Investigation of status, characteristic, and emission sources of airborne ultrafine particles in Indonesia

Student: Muhammad AMIN (1924052006) | Supervisor: Prof. Masami Furuuchi

Abstract. In this study, the particulate matters down to the ultrafine particles (UFPs) were evaluated to discuss the status, characteristic, and also their sources in Indonesia during diurnal and nocturnal times, dry and rainy season, and also before and during the COVID-19 outbreaks. Ambient nano sampler was used to collect the samples and then analyzed its carbon components by using the IMPROVE-TOR protocol. Air mass trajectory was overlapping with the hotspot information to discuss the possible influence of biomass burning. Regardless the interval times, the UFPs were stable both diurnal and nocturnal with slightly higher during diurnal due to the lower planetary boundary layer (PBL). EC concentration, particularly soot-EC was higher during diurnal than nocturnal due to the higher number of vehicles. Seasonal different of UFPs in Indonesia was founded in the east coast of Sumatra Island in where the biomass burning particularly from peatland fires was contributed. In contrast, in the west coast of Sumatra Island, throughout the year, the PMs level was very stable because the similarity of the air mass origin in both rainy and dry season. Then, the PMs level during the covid-19 pandemics was totally decrease especially for UFPs, up to 68% compared with the value before the pandemics. It was in line with the soot-EC concentration where during the pandemics, it was 2 to 14 times lower than before the pandemic covid-19 because of the decreasing of vehicles used.

1. Introduction

Ambient particulate matters (PMs) has become an important issue since it was linked directly to the human health, especially ultrafine particles (UFPs). UFPs is the particle with the aerodynamic diameter is less than 100 nm. Due to its size, it can penetrate to the deepest part of human body and caused a harmful effect such as inflammation, asthma, lung fibrosis, etc. Not only because of its size, but also due to its chemical components which make the UFPs more harmful, such as carbonaceous component.

In Indonesia, since 1990s, the PMs level has started evaluated, however, the UFPs information is did not cover yet. Hence, this study tries to fill the gap by evaluating the UFPs included the status, characteristic and also its sources. To address it, the different of interval times, diurnal and nocturnal, rainy and dry season, and also before and during the pandemic covid-19 was evaluated.

2. Methodology

2.1. Air sampler and sampling site

To collect the UFPs, ambient nano sampler (ANS) developed by Furuuchi et al., (2010) were used with the flowrate 40 l/m. 5-quartz fiber filters (QFFs) and 1-inertial filter (IF) were used to collect the particles. Sampling sites were located in Sumatra Island or one out of the five major Island in Indonesia. The monitoring was performed from 2018 – 2021.

2.2. Hotspot and air mass trajectory

To specify the influenced of biomass burning, the hotspot information was used provided by Moderate-Resolution Imaging Spectroradiometer (MODIS) and overlapping with the air mass trajectory provided by air resources laboratory which are available online.

2.3. The number of vehicles

To discuss the different emission during diurnal and nocturnal, the vehicle number based on types were counted manually using handheld counters.

3. Result and discussion

3.1. Diurnal and nocturnal UFPs

The **Fig.1** was displayed the PMs concentration during diurnal and nocturnal in roadside (RV) and riverside (RV). The level of PMs including UFPs were increased during nocturnal might be due to the lower of planetary boundary layer (PBL). However, its fraction in the total of particles (TSP) were stable (17 – 19%) regardless the times and its was higher compare to the value recorded in South East Asia (SEA) countries. The UFPs level in RS were higher than RV due to the location nearby one of the busiest streets. The highest concentration was found in the particle 0.5-10 µm in both day and nighttime.

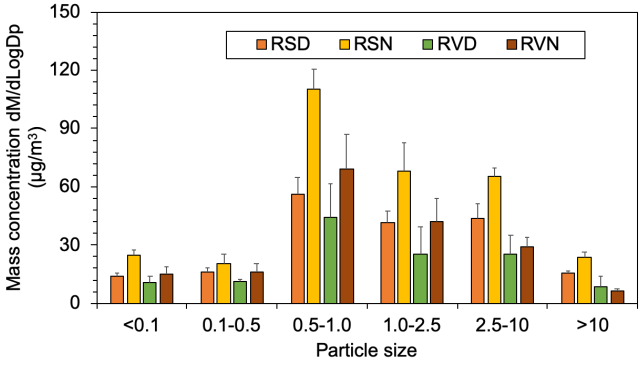

Fig.1. Average of mass (dM/dLogDp) concentration of each size PMs in RS and RV at diurnal and nocturnal in Jambi city

The **Fig. 2** was shown the 8-carbonaceous fraction in all sizes of particles. It can be seen that the fraction of OC1 and EC3 were higher in the UFPs compare to other sizes. OC1 is freshly emission and very volatile in the atmosphere. While EC3, is the fresh emission from vehicle combustion which is very persistent in the atmosphere. The EC3 during diurnal was higher than nocturnal due to the higher number of vehicles.

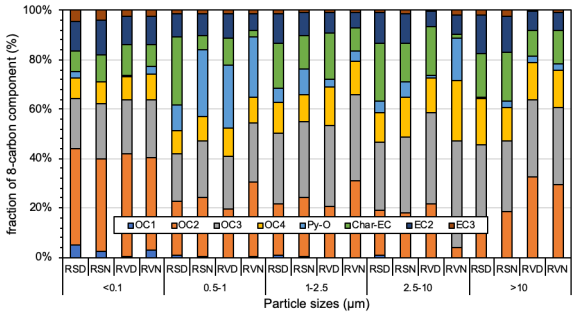

Fig.2. Fraction 8-carbonaceous component for both RS and RV at diurnal and nocturnal

Fig.3 was shown the biomass burning effect both for diurnal and nocturnal by using the OC/EC vs. EC correlation along with the data from the urban correlation in east Asian countries. The UFPs, regardless the location and times, were just slightly move from urban correlation indicated more affected by vehicles emission, while the data of particle 0.5-1 µm was move the upper-right side, indicated it was

influenced by the biomass burning particularly peatland fires, even some data were located in the peatland fire correlation.

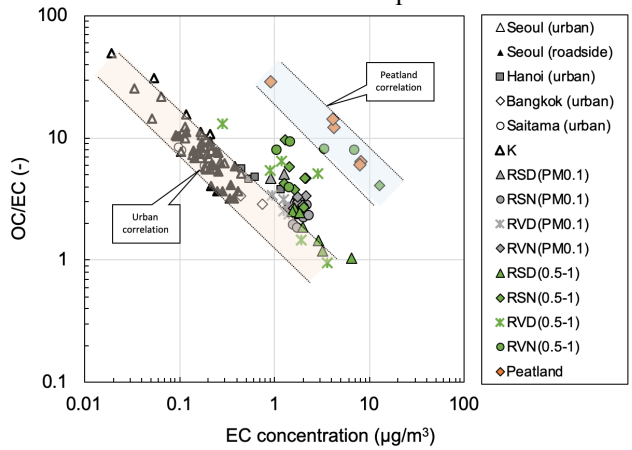

Fig. 3. OC/EC vs EC in RS and RV and urban sites in several Asian countries

3.2. Dry and rainy season of UFPs

The **Fig. 4** was shown concentration of UFPs during dry and rainy season in three different cities in Sumatra Island, Indonesia. Padang city were located in the west coast, in where the biomass burning effect from the peatland fires where negligible. As a result, the UFPs were stable throughout the year. In contrast, the cities located in the east coast of Sumatra Island, the increasing of UFPs from rainy to dry season was founded. Both of cities was surrounded by peatland that might be one of the sources of PMs during dry season. Not only in UFPs, other particles size as seen from **Fig. 5** also increased in the east coast and quite similar in the west coast of Sumatra Island.

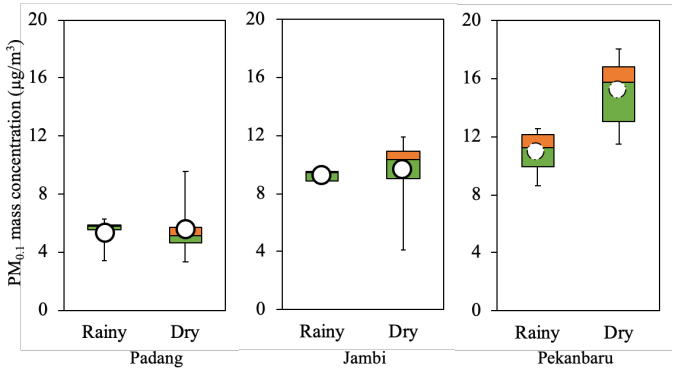

Fig. 4. Seasonal UFPs mass concentration in Sumatra Island, Indonesia

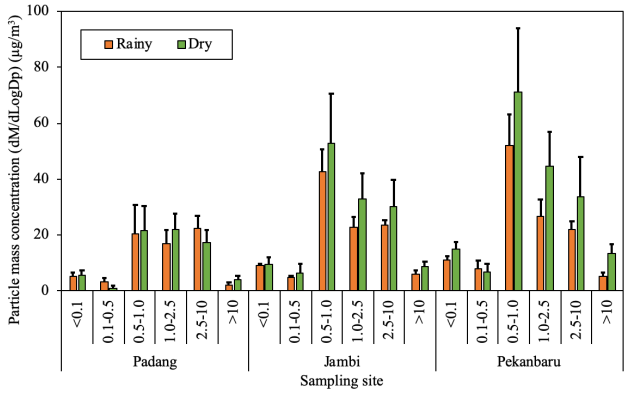

Fig. 5. Particle size distribution observed at the study sites in Sumatra-Island

In **Fig. 6.** The different of air mass origin arrived at the sampling site was shown. In west coast, regardless the season, the air mass coming from the sea. In the east coast, in the rainy season originated from the sea and in dry, it was coming from the southern parts of Sumatra Island and passing through many hotspots, indicated more affected by biomass burning

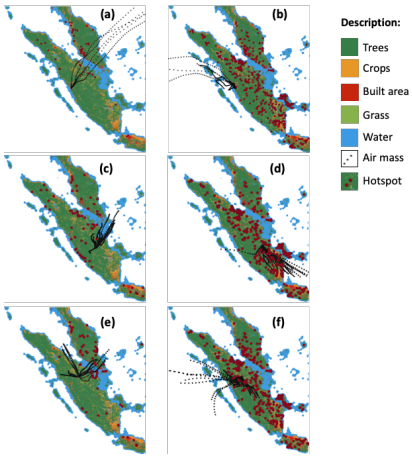

Fig. 6. Overlap land cover of Sumatera Island and air mass trajectory during dry and rainy season in all sampling location (a) Padang (rainy), (b) Padang (dry), (c) Jambi (rainy), (d) Jambi (dry), (e) Pekanbaru (rainy) and (f) Pekanbaru (dry)

3.3. Dry and rainy season of UFPs

The **Fig. 7 (a-b)** were shown the concentration of UFPs and soot-EC before and during the pandemic in Indonesia. The UFPs were dramatically decreased during the pandemic, up to 68% due to the limitation of human activities especially outdoor. As a result, the number of vehicles operated should be decreased. It confirmed by the lower concentration of soot-EC during the pandemic than before pandemic. As well-know, the soot-EC is originated from vehicles emission. Hence, during the pandemic, the air quality was improved in Indonesia and vehicles was play an important role as the sources of UFPs.

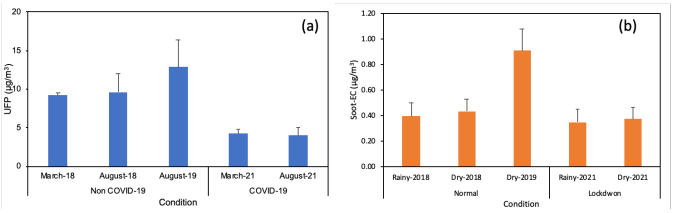

Fig.7. The comparison of UFPs (a) and soot-EC (b) concentration before pandemic COVID-19 vs during the pandemic COVID-19 in Sumatra Island, Indonesia

4. Conclusion

The UFPs level, characteristic and emission sources were evaluated in Indonesia from 2018 – 2021 in where diurnal soot-EC were higher than nocturnal due to the lower number of vehicles. Also, the stable level in west coast regardless the season and increasing in the dry season in the east because of the presence of peatland fires. Then, during the pandemic outbreaks, the UFPs level also decreased along with the decreasing of soot-EC as one of the indicator of vehicles emission. Thus, during the pandemic, the air quality was improved in Indonesia.

令和４年　１　月　28　日

学位論文審査報告書（甲）

１．学位論文題目（外国語の場合は和訳を付けること。）

Investigation of status, characteristic, and emission sources of airborne ultrafine particles in Indonesia（インドネシアにおける大気中超微粒子の現状とその特性および発生源に関する研究）

２．論文提出者　(1) 所　　属　環境デザイン学専攻 大気環境工学　研究分野

(2) 氏（ふり）　名（がな）　Muhammad Amin（ムハマド　アミン）

３．審査結果の要旨（600～650字）

提出された論文に対し，書面および口述審査を実施し，以下のように判断した。

本論文は，肺深部への高い沈着率と有害成分比率などから健康リスクが懸念される大気中ナノ粒子（PM0.1）に着目し，これまで未知であったインドネシア・スマトラ島内の様々な地点でその現状と特性を短期的・長期的に調査して，道路交通等のローカル発生源の昼夜・季節影響，越境汚染，コロナ禍などの影響を考察したものであり，インドネシアにおけるナノ粒子汚染の現状および環境指標としてのナノ粒子の持つ特徴・意義を明らかにしている。PM0.1粒子濃度と含有無機炭素成分への明確な道路交通影響があり，PM0.1への越境汚染起源のバイオマス燃焼影響は相対的に少ない一方，特定の粒子径範囲（0.5-1μm）に越境汚染影響が明瞭に現れること，コロナ禍の影響で特にPM0.1の質量濃度，含有炭素濃度が減少すること等を示した。これらの結果から，人間活動に関わる大気汚染影響指標としてのPM0.1特性の有用性に加えて発生源影響の粒子径依存性を明らかにし，大気中に浮遊する粒子の特性に基づく適切な発生源影響評価の方向性を示した。

以上のとおり，本論文で示された環境指標としてのナノ粒子の特性とその意義は，ナノ粒子リスクの把握とその対策のための指針を示す上で重要なブレイクスルーを達成するとともに，大気中ナノ粒子の特性と発生源に関する様々な新しい知見も与えている。一連の成果は３編の英語論文にまとめられ，国内外の学会・ワークショップで英語での発表も多くあることから，英語の語学力も十分と認められる。以上より，博士（学術）の学位を授与するに値すると判断する。

４．審査結果　(1) 判　　定（いずれかに○印）（合　格）・　不合格

(2) 授与学位　博　士（　工学　）