Article

Diesel Emissions Increase Air Pollution during the Carnival Festival in Salvador, Bahia-Brazil

Nelzair A. Vianna[a,b,c]*, Priscila Novaes[c], Nelson Gnoatto[d], Simone Miraglia[e], Paulo H. Saldiva[b] and Leonardo R. Andrade[f]*

[a]Oswaldo Cruz Foundation, FIOCRUZ, Salvador, BA, Brazil
[b]Laboratory of Atmospheric and Experimental Pollution, School of Medicine, University of São Paulo, São Paulo, SP, Brazil
[c]Secretaria Municipal de Saúde de Salvador, Salvador, BA, Brazil
[d]Faculty of Dentistry, Federal University of Bahia; Faculty of Dentistry, State University of Feira de Santana, BA, Brazil
[e]Institute of Enviromental, Chemistry and Pharmaceutics Sciences (ICAQF), Federal University of São Paulo, São Paulo, SP, Brazil.
[f]Laboratory of Biomineralization, Institute of Biomedical Sciences, Federal University of Rio de Janeiro, Rio de Janeiro, RJ, Brazil.
*Corresponding authors: NAV: Laboratory of Epidemiology and Biostatistics, Oswaldo Cruz Foundation, Brazilian Ministry of Health. Av. Waldemar Falcão, 121, Candeal, Salvador, BA, Brazil, 40296-710
Email: nelzair.vianna@bahia.fiocruz.br
LRA: Av. Carlos Chagas Filho 373, room F2-30, ICB, CCS, UFRJ, Cidade Universitária, Rio de Janeiro, RJ, Brazil, 21941-902
Email: andrade@histo.ufrj.br

List of abbreviations

PM: Particulate matter

NO_2: Nitrogen dioxide

B50: petroleum diesel with 50% of vegetable oil

CO_2: Carbon dioxide

Abstract: Atmospheric pollution arising from diesel-powered engines can result in acute and chronic diseases of the respiratory and cardiovascular systems. The annual carnival festival that takes place in the city of Salvador, Bahia-Brazil, is a large-scale event that gathers approximately 2m revelers and 170,000 workers who accompany dozens of sound-trucks, or *trios elétricos*, for a period of seven days. These slow-moving sound-trucks run on diesel fuel, constantly exposing those around them to exhaust fumes. The present study aimed to evaluate air quality along the approximately 10km-long carnival parade circuit and determine possible impacts on human health. We applied a three-phase risk analysis strategy from 2007–2009: 1) hazard identification, 2) risk characterization and 3) risk management. Our quantification of atmospheric particulate matter 2.5 (PM2.5) and nitrogen dioxide (NO_2) concentrations revealed variable levels of PM2.5 ranging from 19 μg/m^3 to 580 μg/m^3, with peaks of up to 800 μg/m^3 at sound-truck concentration areas. We then assessed the effects of air pollution on human health using ophthalmologic parameters obtained from 28 carnival volunteers, who often presented symptoms of eye irritation. Finally, we established strategies to communicate the study's objectives and obtained results to the population through media outlets and open discussions with government agencies. According to our risk analysis, carnival sound-trucks represent the main source of atmospheric PM2.5 and NO_2 pollution during the annual 7-day carnival festival. As a consequence of our research, the municipal government of Salvador issued an addendum to its carnival legislation mandating organizers to monitor atmospheric pollution, and, subsequently, all large-scale public events. Municipal government authorities have also promoted a shift from petroleum-based diesel fuel to biodiesel, a less-polluting fuel, for all adapted carnival sound-trucks. Our approach, which employed easily accessible and inexpensive methodology, provided substantial scientific evidence to support improvements in the regulation of air quality during large-scale public events held in the city of Salvador.

Keywords: environmental health; risk communication; risk management; particulate matter; risk analysis; mass event

1 Introduction

Air pollution emitted by vehicle exhausts has been directly associated with acute and chronic diseases, affecting mainly the respiratory and cardiovascular systems [1- 5]. Among all atmospheric pollutants, particulate matter (PM) with an aerodynamic size inferior to 2.5 μm (PM2.5) is considered the most toxic contaminant encountered in urban areas [6]. One of the main sources of PM2.5 is diesel-powered vehicles, which emit 100 times more particles than gasoline engines [7]

The carnival festival in the city of Salvador (capital of the state of Bahia, Brazil) is the largest mass-scale event of its kind in the world, involving the participation of approximately 2 million people, including 170,000 workers [8] (Figure 2). Groups of thousands of people parade along extensive carnival circuits, following dozens of sound-trucks, or *trios elétricos*, featuring famous singers and bands performing on open-roof sound-trucks. Besides these sound-trucks, additional support-trucks provide additional infrastructure, including bathrooms, restrooms and mobile food and drink stands to serve revelers. Sound- and support-trucks, in addition to electricity generators, use petroleum-based diesel as a fuel source. During the annual 7-day festival, revelers and workers are exposed to PM and toxic exhaust pollutants for more than 12 h per day. In addition, many *camarotes*, or constructed VIP viewing areas, are set up along the parade circuits; these structures or buildings are adapted to receive thousands of paying spectators who watch festivities from balconies. According to EMTURSA (the official agency responsible for festival organization), *camarotes* can contain up to four people per square meter. In Brazil, carnival has historically been a very popular festival, with a high degree of public participation. In Salvador, over the years, an increasing number of revelers and the complexity of managing festivities along the parade circuits

has resulted in the imposition of rigorous regulation by the local municipal government. Studies investigating the relationship between carnival revelers and government authorities have found that, while usually respectful, some conflicts do exist, especially with respect to cultural and commercial issues [9].

Developing countries, such as Brazil, may accumulate different types of risk, from those inherent in the technological and industrial expansion occurring in major centers, as well as those associated with basic conditions of social, cultural and environmental vulnerability. The lack of continuous monitoring of air pollutants in Brazilian metropolises remains a public health problem. In this context, the World Health Organization [10] has recommended the use of any comparable methodology, even those considered rudimentary, for the detection and quantification of atmospheric pollutants, principally in regions lacking data. The relevance of providing information regarding any indicators of pollution levels has elevated the debate among the population and government officials with regard to the risks presented to human health by air pollution [11]. Consequently, public policies should include the mitigation of risks to which the population is exposed, as well as constant air-monitoring programs. Several authors have mentioned the need to apply different methods to provide scientific evidence pertaining to the actual risks presented by air pollutants with respect to human health, and then communicate this information to the public and government [11-15]. Methodological approaches that could be applied uniformly across the entire territory represent one of the greatest challenges for the Brazilian public sector [16,17].

The methodology of risk analysis employs different environmental health indicators to support public policy decision-making, thusly guiding risk management strategies [18]. The crucial steps for the development of risk analysis indicators are: hazard identification, the characterization of possible effects on human health and data communication. The overall risk analysis becomes more complex when environmental, climatic, social and economic conditions differ from one locality to another. Risk communication is not only a manner of communicating research findings to the community and stakeholders, but also a way to provide suitable recommendations to improve the current scenario [19]. The risk analysis approach involve scientific methods and decision-making, according to principles adopted by National Research Council [20] and Society of Risk Analysis. Risk analysis has many applications, including air pollution, climate change, traffic safety, criminality and terrorism, among others [21]. Aven and Zio [22] on the foundations of risk assessment and risk management, define risk analysis as knowledge about risk-related phenomena, processes, events, etc., as concepts, theories, frameworks, approaches, principles, methods, and models to understand, assess, characterize, communicate, and (in a wide sense) manage risk, in general and for specific applications.

To date, the possible health impacts of air pollution generated by diesel sound-trucks have never been evaluated in a local context. Accordingly, our study aimed to apply a 3-phase risk analysis approach in an attempt to quantify the effect of air pollution during this large-scale event as follows: 1) hazard identification, 2) risk characterization/risk assessment, and 3) risk management (including risk communication).

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Figure 2. Groups of thousands of people parade along extensive carnival circuits, following dozens of sound-trucks or *trios elétricos*, included vulnerable workers.

2 Materials and methods

2.1 Study design

The present study employed a risk analysis approach separated in three phases, as illustrated below (Figure 1):

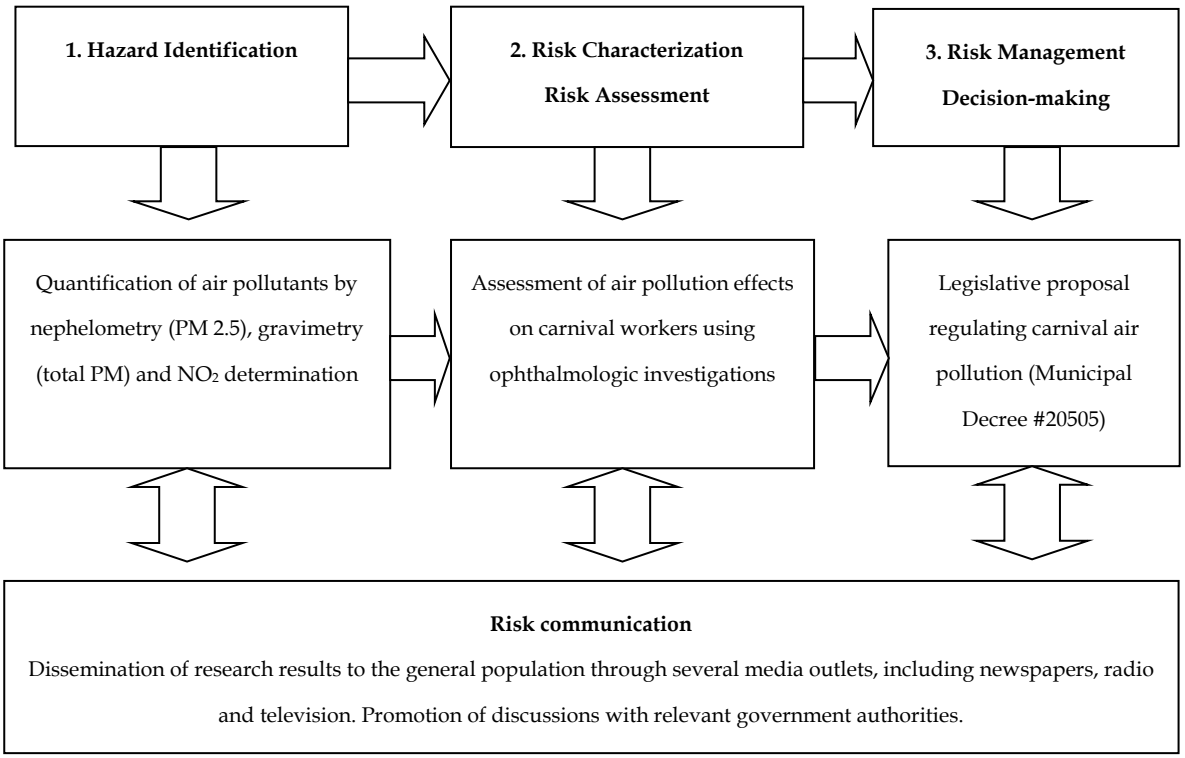

Figure 1. Risk analysis approach separated in three phases

2.2 Area of study

The city of Salvador (12°58′29″S 38°28′36″W), the capital of the state of Bahia, encompasses a metropolitan area of 693 km², with approximately 2.9m inhabitants and a total car ownership of 887,831 vehicles [24], Salvador has a tropical rainforest climate, receiving a constant breeze from the Atlantic Ocean, with average annual temperatures around 25.3ºC, 80% humidity and 2,144 mm of

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average annual rainfall. The annual carnival festival usually occurs in February, during the summer season, which has an average rainfall around 142 mm. Data collection took place from 2007-2009 during the 7-day carnival periods along two parade circuits: *Dodo* (4 km-long) and *Osmar* and *Batatinha* circuit (7 km-long).

2.3 Phase 1: Hazard identification

2.3.1 Nephelometry

Regular vehicular traffic is blocked along the parade routes throughout the duration of the 7-day carnival festival. Since vehicle exhausts are mostly responsible for generating PM2.5, carnival sound-trucks essentially represent the sole source of atmospheric PM2.5 emissions. We quantified PM2.5 along the carnival circuits and in *camarotes* using a DUSTTRAK 8250 portable aerosol monitor (TSI Inc, MN, USA). PM2.5 atmospheric concentrations were analyzed in four situations: (1) At a control site, with no sound-trucks but surrounded by numerous revelers; (2) Alongside newer sound-trucks, with less than two years of use (N = 5); (3) Alongside older sound-trucks, 10 years or older (N = 5) and (4) At a carnival concentration area, in which dozens of sound-trucks sit idle while waiting their turn to commence. The number of revelers accompanying different musical groups that performed on the top of sound-trucks ranged from 1,000–4,000 thousand people each day. PM2.5 concentrations were acquired for 4 h each day at similar time periods for seven consecutive days during the 2007-2009 Carnival festivals, with sampling intervals of 1 min, a flow rate of 1.7 liters per minute (L/min) and a range detection of 0.001 - 100 mg/m^3. The portable aerosol monitor quantified the air at various points around the sound-trucks, including next to the sound-truck itself and its site of generator exhaust, simulating the revelers' behavior during the parade.

The air quality of four *camarotes* (500 - 1,000 m^2) with an attendance of 300 to 2,000 people per day, located along the two carnival parade circuits, was also analyzed for 4 h each day. These *camarotes* include ample balcony areas where paying spectators closely watch the parade below. PM2.5 concentration was measured when sound-trucks were passing by and afterwards. In addition, we also analyzed air-conditioned indoor areas where people congregate to eat or see private shows during the festival at nighttime. Similar areas were analyzed in each of the four *camarotes*.

2.3.2 Gravimetry

This simplistic technique determines the total amount of dust (or PM) deposited at a specific point during a window of time [25]. The day before the carnival festival began, ten locations distributed along the two parade circuits (five on each) were chosen for gravimetric analysis. This method consisted of fixing a clean cardboard paper with a 20 x 15 cm slot at a height of 3m on concrete utility poles. Prior to placement, each pole surface was brushed off and washed with distilled water. Following the 7-day Carnival period, the suspended dust that had accumulated on the concrete pole at each demarcated area was carefully collected using moistened clean cotton gauzes, previously weighed in the laboratory. Gauzes were dried at 60^{o}C, weighed on an analytical scale, with results are expressed as weight differences before and after dust collection.

2.3.3 NO_2 quantification

To measure the cumulative concentration of NO_2 exposure during the 7-day carnival festival, the passive method described by Novaes *et al.* [26] was used. Passive sampler devices were placed along nine sites along the parade circuits (Praça Municipal – control area, Casa de Itália, Vitória, Canela, Piedade, Farol da Barra, Praça Castro Alves, Ondina-Espanhol, Ondina-Apart) for seven days. These samplers contained a sterile cellulose filter soaked with 2% triethanolamine, 0.05% *o*-methoxyphenol and 0.025% sodium metabisulfite. The nitrite produced during sampling was

quantified colorimetrically, as previously described Novaes *et al*. Daily exposure levels were estimated by dividing the cumulative NO_2 measurement by the total number of days of exposure.

2.4 Phase 2: Risk characterization – exposure assessment

The effects of air pollution on human health were evaluated using ophthalmologic parameters (eye symptoms and cytology of the conjunctiva), according to Novaes *et al*. [23]. As the ocular surface is directly exposed to environmental air, pollutant effects can be evaluated via clinical observations and minimally invasive laboratory techniques. Twenty-eight volunteers (sound-truck staff) were studied, all of whom were directly exposed to vehicle emissions throughout the 7-day carnival period. After signing a term of informed consent, volunteers were clinically observed and asked to report the frequency of the following eye symptoms: foreign body sensation, irritation, red eyes, dry eyes, eyestrain or tired eyes, burning sensation, photophobia, tearing, itchiness or mucus discharge.

Impression cytology was performed to analyze the integrity of the ocular surface epithelium and to detect the presence of goblet cells via the following procedure: a drop of topical anesthetic (tetracaine hydrochloride) was placed in each eye and left for 5 min; a sterile membrane filter measuring 15 mm in diameter (Millipore, cellulose ester, 22 μm pore) was gently pressed for 10 sec against the inferior tarsal conjunctiva; after instillation, this filter was peeled off and transferred to falcon tubes containing absolute ethanol. All tubes were then placed in Styrofoam boxes and transported to the Laboratory of Pathology of the University of São Paulo Medical School for processing and analysis. Membrane filters were rehydrated in 70% ethanol, sequentially immersed in Schiff's reagent after periodic acid, sodium metabisulfite, Gill's haematoxylin, Scott's tap water, 95% ethanol and absolute ethanol. Next, xylene was applied to clarify the filters and slides were examined by light microscopy (Axioplan, Zeiss). Goblet cells were counted in 10 different fields using a 40x objective lens.

2.5 Phase 3: Risk management

Risk communication plays a central role in the process of risk analysis. The present project schedule was previously discussed with and approved by the relevant government sectors responsible for the organization and administration of the annual carnival festival. Quantification of PM2.5 within *camarotes* was previously authorized by their respective owners and operators. All carnival workers, as well as the local population, were informed regarding this air quality study in advance via press conferences and newspaper articles. The obtained results were presented to and discussed with local health and environmental agencies, the academic community and media institutions in general.

2.6 Statistical analysis

Statistical analysis was performed using R software, version 2.3.1, and SPSS statistical software, version 15 (SPSS Inc., Chicago, IL, USA). A multiple linear regression model was employed to analyze data from Phase 2, in which the dependent variable was tarsal cytology, while explanatory variables consisted of mean NO_2 concentrations, number of days of pollutant exposure, number of hours worked per day and dry eye symptoms. Correlations between goblet cell counts and corresponding NO_2 exposure levels were determined using Spearman's correlation. The effect of air pollutants on goblet cell counts was also correlated by analysis of variance (ANOVA) and Bonferroni's post hoc test. The level of statistical significance was set at 5%. PM data were tabulated based on descriptive statistics (mean, median, standard deviation, minimum, maximum and quartiles).

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3 Results

3.1 Hazard identification

3.1.1 Nephelometry

PM2.5 concentrations in the four different conditions varied from 19 μg/m³ (control site - no sound-trucks) to 580 μg/m³ (concentration area of the sound-trucks) (Table 1). As expected, older sound-trucks discharged the highest amounts of PM2.5 (210 μg/m³) in the atmosphere compared to newer sound-trucks (52 μg/m³). Peaks up to 800 μg/m³ were measured at the sound-truck concentration area, in which more than 15 sound-trucks idle prior to making their way along the parade route.

	Control site (no sound-trucks)	Newer sound-trucks	Older sound-trucks	Sound-truck concentration area
Mean (mg/m³)	19.1	52.4*	210*	580*
SD	2.5	9.4	69.1	134

Table 1. PM2.5 concentrations (in μg/m³) acquired by nephelometry generated by newer and older sound-trucks, as well as at the control site and the concentration area. Values are expressed as means and standard deviations. *significant difference in comparison to control ($p<0.05$).

The PM2.5 quantified at *camarote* balconies and indoor air-conditioned areas is shown in Table 2. The mean PM2.5 value quantified when the sound-trucks and revelers passed in front of the *camarotes* raised from 53 to 390 μg/m³ in the balcony areas, suggesting that this increase may be associated with dust suspension and sound-truck exhaust. We detected a mean of 1,265 mg/m³ in air-conditioned areas inside the *camarotes*, with peaks up to 1,600 μg/m³. The high PM2.5 concentration measured in these areas was not related to truck exhaust, but rather to fog machines.

	Balconies with no sound-trucks nearby	Balconies with sound-trucks passing by	Indoor areas
Mean (μg/m³)	53.7	390*	1,265*
SD	15.4	180	650

Table 2. Means and SD of PM2.5 concentrations measured by nephelometry in four *camarotes*. Measures were acquired when sound-trucks were passing in front of the balconies or not, and in indoor areas. * significant difference compared to controls ($p<0.05$).

3.1.2 Gravimetry

No significant differences were observed between the total PM deposited on the poles along the parade circuits and those located off the circuits. However, the amount of PM that adhered on poles located at the carnival sound-truck concentration area was significantly higher than in the other two areas along the circuits (Table 3). Even though gravimetry is much simpler in comparison to mechanical monitoring, for instance, total PM results were comparable with nephelometry (PM2.5). It became clear, as demonstrated by the two PM monitoring methods used herein, that the air in the carnival sound-truck concentration area was highly polluted with respect to PM2.5. Around 5,000 people gather in this concentration area to watch the spectacle.

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	Control site (no sound-trucks)	Parade circuit sites	Sound-truck concentration area
Mean (mg)	15.5	20.9	35.6*
SD	2.3	4.6	6.7

Table 3. Concentration of total PM measured by gravimetry (in mg). * significant difference compared to controls ($p<0.05$).

3.1.3 NO_2 determination

The cumulative concentration of NO_2 varied from 30 μg/m³ (control area with no sound-trucks) to 79 μg/m³ (sound-truck concentration area) among the nine areas analyzed, as shown in Table 4. As expected, the control site presented the lowest NO_2 concentration, while the Vitória and Casa de Itália sites had the highest concentrations, and presented the only significant differences to the control site.

Sites	Praça Municipal (control) **	Vitória	Canela	Piedade	Casa de Itália	Farol da Barra	Castro Alves	Ondina Espanhol	Ondina Apart
Day 1	30	74*	65	47	70	43	40	57	36
Day 7	31	79*	70	49	76*	45	42	61	38

Table 4. Concentration of NO_2 obtained by the passive sampler method (μg/m³) analyzed on Day 1 and Day 7. *indicates significant differences at Vitória, the carnival sound-truck concentration area site, compared to controls ($p<0.05$); ** Praça Municipal site is the carnival no sound truck area.

3.2 Risk characterization - Exposure assessment

The most frequent eye symptoms observed in carnival volunteers were: stinging sensation (64%), ocular irritation (54%) and redness (46%). Some volunteers complained about more than one eye symptom. Under linear regression analysis, a significant correlation was seen between the number of goblet cells (or PAS positive areas) and NO_2 concentrations ($p<0.05$, $R^2=0.33$), indicating that volunteer eyes were more affected in areas with higher NO_2 concentrations. This was confirmed by impression cytology, with four times the number of goblet cells found in volunteers working in Vitória than those working around Praça Municipal (control site) (Fig. 1).

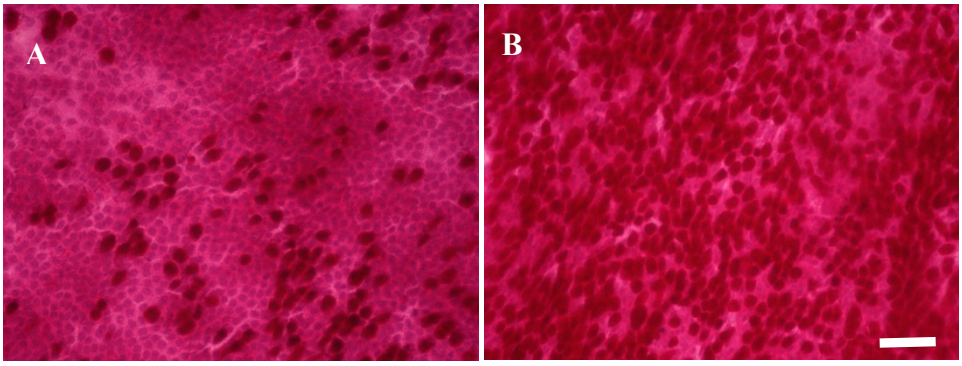

Fig. 1. Representative images of impression cytology collected from two volunteers. 1A: Cytology of a volunteer who worked in the lowest NO_2 concentration area, showing 85 ± 12 PAS-positive (darker) cells per field. 1B: Cytology of a volunteer who worked in the highest NO_2 concentration area, presenting numerous goblets cells (350 ± 58 PAS-positive cells per field), 4x higher than the other volunteer. Scale: bar = 50 mm

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3.3 Risk management

An important element of this study entailed risk communication. Our group held discussions with the Salvador Environment Agency (SEMA) regarding planned actions during carnival, including air monitoring, the clinical approach employed regarding volunteers and risk communication to the general public. Table 5 delineates 11 reports published in different Brazilian newspapers (mostly in the state of Bahia) regarding this project to monitor air pollution during the 7-day carnival festival. These reports, published in 2007, informed the public about possible risks related to the PM generated by the sound-trucks with respect to the health of carnival workers and revelers. Since our initial hypothesis was that diesel-fueled sound-trucks would increase the PM on the parade circuit was confirmed, the following reports published in 2008 discussed the possible influences of air pollution on human health.

A significant consequence of our work was modifications in legislation concerning atmospheric pollution pertaining not only to the Salvador carnival festival, but also to other large-scale open-air festivals. A municipal decree (decree no. 20,505; Art.12; page 9).#20,505, published on December 28, 2009, (Prefeitura Municipal de Salvador, 2009), included a term of responsibility in which SEMA became obligated to monitor emitted air pollution levels during any mass event occurring in Salvador.

Report title	Publication name and date
Air monitoring in Carnival	Bahia Viva, Salvador, p. 22 - 23, Apr.5, 2008.
Air pollution limits exceeded in carnival	A Tarde, Salvador, Feb. 15, 2008.
Research monitors air pollution	Correio da Bahia, Salvador, p.3, Jan. 31, 2008.
Salvador is one of the champions in respiratory diseases	Correio da Bahia, Salvador, p.4, Sep. 15, 2007.
Air is more polluted in Salvador	A Tarde, Salvador, p. 7 -. 7, May 11, 2007.
Decarbonizing the Bahian carnival	Folha de São Paulo, São Paulo, Feb. 18, 2007.
Municipal Secretary of Health monitors the emission of pollutants emitted by sound-trucks during Carnival	Diário Oficial do Município, Salvador, Feb. 17, 2007.
Bromeliads will indicate if Carnival causes pollution	A Tarde, Salvador, p. 5 – 5, Feb. 14, 2007.
Air quality will be monitored	Correio da Bahia, Salvador, Feb. 14, 2007.
Biochemistry will monitor air quality during Carnival in Salvador	Tribuna da Bahia, Salvador, p.9 – 9, Feb. 14, 2007.
Carnival revelers raise dust and call the attention of specialists	ASCOM/SEMA, Salvador, Feb. 06, 2007.

Table 5. List of reports published in periodicals from 2007 to 2008. Most of these appeared in local newspapers.

4 Discussion

Our study sought to collect information on air quality during a specific event, the 7-day carnival festival that takes place annually in Salvador-Bahia, Brazil, the biggest street festival in the world, and subsequently produce risk analysis information to benefit the population and inform government institutions. Each day, thousands of people gather around carnival sound-trucks, powered by petroleum diesel, for extended periods. In accordance with risk analysis methodology [18}, three steps were essential to our approach: 1- risk characterization, 2- risk assessment and 3- risk communication. The first stage determined air quality based on levels of total PM (gravimetry), PM2.5 (nephelometry) and NO_2 (passive method) along the parade circuits and in a control area. The levels of PM2.5 generated by the sound-trucks reached up to 23 times higher than the daily average level recommended by the WHO: 25 $\mu g/m^3$. The method applied to estimate total PM throughout the carnival festival indicated that the area in which the carnival sound-trucks concentrate prior to

proceeding along the parade routes presented the highest concentrations of total PM. According to the WHO, the use of alternative methods for the detection of pollutants should be encouraged in locations where resources are scarce. Our results show that the use of a rudimentary technique (gravimetry) to monitor air quality was nonetheless validated by a more robust method (nephelometry). It is important to note that researchers must use caution with respect to data interpretation and conclusions reached using the gravimetry method.

Our risk assessment approach showed that minimally invasive techniques and a short questionnaire on eye symptoms were capable of demonstrating the significance of health impacts arising from air pollutants encountered along the parade circuits in Salvador. A potential consequence of these eye exam findings would be a more robust search to identify other adverse health effects, especially with respect to respiratory and cardiovascular systems [27] . A significant association between the numbers of goblet cells was observed in volunteers who worked at locations with higher NO_2 exposure levels. Ocular surface cells exhibit a response to acute short-term exposure to elevated levels of indoor and outdoor air pollution. An increase in goblet cells on the ocular surface and other mucosal surfaces has been previously documented when humans are chronically exposed to air pollution [28-36].

According to the WHO [10], risk communication (phase 3) is essential to the establishment of air quality programs, especially when supported by scientific data. Risk communication should extend to all potential stakeholders, including public and private sectors, researchers on an interdisciplinary context, the media and the general public [37]. Our study attempted to disseminate relevant scientific findings through the scholarly field and the media outlets to facilitate dialogue and raise awareness among the public. The present work contributed significantly to facilitate discussion among scholars and with government officials, and, as a consequence, actions have been taken by appropriate government authorities.

Within the limits of data analysis and its uncertainties [20], the risk analysis approach of the present investigation may be used as parameters for both quantitative and qualitative evaluations in multiple interdisciplinary scholarly fields.

We considered our interaction with government officials satisfactory with respect to the planning and execution of our work. The most relevant impact of our work resulted in the issuance of Decree #20.505/2009 by the municipality of Salvador [38], which delegated the responsibility of monitoring air quality during carnival and other large-scale public events to the appropriate environmental authorities. During our discussions, a consensus was reached regarding the need to control pollutant emissions during these types of mass-scale festivals.

Based on our results, in 2008 local government officials, in association with the private sector, launched a campaign entitled “Sustainable Carnival,” which promoted the use of biodiesel, a fuel that emits far fewer particulate matter than conventional diesel [40]. In its first year, the campaign had little effect due to difficulties faced by supplying the quantity of biodiesel needed to meet the demands of carnival. In 2009, improvements were made and the campaign successfully supplied biodiesel to all adapted carnival sound-trucks. The number of sound-trucks running on clean energy has increased and the government issued a certificate of quality these "biodiesel trios." In 2013, B50 biodiesel (petroleum diesel mixed with a 50% ratio of vegetable oil) was used in more than 120 carnival sound-trucks, which translated into 73 tons less CO_2 released into the atmosphere [39]. According to Cox, [40] a “good” decision procedure might be defined as one that, despite all uncertainties, performs almost as well as some ideal procedure. Though biodiesel has been cited as a source that emits less pollutants, Yang *et al.* [41] called attention to the fact that, in comparison to premium diesel fuels, diesel-waste-cooking oil-butanol blends could increase CO emissions, yet may significantly reduce the emissions of PM10, PM2.5, and NOx. Accordingly, policies that promote biodiesel as a “safe” alternative to conventional diesel fuels must be considered with caution. The comparative *in vivo* health effects of diesel and biodiesel emissions are not well characterized, however Li et. al.,[42] revealed that diesel exhaust at a relatively high concentration (500 lg/m3) can induce inflammation acutely in healthy mice and exacerbate some components of allergic responses,

while comparable concentrations of B20 or B100 soy biodiesel fuels did not elicit responses different from those caused by air exposure alone.

5 Conclusions

The present study demonstrates that carnival sound-truck exhaust represents the main source of PM2.5, and possibly even total atmospheric PM, to which carnival revelers and workers are exposed. We further showed that the eye symptoms and conjunctival responses presented by the studied volunteers were likely associated with air pollution encountered along the carnival parade circuits. Further study is warranted to comprehensively evaluate the additional health impacts of air pollution in this context, especially on respiratory and cardiovascular systems. Our risk communication and risk management was shown to have a significant impact through the modification of public policy, as the monitoring of air quality has recently become mandatory at all large-scale public events held in the city of Salvador. Government actions have also stimulated the use of less-polluting fuels for the dozens of sound-trucks operating during the carnival festival.

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Conflicts of Interest: "The authors declare no conflict of interest."

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