INVESTIGATING METHANE EMISSIONS FROM LANDFILL IN THE METROPOLITAN REGION OF SÃO PAULO

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Abstract

This research addresses the escalating global levels of atmospheric methane, emphasizing the critical need for understanding its sources and behavior. Landfills are identified as methane super emitters, because its rates range from 1,000 to 3,000 kg/h. Focusing on the Landfill in the district of São Mateus, in the city of São Paulo, the study aims to investigate the significance of landfills in the rising methane levels, emphasizing the impact of super emitters and methane hotspots. Field campaigns conducted on February 15th and April 06th, 2023, utilized a portable greenhouse gas analyzer (ABB) to measure methane concentrations. Meteorological parameters from ERA5 and the AERMOD Modeling System were used for a comprehensive analysis. The results highlight elevated methane concentrations around the Landfill, emphasizing its role as a significant methane super emitter. The study underscores the importance of such analyses in understanding the impact of landfills on atmospheric methane levels.

Introduction

One of the main Greenhouse Gases (GHGs) that is very important to study is Methane (CH_4), as it is a gas with a high global warming potential. Its natural concentration is about 2.0 ppm. The waste sector is the second largest emitter of CH_4 in Brazil, through landfills due to decomposition of organic matter disposal through microbial production. A landfill is considered a super emitter of methane due to its high emission rate, between 1,000 and 3,000 kg/h [1-5].

The production of biomethane, generated by power generation plants using the gas, is one of the actions that has the most potential to recover the CH_4 emitted, reducing emissions [6]. There is a growing interest in researching methane emissions from landfills due to the substantial amount emitted and the gas's potential to contribute to global warming. The CH_4 map visualization platform, Spectra Basic, created by GHGSat, presents events with high concentrations of CH_4 in several sectors, including the waste sector, with emission rates varying between 1.815 kg/h, on July 31st, in a landfill in Bahia, Brazil, and 5.776 kg/h on August 22nd, in Rio Grande do Sul, Brazil [7].

The landfill in the district of São Mateus (latitude: -23.63559444, longitude: - 46.42729722), located in the Metropolitan Region of São Paulo, Brazil, receives about 7,000 tons of waste per day. To comprehend CH_4 dynamics, a case study of the landfill was conducted to observe its elevated emission rates and concentrations. To observe emissions from the landfill, CH_4 was measured at a nearby point (latitude: -23.64163056, longitude: -46.42104444).

Materials and Methods

Greenhouse Gases Analyzer

To assess methane concentrations near the landfill site, a portable device designed for analyzing GHG such as CH_4, CO_2 and H_2O was used. The ultra-sensitive analyzer utilizes Off-Axis Integrated Cavity Output Spectroscopy technology (OA-ICOS), which enhances laser absorption, thereby enhancing the accuracy of collected data [8]. The gas concentration is determined by measuring the variation in light absorption intensity by the gas [9]. With the gas analyzer, in a car, the researchers went to a point that was as close as possible to the landfill disposal area, that is, at a stopping point on the landfill's side highway. The inlet of the equipment was positioned outside the car window so that concentrations could be monitored continuously.

Air Quality Dispersion Modeling

Recommended by the U.S. EPA, the AERMOD is a steady-state plume model that employs Gaussian dispersion to simulate how topography affects plume behavior. The model incorporates air dispersion based on the turbulence structure of the planetary boundary layer, surface and elevated sources, and simple and complex terrains [10,11]. This methodology is composed of the following elements:

- AERMAP: Organizes topographic data to be used in the model, resulting in more accurate modeling. The topography used for the research was estimated by the GMTED2010 (Global Multi-Resolution Terrain Elevation Data 2010) elevation model [12,13];
- AERMET: Processes and organizes meteorological data for the model. One of the most significant impacts is observed in the utilization of roughness, where higher roughness values lead to increased dispersion of pollutants. Other meteorological data used were reanalysis data provided by ECMWF, called ERA5, which provides hourly estimates of wind and surface parameters, with a resolution of 31 km [14,15];
- AERMOD: Processes source data, topography data, and meteorological data, results of the pre processors AERMAP and AERMET. By adjusting the peak concentration, the mean concentration is derived by summing the resultant concentrations [16]. The inverse modeling technique calculated by AERMOD uses a transfer matrix, which determines how each aspect of scattering from a point source with an emission rate affects a receiver, resulting in a net concentration [17];
- AERPLOT: Uses AERMOD output data to visualize graphical data, representing pollution plumes.

The processors were used to simulate the CH_4 plume, estimating the concentrations, which would later be compared with the concentrations measured in the field, with the analyzer. This way, it would be possible to estimate the methane emission rate for the measurement days.

Results

Methane Concentration Measurements

To observe the values of methane concentrations in locations close to the waste disposal area of the São Mateus landfill, a GHG analyzer was used. The following chats present two observations regarding the representation of the data obtained. The blue dotted line represents the raw data, that is, the data from the equipment per second. The solid orange line represents the average methane concentration at every minute.

On February 15th, 2023, the measurement took place at a point near the waste disposal of the landfill for about 1 h, observing a CH_4 concentration mean of approximately 22 ppm (Figure 1), that is 11 times the background value.

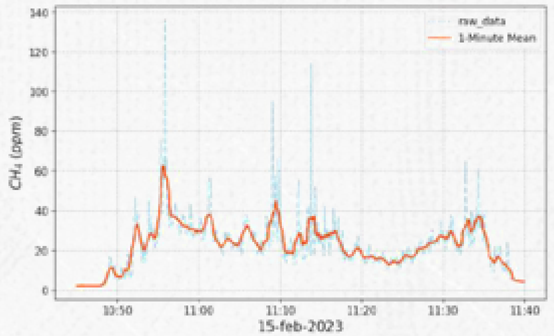

Figure 1: Chart of raw data concentration at every second and the one-minute mean for February 15th

On April 06th, 2023, the measurement took place at the same place as the other measurement day, for approximately 1 hour (Figure 2), during which the concentrations were unstable. The average concentration on this measurement day was about 4 ppm, but it is visible that, at certain moments, the concentration mean was over 10 ppm, which means 5 times the background value.

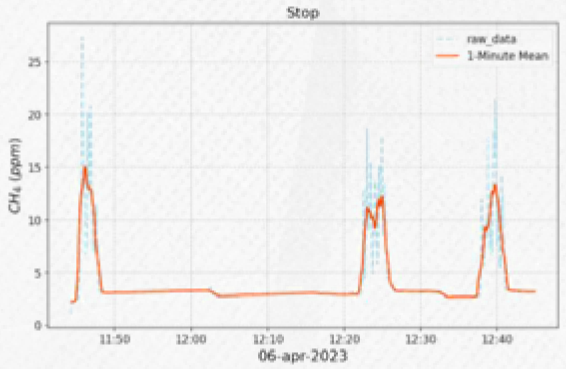

Figure 2: Chart of raw data concentration at every second and the one-minute mean for April 06th

Plumes and Emission Rates with AERMOD

The dimensions of the landfill were considered as a rectangular area, 500 meters width and 930 meters length. The roughness value was estimated at 0.19. Emission rates were estimated until the concentration at the point was in accordance with the concentration measured at the same location and with previous studies, likewise.

The visualizations in Google Earth show the contours lines of the receptor points estimated by the model, colored to reflect their concentration values. Blue indicates the concentrations farthest from the source (lower), and red, the concentrations closest to the source (highest). Below the results images is the table legend of the graphic representations of each day, showing the variation of concentration values for each line.

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On February 15th, the reference was 22.25 ppm (white x in Figure 3) at the measurement point near the landfill, and the emission rate was estimated at 25,344.36 kg/h.

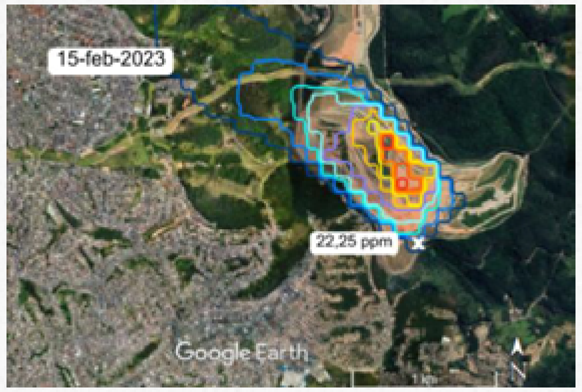

Figure 3: Representation of the graphic data, showing the concentration reference (white x) for February 15th, 2023

Table 1: Subtitle for Figure 3 of the ranges of concentration values in µg/m, as a result of the model, and in ppm, on February 15th, 2023.

	Concentrations	
	83.260 µg/m³ up to Maximum	127,96 ppm up to Maximum
	75.690 µg/m³ up to 83.260 µg/m³	116,33 ppm up to 127,96 ppm
	68.120 µg/m³ up to 75.690 µg/m³	104,69 ppm up to 116,33 ppm
	60.550 µg/m³ up to 68.120 µg/m³	93,06 ppm up to 104,69 ppm
	52.980 µg/m³ up to 60.550 µg/m³	81,43 ppm up to 93,06 ppm
	45.410 µg/m³ up to 52.980 µg/m³	69,79 ppm up to 81,43 ppm
	37.850 µg/m³ up to 45.410 µg/m³	58,17 ppm up to 69,79 ppm
	30.280 µg/m³ up to 37.850 µg/m³	46,54 ppm up to 58,17 ppm
	22.271 µg/m³ up to 30.280 µg/m³	34,23 ppm up to 46,54 ppm
	15.140 µg/m³ up to 22.271 µg/m³	23,27 ppm up to 34,23 ppm
	7.569 µg/m³ up to 15.140 µg/m³	11.63 ppm up to 23,27 ppm
	Minimum up to 7.569 µg/m³	Minimum up to 23,27 ppm

On April 06th, the reference was 4.41 ppm (white x in Figure 4), at the measurement point near the landfill, resulting in the estimated emission rate of 1,145.02 kg/h.

Figure 4: Representation of the graphic data, showing the concentration reference (white x) for April 06th, 2023

Table 2: Subtitle for Figure 4 of the ranges of concentration values in µg/m, as a result of the model, and in ppm, on April 06th, 2023.

	Concentrations	
◆	31.210 $\mu g/m^3$ up to Maximum	47,24 ppm up to Maximum
◆	28.380 $\mu g/m^3$ up to 31.210 $\mu g/m^3$	42,96 ppm up to 47,24 ppm
◆	25.540 $\mu g/m^3$ up to 28.380 $\mu g/m^3$	38,66 ppm up to 42,96 ppm
◆	22.700 $\mu g/m^3$ up to 25.540 $\mu g/m^3$	34,36 ppm up to 38,66 ppm
◆	19.860 $\mu g/m^3$ up to 22.700 $\mu g/m^3$	30,06 ppm up to 34,36 ppm
◆	17.030 $\mu g/m^3$ up to 19.860 $\mu g/m^3$	25,78 ppm up to 30,06 ppm
◆	14.190 $\mu g/m^3$ up to 17.030 $\mu g/m^3$	21,48 ppm up to 25,78 ppm
◆	11.350 $\mu g/m^3$ up to 14.190 $\mu g/m^3$	17,18 ppm up to 21,48 ppm
◆	8.513 $\mu g/m^3$ up to 11.350 $\mu g/m^3$	12,89 ppm up to 17,18 ppm
◆	5.675 $\mu g/m^3$ up to 8.513 $\mu g/m^3$	8,59 ppm up to 12,89 ppm
◆	2.838 $\mu g/m^3$ up to 5.675 $\mu g/m^3$	4,30 ppm up to 8,59 ppm
◆	Minimum up to 2.838 $\mu g/m^3$	Minimum up to 4,30 ppm

Conclusions

The concentrations of CH_4 were investigated to understand the influence of landfill emissions in the atmosphere. Areas close to waste disposal have high levels of CH_4.

The estimated emission rates are in accordance with the concentrations measured by the gas analyzer. Although the estimated values are similar to other researches, the lack of updated and accurate data was an obstacle that influenced the effectiveness of the data. Topography, meteorological and landfill information data were estimated to fit the expectations.

The findings reveal a correlation between the two methodologies, where higher concentrations correspond to higher emission rates. In this instance, the average observed concentrations were ten times and twice higher on each measurement day, as the methane natural value is 2.0 ppm.

The research highlights the importance of reducing methane emissions from landfills to combat climate change, hence the growing interest in this area. For future research in this area, the ideal would be to use more current and accurate data. The research highlights the importance of reducing methane emissions from landfills to combat climate change.

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