Innovative Energy & Research
ISSN: 2576-1463

Plocoste et al., Innov Ener Res 2016, 5:1
DOI: 10.4172/2576-1463.1000138

Research Article Open Access

Effect of Leachate Recirculation on Landfill Methane Production in a Tropical Insular Area

Plocoste T[*], **Jacoby-Koaly S, Moliníé J and Roussas A**

Laboratoire de Recherche en Géosciences et Energies (LaRGE), Département de Physique, Faculté des Sciences Exactes et Naturelles, Université des Antilles, France

[*]**Corresponding author:** Plocoste T, Laboratoire de Recherche en Géosciences et Energies (LaRGE), Département de Physique, Faculté des Sciences Exactes et Naturelles, Université des Antilles, France, Tel: +590690766121; Fax : +590 590483105; E-mail: tplocost@univ-ag.fr

Received date: May 30, 2016; **Accepted date:** Jun 28, 2016; **Published date:** June 30, 2016

Copyright: © 2016 Plocoste T, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Abstract

Through this study are presented the results of a first test of leachate recirculation on landfill methane production in Guadeloupe archipelago (at the North of the Lesser Antilles, French West Indies, island tropical and humid climate). In French West Indies, methane produced by landfilling is commonly flared without energy recovery. In this paper, assessment is made of the potential for leachate recirculation to increase methane production for energetic purpose in a tropical area. This process could also rapidly reduce the volume of leachate to be treated. The results obtained here show that by injecting 5 m^3 of leachate in several draining leachate wells, a sharp increase in the proportion of methane in biogas is observed just a few days after. The older the waste is, the more efficient this process seems to be. In some parts of the waste dome, the methane proportion is nearly doubled at the biogas wellhead. In island context, leachate recirculation could be a long-term solution to produce energy assuming that the quantity of solid waste sent to landfill remains sufficient to maintain a viable operation of the waste dome, to reduce costs of leachate treatment and to create new space for waste storage.

Keywords: Landfill; Leachate recirculation; Biogas; Energy production; Tropical area

Introduction

For decades, open landfilling was the preferred solution for waste management in Caribbean islands. Landfills can produce serious environmental damage if not properly managed and operated [1]. The most common issue associated with landfill operation is leachate and gases generation [2].

Landfill leachate results from precipitation water, surface run-off, and filtration or intrusion of groundwater percolating through landfill [3]. Treatment of leachate is very difficult as the leachate quantity and quality are highly variable; moreover, leachate increase wastewater volume. Therefore, problems may arise in the treatment of this wastewater [4]. Leachate from landfills requires treatment before being discharged into the environment to avoid surface and underground water contamination [5]. Leachate recirculation is an option for less expensive leachate disposal [6]. By recirculating the leachate, the organic component of the leachate can be reduced by the active biological microorganisms within the refuse mass [7]. This recirculation can enhance waste decomposition rates and methane production as it provides an aqueous environment that facilitates the provision of nutrients and microbes [8, 9]. The increased amount of methane (CH_4) would be beneficial in terms of electricity generation [10]. Leachate recirculation not only improves leachate quality but also shortens the time required for the waste dome stabilization from several decades to 2-3 years [11] and reduces the volume of leachate to be treated by biochemical methods. A rapid stabilization accelerates subsidence of waste volume which permits the recovery of air space to collect new waste. This process could be particularly promising in island context where lack of space to store waste is a crucial issue.

In tropical landfills, where high temperature and high evaporation could lead to insufficient moisture content in the cell, leachate recirculation not only helps to increase the moisture content but also to circulate organic matter back into the cell. However, previous work [1] reports that during the dry season, leachate recirculation may be insufficient to maintain the moisture content, and supplemental water addition into the cell is then required to stabilize moisture levels as well as stimulate biological activity.

Although often valuable, leachate recirculation can lead in some cases to the inhibition of methanogenesis due to high concentrations of organic acids which are toxic inhibitors for the methanogens [12]. Furthermore to avoid limiting phenomena like saturation, the volume of recirculated leachate must be properly adjusted [13].

Leachate recirculation is not currently occurring in landfills of Guadeloupean archipelago. Few data are available on the effects of leachate recirculation on waste in tropical insular environment. The aim of this study is to evaluate the potential impact of leachate recirculation on CH_4 production in the main open landfill of the island.

Materials and Methods

Study area description

La Gabarre is the main open landfill of Guadeloupe archipelago (37 ha in 2015). This landfill has the distinction of being sandwiched between a mangrove swamp and urban areas [14]. In 2016, La Gabarre was composed of 2 main parts: a completely rehabilitated waste dome and an operated area (Figure 1). This study is conducted on the rehabilitated area. Historically, the waste dome has been built over the years by the deposit of the waste following a westward progression. The

Citation: Plocoste T, Jacoby-Koaly S, Molinié J, Roussas A (2016) Effect of Leachate Recirculation on Landfill Methane Production in a Tropical Insular Area. Innov Ener Res 5: 138. doi: 10.4172/2576-1463.1000138

oldest waste are in the east of the rehabilitated dome whereas the latest ones are in the west. At the far west is the operating area.

The rehabilitated waste dome has reached at the end of its operation an area of 12 ha and a height of 24 m. This part has been operated from mid-90 to the end of January 2013. About 2,000,000 tons of waste were stored in this area. The waste in the dome was principally composed of household waste (~52%), bulky refuse (~20%), green waste (~11%) and packaging (such as plastic, wood, carton, etc.) (~10%). Before the beginning of the rehabilitation in December 2010, there was no system to collect and process the biogas and leachate.

Figure 1: Aerial view of the study site with the landfill at the center between the mangrove swamp to the north and urban areas to the south (Séché Environment picture)

Fifty draining wells (with a diameter of 200 mm and a depth of 15 m) have been installed throughout the dome for the biogas collect. Each well has a range of 25 m. The network of 50 biogas extraction wells is connected to a high temperature biogas flare system designed and built by the company BIOME. The biogas flare system has a control panel to operate the flare, display and record the data. The flare system is also measuring the biogas flow with the aid of a Pitot tube flow meter and the gas concentration with a biogas analyzer. Data are recorded each hour to control the flow and quality of the biogas produced by the waste dome [15].

To collect leachate, a trench was dug around the waste dome. To prevent soil and groundwater contamination, a geotextile material is placed at the bottom of the trench. The geotextile material is covered with a layer of gravel on which are placed the perforated collection pipes (with a diameter of 160 mm). The leachate collection pipes are at depth of 1.40 m. Leachate is recovered through drilled holes over the entire length of the pipes. The trench is completed by successively superposing a layer of gravel, the geotextile material and an ultimate 5 cm thick layer of gravel. The leachate collected is pumped toward a holding tank for treatment by a membrane bioreactor (MBR). To monitor the leachate level into the waste dome, 9 draining wells of leachate (with a diameter of 355 mm and a height of 16 m) were drilled. Contrary to biogas wells which are networking, the leachate wells are not connected.

For the entire site (rehabilitated + operating), two peripheral dykes have been built around the landfill to prevent the leachate flow toward the mangrove. One of them also allows the leachate collection.

Leachate recirculation

The test on leachate recirculation was conducted by the landfill operator on January 14, 2016. 45 m^3 of raw leachate was pumped with a tanker truck from the holding tank and transported toward the rehabilitated waste dome. 5m^3 of leachate were injected in each of the 9 leachate wells.

January 2016 was a dry and hot but quite normal month compared to the Guadeloupean climatic means with an average temperature of 25°C and an average rainfall of 77 mm [16]. Most of the rains fell between 4th and 8th January. Precipitation remained low from 14th to 23rd January and a moderate rainfall event occurred on 24th January.

Methane proportion

To assess the impact of leachate recirculation on the proportion of methane, 13 biogas wells spread around the leachate wells have been selected (Figure 2).

With a 25 m range, these biogas wells can describe the evolution of methane in biogas for the entire rehabilitated waste dome part.

The methane proportion in the biogas was measured with the SEWERIN Mutitec 540, a multiple gas measuring device with infrared sensors optimized for biogas and landfill gas. This equipment can measure six gases simultaneously but the use of infrared measuring techniques for methane and carbon dioxide means that there is no possibility of misleading results due to interaction with other gases whose measurement makes use of electro-chemical sensors [17]. In less than 5 minutes, results are displayed on the equipment's screen and are stored in the device. At La Gabarre landfill, the infrared sensor of the Multitec was placed directly in the manhole of the selected draining wells.

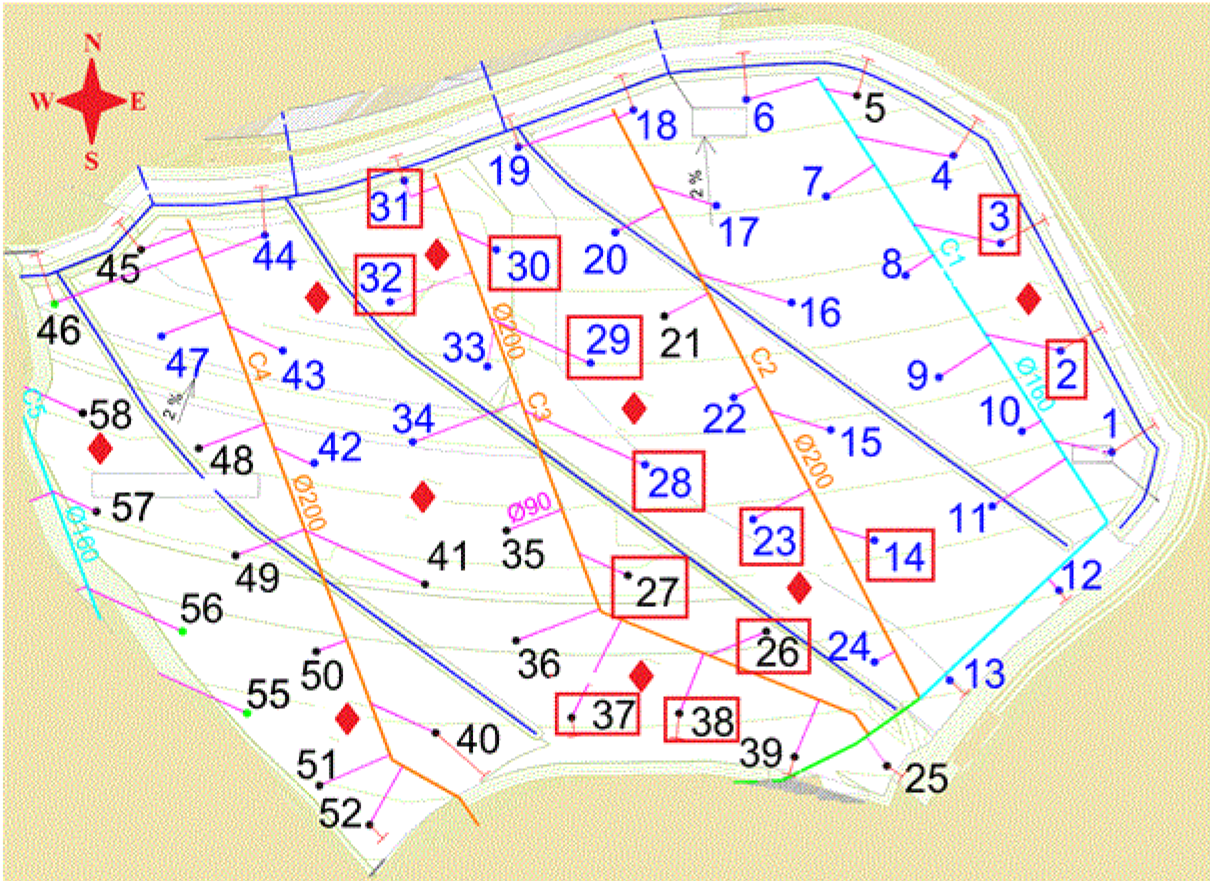

Figure 2: Map on the distribution of the leachate wells (red diamonds) and biogas wells (mapped by their numbers), on the rehabilitated dome. The biogas wells appearing in blue on the biggest right side of the map are the ones dug during the first step of the dome rehabilitation. The numbers in the red boxes are associated to the 13 selected biogas wells.

The measurement campaign began 8 days before the leachate injection (January 6) and ended 11 days after (January 25). After adding the leachate (January 14), the impact on methane production cannot be observed instantly. Indeed, sufficient time is necessary to allow the leachate to moisten all the waste layers and the methanogenic microorganisms to feed. To characterize the influence of the outside temperature on biogas quality, measurements have been performed at different hours in the day. No significant difference was observed. Therefore, for the results below, the methane values presented were collected at noon.

Results and Discussion

The results of the measurement campaign are presented in Table 1. The leachate injection in the biogas wells occurred on January 14, 2016.

Methane proportion before leachate injection

On January 6th, methane proportions range from 28.5% to 57.5% ($[CH_4]_6$ in Table 1). Methane proportions are not homogeneous over the entire dome. This can be explained by the nature of the stored waste and the state of progress of the methanogenesis. Until 2009, this landfill was used to store both hazardous and municipal waste: household waste, industrial waste, old cars, tires etc. As a result of regulatory change in 2009, only municipal solid waste were deposited at La Gabarre. Contrary to municipal solid waste hazardous wastes produce methane in smaller quantities. Added to waste composition, methanogenesis stage is a key parameter for methane production. More the methanogenesis is advanced and less there is organic matter remaining in the waste to produce methane. Biogas wells with the lowest proportions are in areas with old waste (collected before 2009) and those with values greater than 50% in areas with waste stored after 2009. When cross-checking the map of Figure 2 against data of Table 1 for 6th January, it can be verified that the biogas wells with the lowest methane proportions (lower than 50%) are on the right of the map, that is to say in the oldest part of the rehabilitated dome at the east. The greater values (50% and more) are farther west (on the left of the map).

	Methane in landfill biogas (%)													
Wells number	**2**	**3**	**14**	**23**	**26**	**28**	**29**	**30**	**31**	**32**	**37**	**38**	**27**	**Mean on all wells**
$[CH_4]_6$	43.4	32.5	44.6	28.5	46.3	40.2	32.1	51.2	53.7	57.5	55.4	51.5	48.4	45.0
$[CH_4]_{18}$	53.5	44.4	57.5	42.8	48.8	53.5	59.7	58.5	59.5	58.9	55.8	55.5	54.6	54.1
$[CH_4]_{19}$	45.8	35.3	50.6	23.7	31.2	57.5	47.8	55.6	52.5	57.8	50.2	47.5	51.4	46.7
$[CH_4]_{21}$	43.2	34.2	50.4	22.4	30.1	54.5	45.4	54.5	48.5	57.6	51.5	47.3	51.5	45.5
$[CH_4]_{25}$	38.6	27.7	45.7	18.8	32.5	54.6	35.7	52.8	35.2	52.7	47.8	42.2	48.3	41.0
	Methane in landfill biogas compared to June 6th measurements													
$[CH_4]_{18}/[CH_4]_6$	123%	137%	129%	150%	105%	133%	186%	114%	111%	102%	101%	108%	113%	124%
$[CH_4]_{19}/[CH_4]_6$	106%	109%	113%	83%	67%	143%	149%	109%	98%	101%	91%	92%	106%	105%
$[CH_4]_{21}/[CH_4]_6$	100%	105%	113%	79%	65%	136%	141%	106%	90%	100%	93%	92%	106%	102%
$[CH_4]_{25}/[CH_4]_6$	89%	85%	102%	66%	70%	136%	111%	103%	66%	92%	86%	82%	100%	91%

Table 1: Methane values in landfill biogas at La Gabarre before and after leachate injection for the rehabilitated waste dome. The last four lines indicate the ratio of methane proportion on January 18, 19, 21 or 25 to the methane proportion on June 6.

Methane proportion after leachate injection

The first measurements for evaluating the impact of leachate recirculation on methane production in biogas were performed on January 18 ($[CH_4]_{18}$ in Table 1). For most of biogas wells, the same trend is noted. An increase in the methane percentage between January 6 and January 18, then a decrease until January 25. It should be recalled here that the biogas quality is usually expressed in terms of methane percentage. Greater this percentage is, better is the biogas quality. If methane utilization for energetic purpose is planned, it is important to improve the methane proportion in biogas. Two conditions have to be fulfilled to technically and economically justify the use of methane as a source of heat and electricity. First, the methane content must reach 35-40%, and secondly, the output should exceed 30 m^3h^{-1} [18,19]. In Table 1, there is none of the wells with a methane proportion less than 40% in $[CH_4]_{18}$. At biogas well number 29, methane percentage is nearly doubled after leachate recirculation (the ratio of $[CH_4]_{18}$ to $[CH_4]_6$ is 186%). For the wells 2, 3, 14, 23, 28 and 29, this same ratio is greater than 120%. Among the 13 selected wells, these wells are roughly those located further east in the oldest part of the dome. For wells 32 and 37 further west, the effect of leachate recirculation is the least pronounced (the ratios of $[CH_4]_{18}$ to $[CH_4]_6$ are respectively 102 and 101%). On average, taking into account all the 13 wells, the increase on methane proportion compared to January 6th is about 24%.

From January 18 to January 21, the increase of methane proportion compared to January 6 becomes lower and lower and falls to a mean value of 2% on June 21 (mean $[CH_4]_{21}/[CH_4]_6$ is 102%). On January 25th, the methane proportion is on average 9% lower than the January 6th one (mean $[CH_4]_{25}/[CH_4]_6$ is 91%). It is possible that the rain event of the day before could have slowed the methanogenesis process. Indeed, previous works have discussed on excess water as a limiting factor of methanogenesis [20]. For January 25th , only wells 14, 28, 29 and 30 keep methane proportion values greater than January 6 ones.

Table 2 exhibits monthly average methane proportions in biogas from October 2015 to April 2016. It could be seen that thanks to the test on leachate recirculation, January 2016 value is the only one greater than 40% during this period. But overall, the biogas quality is quite variable since November and December 2015 as well as April 2016 do not reach the 35% threshold mentioned before for energetic recovery.

Year	Month	CH4 (%)	CO2 (%)
2015	October	35.2	28
	November	32.2	25
	December	29	23.5
2016	January	45.5	31
	February	39.5	25
	March	38.3	24
	April	25.6	18

Table 2: Biogas quality at La Gabarre for the rehabilitated waste dome.

The results above show that leachate recirculation was quickly efficient at La Gabarre to increase biogas quality and so methane production. Just after the beginning of leachate recirculation, we approach the 60% methane proportion in biogas stated by literature [21]. This increase proves that the addition of leachate to moisten the waste in La Gabarre landfill could accelerate methane production. As previously mentioned by Sanphoti et al. [1], leachate recirculation also contributes to circulate organic matter back into the rehabilitated waste dome.

Conclusion

This study presents a first test of leachate recirculation on methane production in Guadeloupe archipelago. By injecting 45 m^3 of raw leachate in a waste dome of 12 ha, a strong increase in biogas quality and methane production is noted. For some biogas wells, methane values measured after the recirculation are roughly 1.5 to 2 times greater than the values observed before. The acceleration of methane production through the leachate recirculation can constitute an additional source of energy for Guadeloupe.

The results obtained in this study show that raw leachate used for leachate recirculation is favorable to methane production. This process may reduce the quantities of leachate to be treated by membrane bioreactor and improve leachate quality. It would be interesting to repeat the same measurements using a treated leachate of better quality for the injection. Some organisms in the leachate limiting the methanogenesis could be eliminated following the treatment of the leachate.

On the environmental point of view, leachate recirculation could quickly stabilize the waste dome. This would reduce risks of pollution due to leachate and biogas. Located in a sensitive area, this process will limit the occurrence of mangrove pollution.

In terms of space, the rapid stabilization of the waste dome will reduce the volume of stored waste. In island context, lack of space to store waste is still an issue. In the same time, this quick stabilization of the dome arises the question of the long term economic viability of the landfill operation for energetic purpose especially since the biogas quality fails to fulfill the requisite threshold at certain times. It is important to make sure that the volume of waste collected in Guadeloupe is sufficient to allow the recovery of methane for a permanent and continuous energy production.

Future studies should be done to have a better idea about the duration of the effects of leachate recirculation on landfill biogas, depending on waste composition and volume and methanogenesis step.

Acknowledgment

We take this opportunity to thank Séché Environment for providing us data on the leachate recirculation tests at La Gabarre landfill. The authors thank Ms Phibel Malika for the technical information she gave us.

References

1. Sanphoti N, Towprayoon S, Chaiprasert P, Nopharatana A (2006) The effects of leachate recirculation with supplemental water addition on methane production and waste decomposition in a simulated tropical landfill. Journal of Environmental Management 81: 27-35.
2. Komilis DP, Ham RK, Stegmann R (1999) The effect of landfill design and operation practices on waste degradation behavior: a review. Waste Management and Research 17: 20-26.
3. Ince NH (1998) Light-enhanced chemical oxidation for tertiary treatment of municipal landfill leachate. Water environment research 70: 1161-1169.
4. Sponza DT, Ağdağ ON (2004) Impact of leachate recirculation and recirculation volume on stabilization of municipal solid wastes in simulated anaerobic bioreactors. Process biochemistry 39: 2157-2165.
5. Chan GYS, Chu LM, Wong MH (2002) Effects of leachate recirculation on biogas production from landfill co-disposal of municipal solid waste, sewage sludge and marine sediment. Environmental Pollution 118: 393-399.
6. Cureton PM, Groenvelt PH, McBride RA (1991) Landfill leachate recirculation: effects on vegetation vigor and clay surface cover infiltration. Journal of Environmental Quality 20: 17-24.
7. Qasim S, Chiang W (1994) Sanitary Landfill Leachate: Generation, Control and Treatment. CRC Press.
8. El-Fadel M (1999) Leachate recirculation effects on settlement and biodegradation rates in MSW landfills. Environmental Technology 20: 121-133.
9. Rastogi M, Hooda R, Nandal M, Scholar D (2014) Review on anaerobic treatment of municipal solid waste with leachate recirculation.
10. Jaramillo P, Matthews HS (2005) Landfill-Gas-to-Energy projects: Analysis of net private and social benefits. Environmental Science & Technology 39: 7365-7373.
11. Reinhart DR, Al-Yousfi AB (1996) The impact of leachate recirculation on municipal solid waste landfill operating characteristics. Waste Management and Research 14: 337-346.
12. Rolle E, Boni MR, Carucci G (1997) Effects of leachate salinity on the aerobic and anaerobic mineralization of the municipal solid waste organic fraction. Environmental technology 18: 203-209.
13. San I, Onay TT (2001) Impact of various leachate recirculation regimes on municipal solid waste degradation. Journal of Hazardous Materials 87: 259-271.
14. Plocoste T, Jacoby-Koaly S, Molinié J, Petit RH (2014) Evidence of the effect of an urban heat island on air quality near a landfill. Urban Climate 10: 745-757.
15. Plocoste T, Jacoby-Koaly S, Petit RH, Roussas A (2016) Estimation of methane emission from a waste dome in a tropical insular area. International Journal of Waste Resources 6: 1-7.
16. Météo-France (2016) Bulletin Climatique Guadeloupe.
17. http://www.sewerin.com/cms/en/products/detailview/multitec-540.html
18. Haubrichs R, Widmann R (2006) Evaluation of aerated biofilter systems for microbial methane oxidation of poor landfill gas. Waste Management 26: 408-416.
19. Pawłowska M (2014) Mitigations of landfill gas emissions. CRC Press.
20. Oonk H (2010) Literature review: Methane from landfills methods to quantify generation, oxidation and emission. Innovations in Environmental Technology.
21. Williams PT (2005) Waste treatment and disposal. John Wiley & Sons.