is a very interesting alternative because it allows energy generation to be further decentralized. Biogas technical capacity is fairly well developed in Argentina. An inventory of biogas plants in Argentina list 105 anaerobic digesters in 16 provinces belonging to the public sector, the private sector, production cooperatives and non-governmental organizations (Goicoa, 2016). A survey of 61 of those biogas plants indicates that a large number of plants belong to the private sector (53.1%) with the objective to treat effluents and only a small portion (6%) to get energy. The biogas plants in the public sector are mainly used to treat effluents and a 33% are used for research and teaching. Several plants belonging to municipalities present operational and management problems. There are important differences between public and private. The private sector has larger plants built in rural areas using USAB, cover lagoons and continuous-flow stirred tank reactors with imported technology and materials. A common ground in both sectors is the lack of heating and mixing of the digesters indicating that the plant is not working in the optimum biological condition. The more common substrates are industrial and agro wastes (86%). The rest is organic municipal wastes with a small contribution from crops. The 42.6% of the plants do not use the biogas, 44.3% use the biogas for heating and only 12% have some sort

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of electrical use. Besides, Argentina has programs (EMGIRSU and PROBIOMAS) and two institution (INTA and INTI) targeting the development of the biogas technology. Biogas was included with a small participation (15 MW over 1000 MW) in the recent program RenovAr (2016) which offered a favorable tariff for renewable energy based electricity production.

To date, a wide range of studies have evaluated the impacts associated with biogas generation systems using the life-cycle assessment (LCA) (Borjesson and Berglund, 2006; Jury et al., 2010; Dressler et al., 2012; Lijó et al., 2014a; Morero et al., 2015b). These studies analyze a large variety of raw materials and end uses of biogas. Bacenetti et al. (2016) reviewed the LCA studies carried out in different countries focusing on agricultural AD plants. The review shows that the goal, scope, life cycle impact assessment methodology and feedstock vary widely making it difficult to compare the different LCA studies and to obtain common conclusions on the environmental impact of biogas production. Bacenetti et al. (2016), also, analyzed four plants and pointed out that energy crops production, anaerobic digester operation, and digestate emission from open tanks are the main contributors to environmental impacts. At the same time, papers have been published associated with the co-digestion of biogas, most of which focused on the use of crops as co-substrates (De Vries et al., 2012; Lansche and Müller, 2012; Poeschl et al., 2012a; Bacenetti et al., 2013; Lijó et al., 2014b). The advantage to this solution is that plants can achieve higher yields compared to the use of a single raw material. Additionally, the quality of the biogas is improved. Recent studies evaluating the co-digestion of livestock manure from organic waste (Poeschl et al., 2012b; De Vries et al., 2012; Rodriguez-Verde et al., 2014; Lijó et al., 2015) concluded that the use of organic waste as a co-substrate generates less of an environmental impact than does the use of energy crops. In addition, these studies demonstrate the environmental benefits of using the waste, resulting from the absence of impacts in its production, as opposed to the high environmental impacts of energy crop production. These works conclude that to maximize the environmental benefit, a higher proportion of agricultural or organic waste should be included in co-digestion. Therefore, an interesting alternative is to evaluate the co-digestion of the most abundant waste generated in a city.

This paper, carried out for first time in Argentina, analyzes the environmental impacts and the economic and energetic requirements of biogas production by digesting the sewage sludge (SS) produced in the wastewater treatment plant in a medium city. The SS is co-digested with the organic fraction of municipal solid waste (OFMSW), and the basis of the study is the life cycle assessment (LCA). The LCA was performed according to ISO 14040-44 (ISO 14044: 2006) using the SimaPro simulator (Pré Consultants, 2015).

2. Materials and methods

In Argentina, the largest amount of waste is disposed in sanitary landfills or in informal dumps without proper treatment. Only the 60% of the population reaches an adequate treatment of waste (SAyDS, 2015). In localities that have built landfills, there is no separation of organic waste generally, and the organic matter has the same disposal as non-recyclable waste. Therefore, it is interesting to propose alternatives to reduce both the environmental impacts and the costs of waste treatment to generate an attractive project.

The bioenergy processes included the collection and transportation of wastes, anaerobic digestion, biogas treatment (desulphurization, upgrading) and digestate management according to its use (organic fertilizer or incineration). The study was performed according to the daily production of OFMSW (17.5 t) and SS (24.4 m^3) in a medium-sized city (34,000 inhabitants) in Argentina.

2.1. LCA methodology

The LCA was conducted according to ISO 14040-44 (ISO 14040: 2006; ISO 14044: 2006) in four phases: the goal and scope definition phase, the inventory analysis phase, the impact assessment phase and the interpretation phase.

2.1.1. Goal and scope definition phase

The objectives and scope of the LCA were to determine the environmental impacts associated with each Stage of biogas production from the co-digestion of SS and OFMSW and its subsequent use as biomethane or electricity. In addition, we evaluated the environmental impacts associated with the management of digestate.

2.1.2. Functional unit

The functional unit chosen was the amount of organic waste (feedstock) that was annually digested (21,000 t). This amount corresponded to the OFMSW and SS generated in the town with the addition of glycerol, which was added to improve biogas production.

2.1.3. System boundaries

The boundaries of the system include the transport of the different feedstocks to the biogas plant and the materials and energy used. The materials and energy included those used in anaerobic digestion, in the desulphurization plant, in the upgrading biogas plant and in the conditioning of biogas for final use either as biomethane or as CHP. In addition, two digestate end-use options (organic fertilizer or incineration) were evaluated. Finally, the total process was compared in environmental and economic terms with a current waste treatment practice (landfill).

The system boundaries of the system under assessment was divided into four stages: feedstock transport (Stage 1), biogas production plant (Stage 2), digestate management (Stage 3) and biogas treatment plant (Stage 4). In Fig. 1 the system boundaries of each Stage are shown.

2.1.4. Inventory data

For this study the inventory data was collected from different sources, simulations and procedures. Sections 2.1.4.1–2.1.4.4 describe how the inventory of each Stage was made. Data regarding the production of mineral fertilizers, electricity, heat, diesel and sanitary landfill infrastructure were obtained from the ecoinvent database version 3 (Weidema et al., 2013).

2.1.4.1. Stage 1: feedstock transport. In Stage 1, the inputs and outputs were considered. These were associated with the transport of the feedstocks through the anaerobic digestion plant and the energy used in the municipal solid waste plant. It was assumed that the anaerobic digestion plant was located on the same site as the sewage treatment plant, so there would be no transport of SS. Data from a real plant located in a medium-sized city of Argentina (Groppelli et al., 2008) were used to calculate the electricity consumption of the municipal solid waste plant (related to the sorting, crushing and pressing of the OFMSW). Moreover, the transportation distance of OFMSW from the landfill to the anaerobic digestion plant was considered to be 9 km. The biodiesel plant (which produces glycerol as a by-product) was located 50 km from the biogas plant. Table 1 summarizes the annual inventory for the first Stage.

2.1.4.2. Stage 2: biogas production plant. The anaerobic digestion scenario was simulated using GPS-X v6.0.2 (Hydromantis, 2010).

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