

Human Health Risk to Ultrafine Particles in Jakarta

Budi Haryanto

Abstract

In Jakarta, the main pollution sources are vehicles and industry, with motorized traffic accounting for 71% of the oxides of nitrogen (NO_x), 15% of sulphur dioxide (SO₂), and 70% of particulate matter (PM₁₀) of the total emission load. Both urban population size and the fraction of the population that owns a private vehicle are increasing. The study objective is to determine the numbers of ultrafine particulate matter with an aerodynamic diameter of 0.1 μm or less, or PM_{0.1} inhaled by elementary school children, commute workers with private car and commute workers with public transport. A cross-sectional study design is implemented in Jakarta 2005. Ten elementary school children, ten commuters with private car and ten commuters with public transports are purposively selected as subjects and measured personally for 3 x 24 hours using Condensation Particle Counter (CPC) real-time personal exposure measurement (measured in terms of the number of particles per cubic centimeter, or # cm⁻³). The average concentration of ultrafine particulate matter of elementary school children at home, on the road and at school is 29,254/cm³, 147,897/cm³ and 61,033/cm³ respectively. For those commuters with private car at home, on the road and at office is 29,213/cm³, 310,179/cm³ and 42,496/cm³ respectively. For those commuters with public transport, the concentration average of at home, on the road and at office is found higher: 35,332/cm³, 453,547/cm³, and 69,867/cm³, respectively.

Key words: Ultrafine particles, human health risk

Abstrak

Perhatian terhadap pencemaran udara ini menjadi semakin meningkat ketika banyak ditemukan dampaknya pada anak-anak, terutama kaitannya dengan insidens dan prevalens asma. Sumber utama pencemaran udara di Jakarta adalah dari kendaraan bermotor dan industri, dimana transportasi berkontribusi terhadap 71% NO_x, 15% SO₂, dan 70% partikel debu kurang dari 10 mikrometer (PM₁₀). Tujuan penelitian mengetahui jumlah partikel debu berdiameter ultrafine (partikel berukuran <0,1 μm) yang terhirup oleh anak sekolah dasar, pekerja pengguna kendaraan pribadi dan kendaraan umum. Studi ini menggunakan desain *cross-sectional* dan dilakukan di Jakarta tahun 2005. Sebanyak 30 responden anak sekolah dasar, pekerja pengguna kendaraan pribadi dan kendaraan umum dipilih secara purposif sebagai subyek penelitian. Jumlah partikel ultrafine terhirup secara individu diukur selama 3 x 24 jam menggunakan Condensation Particle Counter (CPC) real-time personal exposure measurement (jumlah ultrafine partikel per cm³). Rerata konsentrasi partikel ultrafine terhirup pada anak sekolah dasar di rumah, di perjalanan, dan di sekolah adalah berurutan sebagai berikut: 29.254/cm³, 147.897/cm³ dan 61.033/cm³. Pada pekerja pengguna kendaraan pribadi di rumah, di perjalanan, dan di kantor diperoleh rerata konsentrasi secara berurutan sebagai berikut: 29.213/cm³, 310.179/cm³ dan 42.496/cm³. Sedangkan pada pekerja pengguna kendaraan umum adalah: 35.332/cm³ di rumah, 453.547/cm³ di perjalanan, dan 69.867/cm³ di kantor.

Kata kunci : Partikel ultrafine, risiko kesehatan manusia

Widespread concern about the ultrafine particles or nano-particles, particles less than 0.1 mm in mass median aerodynamic diameter, is relatively recent. Some people believe that ultrafine particles may be the most harmful constituent of particulate matter. While this idea still only a hypothesis, it is plausible because ultrafine particles can enter deep into the lungs, and cross the lung wall to circulate throughout the body inside the blood. Robust health studies to establish a dose-response relationship have not yet been done, in part owing to the difficulty of such studies.

Ultrafine particles have been implicated to affect cardiopulmonary systems.¹ Indeed, two in-vivo studies have demonstrated that ultrafine particles induce prominent airway inflammation as compared with larger particles.² These studies were also confirmed by Leuren Moret, a UC-Berkeley geo-scientist, referring a study of University of Rochester: "The increased toxicity of the nano-particles is due to its size. The smaller of the ultrafine-particles size the more severe its health effects. When mice exposed to virus-size particles of Teflon (0.13 microns), there were no ill effects. But, when mice were exposed to ultrafine-particles of Teflon for 15 minutes, nearly all the mice died within 4 hours". Similar opinion is also raised by Vyvyan Howard, a British toxicopathologist: "Because of its size, ultrafine-particles having high mobility and can easily enter the body when inhaled through the nose. They can cross the olfactory bulb directly into the brain through the blood brain barrier, where they migrate all through the brain. Ultrafine particles were also known for more toxic than micro-sized particles of the same basic chemical composition".³⁻⁶

A majority of people's exposure to ambient particles in Jakarta (and in most urban areas worldwide) is attributable to motor vehicles. Emissions of particles in Jakarta are expected to increase. Both urban population size and the fraction of the population that owns a private vehicle are increasing. Increased demand for products and services requires increased movement of people and goods. One goal for environmental policies is to ensure that future growth is accompanied by environmental improvements.⁷⁻¹⁰

Health risk assessments are important in quantifying the benefits from environmental improvements. Unfortunately, few exposure assessments or risk assessments have been done outside of the US and Europe. Vehicle emissions are significantly higher in Jakarta than in the US and Europe, so exposures and per capita health effects are likely to be more significant.^{8,11,12}

The study objective is to measure individuals' exposure to ultrafine particles in Jakarta in order to assess health risks attributable to air pollution. The aim is to determine the levels of ultrafine particles among: high-exposure population (commuters in air conditioned/non-

air conditioned public transports) and typical-exposure population (commuters in air conditioned/non-air conditioned vehicles and elementary school children in open and closed type buildings).

Methods

A cross-sectional study design is implemented for assessing the ultrafine particles concentrations in targeted population groups in Jakarta city in 2005. This study design provides the magnitude of health risks caused by ultrafine particles exposures among the selected target groups at one observation time. The study population is certain non-smoking population in high-exposure and certain population in typical-exposure to motor vehicle exhaust pollution. The approach used is to measure personal/individual exposure to ambient ultrafine particles using individual air-sampling equipment for one to three days. Three groups of population are selected: commuters with private car, elementary school students, and commuters with public transports. Location of the survey is in Jakarta greater area involving commuters living surroundings Jakarta who work in Jakarta. Those Jakarta's suburbs included Bekasi City, Bogor City, Depok City, Ciputat Subdistrict, Pamulang Subdistrict, Tangerang City, and Serpong Subdistrict. A non-probability purposive sampling design is used to assess individual concentration (ultrafine particles) in two different levels of exposure groups. A total of 30 individual subjects in two groups of exposure levels selected, they were: 1) occupation with high exposed to ultrafine particles and, 2) occupation with typical exposed to ultrafine particles. Since the study design used is cross-sectional survey and the personal measurements to ultrafine particles is quite new to be carried out in Indonesia's study, the data collected is much more showing the magnitude of human risk to ultrafine particles rather than generalizing it in to general population. This study involved 10 commuters with private car, 10 elementary school students, and 10 commuters with public transports.

The core Personal Exposure Measurement study involved measured people's exposure to ultrafine particles. Students at the University of Indonesia (data collectors) traveled with subject volunteers, recording information about the subject's activities. There were 2 data collector teams of 2 students per team for measuring one individual subject. Students from the University of Indonesia (UI) followed subjects either during a 24-hour sample or during their morning and afternoon commutes. Subjects in the latter group are informally referred to as having a 6-8 hour sample, because this is the approximate amount of time necessary to gather data before, during, and after the morning and afternoon commute. Each sample began with a team of three UI students traveling to the volun-

Table 1. Characteristics of Subjects

	Student	Private Car	Public Transport
Number of respondents	5	6	8
Age, year	8 – 11	24 – 54	25 – 52
Distance from home to school or office, Km	0.2 – 21	23 – 100	15 – 51
Number of measurements	1 – 3	1 – 3	1 – 2
Length of measurement time, average hour	14	19	8

teer's house with the equipment. During the day, students carry the three pieces of equipment and record information about the subject's activities (e.g., indoors or outdoors; during travel, vehicle time and roadway congestion). For a 6-8 hour sample, students sample during the morning and afternoon commutes and for approximately 30 minutes at the subject's location (home or work) before and after commuting. For a 24-hour sample, students begin sampling at approximately 5:00 am, and travel with the person for the whole day. Upon returning home in the evening, the equipment set up to operate independently overnight. In the morning, students return to collect the equipment.

Subject groups of this level of exposure are commuter with public transports. Commuter public transports are measured for a total of 6-8 hours in a day with the measurement focus on transport exposure, therefore approximately 1-2 hours measurements at home, 1-2 hours at office, and 2-3 hours on the road. To measure these two high exposure groups data collectors carry the three pieces of equipment and record information about the subject's activities. The captured data from CPC downloaded directly after data collection from every single individual subject.

Instruments used for data collection are: 1) Structured questionnaire containing of subject's demographic characteristic, time of exposure, mode of transportation, and health symptoms experience. 2) A set of equipment for measuring individual exposure is used, a condensation particle counter (CPC) TSI Model 3007 to measure particle number. The equipment reported real-time exposure concentrations. Readings can be downloaded daily onto a laptop computer. At times, the data recording was stopped briefly during a sample to work on the equipment, for example, to change the batteries or to add more alcohol to the CPC. The CPC reports the number of ultrafine particles (diameter less than 100 nm or 0.1µm) with a 10-second resolution. Data is stored in internal memory and can be displayed in real time on a computer screen. The CPC may be operated on batteries or line power and is the only known ultrafine particle counter that is both portable and operates on harmless alcohol.

Results

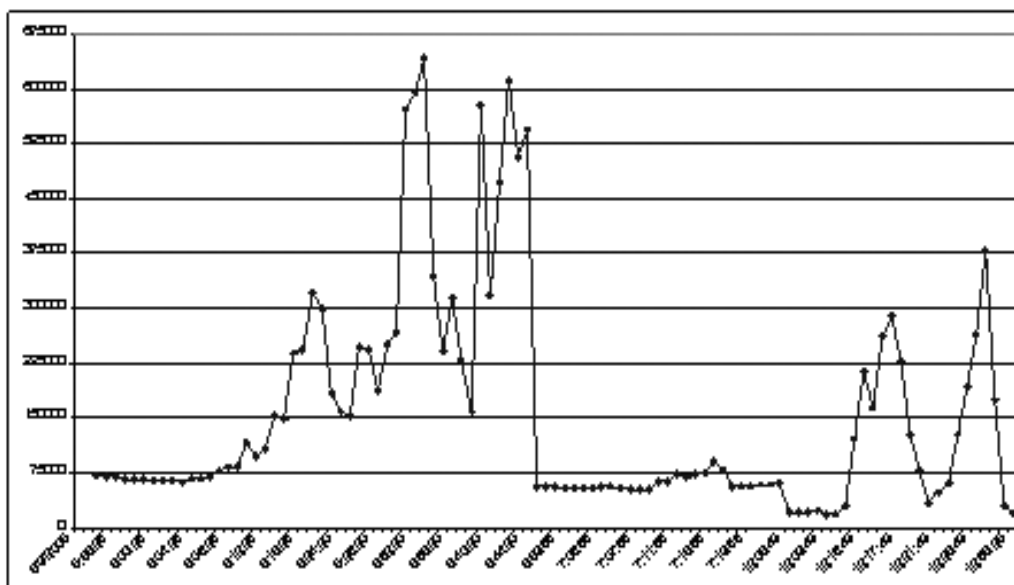
Not all of subjects can be measured for their personal exposure to ultrafine particles due to only one CPC available, they are 5 elementary students, 6 commuters with private car and 8 commuters with public transport. The range of ages among elementary school are 8 – 11 years and for commuters are comparable between those using private car and public transport, 20s – 50s years old. About half of elementary school children living near their school with the distance between 200 M to 2 Km and the rests living quite far from their school with distance about 6 Km to 21 Km. Those commuters with private car relatively staying quite far from their office as well as those with public transport, 23 – 100 Km and 15 – 51 Km respectively. The number of personal exposure measurements range from 1 to 3 times and the average of length of measurements are vary among subjects, 14 hours for elementary school children, 19 hours for commuters with private car and 8 hours for commuters with public transport (Look Table 1).

The limited time and difficulties in operational of data collection, such as to follow closely the subject during his/her real time activities affected to the participation rate. Time allocated for the study only 90 days and data collection for those 19 subjects spent about 55 days non-stop. In general, the activities of subjects are grouped into three most common activities in order to differentiate the concentration doses of ultrafine particles, they are activities: at home, on the road, and at school or in the office. The Table 2 shows the concentration doses of ultrafine particles among subject's groups (Look Table 2).

Picture 1 shows the number of particles per cm³ the school child during at home or at school of below 75 000. Meanwhile, when the child on the road from home to school or back home, the number of particles are very huge with almost 400 000 in the morning and almost 150 000 at noon (Look Picture 1). Picture 2 shows the number of particles per cm³ the school child during at home or at the office of below 100 000. Meanwhile, when the subject on the road from home to office or back home, the number of particles are very huge with almost 500 000 in the morning and almost 600 000 in the afternoon (Look Picture 2).

Table 2. Number of Ultrafine Particles per cm^3 Air of Subject's Groups by Activities

Subjects/Activities	Number of Ultrafine Particles/ cm^3		
	At Home	On The Road	School or Office
Children	27,731	118,265	34,609
Private car			
Air-conditioned	63,050	158,526	41,647
Non Air-conditioned	22,742	325,818	51,314
Public transport			
Air-conditioned	14,843	145,077	21,841
Non Air-conditioned	20,097	281,533	18,998

Picture 1. Distribution of The Number of Ultrafine Particles/ cm^3 of a School Child by Time

Picture 3 shows the number of particles per cm^3 the school child during at home or at the office are below 50 000. Meanwhile, when the subject on the road from home to office or back home, the number of particles are very huge with almost 270 000 in the morning and almost 225 000 in the afternoon (Look Picture 3).

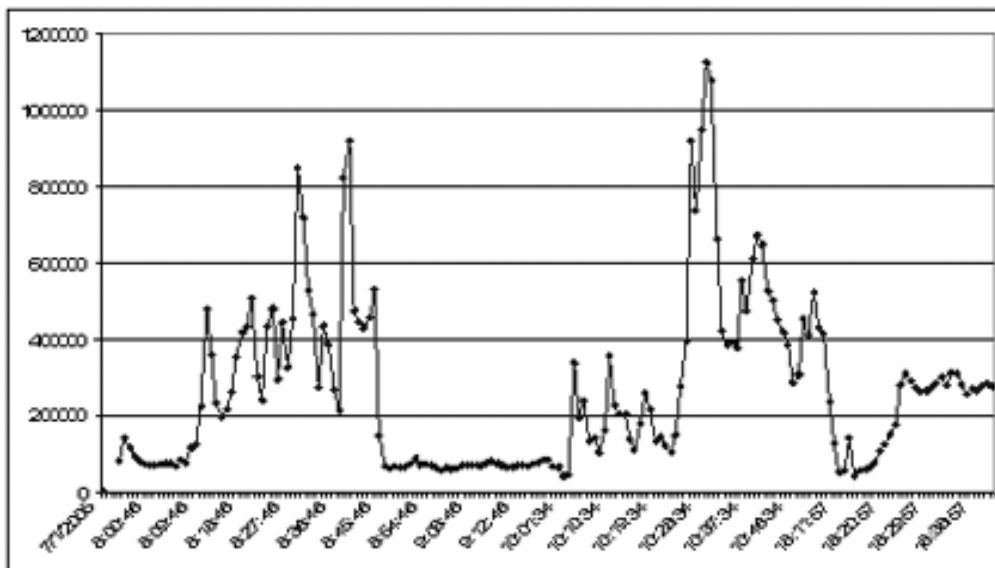
Discussion

The distance from home to school or office affects the length of time during on the road and obviously related to concentration doses of ultrafine particles inhaled. The pattern of school children individual's number of ultrafine particles by activities is quite similar among each other, in which about small number of particles found at home and at school, while a very high number of particles, about four times higher than at home or at school, found during traveling on the road.

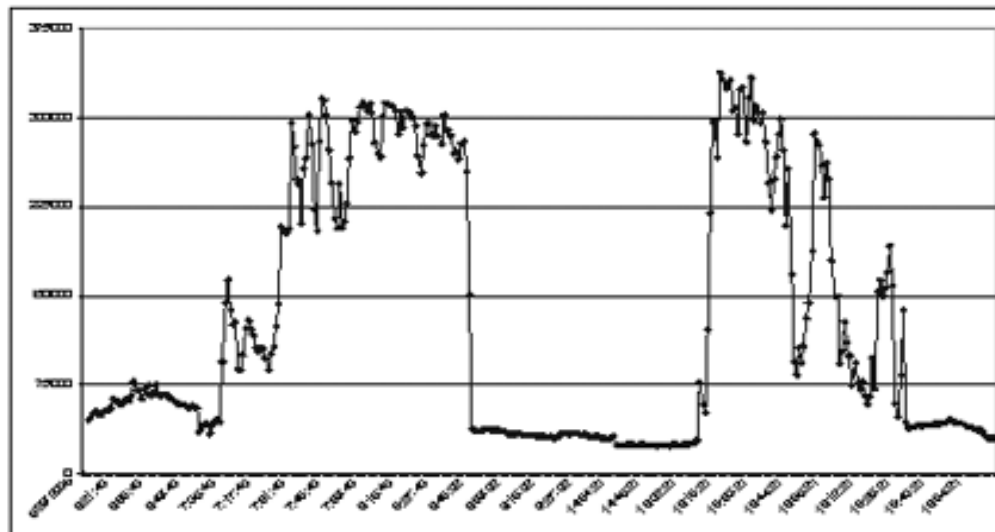
The similar pattern was found among commuters with private car, in which the individual's number of ul-

trafine particles by activities is also quite similar among each other with about small number of particles found at home and in the office but a very high number of particles, about two to six times higher in average than at home or office, found during traveling on the road. However, a significant difference of the number ultrafine particles average was found between those commuter using air-conditioned car and non-air-conditioned car. Those commuters with non-air-conditioned car exposed to ultrafine particles during travelling on the road about two to four folds than those with air-conditioned car. It seems that car with closed windows give more protection from road's ultrafine particles.

The pattern of commuters with public transport individual's number of ultrafine particles by activities is also quite similar among each other, in which small number of particles found at home and in the office, while a very high number of particles, about ten to fourteen times higher in average than at home or in the office, found



Picture 2. Distribution of The Number of Ultrafine Particles/cm³ of a Commuter With Private Car by Time



Picture 3. Distribution of Number of Ultrafine Particles/cm³ of a Commuter With Public Transport by Time

during traveling on the road. A significant difference of ultrafine particles average number was found between commuters with air-conditioned public transport and non-air-condition public transport. During travelling on the road, the average number of ultrafine particles inhaled by commuters with non-air-conditioned public transport found two folds higher than those with air-conditioned public transport. This finding shows that closed-windows of public transport also protecting the exposure of ultrafine particles from roads.

The more risk to health disorders is associated with

more numbers of ultrafine particles inhaled, as a given mass of ultrafine particles contains thousands to tens-of-thousands greater number of particles, with a correspondingly larger surface area, than an equivalent mass of larger particles. This implies that a given mass of ultrafine particles will impact a larger surface area of lung tissue than will an equal mass of larger particles, thus increasing exposure.¹³

Exposure to ultrafine particles may lead to adverse health effects. Several recent studies have produced intriguing health-related findings. A daily mortality study in

Erfurt, Germany, was the first epidemiology study that examined and found significant associations between exposure to ultrafine particles and mortality from respiratory and cardiovascular disease. Human exposure studies have shown that individuals with moderate to severe airway obstruction receive a greater dose of ultrafine particle than do healthy individuals. In addition, that ultrafine particles pass rapidly into the human circulatory system, implying a clearance mechanism exists for ultrafine particle in the lungs, however, at the same time increasing the number of particles in the blood and thus increasing exposure to other organs. These results suggest that certain sensitive sub-populations, like individuals with chronic obstructive pulmonary disease, may be at greater risk than healthy individuals when exposed to ultrafine particle due to an increased dose in the lungs which leads to an increased dose in the circulatory system.¹⁴

Finally, a toxicology study published in 2002 indicates that ultrafine particle is more potent than fine or coarse particulate matter toward inducing cellular damage—a possible indicator of the biological mechanism of how ultrafine particle exposure can affect human health. It should be noted that relatively few reports have been published on the health effects of ultrafine particle. The first epidemiology study was published only a few years ago, which is in contrast to the hundreds of epidemiology studies on PM₁₀ and PM_{2.5} published over the last two decades.¹⁵ The findings of this study reflect of high exposure of ultrafine particles outdoor, especially when travelling from home to school or office. The closed windows of transportation used during on the travelling protect the exposure of ultrafine particles.

Conclusion

Ultrafine particles concentration is found very high especially when the respondents on the road and along with the length of time spending on the road give respondents more risk to have respiratory and lung diseases related to air pollution. Those commuters using non-air conditioned public transport found having more concentration of ultrafine particles than other groups. However, high number of ultrafine particles found at home, at school, in the office, and on the road will give the high risk of having respiratory diseases, lung diseases, and coronary heart diseases among all of respondents. Therefore, in order to reduce the risks, it is suggested that commuters should reduce their length of time during trip on the road and avoid traffic jam during on the road. Providing adequate ventilation and air circulation at home as well as in the office are needed for healthier breathing. Improving management of transportation to reduce traffic jams is also strongly recommended to local

government.

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