



A study on the impact of fire crackers on airborne microflora during diwali

N.K. Udaya Prakash^{a,*}, N. Sripriya^b, K. Gowtham^b, S. Suresh^b, B. Sampathkumar^a,
S. Bhuvaneswari^c

^a Department of Biotechnology, School of Life Sciences, Vels Institute of Science, Technology and Advanced Studies, Chennai, India

^b R and D, Marina Labs, Chennai, India

^c Department of Botany, Bharathi Women's College, Chennai, India

ARTICLE INFO

Keywords:

Atmospheric science
Airborne bacteria
Airborne fungi
Andersen N-6 sampler
Diwali
Fire crackers

ABSTRACT

Diwali is celebrated widely in Asian countries, with a custom of firing crackers. Crackers pollute the environment with noise, particulate matter and chemicals. There are reports on the variation of particulates during firing crackers but none on airborne microbes. The present study was conducted to know the impact of fire crackers on airborne microflora. The air samples were collected 3 days prior to Diwali, on Diwali and 3 days after Diwali during the year 2017 at 15 different areas in Chennai, India. Andersen N-6 viable particle air sampler was exposed with petridishes containing nutrient agar and potato dextrose agar for the isolation of bacteria and fungi respectively. An average of $1,904 \pm 2.5$ CFU/m³ of bacteria recorded prior Diwali was reduced by 53.23% on Diwali and increased by 27.37% after Diwali. This reduction on Diwali is attributed to the exposure of bacteria to chemicals emitted by the crackers. For fungi, an average of 235.57 ± 1.67 CFU/m³ was recorded prior Diwali, with an increase of 78.5% on Diwali. The increase in fungal count might be due to the release of spores by ground crackers. The study shows that bacteria are susceptible to the chemicals emitted by fire crackers when compared with fungi.

1. Introduction

Diwali, commonly known as the festive of lights, is celebrated widely in Asian countries like India, Singapore and Malaysia. As a part of celebration, crackers are fired. Fire crackers are classified into those exploding at the ground level and in air (Devara et al., 2015). Crackers contain chemicals such as salts of potassium (K), sulphur (S), manganese (Mn), sodium (Na), aluminum (Al), iron (Fe), strontium (Sr), barium (Ba) and charcoal (Wang et al., 2007). When crackers are fired, it is reported that there is an increase in levels of ozone, sulphur dioxide (SO₂), nitrogen oxide (NO₂), particulate matter (PM), black carbon and poly-aromatic hydrocarbons in the atmosphere (Attri et al., 2001; Barman et al., 2008; Xu et al., 2018).

The impact of firing crackers on ambient air quality has been studied by authors from different countries. The increase in particulate matter, heavy metals, SO₂, NO₂, etc., after fireworks was reported in California, USA (Liu et al., 1997; Seidel and Birnbaum, 2015) and Mainz, Central Germany (Drewnick et al., 2006) during their Independence day and new year celebrations, respectively. In the pyrotechnic displays following FIFA World cup at Milan, Italy, the concentration of PM₁₀ and metals (Sr,

Mg, K, Ba and Cu) were found to increase significantly (Vecchi et al., 2008). In China, the concentration of PM_{2.5} and water soluble ions were found to be elevated, following the firework display during new year celebrations (Yang et al., 2014).

In India, the concentration of SO₂ increased by ~10 folds, whereas NO₂, PM₁₀ and total suspended particles increased by 2–3 times during Diwali, when compared with non-Diwali period, at Hisar, Haryana (Ravindra et al., 2003). The level of black carbon was found to increase by 3–4 times due to firing of crackers during Diwali, at Thiruvananthapuram, Kerala (Babu and Moorthy, 2001). At Hyderabad, Kulshrestha et al. (2004) reported the increase in metallic concentration of Ba, K, Al and Sr as much as 1,091; 25; 18 and 15 times respectively, when compared with the previous day of Diwali. Similarly, the air quality of Lucknow was affected due to emission of PM₁₀, SO₂, NO_x and trace metals during Diwali celebrations (Barman et al., 2008).

According to System of Air quality Forecasting And Research (SAFAR) network, continuous assessment of air quality through monitoring stations in Delhi recorded high concentrations of PM_{2.5} and PM₁₀ during Diwali, when compared to non-Diwali periods. This increase was noted to contribute to the excess number of cardiovascular and respiratory

* Corresponding author.

E-mail address: nkudayaprakash@gmail.com (N.K. Udaya Prakash).

<https://doi.org/10.1016/j.heliyon.2019.e02202>

Received 3 May 2019; Received in revised form 17 June 2019; Accepted 29 July 2019

2405-8440/© 2019 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

mortalities during 2010 (Beig et al., 2013). In the same year, the concentration of PM₁₀ and SO₂ increased by ~5 times on Diwali, when compared with non-Diwali period, at Kolkata. Additionally, the concentration of the metals - Al, Zn, Pb and Cd increased by 5–12 times; Cu, Fe and Mn by 25–40 times and Co and V by 70–80 times (Chatterjee et al., 2013). A 3-year study (2009–2011) at Hyderabad revealed that high concentrations of O₃, NO_x, black carbon and SO₂ were recorded during Diwali, suggesting that the air quality was affected due to fire crackers (Yerramsetti et al., 2013).

Although many reports are available on the impact of firing crackers on particulate matter, heavy metals, ozone, oxides of sulphur and nitrate, there is no study on the impact of fire crackers on airborne bacteria and fungi. Hence, the current study aims at knowing the impact of fire crackers on airborne microbes, i.e. bacteria and fungi, and their total colony forming units (CFU) during Diwali, which is the first of its kind.

2. Materials and methods

2.1. Air sampler

Andersen N-6 viable particle air sampler (Aerotech laboratories, Inc. Phoenix, Arizona, USA) was used to conduct this study. The sampler, made of Aluminium, possesses 200 holes in a radial pattern, with cut-off diameter of 0.65 µm. The sampler was connected to vacuum pump (Zefon International Inc. St. Petersburg, Florida, USA) and operated for 4 min at each site, with the suction rate of 28.3 L/min.

2.2. Sampling site

The air samples for the presence of bacteria and fungi were taken from 15 different sites as replicates, across Chennai city (13.08° N, 80.27° E) in Tamil Nadu, India. The metropolitan city, being the capital of the state of Tamil Nadu, is located on the Coromandel coast off the Bay of Bengal at an elevation of 6.7 m and is spread over an area of 178.20 sq. km. Air sampling was conducted at the localities of Perambur, Moolakadaï, Madhavaram, Purasawakkam, Kilpauk, Basin Bridge, Koyambedu, Royapuram, Mylapore, Guindy, Adyar, Kodambakkam, Choolaimedu, Arumbakkam and Anna Nagar in the city of Chennai. The location of the sampling sites is represented in Fig. 1.

2.3. Sampling procedure

The sampler was disinfected with 70% alcohol and then loaded with petridishes containing nutrient agar (0.5% Peptone; 0.5% Sodium chloride; 0.15% Beef extract; 0.15% Yeast extract; 2% Agar) and potato dextrose agar (20% Potato infusion; 2% Dextrose; 2% Agar) amended with an antibiotic, streptomycin, prior to operation. The sampler was placed at a height of 1 m and was operated for 4 min at each sampling site. The air samples were collected 3 days prior to Diwali (15th October), on Diwali (18th October) and 3 days after Diwali (21st October), in the year 2017. The plates were incubated at 37 ± 2 °C for 24–48 h and 28 ± 2 °C for 3–5 days, for the enumeration of bacteria and fungi respectively.

2.4. Data analysis

The number of colonies grown on the exposed petridishes was enumerated after the incubation period and converted to Colony Forming Units (CFU) per cubic meter of air as follows:

Suction rate of the sampler = 28.3 L/min
Duration of each sampling = 4 min
Amount of air sampled in 4 min = 113.2 L
Let the number of colonies recorded = X

$$\text{Colony Forming Units (CFU) / m}^3 \text{ of air} = \frac{1000 \times X}{113.2}$$

The average CFU/m³ was recorded from the total CFU/m³ as:

$$\text{Average CFU / m}^3 = \frac{\text{Total CFU / m}^3}{\text{Total number of sampling sites (15)}}$$

Statistical analysis was performed by One-Way analysis of variance (ANOVA) with 5% level of significance, using GraphPad Prism, version 6.01 (San Diego, CA).

3. Results and discussion

3.1. Airborne bacteria

Altogether, a total of 28,560.07 ± 37.48 CFU/m³ of bacteria was recorded from all the 15 sites studied on the day prior to Diwali, which declined to 13,356.89 ± 12.49 and 20,742.05 ± 24.99 CFU/m³ on Diwali and after Diwali. An average of 1,904 ± 2.5; 890.46 ± 0.83 and 1,382.80 ± 1.67 CFU of bacteria per m³ of air was recorded on the respective days. A decline of 53.23% of total CFU was recorded on Diwali day. On the day sampled after Diwali, the total CFU was found to increase by 55.29% when compared to that on Diwali day and decrease by 27.37% when compared to the day prior to Diwali.

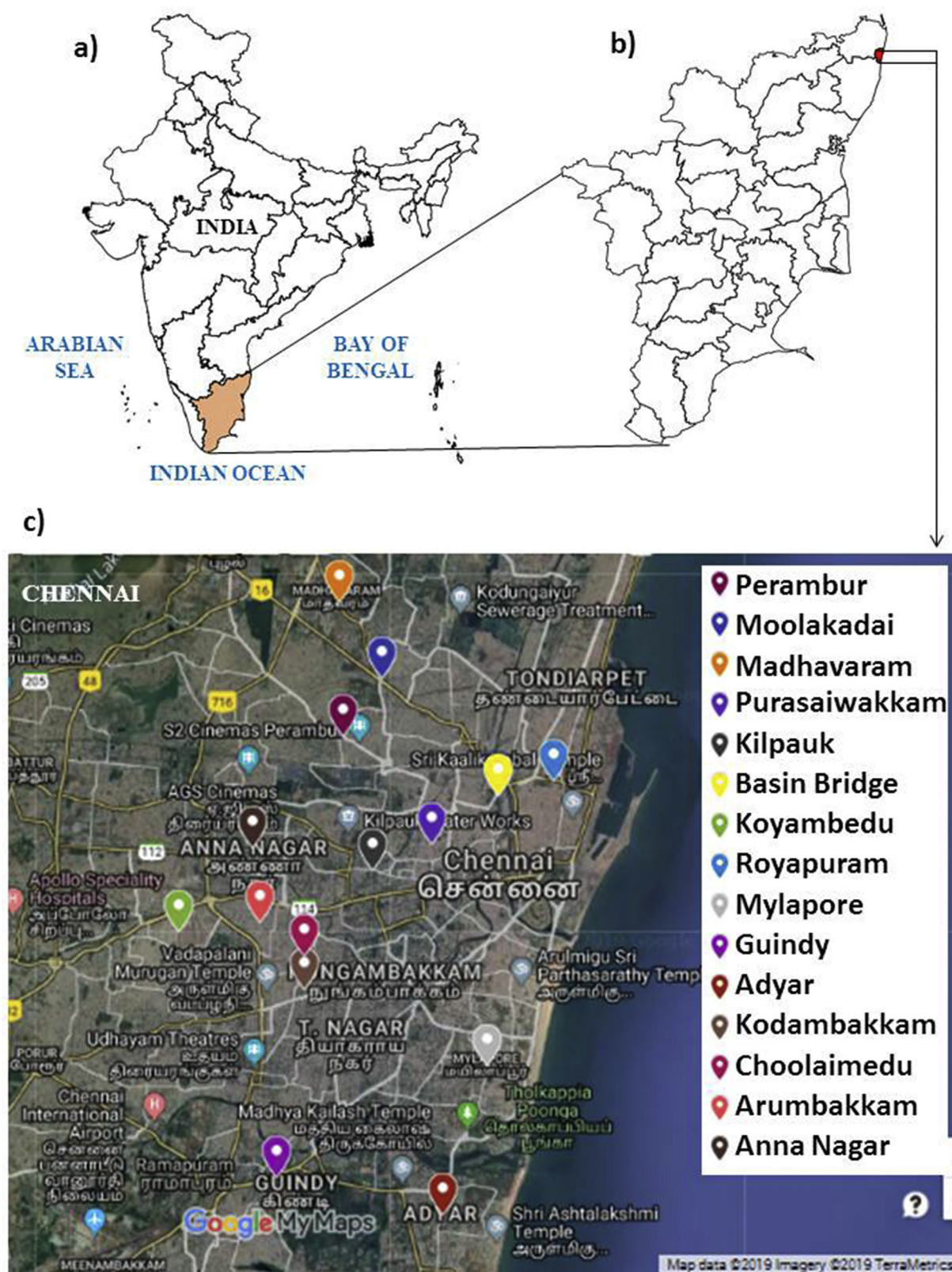
Significant difference was observed in the total number of CFU/m³ of bacteria (P = 0.0002) among the days sampled. Among the 15 sites, the maximum CFU/m³ for bacteria was recorded at Perambur, followed by Choolaimedu, with 3,321.55 ± 37.48 and 2,800.35 ± 37.48 CFU/m³ respectively, prior to Diwali. At these sites, the CFU/m³ reduced by 81.91% and 60.88% on Diwali. However, a drastic decline of 98.29% was recorded at Madhavaram on Diwali (44.17 ± 12.49 CFU/m³) when compared to that recorded prior to Diwali (2,588.34 ± 12.49 CFU/m³). Post Diwali, the CFU was found to be the highest at Perambur.

Notably, the bacterial count was found to reduce in all the sites on Diwali and increase after Diwali, when compared to 3 days prior Diwali. The CFU/m³ of air recorded for bacteria at different sites on different days during Diwali celebration is represented in Fig. 2.

In the present study, the reduction in total bacterial CFU/m³ of air in all the sites studied could be attributed to the impact of the chemicals emanated by fire crackers. The making of fire crackers include chemicals such as black carbon, nitronium perchlorate, hydrazinium nitroformate, polysulfide, polyvinyl chloride, polyurethane, toluene-2,4-diisocyanate, triethanolamine and salts of aluminium, magnesium, beryllium, boron, antimony, titanium, iron, ammonium, barium & potassium (Russell, 2000). On ignition, the crackers release particulate matter, elements and their oxides. The increase in the concentration of metals during pyrotechnic displays has been recorded by different studies, as mentioned earlier in the introduction section. Metals and metal oxides are known to inhibit the growth of bacteria by interacting with the phospholipid bilayer, binding to cytosolic proteins or formation of reactive oxygen species (Gold et al., 2018). In addition, pyrochemicals are known to act on microbes either as free radical or in molecular state, thus destructing the cell wall or the genetic material (Kim et al., 2016). The results of the present study correlate with a previous one which ascertained the impact of pyrochemicals on microbial diversity in soil, leading to reduction in bacterial count (Dhasarathan et al., 2010).

3.2. Airborne fungi

The fungal count recorded on the day prior to Diwali was 3,533.57 ± 24.99 CFU/m³. This was found to increase on Diwali day (6,307.42 ± 12.49 CFU/m³) by 78.5%. However, no significant difference was observed on the count on the days prior and after Diwali, with the average CFU/m³ being 235.57 ± 1.67 and 236.16 ± 1.67. Among the sampling sites, the maximum CFU/m³ of fungi was recorded at Royapuram, followed by Perambur with 371.02 ± 12.49 and 326.86 ± 12.49 CFU/m³ respectively, prior to Diwali. The least CFU/m³ was recorded at Madhavaram (8.83 ± 12.49 CFU/m³).



Source : a & b - Gramener (<https://gramener.com/indiamap/>)
c - Google MyMaps

Fig. 1. City Map showing the location of sampling sites.

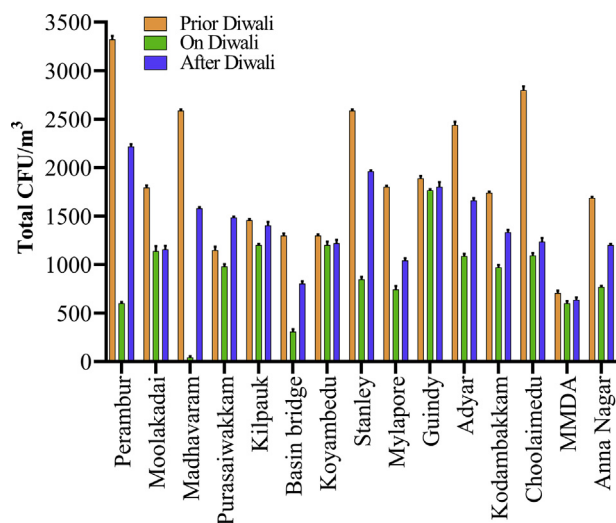


Fig. 2. Total number of CFU/m³ of airborne bacteria recorded at different sites.

The increase in CFU of fungi was recorded on Diwali, at all the sites studied. The highest CFU/m³ was recorded at Royapuram with nearly 2-fold increase on Diwali day. Koyambedu recorded the highest CFU/m³ (441.70 ± 24.99) on the day sampled after Diwali celebrations. Analysis by ANOVA revealed that significant difference was observed among the sampling days, with the P value less than 0.0001. The total CFU/m³ of fungi recorded at different sites on different days during Diwali celebrations is represented in Fig. 3.

The major stages in the transfer of fungal spores are source, take off, dispersal, deposition and effect. The flow of air at the source enables the spore to take off and disperse. Turbulence of air, either mechanical or thermal, is the major factor for dispersal of spores in the outdoor atmosphere (Dijksterhuis and Samson, 2007; Gregory, 1945). Noise, light, smoke and floating materials are the primary effects of fireworks. In accordance to the movement of smoke puffs, spores are dispersed into the turbulent boundary layer (Zadoks et al., 1969). The increase in CFU of fungi on Diwali as recorded in the present study is attributed to the firing of ground crackers which has created turbulence at ground level, thereby liberating the fungal spores and increasing the fungal CFU. Fungal spores possess multilayered complex cell wall (Harper et al., 2018), due to which they are more resistant to chemical exposure (Li and Wang, 2003) when compared to bacteria. After Diwali, as firing crackers ceased, the

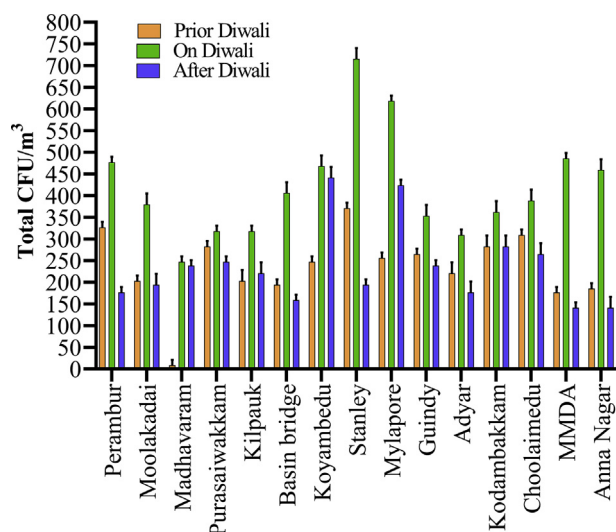


Fig. 3. Total number of CFU/m³ of airborne fungi recorded at different sites.

turbulence of air got reduced, thus resulting in similar CFU as that recorded prior to Diwali.

4. Conclusion

A study on the impact of fire crackers on airborne microbes during Diwali was conducted at 15 different sites across Chennai city, India. The samples were collected 3 days prior to Diwali, on Diwali and 3 days after Diwali in the year 2017, using Andersen N-6 viable particle air sampler. The study reveals a decrease in airborne bacteria and increase in airborne fungi on Diwali. The decrease in bacterial count is attributed to their exposure to chemicals emitted by fire crackers. The increase in fungal count is due to the explosion of ground crackers which resulted in turbulence and release of fungal spores from ground to the atmosphere. Further, the study shows that bacteria are more susceptible to the chemicals emitted by fire crackers when compared with fungi.

Declarations

Author contribution statement

Udaya Prakash Nyayiru Kannaian: Conceived and designed the experiments; Wrote the paper.

Sripriya N: Performed the experiments; Wrote the paper.

Gowtham K, Suresh S: Performed the experiments.

Sampathkumar B: Analyzed and interpreted the data.

Bhuvaneswari S: Conceived and designed the experiments.

Funding statement

This work was supported by internal fund of R & D, Marina Labs, Chennai (Grant Number: ML-2017-RD002).

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

References

- Attri, A.K., Kumar, U., Jain, V.K., 2001. Formation of ozone by fireworks. *Nature*.
- Babu, S.S., Moorthy, K.K., 2001. Anthropogenic impact on aerosol black carbon mass concentration at a tropical coastal station: a case study. *Curr. Sci.*
- Barman, S.C., Singh, R., Negi, M.P.S., Bhargava, S.K., 2008. Ambient air quality of Lucknow city (India) during use of fireworks on diwali festival. *Environ. Monit. Assess.*
- Beig, G., Chate, D.M., Ghude, S.D., Ali, K., Satpute, T., Sahu, S.K., Parkhi, N., Trimbake, H.K., 2013. Evaluating population exposure to environmental pollutants during Deepavali fireworks displays using air quality measurements of the SAFAR network. *Chemosphere*.
- Chatterjee, A., Sarkar, C., Adak, A., Mukherjee, U., Ghosh, S.K., Raha, S., 2013. Ambient air quality during diwali festival over Kolkata - a mega-city in India. *Aerosol Air Qual. Res.*
- Devara, P.C.S., Vijayakumar, K., Safai, P.D., Made, P.R., Rao, P.S.P., 2015. Celebration-induced air quality over a tropical urban station, Pune, India. *Atmos. Pollut. Res.*
- Dhasarathan, P., Theriappan, P., Ashokraj, C., 2010. Microbial diversity in firework chemical exposed soil and water samples collected in Virudhunagar district, Tamil Nadu, India. *Indian J. Microbiol.*
- Dispersal of fungal spores through the air. In: Dijksterhuis, J., Samson, R.A. (Eds.), 2007. *Food Mycology: A Multifaceted Approach to Fungi and Food*. CRC Press.
- Drewnick, F., Hings, S.S., Curtius, J., Eerdekens, G., Williams, J., 2006. Measurement of fine particulate and gas-phase species during the New Year's fireworks 2005 in Mainz, Germany. *Atmos. Environ.*
- Gold, K., Slay, B., Knackstedt, M., Gaharwar, A.K., 2018. Antimicrobial activity of metal and metal-oxide based nanoparticles. *Adv. Ther.*
- Gregory, P.H., 1945. The dispersion of air-borne spores. *Trans. Br. Mycol. Soc.*
- Harper, C.J., Taylor, E.L., Walker, C., White, J.F., Serbet, R., Krings, M., 2018. Fungal sporulation in a Permian plant fragment from Antarctica. *Bull. Geosci.*
- Kim, J.G., Yousef, A.E., Dave, S., 2016. Application of ozone for enhancing the microbiological safety and quality of foods: a review. *J. Food Prot.*

- Kulshrestha, U.C., Nageswara Rao, T., Azhaguvel, S., Kulshrestha, M.J., 2004. Emissions and accumulation of metals in the atmosphere due to crackers and sparkles during Diwali festival in India. *Atmos. Environ.*
- Li, C.S., Wang, Y.C., 2003. Surface germicidal effects of ozone for microorganisms. *Am. Ind. Hyg. Assoc. J.*
- Liu, D.Y., Rutherford, D., Kinsey, M., Prather, K.A., 1997. Real-time monitoring of pyrotechnically derived aerosol particles in the troposphere. *Anal. Chem.*
- Ravindra, K., Mor, S., Kaushik, C.P., 2003. Short-term variation in air quality associated with firework events: a case study. *J. Environ. Monit.*
- Russell, M.S., 2000. *The Chemistry of Fireworks*. Royal Society of Chemistry, UK.
- Seidel, D.J., Birnbaum, A.N., 2015. Effects of Independence Day fireworks on atmospheric concentrations of fine particulate matter in the United States. *Atmos. Environ.*
- Vecchi, R., Bernardoni, V., Cricchio, D., D'Alessandro, A., Fermo, P., Lucarelli, F., Nava, S., Piazzalunga, A., Valli, G., 2008. The impact of fireworks on airborne particles. *Atmos. Environ.*
- Wang, Y., Zhuang, G., Xu, C., An, Z., 2007. The air pollution caused by the burning of fireworks during the lantern festival in Beijing. *Atmos. Environ.*
- Xu, Z., Nie, W., Chi, X., Huang, X., Zheng, L., Xu, Z., Wang, J., Xie, Y., Qi, X., Wang, X., Xue, L., Ding, A., 2018. Ozone from fireworks: chemical processes or measurement interference? *Sci. Total Environ.*
- Yang, L., Gao, X., Wang, X., Nie, W., Wang, J., Gao, R., Xu, P., Shou, Y., Zhang, Q., Wang, W., 2014. Impacts of firecracker burning on aerosol chemical characteristics and human health risk levels during the Chinese new year celebration in Jinan, China. *Sci. Total Environ.*
- Yerramsetti, V.S., Sharma, A.R., Gauravarapu Navlur, N., Rapolu, V., Dhulipala, N.S.K.C., Sinha, P.R., 2013. The impact assessment of Diwali fireworks emissions on the air quality of a tropical urban site, Hyderabad, India, during three consecutive years. *Environ. Monit. Assess.*
- Zadoks, J.C., Klomp, A.O., Van Hoogstraten, D., 1969. Smoke puffs as models for the study of spore dispersal in and above a cereal crop. *Neth. J. Plant Pathol.*