Ultrafine particles ($PM_{0.1}$) and climate-related urban health vulnerability during biomass-burning haze episodes in Upper Southeast Asia

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Introduction

Air pollution associated with biomass-burning haze has become a major climate-related disaster risk in Upper Southeast Asia (USEA), particularly during prolonged dry seasons and extreme climate variability. While fine particulate matter ($PM_{2.5}$) has been widely investigated, ultrafine particles (UFP; $PM_{0.1}$, particles ≤0.1 μm) remain poorly understood despite their potential impacts on urban health vulnerability, atmospheric warming, and climate resilience.

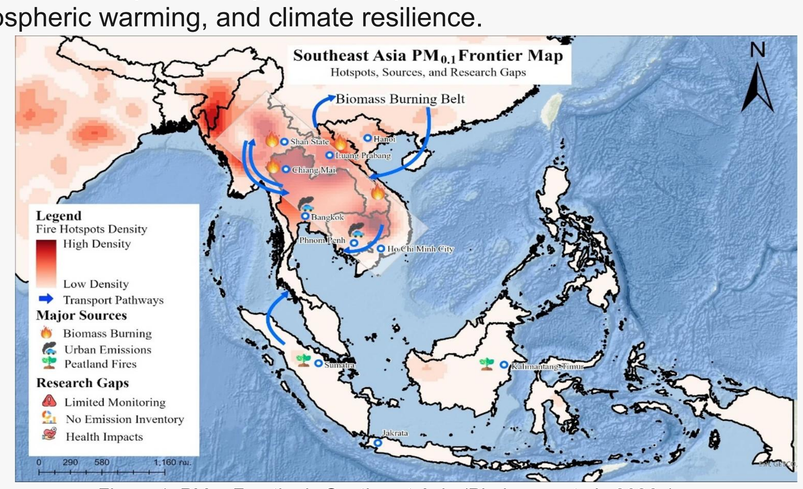


Figure 1. $PM_{0.1}$ Frontier in Southeast Asia (Phairuang et al., 2026a)

Figure 1 shows $PM_{0.1}$ pollution in Southeast Asia is strongly influenced by biomass burning, urban emissions, peatland fires, and regional air circulation. Despite these significant pollution sources, major gaps remain in $PM_{0.1}$ monitoring and understanding, highlighting the need for expanded research and stronger regional cooperation in transboundary air quality management.

Therefore, this study aims to

(1) Examine the spatial and temporal characteristics of $PM_{0.1}$ and carbonaceous aerosols during biomass-burning episodes across Cambodia, Thailand, and Myanmar.
(2) Assess the implications of $PM_{0.1}$ for atmospheric warming and urban health vulnerability in USEA.
(3) Provide evidence to support $PM_{0.1}$ monitoring, air quality management and climate adaptation strategies in USEA.

The results of this study will support research and policy on air pollution control and environmental management in developing countries.

Methodology

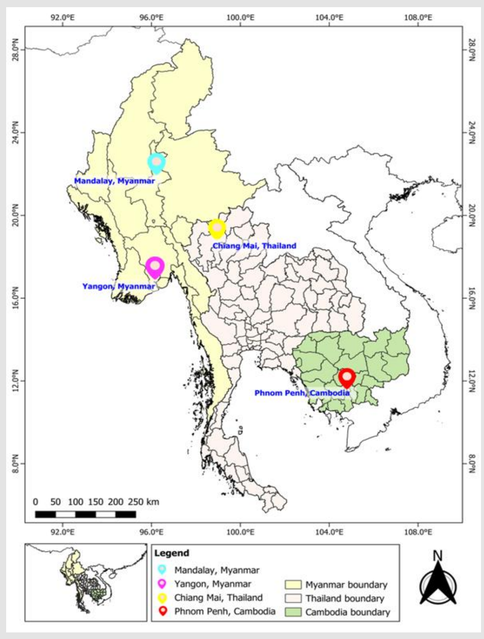


Figure 2. Sampling locations of size-fractionated PM down to $PM_{0.1}$, across major urban areas in USEA

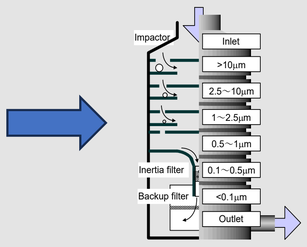
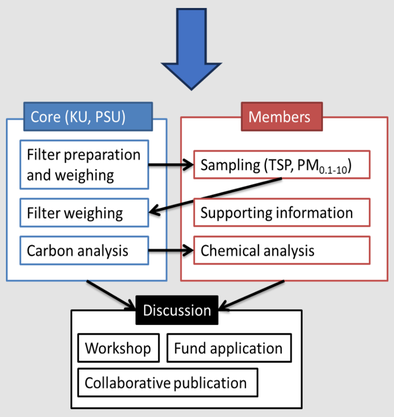


Figure 3. $PM_{0.1}$ Sampler (Nano-Sampler)



1. Ambient size-fractionated particle sampling

Samples were collected continuously at each site starting in March 2020. During haze, Chiang Mai, Phnom Penh, Yangon, and Mandalay were sampled simultaneously to ensure temporal consistency and comparability.

2. Thermal/Optical Carbon Analysis

The Multi-wavelength Thermal/Optical Carbon Analyzer (Model 5L, Sunset Instruments Inc., Oregon, USA) was employed to measure OC-EC.

3. Secondary Organic Carbon (SOC)

SOC is produced through atmospheric chemical reactions, whereas POC is emitted directly from sources. SOC and POC were estimated using the EC-tracer method.

4. Effective Carbon Ratio (ECR)

ECR assesses the radiative effects of carbonaceous aerosols by comparing SOC with POC and EC. Low ECR values indicate warming effects from light-absorbing aerosols, whereas high ECR values suggest cooling effects from light-scattering aerosols.

5 Backward Trajectory and Hotspot Analysis

Air mass transport pathways were analyzed using 72-hour HYSPLIT backward trajectories at 1,000 m altitude. MODIS hotspot data were used to identify biomass-burning sources.

Results

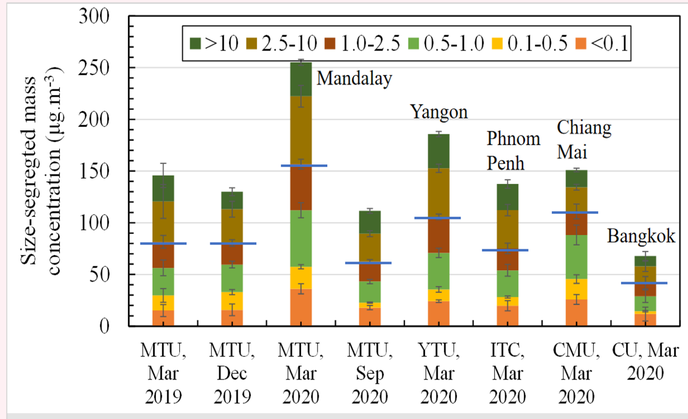


Figure 4. Size-segregated PM concentrations across major urban areas in USEA

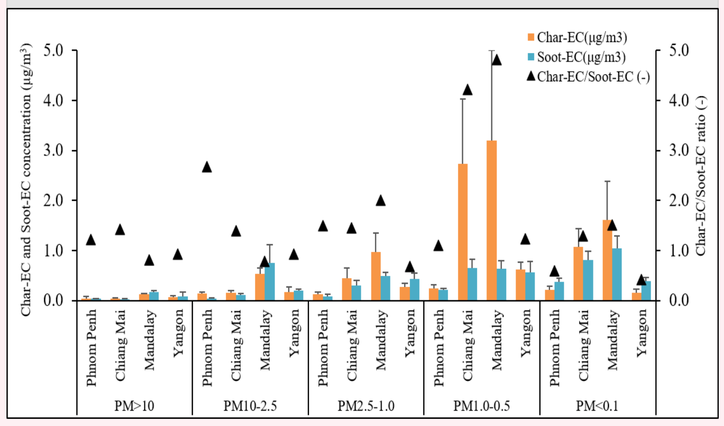


Figure 5. Char-EC, Soot-EC, and Char-EC/Soot-EC ratios

Table 1: Estimation of the effective carbon ratio (ECR) of each PM size

PM sizes	ERC-Phnom Penh	ERC-Chiang Mai	ERC-Mandalay	ERC-Yangon
> 10 μm	0.20 ± 0.13	0.18 ± 0.11	0.15 ± 0.16	0.34 ± 0.31
2.5-10 μm	0.29 ± 0.27	0.21 ± 0.12	0.25 ± 0.21	0.52 ± 0.40
1.0-2.5 μm	0.34 ± 0.21	0.23 ± 0.19	0.35 ± 0.31	0.39 ± 0.30
0.5-1.0 μm	0.75 ± 0.36	0.15 ± 0.14	0.35 ± 0.27	0.52 ± 0.43
< 0.1 μm	0.18 ± 0.16	0.13 ± 0.10	0.22 ± 0.16	0.43 ± 0.23

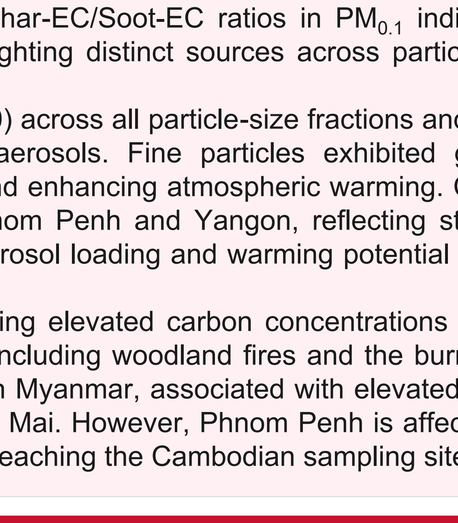


Figure 6. Hotspot distribution and 3-day backward trajectories during the biomass burning episode in MSEA

Key Findings

As shown in Figure 4, March 2020 haze episodes dramatically increased particle mass concentrations, with Mandalay showing the highest aerosol loading among all sites. Particles in the 0.5–10 μm range dominated total mass, highlighting the strong influence of regional biomass-burning emissions. $PM_{0.1}$ was consistently detected across all locations, indicating persistent contributions from local urban sources, particularly traffic and diesel combustion.

As displayed in Figure 5, Char-EC concentrations peaked in the $PM_{0.5\text{-}1.0}$ and $PM_{0.1}$ fractions, particularly in Chiang Mai and Mandalay, indicating strong combustion-related emissions. High Char-EC/Soot-EC ratios (>2) in $PM_{0.5\text{-}1.0}$ suggest a dominant influence of biomass burning. Lower Char-EC/Soot-EC ratios in $PM_{0.1}$ indicate a greater contribution from local fossil fuel and diesel emissions, highlighting distinct sources across particle-size fractions in USEA.

As shown in Table 1, the ECR values were consistently low (<1.0) across all particle-size fractions and sites, indicating the presence of strongly light-absorbing carbonaceous aerosols. Fine particles exhibited greater absorption of solar radiation, potentially suppressing SOC formation and enhancing atmospheric warming. Chiang Mai and Mandalay showed higher light-absorption capacity than Phnom Penh and Yangon, reflecting stronger biomass-burning influences and suggesting elevated carbonaceous aerosol loading and warming potential across Mainland Southeast Asia.

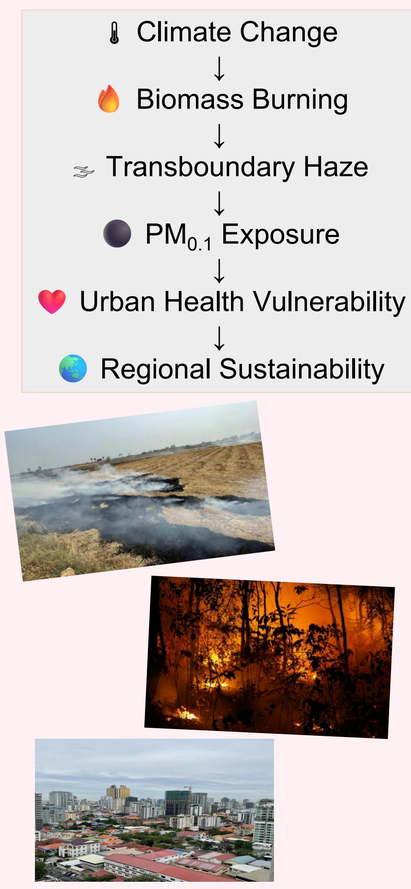
As shown in Figure 6, the back-trajectories were observed during elevated carbon concentrations on the sampling dates. This area has been affected by open biomass fires, including woodland fires and the burning of crop waste. The study site observed an air mass originating in western Myanmar, associated with elevated levels of particle-bound carbon, that reached Yangon, Mandalay, and Chiang Mai. However, Phnom Penh is affected by the easterly air mass that passes hotspots in southern Vietnam before reaching the Cambodian sampling site.

Conclusion

Climate–Haze–Health Nexus of $PM_{0.1}$ in Upper Southeast Asia

Key Conclusions

- **Aerosol Dominance**: Carbonaceous aerosols dominate haze events and contribute to warming; finer particles exert a stronger effect.
- **Urban Vulnerability**: Urban populations in USEA are increasingly vulnerable to $PM_{0.1}$ exposure, particularly children, older adults, and individuals with pre-existing cardiopulmonary diseases.
- **Dual-Regime System**: Traffic shapes $PM_{0.1}$ locally, while regional biomass-burning influences coarser particle fractions.
- **Nexus Framework**: $PM_{0.1}$ emerges as a key indicator linking climate change, biomass-burning haze, urban health vulnerability, and regional sustainability in Southeast Asia.



Policy Implications & Recommendations

- $PM_{0.1}$ should be recognized as both an air quality and climate-related health risk indicator for vulnerable urban populations.
- Key challenges include limited monitoring networks, non-standardized measurement methods, and insufficient emission inventories.
- Regional cooperation is needed to expand $PM_{0.1}$ monitoring, harmonize methodologies, and integrate $PM_{0.1}$ into air quality and climate policies.
- Bridging science and policy is essential for addressing emerging nanoparticle pollution and strengthening climate resilience in USEA.

References / Footnotes

1. Phairuang, W., Paluang, P., & Furuuchi, M. (2026a). *Is Southeast Asia ready for $PM_{0.1}$? Ultrafine particulate pollution at the frontier of regional air quality research*. Air Quality, Atmosphere & Health, 19(6), 134.
2. Phairuang, W., Htet, A.N.N., Hmwe, C.S.S., Myint, Z.H., Tial, M.K.S., Palaung, P., & Furuuchi, M. (2026b). *A dual-regime aerosol system in urban Myanmar: local diesel emissions dominate ultrafine particles ($PM_{0.1}$), while regional biomass burning controls larger particle mass*. Air Quality, Atmosphere & Health, 19(5), 116.
3. Phairuang, W., Ho, S., Taing, C., Aun, S., Hang, L., Chetiyanukornkul, T.,...& Furuuchi, M. (2026c). *Carbonaceous signatures of ambient particles down to ultrafine particles ($PM_{0.1}$) across upper Southeast Asia: linking biomass burning, urban emissions and transboundary exposure*. Air Quality, Atmosphere & Health, 19(4), 90.
4. Tial, M.K.S., Suriyawong, P., Chetiyanukornkul, T., Paluang, P., Amin, M., Putri, R.M., ... & Phairuang, W. (2024). *Characterization of $PM_{0.1}$ mass concentrations and elemental and organic carbon in upper Southeast Asia. Atmospheric Pollution Research*, 15(8), 102157.

Acknowledgments

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