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Energy and environmental potential of solid waste in Brazil

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A B S T R A C T

The economic progress and sustainable developments are linked to the optimization and energy conservation. Conventional methods of production and energy utilization usually embed harmful environmental impacts, and hence the challenge to scientists to seek for mechanisms of energy production and use which are less harmful or better still free of unfavorable environmental impacts. Studies point out that municipal solid waste has great energy potential and its reuse, specifically the production of biogas from landfills and the recycling of solid waste presents a favorable mechanism to optimize energy use and preserve it. The present investigation includes the energy savings and the avoided emissions of CO_2 to the atmosphere as a result of recycling and production of biogas from landfills in one metropolitan with more than one million inhabitants and in Brazil. The results show that the rate of CH_4 production from the Brazilian waste landfills can avail for Brazil about 41.7 MW and the reuse of recyclables can avail to the energy system an additional quantity of 286 GJ/month enough for the consumption of 318,000 families.

1. Introduction

The energy development in the twentieth century raised the average energy consumption per capita in the world to more than ten times the consumption of primitive man. In the period 1973–2006, the world's energy supply increased from 6115 Mtoe (where toe is the equivalent tons of oil) to 11,741 Mtoe, that is in a period of 33 years the recorded increase was 92% (MME (Ministério de Minas e Energia), 2009). This indicates that energy has become an essential commodity for the man's comfort and welfare (Martinez and Ebenhack, 2008; Gómez and Silveira, 2010). On one hand it is difficult to imagine life without power, on the other hand the environmental impacts of energy production and use has been an incognita. The emission of greenhouse gases, Carbon dioxide (CO_2) and Methane (CH_4) released by the action of man himself, is bringing irreversible effects for humanity as reported in the subsequent documents from the Intergovernmental Panel on Climate Change (IPCC) since 1990 (IPCC, 2007).

The continuous increase of energy production and consumption and the consequent impacts of these accelerated demands have required a change of behavior of the society and also drove research to alternative means of use and reuse of new energy sources. The solid waste, for example, constitutes one of such new sources of energy (Lino et al., 2010).

Solid waste is a by-product from human activities, and is characterized by the negative impacts that may cause to the man and the environment when disposed in an inappropriate way without treatment. Due to the continuously increasing amount of solid waste generated, particularly in capitals and major urban centers, the challenge for governments is to reduce the waste harmful impacts to both health and the environment (Unstat (United Nations Statistic Division), 2007).

Mechanisms of reducing these impacts include systems of organic solid waste composting producing organic fertilizers for agriculture purposes; recycling solid waste such as paper, cardboard, glass and metals back to the productive sector to replace raw material partially or fully, and finally the waste-to-energy mechanism whereby anaerobic digestion converts organic matter deposited in landfills to CH_4 for energy production (Cetesb (Companhia Ambiental do Estado de São Paulo), 2001; IPCC, 2007; Lennox and Neuwkoop, 2010).

The landfill gas or the biogas, composed principally of CH_4 and CO_2 proved to have many attractive applications as in power generation for isolated communities, fueling public service such as buses and trucks and other many applications of interest. Many examples of this type can be verified in Europe, USA and Canada (IPCC, 2007).

In 1994, the United States Environmental Protection Agency (USEPA) established the Landfill Methane Outreach Program to encourage the implementation of projects for recovery of landfill gas as energy source in the United States. The program identifies landfills with the potential to generate energy at competitive costs and without unnecessary barriers to use that source in various spheres of government. This initiative is part of the

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Climate Change Plan. In 2001, biogas was utilized in approximately 950 landfills (EPA, 2005).

In Brazil, the biogas from the landfill is marginally used. In the 1970s, two projects were implemented. One for the Gas Company of São Paulo (Comgas) and the other two companies in Rio de Janeiro, State Gas Company and Municipal Urban Cleaning Company (GEC/Comlurb). The first company distributed gas from landfill to a residential complex nearby. In case of the second company the biogas was collected, purified and injected in the gas distribution network supplying gas for the city of Rio de Janeiro. About 1000 m^3/day was placed in the network. In 1985, gas became the fuel for the fleet of 150 municipal trucks and also for a fleet of taxis. This project lasted 10 years (Cetesb, 2001).

Besides the landfill biogas, recycling of solid waste is another mechanism that permits energy and raw materials savings. Studies on the subject indicate that (Lino, 2009; Lino et al., 2010), recycling is the process that when applied, considering the technical and scientific aspects could have substantial energy and environmental benefits.

In the recycling industry, the recyclables such as paper and cardboard, plastics, glass and metals are sorted, adequately processed, prepared and sent back to the production chain as recycled matter. This leads to the use of less quantities of raw material in the industrial sector, reduction of water and energy and consequently avoiding CO_2 emissions to the atmosphere, creation of new job posts, increasing the useful life of landfills, reduction of public expenditure for waste treatment in the deposition areas and finally the social inclusion of less qualified citizens in the active society working mass (Lino, 2009; Lino et al., 2010).

This paper presents the evaluation of the energy saved by recycling, the corresponding CO_2 that is not emitted to the atmosphere as well as the amount of CH_4 and CO_2 generated by the decomposition of organic waste deposited in landfills in Brazil and one of the largest cities of the State of Sao Paulo, that is, the municipality of Campinas (SP). The calculations were extended also to the socioeconomic aspects of recycling.

2. Solid waste

The solid waste resulting from activities such as the industrial, residential, commercial, hospitable, agriculture and similars (ABNT (Associação Brasileira de Normas Técnicas), 2004), is generally composed of organic degradable matter (leftovers, paper and others); of non-degradable organic material (plastics) and of non-degradable inorganic matter (glass, metal and others). These latter materials if disposed in the ambient, can take hundreds of years to decompose and its accumulation leads to reducing the useful life of landfills.

In some developed countries such as Japan, Sweden, Belgium and Denmark, the index of reuse of solid waste is over 90%. In countries in Asia and Latin America, not all the solid waste is collected and in highly populated countries such as China and India and others such as Turkey, Mexico and Brazil almost 90% of the solid waste (whose major part is organic) considered as the principal source for producing CH_4 is usually destined to landfills and dumps freely liberating huge quantities of CO_2 and CH_4 to the atmosphere (Unstat, 2007; IBGE (Fundação Instituto Brasileiro de Geografia e Estatística), 2002).

2.1. Solid waste in Brazil

Brazil is the biggest country in Latin America occupies about 50% of the territorial area of the continent with a population of 194 millions in 2010, of which 84% are concentrated in the urban areas (IBGE (Fundação Instituto Brasileiro de Geografia e Estatística), 2009). According to the data of Brazilian Institute of Geography and Statistics, IBGE (2002), the country collects about 228.5×10^3 t/day of solid waste of the residential and commercial industrial types. This collection refers to 95.3% of the solid waste collected in the country of which 95% is disposed in dumps and landfills, etc (IBGE, 2002).

In 2000, the existing 5.993 dumps received per day about 48,600 t/day, about 84,600 t/day were disposed in 1868 controlled landfills, about 83,000 t/day in 1452 sanitary landfills, and 2000 in places not fixed, 1600 t/day at unspecified sites, 1000 t/day were delivered to 325 incinerators, 6500 t/day were destined to 260 composting plants and 2300 were sent to 596 recycling plants (IBGE, 2002).

The quantity of residential solid waste collected in Brazil represents 55% of the total collected in the country or 125×10^3 t/day or an average value of 0.74 kg/inhabitant day. Almost 77% of this residential solid waste is organic matter and the rest, 23% is inorganic. This information is obtained from IBGE (2002) relative to 2000 when the Brazilian population was 169 millions inhabitants.

2.2. Solid waste: biogas production and recycling

The landfill gas is generated in the bio-digestion of organic waste in landfills by the anaerobic digestion process (without the presence of oxygen). It is estimated that each ton of municipal solid waste deposited generates between 160 and 250 m^3 of biogas (IPCC, 2007), in the proportion of approximately 55% CH_4, 44% CO_2 and 1% other gases. Hence, one ton of municipal solid waste produces approximately 88–138 m^3 of CH_4. Thus, it is estimated that from 40 million to 60 million tons of CH_4 are generated yearly in landfills (Humer and Lechner, 1999).

According to Humer's and Lechner estimates (1999), an urban landfill in operation with 20 m thickness has an emission factor of about 340 l CH_4/m^2 day. Reinhart and Cooper (1992) estimate that the production of CH_4 in landfills is about 10.5 million t/year. Another estimate shows that global emissions of CH_4 in landfills are 60 million t/year, of which 15% are due to the Chinese landfills. Landfills can produce about 125 m^3 of CH_4 per ton of waste in a period of 10–40 years. According to the Company of Environmental Sanitation Technology, Cetesb (2001), this generation in Brazil is 677 t/year and represents about 945 million m^3/year.

Studies show that the use of biogas produced in landfills can generate energy, environmental and economic benefits to governments and local societies. The estimated electric power generation is 300–500 MW from municipal solid waste in Brazil, which corresponds to 650,000 t of CH_4 per year. By the anaerobic digestion of the organic solid waste deposited in landfills, the produced CH_4 (which is a very harmful greenhouse gas, 21 times greater than CO_2) will not be emitted to the atmosphere and can be converted into Carbon Credit. Also it is possible to reduce substantially or even avoid the risk of fires and explosions in landfills due to the high concentration of CH_4 in biogas (Brito Filho, 2005; IPCC, 2007).

Recycling can be used as an alternative way to reuse material and energy associated with the recyclable waste (paper, cardboard, plastics, glass and ferrous metals). A brief description of some of the most common technologies used in the recycling processes as in McDougall et al. (2001).

2.2.1. Paper and cardboard

Paper manufacturing relies on the fact that wet cellulose fiber bind together with hydrogen bonds when dried under pressure.