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ORIGINAL ARTICLE

Fires in sugarcane cultivation and associated respiratory diseases in a municipality in Pernambuco

Queimadas no cultivo da cana-de-açúcar e doenças respiratórias associadas em um município de Pernambuco

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ABSTRACT Sugarcane holds a central position in Brazilian agribusiness. Its pre-harvest burning has been a long-standing practice in Pernambuco, exacerbating public health issues. This ecological time-series study analyzed the relationship between regular sugarcane burning and hospitalizations for respiratory diseases in Escada, Pernambuco, Brazil. Hospitalization rates among children under five and adults over sixty were compared, along with correlations involving fire hotspots, particulate matter concentration (2.5 ×m), and relative air humidity in the studied municipalities. The annual evolution of private health plan beneficiaries in Escada was also examined. Data were systematized in a historical series from 2010 to 2019. Hospitalization rates in the case municipality were lower, with a statistically significant difference ($p < 0.005$) compared to the control group. No significant correlation was observed between hospitalizations and the monthly distribution of fire hotspots. However, a significant correlation was found between relative humidity and respiratory outcomes among older adults in the municipalities. The low hospitalization rates in the case municipality suggest potentially underreported cases, possibly linked to expanding private health plan coverage.

KEYWORDS Crop production. Saccharum. Air pollutants. Respiratory tract diseases.

RESUMO *A cana-de-açúcar ocupa posição central no agronegócio brasileiro. Sua queima prévia à colheita manual é prática secularmente conservada em Pernambuco, intensificando os problemas de saúde da população. Neste estudo ecológico de série temporal, analisou-se a relação entre a queima regular da cana-de-açúcar e as hospitalizações por agravos respiratórios no município de Escada-PE. Compararam-se as taxas de hospitalizações em menores de 5 e maiores de 60 anos de idade, bem como as correlações com as ocorrências de focos de calor, a concentração de material particulado de 2,5 micrômetros e a umidade relativa do ar nos municípios estudados. Também se analisou a evolução anual do número de beneficiários de planos privados de saúde em Escada. Os dados foram sistematizados em uma série histórica de 2010 a 2019. As taxas de hospitalizações no município-caso foram menores, com diferença estatística significativa ($p < 0,005$) quando comparada ao grupo controle. Não foi observada correlação estatística entre as hospitalizações e a distribuição mensal dos focos de calor. Verificou-se correlação significativa da umidade relativa do ar com os desfechos respiratórios na população idosa nos municípios. As baixas taxas de hospitalizações no município-caso sugerem subnotificação das ocorrências, podendo estar relacionadas à expansão da cobertura dos planos privados.*

PALAVRAS-CHAVE *Produção agrícola. Saccharum. Poluentes atmosféricos. Doenças respiratórias.*

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Introduction

The Pernambuco Zona da Mata region is characterized by an economy historically based on the sugarcane monoculture. This model drives the expansion of the planted area and production to meet the needs of the agro-export market, which incorporates new, hard technologies to increase productivity but preserves and escalates old conflicts, besides creating others that emerge as a reflection of the exploitation of the environment and the labor force of workers. It enslaved Black people for centuries, and after abolishing the slave regime, it continued to exploit less educated, poor Black people. In the sugarcane fields, this exploitation is manifested through degrading work, long working hours, low wages, payment-for-production, and other features that even refer to work analogous to slavery[1]. It is no wonder that the Zona da Mata has always been one of the most densely populated regions and has the most significant social inequality in Pernambuco[2,3].

Part of the archaic cultivation cycle consists of regularly burning sugarcane straw, with the justification of facilitating its harvest. This practice is still common in rural Brazil, which is justified by producers' argument that mechanized harvesting is difficult due to the rugged characteristics of the region's topography. In Pernambuco, the rugged terrain and low labor costs mean that the sugar and alcohol industry maintains the method of regular burning and manual harvesting to the detriment of mechanized harvesting[4,5].

Air pollution generated by biomass and sugarcane straw burning is associated with an increased prevalence of respiratory diseases in the population. Cases of pneumonia, asthma, bronchitis, and acute bronchiolitis are common[6,7], besides other symptoms such as dry cough, fatigue, and nose and throat irritation[8], especially in children and older adults, who are more susceptible to these illnesses[9,10]. Likewise, other characteristics, such as humidity, can act together with pollution and end up deteriorating respiratory conditions[10].

These problems can be aggravated in the Pernambuco Meridional Forest (PEMM) region because of the proximity of sugarcane plantations to urban areas, exposing a larger contingent of people due to a higher population density[1,3,11]. Escada is located in the PEMM, 60 kilometers from the state capital. Even before being elevated to the municipality category in 1854, it was prominent in the region's economy, especially at the end of the sugar cycle period, in the mid-18th century, when it was famous for its opulent sugar cane mills[2,12]. Currently, the municipality depends on industrial and agricultural activities. It is among the 25 largest economies and the 30 largest Gross Domestic Products per capita in Pernambuco[12].

Health indicators should reflect a population's health situation and support health surveillance actions, as they comprise summary measures that contain relevant information on specific attributes and dimensions of the health situation, in addition to the performance of the health system[13,14]. Therefore, the study of the influence of sugar and alcohol activity on these health indicators is an important feature to be considered when elaborating public health policies in the region to adapt the social needs of economic development and health protection[14].

Given the need to propose an analysis of the health harm by sugarcane agro-industrial activity so that measures can be adopted to strengthen the public health system in the territory, this study aims to analyze the relationship between the regular sugarcane biomass burning and hospitalizations for respiratory problems in the population of Escada, Pernambuco, Brazil.

Material and methods

This is an ecological, comparative epidemiological study of a time series from 2010 to 2019, with secondary data related to hospitalizations of the population in the age groups of children under 5 and older adults over 60, for causes selected from chapter X of the International Classification of Diseases and Related Health Problems (ICD-10)[15]: pneumonia, asthma, bronchitis, and acute bronchiolitis. Hospitalization rates were compared in case and control municipalities in a one-to-four ratio.

The age group breakdown was selected due to the greater vulnerability of children and older adults to air pollution-related respiratory diseases[16,17]. The study site selected for developing the research was Escada, Pernambuco, Brazil, since it stood out as one of the five territories with the largest sugarcane planted area in that state from 2016 to 2019, leading the ranking in 2016 and 2017[12]. The four control municipalities were selected per the following criteria.

Initially, all municipalities in Pernambuco with a Social Vulnerability Index (SVI) similar to the case municipality in 2010 were selected, accepting a variation of up to 0.1 points either way. We aimed to include municipalities with similar social, economic, and environmental vulnerability conditions. Subsequently, all municipalities that met at least one of the exclusion criteria adopted in the research were excluded, resulting in the selection of four municipalities as the control group.

The exclusion criteria adopted for the control municipalities were: a) registering at least one hectare of sugarcane planted area from 2010 to 2019; b) being a developed urban center or belonging to the Metropolitan Region of the capital, Recife; c) having a developed industrial hub; d) bordering an important sugarcane producer; e) being an agricultural, plastering, cement or clothing hub municipality. The municipalities of Cumaru, Itaíba, Paranatama, and Santa Terezinha were selected based on these criteria.

The nonparametric Mann-Whitney test was adopted for the statistical analysis of the temporal distribution of hospitalization rates related to respiratory diseases throughout the historical series for both age groups of the case and control groups, which is recommended for comparing independent samples, using the median as the measure that best represents the center of distribution throughout the historical series and assisting in the observation of values and their statistical equality or difference conditions[18].

In order to analyze the relationship between the number of hospitalizations for respiratory diseases and sugarcane straw burning, we cross-referenced monthly data collected from the Hospital Information System of the Unified Health System (SIH/DataSUS)[19] and data on hotspots obtained from the Burning Database (BDQueimadas)[20] of the National Institute for Space Research (INPE), in addition to air pollution data, indicated by the concentration of particulate matter of 2.5 micrometers ($PM_{2.5}$), and relative air humidity, which were obtained from the Integrated Environmental Services System (SISAM), also made available by INPE.

Furthermore, the annual evolution of the number of beneficiaries of private health plans in Escada, made available by the National Supplementary Health Agency (ANS), was correlated with the number of hospitalizations for respiratory diseases registered in SIH/DataSUS in the study period. We verified a possible association between the coverage of the private health network in the case municipality and the demand for hospitalizations in the local SUS network since the data analyzed in this article refer only to cases hospitalized in the public health system. The behavior of the variables was described using time

series graphs, and the association analysis was performed using Pearson correlation[21].

Considering that the study only used data obtained from secondary open-access sources, with no access to personal information or information that could expose the dignity of the people participating in the study, this research did not require the appreciation and approval of the Research Ethics Committee, as defined by Resolution Nº 510/2016 of the National Health Council (CNS) and the National Research Ethics Commission (CONEP)[22].

Results

Hospitalizations for respiratory diseases

In Escada, the rates of hospitalizations for respiratory diseases in the age groups under 5 and over 60 were lower than those observed in the control municipalities throughout the historical series. Using the Mann-Whitney U test, the comparative analysis revealed a statistically significant difference ($p < 0.005$) for both age groups, as shown in *table 1*.

Table 1. Nonparametric statistical analysis of monthly hospitalization rates for pneumonia, asthma, bronchitis and acute bronchiolitis, in the age groups under 5 and over 60 years old, in case and control municipalities, from 2010 to 2019

Groups	N	Mean score	Total score	Mann-Whitney U-test	Z	P-value	Percentiles		
								50	90
Case (< 5 years)	120	69.31	8318.0	1058.0	11.420	8.39^{-38}	0.195	0.973	2.999
Control (< 5 years)	120	171.68	20602.0				0.445	1.009	3.674
Case (> 60 years)	120	11.12	13454.0	44.0	13.306	9.93^{-66}	2.543	3.813	5.370
Control (> 60 years)	120	179.38	21526.0				5.173	6.956	9.328

Source: Prepared by the authors.

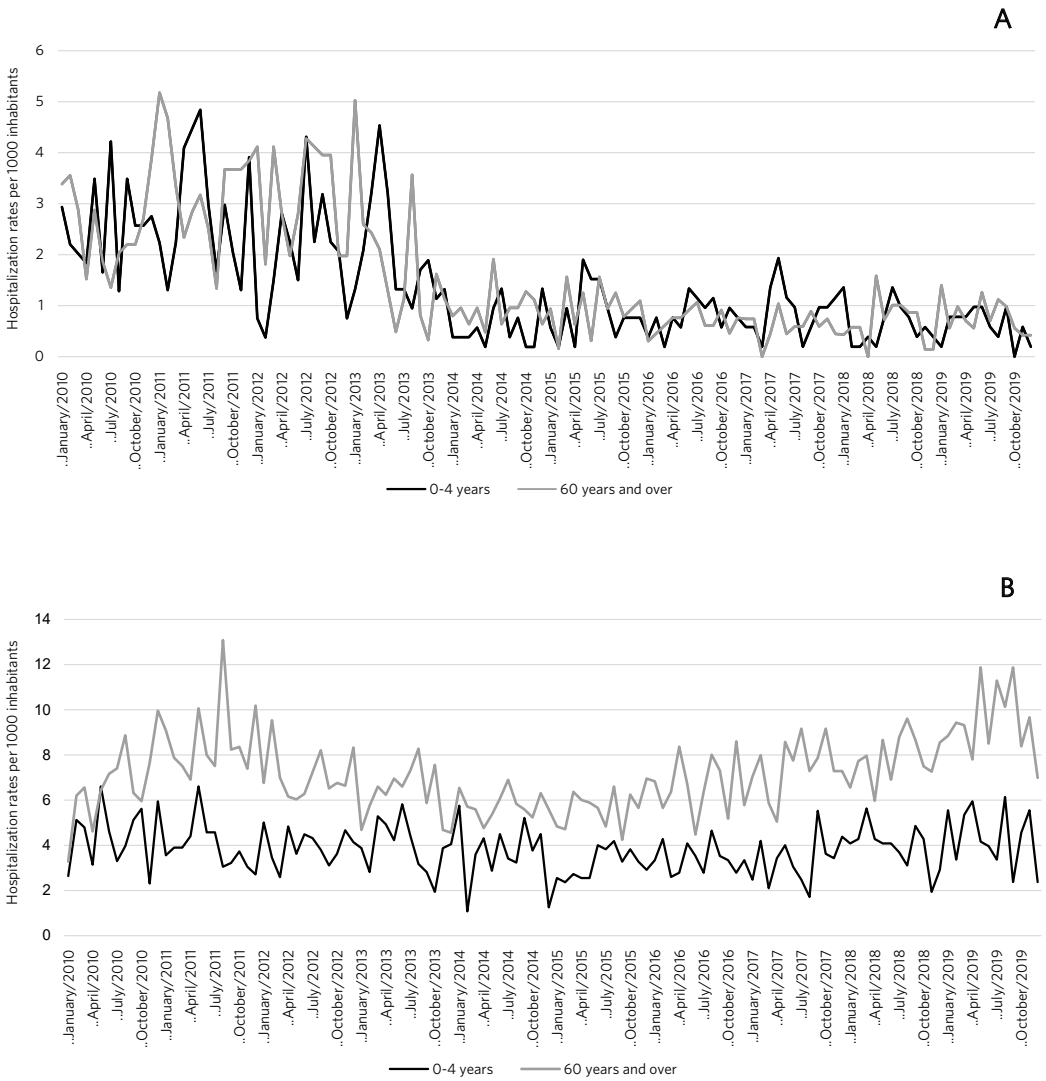
For children under 5, the median ratio (50th percentile) of the hospitalization rate for respiratory conditions is higher in the group of control municipalities. It registers 103.70%, while the median ratio is 314.33% for older adults over 60, suggesting a greater vulnerability of older adults to pneumonia, asthma, bronchitis, and acute bronchiolitis.

Comparing the historical series showed that the distribution of hospitalization rates for respiratory diseases in children under 5 was higher in the control group in all percentiles throughout the decade analyzed. As for the population over 60, a higher median was observed in the case municipality early in the decade (10th percentile), followed by a significant reduction in the following years, which indicated higher medians for the control group (50th and 90th percentiles).

The behavior of hospitalization rates for respiratory diseases for both age groups throughout the historical series analyzed indicates a similar seasonal pattern in case and control municipalities (*graph 1*). Hospitalizations due to these conditions were generally lower in January, with an increase in the second quarter of each year and higher records from April to July. This seasonal pattern is repeated

across historical series, with more hospitalization cases in the age group of over 60 in all months of the year in the group of control municipalities.

Graph 1. Monthly distribution of hospitalization rates for pneumonia, asthma, bronchitis and acute bronchitis in case (A) and control (B) municipalities, stratified into children under 5 years of age and those over 60 years of age, from 2010 to 2019

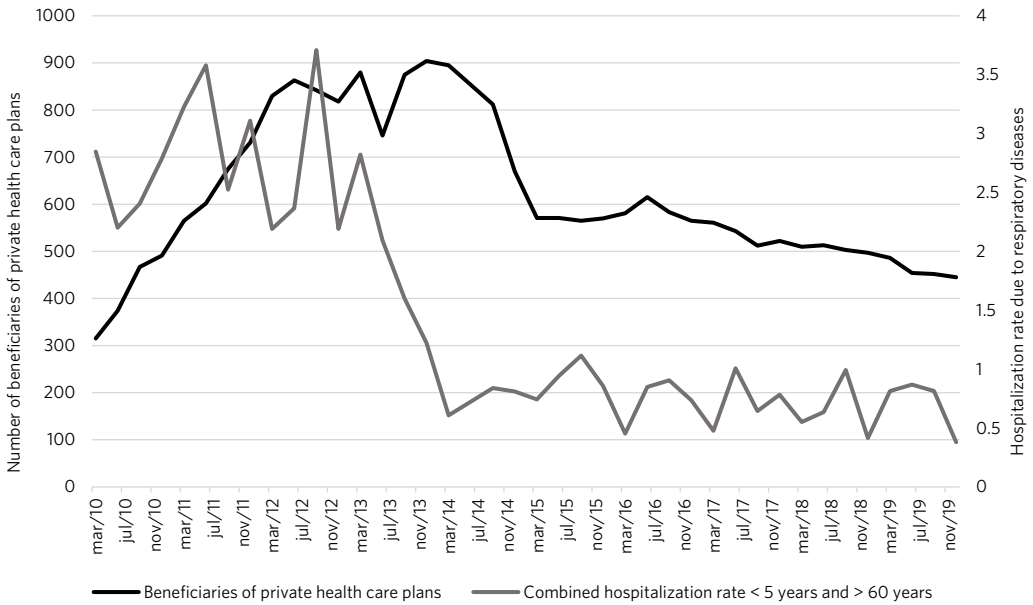


Source: Prepared by the authors.

The combined analysis of the annual rates of hospitalizations for respiratory diseases for both age groups in the case municipality showed a significant drop in the number of hospitalizations starting in 2013. This period is marked by the highest number of beneficiaries

of private health plans, per data collected in the ANS databases, with an increase of up to 262.54%, which may help to explain the reduction in the number of hospitalizations in the local SUS network and recorded by SIH/DataSUS.

Graph 2. Comparison between the number of beneficiaries of private health care plans and the combined hospitalization rate for the age groups under 5 and over 60 in the municipality of Escada-PE, from 2010 to 2019



Source: Prepared by the authors.

In turn, when analyzing the correlation between hospitalization rates and the variation in the number of beneficiaries of private supplementary health plans in the municipality in question, a level of statistical significance ($p < 0.05$) was observed for the age group of children under 5 (coefficient 0.167065), and for the two age groups combined (coefficient 0.254708), with a weak to moderate positive correlation level.

Seasonality of environmental variables

HOTSPOTS

During the study period, the case municipality registered 896 hotspots, representing 218.86% more registered cases than the mean of the group of control municipalities, which had an

average of 281 hotspots. Unlike the seasonal pattern of hospitalizations for respiratory diseases, which were more prevalent from March to July in the case municipality and control group, two groups of municipalities studied, the monthly distribution of hotspots in the case municipality is concentrated between September and February, equivalent to the sugarcane harvest season.

THE 2.5 µM PARTICULATE MATTER ($PM_{2.5}$)

In the case municipality, the mean concentration of $PM_{2.5}$ is higher than in the control municipalities in all months of the years analyzed in the historical series. From the analysis of the monthly distribution of mean $PM_{2.5}$ concentrations, we can infer that the amount of particulate matter detected has a seasonal pattern in the group of control municipalities, with higher means observed from September to February. However, in the case municipality, the seasonality pattern does not repeat itself and has uniform distribution throughout the studied period.

RELATIVE AIR HUMIDITY

The two groups of municipalities had a similar seasonal pattern regarding the variation in the mean relative humidity monthly distribution. This feature is due to the region's autumn and winter periods, concentrated from April to September and marked by increased rainfall throughout the state. Due to its location in the Zona da Mata region of Pernambuco, Escada is closer to the coast than the control municipalities, which are distributed throughout the Agreste and Sertão regions of Pernambuco, and that is why they have lower relative humidity levels, albeit with similar seasonality patterns. All data cited are represented in *table 2*.

Table 2. Distribution of monthly means of hotspots and concentration indices of $PM_{2.5}$ particulate matter and relative air humidity in case and control municipalities, from 2010 to 2019

Months	Escada	Cumaru	Itaíba	Paranatama	Santa Terezinha
			Means of hotspots		
January	12.8	4.5	5.8	0.7	3.3
February	7.0	2.3	7.0	0.1	1.0
March	3.0	2.0	5.5	0.7	0.6
April	2.0	2.3	4.3	0.5	0.3
May	0.7	0.9	2.6	0.2	0.5
June	0.1	0.2	1.9	0.2	0.3
July	0.2	0.1	0.3	0.2	0.2
August	0.7	0.2	1.1	0	0.8
September	5.0	0.7	2.1	0.6	0.7
October	14.9	1.4	3.9	0.3	4.9
November	24.2	4.2	7.9	0.7	9.6
December	19.0	2.7	10.3	0.2	11.6

Table 2. Distribution of monthly means of hotspots and concentration indices of $PM_{2.5}$ particulate matter and relative air humidity in case and control municipalities, from 2010 to 2019

Months	Escada	Cumaru	Itaíba	Paranatama	Santa Terezinha
			Means $PM_{2.5}$		
January	9.354	8.403	6.153	6.507	6.917
February	9.369	8.436	5.638	6.213	6.367
March	9.359	8.329	5.273	6.005	5.322
April	10.250	7.551	4.457	5.289	4.117
May	9.807	6.923	4.307	5.060	3.737
June	9.092	6.764	4.372	5.177	3.789
July	8.659	7.054	4.527	5.260	4.500
August	8.410	7.735	5.294	5.961	6.016
September	8.535	7.869	5.732	6.241	7.242
October	9.224	8.327	6.105	6.318	7.359
November	9.076	8.320	6.291	6.644	6.912
December	8.870	8.545	6.223	6.465	7.160
			Means of relative air humidity		
January	82.269	81.704	70.940	78.852	68.968
February	81.951	81.037	71.200	79.371	69.291
March	82.172	81.296	70.974	78.353	69.753
April	84.128	83.135	76.202	82.243	72.223
May	86.015	85.218	81.328	86.083	73.152
June	86.873	86.339	83.273	87.844	73.369
July	86.468	87.158	83.786	88.421	73.127
August	83.861	84.821	80.147	85.512	69.777
September	82.173	82.669	75.688	82.368	67.604
October	80.872	80.950	72.582	79.679	66.932
November	79.471	79.485	68.088	76.077	65.328
December	79.581	79.374	68.687	76.227	66.376

Source: Prepared by the authors.

Correlation between hospitalization rates for respiratory diseases and environmental variables

The temporal distribution of hotspot occurrences and $PM_{2.5}$ concentrations in association with the monthly hospitalization rates for respiratory diseases in both age groups showed a weak or insignificant negative statistical correlation per the parameters obtained by the analysis model adopted. Likewise, the analysis of the correlation between hospitalization rates and the mean monthly concentration of $PM_{2.5}$ illustrates little related behavior between these variables.

In contrast, the analysis of the association between hospitalization rates and relative air humidity showed a statistically significant correlation for the age group over 60 in the case municipality (negative correlation) and the control group (positive correlation), as shown in *table 3*.

Table 3. Correlation coefficients between the rate of hospitalizations due to pneumonia, asthma, bronchitis and acute bronchiolitis, in the age groups under 5 and over 60 years old, and the occurrence of hot spots, $PM_{2.5}$ concentration index and relative humidity, in the case and control municipalities from 2010 to 2019

	Correlation coefficients		
Groups	**Hospitalization rate vs. Hotspots**	**Hospitalization rate vs. $PM_{2.5}$ concentration**	**Hospitalization rate vs. Relative humidity**
Case (< 5 years)	-0.304	-0.257	-0.169
Case (> 60 years)	-0.267	-0.319	-0.345
Control (< 5 years)	-0.104	-0.049	0.054
Control (> 60 years)	-0.033	-0.111	0.249

Source: Prepared by the authors.

In the case municipality, the burning of sugarcane straw ends in February. In April, there is an increase in relative humidity due to the beginning of the rainy season (autumn and winter) in the Zona da Mata region of Pernambuco, which, because of its proximity to the coast, can reach around 90% during the rainiest periods in the region.

Discussion

Scientific literature indicates that the overlapping effects of air pollution from biomass burning and climate variables can influence the prevalence of hospitalizations for respiratory diseases in more vulnerable age groups. It also highlights a seasonal pattern for respiratory conditions more sensitive to environmental and social factors[23-26].

Similarly, age group-stratified analyses show an association between the concentration of fine particulate matter derived from atmospheric emissions associated with fires and the increase in the incidence of Chronic Obstructive Pulmonary Disease (COPD), infections, and respiratory complications, predominantly in older adults[16], in addition to asthma, bronchitis, and respiratory conditions, generally in the child population[17].

Additional studies show a potential direct relationship between the size of the area subjected to fires and the increasing prevalence of acute respiratory diseases[27]. Notably, human exposure to toxic biomass combustion particles is more intense in locations close to hotspots[28]. In this context, it would be expected that, throughout the historical series, the volume of hospitalizations in the municipality analyzed would increase proportionally to the expanded sugarcane-cultivated area, a trend not identified in the present investigation.

The literature shows evidence[28] of significant differences in hospitalization rates for respiratory diseases during burning periods compared to non-burning periods. In addition, positive correlations between hotspots resulting from fires and mortality rates for respiratory diseases and COPD[25] were observed. Such associations, however, were not observed in the period and geographic context addressed by the study in question.

This study's observations corroborate the literature that relates the seasonal increase in the incidence of respiratory diseases in more vulnerable age groups with climate variants[29-31], indicating a positive correlation between air humidity and the number of hospitalizations. However, this does not exclude the hypothesis that fires interfere with the population's disease process since other studies[32,33] pointed to the association between the regular practice of fires and negative consequences for respiratory health through a positive correlation between the variation in

hotspots and records of respiratory problems in children aged 4 and 5.

Significant associations have also been reported between air pollution and hospitalizations for respiratory diseases[34-36], further evidencing that exposure to fire pollutant emissions poses a potential risk to human health, increasing the number of hospitalizations for respiratory diseases[36-38] and deaths[25,37,39]. The prevalence of respiratory problems in the child population showed higher rates in municipalities characterized by high socioeconomic stratification associated with income from sugarcane and the emission of fine particulate matter ($PM_{2.5}$)[40].

Regarding the effects of burning sugarcane straw on respiratory health outcomes in areas with significant agricultural production of this crop, in the Midwest macro-region, epidemiological studies have revealed correlations with increasing outpatient care demand, especially for asthma and bronchitis, hospitalizations, mainly due to pneumonia, and mortality associated with COPD[40-42]. Similarly, research conducted in the Southeast identified statistically significant associations between growing hospitalizations due to pneumonia and when sugarcane burning started in municipalities considered production hubs in the sugar-alcohol sector[28-43].

In addition, it is common to see dead animals in crops, vegetation in adjacent areas completely devastated by fire, families falling ill, and workers being forced to leave their jobs due to air pollution produced during the burning process. It is no exaggeration to say that the environmental impacts caused by the sugarcane straw burning threaten the ecosystem's preservation by devastating Atlantic Forest fragments[44,45]. These elements point to the need to conduct studies with other methodological designs and collect primary data in the territory to assess the impacts of biomass burning on socio-biodiversity and exposed populations in more depth.

Therefore, the results suggest a possible significant underreporting of hospitalization cases for respiratory diseases in Escada. This finding leads to the hypothesis that this underreporting may derive from a combination of environmental and social factors, such as i) chronic illness among the population, considering that long periods of uninterrupted exposure throughout the year can cause illness during the year; ii) the migration of patients to the supplementary health services network, significantly reducing hospitalizations in the local SUS network; iii) weaknesses in health information systems, which may not be adequately recording cases of illness.

The literature identifies contributing factors to the underreported diseases, which are primarily related to the clinical practice of health professionals, the difficulties inherent in the reporting process, the clinical and sociodemographic complexity of patients or family members, and the pathology's diagnostic particularities. However, the main obstacle to adequate reporting appears to lie in the difficulty of doctors to establish accurate diagnoses, in the failure to report and delegate the reporting responsibility to other professionals, and, when reporting occurs, in conducting the process under the exclusive responsibility of the nursing team, often in a context far from the patient, resulting in late reporting[46,47].

Chronic exposure to toxic particulates emitted by regular biomass burning can produce population hypersensitivity in vulnerable groups in sugarcane-producing municipalities[29,38,48]. This leads to chronic illness among the population, which begins to assume that symptoms are commonplace and thus fails to seek out the public health system.

On the other hand, the arrival of large projects in the region, such as the Port of Suape expansion[49] and the BR-101 highway widening[50] in the mid-2010s, brought new employment prospects to the population of the municipality in question. These new jobs offered better wages and benefits to workers than the sugarcane agribusiness. Among the remunerative benefits was access to private supplementary health plans. As a result, the

number of beneficiaries of these private plans in the municipality in question grew considerably during the first half of the 2010s, coinciding with the beginning of declining reports of hospitalizations for respiratory diseases in Escada.

As Brazilian supplementary healthcare has been growing year after year[51,52], the unequal access to hospitalizations increases as the population's coverage by private health insurance with hospital segmentation gradually expands. A sharp increase in the rate of hospitalizations among beneficiaries of private plans with hospital coverage was observed from 2015 to 2019, with 9.5 hospitalizations per 100 people in 2015 and 13.9 hospitalizations per 100 people in 2019, a more significant variation than that recorded in hospitalizations in the SUS[51].

Likewise, the influence of the expanded access to the private healthcare network on demands in the local SUS network can be better observed in small municipalities[53-55] since the provision of medium-complexity outpatient and hospital services in Brazilian health regions occurs through hybrid structures – composed of public and private entities –, with a predominance of the municipal public provider in the outpatient sphere and private philanthropic institutions in the hospital sphere[53].

From a legal standpoint, given the need to ban the use of fire in sugarcane crops, mechanized harvesting is the solution to mitigate the environmental impacts caused by fires. However, there must be compensatory policies to bring these workers back into the job market. In this sense, the state of São Paulo enacted Law Nº 11.241/2002, which aimed to gradually eliminate sugarcane straw burning and regulate the activity when mechanization was unfeasible[56].

As in most Brazilian states, the legislation of Pernambuco does not yet provide for the elimination of sugarcane burning and the gradual transition to mechanization in the context of environmental impacts, only regulating the practice through Normative Instruction CPRH Nº 08/2014, which establishes limits on time, burned area, and proximity to urban areas[57]. Likewise, no national legislation bans the use of fire during harvesting, leaving it up to the Judiciary to assess the merits of the matter in lack of a clear legal framework.

It is necessary to consider that the approach adopted in this study has limitations, notably due to the data selection, which only analyzes cases of severe respiratory conditions that required hospitalization but does not include cases of mild and moderate conditions treated or not in primary care and emergency and urgent care services.

In addition, this study analyzed the data available in DataSUS. However, it did not include cases of hospitalizations in the private health network, which is a relevant limitation for small municipalities with a substantial increase in the migration of users from the public health system to the private system, as is the case here.

Furthermore, the scientific literature analyzed shows the need to adopt intersectoral public actions to tackle the problem of fires – whether in sugarcane crops or in the opening of pastures and arable areas in the North and Midwest –, notably aimed at combating air pollution and the risk to human health resulting from these activities, with the integrated participation of civil society, health surveillance agencies and the defense of diffuse rights[58-62].

For this to happen, it is also necessary to invest in science and the development of methodologies and research dedicated to better elucidating the population's illness process combined with the social and environmental factors involved, promoting monitoring tools that allow us to understand how much the variability of climate elements and environmental pollution influences the illnesses studied.

Conclusions

Although sugarcane burning has been in place for centuries in the studied area and is even

part of the setting, academia, and the government have paid little attention to the problem in the region. In the former, few studies aimed to collect data and propose solutions. At the same time, the latter has postponed, or even neglected, the enactment of rules and legal deadlines for ending the practice, using arguments based solely on economic issues without considering public health.

This study seeks to clarify the biomass burning impact on the health of the population living in the sugarcane region and exposed to health-threatening situations almost daily. The periodic occurrence of several hotspots and the consequent release of air pollutants throughout more than half the year are critical risk factors to human health, requiring intervention by the public authorities and joint action by the State and organized civil society.

The low correlation between the outcomes studied and biomass burning may indicate a significant underreporting of respiratory diseases, which has been increasing over time and deserves attention from managers and researchers. Some non-exclusive hypotheses were raised to explain this fact grounded on the population's chronic illness, constant exposure to pollutants, and the migration of hospitalizations to the supplementary health network, resulting from social factors and the region's development and economic diversification.

On the other hand, the SIH/DataSUS data used in the analysis are generated primarily for accounting purposes and were not initially intended for epidemiological investigations, which may imply a certain degree of intrinsic inaccuracy. Additionally, it is plausible to infer the underreporting of specific health problems' prevalence due to the healthcare network's technological profile and possible gaps in diagnostic coding.

In addition to all this, it is necessary to consider the economic influence of agribusiness and the penetration of its coalition of defense of interests in the spheres of power, which direct public policies to places that are beneficial to them, whether due to the lack or slowness in regulating the sector or the apparent laxity with which the issue of pollution has been treated in the courts.

This study is expected to contribute to the debate on public health by presenting information necessary for developing and establishing public policies to curb environmental pollution and agro-industrial activity's impacts on human health.

Collaborators

Araujo FEL (0009-0004-8710-1601)* contributed to the idea of the article, data collection, systematization, analysis, interpretation, writing, and critical review. Campos AG (0000-0002-1085-9236)* contributed to data analysis and interpretation, writing, and critical review of the manuscript. Domingues RC (0000-0003-2025-1125)* contributed to the idea of the article, data collection, systematization, analysis, interpretation, writing, and critical review of the manuscript. Santos RC (0000-0002-4973-123X)* contributed to all stages of manuscript preparation. Bezerra VCR (0000-0003-2267-9512)* contributed to data analysis, interpretation, writing, and critical review. Gurgel AM (0000-0002-5981-3597)* contributed to the research design, discussion, writing, review, and approval of the final version of the manuscript.■

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References

1. Castro J. Geografia da fome: o dilema brasileiro: pão ou aço. 10. ed. Rio de Janeiro: Edições Antares; 1984.

2. Freyre G. O Nordeste. 7. ed. São Paulo: Global; 2004.

3. Rosa MC. O engenho dos movimentos sociais: Reforma agrária e significação social na zona canavieira de Pernambuco. Rio de Janeiro: Garamond; 2011.

4. Ronquim CC. Queimada na colheita de cana-de-açúcar: impactos ambientais, sociais e econômicos [Internet]. Campinas: Embrapa Monitoramento por Satélite; 2010 [acesso em 2025 fev 28]. 45 p.: il. (Embrapa Monitoramento por Satélite. Documentos, 77). Disponível em: https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/878010/1/Doc77.pdf

5. Companhia Nacional de Abastecimento (BR). Acompanhamento da safra brasileira de cana-de-açúcar: safra 2022/23, 3º terceiro levantamento [Internet]. Brasília, DF: Conab; 2022 [acesso em 2025 fev 13]. Disponível em: https://www.conab.gov.br/component/k2/item/download/45671_7a038e9b1579f67261d6351884075e16

6. Nicolella AC, Belluzzo W. The effect of reducing the pre-harvest burning of sugar cane on respiratory health in Brazil. Environ Dev Econ. 2015;20(1):127-140. DOI: http://dx.doi.org/10.1017/S1355770X14000096

7. Ramos D, Pestana PRS, Trevisan IB, et al. The impact of sugarcane burning on hospitalization due to respiratory diseases. Ciênc saúde coletiva. 2019;24(11):4133-4140. DOI: https://doi.org/10.1590/1413-812320182411.32402017

8. Arbex MA, Martins LC, Oliveira RC, et al. Air pollution from biomass burning and asthma hospital admissions in a sugar cane plantation area in Brazil. J Epidemiol Community Health. 2007;61(5):395-400. DOI: https://doi.org/10.1136/jech.2005.044743

9. Ribeiro H, Pesquero C. Queimadas de cana-de-açúcar: Avaliação de efeitos na qualidade do ar e na saúde respiratória de crianças. Estudos Av. 2010;24(68):255-271. DOI: https://doi.org/10.1590/S0103-40142010000100018

10. Fernandes T, Hacon SDS, Novais JWZ. Mudanças climáticas, poluição do ar e repercussões na saúde humana: revisão sistemática. RBClima. 2021;28:138-64.

11. Dias AP, Gurgel AM, Rosa AC, et al. Agrotóxicos e saúde. Rio de Janeiro: Fiocruz; 2018. (Série Fiocruz – Documentos Institucionais; Coleção Saúde, Ambiente e Sustentabilidade; v. 2).

12. Instituto Brasileiro de Geografia e Estatística. Produção agrícola municipal 2020 [Internet]. Rio de Janeiro: IBGE; 2021 [acesso em 2025 fev 9]. Disponível em: https://biblioteca.ibge.gov.br/index.php/biblioteca-catalogo?view=detalhes&id=766

13. Jannuzzi PM. Indicadores demográficos e de saúde. In: Jannuzzi PM. Indicadores sociais no Brasil: conceitos, fontes de dados e aplicações. Campinas, SP: Alínea; 2009. p. 66-80.

14. Gurgel Júnior GD. A reforma do setor saúde e os determinantes sociais da saúde: Construindo interconexões teóricas e metodológicas para abordagem de desafios globais complexos. Rev Bras Epidemiol. 2014;17:53-67. DOI: https://doi.org/10.1590/1809-4503201400060005

15. Wells RHC, Bay-Nielsen H, Braun R, et al. CID-10: classificação estatística internacional de doenças e problemas relacionados à saúde. São Paulo: EDUSP; 2011.

16. Stowell JD, Geng G, Saikawa E, et al. Associations of wildfire smoke $PM_{2.5}$ exposure with cardiorespiratory events in Colorado 2011–2014. Environ Int. 2019;133(PtA):105151. DOI: https://doi.org/10.1016/j.envint.2019.105151

17. Mnatzaganian CL, Pellegrin KL, Miyamura J, et al. Association between sugar cane burning and acute respiratory illness on the island of Maui. Environ Health. 2015;14(1):1-8. DOI: https://doi.org/10.1186/s12940-015-0067-y

18. Rodrigues C, Lima F, Barbosa F. Importância do uso adequado da estatística básica nas pesquisas clínicas. Rev Bras Anestesiol. 2017;67(6):619-25. DOI: http://dx.doi.org/10.1016/j.bjan.2017.01.003

19. Ministério da Saúde (BR). Sistema de Informações Hospitalares do Sistema Único de Saúde (SIH/DataSUS) [Internet]. Brasília, DF: Ministério da Saúde; [sem data] [acesso em 2025 fev 28]. Disponível em: http://datasus.saude.gov.br/

20. Instituto Nacional de Pesquisas Espaciais (BR). Banco de Dados de Queimadas (BDQUEIMADAS) [Internet]. Brasília, DF: INPE; [sem data] [acesso em 2025 fev 28]. Disponível em: http://www.inpe.br/queimadas/bdqueimadas

21. Paranhos R, Figueiredo Filho DB, Rocha EC, et al. Desvendando os Mistérios do Coeficiente de Correlação de Pearson: o Retorno. Leviathan (São Paulo). 2014;(8):66-95. DOI: https://doi.org/10.11606/issn.2237-4485.lev.2014.132346

22. Ministério da Saúde (BR); Conselho Nacional de Saúde. Resolução nº 510/2016, de 7 de abril de 2016. Dispõe sobre a pesquisa em Ciências Humanas e Sociais. Diário Oficial da União, Brasília, DF. 2016 maio 24; Edição 98; Seção I:44-46.

23. Ignotti E, Valente JG, Longo KM, et al. Impact on human health of particulate matter emitted from burnings in the Brazilian Amazon region. Rev Saúde Pública. 2010;44(1):121-130. DOI: https://doi.org/10.1590/s0034-89102010000100013

24. Fonseca FR, Vasconcelos CH. Estudo da distribuição de doenças respiratórias no estado de Santa Catarina, Brasil. Cad Saúde Colet, (Rio J). 2011;19:454-460.

25. Rodrigues PCO, Ignotti E, Hacon SS. Distribuição espaço-temporal das queimadas e internações por doenças respiratórias em menores de cinco anos de idade em Rondônia, 2001 a 2010. Epid Serv Saúde. 2013;22(3):455-464. DOI: https://dx.doi.org/10.5123/S1679-49742013000300010

26. Cruz O, Castro HA, Gonçalves KS, et al. Tendência da mortalidade por doenças respiratórias em idosos e as queimadas no Estado de Rondônia/Brasil: período entre 1998 e 2005. Ciênc saúde coletiva. 2009;14(6):2083-2090. DOI: https://doi.org/10.1590/S1413-81232009000600015

27. Souza KV. Análise espacial do impacto das queimadas de cana-de-açúcar na prevalência dos sintomas de asma de alunos do Município de Campos dos Goytacazes – RJ [dissertação na Internet]. Rio de Janeiro: Escola Nacional de Saúde Pública Sergio Arouca, Fundação Oswaldo Cruz; 2015 [acesso em 2025 fev 15]. Disponível em: https://www.arca.fiocruz.br/handle/icict/14047

28. Ramos D, Pestana PRS, Trevisan IB, et al. Impacto da queima da cana-de-açúcar sobre internações hospitalares por doenças respiratórias. Ciênc saúde coletiva. 2019;24(11):4133-4140. DOI: https://doi.org/10.1590/1413-812320182411.32402017

29. Domingues RC, Gurgel AM, Santos RC, et al. Queima de biomassa da cana-de-açúcar e hospitalizações de crianças e idosos por agravos respiratórios em Pernambuco, Brasil. Cad Saúde Pública. 2023;39(10):e00238422. DOI: https://doi.org/10.1590/0102-311XPT238422

30. Santos LKC. Análise dos condicionantes climáticos e do material particulado fino nas internações por pneumonia em Manaus – Amazonas [dissertação na Internet]. Manaus: Universidade Federal do Amazonas; 2023 [acesso em 2025 fev 15]. Disponível em: https://tede.ufam.edu.br/handle/tede/9395

31. Moraes SL, Almendra R, Santana P, et al. Variáveis meteorológicas e poluição do ar e sua associação com internações respiratórias em crianças: estudo de caso em São Paulo, Brasil. Cad Saúde Pública. 2019;35(7):e00101418. DOI: https://doi.org/10.1590/0102-311X00101418

32. Luana MMS, Castro FR, Bastos DMRF, et al. Impactos das queimadas sobre a saúde da população humana na amazônia maranhense. Rev Pesq Saúde [In-

ternet]. 2016 [acesso em 2025 fev 15];17(3):141-146. Disponível em: http://periodicoseletronicos.ufma.br/index.php/revistahuufma/article/view/5400

33. Souza LSN. Análise de impactos das queimadas sobre a saúde humana: um estudo de caso do Município de Rio Branco, Acre [dissertação na Internet]. Rio de Janeiro: Escola Nacional de Saúde Pública Sergio Arouca, Fundação Oswaldo Cruz; 2008 [acesso em 2025 fev 16]. Disponível em: https://www.arca.fiocruz.br/handle/icict/5258

34. Slama A, Śliwczyński A, Woźnica J, et al. Correction to: Impact of air pollution on hospital admissions with a focus on respiratory diseases: a time-series multi-city analysis. Environ Sci Pollut Res Int. 2020;27(17):22139-22139. DOI: https://doi.org/10.1007/s11356-020-08838-6

35. Gu J, Shi Y, Zhu Y, et al. Ambient air pollution and cause-specific risk of hospital admission in China: A nationwide time-series study. PLoS Med. 2020;17(8):e1003188. DOI: https://doi.org/10.1371/journal.pmed.1003188

36. Réquia Júnior WJ, Amini H, Mukherjee R, et al. Health impacts of wildfire-related air pollution in Brazil: a nationwide study of more than 2 million hospital admissions between 2008 and 2018. Nat Commun. 2021;12(1):6555. DOI: https://doi.org/10.1038/s41467-021-26822-7

37. Johnston F, Hanigan I, Henderson S, et al. Extreme air pollution events from bushfires and dust storms and their association with mortality in Sydney, Australia 1994-2007. Environ Res. 2011;111(6):811-816. DOI: https://doi.org/10.1016/j.envres.2011.05.007

38. Gan RW, Ford B, Lassman W, et al. Comparison of wildfire smoke estimation methods and associations with cardiopulmonary-related hospital admissions. Geohealth. 2017;1(3):122-136. DOI: https://doi.org/10.1002/2017gh000073

39. Haikerwal A, Akram M, Del Monaco A, et al. Impact of Fine Particulate Matter ($PM_{2.5}$) Exposure During Wildfires on Cardiovascular Health Outcomes. J Am Heart Assoc. 2015;4(7):e001653. DOI: https://doi.org/10.1161/jaha.114.001653

40. Bühler HF, Fátima B, Oliveira A, et al. Os impactos socioambientais e na saúde decorrente da cadeia produtiva do etanol no Centro-Oeste do Brasil. Braz J Develop. 2023;9(3):10865-10884. DOI: https://doi.org/10.34117/bjdv9n3-131

41. Rosa AM, Ignotti E, Hacon SDS, et al. Análise das internações por doenças respiratórias em Tangará da Serra – Amazônia Brasileira. J Bras Pneumol. 2008;34(8):575-582. DOI: https://doi.org/10.1590/S1806-37132008000800006

42. Rosa AM, Ignotti E, Hacon SS, et al. Prevalência de asma em escolares e adolescentes em um município na região da Amazônia brasileira. J Bras Pneumol. 2009;35(1):7-13. DOI: https://doi.org/10.1590/S1806-37132009000100002

43. Souza LSV, Nascimento LFC. Air pollutants and hospital admission due to pneumonia in children: a time series analysis. Rev Assoc Med Bras. 2016;62(2):151-156. DOI: https://doi.org/10.1590/1806-9282.62.02.151

44. Scudeleti NL, Ferreira RL, Ambiental G. Auditoria ambiental nas queimadas de cana-de-açúcar para reposição da fauna e flora. Meio Amb Sustent [Internet]. 2014 [acesso em 2025 fev 15];5(3). Disponível em: https://www.cadernosuninter.com/index.php/meioAmbiente/article/view/463

45. Sabadin AC. Do fogo à fumaça: a construção social do problema ambiental das queimadas nos canaviais paulistas. Argumentos. 2020;17(1):85-104. DOI: https://doi.org/10.32887/issn.2527-2551v17n1p.85-104

46. Melo MADS, Coleta MFD, Coleta JA, et al. Percepção dos profissionais de saúde sobre os fatores associados à subnotificação no Sistema Nacional de Agravos de Notificação (Sinan). Rev Adm Saúde. 2018;18(71). DOI: http://dx.doi.org/10.23973/ras.71.104

47. Oliveira CM, Cruz MM. Sistema de vigilância em saúde no Brasil: avanços e desafios. Saú-

de debate. 2015;39(104):255-267. DOI: https://doi.org/10.1590/0103-110420151040385

48. Goto DM, Lança M, Obuti CA, et al. Effects of biomass burning on nasal mucociliary clearance and mucus properties after sugarcane harvesting. Environ Res. 2011;111(5):664-669. DOI: https://doi.org/10.1016/j.envres.2011.03.006

49. Oliveira RV. Suape em construção, peões em luta: o novo desenvolvimento e os conflitos do trabalho. Cad CRH. 2013;26(68):233-252. DOI: https://doi.org/10.1590/S0103-49792013000200003

50. Ferreira J, Lima S, Wellington J, et al. Entre tempos e espaços: duplicação da BR-101 no nordeste do Brasil. Anais do 14º ENANPEGE [Internet]; 2021; Campina Grande. Campina Grande: Realize Editora; 2021 [acesso em 2025 fev 15]. Disponível em: https://editorarealize.com.br/artigo/visualizar/78324

51. Albuquerque C, Machado J. Internações no Brasil: oferta e utilização no SUS e na saúde suplementar de 2015 a 2021 [Internet]. Rio de Janeiro: Observatório de Política e Gestão Hospitalar; 2023 [acesso em 2025 fev 15]. Disponível em: https://observatoriohospitalar.fiocruz.br/debates-e-opinioes/internacoes-no-brasil-oferta-e-utilizacao-no-sus-e-na-saude-suplementar-de-2015

52. Santos IS, Ugá MAD, Porto SM. O mix público-privado no sistema de saúde brasileiro: financiamento, oferta e utilização de serviços de saúde. Ciênc saúde coletiva. 2008Sep;13(5):1431-1440. DOI: https://doi.org/10.1590/S1413-81232008000500009

53. Silva JFM, Carvalho BG, Domingos CM, et al. A relação público-privada em uma região de saúde: influências sobre a organização da oferta e da demanda de média complexidade no Sistema Único de Saúde em pequenos municípios. Saúde Soc. 2020;29(4):e200019. DOI: https://doi.org/10.1590/S0104-12902020200019

54. Lima LD, Albuquerque MV, Scatena JHG, et al. Arranjos regionais de governança do Sistema Único de Saúde: diversidade de prestadores e desigualdade espacial na provisão de serviços. Cad Saúde Pública. 2019;35:e00094618. DOI: https://doi.org/10.1590/0102-311X00094618

55. Silva JFM, Carvalho BG, Domingos CM. A governança e a relação público-privado no cotidiano das práticas em municípios de pequeno porte. Ciênc saúde coletiva. 2018Oct;23(10):3179-88. DOI: https://doi.org/10.1590/1413-812320182310.13952018

56. Assembleia Legislativa do Estado de São Paulo (SP). Lei nº 11.241, de 19 de setembro de 2002. Dispõe sobre a eliminação gradativa da queima da palha da cana-de-açúcar e dá providências correlatas. Diário Oficial do Estado [Internet], São Paulo, SP. 2002 set 20 [acesso em 2025 fev 28]; Seção I:2. Disponível em: https://www.al.sp.gov.br/norma/?id=217

57. Agência Estadual de Meio Ambiente (PE). Instrução Normativa CPRH nº 008/2014. Disciplina os procedimentos da CPRH referentes à autorização para uso do fogo controlado em propriedades e posses rurais mediante o estabelecimento de normas de precaução relativas ao emprego do fogo em práticas agropastoris e florestais no Estado de Pernambuco e dá outras providências. Diário Oficial do Estado de Pernambuco [Internet], Recife, PE. 2014 ago 1 [acesso em 2025 fev 28]. Disponível em: https://www2.cprh.pe.gov.br/wp-content/uploads/2020/12/Instrucao-normativa_008_14.pdf

58. Gurgel AM, Souto AS, Guedes CA, et al. Espelho sem reflexos: conflitos e vulnerabilidades socioambientais em uma região produtora de cana-de-açúcar. Ciênc saúde coletiva. 2022;27(3):1049-1060. DOI: https://doi.org/10.1590/1413-81232022273.27502020

59. Arbex MA, Santos UP, Martins LC, et al. A poluição do ar e o sistema respiratório. J Bras Pneumol. 2012;38(5):643-655. DOI: https://doi.org/10.1590/S1806-37132012000500015

60. Ribeiro H, Lopes FS, Assunção JV, et al. Queimadas de cana-de-açúcar e efeitos à saúde humana: revisão da literatura. InterfacEHS. 2012;7(3):3-25.

61. Straif K, Cohen A, Samet J. Air Pollution and Cancer. Air pollution and cancer. Lyon: International Agency for Research on Cancer; World Health Organization; 2013. (IARC Scientific Publications; 161).

62. Leão H, Santos R, Araújo N, et al. A qualidade do ar influencia as internações hospitalares por doenças respiratórias em crianças? uma revisão sistemática. ASSOBRAFIR Ciênc [Internet]. 2019 [acesso em 2025 fev 28];9(2):55-70. Disponível em: http://assobrafir-ciencia.org/article/5da73cbf0e8825ed62ba68e3

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