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Proceeding Paper

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 an impact on air quality and human health of the National Capital Territory (NCT) of India, particularly during winter months. 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 sample combustion (ignition, flaming smoldering, smoldering and pyrolysis). We determined the emission factor for the number and mass concentration of particles of different sizes, ranging from 0.34 to 9.05 µm, for MSW burning. Present results confirm the assumption that MSW burning emits the maximum number concentration (No/cm^3) of particles (90%) in the range < 1.0 µm, or fine-mode aerosol.

Keywords: air quality; MSW burning; fine particles

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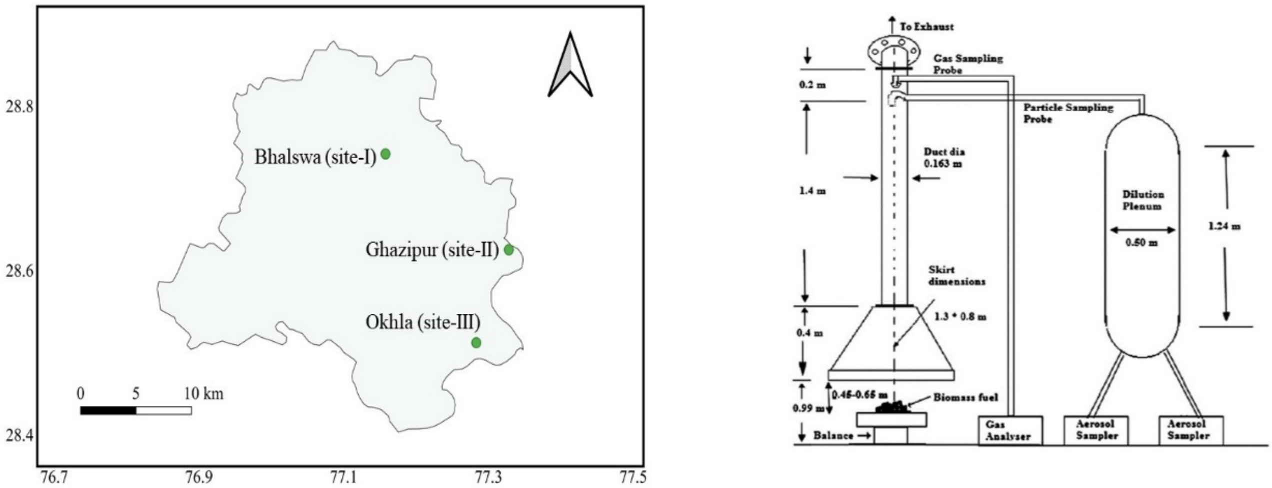
1. Introduction

Municipal Solid Waste (MSW) refers to domestic garbage generated from the kitchen and various domestic activities in household and commercial establishments. MSW comprises organic and inorganic materials such as kitchen and garden waste, plastics, paper, etc. Burning 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, a fraction of the waste is burnt at open places [2,3]. The particulates and other pollutants emitted from this activity cause degradation of air quality and contribute to global climate change. In addition, particulates, via short- and long-term exposure, contribute to various health impacts, including respiratory and cardiovascular disease, increased mortality and cancer [1,4–14]. The present study investigates the emission of different particle sizes in the range 0.30 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 that 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 (accessed on 27 March 2020)). Dried MSW samples were collected from three landfill 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 setup (**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 the burning facility. A detailed description of the characteristics can be found in [15–18]. The sampling point was located above ground level. The first sampling flow was taken from the sampling point and 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 show the evolution of the concentration (dilution ratio 1:100, reported values are after dilution) of differently sized particles over entire burning cycles, during the time from ignition to the smoldering stage (end of sampling) for the three sampling sites, namely, Bhlaswa (Site-I), Ghazipur (Site-II) and Okhla (Site-III), over the 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, the 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 orders less. A similar pattern of variation in number concentration was observed at Site-II and Site-III. High emission of fine particulate may be associated with the breakdown of organic compounds of MSW, as MSW comprises organic and inorganic materials in its composition.

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

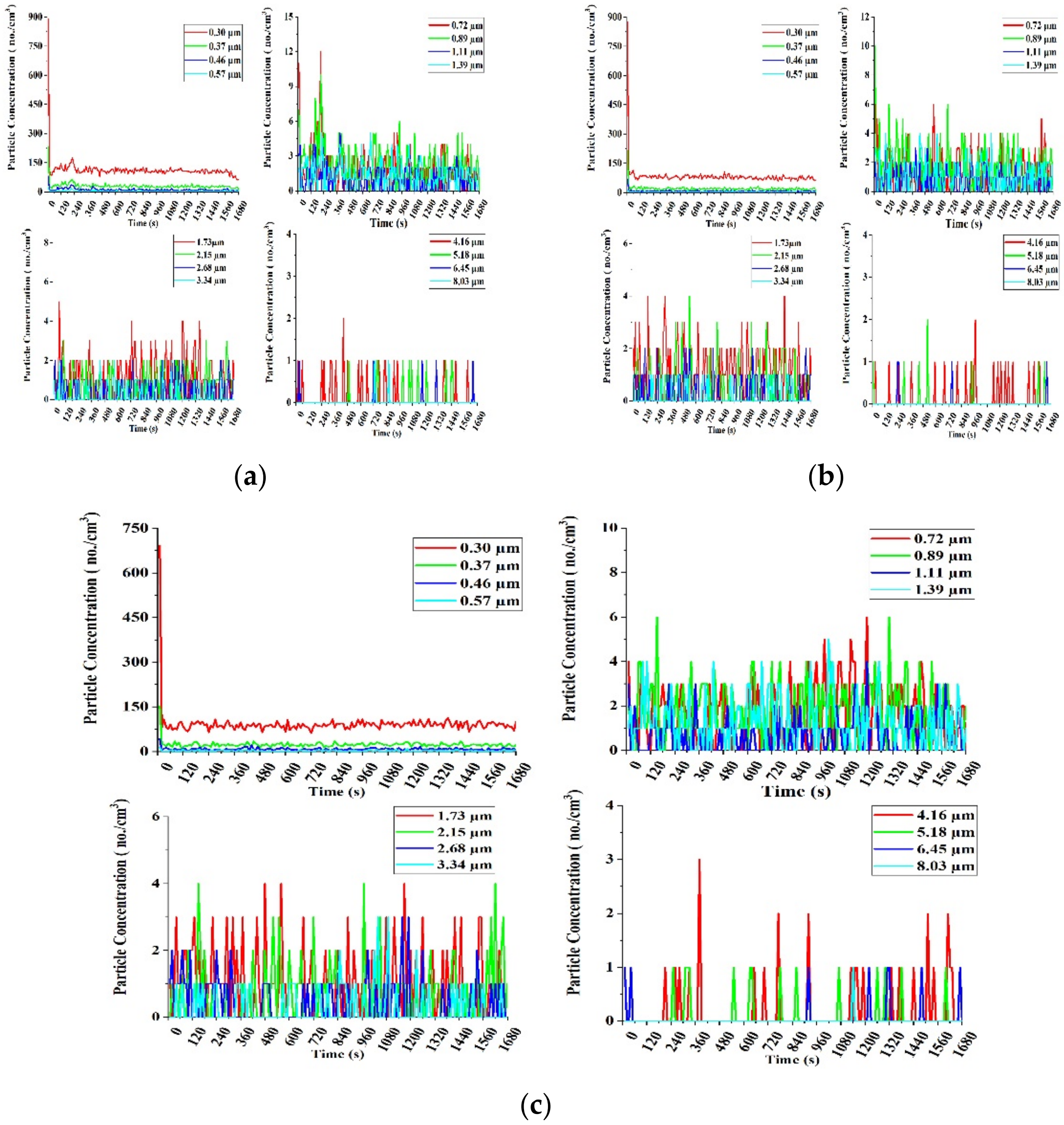


Figure 2. (**a**–**c**) Particle number concentration by size from different phases during burning of MSW samples collected from three sites: (**a**) Bhlaswa (Site-I), (**b**) Ghazipur (Site-II) and (**c**) Okhla (Site-III) (dilution ratio 1:100).

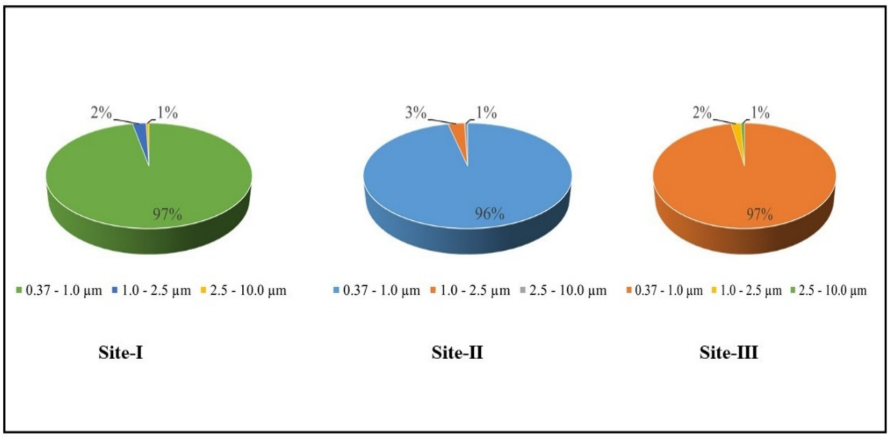


Figure 3. Percentage distribution of particle number concentration for different size ranges (0.37–1.0, 1.0–2.5 and 2.5–10 µm) at Bhlaswa (Site-I), Ghazipur (Site-II) and Okhla (Site-III) (dilution ratio 1:100).

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

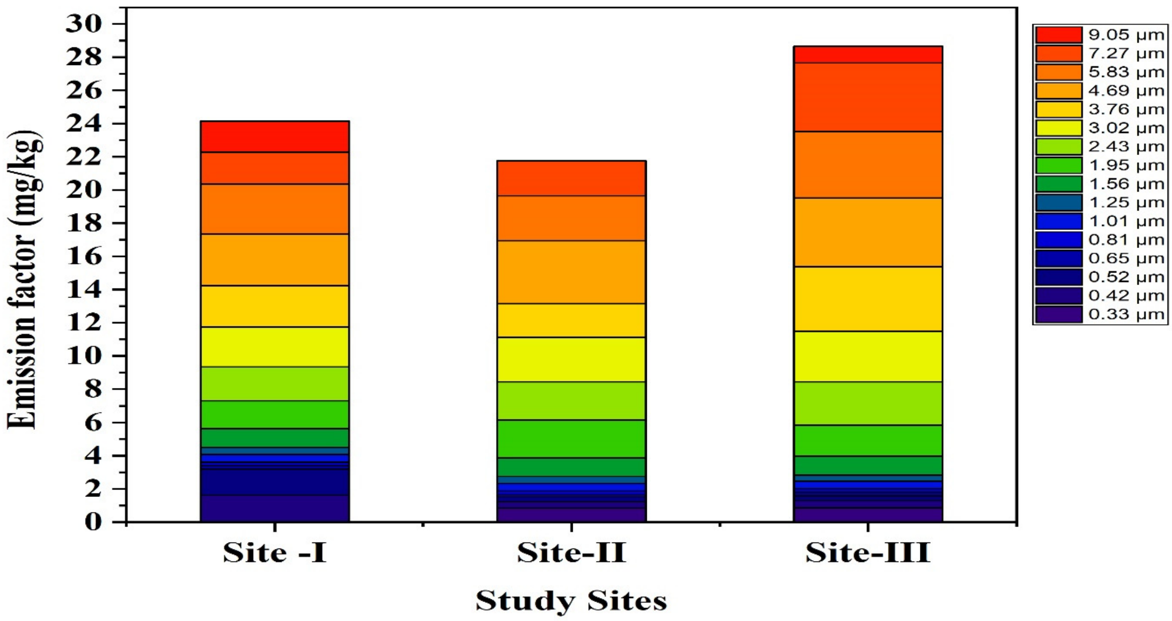


Figure 4. Emission factor (mg/kg) for particles of different size at the sample sites, namely, Bhlaswa (Site-I), Ghazipur (Site-II) and Okhla (Site-III) (dilution ratio 1:100).

The NCT of Delhi generated 10,981.3 TPD MSW, out of which 2–3% undergoes open burning. We estimate 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}.

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 particle size concentration. Overall, the larger particles (i.e., above 2.5 µm) showed the largest mass-based emission factor. These emissions contribute to poor air quality and adverse human health impacts.

Author Contributions: R.A. and A.M. 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. analyzed data and led in drafting the manuscript; S.K.S., B.R.G. and E.N. assisted with data analysis, reviewing, proofreading and supervision; T.K.M. conceptualized the program and was 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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Conflicts of Interest: The authors declare no conflict of interest.

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