Electricity And Illumination Generation Potential By Gas Through Utilization Of Biogas From Sanitary Landfill

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Abstract

Global warming has been becoming target of worldwide discussions due to the increase of concentration of greenhouse gases in the atmosphere, proceeding mainly from the fossil fuels burning. The search for alternatives that promote the substitution of these fuels for renewable sources has been intensified in the last decades and several studies are being done to assure, for instance, the efficient management and minimization of the urban solid residues, seen as a serious problem of the Brazilian big urban centers nowadays. The incorrect final disposal of these residues causes uncontrolled emission of the gases generated in their decomposition and infiltration of percolated liquids in the soil, causing negative impacts to the population health and to the environment, contributing to the aggravation of the greenhouse effect. In this context, this article presents the project of utilization of biogas proceeding from the treatment of urban solid residues for electricity generation and illumination by gas, developed by the Brazilian Reference Center on Biomass – CENBIO, in the Residues Treatment Headquarters - Caieiras, controlled by the Essencis group. This paper describes the activities of the project developed by CENBIO for determination of the potential of electricity generation and gas illumination and, through the obtained results, other landfills can be defined for implementation of a similar project. The utilization of biogas for energy generation provides the rational use of the available sources, reducing the dependency of external energy sources and, since there is the conversion of methane into carbon dioxide, it promotes the reduction of emissions of greenhouse effect gases, since the methane has an about 20 times greater global warming potential, when compared to carbon dioxide.

Keywords: sanitary landfill, biogas, energy generation, gas illumination.

1. Introduction

According to data of the Brazilian Institute of Geography and Statistics (PNSB/IBGE, 2000), only 33% of the Brazilian municipalities have 100% of cleanness and/or garbage collection services, and the remaining residues are then disposed in places without the necessary control, such as dumpsters or open-sky depositories, for instance. This way, the garbage final disposal is one of the serious environmental problems faced by the big urban centers and the uncontrolled emission of the biogas produced in the residues anaerobic decomposition causes environmental problems, such as air and soil pollution and damages to the population's health.

Sanitary landfills are one of the adequate methods for the urban solid residues disposal, because besides disposing of soil impermeabilization and residues covering techniques, they still can promote the gas capture and its later burning, or use of the biogas for energy generation. According to Cunha (2002), the biogas capture in sanitary landfills is viable on the economic, energy and environmental point of view, bringing reduction of costs for the local city hall and a noble destiny to the garbage.

Biogas is formed from the degradation of organic matter and its production is possible from a great variety of organic residues; it is typically composed by 60% methane, 35% carbon dioxide and 5% of a mixture of other gases such as hydrogen, nitrogen, sulphydric gas, carbon monoxide, ammonia water, oxygen and volatile amines (PECORA, 2006). According to Alves (2000), the presence of non combustible substances in biogas (water, carbon dioxide etc.) hinder its burning process, making it less efficient and, therefore, its calorific power diminishes as the concentration of impurities in its composition increases (ALVES, 2000).

Until being compacted and covered, the garbage is uncovered for some time in the landfill, in contact with the atmospheric air. In this period it is already verified the presence of biogas, that will continue being emitted after the covering and finishing of the landfill cell. The formation and generation rate of the main landfill constitutants is variable as time goes by and, in normal conditions, the decomposition rate reaches a peak between the first and second year and continuously diminishes for some years. If biogas is not collected from the landfill cells, it can cause explosions, emanate through the surface and even migrate to close areas, causing damages to the population’s health and to the environment as a whole.

The biogas energy conversion can be presented as a solution to the great volume of produced residues, since it reduces the toxic potential of the methane emission at the same time it produces electric energy, thus aggregating environmental gain and reduction of costs (COSTA, 2002). In this context, CENBIO initiated a project of utilization of biogas proceeding from urban solid residues for electricity generation and illumination by gas, financed by the Ministry of Mines and Energy (MME). The project is in stage of implementation at the Residues Treatment Headquarters (CTR) of Caieiras, located in Rodovia dos Bandeirantes, km 33, SP, controlled by the Essencis Group. CTR Caieiras is the greatest Residues Treatment Headquarters of Latin America, receiving around 10,000 tons of garbage daily.

2. Biogas Generation Potential In The Landfill

For the calculation of the biogas generation potential in the landfill, the *Intergovernamental Panel on Climate Change* - IPCC (1996) methodology equations were used, and calculated from data provided by CTR Caieiras (CAIEIRAS, 2004).

$L_0 = MCF \times DOC \times DOC_F \times F \times {}^{16}/_{12}$, where: Eq. (1)

RSD: domestic solid residue
L_0: methane generation potential of the residue (m^3 biogas/kg_{RSD})
MCF: methane correction factor (%) = 1,0 for sanitary landfill
DOC: degradable carbon fraction (kg_C/kg_{RSD})
DOC_F: dissolved DOC fraction (kg_C/kg_{RSD})
F: methane fraction in the biogas
${}^{16}/_{12}$: conversion of carbon to methane

The degradable carbon fraction (DOC) is calculated according to equation 2 and the dissolved DOC fraction (DOC_F), according to equation 3.

$DOC = 0.40A + 0.16\,(B+C) + 0.30\,D$, where: Eq. (2)

A: percentage of cardboard and textiles = 22%

B+C: food and organic residues = 55%
D: wood residues = 2%

Resulting in DOC = 0.174

$DOC_F = 0.014T + 0.28 = 0.77$, where: Eq. (3)

T: temperature (ºC) in the anaerobic zone of the residues, estimated in 35º C
F = 50%

Therefore, substituting the values previously calculated (Equations 2 and 3) in Equation 1, there is $L_0 = 0.071$ kg $_{CH4}$/kg$_{RSD}$. Considering the CH_4 density (0º C and 1.013 bar) as 0.0007168 t/m³, there is $L_0 = 99.69$ m³$_{CH4}$/t $_{RSD}$. The methane flow, in m³$_{CH4}$/year, can be calculated according to the equations 4.

$LFG = k \times Rx \times L_0 \times e^{-k\,(x-T)}$, where: Eq.(4)

Rx: residue flow in the year (1/year)
x: current year
T: time of residue deposition in the landfill
$t_{1/2}$: average time for 50% of the decomposition = 9 years
k: decay constant (1/year) = 0.077
The results obtained between the years of 2002 and 2040 are represented in Figure 1, right below.

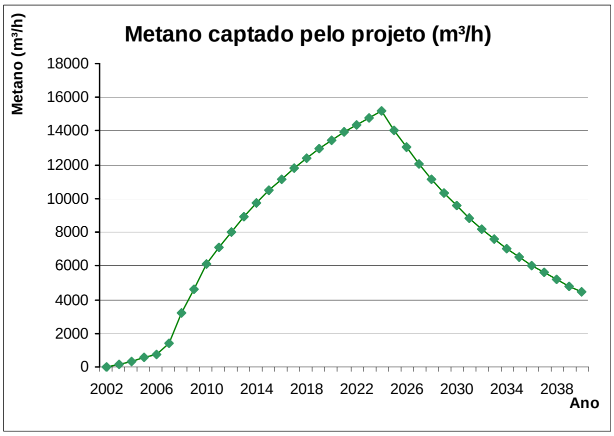

Figure 1. Behavior of the methane flow (FIGUEIREDO, 2007)

The increasing behavior of the curve presented in Graph 1 corresponds to the period in which the landfill receives garbage, because at each garbage ton, a new potential is added. The last year of residues disposal at the landfill is given by the maximum dot of the curve and, in the decreasing, the curve is directed by the constant k, referring to the degradation of organic matter in time. The generated quantity of biogas, according to the calculations previously described, was of 3.241,53 m^3CH_4/h in the year of 2008.

3. Calculation Of The Useful Potency Generated And Available Energy

From the calculation of the methane generation in the years from 2002 to 2040 it is possible to calculate the useful electric potency available for energy generation in the landfill. For determining the available potency and energy, the equations 5 and 6 were used, as it can be seen below.

$$Px = \frac{Qx \times Pc_{metano} \times \eta}{860.000}$$, where: Eq. (5)

Px: available potency each year (kW)
Qx: methane flow each year (m^3CH_4/year)
Pc: methane calorific power = 8,500 kcal/m^3CH_4
η: engine efficiency = 0.28

$$Edisp = \frac{Px}{365 \times 24}$$, where: Eq. (6)

E_{disp}: available energy (kW)
Px: available potency (kW)
365: days/year
24: h/day

The values available for the year of 2008 were: potency of 8.97 kW and energy of 187.31 MWh/day. The conventional technologies for the energy transformation of biogas are the gas turbines, the microturbines and the internal combustion engines. According to studies realized by CENBIO (2005), the Otto cycle engines, besides presenting low cost when compared to the gas turbines and microturbines, have high efficiency when operated with biogas.

4. Case Study – CTR Caieiras

CENBIO chose for the installment of an Otto cycle motogenerator, considering, besides the already mentioned advantages, the possibility of quick installment and easiness in maintenance, since it already is an existent technology in the country. Since it treats of a demonstrative project, an adapted Otto cycle engine of nominal potency of 200 kW was selected for realization of the tests at CTR Caieiras, and it will begin operating in November, 2008.

The gas illumination system, in its final stage of implementation at CTR Caieiras, will count on 7 lampposts lit by biogas, each one with four luminous spots that, according to the manufacturer, consume, each one, 0.4 m^3 of biogas per hour. Therefore, the total biogas consumption by the gas illumination system will be of 11.2 m^3 /h.

According to data from the manufacturer, the electric efficiency of the engine is of 28%. Therefore, by means of the data collected at CTR Caieiras, it is possible to estimate the needed biogas flow to feed it, according to the equation 7, resulting in a consumption of 180.7 m^3/h.

$$\frac{\dot{Q}_{BIOGÁS} \times \%_{METANO} \times PCI}{860} \times \eta = Pot_{GERADA}$$, where: Eq. (7)

% methane: 50%
Lesser Calorific Power: 8500 kcal/m³
$Pot_{GENERATED}$: 200 kW
860: kcal – kW conversion

Since the consumption by the gas illumination lampposts is of 11.2 m³/h, the sum of biogas to be consumed is of 191.9 m³/h, or, considering the 40% methane concentration, 76.76 m³/h of methane. As the methane flow in 2008 is of 3,241.53 m³/h, there will be a surplus of 3,164.77 m³/h that will continue being burned in flare.

5. Conclusion

It could be verified that sanitary landfills represent one of the most interesting alternatives for the final garbage disposal, considering, subsequently, the biogas generation, because they can count on capture techniques of the liberated gases through ducts and burning in flares, where methane, main constitutant of biogas, is transformed in carbon dioxide, with around 20 times lesser global warming potential (EPA, 2008).

From the data conceded by the landfill and by means of the calculations described in this report, it can be observed that CTR Caieiras has enough biogas generation potential to feed the electric energy and gas illumination generation systems, since the biogas consumption to be consumed by the electric energy and gas illumination generation system is of 76.76 m³/h of methane, smaller flow than the one estimated for 2008, whose surplus will keep being burned in flare.

The development and the implementation of technological alternatives aiming at the generation of energy at reduced costs for this segment can generate positive socioeconomic and environmental impacts, reducing the concessionaires overload, besides the reduction of greenhouse gases emission. The use of biogas proceeding from sanitary landfills can promote benefits to the local government, stimulating the adoption of engineering practices that maximize the biogas generation and collection, also reducing the environmental risks.

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