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Waste management studies in a Brazilian microregion: GHG emissions balance and LFG energy project economic feasibility analysis

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ABSTRACT

The appropriate management of municipal solid waste (MSW) is a key issue in today's economy. In Brazil, this has been the subject matter of several studies, since the National Policy on Solid Waste in 2010 established the closure of dumps and encourages the implementation of more appropriate forms of MSW disposal. In order to contribute to the study of MSW management in Brazil, this paper presents a two-step analysis of the MSW management of São Lourenço microregion consortium (MG). In the first step, WARM (USEPA) software was applied in evaluating Green House Gases (GHG) emissions and energy consumption at three alternative scenarios, which were compared to a baseline scenario, where all MSW was sent to landfills. Scenario 1: Reprocessing of all recyclable waste and composting of organic fraction of MSW. Scenario 2: Reprocessing of all recyclable waste but with an organic fraction of MSW landfilling and scenario 3: Incineration of all solid waste. At the second step, the economic feasibility of a project to generate energy from the landfill biogas (LFG) was evaluated in terms of GHG emissions. The most advantageous alternative was scenario 1 because it allowed the reduction up to 90,000 tC_{eq} in relation to the base scenario of MSW management. The economic feasibility of generating energy from LFG was only achieved for the scenarios in which the enterprise was considered as a form of microgeneration as regulated by the National Agency of Electric Energy (ANEEL, in Portuguese), which indicates the need for government incentives so as to reduce the costs of such projects and the need to incorporate new cities into the consortium analyzed, thereby expanding the mass of waste available and also increasing the production of landfill gas.

1. Introduction

The concern on integrated management of municipal solid waste has increased in recent decades especially due to the need to preserve natural resources for the benefit of future generations. Amongst many issues, finding ways to solve the challenges of good and quality management of solid waste is of great importance [23,24,31]. This is peculiar to Brazil where it was only few years ago that the Brazilian National Solid Waste Policy (NPSW) was instituted by Law n. 12,305/2010 [12] and regulated by Decree n. 7404/2010 [13]. The Waste Reduction Model (WARM) [4,23] and the Life Cycle Assessment (LCA) [24,29,31] are important tools when looking for better solutions for municipal solid waste management (MSWM). The inclusion of waste pickers as Brazilian's legal requirements to support decision-makings yet another challenge to the implementation of the NPSW [24]. In addition, considering the landfill option of MSWM, the Intergovernmental Panel on Climate Change (IPCC) methodology [1,22,28,76] and Landfill Gas Emission Model (LandGEM) [4,19,41,73,81] were used to estimate the methane productions [60], which have high potential for use as energy source. NPSW prohibits the existence of “dumps” and recommends the formation of consortia among municipalities for construction, MSW disposal, and management of landfills. Regarding the MSWM, traditional options as shown by Daskalopoulos et al. [22] are landfilling, incineration, composting, and recycling. Where landfillinghasprovento be the cheapest option for management.

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According to Wilson et al. [80], the 'Wasteawere' Integrated Solid Waste Management benchmark indicators include: Physical components, such as collection, disposal, and recycling; and governmental components, such as the inclusion of stakeholders, financial sustainability, sound institutions, and proactive polices. This demonstrates that, these indicators can improve the quality of waste management mainly in developing countries. More attention should be drawn to the development of an updated and detailed data, which will facilitate solutions for MSWM in Brazil.

There is an increasing concern on the issue of Greenhouse Gases (GHG) at the world level. The agreement at COP21 in Paris 2015 which proposes to maintain the mean global temperature below 2 °C above pre-industrial levels and towards 1.5 °C by the year 2100 [69]. Brazil has a national policy on climate change (NPCC), created by Law n. 12,187 [10] and regulated by decree n. 7390/2010 [11]. According to this decree, the baseline of GHG emissions for 2020 was estimated at 3236 $GtCO_2eq$. Therefore, the absolute reduction correspondence was established between 36.1% and 38.9% reduction of GHG emissions, that is, 1168 $GtCO_2eq$ and 1259 $GtCO_2eq$, respectively.

Regarding the diagnosis in the MSW management, the 2014 data from the Brazilian National System of Information on Sanitation [16] presented a diagnosis for MSW final disposal, with 12.3% of waste designated to open dumps and 52.4% to landfills in 2014. This corresponds to the commitment of municipalities and their adaptations to the National Plan for Solid Wastes (NPSW). The disposal of solid waste, in major sanitary landfills, raises a new issue: The emission of GHG from the anaerobic decomposition of the organic fraction [33,34,36], with CO_2 and CH_4 which are the main components of biogas [21]. Coincidentally, both are greenhouse gases issued in global context [33,34,36]. According to Zhu et al. [84], landfill biogas mainly comprises of methane, CH_4 (35–65%); carbon dioxide, CO_2 (15–50%); nitrogen (5–40%); hydrogen (0–3%); oxygen (0–5%); hydrogen sulphide H_2S (0–100 ppm); and other sulfur compounds. In accordance with the fourth Assessment Report of 2007 of the Intergovernmental Panel on Climate Change [33] CH_4 has a possibility for greenhouse effect through Global Warming Potential (GWP) which is 25 times higher than CO_2. However, $CH_{4,}$ colorless, odorless, with highly combustible content and may be subjected to double usefulness when burning which are:

- Conversion of CH_4 to CO_2, with less potential for greenhouse effect;
- Production of electrical energy, thereby replacing energy sources of high environmental impact such as fossil fuels.

The simulations, aiming to account for GHG increments using the United States Environmental Protection Agency Waste Reduction Model (WARM®), under some conditions were carried out by Barros et al. [5]. This was done during the design and implementation study of a Permanent Selective Collection Program (PSCP) at a University campus in Brazil. The results show a scenario in which 90% of the solid waste could be sent for recycling and it would result in an economy of 7 tCO_{2eq} or 74.91 GJ (on an energy basis). Wang et al. [78] and Chang et al. [20] investigated the cost–benefit of GHG emissions for waste management in China. The authors indicated that there is a huge GHG reduction potential in solid waste management in China. These data indicate the potential for GHG emissions reducing from the correct waste management.

Considering the 30% efficiency in the energy conversion based on the report in Ref. [8], Brazil has the potential of generating about 660 MW of electric power from landfills [54] or between 337 MW (254,166 tep; 3,955,951 MWh in 2030) and 601 MW (452,746 tep; 5,265,436 MWh in 2030). This is in view of the potential population size contributing a landfill greater than 200,000 inhabitants [6], as well as the cases of 500,000 and 1,000,000 inhabitants showing good economic revenues [42]. According to Santos et al. [56], if biogas from Waste Water Treatment Plants (WWTP) were considered for energy use, the energy production from all WWTPs of municipalities with population greater than 300,000 inhabitants may correspond to at most 0.25% of the predicted waste fuel consumption by 2020 in Brazil [57]. Ribeiro et al. [53] estimated that, if all Brazilian poultry farms used manure to generate energy, it will be possible to generate 1.277 TWh/y. These data demonstrate the Brazilian potential of energy generation from waste and justify the authors concern about this subject.

Though requiring large area and emitting large amount of GHG, which can be collected for burning or for electricity generation [30], landfills are still the most widely used form of disposal in developing countries; particularly because of its low capital, operation and maintenance cost [2]. One of the ways to mitigate the impact of these structures where they are most frequent, especially in these developing countries, is the utilization of the biogas production. However, these projects often face the problem of financial viability [25,83].

Barros et al. [6] demonstrated that a population of at least 200,000 is necessary for the financial viability of Thermal Power Plant (TPP) for LFG. Rangel [51] also establishes that, the costs of generating energy from biogas, in places such as Brazil, are in general higher than the values of practiced energy sales tariff. In order to increase the financial viability of these enterprises, authors such as Santos et al. [55] and Silva et al. [59] developed methodologies for optimizing the installed power. This was done with the objective of taking advantage of the power in the landfill, to maximize financial attractiveness.

In addition, the Brazilian ANEEL Resolutions 482/2012 [9] and its revision 687/2015 [15] established incentives and opportunities for mini- and microgeneration. These Resolutions were favorable for becoming the energy thermal power plants (TPP) projects economic feasible in smaller landfills because allowed a system of energy credits. According to these Resolutions, undertakings from renewable sources can be beneficial to mini and micro-distributed generation through the compensation system, for example, an arrangement in which the active power injected by consuming unit with micro or mini distributed generation is sold to the local distributor and then compensated by the consumption of electrical energy which activates for the same consumer or for another consumer units of the same ownership [59]. This energy credit system may be used by the investor in its buildings for landfill management or in other companies or industries from yhe same ownership that have a enough energy demand to be fueled by the accumulated energy credits. Thus, the revenue of the investor is equal to the energy economy by sold to the distributor, which values are at least 150 USD/MWh in the country. This fact tends to increase the economic viability of LFG energy projects [55].

Therefore, the present study, using the IPCC model and WARM software, aims to analyze different alternatives for MSW management in the consortium of nine municipalities in the southern part of Minas Gerais State, Brazil and the Inter Municipal Consortium of Environmental Development in the Municipalities of the Microregion of São Lourenço (CIDESA, as acronym in Portuguese). The economic viability of the TPP implementation in this consortium was also analyzed. Since, landfills are the predominant form of solid waste disposal in Brazil. The CIDESA consists of the municipalities of Itanhandu, Carmo de Minas, Olímpio Noronha, Dom Viçoso, Pouso Alto, São Lourenço, Itamonte, Cristina, and Soledade de Minas, presented in the figure below (See Fig. 1).