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Real-Time Monitoring of Particulate Matter During Diwali Festival in Chennai, India

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Abstract: *Worldwide air pollution is an important source of morbidity and mortality. These days air contamination is an unsolvable issue and it directly affects the human prosperity and economy of a country. When compared to natural sources, anthropogenic activities are the major participant in the ambient air pollution problem. The present study aims to determine the Particulate Matter concentration during the Diwali celebration period in the Alandur area, Chennai district, Tamil Nadu, India. In this study area, alarmingly high air pollution was noticed in the year 2017 during Diwali Day. To validate the status of current situation in the study area the research was done in 2021. An ambient air quality sensor was used to monitor* PM_1, $PM_{2.5}$ *and* PM_{10} *particulate matter concentration and particles count. It was found that the maximum concentration was 1498* $\mu g/m^3$ *for* PM_{10}. *It was identified that particles of size <1µm were more in the event of fireworks. Particles with diameter <2.5µm may induce an adverse health effect than larger fine particles. From this study, it is identified that, a complex mixture of transient particles released from fireworks and some of the elements were identified from the collected particulate matter samples such as C, N, O, Na, Al, S, Cl, K, Sr, Ba, Mg, Mn, Sb, Fe, Ca and As. The study found that trace elements available in the fine particles are inhalable and may pose ill effects on human health.*

Keywords: *Firecrackers, Particulate Matter, trace elements, Diwali, Alandur, Chennai*

1.Introduction

Worldwide some of the festivals and events are celebrated with firecrackers. Interestingly, the Festival of Lights commonly known as 'Diwali 'in India is a popular one. Likewise, Lantern Festival in China and Taiwan, Guy Fawkes in the UK, Independence Day in the USA, Las Fallas in Spain Mascletas a pyrotechnic event in Spain, European World Cup football celebrations, Bastille Day in France, Bonfire Night in England, Canada Day and other New Year's celebrations,weddings celebrations, sports competitions, political meeting are celebrated with firecrackers. Diwali is celebrated all over India during the winter season. India has a rapid increase in population, industry, vehicle and energy consumption, especially in urban cities which has led to associated air pollution problems. As a part of celebration firecrackers are burnt which is made up of oxidizing agents (such as potassium nitrates, potassium chlorate, potassium perchlorates, nitrates of barium and strontium, iron oxide) and fuels.The fuel sources for the ignition of fireworks may include metal fuels (aluminium and magnesium), also non–metallic fuels sulphur, boron, phosphorus sulphide compounds and organic fuels charcoal, carbohydrates. Also, sodium nitrate is added as binder [1]. A study indicated that strontium salts & lithium salts produce red color ($SrCO_3$,Li_2CO_3), calcium salts ($CaCl_2$, $CaSO_4•2H_2O$) produce orange color, incandescence of iron or charcoal produce gold colour, sodium compounds ($NaNO_3$,Na_3AlF_6) produces yellow colour, white hot metal (BaO) produces electric white color, barium compounds with chlorine ($BaCl^+$) produces green colour, copper compounds and chlorine produces blue color, mixture of strontium (red) and copper (blue) compounds produces purple color, burning aluminium, titanium or magnesium powder produces silver color [2]. Antimony (Sb) is used to create firework glitter effects [3].

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Firecrackers pollute the indoor and outdoor environment with high noise and toxic chemicals. Various toxic gases and particulate matter of different sizes are emitted from the bursting of fire crackers. Gaseous pollutant SO_2 [4,5,6], Nitrogen dioxide [4,6], Nitric oxide [7], Benzene, Toluene, Ethylbenzene and Xylene-volatile aromatic compounds (BTEX) [8], Perchlorate [9] and Chloride [9,5] were found to be at a higher level during firework events. Fleischer et al reported that during the New Year celebration, firework events released aerosols of organic toxic species, including octachlorinated dioxins, furans and hexachlorobenzene [10].

1.1 Health effects due to Particulate matter

Generally, particulate matter less than 10 micrometers in diameter can get deep into the lungs and some may even get into bloodstream. According to USEPA the particulate matter size <10µm are called as coarse particles, <2.5µm are named fine particles and <0.1µm are termed ultrafine particles. Particulate matter of size less than 2.5µm in diameter pose the greatest risk to human health. These smaller particles pass through the nose and throat and enter the lungs. Once inhaled, these particles can affect the lungs and heart and also causes serious health effects in individuals. People with heart or lung disease, people with diabetes, older adults and children (up to 18 years of age) are greatly prone to high risk. Larger particles (> 10 µm) are generally of less concern because they usually irritate the eyes, nose, and throat. Particle pollution can last from hours to days and short-term exposure to these pollutants has effects in the human health.

Environmental protection Agency (EPA) informed that the fine particulate matter pollution poses serious health threats to human which causes early death (both short-term and long-term exposure), Causes cardiovascular harm (e.g., heart attacks, strokes, heart disease, congestive heart failure) respiratory diseases (e.g., worsened asthma, worsened COPD, inflammation), cancer, harm to the nervous system (e.g. reduced brain volume, cognitive effects), reproductive and developmental problem [11]

United Nations International Children's Emergency Fund (UNICEF) reported that 600000 children die every year in developing countries due to air pollution [12]. A study reported that exposure to PM_1, $PM_{2.5}$, PM_{10} during the first three years of life were associated with the increased risk of Autism Spectrum Disorder(ASD) [13].A similar study was conducted and stated that 7-14 years of children when exposure of PM_1 particles led to lower lung function than $PM_{2.5}$ particles [14]. Recently, World Health Organization (WHO) revised the Air Quality guidelines in the year 2021 after 16 years and reported that annual and 24 h average for $PM_{2.5}$ and PM_{10} are 5,15 and 15,45 respectively [15]. In the present study an effort is being made to monitor the particulate matter concentration during Diwali festival 2021.

2. Materials and methods

Alandur is an urban area in the Chennai district of Tamil Nadu, one of the many zones of the Chennai Corporation. The site is well connected with Grand Southern Trunk Road (NH 45) and International Airport. The neighbouring towns of Alandur include Guindy industrial Estate and Adambakkam. Alandur is located between 13.03° North and 80.21° East on geographical coordinates. It stands at an elevation of 12 m above the mean sea level. As Alandur lies on the thermal equator, it has a tropical climate. The hottest months in the study area are from May to early June and the temperatures vary between 35°C to 40°C. December and January prove to be relatively cooler months in Alandur, where temperature fluctuates between 15°C to 22°C [16]. Average annual temperature is 27.9°C and precipitation is about 1014 mm/year [17]. This area is busy with vehicular movement and it is one of the congested areas in Chennai. In the year 2017, the study area has experienced higher concentration of $PM_{2.5}$ and it was found to be about 999 $\mu g/m^3$ [18]. The location of the monitoring site is presented in Figure 1.

Figure 1. Study Area-Alandur, Chennai

Measurements were carried out near the Alandur bus depot, Chennai. Air Quality sensor (Prana air-Smart air monitor, 2000mAh,3.7V, Li-ion cell, China) was used to measure PM_1, $PM_{2.5}$ and PM_{10} concentration in terms of µg/m^3. The sensor operate with laser light and have no fans to draw the air into the device and also working with light scattering method. Samples of particulate matter PM_1, $PM_{2.5}$ and PM_{10} were collected for each day using EPAM HAZ DUST sampler (Environmental Particle Air Monitor EPAM -5000) with micro glass fiber filter of 47 mm diameter. The air quality sensor was used to measure particulate matter concentration and particles number count. Both sensor and dust sampler were kept at breathing level near the MKN circle for 15h period.Collected samples were taken for size fraction by using Scanning Electron Microscope (Carl Zeiss MA15/EVO 18,German) and elemental analysis was done using energy dispersive X-ray spectroscopy (Oxford Instruments Nano Analysis INCA Energy 250 Microanalysis System,German)

3. Results and discussions

3.1 History of air pollution at study site

Usually during Diwali festival, celebrations with fireworks starts before the day of festival and it continues for a day to two. It is shown in Figure 2, the minimum, maximum and average value of $PM_{2.5}$ concentrations over the period of 5 years 2015, 2017, 2018, 2019, 2020, highlighting only celebration week represented as 2a, 2b, 2c, 2d and 2e respectively (arrow mark indicates the Diwali day for the mentioned years). Data were collected for a total of 7 days period in which 3 days before and 3 days after the Diwali Celebration. In the year 2017 it is remarkable that the maximum concentration of $PM_{2.5}$

was 999 μg/m^3 during prediwali and on the day of Diwali day, which is 10 fold greater than the 24 h average concentration of Central Pollution Control Board (CPCB) standards (Annual average 60 μg/m^3, 24 h average 100 μg/m^3 [18]) and 66 fold greater than the WHO revised guidelines 2021 prescribed for 24 h average (Annual average 5 μg/m^3, 24 h average 15 μg/m^3). In addition, average concentration of particulate matter was 154μg/m^3 on the day of the celebration. Similarly, in the years 2015, 2018 and 2019 $PM_{2.5}$ concentration was observed above the permissible limit. The same kind of study reveals that smoke plumes generated from fireworks can raise atmospheric particulate matter (PM) levels from tens to thousands of μg/m^3[9].

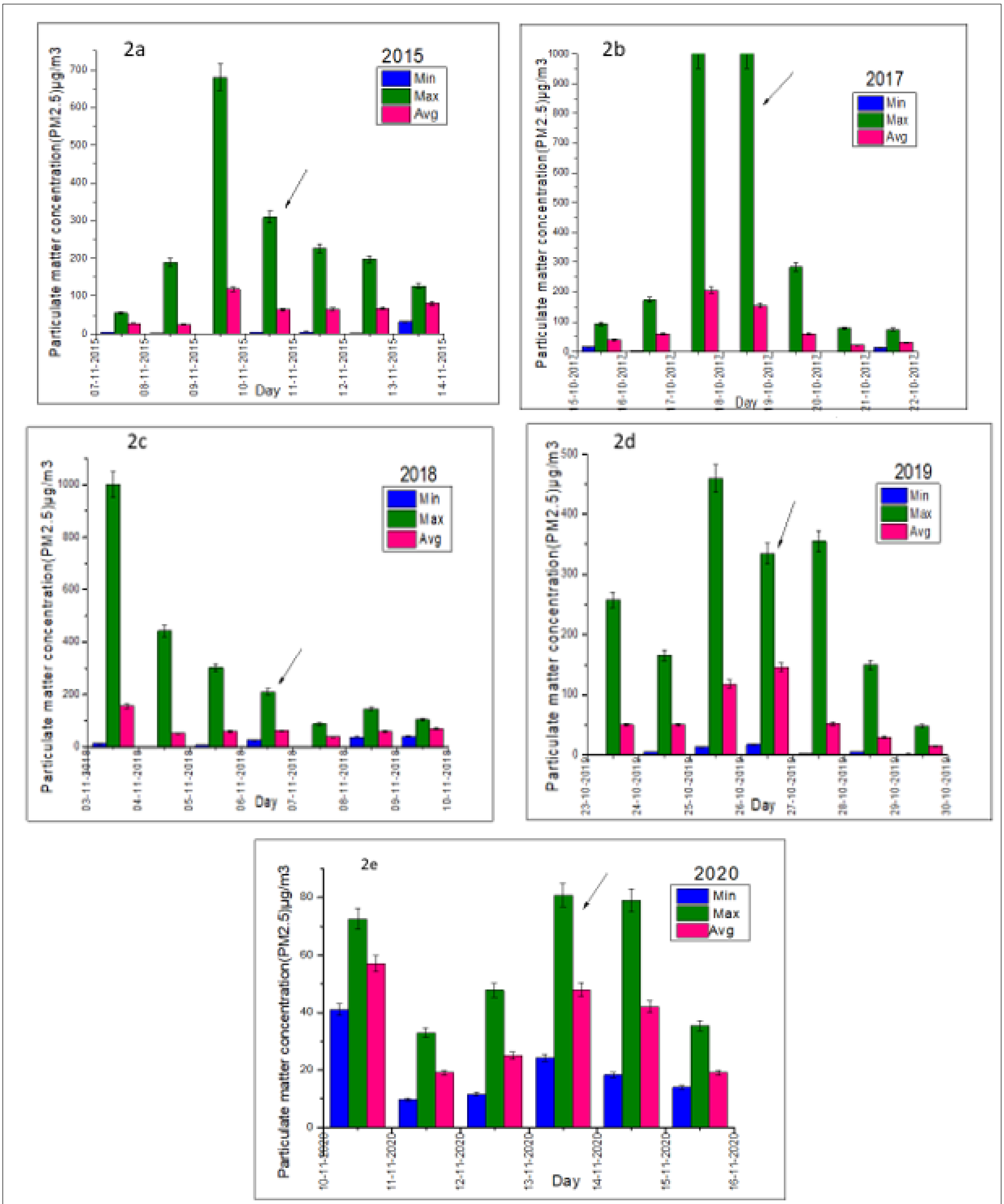

Figure 2. $PM_{2.5}$ Concentration during diwali celebration in the study area for the period 2015-2020

3.2 Temporal variation of particulate matter concentration at study site

The bursting of firecrackers on Diwali day, as expected may deteriorate the ambient air quality. Real time particulate matter concentration and particle count are presented in Figure 3 and Figure 4, respectively. The pollutant concentration was significantly higher as compared to normal day which is shown in Figure 3. Monitoring particulate matter at respiratory level was done at each 1 h period for totally 15 h duration from 7.00 am to 9.00 pm.

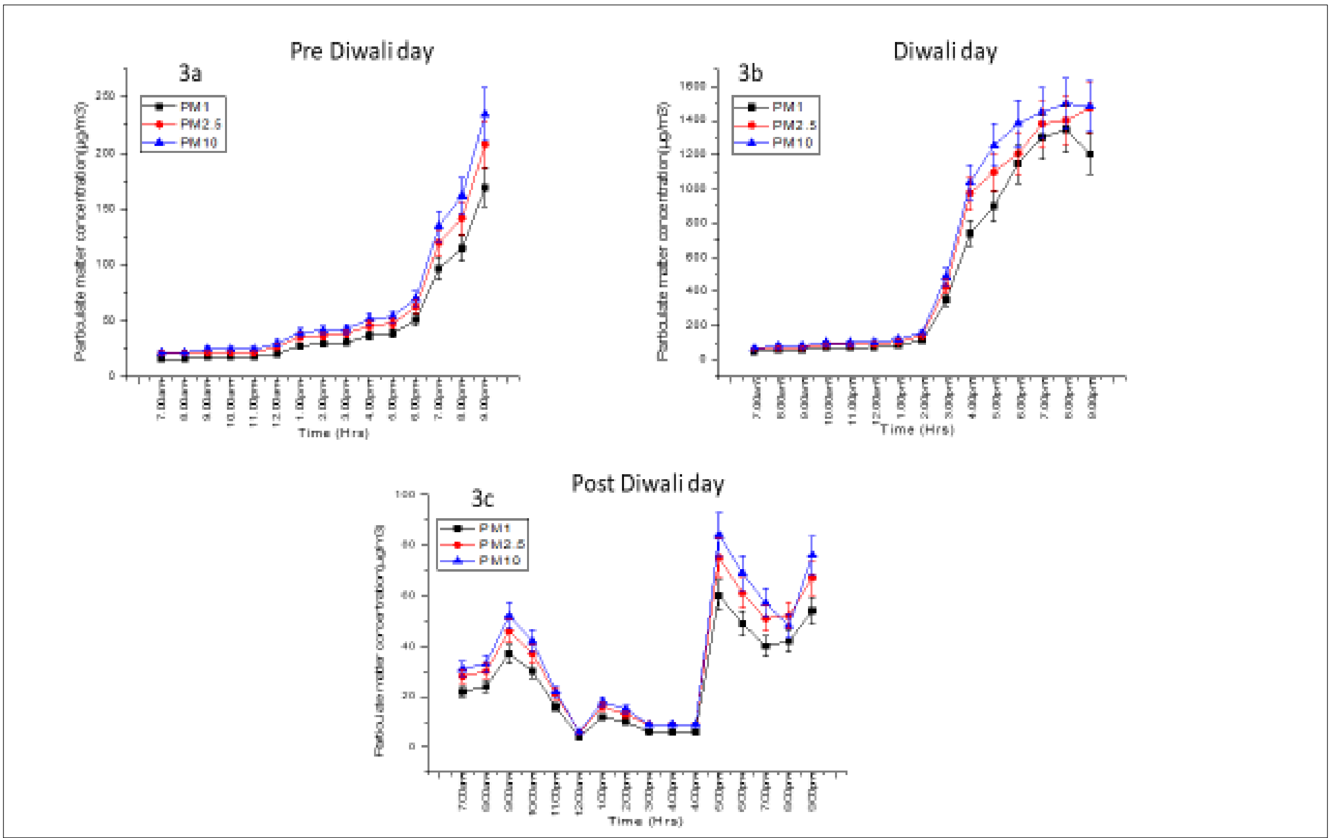

Figure 3. PM_1, $PM_{2.5}$, PM_{10} Particulate matter concentration during Diwali celebration 2021

Figure 3a represents prediwali day (3/11/2021), which experienced the higher concentration of particulate matter during late evening hours. In the study location, for the day of Diwali (4/11/2021) measured PM data is presented in Figure 3b, showing that there was a minimum concentration during morning hours most probably due to a rainfall, but particulate matter concentration increased towards late evening hours. Figure 3c represents Post Diwali day (5/4/2021), showing a quick decrease in particulate matter concentration which may be due to less use of firecrackers and the atmospheric conditions with average wind speed about 2.5 m/s (CPCB) [18]. From the study it was identified that PM_{10} concentration is higher when compared with $PM_{2.5}$ and PM_1 concentration, but the particles number concentration were more in the the range of 2.5 μm to 0.3 μm size. Primož et al [19] found that there was a close correlation with the timings of the fireworks displays in the Slovenia region and PM_{10} concentration exceeded the one day limit value during Christmas and New year celebration. Higher particulte matter concentration of PM_{10} and $PM_{2.5}$ reported that 1046 μg/m^3 and 842 μg/m^3 respectively. Another study reported that the number of aerosol particles was higher in the range of 0.1 to 0.5μm size during lantern festival [8]. A similar research stated that PM_{10} and $PM_{2.5}$ particles emitted from the lantern festival firework event, mainly primary aerosols emitted in the form of fine particles of these secondary formation of acidic anions are also formed as coarse particles. The study found that the smoke from firework are acidic and inorganic in nature [5].

In this study the air quality sensor classified air borne particles from 0.3µm to 10 µm size with a cut-off diameter of 10 µm, 5 µm, 2.5µm, 1 µm, 0.5 µm and 0.3 µm respectively. Figure 4 represents the particle number concentration for the pre, post and Diwali day and it was identified that fine particles concentration more than the coarse particles and also particles number concentration were more in the the range of 2.5 µm to 0.3 µm size. A similar research identifed that the particle number concentration decreased with increasing particle size [20]. Another study found that fine and ultrafine particulate matter are formed from high temperature combustion process such as vehicular emission, coal combustion, industrial manufacturing process and chemical reaction in the atmosphere [21].

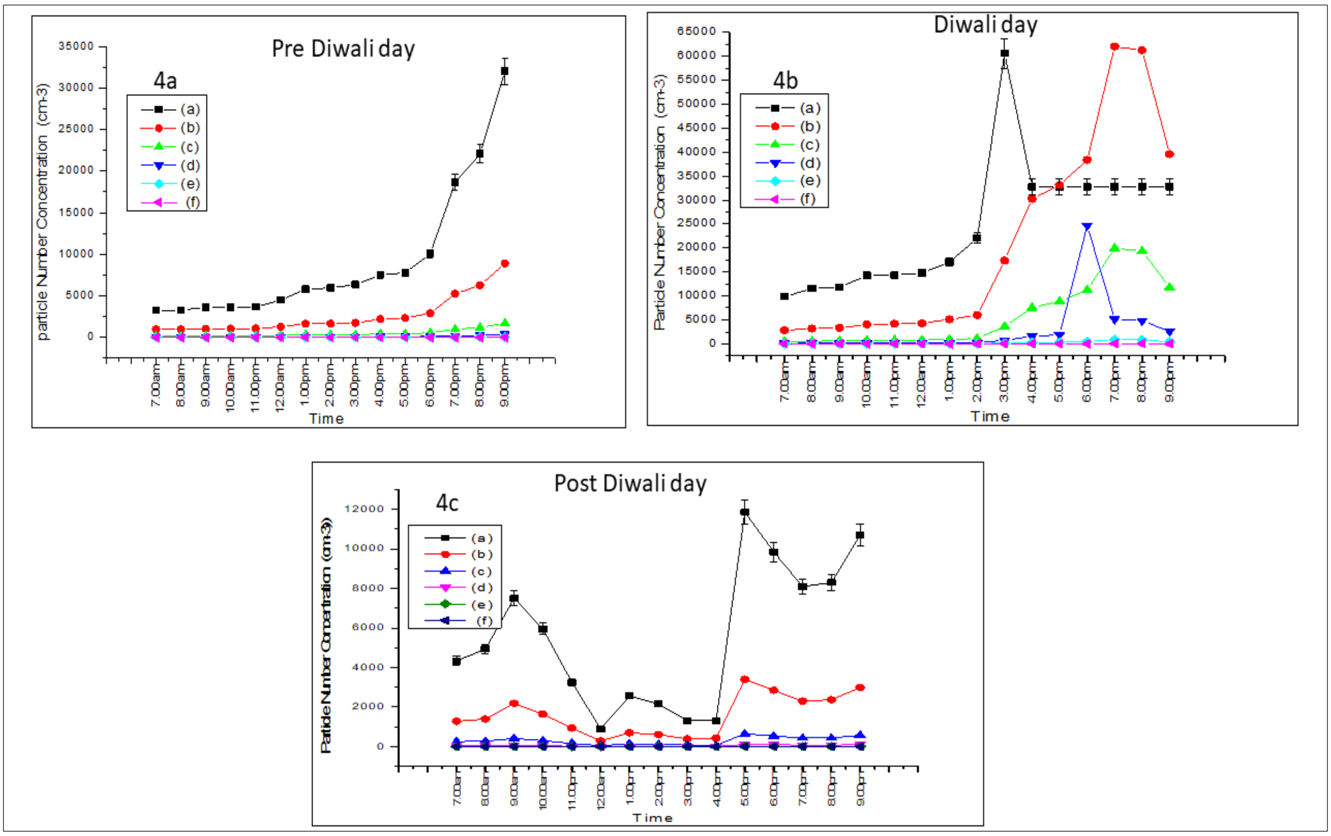

Figure 4. Particle Number Concentration in the Study Area during Diwali 2021
(a:> 0.3µm b: >0.5µm c: >1µm d: > 2.5µm e: >5µm f: >10µm)

3.3. Elemental analysis

Further the EDAX images are presented in Figure 5 and the results of elemental analysis are shown in Figure 6. The figure shows that the weight percentage of the elements on the day of Diwali as observed for PM_{10} particle size is in the order of Sr:37.72 > K:22.8 > S:19.88 > Sb:5.30 > Ca:4.89 > Ba:3.76 > Si:3.34 > Cl:0.80 > Na:0.67 > Al:0.63 > Mg:0.20. Similarly, $PM_{2.5}$ contains the following elements C:43.39 > O:38.87 > Si:6.75 > N:5.4 > Na:2.40 > Ba:1.52 > K:0.72 > As:0.58 > Cl:0.27 > Mn:0.06 > Mg:0.03 > Fe:0.02. The elements available from the PM_1 particles are as follows O:50.54 > Si:28.73 > Na:6.47 > Ba:5.68 > Al:3.37 > K:2.77 > Mg:1.66 > Fe:0.62 > Pb:0.15. Further this study found that there may be chance for formation of secondary pollutants from the firework emissions [22].

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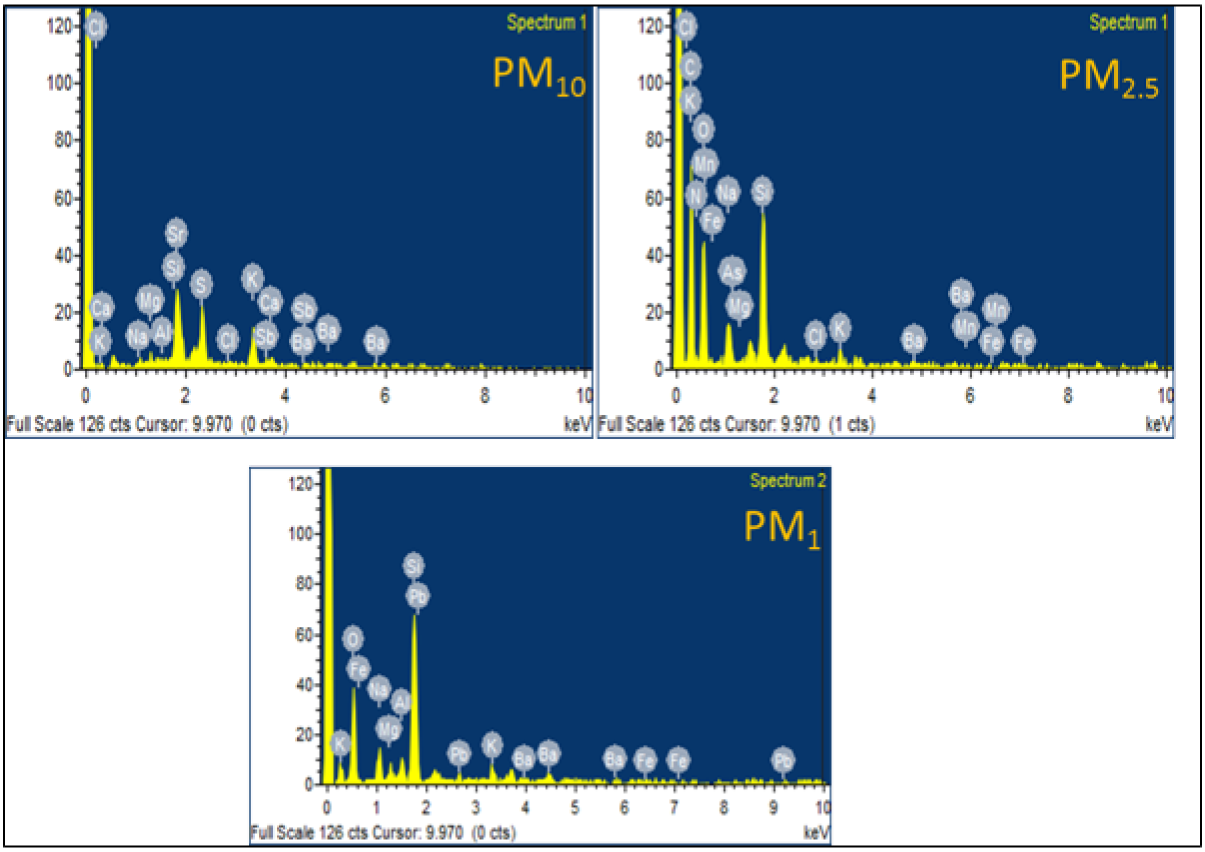

Figure 5. EDX of PM_1, $PM_{2.5}$, PM_{10} concentration in the study area

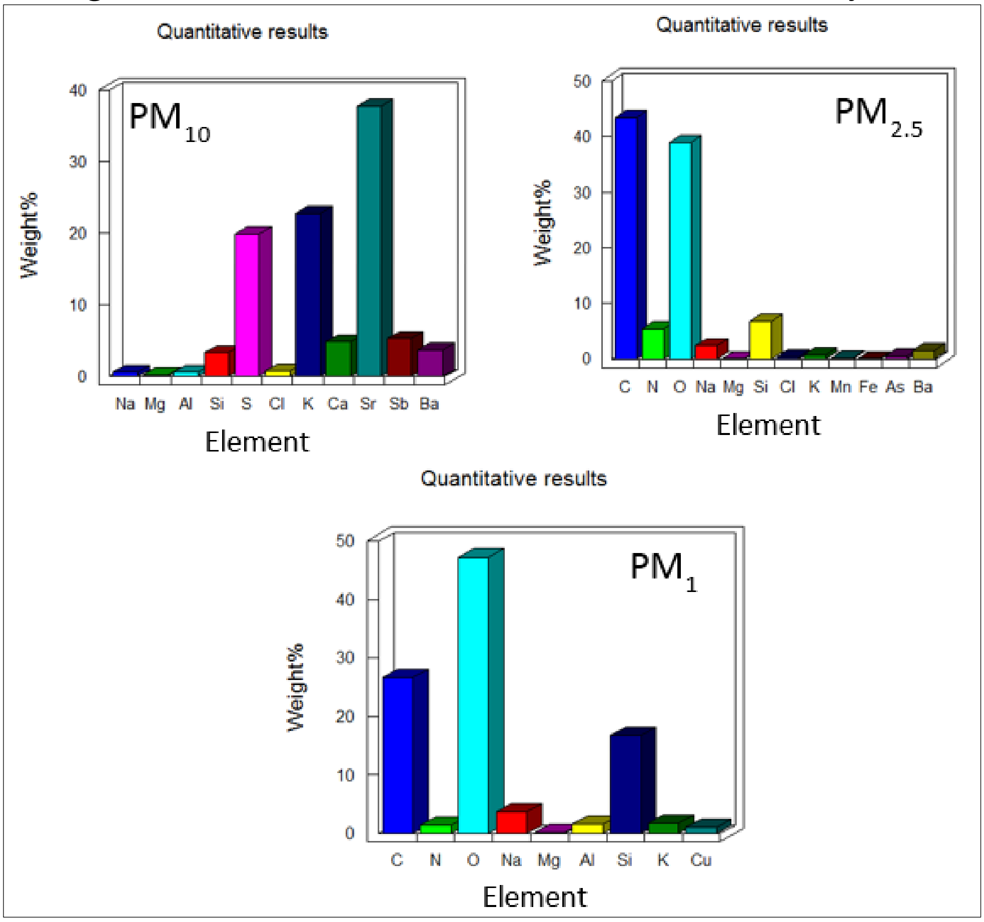

Figure 6. Quantitative representation (EDAX) of PM_1, $PM_{2.5}$, PM_{10} particles in the study area

In the literature survey some of the metallic elements present in the particulate matter were identified at higher levels during firework events. Vecchi et al. [23] studied that fire work displays during the FIFA World Cup 2006 celebration increased the concentration of metals, such as Sr (120-fold), Mg (22-fold), K (12-fold), Ba (11-fold), and Cu (6-fold), in ambient PM_{10} in Milan, Italy. Pramod Kumar et al., [24] found that during diwali celebration in India there was an average concentrations of particulate matter (in μg/m^3) released from fire cracker, in order: aluminum (19.47) > magnesium (11.39) > sulfur (7.69) > potassium (6.50) > iron (0.74) > zinc (0.30) > lead (0.13) > copper (0.09).

3.4. Results of previous research for firework pollution and health effects

Fireworks give a visual pleasure which may result in serious accidents and lethal injuries [25] and colored fireworks could generate ozone at the ground level, which is a strong and harmful oxidizing agent which may affect the human health [26].

A case study observed that breathing fireworks smoke produces cough, fever and dyspnea, all of which contribute to acute eosinophilic pneumonia [27]. Most particles emitted from firecrackers are fine (1–2 μm) particles and therefore potentially respirable [28] and inhalation of finely powdered aluminium particles has a causative fibrotic effect on the lungs [29]. A study demonstrated that the firework emission can produce serious health effects in mammalian cell and lungs irrespective of the particle size [30]. A study revealed that there is a decrease in air borne bacteria due to exposure of toxic chemicals on Diwali day [31]. Mariselvam et al conducted a health survey in the year 2017 and stated that about 45% of urban people were facing problem with eye irritation during the Diwali festivals [32]. Antimony (Sb) is used to create glittering effect to the firecrackers and OSHA reported that inhalation of antimony trioxide causes carcinogenic (Group - 2B) to human being [33].

The increased level of particulate matter led to a 67% increase in hospital admission. The prolonged exposure time to metals such as Zn, Co, Sr, Ni, Fe and Cd alone during Diwali period increased the health risk level by 0.5% [34].

4. Conclusions

The concentration changes that appeared several times within short periods of time were noticed for PM_1, $PM_{2.5}$ and PM_{10} and it is noticed that higher particle are released in the range of fine and ultra fine particle size. The concentration of particulate matter is in the range of PM_{10}>$PM_{2.5}$>PM_1 and the particle number concentration is increasing towards ultrafine particles size. The transient particles released by fireworks consist of complex mixtures of different trace elements. The notable trace elements in the study area are strontium, potassium, sulphur, antimony, calcium, barium, chlorine, sodium in PM_{10} particles. $PM_{2.5}$ particles consist of carbon, oxygen, silica, nitrogen, sodium, barium, potassium, arsenic, chlorine, manganese, magnesium and iron. Particle size less than 1 μm contain the elements such as oxygen, silica, sodium, barium, aluminium, potassium, magnesium, iron and lead. It is evident that the elements present in the particulate matter size less than 2.5 μm are easily inhalable which may cause ill effects. Therefore, it is important for human health to focus on the risk of high concentrations of toxic elements released from firework events.

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References

1.JOHN A. CONKLING, CHRISTOPHER J MOCELLA Chemistry of Pyrotechniques –Basic Principles and Theory 2019. IIIrd Edition CRC press.
2.MARTÍN-ALBERCA, C., & GARCÍA-RUIZ, C. *Trends in Analytical Chemistry*, ***56***, 2014, 27–36. https://doi.org/10.1016/j.trac.2013.12.010
3. ***https://fireworksscience.weebly.com/elements.html

4.KELLY, F. J. (2003). Oxidative stress: Its role in air pollution and adverse health effects. *Occup. Environ Med*, **60**, 2003 612-6.
5.WANG, Y., ZHUANG, G., XU, C., & AN, Z. The air pollution caused by the burning of fireworks during the lantern festival in Beijing. *Atmospheric Environment*, ***41***, 2007, 417–431. https://doi.org/10.1016/j.atmosenv.2006.07.043
6.SHI,Y.,ZHANG, N., GAO, J., LI, X., & CAI, Y. Effect of fi reworks display on perchlorate in air aerosols during the Spring Festival. *Atmospheric Environment*, ***45***, 2011, (6),1323–1327. https://doi.org/10.1016/j.atmosenv.2010.11.056
7. TSAI, H., CHIEN, L., YUAN, C., LIN, Y., JEN, Y., & IE, I. Influences of fireworks on chemical characteristics of atmospheric fine and coarse particles during Taiwan' s Lantern Festival. *Atmospheric Environment*,***62***,2012, 256–264. https://doi.org/10.1016/j.atmosenv.2012.08.012
8. LIN, S. C. T., & LEE, C. Y. C, The impact of ground-level fireworks (13 km long) display on the air quality during the traditional Yanshui Lantern Festival in Taiwan, *Environ Monit Asses*, **172**, 2011, 463–479. https://doi.org/10.1007/s10661-010-1347-1
9. JOLY, A., SMARGIASSI, A., KOSATSKY, T., FOURNIER, M., DABEK-ZLOTORZYNSKA, E., CELO, V., MATHIEU, D., SERVRANCKX, R., RÉAL, D., MALO, A., & BROOK, J. Characterisation of particulate exposure during fi reworks displays. *Atmospheric Environment*, ***44,*** 2010, (34), 4325–4329. https://doi.org/10.1016/j.atmosenv.2009.12.010
10. FLEISCHER, O., WICHMANN, H., LORENZ, W., Release of polychlorinated dibenzo-p-dioxins and dibenzofurans by setting off fireworks. *Chemosphere*, **39**, 1999, 925–932.
11. ***https://www.epa.gov/pm-pollution/particulate-matter-pm-basics
12.YAVAŞ, S. P. The Effect of Firework Explosion at the Fireworks Factory on Air Pollutant Levels. *Anatol. J. Family Med*, **4,**2021(1),80-84, https://doi.org/10.5505/anatoljfm.2021.49469
13 .CHEN, G., JIN, Z., LI, S., JIN, X., TONG, S., & LIU, S. Early life exposure to particulate matter air pollution (PM1, PM2.5 and PM10) and autism in Shanghai, China: A case-control study, *Environment International*, ***121***, 2018, 1121–1127. https://doi.org/10.1016/j.envint.2018.10.026
14. YANG, M., GUO, Y., BLOOM, M. S., DHARMAGEE, S. C., & MORAWSKA, L., Is PM 1 similar to $PM_{2.5}$? A new insight into the association of PM 1 and PM 2. 5 with children's lung function, *Environment International*, ***145***, 2020, 106092, https://doi.org/10.1016/j.envint.2020.106092
15. *****WHO Global Air Quality Guidelines 2021
16. *****https://www.alanduronline.in/city-guide/about-alandur
17. *****https://en.climate-data.org/asia/india/tamil-nadu/alandur-32223
18. *****https://app.cpcbccr.com/ccr/#/caaqm-dashboard-all/caaqm-landing/caaqm-data-availability
19. MLAKAR, P., BOŽNAR, M.Z., GRAŠIČ, B. AND POPOVIĆ, D. (2012) 'Fireworks air pollution in Slovenia', Int. J. Environment and Pollution, **50**, (2012), 1/2/3/4, pp..31–40
20. A. HELD, A. ZERRATH, U. MCKEON "Aerosol size distributions measured in urban, rural and high-alpine air with an electrical low pressure impactor (ELPI)," Atmospheric Environment, **42**, 2008, 36, 8502–8512, 10.1016/j.atmosenv. 2008.06.015
21.TAIWO, A. M., BEDDOWS, D. C. S., SHI, Z., & HARRISON, R. M. Mass and number size distributions of particulate matter components: Comparison of an industrial site and an urban background site. *Science of the Total Environment*, ***475***, (2014).29–38. https://doi.org/10.1016/j.scitotenv.2013.12.076.
22. SARKAR, S., KHILLARE, P. S., JYETHI, D. S., HASAN, A., & PARWEEN, M., Chemical speciation of respirable suspended particulate matter during a major firework festival in India. *Journal of Hazardous Materials*,***184***, 2010, (1–3), 321–330. https://doi.org/10.1016/j.jhazmat.2010.08.039.
23.VECCHI, R., BERNARDONI, V., CRICCHIO, D., ALESSANDRO, A. D., FERMO, P., LUCARELLI, F., NAVA, S., PIAZZALUNGA, A., & VALLI, G. *The impact of fireworks on airborne particles*. ***42***, 2008,1121–1132, https://doi.org/10.1016/j.atmosenv.2007.10.047
24.PRAMOD KUMAR AND N.C. GUPTA., Firework-Induced Particulate and Heavy Metal Emissions During the Diwali Festival in Delhi, India. *Journal of Environmental Health*, **81**,2018, E1-E8.

25.BULL, M.J., AGRAN, P., GARDNER, H.G., LARAQUE, D., POLLACK, S.H., SMITH, G.A., SPIVAK, H.R., TENENBEIN, M., BRENNER, R.A., BRYN, S., NEVERMAN, C., SCHIEBER, R.A., STANWICK, R., TINSWORTH, D., GARCIA, V., TANZ, R., NEWLAND, H., American Academy of Pediatrics. Committee on injury and poison prevention. Fireworks-related injuries to children. Pediatrics **108**, 2001,190-191.
26. ATTRI, A.K., KUMAR, U., JAIN, V.K., Microclimate: formation of ozone by fireworks. *Nature* **411**, 2001, (6841), 1015.
27.HIRAI, K., YAMAZAKI, Y., & OKADA, K. (2000), *Acute Eosinophilic Pneumonia Associated with Smoke from Fireworks*. ***39***, *(2000)*,5,401-403.
28.LIU, D., RUTHERFORD, D., KINSEY, M. & PRATHER, K. A., Real-Time Monitoring of Pyro Technically Derived Aerosol Particles in the Troposphere. *Anal chem*, ***69***, 1997, 1808–1814.
29.MITCHELL J, MANNING GB, MOLYNEUX M, LANE RE, Pulmonary fibrosis in workers exposed to finely powdered aluminium. *Br J Ind Med*;18, 1961,10-23.
30.HICKEY, C., GORDON, C., GALDANES, K., BLAUSTEIN, M., HORTON, L., CHILLRUD, S., GORDON, T. Toxicity of particles emitted by fireworks. *Particle and Fibre Toxicology*, **17** 2020 (1). https://doi.org/10.1186/s12989-020-00360-4
31. PRAKASH, N. K. U., SRIPRIYA, N., GOWTHAM, K., SURESH, S., SAMPATHKUMAR, B., & BHUVANESWARI, S., A study on the impact of fire crackers on airborne micro flora during diwali. *Heliyon*, ***5***, *2019,* e02202, https://doi.org/10.1016/j.heliyon.2019.e02202
32.KRISHNAN, M.A., DEVARAJ,T.,VELAYUTHAM, K., PERUMAL,V.,SUBRAMANIAN, S., Statistical evaluation of $PM_{2.5}$ and dissemination of $PM_{2.5}$, SO_2 and NO_2 during Diwali at Chennai, India. *Natural Hazards*, ***103***, 2020, 3847–3861. https://doi.org/10.1007/s11069-020-04149-8
33. ***https://www.osha.gov/chemicaldata/526
34.GARAGA, R., & HARSHA, S. Characterization of PM_{10} and Impact on Human Health During the Annual Festival of Lights (Diwali),*Journal of Health & Pollution*, ***8***, 2018, 20. doi.org/10.5696/2156-9614-8.20.181206

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