Analysis of indoor and outdoor particulate (PM$_{2.5}$) at a women and children's hospital in West Jakarta

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Abstract: Air quality monitoring is very important to provide public information about the impacts of air pollution on health, especially in health centers. Particulate less than 2.5 micrometer (PM$_{2.5}$) is the main parameter of air pollution. This research aims to measure indoor and outdoor PM$_{2.5}$ at a women and children's hospital in West Jakarta. The method for collecting data of PM$_{2.5}$ was with a low-cost sensor (LCS), which also collected temperature and humidity data. The LCS was collocated with two ambient air quality monitoring stations (AQMS) as the references. Field measurements at hospital were conducted for three months. The data are statistically analyzed with the openair model. The results show that LCS and AQMS followed a similar trend. Outdoor PM$_{2.5}$ concentration is always higher than indoor. Peak hourly outdoor concentrations usually occur around midnight (24:00–03:00). The indoor peak concentrations are between 06:00–12:00. The indoor PM$_{2.5}$ tend to be stable, while the outdoor varies throughout the day. The ratio of PM$_{2.5}$ concentration (24-hour) indoor to outdoor is 0.8. In conclusion, the relation between indoor and outdoor air pollution is still not comprehensive due to temperature and humidity factors. All indoor and outdoor PM$_{2.5}$ are above WHO Air Quality Guideline.

1. Introduction

Air pollution is an issue that is long-standing. The presence of chemicals, contaminants or biological substances in the environment that could affect living beings is air pollution itself [1]. In 2019, at the end of July, the Jakarta Air Quality Index reached a level of 195, with an unhealthy status. In general, the major sources of air pollution are derived from secondary sulphate, wood burning, emissions of gases and dust. In urban areas, there are higher levels of air pollutants, particularly particulate matter (PM). Suspended particulate matter (SPM) and inhaled particulate matter in each urban environment was reported to be greater than the level controlled by National Ambient Air Quality Standards (NAAQS) beyond the SPM for industrial areas during a typical 24 hour monitoring period [2].

Currently, particulate less than 2.5 micrometer (micron) in diameter (PM$_{2.5}$) or “fine particles” is important in ambient air quality monitoring because it is closely related to the impacts of air pollution on human health. However, until 2018 the PM$_{2.5}$ measurement in Indonesia, with an area of 1,905,000 km$^2$, only 14 units of PM$_{2.5}$ Air Quality Monitoring Stations (AQMS) were available [3], which are not proportional to Indonesia’s area. The availability of low cost air sensors (LCS) now allows individuals, communities, researchers and others to collect their own air quality data. Hence, with the limitation number of AQMS, the LCS can be used as a correction factor for PM$_{2.5}$ mass concentration [4] to give
better idea how the air quality status is around us. Furthermore, it is interesting to distinguish the different between indoor and outdoor (ambient) air quality.

This research aims to measure PM$_{2.5}$ relation of indoor and outdoor air quality at a women and children’s hospital, Rumah Sakit Anak dan Bunda Harapan Kita (RSABHK), in West Jakarta. The indoor measurement was done in the lobby area of the hospital because of the nature of people passing by. At the entrance to the lobby, the exterior calculation was carried out. The indoor position is measured because there is less airflow, so the indoor PM$_{2.5}$ mass in the air could be greater than the outdoor mass. Outdoor locations is measured because PM$_{2.5}$ mass in ambient air is mostly generated from vehicle fuel and power sources combustions [5]. The location of RSABHK near Letjen S. Parman Street has the potential to be exposed by PM$_{2.5}$ sources.

2. Research methods

2.1. Instruments for measurement of PM$_{2.5}$

The LCS Edimax AirBox AI-1001W V3 is one of air quality instruments that specialized on PM$_{2.5}$ detection both indoor and outdoor [6]. It is widely used in Taiwan, more than 1,000 units are already deployed to supports Smart City development in Taiwan. The laser dispersion style sensor is fitted with the LCS Edimax AirBox AI-1001W V3. It will quantify the number of particles on the basis of the current particles in the field. It measures RH and temperature as well. Edimax is a sensor-to-the-cloud Internet of Things (IoT) platform that enables observation to be directly connected to the internet and enables 24-hour observation [6]. The specification as follows: dimension of (150x110x47) mm; PM$_{2.5}$ sensor of 0–500 μg/m$^3$ the smallest size is at 0.3 μg; weight of 210 grams; sensor temperature of 0–60 °C ± 1 °C; sensor humidity of 0–100 % RH ± 5% RH; operation temperature of -10–60 °C; 1 internal antenna, power adapter of micro USB power port x 1, DC 5V 1A; reach ratio of 150 m at maximum; and installation height of minimum of 100 cm above ground.

Collocation test was conducted twice for a week (6-12 September 2019). First, between LCS Edimax AirBox AI-1001W V3 and AQMS Thermo 5014i Beta owned by the Meteorology, Climatology, and Geophysical Agency (BMKG) at Kemayoran (coordinates of -6.155922, 106.842477), hereinafter referred to as PM$_{2.5}$ BMKG 5014i Beta. Thermo Scientific™ 5014i Beta Continuous Ambient Particulate Monitor uses the radiometric principle of beta attenuation through a known area on a fibrous filter tape to continuously detect the mass of deposited ambient particles. Second, between LCS Edimax AirBox AI-1001W V3 and AQMS Met One Instruments, Inc. Model BAM-1020 owned by the Government of Jakarta’s Environmental Laboratory (LLHD) at Hotel Indonesia Roundabout (coordinates of -6.194603, 106.823617), hereinafter referred to as PM$_{2.5}$ LLHD BAM-1020. The BAM-1020 automatically measures and records airborne particulate concentration levels (in μg/m$^3$) using principle of beta ray attenuation. The two units of LCS were installed at a nearly similar height to PM$_{2.5}$ inlet suction of AQMS at 2.5–3 m of height.

2.2. Measurement of PM$_{2.5}$ at a women and children’s hospital (RSABHK)

Measurements with LCS Edimax AirBox AI-1001W V3 were carried out in two sampling locations, inside (indoor) and outside (outdoor) of RSABHK for three months (October–December 2019). Indoor measurement was conducted by installing the LCS in lobby area of the hospital, specifically the connecting hall between the information service area and pharmacy (the hall parallel to the Edelweiss room entrance) with coordinate -6.184360, 106.798125. Outdoor measurement was conducted by installing the LCS at the entrance to lobby, specifically a valley parking post facing towards RSABHK area with coordinate -6.184209, 106.797477.

2.3. Analyzing air quality data with openair model

Openair is an open source tools, an R package developed for analyzing air quality data [7]. Some of the features are: utility functions such as timeAverage and selectByDate to handle atmospheric composition data; flexible plot conditioning to easily plot data by hour or the day, day of the week, season etc.
Through the openair type option available in most functions; and many functions for air quality model evaluation using the flexible methods e.g. the type option to easily evaluate models by season, hour of the day etc. These include key model statistics, Taylor Diagram, Conditional Quantile plots. Almost all the functions in openair that are used for analyzing air pollution measurement data can also be applied directly to model output data. This study is applying some of these functions to analyze the measurements, both from collocation and RSABHK.

2.4. Air quality standards for PM$_{2.5}$

The measurement results for indoor air quality will be compared to Regulation of the Minister of Health of the Republic of Indonesia No. 1077 in 2011 (Permenkes 1077/2011) regarding Air Sanitation Guidelines for Indoor Space [8]. PM$_{2.5}$ standard for 24-hour measurement is 35 μg/m$^3$, temperature is 18–30 °C, and humidity is 40–60 % RH.

For outdoor air quality standard is based on Indonesia’s Government Regulation No. 41 in 1999 (PP 41/1999) regarding Air Pollution Control. In this regulation there is National Ambient Air Quality Standard (NAAQS) for 24-hour measurement of PM$_{2.5}$ is 65 μg/m$^3$ [9]. This standard is also the same as Decree of the Governor of DKI Jakarta No. 551 in 2001 (KepGub Jakarta 551/2001) regarding Determination of Ambient Air Quality Standards and Noise Level Standards in DKI Jakarta Province [10]. However, there is a stringent World Health Organization (WHO) Air Quality Guidelines in 2005 for PM$_{2.5}$ (24-hour) which is 25 μg/m$^3$ [11].

3. Results and discussion

3.1. Indoor PM$_{2.5}$ measurement result

Hourly PM$_{2.5}$ indoor concentration shows the highest concentration occurs between 06:00–12:00 and the lowest around 18:00 that happened almost every day. The lowest daily (24-hour) concentration tends to happen on Saturdays. The 24-hour concentration of PM$_{2.5}$ on weekdays is generally higher than on weekends (Figure 1). This pattern corresponds to the hospital's active time period at RSABHK.

Figure 1 also shows the highest hourly temperatures generally occur at 12:00. Whereas peak hour humidity usually occurs between 12:00–16:00 which reaches 68 %RH. The relationship of temperature to PM$_{2.5}$ concentration is directly proportional, whereas humidity to PM$_{2.5}$ concentration is inversely proportional. The effect of humidity on PM$_{2.5}$ concentration is somewhat higher than temperature. However, the relationship between temperature and humidity is not significant to indoor PM$_{2.5}$.

The daily (24-hour) PM$_{2.5}$ concentration ranged from 40–50 μg/m$^3$ above the Permenkes 1077/2011 PM$_{2.5}$ standard for a 24-hour measurement of 35 μg/m$^3$. The average daily temperature measured was
around 26 °C, still meeting the 18–30 °C standard. Measured daily average humidity ranged from 60 %RH, slightly exceeding the standard 40–60 % RH (Figure 1).

Monthly PM$_{2.5}$ concentrations show that from October it continues to decline until December 2019. The climate of Jakarta in November starts to enter the rainy season according to BMKG, so the influence of PM$_{2.5}$ influx from outdoor is expected to decrease, although the activity inside the hospital is relatively remain the same. Hospital visitor data is needed to clarify this relationship. Since RSABHK is a hospital for women and children, patients who come are usually accompanied by more than one person.

3.2. Outdoor (ambient) PM$_{2.5}$ measurement result

Outdoor concentrations of hourly PM$_{2.5}$ show the highest concentration occurs around midnight, between 00:00–03:00 and the lowest between 13:00–17:00, which happened nearly every day. The highest daily (24-hour) concentration occurs on Thursdays and the lowest tends to happen on Saturdays. The 24-hour concentration of PM$_{2.5}$ on weekdays is generally higher than on weekends (Figure 2). This pattern might be related to the hospital’s active time period at RSABHK.

Figure 2 also shows the highest hourly temperatures typically occur around noon at 12:00. While peak hour humidity usually occurs between 00:00–06:00 which reaches 80 %RH. The relationship of humidity to PM$_{2.5}$ concentration is somewhat directly proportional, whereas temperature to PM$_{2.5}$ concentration is a bit inversely proportional. The effect of humidity on PM$_{2.5}$ concentration is slightly higher than temperature. However, the relationship between temperature and humidity is not significant to PM$_{2.5}$ concentration in outdoor measurement.

The daily (24-hour) PM$_{2.5}$ concentrations ranged from 50–65 μg/m$^3$ still meet both the PP 41/1999 and KepGub Jakarta 551/2001 PM$_{2.5}$ standard for a 24-hour measurement of 65 μg/m$^3$. However, all measurements are double or above the WHO Air Quality Guidelines 2005 of 25 μg/m$^3$ (24-hour). It is quite an irony for the health facility. The average daily temperature measured was around 27 – 30 °C, and average humidity ranged from 62–90 %RH, which normal for outdoor condition (Figure 2).

Monthly PM$_{2.5}$ concentrations show that from October it continues to decline until December 2019, although concentrations in December was higher than in November. As mentioned earlier, the climate of Jakarta in November starts to enter the rainy season according to BMKG, therefore the ambient PM$_{2.5}$ concentration is expected to decrease because of wet deposition. The RSABHK is actually located in a complex with the National Cardiovascular Center Harapan Kita (RSPJNHK). Hence outdoor activities are very crowded when observed from the density of vehicle parking and visitors passing by. The high concentration of PM$_{2.5}$ on ambient air will harm the people who conduct their activities outdoor.
3.3. Relationship between indoor and outdoor (ambient) air quality of PM$_{2.5}$

The difference in measurement results between PM$_{2.5}$ concentration indoor and outdoor can be seen in Figure 3. During the three months of measurement, the ambient PM$_{2.5}$ concentration is always higher than indoor. Peak hourly ambient concentrations usually occur around midnight (24:00–03:00), except Mondays that occur at 06:00. Whereas for indoor peak concentrations of flatter hours are common between 06:00–12:00. PM$_{2.5}$ concentrations are relatively the same between indoor and outdoor occurs during 12:00–16:00, which mean almost no influx of PM$_{2.5}$ from outdoor to indoor.

![Figure 3. PM$_{2.5}$ concentrations at RSABK: indoor vs. outdoor, October–December 2019.](image)

For both indoor and outdoor air, PM$_{2.5}$ concentration on weekdays is higher than weekends. Saturday is the day with the lowest concentration and Thursday is also the day with the highest concentration. Fluctuating outdoor PM$_{2.5}$ concentrations may be due to the influence of varied activities, but for indoor relatively stable in accordance with routine hospital activities. PM$_{10}$ and PM$_{2.5}$ originate from different emissions sources, and also have different chemical compositions. In outdoor air, emissions from combustion of gasoline, oil or diesel fuel produce much of the PM$_{2.5}$ pollution, along with a significant proportion of PM$_{10}$ [12].

PM$_{2.5}$ monthly concentrations from October to December 2019 tend to decrease both indoors and outdoors, except outdoors in December slightly higher than November. This possibility could be caused due to entering the rainy season. Therefore, this still needs to be investigated again with a longer sampling period that includes proportional dry and rainy seasons. Indoor PM$_{2.5}$ would be expected to be the same as, or lower than, outdoor levels. The higher outside concentration will also threaten practices involving the indoor area to enter and leave, which would induce partition movement on particles stuck within a small room, as the number of particles would begin to increase [13].

In indoor conditions, the average concentration of PM$_{2.5}$ (24-hour) ranging from 40–50 $\mu$g/m$^3$ has exceeded the standard of 35 $\mu$g/m$^3$ (Permenkes 1077/2011). While the average daily concentration of 24-hour ambient PM$_{2.5}$ ranges from 50–65 $\mu$g/m$^3$ still meets NAAQS of 65 $\mu$g/m$^3$ (PP 41/1999 and KepGub Jakarta 551/2001) every day with the exception of Thursday there is a tendency slightly exceed the NAAQS. PM$_{2.5}$ outdoor concentrations can be higher up to 30% than indoor. The ratio of PM$_{2.5}$ concentration (24-hour) indoor to outdoor is 0.8 in general.

However, if both compared with the 25 $\mu$g/m$^3$ from WHO Air Quality Guideline 2005, all days have passed the air quality standard, which could reach two times higher. Translation from concentration to air quality status that can be understood by the public is called the air quality index (AQI), which usually consists of good, moderate, unhealthy, very unhealthy and dangerous categories. Based on PM$_{2.5}$ concentrations of indoor and outdoor RSABHK can be categorized from moderate to unhealthy.
The impacts of PM$_{2.5}$ to human health is detrimental. When a large concentration of PM$_{2.5}$ or fine particles are inhaled, it can carry potential health risks starting with symptoms such as coughing, sneezing, running nose or shortness of breath. Long term exposure to PM$_{2.5}$ can reduce lung function and cause respiratory illness, it has “also been shown to cause a persistent inflammatory response even in the relatively young and to increase the risk of infection by viruses that target the respiratory tract” [14]. In 2015, the International Agency for Research on Cancer (IARC) concluded that particulate matter in outdoor air pollution causes lung cancer [15].

It is necessary to take measures to control PM$_{2.5}$. Before being able to apply the WHO Air Quality Guidelines, it must at least meet the NAAQS of PP 41/1999 (KepGub Jakarta 551/2001) for outdoor and Permenkes 1077/2011 for indoor air. In principle, there are three control efforts namely from the source, exposure and receptor. Control at the source can be in the form of control over emission sources. Control of PM$_{2.5}$ exposure can be done by installing indoor air filters. Hospital workers and visitors or patients must be informed of the hospital's air quality status so that they can make efforts to protect themselves by using personal protective equipment such as appropriate masks.

4. Conclusions
This study concludes that all indoor concentrations of PM$_{2.5}$ (24-hour) ranging from 40–50 $\mu$g/m$^3$ have exceeded the Regulation of the Minister of Health No. 1077 of 35 $\mu$g/m$^3$. Meanwhile the outdoor concentrations of PM$_{2.5}$ (24-hour) from 50–65 $\mu$g/m$^3$ meet the NAAQS of 65 $\mu$g/m$^3$, except Thursday.

However, if both compared to 25 $\mu$g/m$^3$ 24-hour mean PM$_{2.5}$ of WHO Air Quality Guideline, all days are above the limit, and could be two times higher. Thus indoor and outdoor PM$_{2.5}$ concentrations can be categorized from moderate to unhealthy conditions. Outdoor PM$_{2.5}$ can be higher up to 30% than indoor. The ratio of PM$_{2.5}$ concentration (24-hour) indoor to outdoor is 0.8 in general.

The hospital needs to make an effort to control the indoor and outdoor PM$_{2.5}$ concentrations in order to reduce the health impacts. Further research that cover both dry and rainy seasons is suggested and collocation of low cost sensor and standard air quality monitoring after the sampling is also suggested.

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