SANITARY LANDFILL LEACHATE TREATMENT USING UNITARY EVAPORATION EQUIPMENT

H.A.M. BACELAR*, A.L.G. CANTANHEDE*, I.C. FIGUEIREDO*, A.S.P. SANTOS*

* Water Resources and Environmental Department, Federal University of Rio de Janeiro – Brazil.

SUMMARY: In some countries the biogas generated in the sanitary landfill is not yet used to supply a power plant, normally it is only burnt with the intention of reducing the intensity of pollution launched to the atmosphere. This wastefulness is due mainly to the lack of investment in projects and equipments that demand high initial capital. One of the used innovative technologies in the entire world for the leachate treatment is the forced evaporation, with the intention of producing an equipment of easy operation, and low cost of manufacture and maintenance, to be mainly used in small landfills. The Unitary Evaporator that was developed currently is in operation at Jardim Gramacho metropolitan landfill, located at Duque de Caxias, Brazil. This equipment of small dimensions is capable to treat roughly 40 liters of leachate by hour, using to as an advantage the biogas produced in the own landfill to make it possible the leachate treatment. The tests and studies carried out till the moment are presented in this paper.

1. INTRODUCTION

World-wide the economic growth and the high demand for energy have led to intense fossil fuel consumption as oil, coal and natural gas, increasing the greenhouse gases emission. This has been aggravated in developing countries, where the demographic growth and of the urbanization is not usually followed by the expansion of the infrastructure, mainly in the basic sanitation area. Thus, great part of the urban and industrial residues is launched without treatment in the atmosphere, waters or on the ground.

In order to reduce this accelerated consumption and to prevent greater environmental disasters, there is being developed projects for the renewable fuel exploitation, such as biogas produced in enormous amounts in the sanitary landfills.

The metropolitan landfill of Jardim Gramacho, located at Duque de Caxias City, Rio de Janeiro State, initiated its operation in 1978, and has an area around 1,300,000 m^2. Currently the landfill receives about 7,200 daily tons approximately solid residues and generates 1,500 m^3 of leachate per day. The diversified composition of the leachate makes it difficult its treatment, implying in the necessity of an adequate evaluation of the technical and economic parameters and for the choice of the technology to be applied.

Proceedings Sardinia 2009, Twelfth International Waste Management and Landfill Symposium
S. Margherita di Pula, Cagliari, Italy; 5 - 9 October 2009

The Municipal Company of Urban Cleanness of Rio of Janeiro City (COMLURB), the operator of the Gramacho landfill, developed equipment in 2005 called Unitary Evaporator (UE), used in the leachate evaporation process through the gas generated in the landfill. There is an estimated capacity of daily capture of 150 thousand cubical meters of biogas, fuel enough to estimated 375 thousand litters of leachate per day. However, the cost studies had shown that this equipment in large landfills not be can economically viable compared with other treatments.

The main objectives of this research are: 1) to calculate the capacity of evaporation of the Unitary Evaporator of leachate being used as an alternative for the treatment of the leachate; 2) to characterize and to determine the thermal efficiency of biogas as input energy; 3) to analyze the generated residues of the process; 4) to study the costs for implantation of the equipment.

2. STUDIES REALIZED IN THE LEACHATE EVAPORATION

2.1 Functioning and income of the Unitary Evaporator

The evaporation of the leachate through the Unitary Evaporator was developed of the following form: first a storage pond was constructed next to a well to biogas, and after that the Unitary Evaporator next to them was located. A vehicle carries the leachate until the storage pond, that will feed the Evaporator with a constant level; to control the leachate volume of entrance in the equipment a hydrometer was installed. The biogas is lead by a tubing for the interior of the equipment, where it processes its burning with consequent release of caloric energy and evaporation of the leachate.

For collection of the condensed steam, a steel part was used in the cone formats that forms an internal narrow channel that fulfils the container settled in the equipment.

The monitoring of the operation of the Unitary Evaporator was carried daily by COMLURB with the support and orientation of the Federal University of Rio de Janeiro (UFRJ). The parameters for operational control are: dates and schedule of leachate supplying, the supplied volume, estimated volume, ambient temperature and rainfall index. Through these data, it becomes possible to evaluate the income of the evaporation presented by the equipment, in litters for the moment, as well as the possible interferences of the local climatic conditions in this income.

In Figure 1, it is possible to observe the Unitary Evaporator functioning at Jardim Gramacho landfill.

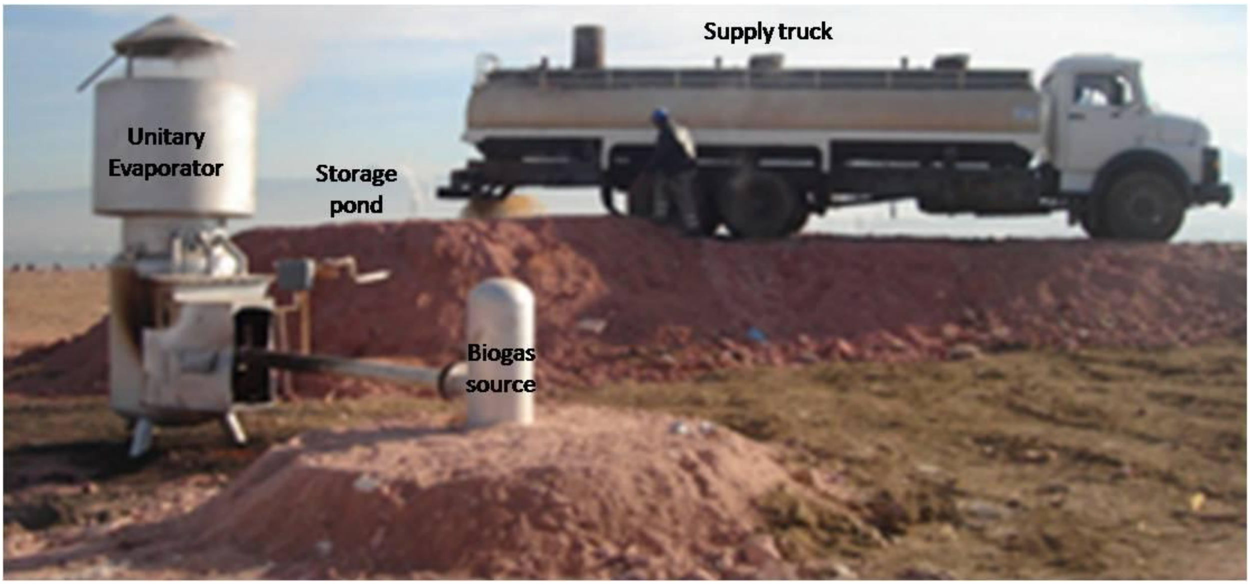

Figure 1. Experimental facilities at Gramacho Sanitary Landfill

2.2 Characterization and determination of the thermal efficiency of the biogas

The analyses of biogas had been carried through with aid of portable chromatograph, that quantifies composites CH_4, CO_2, H_2O, H_2S and others; and with the gas analyzers: Dräger X-am 7000 (capable to quantify CH_4, CO_2, H_2S and others) and GEM 2000 (capable to quantify CH_4, CO_2, O_2 and others). The portable chromatograph (see Figure 2) still supplies complementary information to them of the biogas sample, such as: molar weight, specific heat to be able calorific upper/lower, density, viscosity, specific mass and factor of compressibility.

To measure the outflows of the wells of biogas that feed the UE, an outflow measurer type turbine was used connected to the exit of the well and fed by two batteries (see Figure 3).

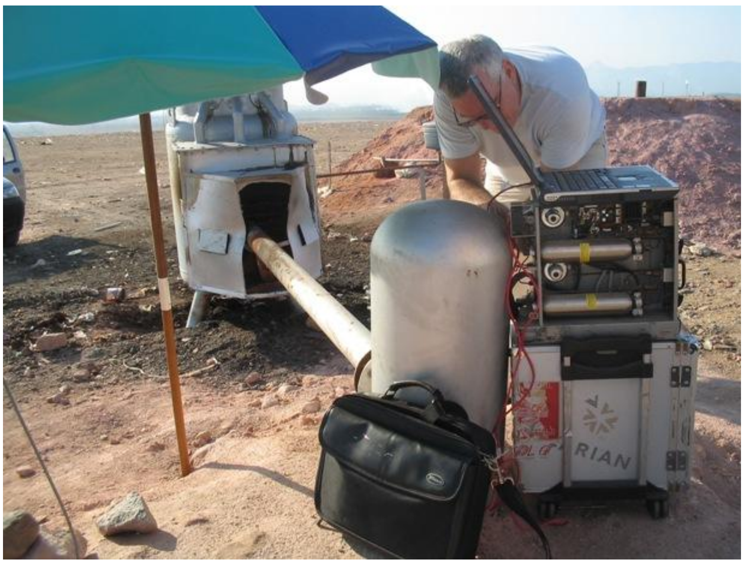

Figure 2. Monitoring of biogas using the portable chromatograph.

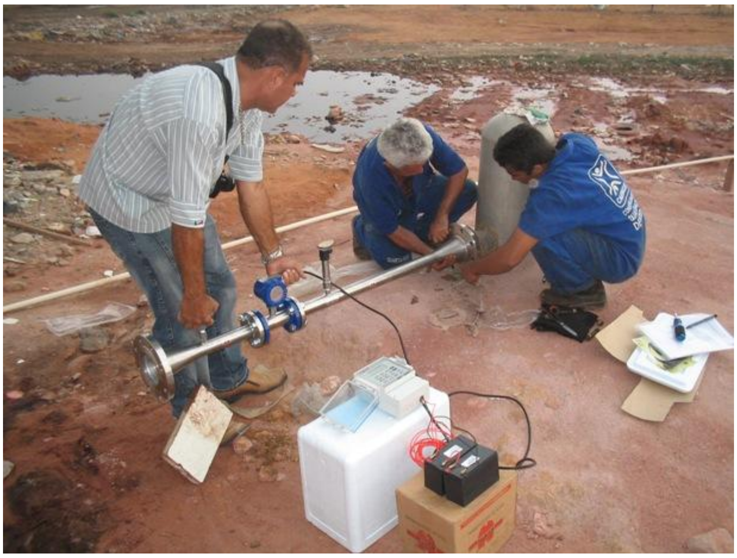

Figure 3. Measurement of the outflow of a well of biogas

2.3 Analyses of the samples of the field residues

In the evaporation process are generated the following wastes: a) waste 01: presents viscous aspect and it is resultant of non evaporated leachate; b) waste 02: is a solid waste accumulated during the evaporation process and removed by the equipment periodic cleaning; c) vapors: there are gases issued from the UE, obtained in leachate evaporation process; d) particulates: there are wastes issued by the biogas combustion process.

Samples of raw leachate, steam condensate and evaporation wastes (Waste 01 and Waste 02) are periodically collected and analyzed by the following parameters: COD, BOD, chloride, alkalinity, ammonia, solids, and pH.

For characterization of the atmospheric emissions originated by the combustion system of the biogas, a portable analyzer of gases was used. This equipment allowed quantifying the emissions of: Nitrogen Oxides (NOX), Nitric Oxide (NO), Oxygen (O_2), carbon Dioxide (CO_2) and carbon Monoxide (CO) in the exhaust gases, through one pipe located in the lateral of the UE. The assays had been carried through in conformity with the program of self-control of emissions for atmosphere - PROCON AIR, instituted by the standard FEEMA DZ-545, approved for Deliberation CECA nº 935 - 07/08/1986.

3. STUDIES OF COST FOR IMPLANTATION

3.1 Manufacture, operation and maintenance

To make it possible the Unitary Evaporator production after the research ending, the following referring cost studies for each unit had been made, considering a useful life of 5 years:

- Manufacture - including the pond or reservoir of accumulation of the leachate one - US$ 4,500.00;
- Operation - referring to the parcel to the wage of the responsible employee for the daily monitoring – US$ 2,500.00/year;
- Maintenance - material and hand of workmanship for semi-monthly cleanness, protection painting and the substitution of the internal inox steel flutes – US$ 650.00/year.

Therefore it is possible estimate an annual total cost of US$ 4,050.00. Knowing that the equipment has capacity to evaporate up to 350 m³ of leachate per year, the operational total cost of the treatment will be of approximately US$ 11.60/m³.

However, considering that this equipment will be implanted in sanitary landfill of medium or small size, the operational cost of UE can be restricted at the cost of maintenance, that is, US$ 2.50/m³.

Of course the referring costs of the periodic tests will still exist, destined to take care of to the requirements required for the responsible environmental agencies. However it will exist as an income, the related carbon credits for the exploitation of biogas in sanitary landfills.

4. RESULTS AND DISCUSSION

4.1 Functioning and income of the Unitary Evaporator

During the research, of April of 2007 the July of 2008, the UE operated in three distinct wells getting varied incomes. This performance suffered influence from the outflow of biogas in each well, the lesser the outflow of biogas lesser will be the income of the equipment. The following comments had been verified: (a) the wells are different, making it difficult the comparison of its results; (b) during the operation in wells 01 and 02, similar conditions of temperature and rainfall index had been registered, but with differentiated income (the income of I in well 01 was greater that the income gotten in well 02); (c) The low incomes presented for I in the well of biogas nº 03, are related to very small gas production in this well; it was not obtained the minimum to be determined by the outflow measurer and therefore had not been considered in the calculations for average of the performance. In Table 1 the results of the performance of the Unitary Evaporator are divided in function of the wells of biogas where the equipment was installed.

Table 1. Summary of the performance of UE including given meteorological pertinent

Month / Year	*Average Temperature (ºC)*	*Rainfall Index (mm/month)*	*Evaporated Total Volume (L)*	*Total Time of Evaporation (h)*	*Average Income (L/h)*
April / 2007	24	137	10,435	231	45.2
May / 2007	23	86	16,900	513	33.0
Total – Well 1			*27,335*	*744*	*36.8*
June / 2007	22	81	12,430	390	31.9
July / 2007	21	56	15,350	574	26.7
August / 2007	22	51	7,560	259	29.2
September /2007	22	86	13,840	505	27.4
October / 2007	23	89	13,490	494	27.3
February /2008	27	152	2,270	77	29.5
March / 2008	26	189	4,220	154	27.3
Total – Well 2			*69,160*	*2,453*	*28.2*
May / 2008	23	36	3,560	292	12.2
June / 2008	22	25	8,580	690	12.4
July / 2008	21	18	6,050	553	10.9
August / 2008	22	40	8,680	689	12.6
September / 2008	22	67	6,490	721	9.0
October / 2008	23	68	3,840	481	8.0
Total – Well 3			*37,200*	*3,426*	*10.9*

Source: Temperature – The Weather Channel – http://br.weather.com - Rainfall Index: http://simerj.com

As it can be verified, the average income of the Unitary Evaporator is around the 30 litters for the moment, being able to arrive a daily average income around 1.0 m³/day.

The variables that interfere directly with the performance of the equipment are the composition and the outflow of biogas extracted of from the landfill.

4.2 Characterization and determination of the thermal efficiency of biogas

The Table 2 it presents the results of the monitoring of the gases through the portable chromatograph and of analyzer GEM 2000, for the period of October 2008.

Table 2. Monitoring of biogas

Equipment	Average composition				
	CH_4 (%)	CO_2 (%)	H_2O (%)	H_2S (ppm)	Others (%)
Chromatograph	56.9	38.1	1.8	277.0	3.2
GEM 2000	58.8	40.6	-	-	0.6

The Table 3 presents the same resulted complementary of the gas measurement supplied by the portable chromatograph period above.

Table 3. Average result of the characteristics of biogas

Biogas	MW humid	MW dry	c	Adiabatic Coefficient	SCC	ICC	Density	Viscosity	SM
	Kg/Kmol	Kg/Kmol	cal/gmol °C		MJ/m^3	MJ/m^4	Kg/m^3	Cp	Kg/Nm^3
Average	27.11	26.78	12.27	1.41	19.27	19.62	1.185	0.577	0.062
Minimum	26.87	26.68	12.16	1.39	18.22	18.71	1.141	0.572	0.062
Maximum	27.34	26.87	12.38	1.42	20.31	20.52	1.228	0.582	0.062
Data	2	2	2	2	2	2	2	2	2

MW: Molar Weight SCC: Superior Calorific Capacity SM: Specific Mass

In November of 2008 the outflows of the wells of biogas had been measured nº 03 and 04. Nº 03 with the given measurer was not possible to determine the outflow of the well as its values had been inferior to the minimum limit of detection of the equipment. This behaviour is resultant of the small production of biogas with consequent reduction of the efficiency of UE in this well. The measurement in the well nº 04 found the outflow of $12m^3/h$. With the data of the outflow of the well, associated to the average income gotten by UE (30L/h) and to the average calorific power determined by chromatography (6,370 $Kcal/m^3$), it was possible to determine the thermal efficiency of biogas in the process of the evaporation ($0.4m^3/L$ of leachate estimated), correspondent the 2,548 Kcal/L.

4.3 Analyses of the samples of the field residues

The Table 4 presents the results of the analyses of the samples of the Rude Leachate one; the Table 5 the results of Residue 01 (pasty); the Table 6 the results of the Condensed Steam; and the Table 7 the results of Residue 02 (solid residue only collected in the opening of I stops general cleanness).

One concludes briefly that: (a) the showed residues had presented high values of shunting line standard and coefficient of variation for most of the analyzed parameters, similar behaviour to the observed one for the Rude Leachate one; (b) Residue 01 presented high concentration of organic substance, ammonia, solids and chlorides. Its pH is characteristically basic; (c) The Condensed Steam presented pH next to the neutrality (similar to the rude leachate one), low concentration of COD, ammonia and chlorides. Its detention is assumed that the ambient conditions make it difficult the setting of ammonia in the sample, making it difficult; (d) the only sample of collected Residue 02 presented pH acid, high concentration of COD and ammonia.

Table 4. Analyses of the samples of field of the Rude Leachate one.

ANALYSES	COD	BOD	Chlorides	Alkalinity	NH4	Solids	pH
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
Average	2493	326	3851	6210	1277	102	7.8
Standard Deviation	667	164	809	1980	948	121	0.4
Data	21	6	21	21	17	21	21

Table 5. Analyses of the samples of field of Residue 01

ANALYSES	COD	BOD	Chlorides	Alkalinity	NH4	Solids	pH
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
Average	37293	-	79294	40095	342	5986	8.9
Standard Deviation	15012	-	46426	23121	296	5081	0.4
Data	21	8	21	21	17	21	21

Table 6. Analyses of the samples of field of the Condensed Steam

ANALYSES	COD	BOD	Chlorides	Alkalinity	NH4	Solids	pH
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
Average	165	-	48	340	145	11	7.6
Standard Deviation	179	-	30	90	44	11	0.6
Data	7	7	6	7	7	7	7

Table 7. Analyses of the samples of field of Residue 02

ANALYSES	COD	NH4	pH
	mg/l	mg/l	
Result	23260	3915	4.1
Data	1	1	1

In August 2008 three analyses of the gases emitted for the system of combustion of I had been carried through, presented in table 8.

Table 8. Results found in the analyses of the system of combustion of UE

Sampling	NOX (mg / Nm^3)	NO (mg / Nm^3)	O_2 (%)	CO_2 (%)	CO (ppm)
Nº 01	72	43	0.6	11.4	25,535
Nº 02	72	46	0.7	11.5	25,603
Nº 03	66	40	0.9	11.3	25,578

All the analyzed parameters are only limited by the legislation the Nitrogen Oxide concentrations (NOx), which resulted that they must be expressed in the unit of concentration mg/Nm^3, in dry base and 3% of oxygen excess.

For thermal power nominal minor than 70 MW, the Resolution of the National Advice of the Environment (CONAMA) nº 382, of 26/12/2006 establishes a limit of 320 mg/Nm^3 for Nitrogen the joined Oxide average emitted for the atmosphere, through the processes of generation of heat from the external gas combustion. In table 9 the results and the corrected concentrations are presented 3% of excess of O_2.

Table 9. Results found in the analyses of NOx in the combustion of EU

Sampling	Measured oxygen (%)	Measured concentration (mg NOX/Nm^3)	Corrected concentration 3% of O_2 (mg NOX/Nm^3)
Nº 01	0.6	72	64
Nº 02	0.7	72	64
Nº 03	0.9	66	59

The average gotten for the three Nitrogen Oxide samplings was of 62 mg/Nm^3, five times lesser that the limit established for the CONAMA.

5. CONCLUSIONS

The Unitary Evaporator is an equipment of low cost, of easy implantation, use and maintenance, and of great advantage mainly for landfills of small and average size.

As the equipment uses biogas produced in landfills as caloric power plant, it makes possible the generation of carbon credits, a time that the beginning of the process if bases on the burning of biogas.

It is important to emphasize that the project is still in process of development and study, and the carried through analyses had still not been able to determine completely if it will have to suffer new alterations.

With the advance of the research it will be possible to get better resulted through a new model in test phase, as well as the exploitation of some residues generated in the process of the evaporation.

ACKNOWLEDGEMENTS

The company of urban cleanness of Rio de Janeiro (COMLURB), the financier of studies and projects (FINEP), and the program of research in basic sanitation (PROSAB).

REFERENCES

Bacelar H.A.M., Cantanhede A.L.G. and I. C. Figueiredo. (2009). Analysis of the residues generated in the evaporation of leachate produced in sanitary aterros using unitary evaporator. Third inter-American congress of solid residues of AIDIS - Argentine.

National advice of Environment - CONAMA. Resolution nº 382, that it establishes in its Attached I maximum limits of emission in processes of generation of heat from the external fuel combustion diverse, 2006.

Program of Self-control of Emissions for Atmosphere - PROCON AIR, instituted for Line of direction FEEMA DZ-545, approved for Deliberation CECA in the 935, 1986.