Fine and Coarse Particle Concentration and Composition Measured In Urban And Non Urban Area Bandung, West Java - Indonesia

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Abstract. Atmospheric particulate concentrations for fine (particulate matter less than 2.5 micron) and coarse particles (particle with diameter 2.5-10 micron) were measured in 2 locations which are Tegalega and Dago Pakar Bandung. Tegalega represents an urban mixed site while Dago Pakar represents rural site. Samples on each location were collected over one or two days-time periods during dry and wet season using Dichotomous sampler and Low Volume Sampler (LVS). Meteorological conditions were also measured simultaneously in the sampling locations. Samples were further analyzed to determine concentrations of particulate mass, elements, sulfate, nitrate and ammonium. The results from this study show that the concentrations of the particulate mass were higher during the dry season than in the wet season for both locations, mixed and background sites. The average fine particles concentrations at mixed site were 37 and 49 µg/m³ for the wet and dry seasons respectively. The average coarse particles concentrations were 27 and 33 µg/m³ for wet and dry seasons respectively. The average mass concentrations of fine particles at the rural site were 30 and 45 µg/m³ for wet and dry seasons respectively, while for the coarse particles the concentrations were 13 for wet season and 17 µg/m³ in dry season. Concentration of Black Carbon, sulfate, nitrate, and ammonium mostly existed in the fine fraction while crustal elements dominated the coarse fraction. Black Carbon, Sulfate, nitrate and ammonium contributed about 55 % to the total mass of the fine particles at Mixed site (Tegalega) and about 52 % at rural site (Dago Pakar) in dry season. Fine particulate contribute about 57 % to the PM10 in Tegalega and about 73% in Dago Pakar (rural site). This indicates that fine particles may come from other places (transported) in the rural area.

Keywords : total suspended particle (TSP), PM10 , PM2.5, Black Carbon (BC), nitrate, sulfate, ammonium, elements, fine particle, coarse particle

1. Introduction
Atmospheric particulate matter is one of the major pollutants concerned in the ambient air due to the effect of material to the environment and human health. Particulate with size particles less than 10 µm diameter could go through the human respiration system, and particulate with size less than 2.5 µm could penetrate deep into the lung and cause lung damage. Particle larger than 10 µm diameter generally do not penetrate deep into the lung. However, these size particles cause the major dry deposition to the earth surface which cause the problem to the environment [2] and [3]. Because the effect of the particulate matter to human health and environment is very large therefore chemical
compositions such as sulfate, nitrate, metals contained in the particles (PM10, PM2.5) are very important and need to be investigated.

Bandung is the capital city of West Java province with unique climate and topography. The pollution levels in Bandung are incredibly exceeded the Indonesian Ambient Air Quality standard for particulate matter. Results from earlier study in Bandung [1] showed that the particulate concentration from 14 monitoring locations out of 16 monitoring locations exceeded the Indonesian ambient air quality standard for 24 hour average (260 μg/m3). The study conducted in Braga Street [4] still show that the concentration of atmospheric particulate in Jalan Braga exceed the ambient air quality standard and the PM10 contributes from 75 to 95 % of the total suspended particulate matter. While study conducted in Ganesha and Merdeka streets also indicated a big portion of fine particles to the total PM10 [8]. Since the contribution of the PM10 as well as PM2.5 to the total suspended particulate is very significant, therefore further or intensive study on PM10, PM2.5 were conducted in Bandung.

The purpose of this study is to measure the fine and coarse particle concentrations in the ambient air and to determine the chemical compositions of such particles. The study was conducted during the wet and dry season in Bandung during the period of 2001-2003.

2. Methodology

Fine and coarse particulate samples were collected at Tegalega (mixed site) and Dago Pakar (rural site) during wet and dry season 2001-2003. Tegalega is located on the roof of two story buildings in mixed area (commercial and traffic), while Dago Pakar is located in the north side of Bandung with rural activities. Description of sampling location is presented in the figure 1 and table 1. Atmospheric fine and coarse particulate concentrations were measured over 24-36 hours period using a dichotomous sampler and Low Volume Sampler (LVS). Dichotomous sampler has two cut size diameters, which are PM smaller than 2.5 μm (fine) and PM with size 2.5-10 μm (coarse). This sampler has a low-flow rate of 17.68 L/min. while the LVS were operated at 3.5 L/min and 20 L/min for PM2.5 and PM10, respectively. Meteorological conditions were also measured simultaneously during the sampling period.

![Figure 1. Map of Sampling Locations in Bandung](image)

Particles collected on the filters from dichotomous sampler were analyzed using gravimetric method by weighing the filters before and after sampling to determine ambient particulate concentration. Element concentrations were measured using Atomic Absorption Spectrophotometer with flame ionization and graphite furnace detectors. Prior to AAS analysis, the samples were extracted using Microwave Digestion. The water soluble ions were analyzed by ion chromatography (DX-100). In analyzing anions the eluent of 1.7 mM NaHCO3/1.8 mM Na2CO3 was used at flowrate
2.5 L/min. The concentration of black carbon (BC) in the fine fraction of the samples was determined by reflectance measurement using an EEL type Smoke Stain Reflectometer. The BC values were measured from coarse fraction filters and then converted to fine fraction values. Secondary standards of known black carbon concentrations are used to calibrate the reflectometer.

Background contamination was routinely monitored by using operational blanks (unexposed filters) which were processed simultaneously with field samples. The concentrations would then be blank corrected.

### Table 1. Geographical location of the sampling sites

| Sites       | Latitude    | Longitude   | Elevation (m asl) |
|-------------|-------------|-------------|------------------|
| Tegalega    | 6°56’32”S  | 107°37’28”E | 708              |
| Dago.Pakar  | 6°51’41”S  | 107°37’42”E | 825              |

3. Results and Discussion

3.1. Fine and Coarse Particle Concentrations

The mass concentrations of fine and coarse particles during wet and dry seasons from urban mixed site (Tegalega) and non-urban (Dago Pakar) site are presented in the Figure 2 and 3. Basically, the concentrations of both fine and coarse particles were higher during the dry seasons. In Tegalega, concentrations of coarse particles increased during dry season and the contribution between fine and coarse particles was almost balance. This can be caused by increasing the windblown dust and road dust during the dry season. Different from Tegalega site, at Dago Pakar site, the fine particle concentrations were consistently higher compared to the coarse particles during wet or dry season as presented in Figure 3.

The PM concentrations at Dago Pakar site (non-urban site) during the dry season were mostly lower than at Tegalega site. The average fine (PM$_{2.5}$) concentration was very similar to the Tegalega site during the dry season, however, the coarse particle concentrations were much lower at Dago Pakar. The average coarse particle concentration in Tegalega (Urban) was almost two times higher than the coarse concentration in Dago Pakar (non-urban). This indicates that there is possible transport of fine particles from urban to non-urban areas, and there was no significant contribution of coarse particles from the local source at non-urban, Dago Pakar site. It can also be seen that the concentrations were much higher during the transition periods (transition between wet and dry season). This may be caused by the various wind directions and speeds occurred during this time period.

![Figure 2. Concentrations of fine and coarse particles at Tegalega during wet and dry season](image-url)
The fine particles contributions to the PM$_{10}$ were very high for both locations. Figure 4 shows the contribution of fine particles to PM$_{10}$ at both locations. It can be seen that fine particles contribute about 67% to the PM$_{10}$ at Tegalega and about 80% at Dago Pakar site during wet season. While in the dry season, PM$_{2.5}$ (fine particles) contributions to PM$_{10}$ were 57% and 73% at Tegalega and Dago Pakar sites respectively. Again, this indicates that there is no local source of the coarse particles at background site and may only small amount that could be transported from other places.

The average fine and coarse particle concentrations, standard deviation and range of concentrations at both mixed site (Tegalega) and non-urban site (Dago Pakar) are presented in the Table 2. The tables show the average concentrations, standard deviations, minimum and maximum concentrations as well as slope and $R^2$ of the PM$_{2.5}$ and PM$_{10}$ correlation. The concentrations in the mixed site area Tegalega were consistently higher compared to the rural site Dago Pakar. The concentration of fine particle and PM10 in Tegalega ranged from 27 to 88 and 52 to 117 µg/m$^3$ respectively. This results are higher compared to the study in the semi industrial area in Bandung which was range from 4 to 22.2 µg/m$^3$ for fine particle and 24.5 to 77.1 µg/m$^3$ for the PM10 [10]. In addition, the study by Santosa et.al showed that the average concentration of fine and coarse particles in Bandung were 14.03 and 11.88 µg/m$^3$ respectively [11]. The average coarse particle concentration were similar to that of in Dago Pakar.
Table 2. Summary of Dichotomous particulate matter measurements (Avg±std and range) in µg/m3 in Bandung in the years 2001-2003.

| Stations         | Fine                  | Coarse               | PM10                  | PM2.5/PM10 |
|------------------|-----------------------|----------------------|-----------------------|------------|
|                  | Av±std     | range     | Av±std     | range     | Av±std     | range     | Slope    | R²        |
| Dry season       |            |           |            |           |            |           |          |           |
| Tegalega (Mixed )| 49±14      | 27-88     | 33±8       | 15-50     | 81±16      | 52-117    | 1.01     | 0.80      |
| Dago Pakar (rural)| 45±12     | 28-66     | 17±4       | 6-25      | 61±13      | 43-84     | 1.06     | 0.91      |
| Wet season       |            |           |            |           |            |           |          |           |
| Tegalega         | 37±8       | 27-55     | 27±14      | 12-62     | 55±30      | 0-93      | 1.1      | 0.53      |
| Dago Pakar       | 30±12      | 10-42     | 13±5       | 5-21      | 40±17      | 0.56      | 0.95     | 0.81      |

The correlation between the fine (PM\(_{2.5}\)) and the PM\(_{10}\) concentrations is presented in the figure 5 and 6. The high correlations between the PM\(_{2.5}\) and PM\(_{10}\) indicated that there is possible similar sources for PM\(_{2.5}\) and PM\(_{10}\). For Tegalega site, lower correlation was obtained for wet season, since the number of sample was small.

**Figure 5.** Correlation between PM\(_{2.5}\) and PM\(_{10}\) for Tegalega Site during wet and dry season

**Figure 6.** Correlation between PM\(_{2.5}\) and PM\(_{10}\) for Dago Pakar Site during wet and dry season
3.2. Chemical Composition

The compounds analyzed in this study include ions (NH4, SO4, NO3, Cl, F), Black carbon (BC) and elements. The elements were grouped into two categories which are crustal elements (K, Mg, Ca, Si, Al, Na, Mn, and Ti), and anthropogenic elements (Pb, Cd, Co, Cu, Sb, As, Fe, Cr, Zn, V, Ni, La, Sc, Th, I).

The average Concentrations of Elements, Ions (Sulfate, Nitrate, Chloride, Fluoride, and Ammonium) and Black Carbon (BC) from both locations during wet and dry seasons are presented in Figure 7 and 8. Figure 7 shows the average concentrations of compounds (NH4, SO4, NO3, Cl, F), BC, crustal and anthropogenic elements in the fine particles from both locations during the wet and dry season. While average concentrations of compounds in the coarse particles are presented in Figure 8.

During the Wet season (for Tegalega and Pakar sites) Black Carbon (BC) was not analyzed due to the equipment problem. Most of the fine particles contained NH4, SO4, NO3, elemental carbon (Black Carbon) and metals. Element carbon, Sulfate and Nitrate take a big portion of the fine particles for both seasons. This agrees with the current work on PM2.5 composition under Spartan Net- Work, which shows that most of the urban PM2.5 compose of Ammonium sulfate, BC, and Ammonium Nitrate as well as crustal material [5]. As a comparison, the study in Beijing also found that Sulfate, Nitrate and Ammonium contributed a big portion of PM2.5. [7]. The major component of PM2.5 in most of the cities in Asian cities (Bangkok, Beijing, Manila, Chennai, and Hanoi) were OM, EC/BC, SO42-, NH4+, and NO3-. [7]. Meanwhile, crustal elements and nitrate took a big portion of coarse particles. Coarse particle are usually came from materials of geological origin through mechanical activities such as grinding, and wind blowing [9].

Concentration of Black Carbon, Sulfate, Nitrate, and Ammonium mostly existed in the Fine fraction while Crustal elements dominated the coarse fraction. Based on the figure 7, Black Carbon, Sulfate, Nitrate, and Ammonium contributed about 56.4 % to the total mass of the Fine particles at Urban Mixed site (Tegalega) and about 51 % at rural site (Dago Pakar) during Dry season. Black Carbon itself contributed about 20.8% to the total fine particles in Tegalega. The study in Serpong area also found that BC contributed about 13-25% to total fine particles [12]. In the wet season, Sulfate, Nitrate, and Ammonium Contributed about 32 % to the total mass of Fine Particle in Tegalega and 29% in Dago Pakar. The high concentration of Sulfate in Dago Pakar may be caused by the active volcano which located about 10 km in northwest side of the Dago Pakar site.

The coarse fractions were mostly dominated by Crustal and Anthropogenic elements. The average contributions in Dry season were about 26 % and 17 % for Tegalega and Dago Pakar sites respectively. In the Wet season, Crustal and Anthropogenic elements contributed about 44% and 43% for Tegalega and Dago Pakar sites respectively. The high Crustal elements concentrations in the coarse particles may be caused by the windblown dust as the high wind speeds were found during the Wet season. During the Wet season, the wind was mostly blown from west to east direction, where there are many limestone productions in the west side of Bandung city that could potentially contribute generating coarse particles containing of Ca and Mg. Figure 8 also shows that the concentrations of anthropogenic elements were much higher in the urban site Tegalega than in the non-urban area. Steel smelters near the urban mixed site may cause the high concentrations of anthropogenic elements such as Fe and Zn.
4. Conclusions
The concentrations of fine and coarse particles were mostly higher during dry season than in the wet season for both locations. Coarse particles concentrations were two times higher in Tegalega site than in Dago Pakar in both wet and dry season. Fine particles in Bandung take a big portion of PM10 and there is no difference between concentrations of fine particles in the mixed site and rural site. Fine particles mostly consisted of the element carbon or BC, Sulfate, Nitrate, Ammonium and small portion of metals. The coarse particles mostly consisted of big portion of crustal material. Crustal element concentrations in the coarse particles were higher in the wet season than in the dry season.

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