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Sugar cane burning in Brazil: respiratory health effects

ABSTRACT

The article aimed to update scientific literature information about respiratory health effects caused by sugarcane burning, considering the expansion of sugarcane plantations in Brazil and in the state of São Paulo. Articles published between 1996 and 2006, which deal with the health effects of sugarcane burning and/or air pollutants originating from this burning, were discussed. These studies suggest that part of the population – especially the elderly, children and asthmatics – suffers health effects of sugarcane burning. As a result, these people require health care, thus affecting health services and their families.

DESCRIPTORS: Combustion, adverse effects. Saccharum. Air Pollutants, adverse effects. Respiratory Tract Diseases. Agricultural Zones. Review [Publication Type].

INTRODUCTION

There has been great expansion of the sugar and alcohol sector in Brazil, with the construction of more than 100 new mills and the expansion of alcohol participation in the energy matrix. This increase has risen from 6.8% in 1978 to 13.5% in 2004, regardless of debates about possible public health impacts. This country is the largest world producer and exporter of alcohol, considered as clean fuel, because it originates from sustainable sources. The Brazilian production of sugarcane reached 436.8 million tons in the 2005/2006 harvest. The state of São Paulo, except for the coast and the Serra do Mar and Vale do Ribeira areas, produces about 60% of the Brazilian sugarcane.

Sugarcane harvesting is mechanized in 25% of the Brazilian production and 40% of São Paulo's production; the rest is manually cut and suffers pre-harvest burning. In the state of São Paulo, sugarcane harvest happens between May and November, coinciding with the low rain precipitation period and worst conditions of air pollutant dispersion. Thus, it is more likely that fires will have a negative impact on the air quality and the health of those who live in the sugarcane regions.

Scientific literature regarding the effects of sugarcane burning on health is still very limited. There are studies on health effects caused by biomass burning in general, which, at times, mention sugarcane. Ribeiro & Assunção (2002)²¹ published a review of these studies, focusing on emissions in the lower atmosphere that originate from biomass burning. The present study updates this review, covering the 1996-2006 period. Its objective is to comment on current scientific production about the effects of sugarcane burning on respiratory health and their main conclusions, aiming to contribute to the analysis of this issue and suggest questions for future research.

The bibliographic research was made on the following databases: Cambridge Sociological Abstracts databases – environmental sciences and pollution management; University of California Libraries Database; Science Direct; and

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Web of Science. Articles that dealt with health effects of sugarcane burning and/or the measurement of air pollutants produced by this burning were researched. This research focused on the impacts of sugarcane burning on the atmosphere and the effects on respiratory health, excluding other environmental impacts on soils and water bodies.

Brazilian library archives were also consulted – at the University of São Paulo and at the *Companhia de Tecnologia de Saneamento Ambiental* (CETESB – Environmental Sanitation Technology Company), as well as American archives – at Berkeley University in California and at the Environmental Protection Agency (EPA) in San Francisco, in 2006.

HEALTH EFFECTS CAUSED BY SUGARCANE BURNING

Burning of sugarcane residues is a common practice all over the world, especially in developing countries, though not exclusive to them. This type of burning significantly contributes to pollution in southeast Louisiana, in the United States, where this practice has increasingly been objected to by the population (Boopathy et al⁶ 2002). Such practice is allowed by the state legislation, arguing that there is no scientific evidence of negative impacts. In order to provide information on possible health effects, a study based on hospital visits of 6,498 patients diagnosed with asthma was carried out, during the years of 1998-1999, at a hospital in the city of Houma, in this same American state. Temporal analysis and control table with three standard-deviation limits were used to analyze the already existing observations. During two years, the monthly average of hospitalizations due to asthma was 270.8. Women comprised 56.9% of patients, and babies showed the highest rates, with 1,639 visits, followed by the 5-to-10-year-old children group. The months with the highest number of hospitalizations were October and December (33.06% of all hospitalizations), thus indicating an increase in the tendency of asthma-related hospitalization during the months of sugarcane straw burning (Boopathy et al⁶ 2002).

In India, case-control studies among sugarcane and sugar mill workers, fitted to confounding factors, indicated increased risk of lung cancer among workers who always worked in sugarcane plantations (odds ratio – OR=1.92, 95% confidence interval – 95% CI: 1.08;3.40). Higher risks were found for work involving soil preparation and after-harvest burning (OR=1.82, 95% CI:0.99;3.35). Workers involved in sugarcane burning for more than 210 days of their lives had a 2.5 times higher risk compared to those who had never been involved in the burning. Among smokers who

worked with burning, the risk was six times higher. This risk increased according to the time spent in burning practices and the number of cigarette packs smoked (Amre et al³ 1999).

In Brazil, research focuses on the state of São Paulo, where the population living in sugarcane areas is exposed to air pollutants originating from burning. Several studies have been performed in the city of Araraquara, in the state of São Paulo, as there are vast sugarcane plantations around it. Zancul^a (1998) carried out air quality assessment of the city, surveyed by one of the mobile laboratories of CETESB's telemetry network, located in a completely urbanized, central area. For a period of 49 days, during the sugarcane harvest time, Zancul noticed that the air quality index remained good for CO, SO₂, inhalable particles and nitrogen oxides on most days. However, due to the presence of ozone, the index in Araraquara was regular during 85% of the sample days and inadequate during 10% of these. The study did not find evidence of the origin of precursor gases, but suggests they have been released by sugarcane burning and vehicles, or have been transported by wind from other regions. A survey on the number of inhalations, conducted in the city's health centers, revealed higher numbers during the burning period, compared to the productivity of some of the region's sugar and alcohol factories, the precipitation index and the annual seasons.

Moreover, an epidemiological survey was conducted in Araraquara, from June 1st to August 31st, concluding that sugarcane burning may have harmful effects on the population exposed (Arbex et al⁴ 2000). A total of four containers were strategically placed in this city to collect particles. These data were compared to the number of hospital visits and of patients who needed inhalation in one of the main hospitals of the city. The association between sediment weight and number of visits was assessed by the regression model, which was controlled by season, temperature, day of the week and rain. The authors found significant dose-dependent relationship between the number of visits and the amount of sediment. The relative risk (RR) of hospital visits associated with the increase in 10mg of sediment weight was RR=1.09 (95% CI:1;1.19) and RR=1.20 (95% CI:1.03;1.39) for inhalation on the most polluted days. However, Arbex et al⁵ (2004) argued that several factors contributed to worsen the air quality during the sugarcane harvest time in addition to burning, such as the heavier flow of trucks and machines, as well as the dust on the roads.

In another study conducted in the city of Piracicaba, in the state of São Paulo, daily hospitalizations due to respiratory diseases were quantified, in children, adolescents (below 13 years of age) and elderly people

^a Zancul A. O efeito da queimada de cana-de-açúcar na qualidade do ar da região de Araraquara [dissertação de mestrado]. São Carlos: Escola de Engenharia de São Carlos da USP; 1998.

over 65 years of age, by means of data from the *Departamento de Informática do Sistema Único de Saúde* (DATASUS – Brazilian Health System's Computer Department). Analyses indicated that biomass burning and re-suspension of eroded soil material are responsible for 80% of fine particulate matter (PM 2.5). Relative risk of hospitalizations due to respiratory diseases in children and adolescents was significantly associated with inter-quarter variation of PM10, PM2.5, black carbon of aluminum, silicon, manganese, potassium and sulfur. PM increase in 10 µg/m³ was associated with an increase in 21% in hospitalizations. Among the elderly, the relative risk of hospitalizations due to respiratory diseases was associated with the inter-quarter variation of PM10, black carbon and potassium. The burning period had 3.5 times more hospitalizations than the non-burning period (Cançado 2003).^a However, the author warns of confounding factors such as the air temperature and precipitation, as a great part of the burning period coincides with winter and dry weather, not controlled by the study.

Lopes & Ribeiro¹⁵ (2006) analyzed spatial correlations when gathering the following into a geographic information system: fires, sugarcane areas, and hospitalizations due to respiratory diseases, recorded by the DATASUS, from 2000 to 2004, in the state of São Paulo and, on a regional scale, in the city of Bauru. On both scales it was possible to verify higher rate of hospitalizations due to respiratory diseases in areas where there is sugarcane burning.

Other studies measured atmospheric emissions by different pollutants originating from sugarcane burning, regardless of health effects. However, by means of these results, possible human health risks can be inferred.

In the United States, in 1975, the EPA analyzed sugarcane burning emissions in an experiment with whole sugarcane and only with straw in an incinerator. Emissions of particulate matter, carbon monoxide, hydrocarbons, benzopyrene (BaP), and trace metals – beryl, cadmium, chrome, copper, and nickel – were determined. It was verified that 90% of the particles were less than 0.5 µm in diameter. The emission factors found, with a 99% confidence level, were: 4.1-6.5 pounds per ton of particulate matter; 47.7-71.2 pounds per ton of carbon monoxide; 2.3-14 pounds per ton of hydrocarbons (Darley & Lerman, 1975).^b Particles that were smaller than 10µm (PM10), carbon monoxide and hydrocarbons are harmful to the health.

Godói et al⁹ (2004) analyzed aerosol samples with less than 10µm in diameter, in the city of Araraquara, during harvest time, using a Hi-vol air sampler, 5 km away from sugarcane plantations. The authors found daily

concentrations of total particulate matter that varied from 76.3 µg/m³ to 181.8 µg/m³ and average concentrations of 103 µg/m³. These concentrations are below the daily standard air quality, but above the annual standard established by the Brazilian legislation. The total concentrations of polycyclic aromatic hydrocarbons (PAHs) measured were between 13 and 94 ng/m³, comparable to the values found in Naples, in Italy, and above those measured in Santiago de Chile, and in Seoul, in South Korea. The PAH analysis indicated high levels of B[a]P (1.9 ng/m³), of special interest due to its carcinogenic properties and the fact that it is at higher levels in major cities in the world such as London, in England. As benzopyrene is usually present in grass burning, the authors suggest that, in Araraquara, it originates from sugarcane burning, not from urban activities.

Oppenheimer et al¹⁹ (2004) used a compact ultraviolet spectrometer to measure nitrogen dioxide (NO₂) emission from sugarcane burning in the state of São Paulo. NO₂ emission from a 10-hectare plot of land reached a peak of 240g (NO₂)/s, and added up to approximately 50kg of N, or about 0.5g (N)/m². Nitrogen emission such as NOx (NO+NO₂) was estimated at 2.5g (N)/m², equivalent to 30% of nitrogen fertilizer applied to crop fields.

During a period of one year, aerosols were measured in the city of Piracicaba. The average concentrations of PM 2.5 and coarser particles (2.5 to 10µm) were statistically higher in the dry season than in the rainy one. Component analysis indicated that sugarcane burning was the main source of PM 2.5 (60%), Soil dust was responsible for 14%, while factories and combustion, 12% each. Re-suspended soil dust was the major source of coarser particles, followed by industrial emissions and sugarcane burning. The authors concluded that sugarcane and farming practices were the main sources of inhalable particles around the city, also affecting the chemical composition of rainwater (Lara et al¹³ 2001; Lara et al¹⁴ 2005).

Measurements outside the areas immediately surrounding the fires indicated the background level and the fact that, during the burning period, smaller particles were more acid, contained higher concentrations of sulphates, nitrates and organic species, but insufficient NH₄⁺ and K⁺ to reach neutrality. In the winter, the relative contribution of emissions from transportation and factories decreased due to the increase in emissions from biomass combustion and other harvest time-related activities. The concentrations of pollutants were lower than what is usually found in polluted urban zones. Nonetheless, the authors concluded that pre-harvest sugarcane burning influences the aerosol chemistry on a regional scale; also, that the differences between air masses from

^a Cançado, JED. A poluição atmosférica e sua relação com a saúde humana na região canavieira de Piracicaba – SP [tese de doutorado]. São Paulo: Faculdade de Medicina USP; 2003.

^b Darley EF; Lerman SL. Air pollution emissions from burning sugar cane and pineapple residues from Hawaii. North Carolina: Environmental Protection Agency; 1975. (EPA Publication, 450/3-75-071)

distinct origins were small. On the other hand, they assessed that, in urban areas and their surroundings, vehicle emissions had a greater impact (Rocha et al²³ 2005; Allen et al¹ 2004; Rocha et al²² 2003).

HEALTH RISKS

Despite their restrictions and cautious conclusions, the studies analyzed indicate health risks in adverse atmospheric conditions, caused by sugarcane straw burning. These risks can be higher among children, elderly people and asthmatics, mainly resulting in higher demand for health care. Until recently, studies on sugarcane were mostly concerned about workers in the productive process, such as Phoolchund's investigation²⁰ (1991), which showed that sugarcane cutters were at higher risk of lung cancer as a consequence of foliage burning. As the global environmental crisis worsened and people became more aware of this issue, especially as regards climate changes resulting from polluting human activities, there has been an increase in biofuel production. Among these fuels, sugarcane is the fastest-growing one. However, its burning has increasingly been opposed by public opinion, allegedly due to its environmental and human health impact, even though Brazilian health organs have had little participation in this discussion. In the state of São Paulo, due to the environmentalists' pressure, the law that foresees gradual elimination of fire utilization to facilitate sugarcane cutting, until 2021 for mechanized areas, and until 2031 for non-mechanized areas, was approved in 2002.

The few studies on the effects of sugarcane burning hint at the health impacts on the general population, though many questions are still left unresolved.

On the other hand, research on the health effects of biomass burning, especially as regards uncontrolled forest fires (Ribeiro & Assunção²¹ 2002), may help to define a health policy for this issue and guide future research.

Frankenberg et al⁸ (2005) concluded that individuals exposed to biomass smoke experienced more difficulty in their daily activities, even though general and respiratory health effects were more difficult to interpret.

Kunii et al¹² (2002), while assessing the effects of Indonesian forest fires, including interviews and pulmonary function tests in 54 people, verified that more than 90% presented with respiratory symptoms and that elderly people suffered severe deterioration of their health condition. By means of multivariate analysis, the study showed that gender, history of asthma and frequency of mask use were associated with the severity of the respiratory problem.

Negative effects of Indonesian fires were also assessed in the Malaysian population (Sastry²⁵ 2002). Mott et al¹⁸ (2005) investigated the exposure effects on the cardio-respiratory health of hospitalized people in the Kuching region, in Malaysia. The authors selected admissions

from 1995 to 1998 to verify if hospitalizations during or after fires in neighboring countries exceeded the predicted number of hospitalizations, in accordance with historical records. There was statistically significant increase in the number of hospitalizations due to respiratory diseases, especially asthma and chronic obstructive diseases. Survival analysis indicated that people over 65 years of age, who had been previously hospitalized for any reason, with any respiratory, cardio-respiratory, or chronic obstructive pulmonary disease, were more likely to be hospitalized again after the burning period. These cited articles reveal the relationship between non-localized, cross-border pollution caused by biomass burning and the vulnerability of some specific groups of the population, especially elderly people and those who suffer from any of the foregoing diseases.

According to Sapkota et al²⁴ (2005), in addition to affecting neighboring communities, pollution originated from forest fires can travel thousands of miles to heavily populated urban areas. Fire effects in Canada resulted in a high concentration episode (up to 30 times higher) of particulate matter, especially finer one, in the city of Baltimore, in the United States. In 2003, forest fire smoke in Siberia was tracked by means of airplane and ground observations, thus indicating their transportation to North America. This caused an increase in background pollution in Alaska, Canada and the northeast Pacific Ocean by 23–37 ppbv of carbon monoxide and 5–9 ppbv of ozone. This increase in background ozone contributed to the air quality standard for ozone being exceeded in the northeast Pacific Ocean. According to the authors, regional air quality and health are connected to global atmospheric processes (Jaffe et al¹¹ 2004). Similarly, research has pointed to the effects of sugarcane burning on a regional scale. Nonetheless, as this burning may have greater spatial influence, the size of the population under the risk of health effects would be larger.

According to Jacobson¹⁰ (2004), the elimination of particles originated from burning may cause an increase in atmospheric temperature in the short run, and cooling of the climate in the long run due to elimination of carbon dioxide. Analytically, biomass burning always leads to carbon dioxide accumulating, even when vegetation recovery and sprouting cycles are equivalent to emission flows. Thus, Jacobson concluded that biomass energy is only partly renewable, because its burning contributes to global warming.

Another concern related to burning is the transport of fungus spores and bacteria for long distances. Mims & Mims III¹⁷ (2004) verified the presence of fungus spores and bacteria, including the *Alternaria*, *Cladosporium*, *Fusariella* and *Curvularia* genera, in smoke originating from biomass burning. The authors argue that sugarcane rust caused by the *Puccinia melanocephala* fungus in the Dominican Republic was transported from Africa by convection originated from the fire, which would have taken spores to the upper atmosphere, where they would

have moved on to the Caribbean. Thus, burning could contribute to the spread of pathogenic microbes. Fungus spores (such as *Alternaria*) cause allergic reactions and trigger asthma attacks, as well as smoke inhalation.

Recently, epidemiological studies have showed evidence of the relationship between air pollution and cardiovascular diseases, particularly myocardial infarction. According to Vermeylen et al²⁶ (2005), ozone can have direct, harmful cardiovascular effects, whereas other gases can increase the negative effects of particulate matter. Particles with smaller diameter have a greater impact, but PM10 can quickly penetrate and deposit on the trachea and bronchioles. PM2.5 can reach narrow airways and alveoli, whereas ultra-fine particles, smaller than 100 nm (0.1 µm), have high alveolar deposition. The total number of deposited particles may increase four to five times during exercise, due to higher ventilation. Ultra-fine particles represent most part of the particulate matter and have higher area/mass ratio, which would increase biological toxicity, as they can go directly into the bloodstream. The populations at highest risk are the elderly, those with chronic pulmonary or coronary disease, and diabetics. Whereas acute air pollution can trigger myocardial infarction in hours or days among those who are susceptible, chronic exposure to pollutants increase the risk of cardiovascular diseases that may be related to chronic pulmonary inflammation.²⁶ Sugarcane burning would simultaneously have both effects: acute air pollution in the neighboring areas and diffuse air pollution in the long run, on a regional scale.

During burning, combustion is incomplete, with the formation of compounds that are not completely oxidized, thus irritating to the respiratory system and, in some cases, carcinogenic. Malilay¹⁶ (1999) affirmed that fine particulate matter reach the alveoli and in great concentrations get into the bloodstream or stay in the lungs, resulting in chronic diseases such as emphysema. Toxic organic vapors such as PAHs are possibly carcinogenic. Carbon monoxide may cause hypoxia by preventing blood from carrying enough oxygen. Fetuses are particularly susceptible, as they cannot compensate for the oxyhemoglobin reduction without sustained increase in cardiac frequency. Aldehydes are irritating to the mucosa and some, such as the formaldehyde, can be carcinogenic. Volatile organic compounds may irritate the skin and eyes, and cause drowsiness, cough and wheezing; in addition, some of them are carcinogenic. In high concentrations, ozone can affect the pulmonary function; whereas, in low concentrations, it can cause cough, choking, breathlessness, mucus, throat burning and irritability, nausea, and a decrease in pulmonary function when exercising (Malilay¹⁶ 1999).

FINAL CONSIDERATIONS

Despite the weight of farming residue burning as an old practice, spread around tropical countries to control

plagues and eliminate harvest residues, there are public health issues that need to be further studied at this time of expansion of biofuel production.

Yevich & Logan²⁸ (2003) estimated that, in 1985, 400Tg of farming residues were burned in fields, and that Brazil was the country that most generated these residues in Latin America, especially sugarcane straw. According to the authors, this biomass burning has a significant impact on the global atmospheric chemistry, as it produces great amounts of carbon monoxide, nitrogen oxides and hydrocarbons, thus representing non-neglectable contribution with negative effects, particularly in the regional sphere.

Pre-harvest sugarcane burning aims, above all, to eliminate its residue, straw, in order to facilitate manual harvesting or decrease its volume for incorporation into the soil. Among the difficulties for total elimination of burning, as foreseen by the state of São Paulo's legislation, are the producers' restrictions regarding the price and deficiencies of mechanic harvesters; as well as the manual cutters', who earn per harvest and can perform better and be at a lower risk of harm from poisonous animals found in the burned sugarcane (Braunbeck & Magalhães⁷ 2004; Weekes²⁷ 2004). Sugarcane plantations represent the highest farming workforce demand in the state of São Paulo (35%), especially the ones with low level of education (Braunbeck & Magalhães⁷ 2004). Furthermore, there have been unexplained deaths of workers in the plantations. Alves² (2006) attributes them to the physical effort to achieve better cutting productivity. However, there could be a relationship between sugarcane burning and these deaths, as heavy physical exercise performed during cutting, in a place where there is a high amount of soot, would contribute to increase respiratory health risks. This relationship needs to be investigated.

Moreover, future studies on this issue need to focus, in addition to respiratory diseases and their symptoms – particularly excessive asthma cases –, on other effects and risks, such as tumors, cardiovascular diseases, impacts on daily activities of the affected people, re-hospitalization of the elderly and biological risks.

Replacement of burning by mechanic harvesters will certainly benefit health conditions of those living in the sugarcane areas. However, to actually guarantee improvement in the cutters' health, programs for their re-qualification and hiring need to be developed and executed immediately.

Finally, even with the enforcement of the law that forbids burning in the state of São Paulo, sugarcane will continue to be burned in the rest of the country and its residues will still be burned in power plants (Rocha et al²³ 2005). Thus, a national policy to prevent health hazards will also depend on the efficacy of fire control across the country, as well as power plant emissions.

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