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Original article

Evaluation of the treatment of municipal solid waste as renewable energy resource in Campinas, Brazil

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ABSTRACT

Treatment and final destination of municipal solid waste (MSW) in Brazil has been a problem waiting for solution to alleviate environmental and public health negative impacts, since almost all MSW collected is dumped in landfills and open and covered dumps. Specifically in Campinas, a metropolis with more of one million inhabitants, the local landfill was closed since 2014 and since, the collected MSW is dumped in the landfill belonging to a neighbouring city. In an attempt to contribute to the solution of the problem, the authors elaborated two scenarios for waste treatment with energy recovery and social inclusion. The most recent characterization data of the municipality was used in assessing the two proposed scenarios of incineration and biodigestion and recycling of 20 percent of the available recyclables. The comparative results indicate that biodigestion and incineration can generate electricity enough for 1% and 39% of the residencies of Campinas, respectively. The commercialization recyclables corresponds to 1120 minimum national salaries, which is sufficient for sustaining the twelve cooperatives of waste pickers. From the comparative assessment, the authors believe that incineration and recycling can be a possible solution to minimize the problem of MSW in the city.

Introduction

The increase of the world population, the technological innovations, and deep changes in habits and lifestyle patterns in the last decades stimulated consumption with a strong reflex on the rate of generation of solid waste. World Bank [1] estimates show daily generated solid waste of about 1.3×10^9 tons with perspective increase to about 2.2×10^9 tons until 2025. Solid waste needs to be daily collected, and adequately treated for sanitary and public health issues and this is one of the biggest difficulties currently facing public authorities, mainly in development countries [2,3].

WHO/UNICEF [4] reports that many cities in the world do not have yet adequate solution for their solid waste. In Brazil, for example, most of the 5570 municipalities dispose their MSW in about of 4200 dumps (covered and uncovered). Disposition of MSW in dumps is a serious problem because of the risks to public health due to emissions and contamination of underground water and soil [4,5]. ONU estimated a loss of annual of Gross Domestic Product (GDP) of the municipalities of 3% to 7% due to the inadequate public sanitation, which affect principally poor population in developing countries [6].

Besides the negative impacts on public health and the ecosystem, the inadequate treatment of MSW also contributes to global warming. During decomposition, organic wastes release ambient offensive gases, mainly Methane (CH_4) and Carbon dioxide (CO_2) denominated as greenhouse gases (GHG). The warming power of CH_4 is 28 times more than that of CO_2 [7]. The world emissions from landfills represent 11% of the anthropogenic emissions [8]. According to IPCC [9], the gases released into the atmosphere are increasing since 1950s causing warming our Planet. The results are climate changes, observed by the warming of oceans' water, increase of sea water level, melting of the icebergs and ice blocks. The reports from Intergovernmental Panel Climate Change (IPCC) alert about the possible drastic consequences and propose relevant and urgent recommendations to alleviate these problems [9]. Therefore, the reversion of this situation is the greatest challenge of the 21 century.

The route towards local and global sustainability require in general changing the society paradigm to adopt adequate individual and collective practices starting with their own generated waste [3,10,11]. Ever good initiatives such as the 3Rs (Reduce, Reuse and Recycle) and the thermal or biological treatments of the rest of MSW to produce energy and neutralize its ambient offensive effects are among the most recommended actions. The literature is rich with studies related to the energy, economic and environmental potential of solid waste which when adequately treated can have a big contribution to the general

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welfare, social inclusion and public health [12–14].

Researchers as Lino and Ismail [2], Lino [3], Reddy [10], Rada [14], Jones [15], Maize [16], Rada et al [17,18], Ozbay and Durmusoglu [19], Consonni et al. [20] and many others defend the idea of MSW treatment for energy production and also as a mechanism for social inclusion. Experiences related to thermal treatment and biodigestion of MSW with energy generation and recycling are reported in countries in Asia, Europe and America [2,14,21–29].

Waste treatment practices have improved considerably in the EU. In the period 1990–2012, for example, energy from the treatment of MSW represented about 29% of the total energy from renewable sources, increasing from 2,084.8 ktoe to 8,738.3 ktoe [11,30]. In 2013, about 43% of the EU's generated MSW was recycled or composted [11,31,32]. EEA [31] reports that landfilling is the least environmentally friendly waste disposal method and has been gradually replaced by incineration and even more so by recycling and composting. Following a hierarchy of management to treat their solid waste, in 2013, countries such as Japan, Denmark, Germany, Netherlands, Sweden, Belgium and Switzerland disposed less than 3% of MSW in sanitary landfill, incinerated more than 35% and composted and recycled more than 40%, except Japan who composted and recycled about 18%. While this, three highly populated countries that is, EUA, China and Brazil are highly dependent on landfills where they dispose most of the generated MSW [11,33–36].

Municipal solid waste management cycle

Generation, composition and collection

Solid waste generation started with human civilization and is intrinsically related to population, urbanization and living standard. It is generated throughout the life cycle of the product, i.e. from the production and extraction of raw material and in subsequent steps to production processes until final consumption [3,28]. The treatment process includes a set of steps. On this issue, there is vast literature focusing on the different steps of MSW management (MSWM). Rada et al. [37], Lino [3,28], Longo and Wagner [38] consider that MSWM is a multidisciplinary activity that includes generation, source separation, storage, collection, transfer and transport, processing and recovery, and, last but not least, disposal. As in [39,40] waste management includes a set of actions devoted to searching for waste management solutions, which take into consideration the political, economic, environmental, cultural and social aspects, as bases for the sustainable development and protection of the health of the population.

The analysis of the World Bank data [1] shows that not all generated MSW is collected. Economically developed countries usually collect more solid waste. Countries with population of high income per capita such as in USA, Canada and Japan collect about 98% of generated MSW; countries with population of average high income such as Mexico, Russia and Lebanon collect about 85%; countries with population of average low income such as in Brazil, China, India and Turkey collect about 68%, and finally countries with population of low income such as Ethiopia and Tanzania collect about 42%.

Implantation and realization of MSW collection in economically less developed countries frequently faces shortage of funds destined to public service. In Brazil, the allocated budget for this service is around 3–7% of the total municipality budget where the public collection of MSW consumes 70–80% [28]. For these reasons optimization of the collection process including evaluation of the type of transport and routes, etc. in order to reduce its costs turn to be extremely important [41,28]. The use of available computational techniques such as WebGIS [42] can optimize the circulation route and improve the efficiency.

Mamun et al. [43] presented a method for real time solid waste bin monitoring with an optimization model to optimize solid waste collection route using real time bin information, and found that the results can reduce the operation costs.

The next step in MSW management is to obtain information about the volume, types and mass of collected MSW. This information is crucial for choosing the method of treatment [17,20,44–46]. Generally, the quantity and type of collected MSW are different for different countries, cities and even according to the social class of the community [5]. Details on the composition and type of material contained in the collected mass (organic and inorganic matters) is normally obtained from the gravimetric characterization [47, Unpublished report[1]] realized according to internationally accepted methodology available in USEPA [48] and ABNT [49].

The mass of MSW consists of degradable organic matter such as food leftovers, paper, cardboard and pruning of plants; none degradable organic matter such as plastic and inorganic matter such glass and metals, which take hundreds of years to decompose. According to [1], rich countries generate more packaging waste while poor countries generate more organic residue. Due to the massive volume of generated MSW, developed countries have created mechanisms to engage the production sector and consumers in the treatment process to reduce the ever increasing amounts of wastes and effectively reuse or eliminate it [1,29,30,35].

Recycling

Recycling is one of the treatment processes, which starts with the selective collection of MSW at homes and ends in the industry where recyclables are transformed to secondary material. In this way, paper, cardboard, plastics, glass and metals return to the production chain saving energy [12,35,44]. Lino and Ismail [2], Bing et al. [50] and Baeyens et al. [51], consider that waste recycling is a multi-disciplinary problem that needs to be considered at different decision levels simultaneously. The success of materials recycling depends upon its ability to consistently transform material wastes into high quality and marketable products, ensuring a stable market for the end products, and cost-effective manufacturing manner.

For these reasons, separation of recyclables at source is considered as an important step in the recycling process, and entirely depends on the operational model and adhesion of the population to selective collection programs [41,12,52,53].

Solid waste is a renewable energy resource. Energy content of MSW ranges from 8 to 11 MJ/kg while the Refuse Derived Fuel (RDF) composed of dry MSW has a calorific value varying from 12 to 17 MJ/kg [15,42,54]. Comparatively, a ton of MSW and one barrel of petroleum both release nearly the same amount of heat, about 7GJ [15]. This reinforces the inherent potential of MSW as a viable option for energy generation, promoting public health and reducing environmental impacts.

Thermal processes

The technologies for thermal processing of MSW to produce energy include gasification, incineration, pyrolysis and treatment by plasma torch. In the incineration process, energy is released directly as heat while in the processes of pyrolysis and gasification liquid and gaseous fuels are produced and can be used to generate energy [29,32].

Incineration is a practice most common in many countries. The process involves combustion of MSW in the presence of oxygen in temperature over 850 °C for two seconds to convert MSW to CO_2, water vapor, volatiles and solid ash containing a small amount of residual carbon [5,10,55]. Among the numerous advantages of incineration is the reduction of the volume and mass by 90% and 75%, respectively; elimination of pathogens and generation of heat, which can be transformed to electricity and/or to heat water for district distribution [5,10,29].

[1] Renova Ambiental (2015) - Official unpublished report produced by the company responsible for collection of the MSW in Campinas.