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Use of Drone to Measure Odor Gases in a Refinery Plant

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The objective of this study was to identify odorous gases “fingerprint” and quantify odor throughout the production process of an oil refinery located in Rio Grande do Sul State, Brazil. The NH_3 (ammonia), H_2S/CH_4S (hydrogen sulphide/methylmercaptan), SO_2 (sulfur dioxide) and VOCs (volatile organic compounds) gases were measured during 14 consecutive days around emission sources and throughout the company's production process. The monitoring was performed on main stacks, tanks vent, production process and wastewater treatment station. To measure over the stacks, it was used a Drone DJI to suspend a set of integrated electrochemical sensors that analyze the air continuously. This system made it possible to record the emission from stacks at heights of up to 120 meters above ground level, which was previously impossible to accomplish. Cairpol’s electrochemical sensors were used to provide automatic and continuous measurement. This equipment records the measurements in ppb (part per billion) every minute and stores them in an internal data logger. The odorous gas analysis results showed that the largest sources of emissions are the industrial effluent treatment, which is responsible for the emission H_2S/CH_4S and VOCs and the emission from the oil-water separator is only of VOCs. The flare stack and the Sulfur Recovery Unit’s stack are the main emitters of H_2S/CH_4S and SO_2. However, the coverage radius for the effluent treatment station and the oil-water separator is small due to the emission characteristics, as the emissions at ground level. The main sources of odor emission that can spread and annoy the neighborhood are the stacks as they presented the higher concentrations, henceforth their odor emission can be perceived from kilometers of distance.

1. Introduction

Odor complaints in the vicinity of industries have increased substantially in recent years, and oil refineries are one of the sectors with the highest potential for odor emission. In addition, people who live nearby are concerned about impacts on health due to emissions of gases (Luginaah, 2002). The most common effects reported are nausea, sinus congestion, throat irritations, headaches, and sleep problems, although odor perception and annoyance increase the perception of health impacts (Luginaah, 2000). In a petroleum refinery, the characteristic odors are sulfur compounds (e.g. hydrogen sulfide, mercaptans), nitrogen compounds (e.g. Ammonia, amines) and volatile organic compounds (VOCs) with high odor concentration (Han, 2018).

Emissions in refineries can be fugitive, emitted through valves, pumps and tank reliefs or generated by combustion processes, sulfur recovery unit (SRU), storage tanks, flares and wastewater treatment. However, the majority of odor emissions are related to the point sources and with less contribution to passive and fugitive emissions from wastewater treatment pond and contributions from storage tanks (Damuchali & Guo, 2020).

There are several methods for odor evaluation as the olfactometry techniques (Vieira et al., 2016), use of e-noses (Milan, 2016) and chemical analyses (Kim and Park, 2008). In some processes, the main gases responsible for the odor spread can be used as indicators of the analyzed activity (Capelli, 2013). However, the in situ measurement of such gases is generally limited to local monitoring at ground level.

The measurement of vertical profiles of atmospheric pollutants using unmanned aerial system (UAS) has increased in popularity. This technique has been using for aerosols (Chen et al., 2018) and VOCs (Hien et al.,

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2019). Given the high-resolution data provided by UAS recordings of stinking gases and other pollutants, it is possible to extend the diagnosis of the spatial distribution to smaller scales and to analyze the physical processes acting in the diffusion of each monitored compound (Hien et al., 2019).
In Brazil there are laws regulating air quality, but there are no limits on odor emissions or ambient concentrations (Brancher, 2017). This lack of regulation reinforces the need for odor monitoring work, regardless of the method used, to assist in the creation of national laws.
This paper aims to present the methodology adopted in an odor emission measurement campaign using electrochemical sensors embarked in a UAV. Such methodology for odorous gases monitoring provides the fingerprint of the gases emitted from each process. This is achieved by taking advantage of the drone’s mobility to take measurements over inaccessible spots, allowing a clear identification of which odorous gases are emitted by each source and, very important as well, which stacks could be responsible for the complaint of bad odor in the community.

2. Materials and methods

The present research was conducted in an oil refinery located in the Rio Grande do Sul State, Brazil. The oil refinery process 32,000 m^3 of crude oil per day in a total area of 5.8 square kilometers in order to supply the regional market. The main produced products are diesel fuel, gasoline, gas, fuel oils, aviation fuel, solvents, asphalt, coke, sulfur and propene.
All measurements were performed out from 11/18/19 to 12/02/19, at 53 points at ground level inside the refinery. The position of some of these points were chosen to cover the immediate surroundings of emissions sources. Additionally, other points were set at locations with a perceptible odor verified by the field team. In these cases, the sensors were mounted 1.5 meters from the ground on a tripod (Figure 1). Additionally, measurements were made at the stacks (SRU and flares), over the wastewater treatment lagoon and at the breathing of the storage tanks. A drone (quadricopter) was assembled to bring the monitoring sensors at these particular spots. A support was built to hold the sensors, which was tied to the drone with a string of approximately 4 meters. This distance was defined so that the movement of the drone propellers had no interference in the outcomes of the measurements (Figure 2).
Measurements were performed in the following process areas: Hydrotreating (HDT), SRU, acidic water and waste tanks, oil-water separator, wastewater treatment and flares. All measurements were carried out using Cairsens (ENVEA) electrochemical sensors, which provide automatic and continuous recordings of gases concentration. This equipment records the measurements in ppb (part per billion) every minute. The Cairsens are calibrated in the ENVEA's metrological laboratory using AQMS certified monitors of reference, with an expiry period of one year. These sensors measure close to or below the odor threshold value of the gases evaluated. All four sensors used in the field campaign are listed in Table 1.

Table 1: Electrochemical sensors

Measured Parameter	Range (ppb)	Certified Detection Limit (ppb)	Resolution (ppb)	Measurement Uncertainty
H_2S/CH_4S	0 – 1,000	10	1	± 30 %
NH_3	0 – 25,000	500	1	± 30 %
nmVOC	0 – 16,000	500	1	± 30 %
SO_2	0 – 1,000	50	1	± 25 %

The monitoring data were stored every minute. Ground-level points were measured for at least 30 minutes, while at the stacks, it was about 15 minutes long using the drone at each location.

Figure 1: Ground measurement station and monitoring sensors

Figure 2: Unmanned air vehicle (quadricopter drone) used to take the monitoring sensors close to stack SRU, aerated lagoon and Flare

3. Results and discussion

3.1 Ground level measurements

The odorous gases emitted in the industrial process are from both fugitive and point (stacks) sources. In such conditions, it is not possible to measure the individual contribution of each source as their emissions overlap each other. The results of the monitored maximum values of H_2S/CH_4S, NH_3, COVs and SO_2 were interpolated using a squared distance weighting average to obtain a better outlook and overlap the aerial image of the study area. The data used in the interpolation was the one minute highest concentration from each monitored location considering only ground level measurements. Each location was measured for 30 minutes at least twice and in different weather conditions. Therefore, the chosen maximum value is representative and the results presented next show the worst odor pollution condition.

All NH_3 measurements were below the odor perception limit of 1,580 ppb (Nagata, 2003), for this reason, the interpolation map has not been displayed.

The maximum values monitored of H_2S/CH_4S are located at wastewater treatment, where the highest concentrations were at the raw effluent (point 12) and at the float (point 13). The emission in this process is practically constant in an open area and without a treatment system. Depending on the weather conditions, this odor can spread outside the company land.

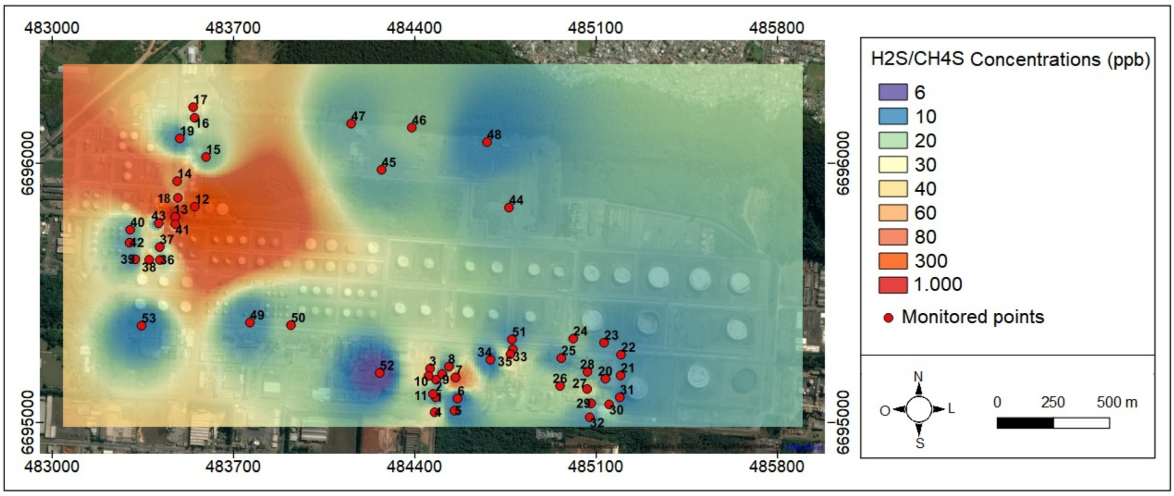

Figure 3: Map of H_2S/CH_4S interpolation of concentrations (in ppb) ground measured only. Red dots show the monitored spots

VOCs' highest concentrations were in the wastewater treatment, primarily at the raw effluent, float and around the lagoon. Near to the merox process (point 7) there was also a high concentration of VOCs with a noticeable odor evaluated by the field team. In addition, the oil-water separator (point 36 and 38) had a continuous emission of VOCs and a strong odor perceived by the field team as well. As this facility is an open space with no emission control, the odor can travel to other areas and outside the company, according to meteorological conditions.

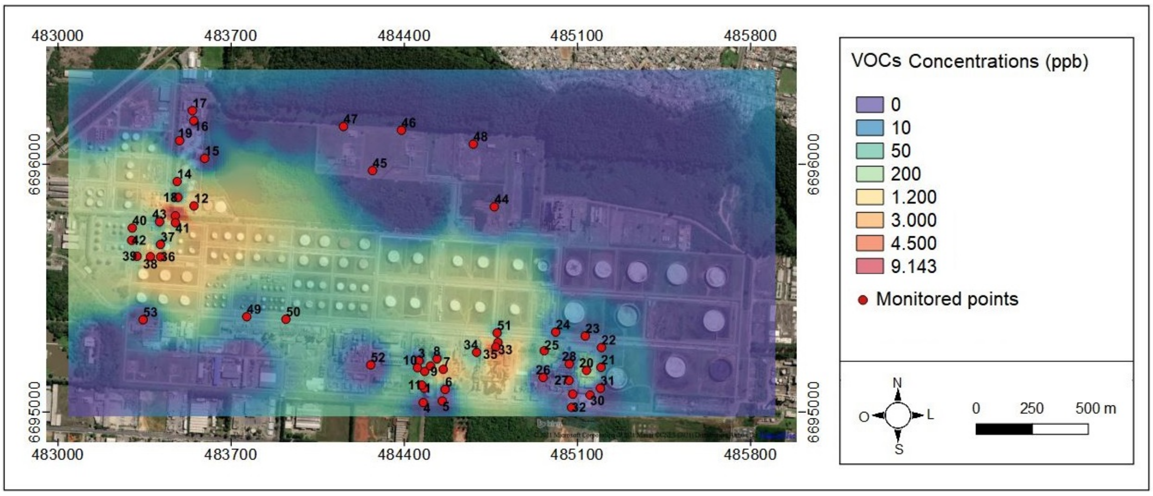

Figure 4: Map of VOCs interpolation of concentrations (in ppb) ground measured only. Red dots show the monitored spots

The SO_2 gas was present in all areas of the refinery uninterruptedly. However, only one monitored value was above the odor perception limit of 870 ppb (Nagata, 2003). Depending on weather conditions or atypical emission conditions, peaks with high concentration and short duration inside the plant may occur, such as the maximum value of 1,000 ppb identified in point 27, located in the SRU.

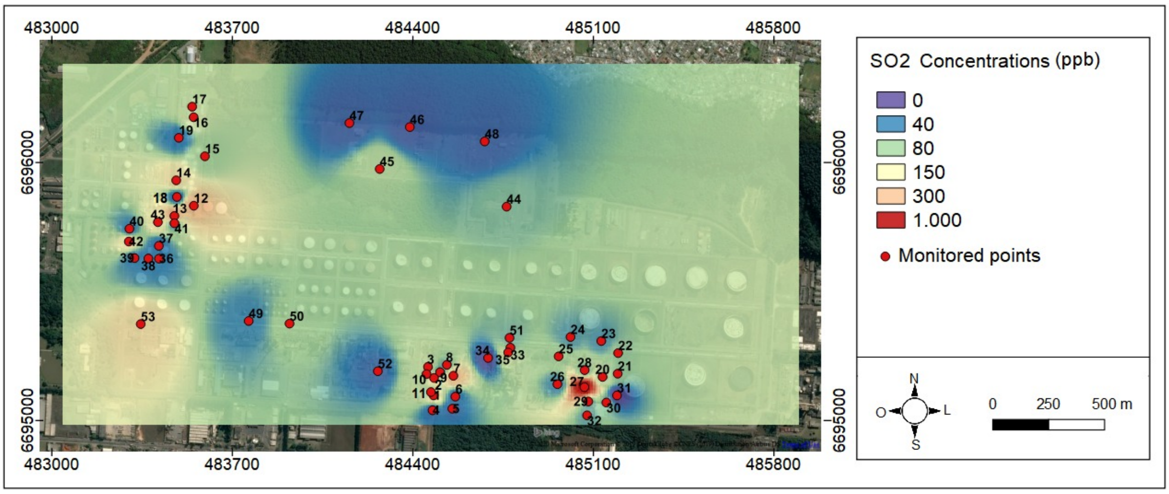

Figure 5: Map of SO_2 concentration interpolation of concentrations (in ppb) ground measured only. Red dots show the monitored spots

3.2 Measurements with the drone

The drone measurements carried out near the stacks showed that these sources are potential emitters of a substantial concentration of stinking gases, most especially H_2S, CH_4S and SO_2, which can raise a concern by the community around the refinery. Nevertheless, the measurements on the flares (Figure 6) indicate a significant variation in the emissions, as some records present high concentrations of SO_2 and low of H_2S/CH_4S, while the opposite situation was observed on another day. It was also evident the lower emissions in Flare 1 compared to Flares 2 and 3. For safety reasons, measurements were made close to the height of the flame, but approximately 70 meters distant from it. Even these far, significant concentrations of gases were detected, which may be higher at atypical moments in the process. These sources (flares) can be characterized as having a great potential to cause odor in the surroundings, because, due to the height of the flare and the emitted concentration, the odor can travel for a few kilometers.

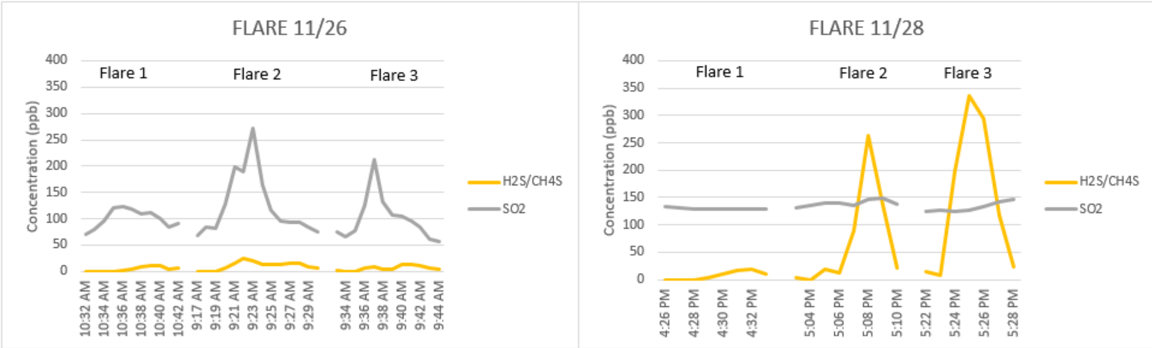

Figure 6: Measurements on Flares

The measurements near the SRU stack (Figure 7) show the highest concentrations of SO_2 and H_2S/CH_4S emitted by this process. The maximum value recorded for both gases was 1,000 ppb, the upper limit of the sensors. Even measuring at a distance of approximately 50 meters from the stack gas outlet, concentrations were high, indicating that H_2S/CH_4S emissions can spread to the community. As the odor perception threshold is low, within the range of 30 to 50 ppb in outdoor environments (Collins and Lewis, 2000), such intense emission can lead to bad odor events depending on weather conditions.

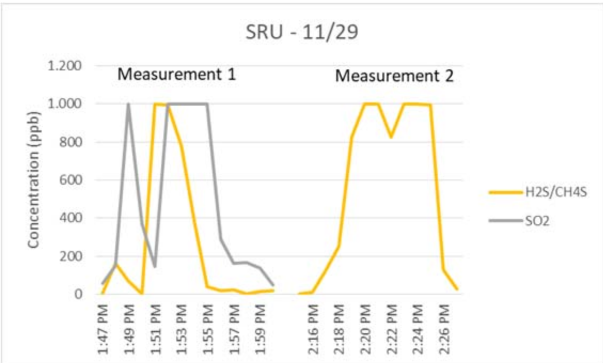

Figure 7: Measurements on SRU

4. Conclusion

The main processes that emit odorous gases have been characterized to obtain the “fingerprint” of each sector. This is essential to correlate whether the odorous gases identified in the community have the same characteristic as the company's emission sources.

Those measurements carried out at ground level around the oil-water separator and the wastewater treatment showed a continuous emission of odor gases. These emissions occur in an open and uncontrolled location, also, close to the boundary of the industrial plant. For this reason, such sources have the potential to cause a bad odor in the vicinity of the refinery. The emission from the oil-water separator is only of VOCs, while for the wastewater treatment the emission is a composition of VOCs and H_2S/CH_4S, mainly at the beginning of the effluent treatment.

Drone measurements showed that the stack of the SRU and the Flares are the main sources of H_2S/CH_4S and SO_2. Due to the characteristics of these sources and the low odor threshold this gases, when they are emitting significant amounts of odoriferous gases, they can spread to the surroundings of the refinery and cause discomfort in the community, or even being noticed in a few kilometers away.

The drone made it possible to carry out measurements in places of difficult access or without any previous access. Such measurements, like those in the middle of the wastewater treatment pond and at the top of the flares, were recorded for the first time. Moreover, the UAVs can be used to assess emissions in critical odor episodes and also during periods of adjustment in the process. A disadvantage of this method is the flight autonomy of drones, which reduce with an increase in the number of sensors, the limitation of the range of sensors and diversity of gas.

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