Effects of fireworks ancient celebrations on atmospheric concentration of particulate matter in Iran

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ABSTRACT

The Chahar-Shanbe Suri culture in Iran is a significant and direct factor leading to air pollution in Iran. This study investigates why and how “Chahar-Shanbe Suri” culture leads to increased air pollution in Iran. Following the fireworks of Chahar-Shanbe Suri in Tehran, Tehran’s air quality index increased by a high slope, and the clean condition with the 49 index at 20 pm was unhealthy for all segments of society with a 177 index at 23 o’clock. Of course, according to the data measured in Tehran’s air quality assessment stations, the air quality index in the areas of the city has risen above or near 200, which indicates a very unhealthy condition. The results of the SEM-EDS indicated that the PM of fireworks in the area make up the largest proportion of atmospheric particles. The chemical composition of particle was the origin of organic matter and the soot combinations from the combustion of sulfur compounds. The people, governments, and industry should work together to navigate positive initiatives. Public education and media navigation are necessary for dealing with the cultural aspects of environmental pollution and also, the management of celebrating can reduce the impact of fireworks on the air quality.

1. Introduction

Air pollution has overtaken poor sanitation to become the main environmental cause of premature death. According to the World Health Organization (WHO), air pollution in 2012 has led to 3.7 million deaths worldwide. These particles include aerosol particles, Ozone (O₃), Nitrogen dioxide (NO₂), and Sulfur dioxide (SO₂) (World Health Organisation, 2014). Human activities and production in factories and industries is a key driver of air pollution, so it is hardly surprising that celebrations and cultural activities can have a profound impact and can increase the concentration of atmospheric particles. One of the best studies is the regularly occurring weekend effect or holidays religious ceremonies, which is defined as the difference of air pollutant concentrations between weekdays and holidays, with a general reduction of major pollutants. Although culture plays an important role in many environmental problems, it is a less-obvious factor affecting air pollution, which is often overlooked by researchers. Some cultural rituals in communities lead to environmental problems. Many of these rituals are accompanied by fire. Fireworks contain chemicals such as Potassium Chlorate, Sodium Oxalate, Sulfur, Charcoal, Potassium Nitrates, Iron and Aluminum dust powder, Strontium Nitrate, Potassium Perchlorate, Barium Nitrate, and Manganese, etc. (Kulshrestha, Rao, Azhaguvel, & Kulshrestha, 2004; Ravindra, Mor, & Kaushik, 2003; Steinhauser, Sterba, Foster, Grass, & Bichler, 2008; Wang, Zhuang, Xu, & An, 2007). The heat generated by the firecrackers can release various particulate and gaseous air pollutants and toxic metals to significant quantity and degrades the air quality as a whole and dangerous conditions caused for all ages. In United States, a study following the 4 July holiday reveals a significant increase in the levels of ambient air Al, Sr, Cu, K, Mg, Br (Liu, Rutherford, Kinsey, & Prather, 1997). This increase in particles may remain in the atmosphere for a long time. While fever, cough, and dyspnea are often reported initially as acute affects, pollution due to fireworks causes chronic respiratory and cardiovascular disease, pulmonary effects, premature death, and cancer (Barman, Singh, Negi, & Bhargava, 2008; Nasir & Brahmaiah, 2015; Sharma, Nayak, & Lal, 2015). Also, chemically resolved size distributions and chemical composition of fine aerosol particles were measured during the New Year’s 2005 fireworks in Central Germany (Drewnick, Hings, Curtius, Eerdekens, & Williams, 2006). In studies, Qin, Tonnesen, and Wang (2004) reported that the average concentrations of Carbon Oxide (CO), PM10, Oxides of Nitrogen (NOx), and Nonmethane...
Organic Compounds (NMOC) at weekends were lower than those on weekdays in southern California. Khandare, Pustode, Rao, and Gajghate (2012) in Nagpur (Central India) reported a 4–10-fold increase in PM$_{10}$ concentration was observed during Diwali. A previous study in northeast India observed an increase in the concentrations of metals, anions, and cations during festival days compared to other days (Deka & Hoque, 2014). Garaga and Kota (2018) indicated that the mean PM$_{10}$ concentration during Diwali, 311 µg/m$^3$, was 81% higher than other days and 3.1-times higher the Indian National Ambient Air Quality Standards. For first observed in the U.S.A. in the 1970s (Jimenez, Parra, Gasso, & Baldasano, 2005), and since then, many studies have reported these effects that are influenced by traffic rush hours (e.g., Cerro, Cerda, & Pey, 2014; Henschel et al., 2015), population size (e.g., Butenhoff et al., 2015), and degree of urbanization (e.g., Huryn & Gough, 2014). Diverse cultural activities in the world can directly enhance primary pollutants, such as the Sunday roast of Victorian England (Brimblecombe, 2012) or barbecues (Tsai, Sopajaree, Kuo, & Yu, 2015). Based on the report of Chatterjee et al. (2013), a five increase in PM$_{10}$ concentration was observed in Kolkata in eastern India during Diwali. Also, based on the research of Ambade and Ghosh (2013), in Rajnandgaon in central India, PM$_{10}$ concentration during Diwali showed a nearly 3-fold increases compared to other days.

There are numerous reports on the impact of key events where fireworks contribute to visibility reduction (Singh, Bloss, & Pope, 2015), illicit use of the metalloid arsenic (Sterba, Steinhauser, & Grass, 2013), toxic metals (e.g., Camilleri & Vella, 2010; Kong et al., 2015), and enhanced particulate loads in German New Year (Drewnick et al., 2006), the U. S.A. on Independence Day (Seidel & Birnbaum, 2015), Slovenia (Mlakar, Božnar, Grašič, & Popovič, 2012), Spain (Moreno et al., 2010), or in India during the Diwali festival (Bhatnagar & Dadhich, 2015; Perrino et al., 2011; Ravindra et al., 2003) or the numerous festivals that occur throughout the summer in Malta (Camilleri & Vella, 2010). Air pollution in Iran has attracted all attention again since recent years. Especially, in densely populated industrial cities, such as Tehran.

The burning of fossil fuels and motor vehicle emissions are regarded as two main primary causes of air pollution in Iran and megacities. There are reports of lower concentrations of atmospheric particles in metropolitan areas such as Tehran during working days, as well as weekend holidays and official holidays. But until now, a study has not been done in the amount of air pollution in a traditional ceremony Tuesday the end of the year (with title Chahar-Shanbeh Suri). This is one of the oldest people in Iran who are happy to illuminate the fire and exploding explosives on this day. There are always deaths and injuries due to fire and explosives. Chahar-Shanbe Suri, one of the most important things to do in Iran is to check out the calendar for annual festivals. Iran holds and celebrates various events and festivals all year round. Some of the rituals and festivals in Iran consist of religious ceremonies and rites, and many others have more historic and ceremonial backgrounds that can be tracked into the pre-Islamic era. There are also many feasts and celebrations to pay homage to many deities and they are mostly farming festivals. The festivals in Iran vary greatly by region due to Iran’s multi-ethnic make-up. One of the most important and old festivals is Chahar-Shanbe Suri. This study investigates why and how Chahar-Shanbe Suri culture leads to increased air pollution Iran and Tehran city.

Due to the arrival of a large amount of particulate matter (PM) from this ancient celebration, it is important to study the concentration of PM and their chemical composition. In fact, the purpose of this study is to investigate the amount of PM from the fireworks on the celebration day. Also, in each sampling period, the chemical composition of the PM was investigated using the Scanning Electron Micrograph-Energy-Dispersive X-ray Spectroscopy (SEM-EDS) method.

2. Methods and materials

Sampling was performed in the city level at a height of 20 m above ground level. Sampling was done by a high-volume sampler with a discharge of 1.6 cubic meters per minute. Fiberglass filters were used to collect atmospheric particles and also, sampling time for each station was from 2 to 14 h. The weighing of the filters was done before and after the sampling. Preliminary SEM/EDS measurements were performed on some of the samples to get elemental information on individual aerosol particles and average particle size and morphology were investigated in each image. Aerosols particles were imaged with a Zeiss EVOSOXP SEM. The X-ray energy spectra were measured using a Bruker Quantax 200 EOS system with a Peltier-cooled X Flash silicon detector. The aerosol samples were coated with a thin layer of conductive material before the measurements were performed.

2.1. Study area

Tehran, one of the most polluted cities in the world and the capital of Iran, has a population of about 10 million people and an area of about 800 km$^2$ on the southern slopes of the Alborz Mountain Range. Also, from the southern part of Tehran, leads to open plains and agricultural fields, as well as Qazvin plain. Tehran’s plain, located in the south of the Alborz
Mountains at an altitude of 900–1500 m, is one of the main gatherings and human activities in the province of Tehran. The geographical location of the study area is shown in Figure 1 (Oroji, 2018). Based on the Air Quality Index (AQI) calculated by the methods described in the Iranian National Standards in 2016, the period under study consisted of 17 clean days (AQI < 50), 260 days with healthy conditions (50 < AQI < 100), 80 days of unhealthy conditions for sensitive groups (100 < AQI < 150), and 9 days of unhealthy conditions (150 < AQI < 200) (Air Quality Control Company (AQCC), 2017). In total, the number of polluted days decreased by 22 days compared with the last year. But the air pollution in the city has always been a problem for people.

According to reports, particulate Organic Matter (OM) was the dominant component during most of the year, with a contribution of 13–54% and an average of 35%. OM and Elemental Carbon (EC) together comprised 44% of fine PM on average, reflecting the significance of anthropogenic urban sources, i.e., vehicles. Most of the Organic Carbon (OC) was formed from water-insoluble compounds (82.5 ± 4.3% on average), suggesting a large contribution from the incomplete combustion of fossil fuels (Oroji, 2018). Based on the annual emission of air pollution in Tehran, the amount of stationary sources of NOx, CO, and PM is 53.2%, 2.5%, and 29.8%, respectively. While, this combination was 46.8%, 97.5%, and 70.2% for mobile sources, respectively (Oroji, Solgi, & Sadighzadeh, 2018).

3. Results and discussion

Since the celebration is held in all cities of Iran, due to the fact that the population of Tehran and the geographical extent of its impact on the celebration in this city is more than other cities. Following the fireworks of Chahar-Shanbe Suri in Tehran, Tehran’s AQI increased by a high slope, and the clean condition with the 49 index at 20 pm was unhealthy for all segments of society with a 177 index at 23 o’clock. Of course, according to the data measured in Tehran’s air quality assessment stations, the AQI in the areas of the city has risen above or near 200, which indicates a very unhealthy condition. The next day (February 14th), the pollutant of the Tehran city index is a suspended particle of fewer than 2.5 microns, but this day increasing concentrations are observed in other pollutants, including carbon monoxide and carbon monoxide. The amount of pollutants in this day was such that the online index of Tehran’s air quality was in a violet (very unhealthy) situation in some areas. According to the pollution index, the condition is declining five days after the celebration. Accordingly, the index of air pollution in Tehran at 11th district, Shadabad, and Rey municipality stations was 202, 240, and 235, respectively. Also, Tehran’s air pollution index was reported in red (very unhealthy) status in 9 other stations on 13 March. The values of SO2, PM10, and PM2.5 are shown in Figure 2. As shown in Figure 2, the concentration of PM2.5 and PM10 continues with a constant trend from 17 February to 19 March 2018. But this trend will show a large increase in 13 and 14 March. Air pollution was in an emergency during the day after the celebration and was in sensitive situations.

The average AQI in the last few days is shown in Figure 3. Based on the current situation and climate change, air stability in February and March is less than normal. But on the day of celebration, at 4:00 pm, the concentration increased and the increase was at most from 20:00 to 4:00. Relative air stability on 14 February caused the weather index to be unhealthy and this situation continues until the very last hours of the night. Such conditions were present in most cities of Iran. But atmospheric conditions did not change the AQI.

Figure 4 shows the SEM micrograph spectrum of aerosol particles in the study area, it is obvious that the particles show irregular, spherical, and cluster shapes. The particles Ca, Fe, K, O, Si, and Al follow the similar trend. Table 1 shows concentrations of elements aerosol particles in central regions of the study area.

This issue has been considered in most countries and is of high importance. Similar studies have been
done in different parts of the world. Tsai et al. (2015) in research found that the average concentration of PM$_{10}$ rose to high levels over Kaohsiung Harbour, influenced by fireworks during Taiwan’s lantern festival. Air pollution from fireworks is frequently observed at the Chinese Spring Festival period; widely celebrated in Asia and within the Chinese diaspora. Firecrackers are thought to drive away evil spirits, that lurk around to torment human beings, but the noise causes them to vanish into thin air (Wong, 1967); however, such celebrations contribute to a reduction in air quality. Gong et al. (2014) reported a reduction in aerosol during the Lunar new Year period and revealed that the concentrations of major
air pollutants had significantly decreased around the holiday, but a short-term peak could be seen for NO$_2$, SO$_2$, and PM$_{10}$ due to fireworks along with peaks in the concentration of a range of metals Cu, Al, K, Sr, Mg, Pb, and Ba (Chang, Lin, Young, & Lee, 2011), dicarboxylic acids (Wang et al., 2007). According to a similar study conducted in China, it was found that 25%, 57%, and 183%, respectively, increase in NO$_2$, SO$_2$, and PM$_{10}$ levels over the previous day. Also, the PM$_{2.5}$ concentration was found to be 6 times higher over a normal day.

Analysis of different elements and ions in fine particulates revealed that over 90% of the total mineral aerosol and 98% of Pb, 43% of C$_{Total}$, 28% of Zn, 8% of NO$_3^-$, and 3% of SO$_4^{2-}$ in PM$_{2.5}$ were from the emissions of fireworks on the lantern night (Wang et al., 2007). In another similar study in Italy, it was reported that one-hour concentration of elements like Ba, Cu, K, Mg, and Sr increased by 12, 6, 11, 22, and 120 times (Vecchi et al., 2008). Following New Year celebration in Mexico City in January 2005 reported that “left a dense gray pall over much of city” and described the air as more polluted over a normal Saturday, Ozone level was reported to climb 190 on a scale with normal cut-off a level of 100 (Victoria Advocate, 2005). Attri, Kumar, and Jain (2001) during their research reported that display of fireworks could produce ozone (O$_3$), a strong and harmful oxidizing agent, at the ground level without the participation of NOx (Attri et al., 2001). In another study in India, the effect of firework display during Deepawali on the mass concentration of atmospheric black carbon reveals over three times increase compared to normal days (Babu & Moorthy, 2001). According to a study conducted in Hisar India, the short-term variation in air quality during Deepawali reported 2–10 times increase in concentrations of total suspended particles (TSP), NO$_2$, SO$_2$, and PM$_{10}$ over a typical winter day (Ravindra et al., 2003). According to a research published in Hyderabad India, following a study of various metals in firework borne particles during Deepawali reported about 1091, 25, 18, and 15 times, respectively, increase in the concentrations of Al, Sr, Ba, and K over a normal day (Kulshrestha et al., 2004). Barman et al. (2008) in Lucknow India reported that an average increase in SO$_2$, NOx, PM$_{10}$ concentrations over pre-Deepawali period and a normal day by 1.95 and 6.59 times, 1.79 and 2.69 times, and 2.49 and 5.67 times, respectively. The PM$_{10}$ samples were further studied for trace metals like Co, Cu, Fe, Ca, Cd, Cr, Mn, Pb, Ni, Zn, and their values were found to be higher than normal days and pre-Deepawali period except Fe (Barman et al., 2008).

However, in some cities, contamination remains in the atmosphere in a short period of time, but particles with a diameter of less than 2.5 microns stay in the atmosphere in most cities for several days.

### 4. Conclusions

In most countries, the end year is always accompanied by fire. One of these celebrations in Iran is Chahar-Shanbe Suri, which is held throughout the cities of Iran. During Chahar-Shanbe Suri in Tehran, widespread use of fireworks caused heavy pollution with extremely high aerosol concentrations. Fireworks sources should be controlled and limited. Besides limiting the usage of fireworks by individuals, the Iran government should also limit firecrackers and fireworks sales. The Chahar-Shanbe Suri culture in Iran is a significant and direct factor leading to air pollution in Iran. Unfortunately, few people recognize the role of culture in dealing with environmental problems. Although cultural changes do not take place over a short time, people can gradually change the traditions, as long as they fully realize the threats and risks that traditions or customs exert on the environment. In the future, policies and laws should be designed to improve the effectiveness of PM$_{2.5}$ control. The people, governments, and industry should work together to navigate positive initiatives. Public education and media navigation are necessary for dealing with the cultural aspects of environmental pollution. People should also be provided more green options to make up for the loss of traditional activities or customs. Consideration should be given the health effects of air pollution in the urban atmosphere. Investigation the relationship between the concentrations of atmospheric particles (such as PM$_{10}$) and the number of people visiting health centers on the days after the celebration can be an important target for future research. Due to the weather condition during the celebrations, the possibility of PM stability in the atmospheric will increase. In these situation, health problems will increase. Assessing these health problems can provide important information for controlling and managing pollution. Size distribution of atmospheric PM can determine the impact on the health of people. Because in a stable atmosphere, ultrafine and fine particles can remain in the atmosphere for a long time.
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