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Municipal solid waste as a valuable renewable energy resource: a worldwide opportunity of energy recovery by using Waste-To-Energy Technologies

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Abstract

The generation rate of Municipal Solid Waste is expected to increase to 2.2 billion tonnes per year by 2025 worldwide. However, in developing countries, collection, transport and disposing of waste is still challenging while, in developed countries, emerging technologies are used to produce different by-products such as heat, electricity, compost and bio-fuels. This study assesses the different waste-to-energy technologies developed to date. This work is divided into four groups: biological treatment of waste; thermal treatment of waste; landfill gas utilization; and biorefineries. Furthermore, integrated solid waste management systems with waste-to-energy technologies are studied and some worldwide examples are provided.

Keywords: Integrated solid waste management systems (ISWM-S); municipal solid waste (MSW); solid waste management (SWM); waste-to-energy technologies (WTE-T).

1. Introduction

Worldwide, increasing population density along with population migration from rural to urban areas and industrial expansion lead to great amounts of waste generation resulting in socio-economic and environmental issues [1]. Overall,

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managing Municipal Solid Waste (MSW) is challenging rather than an opportunity to obtain other commodities such as recycling materials, heat or energy [2]. Nowadays, the world's economies are driven by consumer-based lifestyles, where producing waste is the most evident and unfavorable resource-intensive by-product. MSW can be classified into organic and inorganic (paper, plastic, glass, metals, and other) [3]. Depending on economic development, climate, culture, and energy sources, MSW composition varies from one country to another. Whereas low-income nations have the highest proportion of organic waste, in high income countries, MSW is predominately composed by inorganic materials [4]. A report from The World Bank estimates that currently 1.3 billion tonnes of waste is generated per year all over the world; and by 2025 this amount will increase to 2.2 billion tonnes per year [5]. These data show an urgent need for strategies to treat the increasing rate of MSW generation around the globe. However, although in developed countries waste is used by a resource to produce energy, heat, fuel and compost, in developing countries collection, transport and disposal of waste are current issues [6, 7]. In general, cities that are unable to manage its MSW effectively are rarely able to manage more demanding services such as electricity, health, education, or transportation.

Waste-to-energy technologies (WTE-T) are promising technologies, especially for developing countries, to turn waste into a useable form of energy. In the developed world, WTW-T are being part of their Integrated Solid Waste Management Systems (ISWM-S) to not only produce other by-products but also to address global warming and climate change. Globally, WTE-T play a vital role for sustainable waste management and mitigation of environmental issues [8, 9]. These technologies are generally classified as biological treatment technologies (or Biochemical process) and thermal treatment technologies (or Thermochemical process) [10].

This research assesses biological treatment in terms of anaerobic digestion technologies and thermal treatment in terms of pyrolysis, gasification and incineration technologies, in Section 2.1 and Section 2.2, respectively. Landfill gas utilization technologies along with biorefineries are studied to produce methane and bio-fuels, in Section 2.3 and Section 2.4, respectively. Some examples of ISWM-S using WTE-T are also provided in Section 3. Finally, a critical analysis is made based on the use of WTE-T in developed and developing countries.

2. Waste-to-energy technologies

This section addresses the WTE-T in terms of biological treatment technologies, thermal treatment technologies, landfill gas utilization, and biorefineries.

2.1. Biological treatment technologies

The biodegradable MSW fraction has a high potential for energy production. Biological treatment technologies (BTT) are designed and engineered for natural biological process working with the organic rich fraction of MSW [11]. These treatments are divided into two different processes according to the conditions in which happen: the aerobic process or composting (in the presence of oxygen) and the anaerobic process (in the absence of oxygen). The main product of the anaerobic process is a combustible gas which is a mixture of methane and carbon dioxide. This process requires less energy than the aerobic process and creates much lower amounts of biological heat. The biodegradable fraction is converted into a fuel known as biogas [12]. This biogas is burned to produce heat and/or electrical energy.

2.1.1. Anaerobic digestion technologies

Biogas technologies are classified as 'wet' and 'dry' techniques. Wet technologies process more liquid material whereas dry technologies treat drier materials. Table 1 illustrates the advanced anaerobic digestion technologies to produce biogas, their advantages and disadvantages. In general, 'wet' anaerobic digestion technologies have been adopted in well-established systems to treat municipal wastewater. The digestion process produces biogas and decontaminated water [13]. 'Dry' anaerobic digestion technologies operate with higher solid content and produce greater heat [14]. The production of biogas reduces the amount of waste and, therefore, reduces the amount of waste for disposal in landfills. This biogas is usually used in two ways: to generate electricity and to produce heat in different required processes [15]. Excess heat can be additionally used in district heating networks or in industrial processes; and future studies regarding the use of biogas as vehicle fuel are expected.