

THE USE OF SANITARY LANDFIL GAS FOR THE THERMAL TREATMENT OF LEACHATE – A SIMULTANEOUS REDUCTION OF TWO SOURCES OF POLLUTANTS OF AIR, SOIL AND WATER

USO DO GÁS DE ATERRO SANITÁRIO PARA TRATAMENTO TÉRMICO DE CHORUME – UMA REDUÇÃO SIMULTÂNEA DE DUAS FONTES POLUENTES DE AR, SOLO E ÁGUA

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ABSTRACT – A research is being conducted in the sanitary landfill of Sao Carlos, Brazil, a city with 200,000 inhabitants to verify the feasibility of the thermal treatment of the leachate using the landfill gas as the energy source. The composition and flow rate of both the gas and chorume were determined experimentally. To measure the gas flow rate at the wells a probe was developed and its measurements were compared with information obtained in the literature. Energy and chemical balances were made to verify the availability of energy and the process potential for emission of air pollutants. So far, the results show that there are enough energy to make the leachate incineration feasible, but more research is on the way, since the gas flow rate may have a large variation from well to well and not all of them were probed so far. The chemical balance showed that the air pollution potential for the thermal process is small and even with no gas treatment most of the emissions would be lower than required by the environmental legislation.

KEYWORDS: Energy recovery. Energy conservation. Environment. Biogas. Climate change. Sanitary landfill.

INTRODUCTION

We live in a society where consumption is still a synonym of development. One way products and the excess of packing produce more and more wastes. In Brazil the waste production is relatively modest, approximately 240,000 ton/day but grows 5%/year what means that it tends to double every 15 years. Today, the per capita production of waste is approximately 1kg/person/day (Pacey, J.G.,1986) and not all the sanitary landfills in the country have good control. The rate of waste production tends to grow, making the waste management and disposal a problem of difficult solution, and placing clearly the need for the research of alternatives that are acceptable from the environmental and economic points of view. Among the problems caused by the inadequate disposal of the waste are the spreading of diseases and soil and water contamination by the leachate, the air pollution caused by methane, that is a greenhouse gas (GHG), and the release of odorous compounds. Besides that, there is a crescent shortage of area to landfill the residues. Municipal waste is rich in organic compounds that in contact with air suffer a slow process of oxidation and decomposition. However, in the internal layers of the waste, anaerobic bacteria accelerate the process and the waste decomposition produces gases as methane (CH₄), carbon dioxide (CO₂) nitrogen (N₂) and others in small quantities able to produce unpleasant odors. Methane and CO₂ are the gases of most concern once they can upset the thermal balance of the Earth by absorbing infra-red radiation in the same range of wavelengths that the planet emits to space (emission window). This happens because: a) the fraction of this gas is quite large in sanitary landfills,

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about 50% in volume, and b) its Global Warming Potential (GWP) is about 23 times that of CO₂ (mass basis) considering a time horizon of 100 years (IPCC, 2010).

1. Metodology

The proposed process is the thermal treatment of the leachate using the sanitary landfill gas as the energy source. To determine its feasibility it was necessary to make a balance of energy considering: a) the gas flow rate and its chemical composition (available energy) and b) the leachate's flow rate, specific heat and latent heat of vaporization (energy required). The process should reach temperatures about 900°C considered safe for avoiding the formation of most of the air pollutants (SINDIC, D. R., 2002). To determine which air pollutants could be generated and what kind of treatment, if any, should be applied it was necessary to know the chemical composition of the leachate. At the typical combustion temperatures sulfur forms SO₂ and SO₃, Cl forms HCl and organochlorides, fluorine forms HF, heavy metals can be emitted as gases or adsorbed in the particulate matter (PM) and N can generate NO_x (NO e NO₂). To make the energy balance more favorable it was tried to reduce the leachate's water content using microfiltration a low energy process.

1.1 – Gas and Leachate Sampling

During the year of 2002 leachate samples were regularly collected at the inlet of the storage ponds of the sanitary landfill. Glass bottles with hermetic plastic lids, previously washed with a solution of 50% of HCl were used for its storage, in a freezer at 4°C, until the chemical and physical analysis could be carried out. Soon after collected the samples had their pH determined, showing values around 8. The leachate average temperature during the period of sampling was 24 °C. Samplings of the gas were made as well. To extract the gas, some of the flares were turned off and a hose was introduced deep inside them to avoid any possible dilution by air. The gas suction was carried out using a glass flask previously filled with water and equipped with one tap at each end to allow the water discharge and the gas suction. The hose was previously purged of air by exposing it to the gas flow.

1.2 – Leachate Properties

1.2.1 – Flow Rate

The leachate flow rate was determined several times along the year, using a vessel of 20 L to collect the liquid and measuring the time necessary to make it (Eq 1).

$$V = \left(\frac{\text{container volume}}{\text{fill time}} \right) \times 3,6 (\text{m}^3 / \text{hours}) \quad (1)$$

1.2.3 – Calorific Value

To verify if the leachate could have any residual calorific value a 5000 – IKA Laborotechnik calorimeter was used. The samples had a mass of 5g and the tests were carried out using untreated leachate, microfiltrated leachate and a blend of leachate with ethanol.

1.2.4 – Heavy Metals

For the heavy metal analysis it was used the atomic absorption spectrometry technique with the method of standards addition and a HITACHI, modelo Z 8100 device.

1.3 – Gas Propertieess

1.3.1 – Chemical Composition

It was used a cromatografer Grow-Mac with a thermal conductivity detector and a Porapak Q (2m, 80 a 100 mesh) column.

1.3.2 – Gas flow Rate

The gas flow rate was determined experimentally trough the placement of a probe developed for this purpose in some of the wells after its flares bad been turned off and compared with calculations based on the daily mass of residues disposed in the landfill (CRISTENSEN,et al, 1996). The probe used parts of an early DISA 55M hot wire anemometry system that was modified to give spatial and temporal averages rather than the usual high resolution typical of this type of equipment.

Some details of the probe and its calibration set up are shown in Figures (1).

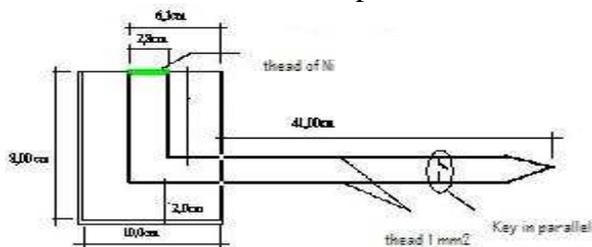


Fig.1 – Schematics of the gas flow rate sampling probe
Source: Autor

2- Results

2.1- Leachate Flow Rate

The leachate flow rate showed a strong variation along the year, with values as high as 8 m³/h during the rainy season (December to March) and about 2 m³/h or bellow, during the rest of the year, Figure(3).

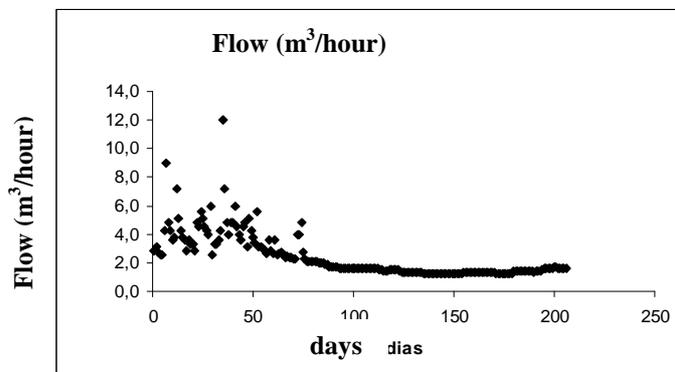


Fig. 3 – Leachate's flow rate from January to August of 2002.
Source: Autor

2.2 – Gas Flow Rate

Measurements were carried out in 3 off the 20 wells of the landfill, showing little variation among them, Table (1).

Table (1)
Gas flow rates for three wells

Well	Anemometer voltage (V)	Gas flow rate (m ³ /h)
W1	7.23	31,5
W2	7.42	32,5
W3	7.54	34,2

2.3 – Leachate Properties

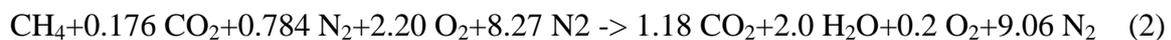
The elements analyzed in the leachate for its potential to produce air pollutants, mainly metals, nitrogen (NO_x) sulfur (SO_x) chlorine (HCl) and fluorine (HF). No calorific value was detected for the leachate, even after microfiltration that, with the system used produced negligible results.

2.4 – Chemical Composition of the Landfil Gas

The chemical composition of the landfill gas and of the gas in the surface of the leachate ponds. In the landfill gas methane has a fraction of 51% in volume, what is a value often reported in the literature. With this composition, the low calorific value of the gas is about 35 MJ/kg. On the leachate ponds methane concentration is much smaller, about 5%, but still significant from the environmental point of view.

2.5 – Availability of Energy

For the energy balance it was admitted that the reactants (air and gas) were at 25°C and 0,1 MPa, all gases (reactants and products) had a perfect gas behavior and enthalpy was a function only of the temperature, so it could be readily determined with the correlations available in the literature for specific heat at constant pressure. For the combustion process an excess of air of 10% was admitted as it is usually high enough to ensure good efficiency of the gas combustion without causing an excessive drop of the incinerator's thermal efficiency. A mean combustion temperature of 900°C was considered adequate once it is sufficiently high to avoid the formation of hazard organic compounds but low enough to avoid excessive NO_x formation and waste of energy. Under these assumptions, the complete combustion of the biogas, considering one mol of methane, is given by Equation (2) and the energy conservation by Equation (3).



In Equation (3) the subscripts P and R are for products and reactants respectively, h_f is the formation enthalpy, Δh its correction from the reference state of 25°C and 0.1 MPa to the condition considered and Q_A is the energy available for the leachate incineration.

$$Q_D = \sum P n_s (h_f + \Delta h_s) - \sum R n_e (h_f + \Delta h_e) \quad (3)$$

An estimate of the landfill production of methane was made and compared to the measurements. In order to obtain a good agreement, the value for the ratio between gas production and waste disposed that should be used was: $R_{\text{CH}_4} = 61.7 \text{ Nm}^3$ of CH₄/t on of waste

The daily load of the landfill is: $m_{Res} = 130$ t/dia what should produce at the present conditions of the sanitary landfill a flow rate of:

$$V_{Z_{CH_4}} = \frac{m_{Res}}{24} \cdot R_{CH_4} \quad (16) \quad V_{Z_{CH_4}} = 334.2 \text{ m}^3/\text{h} \quad (17)$$

So, the leachate flow that could be incinerated is: $V_{chI} = 1.33 \text{ m}^3$ leachate / h. This volume is close but not enough to incinerate all the leachate of the landfill, that have an annual average production of $2 \text{ m}^3/\text{h}$. Removing some water by microfiltration or another low energy process or lowering the temperature of the gases could help in the process.

2.6 – Potential for Emission of Air Pollutants

During the leachate incineration some air pollutants might be formed and released. To evaluate the potential of these emissions, a calculation was made considering that all chemical species of interest in the leachate would be totally converted in some kind of pollutant and released to the atmosphere.

3 – Conclusions

The landfill production of gas was measured in 3 of its 20 wells showing an average of $32.7 \text{ m}^3/\text{h}/\text{well}$. That gives a total of $654 \text{ m}^3/\text{h}$ for the whole landfill or yet an average of $3 \cdot 10^{-3} \text{ m}^3/\text{h}/\text{m}^2$. The mean ratio between methane and waste resulted in 61 Nm^3 of CH_4 /ton of waste. More research is needed and is underway to make a safer estimate. The energy represented for this volume should be close, although not enough, to that required for the leachate incineration at 900°C . The annual average of leachate production was $2 \text{ m}^3/\text{h}$ with a four fold increase during the rainy season. The gas energy would be sufficient for about $1.3 \text{ m}^3/\text{h}$. Some of the potential air pollutants that could be released by the process if their precursors were totally converted and emitted by the stack would be above the legal limits. More accurate estimates are needed for this aspect of the process as it is unlikely that that happens.

RESUMO

A pesquisa está sendo conduzido no aterro sanitário de São Carlos, Brasil, uma cidade com 200 mil habitantes, para verificar a viabilidade do tratamento térmico do chorume utilizando o gás de aterro como fonte de energia. A taxa de fluxo da composição e o gás e o chorume foram determinados experimentalmente. Para medir a taxa de fluxo de gás em poços uma sonda foi desenvolvido e as suas medições foram comparados com os dados obtidos na literatura. Balanços de energia e química foram feitos para verificar a disponibilidade de energia e o potencial processo de emissão de poluentes atmosféricos. Até agora, os resultados mostram que não há energia suficiente para tornar a incineração de chorume viável, mas mais investigações estão sendo realizadas, uma vez que a taxa de fluxo de gás pode ter uma grande variação de poço a poço e nem todos eles foram sondados até o momento. O balanço químico mostrou que o potencial de poluição do ar para o processo térmico é pequeno e, mesmo sem tratamento de gás a maioria das emissões seria menor do que o exigido pela legislação ambiental.

PALAVRAS-CHAVE: Recuperação de energia. Conservação de energia. Meio ambiente. Biogás. Mudanças climáticas. Aterro Sanitário.

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