

PM_{0.1} in Southeast Asian Cities

Subjects: [Meteorology & Atmospheric Sciences](#)

Contributor: Worradorn Phairuang , Muhammad Amin , Mitsuhiko Hata , Masami Furuuchi

PM_{0.1} (particles with a diameter $\leq 0.1 \mu\text{m}$), nanoparticles (NPs), or ultrafine particles (UFPs) were interchangeably used in the scientific communities. PM_{0.1} originated from both natural and human sources.

[Asia](#)[air pollution](#)[health risk](#)[PM0.1](#)

1. PM_{0.1} Mass Concentration in Southeast Asia Atmosphere

The PM_{0.1} fractions in the ambient PM have a very low particle mass concentration but a huge number of particles [1]. Most particles by numbers lie below $0.1 \mu\text{m}$ (100 nm), and they are in the PM_{0.1} range; however, their concentration in terms of mass per volume is very low. No standards for ambient PM_{0.1} have been adopted in Asian countries. The European Committee for standardization announced that the Condensation Particle Counter (CPC) is a standard protocol to measure UFPs [2]; however, only the emission standard for diesel and gasoline direct injection engine road vehicles must meet a type-approval of UFPs for non-volatile particles of $>23 \text{ nm}$ diameter (The Solid Particle Number $>23 \text{ nm}$ method; SPN23) [3]. The most widely used measure UFPs is particle number concentration (PNC) due to their tiny volume and mass concentration. The estimated concentration based on $10 \mu\text{g}/\text{m}^3$ in PM_{2.5} found that PM_{2.5} 1 particle/cm³ equal to PM_{0.02} ($<20 \text{ nm}$) 2.4×10^6 particle/cm³, or PM₁₀ 1 particle/cm³ similar to UFPs 1.0×10^6 particle/cm³ [4]. The particle number concentration and surface area are suitable for measuring UFPs' small mass concentration in the past decades [1].

The average PM_{0.1} mass concentration in SEA has shown in the past decade. The initial study of ambient PM_{0.1} in SEA and published in an international peer-review journal is based on a survey in Thailand from 2014 to 2105 [5]. The PM_{0.1} in Bangkok and Chiang Mai, Thailand, was 14.80 ± 1.99 and $25.21 \pm 4.73 \mu\text{g}/\text{m}^3$, respectively. Bangkok is the capital city in Thailand and one of the densest populated cities in SEA. The high episode of PM_{0.1} in Chiang Mai arises from biomass fires in the dry season (February–April).

In Thailand, PM_{0.1} in Pathumthani, in Bangkok Metropolitan Region areas, also elevated mass concentrations in wet and dry seasons [6]. In Hat Yai, southern Thailand [7], PM_{0.1} was $10.17 \pm 2.23 \mu\text{g}/\text{m}^3$ representing PM concentrations lower than in other parts of Thailand; moreover, Zhao et al. (2016) [8] reported that they compared PM_{0.1} during the dry season (Mar-Apr 2016) in many cities, including Chiang Mai, Bangkok, Songkhla, Riau, Ho Chi Minh City, Phnom Penh, and Kuala Lumpur. The study found that mass concentration ($\mu\text{g}/\text{m}^3$) decreased in the order, Phnom Penh (18.9) > Chiang Mai (16.5) > Hanoi (15.4) > Ho Chi Minh City (13.1) > Riau (12.4) > North Bangkok (11.9) > Hat Yai (10.9) > Kuala Lumpur (9.3) > Bangkok (7.7).

The higher mass concentration in Upper SEA countries than in lower SEA countries due to the dry season during that period that the open biomass burning has been reported by several researchers [5][9][10]. PMs increased every dry season (February–April), and they started to rise around February and peaked in March before decreasing by mid-April [5]. The primary emission source of PMs worsening during the dry season in these areas was identified as open biomass burning, including forest fire and crop residue burning [5][6]. The above-mentioned corresponded with the accumulated fire hotspot locations that were high in the dry season and low in the wet season. Each active fire location represents the center, approximately decreasing by mid-of 1 km pixel flagged as one or more actively burning hotspots/fires [9]. Generally, PM_{0.1} is derived from diesel exhaust, and it was sensitive to biomass burning in this area [5]. In addition, ambient PM_{0.1} in Vietnam and Indonesia is very progressive. In Indonesia, the study by Amin et al. (2021a) [11] and Putri et al. (2021) [12] suggested that the PM_{0.1} mass concentration in the dry season is higher than in the wet season in all monitoring sites. In addition, the mass concentrations by different monitoring sites have attention as follows, urban > suburban > rural. In Vietnam, many studies of PM_{0.1} in Hanoi, the capital city in Vietnam, are more progressive than in other SEA cities [8][13][14][15][16][17][18]. The results show that mass concentrations in different environments in Hanoi ranged from 1 to 17 µg/m³.

2. Sources and Characteristics of PM_{0.1} in Southeast Asia

Regarding the natural sources, primary PM_{0.1} is mainly generated by forest fires, while lesser fractions come from maritime aerosols and volcanic eruptions [19][20]. On the other hand, anthropogenic sources of PM_{0.1} include transportation (on- and off-road automobiles, diesel engines, airplanes, and shipping), industrial combustion processes including biomass combustion and waste incineration, cigarette smoking, and meat cooking [1]. So, the primary emission sources of PM_{0.1} are both natural and anthropogenic sources. Most studies of emission sources of PM_{0.1} in Asia are related to road vehicles [21][22][23]. In an urban area, traffic is the primary source of PM_{0.1} emissions. Diesel engines dominate PM_{0.1} in megacities, including Shanghai, China [24], Hanoi, Vietnam [13], and Bangkok, Thailand [5]. Diesel engines have about two times higher emission factors than gasoline engines [25]. On the other hand, forest fires emit particles that dominate traffic emissions, and the size distribution peaks at approximately 120 nm for a fresh aerosol plume [26]; moreover, Phairuang et al. (2019) [5] stated that open biomass burning in central and northern Thailand dominated the release of carbon components into the atmosphere. The PM_{0.1} particle, primarily derived from motor vehicle emissions, is also strongly affected by open biomass burning in the upper part of Thailand. Hence, this activity significantly affects air quality during the dry season. Similarly, an ambient PM_{0.1} study in Hanoi, Vietnam, showed high mass concentrations of PM_{0.1} during rice straw burning periods [13]; however, some possibly essential sources, such as domestic wood burning, are poorly quantified in SEA [27].

The chemical composition study in NPs is still limited, especially in ambient PM_{0.1} particles; however, a few publications have been from NPs and chemical composition sources. For instance, polycyclic aromatic hydrocarbons (PAHs) dominate PM emissions [27][28]. Most PAHs emissions are generated from incomplete combustion of natural and human sources, including vehicle exhaust, biomass burning, industrial activities, and coal combustion. Hata et al. (2014) [28] studied the characteristics of NPs emitted from biomass fuels burning in

Asia. The result demonstrated that approximately 30% of the biomass fuels burning smoke had a mass of <100 nm. Additionally, PM smaller than 0.43 μm significantly contributed to the toxicity of PAHs and the fraction of Water-soluble Organic Carbon (WSOC). Similarly, Chomanee et al. (2018) [29] considered the PAHs in smoke plumes released from the para-rubber fuel-wood combustion; this result displays that the ultrafine (PM_{0.07}) smoke particles comprised the highest number of PAHs and Benzo[a]pyrene-Toxic Equivalence Quotient (BaP-TEQ). The important fraction of NPs had the most considerable emission of toxicity per unit PM mass compared to fine and coarse PM; this is a critical point to concentrate on smaller particles, especially NPs, on any emission sources due to a lack of reliable information on the origins and magnitudes in SEA countries [5].

Secondary PM_{0.1} aerosol is mainly generated from atmospheric photochemical of gaseous precursors and by condensation of semi-volatile vapors. Such new particle formation can occur during low relative humidity and wind speed at quiet pre-existing particle surface areas and global radiation [30]. Reche et al. (2011) [31] described that new particle formation in an urban area in Europe during warmer and sunny climates is essential to air pollution. In SEA, Thuy et al. (2018) [13] stated that Secondary Organic Carbon (SOC) is more dominant in smaller particles than in larger particles; and the SOC in PM_{0.1} contributes up to 42.7% of the OC level in Hanoi, Vietnam. The secondary atmospheric PM_{0.1} in the SEA environment remains poorly understood. Based on the chemical, optical, and thermal properties of such samples, these carbon components can be broadly classified into two main fractions, i.e., organic carbon (OC) and elemental carbon (EC). The source of OC can be primary (POC) and secondary emissions (SOC), while EC is mainly emitted from primary sources [7][13]. The importance of carbonaceous particulate matter (OC and EC) in the Earth's climate system is becoming more broadly recognized due to its ability to induce climate changes by directly disrupting the Earth's radiative balance via the extinction of incoming solar radiation and indirectly by serving as cloud condensation nuclei (CCN). Carbonaceous particulate matter was also demonstrated to significantly influence air quality and human health [5][11][20].

3. Health Concerns of PM_{0.1}

PM_{0.1} strongly believes in high toxic properties because a high surface area can absorb many poisonous substances. After they penetrate the human organ systems, allowing translocation and interactions to a human body organ and highly potential deeply into circular systems via respiratory mechanism [32]. The World Health Organization (WHO 2013) [33] suggested that the epidemiological data on PM_{0.1} are too scarce to estimate or use in policy-making for air quality control management of PM_{0.1}. The Health Effects Institute (HEI 2013) [34] reflected that the ongoing evidence did not convincingly support the suggestion that PM_{0.1} alone can account for actual conduct for the adverse effects that have been associated with atmospheric pollutants such as PM_{2.5} and PM₁₀.

In health risk assessment, toxicity equivalent concentration (TEQs), calculations based on toxic equivalent factors (TEFs), can be used to estimate health risks associated with PAHs [27]. High concentrations of PMs containing PAHs are well-known in symptoms, i.e., eye irritation, diarrhea, vomiting, and nausea. The detrimental effects of PAHs hang on the mechanism of exposure. Benzo[a]pyrene (BaP) is the well-known PAH to cause cancer on a laboratory scale resulting long term exposure. The BaP-TEQ is a widely used indicator to estimate the exposure to PAHs to human health. On the other hand, there have been limited studies on the characteristics of PM_{0.1} and toxic

PAHs in the Southeast Asian environment; moreover, it is vital to note that finer particles are a more significant source of carcinogenic properties and cause more human health consequences than larger particles due to their higher surface area that can absorb many toxic elements.

Phairuang et al. (2021, 2022) [35][36] investigated the health risk of PM_{0.1} and its trace elements, such as Aluminium (Al), Barium (Ba), Potassium (K), Iron (Fe), Chromium (Cr), Copper (Cu), Nickel (Ni), Sodium (Na), Manganese (Mn), Magnesium (Mg), Titanium (Ti), Lead (Pb), and Zinc (Zn), on humans in Bangkok and Hat Yai, Thailand. PM's primary sources were road traffic, industry, and biomass burning. In addition, the total cancer risk from all carcinogenic elements was high in adults, indicating that the carcinogenic risk is within a tolerable risk assessment range.

Guan et al. (2017) [37], in a study conducted in China, reported that increasing 10 µg/m³ in PM_{2.5} from any emission source was linked to a 3.1% increase in the risk of hospitalization as well as a 2.5% increase in mortality. Crippa et al. (2016) [38] reported that the short-term exposure to the burning of agricultural residues and peat-land fires in heavy haze episodes in 2015 from Indonesia might have caused 11,880 excess mortalities. Most studies have stated the adverse effect of inhaled atmospheric PM_{0.1} on human health to continue lacking in SEA. There are still limited information between PM_{0.1} and disease; however, there have not become fully aware of the critical hazards of ambient PM_{0.1} on human health [1].

References

1. Kwon, H.S.; Ryu, M.H.; Carlsten, C. Ultrafine particles: Unique physicochemical properties relevant to health and disease. *Exp. Mol. Med.* 2020, 52, 318–328.
2. CEN/TS 16976:2016; Ambient Air-Determination of the Particle Number Concentration of Atmospheric Aerosol. European Committee for Standardization: Brussels, Belgium, 2016.
3. Giechaskiel, B.; Lahde, T.; Suarez-Bertoa, R.; Clairotte, M.; Grigoratos, T.; Zardini, A.; Perujo, A.; Martini, G. Particle number measurements in the European legislation and future JRC activities. *Combust. Engines* 2018, 174, 3–16.
4. Li, N.; Georas, S.; Alexis, N.; Fritz, P.; Xia, T.; Williams, M.A.; Horner, E.; Nel, A. A work group report on ultrafine particles (American Academy of Allergy, Asthma & Immunology): Why ambient ultrafine and engineered nanoparticles should receive special attention for possible adverse health outcomes in human subjects. *J. Allergy Clin. Immunol.* 2016, 138, 386–396.
5. Phairuang, W.; Suwattiga, P.; Chetianukornkul, T.; Hongtieab, S.; Limpaseni, W.; Ikemori, F.; Hata, M.; Furuuchi, M. The influence of the open burning of agricultural biomass and forest fires in Thailand on the carbonaceous components in size-fractionated particles. *Environ. Pollut.* 2019, 247, 238–247.

6. Boongla, Y.; Chanonmuang, P.; Hata, M.; Furuuchi, M.; Phairuang, W. The characteristics of carbonaceous particles down to the nanoparticle range in Rangsit city in the Bangkok Metropolitan Region, Thailand. *Environ. Pollut.* 2020, 272, 115940.
7. Phairuang, W.; Inerb, M.; Furuuchi, M.; Hata, M.; Tekasakul, S.; Tekasakul, P. Size-fractionated carbonaceous aerosols down to PM_{0.1} in southern Thailand: Local and long-range transport effects. *Environ. Pollut.* 2020, 260, 114031.
8. Zhao, T.; Hongtieab, S.; Hata, M.; Furuuchi, M.; Dong, S.; Phairuang, W.; Ge, H.; Zhang, T. Ambient nanoparticles characterization by East and Southeast Asia nanoparticle monitoring network. In *Proceedings of the 9th Asian Aerosol Conference, Kanazawa, Japan, 24–26 June 2015*.
9. Phairuang, W.; Hata, M.; Furuuchi, M. Influence of agricultural activities, forest fires and agro-industries on air quality in Thailand. *J. Environ. Sci.* 2017, 52, 85–97.
10. Othman, M.; Latif, M.T.; Hamid, H.H.A.; Uning, R.; Khumsaeng, T.; Phairuang, W.; Daud, Z.; Idris, J.; Sofwan, N.M.; Lung, S.-C.C. Spatial–temporal variability and health impact of particulate matter during a 2019–2020 biomass burning event in Southeast Asia. *Sci. Rep.* 2022, 12, 7630.
11. Amin, M.; Putri, R.M.; Handika, R.A.; Ullah, A.; Goembira, F.; Phairuang, W.; Ikemori, F.; Hata, M.; Tekasakul, P.; Furuuchi, M. Size-Segregated particulate matter down to PM_{0.1} and carbon content during the rainy and dry seasons in Sumatra island, Indonesia. *Atmosphere* 2021, 12, 1441.
12. Putri, R.M.; Amin, M.; Suciari, T.F.; Faisal, M.A.F.; Auliani, R.; Ikemori, F.; Wada, M.; Hata, M.; Tekasakul, P.; Furuuchi, M. Site-specific variation in mass concentration and chemical components in ambient nanoparticles (PM_{0.1}) in North Sumatra Province-Indonesia. *Atmos. Pollut. Res.* 2021, 12, 101062.
13. Thuy, N.T.T.; Dung, N.T.; Sekiguchi, K.; Thuy, L.B.; Hien, N.T.T.; Yamaguchi, R. Mass concentrations and carbonaceous compositions of PM_{0.1}, PM_{2.5}, and PM₁₀ at urban locations in Hanoi, Vietnam. *Aerosol Air Qual. Res.* 2018, 18, 1591–1605.
14. Nghiem, T.D.; Nguyen, T.T.T.; Nguyen, T.T.H.; Ly, B.T.; Sekiguchi, K.; Yamaguchi, R.; Pham, C.T.; Ho, Q.B.; Duong, T.N. Chemical characterization and source apportionment of ambient nanoparticles: A case study in Hanoi, Vietnam. *Environ. Sci. Pollut. Res.* 2020, 27, 30661–30672.
15. Huyen, T.T.; Yamaguchi, R.; Kurotsuchi, Y.; Sekiguchi, K.; Dung, N.T.; Thuy, N.T.T.; Thuy, L.B. Characteristics of Chemical Components in Fine Particles (PM_{2.5}) and Ultrafine Particles (PM_{0.1}) in Hanoi, Vietnam: A Case Study in Two Seasons with Different Humidity. *Water Air Soil Pollut.* 2021, 232, 183.
16. Ha, V.T.L.; Anh, V.D.; Hien, N.T.T.; Dung, N.T.; Shimada, Y.; Yoneda, M. Indoor and outdoor relationship of particles with different sizes at an apartment in Hanoi: Mass concentration and

- respiratory dose estimation. *Vietnam. J. Sci. Technol.* 2020, 58, 736–746.
17. Thuy, P.C.; Le, H.A.; Tuyen, L.H.; Dung, N.T. Size distribution and contribution of particles from rice straw open burning to the atmosphere in Hanoi. *Vietnam. J. Sci. Technol.* 2020, 58, 94–104.
 18. Tran, T.D.; Nguyen, P.M.; Nghiem, D.T.; Le, T.H.; Tu, M.B.; Alleman, L.Y.; Nguyen, V.M.; Pham, D.T.; Ha, N.M.; Dang, M.N.; et al. Assessment of air quality in school environments in Hanoi, Vietnam: A focus on Mass-Size distribution and elemental composition of indoor-outdoor Ultrafine/Fine/Coarse particles. *Atmosphere* 2020, 11, 519.
 19. Schraufnagel, D.E. The health effects of ultrafine particles. *Exp. Mol. Med.* 2020, 52, 311–317.
 20. Amin, M.; Handika, R.A.; Putri, R.M.; Phairuang, W.; Hata, M.; Tekasakul, P.; Furuuchi, M. Size-Segregated Particulate Mass and Carbonaceous Components in Roadside and Riverside Environments. *Appl. Sci.* 2021, 11, 10214.
 21. Chen, S.C.; Tsai, C.J.; Chou, C.C.K.; Roam, G.D.; Cheng, S.S.; Wang, Y.N. Ultrafine particles at three different sampling locations in Taiwan. *Atmos Environ.* 2010, 44, 533–540.
 22. Zhu, C.S.; Chen, C.C.; Cao, J.J.; Tsai, C.J.; Chou Charles, C.K.; Liu, S.C.; Roam, G.D. Characterization of carbon fractions for atmospheric fine particles and nanoparticles in a highway tunnel. *Atmos Environ.* 2010, 44, 2668–2673.
 23. Hata, M.; Zhang, T.; Bao, L.; Otani, Y.; Bai, Y.; Furuuchi, M. Characteristics of the nanoparticles in a Road Tunnel. *Aerosol. Air Qual. Res.* 2012, 13, 194–200.
 24. Ding, X.; Kong, L.; Du, C.; Zhanzakova, A.; Wang, L.; Fu, H.; Chen, J.; Yang, X.; Cheng, T. Long-range and regional transported size-resolved atmospheric aerosols during summertime in urban Shanghai. *Sci. Total. Environ.* 2017, 583, 334–343.
 25. Beddows, D.C.; Harrison, R.M. Comparison of average particle number emission factors for heavy and light duty Vehicles derived from rolling chassis dynamometer and field studies. *Atmos Environ.* 2008, 42, 7954–7966.
 26. Kumar, P.; Pirjola, L.; Ketznel, M.; Harrison, R.M. Nanoparticle emissions from 11 non-vehicle exhaust sources—A review. *Atmos Environ.* 2013, 67, 252–277.
 27. Phairuang, W.; Tekasakul, T.; Hata, M.; Tekasakul, S.; Chomanee, J.; Otani, Y.; Furuuchi, M. Estimation of air pollution from ribbed smoked sheet rubber in Thailand exports to Japan as a pre-product of tires. *Atmos. Pollut. Res.* 2019, 10, 642–650.
 28. Hata, M.; Chomanee, J.; Thongyen, T.; Bao, L.; Tekasakul, S.; Tekasakul, P.; Otani, Y.; Furuuchi, M. Characteristics of nanoparticles emitted from burning of biomass fuels. *J. Environ. Sci.* 2014, 26, 1913–1920.
 29. Chomanee, J.; Tekasakul, S.; Tekasakul, P.; Furuuchi, M. Effect of irradiation energy and residence time on decomposition efficiency of polycyclic aromatic hydrocarbons (PAHs) from

- rubber wood combustion emission using soft X-rays. *Chemosphere* 2018, 210, 417–423.
30. Rimnacova, D.; Zdímal, V.; Schwarz, J.; Smolík, J.; Rimnac, M. Atmospheric aerosols in suburb of Prague: The dynamics of particle size distributions. *Atmos. Res.* 2011, 101, 539–552.
 31. Reche, C.; Querol, X.; Alastuey, A.; Viana, M.; Pey, J.; Moreno, T.; Rodríguez, S.; González, Y.; Fernández-Camacho, R.; de la Rosa, J.; et al. New considerations for PM, Black Carbon and particle number concentration for air quality monitoring across different European cities. *Atmos. Chem. Phys.* 2011, 11, 6207–6227.
 32. Lanzinger, S.; Schneider, A.; Breitner, S.; Stafoggia, M.; Erzen, I.; Dostal, M. Associations between ultrafine and fine particles and mortality in five central European cities-Results from the UFIREG study. *Environ. Int.* 2016, 88, 44–54.
 33. WHO. Review of Evidence on Health Aspects of Air Pollution-REVIHAAP Project: Technical Report; World Health Organization: Copenhagen, Denmark, 2013.
 34. HEI. Understanding the health effects of ambient ultrafine particles. In HEI Perspectives 3. HEI Review Panel on Ultrafine Particles; Health Effects Institute: Boston, MA, USA, 2013.
 35. Phairuang, W.; Inerb, M.; Hata, M.; Furuuchi, M. Characteristics of trace elements bound to ambient nanoparticles (PM_{0.1}) and a health risk assessment in southern Thailand. *J. Hazard. Mater.* 2021, 425, 127986.
 36. Phairuang, W.; Suwattiga, P.; Hongtieab, S.; Inerb, M.; Furuuchi, M.; Hata, M. Characteristics, sources, and health risks of ambient nanoparticles (PM_{0.1}) bound metal in Bangkok, Thailand. *Atmos. Environ. X* 2021, 12, 100141.
 37. Guan, Y.; Chen, G.; Cheng, Z.; Yan, B.; Hou, L. Air pollutant emissions from straw open burning: A case study in Tianjin. *Atmos. Environ.* 2017, 171, 155–164.
 38. Crippa, P.; Castruccio, S.; Archer-Nicholls, S.; Lebron, G.B.; Kuwata, M.; Thota, A.; Sumin, S.; Butt, E.; Wiedinmyer, C.; Spracklen, D.V. Population exposure to hazardous air quality due to the 2015 fires in Equatorial Asia. *Sci. Rep.* 2016, 6, 37074.

Retrieved from <https://encyclopedia.pub/entry/history/show/64601>