BioOne COMPLETE

Report of Particulate Matter Emissions During the 2015 Fire at Fuel Tanks in Santos, Brazil

Authors: Da Silva, Daniela Oliveira, Arôxa, Bruna Hayashida, Klausner, Virginia, De Brito Bastos, Eduardo Jorge, Prestes, Alan, et al.

Source: Air, Soil and Water Research, 13(1)

Published By: SAGE Publishing

URL: https://doi.org/10.1177/1178622120971251

BioOne Complete (complete.BioOne.org) is a full-text database of 200 subscribed and open-access titles in the biological, ecological, and environmental sciences published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Complete website, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/terms-of-use.

Usage of BioOne Complete content is strictly limited to personal, educational, and non - commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

Downloaded From: https://complete.bioone.org/journals/Air,-Soil-and-Water-Research on 28 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

Report of Particulate Matter Emissions During the 2015 Fire at Fuel Tanks in Santos, Brazil

Air, Soil and Water Research
Volume 13: 1–8
© The Author(s) 2020
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/1178622120971251

Daniela Oliveira da Silva[1], Bruna Hayashida Arôxa[1], Virginia Klausner[1], Eduardo Jorge de Brito Bastos[1], Alan Prestes[1] and Alessandra Abe Pacini[2]

[1]Laboratório de Registros Naturais, Instituto de Pesquisa e Desenvolvimento (IP&D), Universidade do Vale do Paraíba (UNIVAP), São José dos Campos, São Paulo, BRA. [2]InSpace LLC, Hamburg, NY 14075, USA.

ABSTRACT: We report a study of the particulate matter emissions related to the 2015 fire outbreak at a fuel tank storage facility located at Santos, a coastal city in Brazil. The facility, managed by the company Ultracargo, had oil tanks (filled with gasoline and ethanol) destroyed by fire that lasted more than a week, between 2nd and 9th April. In this article, we present the atmospheric concentration analysis of particulate matter (PM_{10}) measured over the entire month of April 2015 by the 2 closest stations that integrate the air quality monitoring system of the São Paulo State Environmental Company (CETESB). The results were compared with similar data from the same period of the yesteryear (April 2014). The results were also complemented by the air masses trajectories over the region (obtained with HYSPLIT/NOAA software). Our results do indicate a subtle increase in the particulate concentration during the days of the fire, followed by a fast dissipation over the subsequent weeks. The observed plume dispersion discussion is made considering the meteorological patterns of the region and other environmental and health reported impacts related to the accident.

KEYWORDS: Air pollution, environmental pollutants, fire effects, particulate matter, PM_{10}

RECEIVED: June 17, 2020. **ACCEPTED:** October 8, 2020.

TYPE: Original Research

FUNDING: The author(s) received no financial support for the research, authorship, and/or publication of this article.

DECLARATION OF CONFLICTING INTERESTS: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

CORRESPONDING AUTHOR: Daniela Oliveira da Silva, Laboratório de Registros Naturais, Instituto de Pesquisa e Desenvolvimento (IP&D), Universidade do Vale do Paraíba (UNIVAP), Avenida Shishima Hifumi, 2911, Urbanova, São José dos Campos, São Paulo, ZIP: 12244-390, BRA. Email: fys.dani@gmail.com

Introduction

Fire was reported in 6 fuel tanks at the facility near the port of Santos, belonging to Ultracargo company. The fire started on the morning of April 2, 2015, and it was considered controlled on April 9, 2015. A photo/picture of the fire is shown in Figure 1. The tanks contained gasoline and ethanol exclusively.[2]

The Ultracargo company, part of the Brazilian multinational business group Ultrapar, operates in the liquid bulk distribution and storage segment. The company has 7 terminals installed in Brazil in the cities of Itaqui (MA), Suape (PE), Aratu (BA), Rio de Janeiro (RJ), Santos (SP), Paulínia (SP), and Paranaguá (PR), besides the head office in São Paulo (SP). The region where the Santos (SP) terminal is located, known as Baixada Santista, has a history of environmental problems, with the primary sources of pollution being the industries located in and around the city. These industries are responsible for the untreated sewage that is discharged into the water bodies. Santos is a strategic city for the country, as its port located connects all the productive regions of the Paulista plateau to the world. The Santos Terminal (Figure 2), which has an area of 183 871 m^2, handles fuels, corrosives, chemicals, lubricating oils, and vegetables in 179 tanks with capacities ranging from 100 to 10 000 m^2.[3] As reported on a Brazilian notice website,[4] CETESB stated that this was the second largest fire of its kind in Brazil.

On the authority of the Federal Public Ministry, the fire was caused by an operational error in the suction and discharge pipes, which operated closed, causing a valve to explode.[4]

The apparent consequences of burning fossil fuel, such as fuels, include the possible contamination of plants and animals for up to 5 years, and the occurrence of acid rains in the affected areas. The areas affected by the released pollutants may take up to 10 years to recover.[5] Among the immediate environmental impacts observed during the period of the fires, the press reported mangrove pollution along the Port of Santos. Also, strong smell of fuel was detected in the vicinity, black marks, and soot coming from the Ultracargo yard were observed on cars, buildings, and even on residents. These by-products of the fires can be harmful to the health of residents especially those with previous respiratory diseases and can also cause constant headaches.

Moreover, the water used to extinguish the fires flowed into the nearby lake and mangroves, contaminating these environments, explaining the death of thousands of fish due to low oxygen and increased water temperature. The burning of hydrocarbons and subsequent reaction with water favor the occurrence of acid rain in the region, besides the increasing risks of the direct inhalation of particulate matter (PM_{10}) released by fire into the population, causing or worsening of respiratory diseases.[5]

The Ultracargo company was fined by CETESB on April 14, 2015: R$22 500 000.00 for putting the population at risk and causing environmental damage. By articles 61 and 62 of the federal decree 6514/08, which regulates the Brazilian Environmental Crimes Law (Law 9.605/98), the company had to fulfill some requirements, ie, Review its Emergency Action

Creative Commons Non Commercial CC BY-NC: This article is distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 License (https://creativecommons.org/licenses/by-nc/4.0/) which permits non-commercial use, reproduction and distribution of the work without further permission provided the original work is attributed as specified on the SAGE and Open Access pages (https://us.sagepub.com/en-us/nam/open-access-at-sage).

Downloaded From: https://complete.bioone.org/journals/Air,-Soil-and-Water-Research on 28 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

Plan and Risk Management Plan.[6] The company had to submit a Plan for the Removal of Waste generated by the fire, to start a new process to obtain Environmental Licensing under the current legislation, to replace, adapt, or renovate the collapsed facilities and equipment (tanks). In addition, within 30 days following the fire, it had to monitor the surface waters of the Santos estuary and the lagoon at the terminal, and the surrounding vegetation, including the impacted mangroves, adopting the necessary measures for their recovery.[6] In addition, the Ultracargo company had to hire a company to undertake emergency rescue of aquatic and terrestrial wildlife and to monitor all fauna groups directly or indirectly affected by the fire.[6]

The CETESB reported in a statement on April 15, 2015 that the company was fined for discharging liquid effluents into the Santos estuary, mangroves, and the lagoon next to the terminal; for emitting gaseous effluents into the atmosphere; and for endangering the safety of communities and employees, and other facilities located in the same industrial zone. It also caused significant disruption to the well-being of the population and the deaths of thousands of fish (more than 8.5 tons) of various species in the estuary and the Casqueiro river, in Cubatão (SP), which impaired fishing activity. The Ultracargo company was accused of a possible crime of procedural fraud, as the evidence would have been altered, on the report of the State Public Ministry.[4]



Figure 1. Image of the fire in the gas tanks at Ultarcargo.
Source: Globo.[1]

In 2019, 4 years after the fires, representatives of the Federal Public Prosecutor, the State, and the company signed an agreement of R$67.3 million to partially offset the damages from the claim in May.[7] According to the São Paulo Public Ministry, R$28.7 million was to be spent on the payment of fishermen's financial compensation during the first year of fishing management. After, the amount of R$15.3 million would be used for the fishermen's infrastructure, and R$23.5 million for a professional training in terms of handling and conserving fish populations, on the awareness of preserving the environment, aquaculture, sustainability, entrepreneurship, and income alternatives. This amount of money was considered a partial compensation as the complete compensation was worth R$3 billion.[7] As an aggravating factor, there was also the interruption of the activities of other terminals in the region and truck traffic in the Port of Santos.[6]

As discussed by Haddad,[8] the region does not have favorable conditions for air pollutant/smoke dispersion, as there is an industrial pole on the slope of a high mountain, preventing the complete renewal of air. In this region, the smoke does not dissipate in the air because polluting particles do not float indefinitely. The gases react as soon as they encounter trees, and also humans and animals by entering their lungs or eyes. In the smoke released by the fires of Ultracargo's tanks, much fuel and little oxygen were detected, and according to Braga,[9] the black



Figure 2. Ultracargo location by satellite images.
Source: Google Earth.

Downloaded From: https://complete.bioone.org/journals/Air,-Soil-and-Water-Research on 28 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

color of the smoke meant incomplete combustion, becoming a 2-way pollutant containing solid or gaseous particles, generated by fuel evaporation.

It was found more than 120 pollutants generated by burning; the worst of them is particulate matter (PM) that can cause health damage. As discussed by Dockery et al,[10] particulate matter is one of the "most serious threats among all air pollutants to human health and well-being." Particulate matter PM_{10} can be released from the burning of fossil fuels and even certain types of mud, as in the case of the study of Red Mud accident in Hungary.[11]

As stated by CETESB,[12] particulate matter includes solid particles or droplets suspended in a gaseous medium. The particulates are the most prominent forms of pollution as they reduce visibility and cause dirt deposits on windows, painted surfaces, and fabrics. Inhalable coarse particles are categorized into particles with size between 2.5 and 10 µm. The latter are known as PM_{10} typically found near roads or other sources of visible dust. Epidemiological studies show that cities with high chronic particulate levels have high mortality rates, mostly caused by heart and lung disease. Part of these health risk comes from the particles themselves blocking tiny air passages and causing difficulty in breathing.

This article presents a report of the atmospheric concentration of PM_{10} over April 2015 to determine the impacts in the Ultracargo's tanks fires in Santos city. A similar report is done for April 2014, and the results are compared.

Local Air Quality Standards

Brazilian air quality legislation, such as the Brazilian National Air Quality Standards (NAQS), is very similar to the United States (US) law. The NAQS specifies the maximum allowable level for air pollutants, and the maximum concentration of a pollutant is specified according to an average period. The time risk factor is divided into (1) primary, which dictates the adequate safety margin to protect children, the elderly and people with respiratory problems, and (2) secondary, which takes into account damage to agriculture and climate change.[9]

The Brazilian law responsible for air quality standards is Resolution 3 of June 28, 1990, which is determined by the National Council for the Environment (*Conselho Nacional do Meio Ambiente* [CONAMA]). This law states the safety and well-being of the population, and the damage allowed to flora and fauna, materials, and the environment in general. As stated by CONAMA,[13] an air pollutant is any form of matter or energy with intensity, quantity, concentration, or characteristics that is not under the established levels, making the air

1. Inappropriate, harmful or offensive to health;
2. Inconvenient to the public welfare;
3. Detrimental to materials, fauna, and flora;
4. Harmful to the safety, use, and enjoyment of the property and normal community activities.

In CONAMA,[13] Resolution 3, Article 2 establishes the concepts of the following:

1. Primary Air Quality Standards, which is defined by pollutant concentrations that, if exceeded, may affect the health of the population;
2. Secondary Air Quality Standards, which are pollutant concentrations below the minimum adverse effect on the well-being of the population, as well as minimal damage to fauna, flora, materials, and the environment in general.

In Brazil, the primary standard for the annual average of total suspended particles is 80 µg/m^3 of air. The maximum daily concentration is 240 µg/m^3 of air, and this value may be exceeded at most once per year. The secondary standard establishes the geometric annual mean concentration and the maximum daily concentration of 60 and 150 µg/m^3, respectively.[13] In Table 1, the maximum concentrations for 7 air pollutants, particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), monoxide carbon (CO), smoke and inhalable particles, are shown. The air quality index informed by CETESB[14] is calculated using the 5-level classification: "Good" (<40), "Moderate" (41-80), "Inadequate/unhealthy" (81-120), "Very unhealthy" (121-200), and "Hazardous" (>200), see Table 2.

Table 3 presents the relationship between air quality index structure and human health effects. CETESB[14] reports that each pollutant has a different effect on human health. However, the date of the pollutant's release must be considered. For example, suppose a monitoring station can evaluate all pollutants reported in Table 2, then the quality classification at this particular station will be determined by the highest index found, regardless of the pollutant.

In CONAMA,[13] Resolution 3, Article 5 states that the air quality monitoring of municipalities is the State's responsibility. The air quality levels were established for the elaboration of the Prevention of Air Pollution Emergency Episodes, aiming at measures taken by governments and municipalities, as well as by private entities and the general community, to prevent health risks to the population. The presence of high pollutant concentrations in the atmosphere in a short period can be considered a critical episode, demonstrating the importance of this article, which reports the high concentrations of particulate matter emissions (PM_{10}) during the few days of fire.

Dataset and Methodology

This study uses data obtained in Santos—SP, 72 km from the capital São Paulo. The company Ultracargo is located at Santos, near to its port, one of the largest in Latin America. The hourly data on particulate matter (PM_{10}) for April 2014 and 2015 were downloaded in the CETESB website (https://servicos.cetesb.sp.gov.br/qa/). The data for the stations of Cubatão—Centro and Santos—Ponta da Praia were obtained. These 2

Downloaded From: https://complete.bioone.org/journals/Air,-Soil-and-Water-Research on 28 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

Table 1. Air quality standards in Brazil.

POLLUTANTS	AVERAGE TIME	PRIMARY STANDARD (μG/M³)	SECONDARY STANDARD (μG/M³)
PM	24 hours[a]	240	150
	GM annual	80	60
O_3	1 hour[a]	160	160
NO_2	AM annual	100	100
SO_2	24 hours[a]	365	100
	AM annual	80	40
CO	1 hours[a]	40.000	40.000
	8 hours[a]	10	10
Smoke	24 hours[a]	150	100
	AM annual	60	40
Inhalable particles (<10 μm)	24 hours[a]	150	150
	1 hour[a]	320	190

Source: Adapted from CONAMA.[13]
Abbreviations: AM, arithmetic mean; CONAMA, Conselho Nacional do Meio Ambiente; GM, geometric mean.
[a]Cannot be exceeded more than once a year.

Table 2. Air quality index structure.

	INDEX	PM_{10} (μG/M³) 24 HOURS	$PM_{2.5}$ (μG/M³) 24 HOURS	O_3 (μG/M³) 8 HOURS	CO (μG/M³) 8 HOURS	NO_2 (μG/M³) 1 HOUR	SO_2 (μG/M³) 24 HOURS
N1	0-40	0-50	0-25	0-100	0-9	0-200	0-20
N2	41-80	>50-100	>25-50	>100-130	>9-11	>200-240	>20-40
N3	81-120	>100-150	>50-75	>130-160	>11-13	>240-320	>40-365
N4	121-200	>150-250	>75-125	>160-200	>13-15	>320-1130	>65-800
N5	>200	>250	>125	>200	>15	>1130	>800

Source: Adapted from CONAMA.[13]
Abbreviations: CONAMA, Conselho Nacional do Meio Ambiente; N1, good; N2, moderate; N3, inadequate; N4, very unhealthy; N5, hazardous.

Table 3. Air quality with and health effects.

	INDEX	MEANING
N1	0-40	The population is not affected.
N2	41-80	People in sensitive groups (children, elderly citizens, and people with respiratory and heart disease) may experience symptoms such as dry cough and tiredness. The population, in general, is not affected.
N3	81-120	The entire population may experience symptoms such as dry cough, tiredness, burning eyes, nose, and throat. People from sensitive groups (children, elderly citizens, and people with respiratory and heart disease) can have more severe health effects.
N4	121-200	The entire population may experience worsening symptoms such as dry cough, tiredness, burning eyes, nose and throat, and shortness of breath and wheezing. These effects are even more severe in the health of sensitive groups.
N5	>200	The entire population may present serious risks of respiratory and cardiovascular diseases. Increase in premature deaths in people from sensitive groups.

Source: Adapted from—CONAMA.[13]
Abbreviations: CONAMA, Conselho Nacional do Meio Ambiente; N1, good; N2, moderate; N3, inadequate; N4, very unhealthy; N5, hazardous.

Downloaded From: https://complete.bioone.org/journals/Air,-Soil-and-Water-Research on 28 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use



Figure 3. Satellite view of the location of CETESB stations and the location of the fires.
Source: Google Earth.

stations were chosen for their locations, to make comparisons between the location of the fire, the station toward the mainland, Cubatão—Centro Monitoring Station, 23k 355640 7358433, and the other toward the coast, Santos Monitoring Station, 23k 367697 7347234, as shown in Figure 3. The PM_{10} values are monitored in $\mu g/m^3$ and data are acquired hourly.

For better visualization of Cubatão and Santos stations' results, a graph was plotted for each station using hourly resolution data for April 2014 (blue color) and 2015 (red color), see Figure 5A and B, respectively. Furthermore, we calculated the daily averages and plotted them, as shown in Figure 6. Also, the limit of 50 $\mu g/m^3$ for "Good" is drawn as green line, for each studied location as a guideline for good air quality (see Table 2).

The Google Earth Pro software was employed to visualize, using satellite images to observe the fire location, to choose the best stations available for our analysis—Cubatão and Santos. The predominance of wind from the fire and the trend of the possible plume from the fire were determined by the 2014 Santos Air Quality Report prepared by CETESB.

The Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) software was used to generate and identify all plume trajectories from the fires in Santos on April 2 and April 9, 2015 and to show the direction and altitude of each generated plume (see Figure 4). The HYSPLIT software uses archived meteorological data from the National Center for Environmental (NCEP).

Analysis and Results

In Figure 4, each line represents a plume and its trajectory, with direction into the ocean. Also, each plume reaches to a specific height. From April 3 to 6, the plumes reached a height of 500 m. On 7th and 8th, the plumes rose above 1000 m, and on 9th, it descended to 500 m. Figure 4 clearly shows that almost all plumes generated by the tanks' fires have directions toward the ocean, instead of the city.

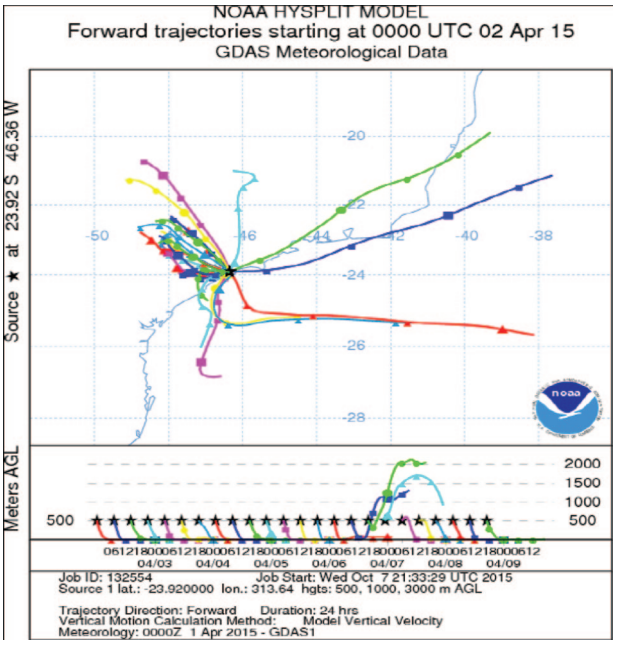


Figure 4. Plumes generated during the days of the fire.
Source: HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory).

The air pollutant in each area depends on the type of source and the released concentration, as well as the dispersal conditions in the atmosphere. The pollutant dispersion varies depending on the characteristics of the environment, including natural or human-made conditions. As claimed by Mota,[15] it is not easy to establish a direct relationship between a given pollutant and its effects on the environment, as the dispersion of the pollutant in the air, the distance reached, the concentration, and the time exposure are the variables that influence the impacts it may have.

The higher the wind speed, the higher is its ability to dilute and disperse pollutants. One of the most critical meteorological characteristics in air pollutant dispersion is atmospheric

Downloaded From: https://complete.bioone.org/journals/Air,-Soil-and-Water-Research on 28 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

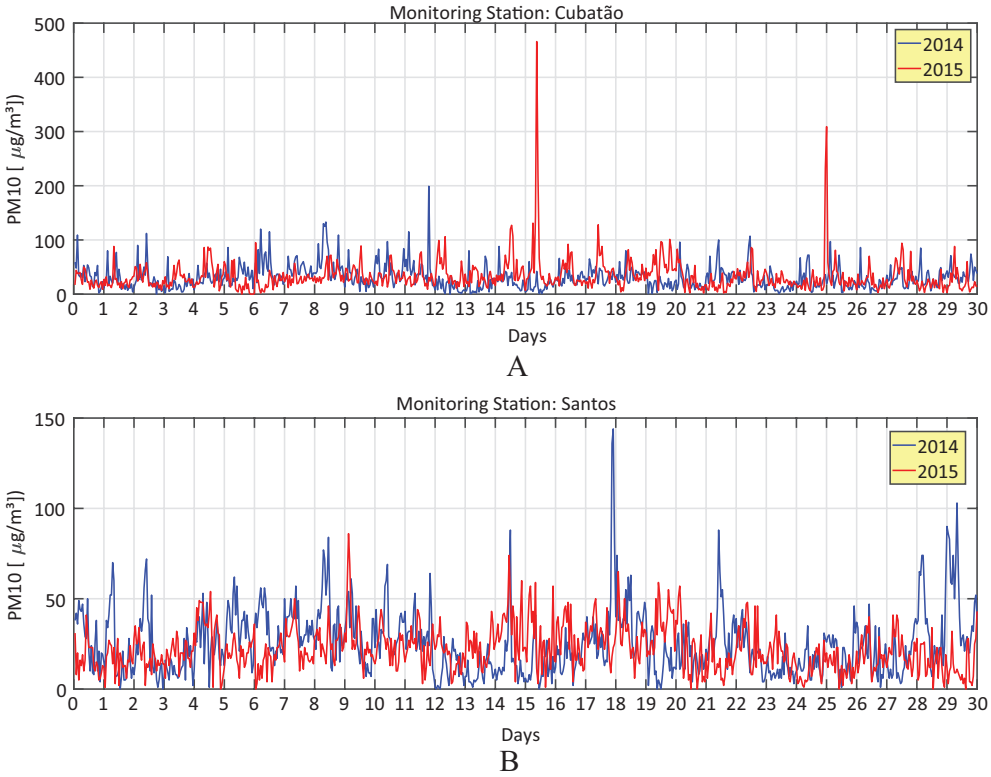


Figure 5. PM_{10} emissions during April 2014 and 2015 monitored at (A) Cubatão and (B) Santos stations.

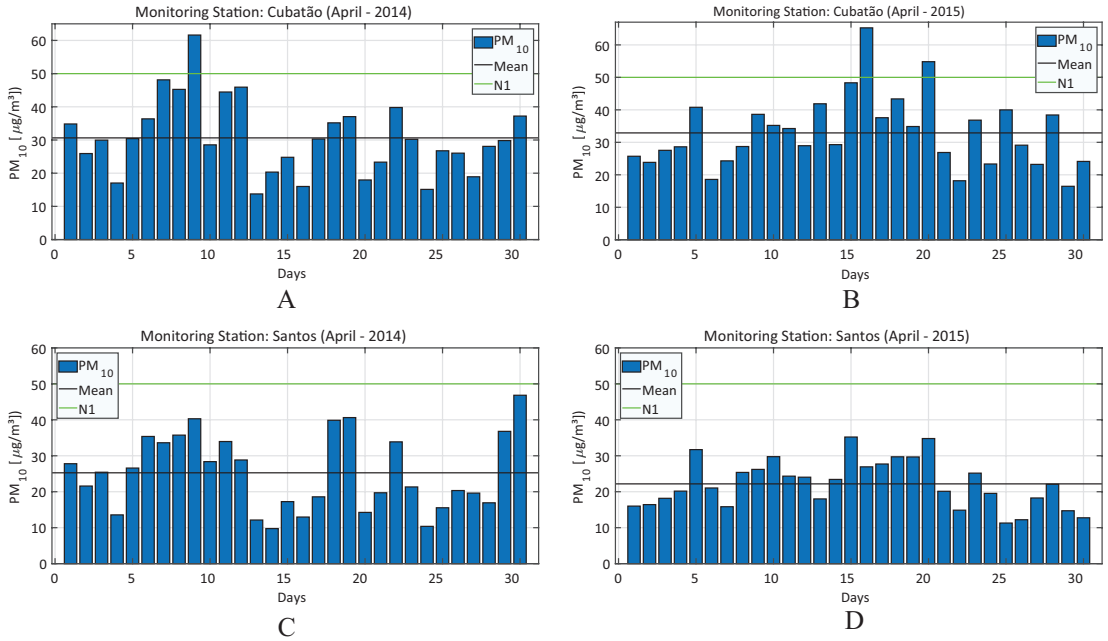


Figure 6. Graphs of PM_{10} emissions monitored at Cubatão and Santos in 2014 and 2015. Figure A corresponds to the PM10 values at the Cubatão station during April 2014. Figure B corresponds to the PM10 values at the Cubatão station during April 2015. Figure C corresponds to the PM10 values at the Santos station during April 2014. Figure D corresponds to the PM10 values at the Santos station during April 2015.

stability, associated with upward and downward movements of air volumes.[16,17] In Figure 4, we see that the plumes generated had different directions. This could be because of the existence of atmospheric instabilities (occurs in the troposphere) observed on the days of the fires, creating winds with the speeds needed to disperse the pollutants. As pollutants need wind speed to disperse, this could account for why there was no fixed direction of the plumes on the days of the fire.

Shie and Chan[18] conducted a study of pollutants emitted by a fire at a refinery in Taiwan. Also, Shie and Chan[18] showed that air monitors used by most regulatory authorities (which are designed to track daily emissions of conventional pollutants) are not suitable for measuring hazardous pollutants that are released in these types of accidents. The use of more sensitive equipment during and after the fire events would be much more effective. However, obtaining the equipment can be

Downloaded From: https://complete.bioone.org/journals/Air,-Soil-and-Water-Research on 28 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

impracticable, and the logistics to reach the site can also be complicated, as in the case of Santos city, the highways were closed due to the fire. So, it is essential to evaluate the data made available by the responsible entities to have a measure of the consequences in the atmosphere and possible damage to human health after the fact. And while not being ideal, the data analyzed here showed an increase in the value of PM_{10} at Cubatão station as we will present next.

Figure 5 indicates that the PM_{10} concentration remained below 50 μg/m^3 on almost every day of April in the 2 years analyzed, characterizing good air quality by CETESB index. In Figure 5A, 2 significant peaks stand out on separate days of April 2015, related to the days when air quality hits their lousiest rate. Similarly, Figure 5B indicates that the 2 analyzed month had most of the measured particulate matter concentrations below 50 μg/m^3, except for 1 day in 2014. Therefore, the air quality was considered regular to good. It is important to note that car traffic and the port area of Santos may have contributed to the increased PM_{10} values on that day. These activities are a major cause of inhalable particles in the atmosphere, as described by Choi and Myong[19] in South Korea. Nevertheless, the focus of our work is to assess the peaks during and on the days following the fires.

In Figure 6A and B, there is an increase in the concentration of PM_{10} above the limit of the N1 level. For 2014, this fact is probably due to the large industrial cluster in Cubatão city. In April 2015, we observed that the peak is in transition from the day 15 to 16. It may be explained by the distance from the fires and Cubatão station. Consequently, the concentration of pollutants resulting from the fires took a few days to be registered in Cubatão monitoring center. This fact may be also explained by the plumes with directions into the continent, see Figure 4.

However, Santos' air quality for April 2014 and 2015 was considered regular to good, as shown in Figure 6C and D. In this case, there was no significant variation in particulate matter concentration values at the Santos monitoring station resulting from the fires.

It is important to mention that CETESB, in its notes, disclosed that there was a zone of atmospheric instability in the region of fires, that is, the thermal profile was superadiabatic, generating turbulence in the atmosphere. According to Braga,[9] these types of thermal turbulences cause large eddies, which could quickly disperse the pollution clouds, leading to pollution of places near the source, characterizing the plume as a looping plume. Analyzing the 2014 Wind Rose for the Santos region (Figure 7), it can be observed that the predominance of the wind comes from the South-Southwest direction, which would lead the pollutants toward the Santos estuary and would prevent them from reaching the municipality of São Vicente. The same wind profile is for 2015.

There was atmospheric instability, and the eddies caused the pollution to be distributed near the tanks, reaching the municipality of Santos and especially the areas surrounding the Ultragargo company. In addition, there was precipitation during the days of the fire, so the airborne pollutant particles were

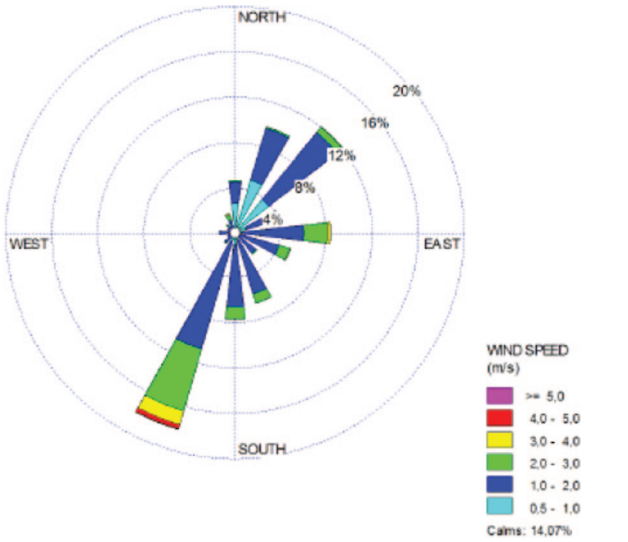


Figure 7. Santos wind rose—Ponta da praia—2014—24 hours.
Source: Santos City Air Quality Assessment Report from 2011 to 2014, CETESB.

sedimented. According to the results from atmospheric instability and the parameters established by CONAMA,[13] it was confirmed that the release of pollutants did not reach a considerable levels of pollution as our results showed.

Mota[15] states that pollution results from the release into an environment, matter, or energy, in such quantities or intensities as to impact negatively the quality and even the existence of life that it normally shelters, or harm them. This may not just be restricted to the occurrence of diseases (for example, respiratory diseases) in humans but also in animals and plants. Any change in an environment (air, water, soil) that results in damage to living organisms or undermines a predefined use for them is considered pollution. As discussed by Mota,[15] pollution and contamination must be distinguished. An environment is contaminated when its state of pollution can cause human disease; however, pollution, in the broadest sense, does not mean risks of disease transmission.

The study of possible damage to health is vital in cases of accidents like this. Hoek et al[20] conducted a population health damage study due to a fire at an oil depot in Hertfordshire, UK. This type of assessment was one of the goals of our article, but we did not obtain permission to obtain hospital data for the region at the time of the fire.

Conclusions

According to the data analyzed and the comparison between the monitored values of particulate matter in April 2014 and 2015, the plume generated by the fire in Ultracargo's tanks did not have a specific direction due to the whirlwinds caused by atmospheric instability in the region. At the time of the fire, it reaches great heights, and along with the whirlwinds, helped in the dispersion of the pollutants (even though the region is not historically prone to dispersion).

The results obtained in our study show no significant change in the average values of particulate matter in Santos station,

Downloaded From: https://complete.bioone.org/journals/Air,-Soil-and-Water-Research on 28 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

proving that the plume was not concentrated in the fire region, and only dispersed in the place of origin. This may be explained by the fact that the plumes generated during the fire days had different directions; furthermore, atmospheric instability was also confirmed at the site. Moreover, there were soot in cars and other locations, and some complaints of respiratory problems were reported. However, no severe cases were registered.

Our results suggest that the release of air pollutants from the fire generated a slight increase in PM_{10} concentration during some days, especially around the April 15, 2015 in Cubatão Station. This fact may be explained by the distance between Cubatão station and the fire origin; in other words, it would take few days after the fire onset for the pollutant to be register at Cubatão.

Although, the levels of PM_{10} was considered normal by the legislation in force. It was expected that there would be no long-term health damage, but only the inconvenience caused on the days of tanks burning and peak concentration. There was environmental damage to the mangroves, which resulted in high fish mortality, affecting the quality of water, food, and the economy. The commercial centers close to the site had to be closed. Truck transportation was blocked for several days, leaving the truckers stationary and unproductive, which had an economical impact in the regions surrounding Santos.

The Ultracargo company should have had an emergency plan in case of any problems occurring with the fuel tanks, the absence of which, in this case, made it difficult to fight the fires promptly. Besides the incorrect methodology applied, the water used flowed into the nearby water bodies. The company in question should have had its mitigation plans updated as risk analysis must be done at the beginning of any project, even before its implementation; but unfortunately, this was not the case due to the lack of planning, leading to a disastrous outcome. The company has not yet concluded paying all the compensations. But most importantly, the damage caused by this accident was not very severe due to the rapid dispersion of the plumes.

In summary, it is crucial to monitor pollutant data, especially during an accident like this, as it helps to understand possible impacts to society. This analysis, plus the analysis of winds and dispersion of these pollutants, forces companies to have social and environmental responsibilities, as their activities directly affect people and animals close to the site and even beyond. This type of analysis is not restricted only to fires, but to various accidents involving air pollutants.

Author Contributions

All authors contributed equally to the development of this work, from the collection and organization of data to the analysis and interpretation, including creating the analysis graphs. DOdS and VK were responsible for implementing the reviewers' comments.

ORCID iD

Daniela Oliveira da Silva https://orcid.org/0000-0002-3851-3368

Data Availability

The PM_{10} data used in this study and from other monitoring stations can be accessed through the link: https://servicos.cetesb.sp.gov.br/qa/. It is necessary to choose which station and time period. The data are available in hourly data.

REFERENCES

1. Globo G. Laudo preliminar de empresa liga incêndio à morte de peixes em santos. http://g1.globo.com/sp/santos-regiao/noticia/2015/04/laudo-preliminar-da-cetesb-liga-incendio-morte-de-peixes-em-santos.html. Published 2015.
2. Ultracargo. Comunicados. http://www.ultracargo.com.br/br/a-ultracargo/destaques#id_2015. Published 2015.
3. Ultracargo. Localidades. http://www.ultracargo.com.br/br/localidades. Published 2012.
4. Globo G. Mpf denuncia ultracargo por poluição causada por incêndio que durou 8 dias. https://g1.globo.com/sp/santos-regiao/noticia/mpf-denuncia-ultracargo-por-poluicao-causada-por-incendio-que-durou-8-dias.ghtml. Published 2018.
5. Pereira CDO. Impactosambientais do maiorincêndio de sp, no terminal da ultracargo no porto de santos, podem durar 5 anos. http://caroldaemon.blogspot.com.br/2015/04/impactos-ambientais-do-maior-incendio.html. Published 2015.
6. CETESB. Cetesb multa ultracargo em mais de R$ 22 milhões pelo incêndio no terminal da alemoa. http://www.cetesb.sp.gov.br/noticia/. Published 2015.
7. Globo G. Acordo de R$ 67,3 mi para danos ambientais causados por incêndio em tanques é assinado em sp. https://g1.globo.com/sp/santos-regiao/noticia/2019/05/15/acordo-de-r-65-mi-para-danos-ambientais-causados-por-incendio-em-tanques-e-assinado-em-sp.ghtml. Published 2019.
8. Haddad F. "a fumaça vai cair em algum lugar," diz especialista em poluição atmosférica: Paulo saldiva diz que as pessoas que já têm doenças, respiratórias ou cardiovasculares, têm risco de adoecer. http://www.atribuna.com.br/noticias/noticias-detalhe/cidades/a-fumaca-vai-cair-em-algum-lugar-diz-especialista-em-poluicao-atmosferica/?cHash=6c44f619f56ef92f1769b054432ec103. Published 2015.
9. Braga B. *Introdução à Engenharia Ambiental: O Desafio do Desenvolvimento S9// ustentável*. São Paulo, Brazil: Pearson Prentice Hall; 2005.
10. Dockery DW, Cunningham J, Damokosh AI, et al. Health effects of acid aerosols on North American children: respiratory symptoms. *Environ Health Perspect*. 1996;104:500-505.
11. Gelencsé A, Kováts B, Turózci B, et al. The red mud accident in Ajka (Hungary): characterization and potential health effects of fugitive dust. *Environ Sci Technol*. 2011;45:1608-1615.
12. CETESB. Qualidade do Ar—Poluentes. https://cetesb.sp.gov.br/ar/poluentes/. Published 2020.
13. Conselho Nacional do Meio Ambiente (CONAMA). *Resolução 003/90*. Legislação Brasileira—Conselho Nacional de Meio Ambiente (CONAMA); 1990.
14. CETESB. Padrões de qualidade do ar. https://cetesb.sp.gov.br/ar/padroes-de-qualidade-do-ar/. Published 2015.
15. Mota S. *Introdução à Engenharia Ambiental*. 3rd ed. Rio de Janeiro, Brazil: Associação Brasileira de Engenharia Sanitarista e Ambiental (ABES); 2003.
16. He JJ, Yu Y, Xie YC, et al. Numerical model-based artificial neural network model and its application for quantifying impact factors of urban air quality. *Water Air Soil Pollut*. 2016;227:235.
17. Wang YQ, Zhang XY, Sun JY, Zhang XC, Che HZ, Li Y. Spatial and temporal variations of the concentrations of PM, PM and PM in China. *Atmos Chem Phys*. 2005;15:13585-13598.
18. Shie RH, Chan CC. Tracking hazardous air pollutants from a refinery fire by applying on-line and off-line air monitoring and back trajectory modeling. *J Hazard Mater*. 2013;261:72-82.
19. Choi H, Myong JP. Association between air pollution in the 2015 winter in South Korea and population size, car emissions, industrial activity, and fossil-fuel power plants: an ecological study. *Ann Occup Environ Med*. 2018;30:60.
20. Hoek MR, Bracebridge S, Oliver I. Health impact of the Buncefield oil depot fire, December 2005: study of accident and emergency case records. *J Public Health (Oxford)*. 2007;29:298-302.

Downloaded From: https://complete.bioone.org/journals/Air,-Soil-and-Water-Research on 28 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use