

Review Article

Potential impact of fireworks on respiratory health

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ABSTRACT

The world-wide use of fireworks with their consequent detrimental effect on the air quality is widely recognized with elevated ambient air levels of particulate matter and its several metallic components and gases identified in several studies carried out during such events. Exposed individuals may be at risk following inhalation of such produced pollutants. This review focuses on the impact of fireworks on air quality and the potential effect of fireworks on the respiratory system of healthy individuals as well as those suffering from underlying respiratory diseases, particularly asthma and chronic obstructive pulmonary disease (COPD). This applies not only to spectators including children but also to pyrotechnicians themselves. An extensive Medline search revealed that a strong evidence of the impact of fireworks on respiratory health is lacking in susceptible as well as healthy individuals with no formal studies on COPD or asthma, other than a few case reports in the latter. The implementation of global strategies to control the use of fireworks and hence improve air quality could possibly reduce their likely detrimental effect on human respiratory health in exposed individuals, but clearly a more targeted research is needed.

KEY WORDS: Air quality, fireworks, respiratory health

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INTRODUCTION

The tradition of celebrating national and cultural events with fireworks is recognized the world over. For anyone who has enjoyed a spectacular fireworks display, a part of the scene was most definitely obscured by the cloud of smoke from the burning fireworks themselves. Over recent years, short-term air quality degradation events have been studied intensively.^[1-3] Several studies carried out in various countries across the world, with the majority in Europe, India, Canada, and China have identified a sharp increase in the concentrations of several firework constituents in the atmosphere following firework displays with resultant variations in air quality. Most of these studies were carried out during world-renowned celebrations such as the Diwali Festival in India, Yanshui Festival in Taiwan, Montreal International Fireworks competition, Lantern Festival in Beijing, Guy Fawkes Night

in the United Kingdom, amongst others. According to an article published by the European Respiratory Society,^[4] all fireworks contain carbon and sulfur, which are necessary for burning. In addition, during fireworks manufacture, a range of substances are added such as arsenic, manganese, sodium oxalate, aluminum, iron dust powder, potassium perchlorate, strontium nitrate and barium nitrate, which act as stabilizers, oxidizers and added colors. The burning of fireworks releases a large amount of air pollutants, particularly sulfur dioxide (SO₂), carbon dioxide (CO₂), carbon monoxide (CO), and particulate matter (PM) along with several metal salts, for example aluminum, manganese, and cadmium.

There is increasing recognition of the detrimental effect of urban air pollution on human health both in the long- and in the short term.^[5-7] Adults exposed to high levels of ambient air pollution have shown increased prevalence of chronic cough, phlegm, and breathlessness^[8] and are therefore at an increased risk of developing respiratory symptoms, asthma, chronic obstructive pulmonary disease (COPD), allergic rhinitis, lower respiratory tract infections, and lung cancers.^[4]

The objective of this paper is to review current literature to attempt to identify the potential detrimental effect of these fireworks on the respiratory health of healthy as well as susceptible individuals.

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MATERIALS AND METHODS

Medline was consulted for this literature search. Search key words included fireworks, asthma, COPD, lung, health, air quality, respiratory system as well as particular firework constituents. Only articles and studies published in English were included. All articles on firework-related injuries were excluded.

Several articles identified the effect of air pollution from a number of sources and its effect on respiratory health and individual lung conditions. When the literature search was narrowed down to the impact of fireworks on air quality and the respiratory system, 43 articles were identified and reviewed. Twenty five addressed the effect of fireworks on air quality, two identified the effect of fireworks on asthma, none identified the effect of fireworks on COPD, and four assessed the association between fireworks and respiratory health in general. So it is evident that a direct correlation between fireworks and the respiratory system has not been extensively studied.

DISCUSSION

Fireworks and air quality

The harmful effects of ambient air pollutants are caused by the formation of reactive oxygen species, which in turn induce oxidative stress in the lungs resulting in a powerful cellular and mediator inflammatory response.^[9] When fireworks are set off, chemicals used in their composition react to ignite and propel the explosives with a resultant noticeable and odorous cloud of PM in the atmosphere. Inhalation of such particles is one of the most important routes of exposure to elevated concentrations of these emissions. PM deposition in the respiratory system mainly depends on the particle size.^[10]

Several metallic elements of PM were found to be at substantially elevated levels in a number of studies during firework events: Aluminum,^[11-16] barium,^[11,13,15-19] copper,^[11,13,18] strontium,^[11,13,15,18-20] antimony,^[11,13] lead,^[13,19,20] magnesium,^[12-14,16,18-20] and potassium.^[13-16,18-20] SO₂,^[9,19,21] nitrogen dioxide (NO₂),^[9,21] nitric oxide,^[20] PM₁₀,^[9,16,17,19,21] total suspended particulate (TSP) matter,^[9,18] PM₁,^[13] PM₂,^[13] PM_{2.5},^[19-21] benzene, toluene, ethylbenzene, and xylene-volatile aromatic compounds (BTEX),^[13] perchlorate,^[21] and chloride^[14,19] also found to be elevated. Concentrations varied to different degrees in the various studies since different fireworks vary in the combination of metals they contain.^[22] There was no standardization as to the method utilized to analyze the pollutants and measurements were taken from varying distances from where the fireworks were let off. Ambient noise level was 1.2 to 1.3 times higher than a normal day,^[23] further contributing to another type of environmental pollution.

Fireworks and respiratory health

A number of health warnings have been issued on the worldwide web for susceptible individuals to avoid firework displays and avoid the inhalation of resultant fumes and airborne PM. A good number of papers have reported associations between airborne particles and a range of respiratory outcomes from symptoms to mortality,^[24] while others have reported associations with pulmonary function deficits, emergency room visits, hospital admissions, and daily deaths.^[25] Despite PM components having widely different physicochemical properties, they may induce similar cellular responses^[24] with a range of sensitivities to pollutants across different "at risk" groups,^[26] particularly patients suffering from lung and heart diseases, namely asthma and COPD in the former group. The individuals' sensitivity to pollution is said to be related to their pulmonary antioxidant defences.^[27] Effects of fine particles on human health depend on the size, shape, number, and mass concentration together with chemical composition^[28] and may implicate that their detrimental effects on human health can affect more individuals for a prolonged period of time.

The impact of fireworks on human health has been reported in the literature and has been attributed to the large amount of chemical components that have been used during the manufacture of these fireworks. In 1975, Bach *et al.* reported a 113% statistically significant increase in treated respiratory illness during a fireworks event but a non-significant 8% decline in pulmonary function.^[29] According to the Swiss study on air pollution and lung diseases in adults,^[4] increments in NO₂, ozone (O₃), and TSPs were associated with decrements in forced expiratory volume in 1 second (FEV₁) and increments in NO₂ and TSPs were associated with decrements in FVC.^[4] Six panel studies performed on patients suffering from chronic pulmonary diseases identified a decrease of peak expiratory flow and an increase in daily symptom and medication use in association with elevated daily particle concentrations.^[30] No studies were identified on the effect of firework emission exposure and the effect on lung function. Joly *et al.* in their study reported on the emissions of fireworks, which was carried out at the level of where people usually stand, and conducted during nine separate firework shows at an amusement park. They concluded that the particles emitted include extremely high levels of PM_{2.5} and are much more likely to enter the respiratory system.^[14] Hirai *et al.* (2000) also found that the inhalation of smoke from fireworks causes cough, fever, and dyspnea and lead to some cases of acute eosinophilic pneumonia.^[31]

Children seem to be particularly susceptible to the harmful effects of ambient air pollution. Compared with adults, children have poor defences against PM and gaseous air pollutants, have a differential ability to metabolize and detoxify environmental agents, and have an airway

epithelium that is more permeable to inhaled air pollutants. Also, children have a greater level of physical activity than adults; hence, their intake of air into the lungs is much greater than that of adults per day.^[5] No studies involving paediatric patients were identified in this field.

Fireworks and asthma

Few investigators have identified the association between asthma and exposure to fireworks. According to researchers from the Institute of Environmental Assessment and Water Research (IDAEA-CSIC), metallic particles in the smoke emitted from the fireworks pose a health risk, particularly to asthmatics.^[22] In India, a 30% to 40% increase in the cases of wheezing, respiratory diseases, exacerbation of bronchial asthma, and bronchitis patients of all ages and gender were reported during the Diwali festival.^[32] A published case report of one fatal and another near-fatal asthma exacerbation within hours of exposure to fireworks were identified.^[33] Numerous articles offering advice to asthmatics to avoid exposure as well as how to manage an exacerbation following exposure were found.^[34,35]

Fireworks and COPD

We could not find any publications identifying an association between COPD and firework exposure. However, several epidemiological studies have implicated exposure to a variety of ambient air particles and gases to exacerbate symptoms of COPD, resulting in increased morbidity and mortality, despite the variances in PM measures used and the health endpoints studied.^[7] Dominici *et al.* reported a near doubling in admissions for COPD exacerbations for every 10 µg³ of increase in PM_{2.5}. Since a number of studies have identified deterioration in COPD patients following exposure to air pollutants, one could speculate that fireworks are most likely to have a detrimental effect on these patients.^[25]

Individual firework constituents/emissions and respiratory health

Prolonged inhalation of fine dusts and chemicals during the manufacturing process may pose a risk to pyrotechnicians themselves following prolonged hours of exposure, especially if no protective equipment is worn. No published data were identified on the relation between inhalation of firework constituents during their manufacture and its effect on the respiratory health of those involved. Underlying respiratory co-morbidities as well as a smoking history may be additional risk factors for such individuals. However, the effects of the certain components used in their manufacture have been studied with respect to their effect on the lungs when used in different fields.

Studies as early as in 1961 on the effect of aluminum from alternative sources have shown that inhalation of finely powdered aluminum has a causative fibrotic effect on the lungs.^[36] Aluminum smelting fumes can also cause bronchoconstriction in susceptible individuals.^[37]

Cast-house workers in the aluminum industry reported significantly more respiratory symptoms than controls, namely continuous trouble with breathing, repeated trouble with breathing, wheezing, asthma attacks (ever), and doctor-diagnosed asthma.^[38] The existence of occupational asthma in aluminum pot room workers has been confirmed by characteristic patterns of repeated peak flow measurements, supported by changes in methacholine responsiveness in workers with suspected work-related asthma.^[39]

Barium chromate was identified as being cytotoxic and genotoxic to human lung cells^[40] but no acute, intermediate, or chronic-duration inhalation estimates of exposure levels posing risk to humans have been carried out. Benign pneumoconiosis in several workers exposed to barium sulfate was reported in one particular study.^[41]

Most respiratory physicians recognize that chronic exposure to respirable cadmium in the workplace may lead to emphysema.^[42] It has been observed that there was an increased number of lung cancers in a United States cohort of cadmium-exposed workers, which has further been strengthened by further data.^[43]

Exposure to copper dust is associated with an excess of deaths from lung cancer in copper miners^[44] and a higher serum copper has been associated with lower FEV₁^[45] while a long-term inhalation of antimony can potentiate pneumoconiosis.^[46,47]

Consistent evidence has shown that asthmatic patients are more sensitive to the effects of inhaled SO₂ than are healthy subjects, with varying responses among asthmatic individuals in the degree of airway resistance and resultant changes in lung function.^[26] A study carried out in Birmingham identified a significant increase in hospital admissions for asthma and respiratory disease in association with daily variations in smoke and SO₂.^[48]

Exposure to ozone, a highly reactive gas, has been noted to result in small changes in airway resistance and repeated exposure has been associated with increased asthma-related symptoms in asthmatic individuals.^[26] It has also been noted to cause decreased lung function, increased airway hyperreactivity, and pulmonary inflammation in healthy individuals.^[27] Ganguly identified a higher concentration of ozone during the fireworks season during Diwali, which has been associated with pneumonia, influenza, asthma and a persistent decrease in lung function.^[49]

An association between repeated exposure to firework emissions and respiratory symptoms has not been definitely identified. However, the association between long-term exposure to fine particulate air pollution has been associated with lung cancer mortality.^[2,3] Thus one might extrapolate this to the heavy exposure to such matter during and after fireworks displays, but formal correlative studies are lacking.

One can argue that typical exposure to such pollutants is limited, as assessed by Singh *et al.*,^[50] ranging from a few hours to a few days, depending on the duration of the firework festival, thus probably only causing minimal exposure. Also, fireworks are often let off following sunset when most people would go indoors to sleep after seeing the show, hence limiting exposure time to the ambient air pollutants. However, Barman *et al.* reported that particles remain suspended for up to 20 hours^[28] and a study carried out in Spain identified a “reservoir of metalliferous particles” which persisted for days after the festival, which was affected by wind, traffic, and other activity.^[22] Short-term exposure to such pollutants for an occasional day may not have such a detrimental effect but in countries like Malta where given the small geographical size of the archipelago of 316 km², 86 religious feasts are held between June and September, and each celebrated with fireworks over approximately three nights of the week. Camilleri and Vella reported significantly higher PM₁₀ and heavy metal concentration levels in the Maltese air between July and August as opposed to September and October when 59 and 11 feasts are celebrated respectively.^[11]

There is limited literature describing the physical characteristics of firework particles themselves including size distribution, number concentrations, modal characteristics as well as particle density.^[51] The latter has been identified as a direct result of particle deposition in the lungs.^[52] In a study performed during the Chinese New Year’s firework events, emissions from fireworks were associated with substantial changes in particle size distributions as well as increasing overall particle number concentrations,^[51] which could influence lung deposition and subsequently trigger a pathological process.

Chemical components and combustion products of fireworks displays and their effect on air quality and health utilized different methods of analysis of the emissions. These alone depended on the distances of the letting off the fireworks from the scene and the timing and duration of collection of data. Additional sources of PM readily available for inhalation must also be taken into consideration, mainly cigarette smoke as well as ambient air pollutants from other sources such as vehicles and industrial pollutants, as these are confounding factors which may further contribute to developing or exacerbating lung disease.

All but one of the studies identified during this literature review were carried out outdoors. The only one performed indoors was carried out in the New Orleans Superdome during which high levels of particulate mass concentrations were initially noted but which decreased rapidly due to the ventilation system. The authors argued that indoor pyrotechnic displays are potentially more hazardous to health since particles are dispersed in a small volume of air and are detonated closer to the spectators than are outdoor pyrotechnic displays.^[53]

During the Spring Festival in Beijing, meteorological conditions seemed to be the main controlling factors of air quality, with high-concentration pollution mainly being related to wind speed, temperature inversion, and humidity.^[54] A two-year data review of ambient air quality in Delhi, India, showed a temporal variation in PM₁₀, PM_{2.5}, and PM₁ with a 1.5 time decrease in the second year which was attributed to the higher mixing height, as well as temperature and wind speed variations.^[55] Weather conditions could therefore influence individuals depending on the weather conditions during the event and may be utilized by the patients to limit their exposure by, for instance, noting the wind direction.

CONCLUSION

Following a thorough review of the literature available, further studies are necessary to consolidate current evidence and speculation. Implementation of strategies and enforcement of regulations to limit the harmful contaminants being used in the fireworks industry as well as legal control on the quantity of fireworks let off, together with additional surveillance of air quality during periods of increased risk should aid to avoid unnecessary morbidity. We recommend that susceptible individuals, mainly patients suffering from respiratory conditions, should avoid heavy exposure so as to avoid the possibility of exacerbations of their illness. Increasing awareness amongst the high-risk groups should decrease morbidity and the number of unscheduled health care visits and hospitalizations.

Further knowledge on the physical properties of firework aerosol particles could improve our understanding of the influence of fireworks on respiratory health. Opting for more environmental friendly techniques using newer technology other than the conventional methods is a further possible solution.

Assessing the respiratory health of firework manufacturers and identifying any potential negative impact are necessary to promote health and safety among these individuals with the possibility of avoiding possible morbidity and mortality.

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