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Particle Size Distribution from Municipal Solid Waste Burning over National Capital Territory, India †

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Abstract: Emission of particulate matter (PM) of different sizes from Municipal Solid Waste (MSW) burning may have impact on the air quality and human health particularly during winter months over National Capital Territory (NCT) of India. MSW samples were collected from three sanitary landfill sites in the NCT Delhi. Experiments were performed to mimic real world burning during different stages of combustion (ignition, flaming smoldering, smoldering and pyrolysis) of the samples. We have determined the emission factor of number and mass concentration of particles of the different sizes ranging from 0.34 μm to 9.05 μm from MSW burning. Present results confirm the assumption that MSW burning emits the maximum number concentration (No/cm^3) of particles (90%) in the range of <1.0 μm, or fine mode aerosol.

Keywords: air quality; MSW burning; fine particles

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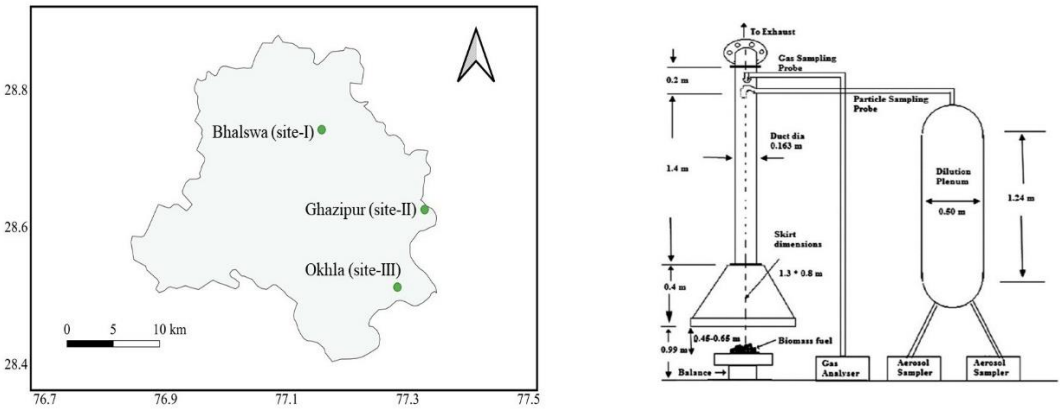
1. Introduction

Municipal Solid Waste (MSW) refers to domestic garbage generated from the kitchen as well as various domestic activities from household and commercial establishments. MSW comprises organic and inorganic materials such as kitchen and garden waste, plastics, paper etc. The burning of MSW is a potential source of particulate matter (PM) and various pollutants such as gases and toxins [1,2]. Out of the total municipal waste generated the fraction of waste are burnt at open places [2,3]. The particulates and other pollutants emitted from this activity cause degradation of air quality as well as contributing to global climate change. In addition, particulate, via short and long-term exposure, contribute to various health impacts including respiratory and cardiovascular disease, increased mortality as well as cancer [1,4–14]. The present study investigates the emission of different particle sizes in the range of 0.30 μm to 10 μm from MSW burning.

2. Materials and Methods

The National Capital Territory (NCT) (28°12′–28°63′ N, 75°50′–77°23′ E) comprises an area of 1484 km^2 which is divided into 9 districts. As per the Census 2011 the total population of NCT was 16,753,235 (https://www.census2011.co.in/census/state/districtlist/delhi.html, last accessed 27 March 2020). Dried MSW samples were collected from three landfilling sites namely Bhlaswa (Site-I), Ghazipur (Site-II) and Okhla (Site-III)

across the NCT (Figure 1). Samples were stored in zip lock bags and burnt under controlled laboratory conditions.



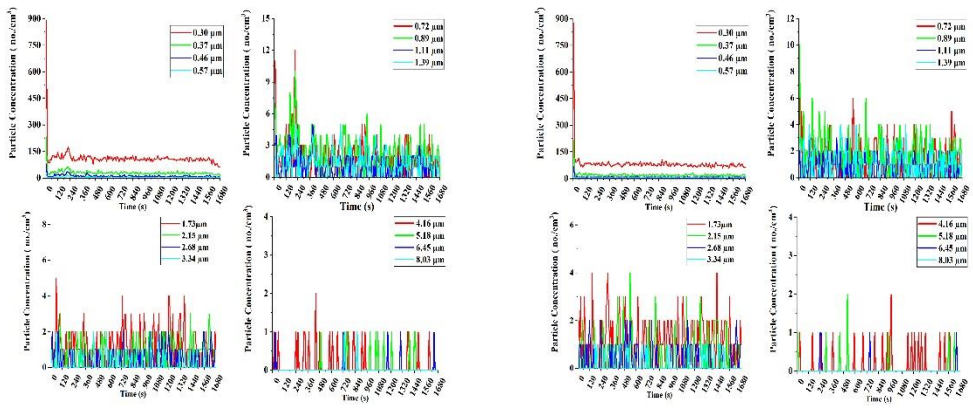
(**a**) (**b**)

Figure 1. Location (**a**) of collection over NCT and experiment set up (**b**).

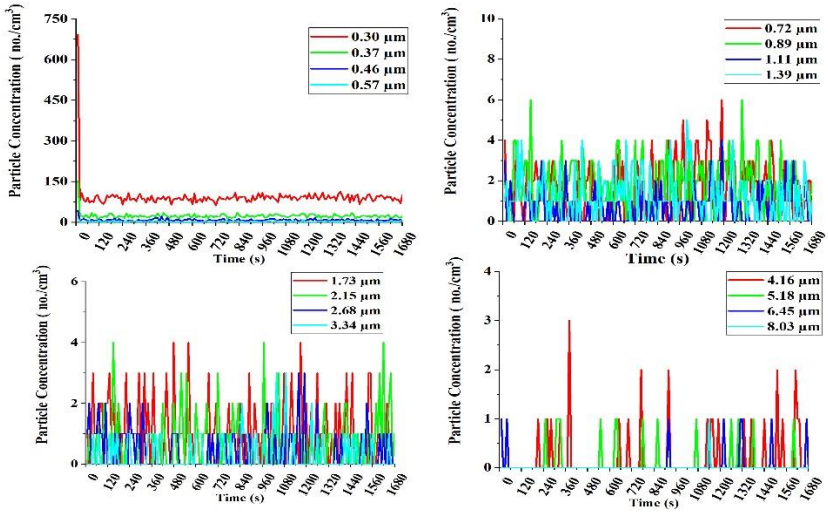
Burning experiments were performed at CSIR-National Physical Laboratory (CSIR NPL), New Delhi, India, using a combustion dilution chamber. Figure 1b gives the schematic diagram of burning facility. A detailed description of the characteristics can be found in [15–19]. The sampling point is located above ground level. The first sampling flow was taken from the sampling point and was directed to a particle diluter (TSI Model 3320) for diluting the samples at a ratio of 1:100. The diluted flow was directed to an aerosol spectrophotometer or Optical Particle Sizer (TSI Model 3330) for size distribution for the combustion experiment in controlled laboratory conditions.

3. Results and Discussion

Figure 2a–c shows the evolution of the concentration (dilution ratio 1:100, reported values are after dilution) of differently sized particles over entire burning cycles, from the time from ignition to the smoldering stage (end of sampling), for three sampling sites namely Bhlaswa (Site-I), Ghazipur (site-II) and Okhla (site-III) over NCT of Delhi. The flaming period emitted a larger particle number concentration compared to ignition and smoldering. It was noticed that for Site-I, during the flaming phase, particle number concentration in the size range 0.30 to 0.5 µm was around 900 # cm^{-3}, whereas, for the other size ranges, it was two order less. Similar pattern of variation in number concentration were observed at Site-II and III. High emission of fine particulate may be associated wth the breakdown of organic compounds of MSW as the MSW comprises organic as well as inorganic materials in its composition.



(**a**) (**b**)



(**c**)

Figure 2. (**a**–**c**) Particles number concentration by size from different phase of MSW burning of MSW samples collected from three sites (**a**) Bhlaswa (Site-I), (**b**) Ghazipur (Site-II), and (**c**) Okhla (Site-III) (dilution ratio 1:100).

Figure 3a–c shows the percentage distribution of emission of particle number concentration for different sizes (dilution ratio 1:100, reported values are after dilution.) Particle concentration in the range 0.37 to 1.0 µm averaged 70,927 ± 2909# cm^{-3}, whereas, particle number concentration for the size 1.0 to 2.5 µm averaged 72,952 ± 2929 # cm^{-3} and from 2.5 to 10 µm averaged 73,418 ± 2940# cm^{-3}). Emission of particle from the Site I were higher than from the other two sites.

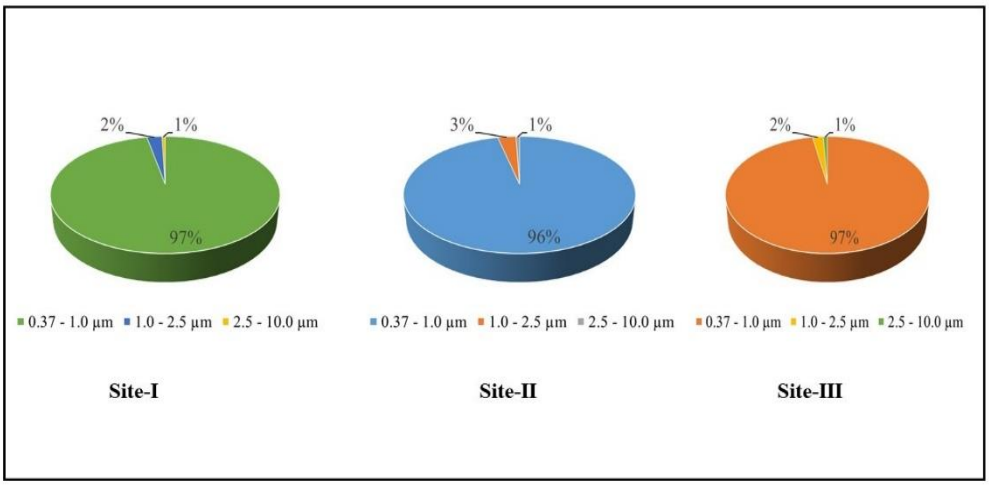


Figure 3. (**a**–**c**). Percentage distribution of particle number concentration for different size ranges (0.37–1.0 µm, 1.0–2.5 µm, 2.5–10 µm) at (**a**) Bhlaswa (Site-I), (**b**) Ghazipur (Site-II), and (**c**) Okhla (Site-III) (dilution ratio 1:100).

Figure 4 shows emission factor of particles of different size (dilution ratio 1:100, reported values are after dilution). Higher emission factors i.e., 20.19 mg $(kg\ fuel)^{-1}$ was recorded for the particles size range 2.5 to 10.0 µm, whereas particles size range 0.37 to 1.0 µm recorded lowest emission factor, i.e., 3.61 mg $(kg\ fuel)^{-1}$. The sample from Site–III recorded higher emission factor as compared with other two sites.

NCT of Delhi generated 10981.3 TPD MSW, out of which 2–3% undergoes open burning. We estimate that this MSW burning accounts for a total emission of 0.68 kg/day of $PM_{1.0}$, 1.71 kg/day of $PM_{2.5}$ and 4.41 kg/day of PM_{10}.

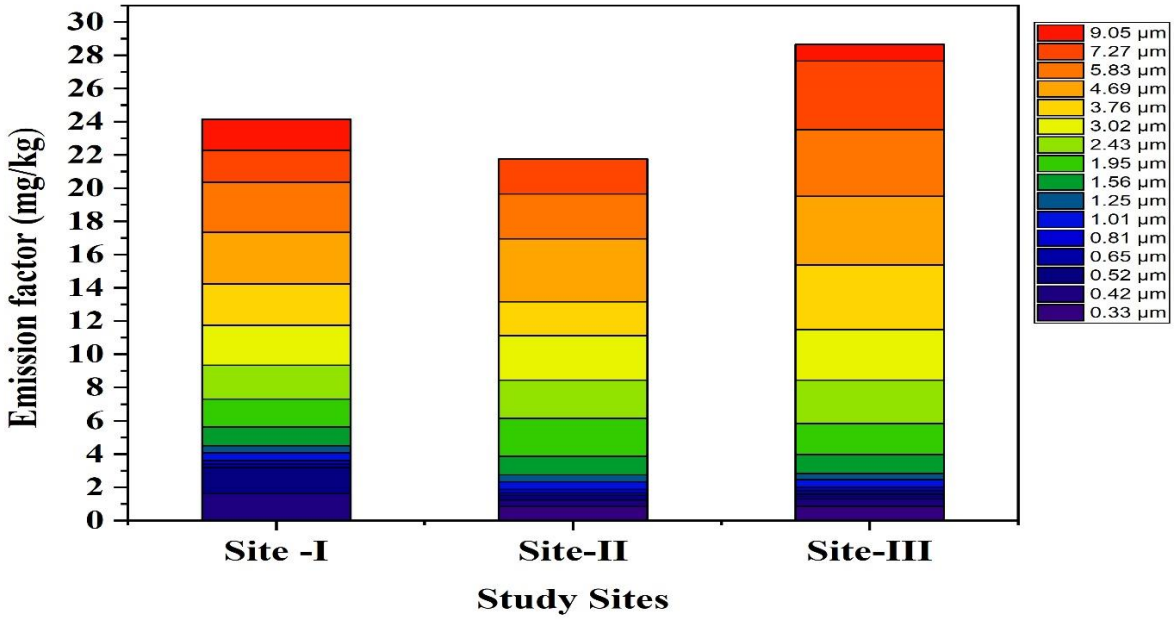


Figure 4. Emission factor (mg/kg) of particle for different size at different sites namely (**a**) Bhlaswa (Site-I), (**b**) Ghazipur (Site-II), and (**c**) Okhla (Site-III) (dilution ratio 1:100).

4. Conclusions

The present study highlights that most of the fine particles (particle diameter up to 1.0 and 2.5 µm) from MSW burning are emitted during the flaming phase, with higher particles size concentration. Overall the larger particles (i.e., above 2.5 µm) showed the largest mas-based emission factor. These emissions contribute to poor air quality and adverse health impacts on human health.

Author Contributions: R.A.: A.M. have collected MSW samples over NCT of Delhi. R.A., S.A., L.Y., R.J. and A.M. designed and performed experimental work. R.A. has analyzed data and taken lead in drafting manuscript. S.K.S., B.R.G. and E.N. assisted with data analysis, reviewing, proofreading and supervision. T.K.M. has conceptualized the programme and involved in data analysis, reviewing, proofreading and overall supervision. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: The datasets developed during this study are available from the corresponding author on reasonable request.

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

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