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Theoretical Estimation of the Potential for the Production of Methane Gas in the Controlled Dump of K'ara K'ara in Cochabamba, Bolivia

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Abstract: Throughout the entire project, it was confirmed that the percentage of solid waste generated by the big cities is higher than that of organic waste. This event is literally common all around the countries of Latin America, especially in Bolivia. During the process of waste recollection, both kinds are taken to disposable sites, known as “Final Disposable Sites”, or “Controlled Waste Sites”. It was detected that during all the dumping process of organic matter, biochemical decomposition is permanently being generated; this procedure is acknowledged as anaerobic process generating biogases like Methane (CH4). Although this biogas is one of the main causes of Global Warming on Earth, it has been detected that it may be useful since it can be considered as an alternate resource for renewable energy. The following research and duly studies presented here will be implemented on the Controlled Waste Site K’ara K’ara in Cochabamba, Bolivia. The determination of this study is to give estimates of the theoretical potential of the volume of Methane gas that was generated in the last thirty months (from September, 2014 to February 2017). In order to obtain such estimate, the First Order of the Mathematic Model Degradation from the Intergovernmental Panel on Climate Change (IPCC, acronym) was applied. Also, the characteristics and percentages of organic matter buried in Botadero K’ara K’ara were taken into account. This data gave an estimate of the volume of how much Methane gas is generated; the result was 66.96 m^3 per ton of solid waste. Moreover, it was also estimated that its yearly emission is about 2.075 m^3, equivalent to 43.575 m^3 of CO_2, an advantage, as long as it is considered, that it is twice as more favorable to global warming. This work was presented at the XXXVI Congress of Sanitary and Environmental Engineering of AIDIS in 2018 in Guayaquil (Ecuador).

Key words: solid waste, controlled dump, biogas generation, climate change, methane

1. Introduction

Climate change is one of the global environmental effects that has been most felt in different regions of the world, this climatological phenomenon has among its main factors the presence and generation of greenhouse gases. These gases have among their major components CO_2 (carbon dioxide) and CH4 (methane). The presence of methane is highly incident because it is 21 times more harmful than carbon dioxide. In general, methane generation occurs through the biochemical decomposition of organic matter, mainly in anaerobic environments, such as the sanitary landfills that exist in cities that bring together the majority of the world population. In the case of the city of Cochabamba (Bolivia) there is the Final Disposal Site (SDF) called K´ara K´ara, which according to the Plurinational State of Bolivia [1] is classified as: Controlled dump. This site began operations in 1987, so it currently has approximately 30 years of continuous operation. Initially, the Dump of K´ara K´ara was a site for composting studies by the Faculty of Agronomy of the Universidad Mayor de San Simon, however over the years, these studies failed but the deposit of garbage, without any type of technical or environmental control

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[2]. Fig. 1 shows the location of the controlled dump of K´ara K´ara.

Starting in September 2014, the Municipality of Cochabamba contracted the final disposal services in K´ara K´ara from the private company COLINA SRL (Cleaning and Environmental Engineering Company), so that among others it is responsible for the technical closure operations of Cell 1 and the sanitary burial of garbage in Cell 2 in accordance with the provisions of Technical Standards NB 742-760 for its adequacy of operation as a Sanitary Landfill. In the almost 27 years of operation of K´ara K´ara as a dump, there is no information on a systematized technical management, which is why there are no reliable or trustworthy data regarding the quantities and volumes of buried solid waste, less even of the buried organic matter and of some process of monitoring and control of the biogases generated by the biochemical decomposition. It is particularly important for the purposes of this study to know the quantities of the organic components that have been buried in the K´ara K´ara Dump and their respective percentages in relation to the total since the start of final disposal operations; all with the aim of estimating the volume of methane gas that can be generated by applying a widely agreed-upon theoretical mathematical model at the international level. Different authors [3] have carried out research on the estimation of methane gas generation in Final Disposition Sites, however for the present case study, the model of the Intergovernmental Panel on Climate Change [4, 5] has been chosen for its relative simplicity and practicality in handling and using the data obtained.

2. Material and Methods

2.1 First Stage

The first stage of the investigation has been to obtain information from the official reports of the Municipal Waste Directorate of the Mayor's Office of Cochabamba, periodically evacuated by the private operator of the Controlled Dump of K´ara K´ara, during the 30 months that they took as sample time for the anaerobic biological decomposition process of buried organic waste. Subsequently, and based on the study carried out by a consulting company for the Departmental Autonomous Government of Cochabamba [6]; the information regarding the amount of waste buried daily and the physical composition and their respective percentages of organic materials have been assumed to be valid.

2.2 Second Stage

A second stage of the investigation has been the search for the most appropriate model in the case of the potential for biogas generation from the anaerobic decomposition of organic matter buried in controlled dumps; to this end, it has decided to use the first order degradation model (FOD) of the Intergovernmental Panel on Climate Change [5].

2.3 Third Stage

In a third stage, the IPCC mathematical model has been applied, fed by the resulting values for the case study of the Controlled Dump of K´ara K´ara in Cochabamba, Bolivia. The results obtained allow us to establish that there is a theoretical potential for the generation of Methane biogas, this being a possible alternative and renewable energy resource, obtained from the biomass contained in the macro cells of buried solid waste.

The calculation procedure has followed the following steps:

(1) Calculation of COD (Degradable Organic Carbon):

$$COD = \Sigma\ (CODi \times Wi) \tag{1}$$

(2) Calculation of the methane generation potential of the waste:

$$L0 = FCM \times COD \times CODf \times F \times 16/12 \tag{2}$$

(3) Calculation of the Methane emission:

$$ECH4 = k \times Rx \times L0 \times e \wedge (- k\ (x\text{-}t)) \tag{3}$$

3. Results and Discussion

(1) Calculation of COD (Degradable Organic Carbon):

COD = Σ (CODi × Wi) Where:

COD = Fraction of degradable organic carbon (DOC) in solid waste

CODi = Fraction of degradable organic carbon (DOC) in solid waste of type i (see Table 1)

Table 1 Percentage of organic solid waste in Cochabamba and its DOC Index [4].

Organic solid waste	Weight percentage (%)	DOC percentage (%) (*)
Papers and Cardboard	3.5 A	40 (0.40)
Food remains	55.52 B	15 (0.15)
Wood	0.91 C	30 (0.30)
Textiles	3.04 D	40 (0.40)
Pruning remains	3.45 E	17 (0.17)

Wi = Fraction of solid waste type i by waste category

COD = (0.40 × A) + (0.15 × B) + (0.30 × C) + (0.40 × D) + (0.17 × E)

COD = (0.40 × 3.5) + (0.15 × 55.52) + (0.30 × 0.91) + (0.40 × 3.04) + (0.17 × 3.45)

COD = 1.40 + 8.33 + 0.27 + 1.22 + 0.59

COD = 11.81 or 0.1181

(2) Calculation of the methane generation potential of the waste:

L0 = FCM × COD × CODf × F × 16/12 Where:

L0 = Methane generation potential of the waste (m^3 biogas/T of RSD)

FCM = Methane Correction Factor

COD = Degradable Organic Carbon (calculated in step 1)

CODf = Fraction of COD that can decompose or biodegrade

F = Methane fraction present in the biogas

Then: L0 = FCM × COD × CODf × F × 16/12

FCM = 0.8 (for deep and unmanaged SDF, Table 3.1 of the IPCC [5]

COD = 0.1181

CODf = 0.77 (0.014 × 35 + 0.28), a temperature of 35°C is estimated for anaerobic conditions

F = 0.5 (50%) Methane in biogas, as recommended by the IPCC [5]

12/16 = 1.33

Replacing values, we have: L0 = 0.8 × 0.1181 × 0.77 × 0.5 × 1.33

L0 = 0.048 kg of CH4/kg of RSD

Considering the density of Methane = 0.0007168 (T/m^3)

L0 = 0.048/0.0007168

L0 = 66.96 m^3 of CH4/T of RSD

(3) Calculation of the Methane emission:

ECH4 = k × Rx × L0 × e ^ (- k (x-t)) Where:

ECH4 = Methane Emission (kg of CH4/year)

k = Reaction constant or decay constant or methane generation rate

Rx = Mass or quantity of the waste deposited in the SDF

L0 = Methane generation potential (m^3 of biogas/T of RSD)

X = current year

t = Year of start of waste deposits in the SDF

Then:

Calculation of average k for organic waste: from Table 3.3 of the IPCC reference [5].

Climatic zone of the SDF K´ara K´ara: Temperate, annual average temperature less than 20°C)

Waste condition: Wet

k = 0.06 (Paper, Cardboard)

k = 0.06 (Textiles)

k = 0.03 (Wood)

k = 0.1 (pruning remains)

k = 0.185 (food remains)

Then the average value of k = 0.09

Rx = 451,093.78 (T): Total amount of waste deposited since September/2014

X = Year 2017

t = Year 2014

Replacing values in the formula: ECH4 = k × Rx × L0 × e ^ (- k (x-t))

ECH4 = 0.09 × 451,093.78 × 66.96 × 〚2.7183〛 ^ (-0.09 (2017-2014))

ECH4 = 2,075.00 m^3 of CH4/year

(4) Biogas calculation:

Since it is admitted that Methane is 50% of the biogas that is generated in the SDF, then the volume of biogas is double that of Methane, therefore:

Vbiogas = 2 × 2075

Vbiogas = 4,150 m^3/year

Amount of CO_2 that is no longer emitted into the atmosphere:

Considering that the capacity to produce global warming of Methane is at least 21 times more than the capacity of CO_2 [5], there is a direct conversion ratio to calculate the volume of CO_2 equivalent per year. Consequently, the calculation of the volume of CO_2 equivalent annually that will potentially cease to be emitted into the atmosphere is:

Equivalent VCO2 year = ECH4 × 21

Equivalent VCO2 year = 2,075 × 21

Equivalent VCO2 year = 43,575 m^3

4. Conclusion

It is evident that an SDF with the controlled dump of K´ara K´ara can become a potential "alternative energy source", based on the use of methane gas generated in the anaerobic decomposition process of the organic matter contained in buried waste

Since the entry into operation of Cell No 2 by the company COLINA srl in September 2014 until February 2017 (30 months), the control and weighing of the amounts of waste that are buried have been substantially improved, which is why which the information and data generated in this period of time have served as the most reliable input for the application of the FOD model of the IPCC

The amount of waste deposited in the 30 months of operation controlled by COLINA srl reached 451,093.78 T, which, based on the physical composition used as the basis for calculation, have allowed the emission of 2,075 m^3/year of CH4 and 4,150 m^3 of biogas, the same as having a project for the capture, recovery and energy use of this by-product of the sanitary burial of organic matter in the controlled dump of K´ara K´ara, would have allowed the generation of alternative bio energies for use in the region

The potential energy use of biogas in the SDF K´ara K´ara would allow to stop emitting greenhouse gases into the atmosphere such as CO_2 and mainly CH4, in such a way as to avoid contributing to the effects of global warming and therefore to climate change

Considering that Bolivia is currently in a process of transforming its energy matrix in favor of renewable energies, more sustainable alternatives, it is recommended that the authorities take into account a possible energy use of the waste biomes and their respective viability through obtaining carbon credits.

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