EVALUATION OF THE BRAZILIAN NATIONAL INVENTORY OF METHANE EMISSIONS FROM WASTES FOR THE SCREENING OF A PRIORITY SECTOR FOR BIOGAS RECOVERY AND UTILIZATION

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(presented at the 2nd International Methane Mitigation Conference - Novosibirsk, Russia, Jun2000)

Abstract

CETESB - the Sao Paulo State Environmental Agency - has elaborated the National Inventory of emissions of methane from waste management in Brazil, following the methodology established by the Intergovernmental Panel on Climate Change - IPCC. The figures obtained for 1994 are 805 gigagrams of methane, 677 corresponding to the municipal solid wastes anaerobic digestion, 43 to domestic wastewater anaerobic treatment and 84 to the anaerobic digestion of industrial effluents. At first, this inventory did not enable an assessment of the emissions in order to seek their mitigation. It was then developed a second methodology searching for detailed information. Data for solid wastes came from municipality administrations throughout the country, in charge for this management. From over 5.000 municipalities, were trimmed out those smaller than 100 thousand inhabitants, providing a sample of 259 cities covering 63% of the county's urban population. Domestic wastewater data was obtained from city authorities and water companies. For industrial wastewater data, were consulted suppliers of anaerobic reactors and State environmental pollution control agencies. Main sources with potential mitigation were identified: solid wastes and specific industrial effluents. The aim of this paper is to discuss the factors involved in this screening process.

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Introduction

The waste anaerobic decomposition, *i.e.*, in absence of oxygen, generates large amounts of biogas, in which the percentage of methane varies. It depends upon the type of waste, its constituents, the design and management of the treatment system, among others. In landfills, where is relevant the moisture content, recovered biogas contains approximately 50 percent of methane.

Anaerobic treatment of effluents generates biogas with about 50% to 70% of methane and 50% to 30% percent of carbon dioxide [1]. Due to the atmospheric air contained in the domestic wastewater, the biogas generated also contains nitrogen, carbon dioxide and other gases [2].

Methane is a major greenhouse gas after carbon dioxide in terms of contribution to global warming. Methane is also a valuable source of energy. The recovering of methane can be an economically and attractive way to mitigate the global warming effects.

Assisting the United Nations Framework Convention on Climate Change (UNFCCC), CETESB, the Brazilian Sao Paulo State Environmental Agency, has elaborated the national inventory of methane emissions from waste management, following the methodology recommended by [3]. This work was based on a statistical data survey in order to define characteristics of the population and the country's industrial sector. It is necessary to know the total urban population, along with the conditions of effluent treatment and waste disposal. That implies in determining the collected, treated and disposal fractions, the nature of sanitation facilities, such as landfills or open dumps, the organic matter emissions and anaerobic sewage treatment in a given year, as well as correction factors related to regeneration and performance of waste generated.

Sources of Methane: the Brazilian Inventory from Wastes

Methane generation from solid waste in Brazil

According to data from the National Home Sample Survey [4], 85% of the population has waste collection services. In Brazil, municipal solid waste generation is estimated to be around 54 thousand metric tons per day, with composition varying according to each region. The generation per inhabitant of a Brazilian city varies from 0.4 to 0.7 Kg/inhab.day. According to the IPCC 1996 methodology [3], net methane emissions from solid waste in Brazil for the years of 1990 and 1994 are respectively 617.95 and 676.89 gigagrams per year [5]. The annual CH_4 emissions were calculated following the equation:

$$Pop_{urb} \text{ x } MSWrate \text{ x } MSW_f \text{ x } MCF \text{ x } DOC \text{ x } DOC_F \text{ x } F\ 16/12 - R) \text{ x } (1 - OX) = \text{Emission } [GgCH_4/year]$$

where:

- Pop_{urb}: Urban population [inhabitants] of the country. Calculated by interpolation from censuses, with a geometric factor.
- MSW rate: Municipal solid waste generation rate per inhabitant per year. CETESB [6], has estimated the urban waste generation per inhabitant according to the population: 0.4kg/inhab/day (cities with less than 100,000 inhab.); 0.5 kg/inhab./day (100,001 - 500,000 inhab.); 0.6 kg/inhab./day (500,001 - 1,000,000 inhab.) and 0.7 kg/inhab./day (more than 1,000,000 inhab.). To Brazil was obtained a city-weighted average of 0.5Kg/inhab/day.
- MSW_f: Municipal solid waste fraction deposited in solid waste disposal sites [adimensional fraction]. Used 85%, based on national statistics.
- MCF: Methane correction factor [adimensional fraction]. Used IPCC default of 60% for the unclassified sites, due to lack of data.
- DOC: Degradable organic carbon in municipal solid waste [adimensional fraction]. Idem, IPCC default of 0.12.
- DOC_F: DOC fraction that really degrades [adimensional fraction]. Idem, 77%, as recommended by IPCC.
- F: CH_4 fraction in landfill gas [adimensional fraction]. Used IPCC value 0.5. A sampled data of landfill gas composition in the metropolitan region of Sao Paulo [7] confirms averaged values from 42,8% CH_4 to 54,2%, with an overall arithmetic average of 49.4%. However, since this is a selected sample of landfills with a potential for methane recovery for energy generation purposes, probably other landfills do not show similar potentials.
- 16/12 Conversion rate from carbon into methane [adimensional fraction]
- R: Recovered methane amount [$GgCH_4$/year]. There is no data available on methane recovery in landfills in Brazil. Thus R = 0.
- OX: Oxidation factor [adimensional fraction]

Methane generation from liquid effluents in Brazil

In Brazil, a great variety of systems are used for wastewater treatment. In spite of this, a huge amount of wastewater is released directly into rivers and the ocean without treatment.

According to [4], 5% of home urban wastewater generated in the country have no collection, while 23% have septic tanks and 46% are served by a central collection system.

IPCC recommends a determination of annual CH_4 emissions from anaerobic domestic, commercial and industrial wastewater anaerobic treatment.

Domestic and commercial wastewater

The IPCC formula, applied for estimating methane from residential and commercial wastewater treatment is:

$$Pop_{urb} \times BOD_5 \text{ rate} \times TWF \times MCF \times MMPC - R = \text{Methane emission } [GgCH_4/year]$$

where:

- Pop_{urb}: Urban population [inhabitants]. As previously described.
- BOD_5 rate: Biochemical Oxygen Demand generation rate [BOD_5/inhabitant]. Adopted 0.050Kg BOD_5/inhabitant/day.
- TWF: Treated wastewater fraction [adimensional fraction]. Further explained, with MCF.
- MCF: Methane correction factor [adimensional fraction]. Used the estimates suggested by the IPCC. A preliminary estimate of wastewater treatment in Brazil produced an estimate for FWT x MCF of 8.3%, within the range of 8%-10% proposed by IPCC [4]
- MMPC: Maximum methane emission factor [adimensional fraction].
- R: Recovered methane amount [$GgCH_4$/year]. Virtually zero.

Industrial effluents

The industrial methane from effluents inventory followed the model suggested by the IPCC, with production data from the main sectors in Brazil. Values are given for annual production in metric tons, except for auto factories, where production is given in vehicle units. The equation suggested by IPCC for these calculations is the following:

$$Prod_{ind} \times EF_{c\ org} \times FWT \times MCF \times MMPC - R = \text{Methane emission } [GgCH_4/year]$$

where:

- $Prod_{ind}$: Industrial production (production units). The inventory for each sector followed the model suggested by the IPCC, with data from the main industrial sectors in Brazil, standardized to metric tons/year.
- $EF_{c\ org}$: Organic load emission factor per unit of production [BOD_5/ unit]. Were commonly observed variations due to different industrial process technologies. Emission factors (kgBOD_5/t year) according to the industry were: metalworking (0.11); car industry (1.93); food and

drink, beer (62.10), canned food (12.50), wine (0.26); slaughterhouse, bovine (7.00), pork (30.00), poultry (3.97), horses (6.40), sheep (6.40), goats (6.40); dairy products, raw milk (11.00), pasteurized milk (22.00), condensed milk (5.60), powdered milk (41.00), butter (29.43), cheese (28.80); sugar (200.00); soluble coffee (156.00); oil and vegetable fat (12.90); canned fish (7.90); soft drinks (2.50); pulp and paper, pulp (55.00), paper (8.00); oil/refineries/petrochemicals (3.40); textile, cotton (155.00), wool (711.00); nylon (45.00); rubber (1.90); chemicals, vynil acetate (0.35), ketone (0.35), acetic acid (63.00), phosphoric acid (1.60), nitric acid 99% (0.25), terephtalic acid (63.00), acrylates (63.00), methanol (0.49), ammonia (0.20), benzene, toluene and xylene (0.10), biphenol a (63.00), butadiene (0.63), caprolactone (63.00), ciclohexane (0.11), dimethylterephtalate (63.00), styrene (1.00), ethylbenzene (0.13), ethyleneglycol (63.00), phenol (63.00), formaldehyde (0.35), methylamines (0.35), nitrocellulose (0.21), dyes (136.00), pvc (10.00); tanning (135.00) and; alcohol (54.00).

- FWT: Fraction of wastewater treated (adimensional fraction). IPCC default of 20%, due to a very difficult bottom-up approach
- MCF: Methane correction factor (adimensional fraction). Default of 90%, IPCC.
- MMPC: Maximum methane emission factor. Used the IPCC suggested value: 0,25gCH_4/gBOD_5
- R: Recovered methane amount (GgCH_4/year). Virtually zero.

Final inventory summary results

Following the methodology established by the IPCC, the results for 1994 are 806 gigagrams/year of methane, being 677Gg (84%) from municipal solid wastes (MSW), 43 Gg (5%) from domestic residential and commercial wastewater anaerobic treatment and 86Gg (11%) from industrial wastewater.

Year	Methane emissions (Gg CH_4/year)			
	Solid waste	Domestic and commercial sewage	Industrial effluents	Total
1990	618,01	39.34	80.00	737,35
1991	636,34	40,51	79,82	756,67
1992	649,68	41,36	82,01	773,05
1993	663,28	42,23	82,71	788,22
1994	677,18	43.11	84,41	804,70

1Gg = 1000t

Municipal solid wastes (MSW) were the major share, equivalent to 84% of total (around 677gigagrams CH_4/yr). Wastewater covers the other inventoried 136 gigagrams/yr (16% of total emissions), subdivided into commercial and residential wastewater (CRWW, accounting with 43gigagrams CH_4/yr or 5%) and industrial wastewater (IWW, 87gigagrams CH_4/yr or 11%), methane from wastewater accounts with a smaller share of total inventoried emissions (15%).

At a first sight, the most evident sector where methane could be recovered is landfills. These concentrate the larger potential reserves of this greenhouse gas and fuel, 84% of the country stocks.

Nearly 50% of the total methane generated by wastes in Brazil are concentrated in 13 landfills, located in major cities. Following this evidence, the U.S.E.P.A has conducted assessments [7]; [8] in order to implement real scale projects with the target of methane utilization. An approach to the municipalities, owners of landfill sites, was made and a couple of bidding for tenders opened to the private initiative. Almost five years later, there are not any of such waste-to-energy schemes implemented in real scale or pilot demonstration projects. Subtle factors contributed to these flaws, leading to a further discussion about which issues to address and/or in which sector concentrate efforts to achieve a successful first development.

The necessity to adopt a standard methodology to compare data from many countries leads to simplifications. Although this practice was very useful to obtain the total methane generated by the waste management in Brazil, it did not enable an assessment of the methane generation in order to seek its mitigation. Together with the defaults, the IPCC also suggests that to the greatest extent possible, local technical information should be taken.

It was thus developed a second methodology searching for information in each local of disposal or treatment of residues. The data collection for the inventory from solid wastes came from municipality administrations throughout the country, with the duty for this management. Considering that Brazil has over 5.000 municipalities, were trimmed out those smaller than 100 thousand inhabitants, providing a sample of 259 cities covering 63% of the county's urban population. State-owned water companies and some city authorities that collect and treat the domestic wastewater in the country were the chosen sources of information. Industries in Brazil, having their emissions limited by legislation, are responsible for the treatment of their effluents. Thus, for the inventory of methane from anaerobic digestion of industrial wastewater, were consulted suppliers of anaerobic reactors and state environmental pollution control agencies.

The survey conducted by CETESB includes figures related to local systems, treatment performance and byproducts generation. The data collected were stocked in access bank for better assessment.

This inventory made possible the identification of the main sources of methane from wastes with potential mitigation, informing the main management technologies applied in Brazil - including liquid and solid wastes treatment and disposal in the country. It also enables to evaluate - geographical, qualitative and quantitatively - the sources of methane emissions by anaerobic digestion

Evaluation of database and identification of priority sectors

Like solid wastes, although in a smaller scale, liquid effluents also offer an attractive potential for energy recovery for anaerobically produced methane. In 1997 more than 125,000 m^3 of industrial wastewater were treated in 121 anaerobic reactors and 134,000 m^3 of domestic sewage treated in 222 anaerobic reactors mainly of the type UASB or anaerobic, totaling 259,000 m^3. [9]. The increase may be noticed if compared with 1994 numbers: a total capacity of 197.400 m^3 in anaerobic effluent reactors [6], [7], [10].

Domestic wastewater presents frequently unsuitable conditions for methane recovery, because of their low organic loads. Industrial wastewater is apparently a good sector to be targeted in order to achieve a successful first pilot project. Private owned sources are easier for establishing contracts. Moreover, there's usually a demand for energy - like heat or electricity. Saving costs and obtaining energy from a reliable source (not subject to blackouts for example) are other major driving forces.

Within the industrial sector, those with higher organic loads in their effluents treated effective or potentially by anaerobic reactors were considered a priority. The food, beverage, sugar and alcohol industries were therefore the first to be screened. Then, other factors like industry location and alternative fuels served as supplementary elements for the selection. Each company's internal needs, culture and policy were the final factors to be considered.

Evaluating the database, were selected companies in the brewery sector, with high flows of effluents plus high and predictable organic loads (around 2,400 mg COD/liter). Moreover, such industries have needs for internal energy and carbon dioxide. The survey has reported that 29 out of 30 records of breweries in the state of Sao Paulo already operate anaerobic reactors in their sites, just needing to have the gas-to-energy schemes set up. Arrangements for demonstration projects are on the way.

At the same time, is expected that the Clean Development Mechanism (CDM) is implemented. Established by article 12 of the Kyoto Protocol; it still needs to be ratified by countries responsible by 55% of the total GHG emissions, including United States, Russia and Ukraine. It is expected that after these ratification, other countries - including Brazil - join the initiatives. The use of CDM or other similar mechanisms is important to viable a compensation process of GHG emissions through projects between developing and OECD countries.

Conclusion

Although the major source of methane from wastes are few landfill sites, screening in a pragmatic approach has determined that industrial wastewater - especially the brewery sector - is the best option to start a first demonstration project of methane recovery. Development of the Brazilian inventory of methane from wastes has shown the importance of gathering data on treatment stations and waste disposal, helping in the development of programs for reducing emissions of pollutants, along with allowing an improvement in waste management, better efficiency for treatment systems, a reduction in the emission of greenhouse gases and increased efficiency in the use of energy.

Acknowledgements

The authors wish to thank all colleagues who collaborated with the national inventory of methane from wastes. This report was supported by Cetesb, United Nations Development Program-UNDP, U.S. Country Studies Program and Brazilian Science and Technology Ministry-MCT.

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