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Exposure of Particulate Matter ($PM_{2.5}$) among Printing Operator Of A Printing Industry in Jakarta 2016 - *A case study*

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Abstract

Particulate matter ($PM_{2.5}$) is an air pollutant known as the fine particle has a diameter of less than 2.5 µm which is also called the respirable particulates that can get into the alveolar region of the lungs (Fierro, 2000). This study aimed to determine the exposure concentration of $PM_{2.5}$ among printing operators who work in the production area of the printing industry. Measuring the exposure concentration of $PM_{2.5}$ was done at 10 points in the 7 SEG that represent 15 locations and 51 operators in conducting their activities. The measurement points were consist of Solna 1 (2 points), Solna 4 (3 points), Magnum 1 (2 points) and HT 2 (3 points). The concentration of $PM_{2.5}$ exposure measured by using the "Haz Dust EPAM 5000" with a flow rate of 2.5 liters/minute for 15 minutes. The results of the exposure concentration of $PM_{2.5}$ exceed the Government Regulation 41/1999 about air pollution control which exposed to 16 people were in Solna machine 1 (0.463 mg/m^3), Solna machine 4 (0.211 mg/m^3), and the bundling paper area of Magnum machine (0.209 mg/m^3). Some control methods can be considered to reduce the concentration such as making an installation dust extractor machine with dust capture hoods, developing work instructions to clean the machine, and using an appropriate masker during work.

Keywords: Particulate Matter 2.5 printing operator, production area.

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1. Introduction

Every day billions of particles are inhaled with the ambient air by every human being. Many of these particles are deposited in the respiratory tract, depending on the size, density, shape, charge, and surface properties of the particles and the breathing pattern of the individual. Particles that inhaled are carried through the respiratory system, transported to the respiratory tract by a sedimentation process, impaction and diffusion (Heyder, Joachim, 2004).

Particulate matter (PM) is the term used for a mixture of solid particles and liquid droplets suspended in the air. These particles originate from a variety of sources, such

as power plants, industrial processes, and diesel trucks, and they are formed in the atmosphere by transformation of gaseous emissions. Particulate matter is composed of both coarse particles (PM_{10}) and fine particle ($PM_{2.5}$) (Fierro, 2000). The concentration of PM_{10} exposure is used to measure of particulate with a diameter less than ten μm and $PM_{2.5}$ with a diameter less than 2.5 μm which are generally used to describe the level of exposure to particulate matter that can harm health (WHO, 2013).

Particulate matter is one of the various types of pollutants that influenced human health. There are some findings which prove that the effect of contaminants on human health. In the small town of Donora, Pennsylvania in 1948 that there is an increase in death rates caused by air pollution which founded 20 deaths. In London, there are 4000 deaths in 1952. These incidents had appeared a lot of research on the health effects due to exposure to particulate matter. PM_{10} is also called the inhalable particulate matter deposited in the upper respiratory tract, and $PM_{2.5}$referred to respirable particulates that could get into the area of the lung alveoli (Fierro, 2000).

According to WHO, in 2013 that individuals who were exposed to particulate matter in a short period or longer can get the risk of increased illness of the respiratory system and cardiovascular system, such as asthma, respiratory symptoms, increased hospital visits and cause death due to cardiovascular disease, respiratory, and lung cancer. In an article review of the research report earlier in 1995 obtained the results on the health effects in paper and wood (pulp) industrial workers exposed to paper dust, chlorine compounds in high concentrations can increase the damage lung function, lung, respiratory diseases, so that it can cause allergies, lead to death (Thoren et al, 1996a in Korhonen et al, 2004).

$PM_{2.5}$ is a cause of respiratory problems that significantly more than the PM_{10} because $PM_{2.5}$ can get into the lungs until the alveoli (Winder & Stacey, 2004). A study conducted by Ericsson et al., 1988 about respiratory disorders and lung function in workers who exposed to the paper dust, led to increasing the distraction or irritation of the upper respiratory tract because of dust into the upper respiratory tract. Workers who have worked more than ten years and are exposed to high dust concentrations can be predicted impaired or decrease of respiratory function compared to workers with shorter exposure to dust.

$PM_{2.5}$ is a cause respiratory problem significantly more than the PM_{10}. The newspaper printing machine which prints daily newspapers releases particulates of paper dust or dry printing ink which can be spread in the work environment, exposing the workers. Therefore, the researcher measured the levels of concentration exposure to $PM_{2.5}$ exposures in the work environment. The concentration of exposure in the work environment can be a typical size of personal exposure to $PM_{2.5}$, although not significantly. This is related to the limitations of the study regarding the tools used to measure

the concentration of particulate exposure, so the researcher only measured particulates in the workplace. This study aimed to determine the concentration of $PM_{2.5}$ exposure on production workers or who operated a printing machine in a printing company through the measurement of $PM_{2.5}$ concentrations in the work environment.

2. Methods

This study used cross-sectional design conducted at a printing industry located in Palmerah, Central Jakarta in June 2016. The total sample printing machine was set based on Similar Exposure Group (SEG) approach. The number of acquired SEG was7 which represented15 locations where 51 operators conducted their activities. Type of printing machine that was measured included Solna 1, Solna 4 Magnum 1 (representing Magnum 1 and 2) and HT 2 (representing HT 1, 2 and 3). The number of measurement points was 10 points consist of Solna 1 (2 points), Solna 4 (3 points), Magnum 1 (2 points) and HT 2 (3 points). Distribution of measurement points was based on the type of machinery and SEG, shown in Table 1. The concentration of $PM_{2.5}$ exposure was measured by using the ”Haz Dust EPAM 5000” with a flow rate of 2.5 liters/minute for 15 minutes for each sampling point. $PM_{2.5}$ exposure concentration measurement obtained from each print engine in each SEG was the concentration of exposure to operators working in each of the printing machines.

TABLE 1: Distribution of measurement points based on the type of machinery and SEG.

Type of Machine	Number of Measure-ment Point	Location	SEG
Solna 4	3	1: Near of desk operator/team leader	1
		2: Cutting or folding paper/folder area	
		3: Paper bundling area	
Solna 1	2	1: Cutting or folding paper/folder area	2
		2: Near mail room	
Magnum 1	2	1: Cutting process and folding paper area	3
		2: Paper bundling area	4
HT2	3	1: Paper bundling area	5
		2: Near to the quiet room, besides the machine, folding process area	6
		3: Mailroom area	7

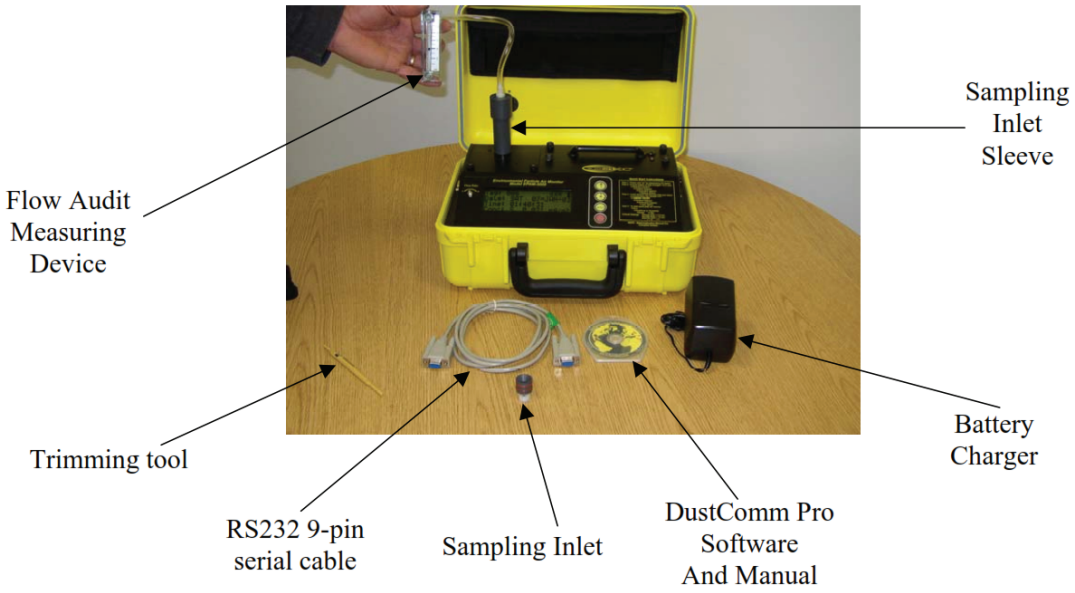

Figure 1: Haz Dust EPAM 5000 (Source: SKC).

3. Results

The detailed measurement results of $PM_{2.5}$ concentration at ten measurement points were shown in Table 2.

The number of operators who worked in the production area based on the location of work in each type of production machine was shown in Table 3.

The results of the measurement as in Table 2 and Table 3 determined the exposure concentration of $PM_{2.5}$ in all printing machines and among operator as it was shown in Table 4.

Table 4 showed that the concentration of $PM_{2.5}$ exposure in the area of Solna machine was higher than exposure in the field of Magnum machine and HT machine. Between Solna machine 4 and Solna machine 1. The highest exposure concentration of $PM_{2.5}$ was in Solna machine 1 (0.463 mg/m^3) which exposed to 7 operators in total. The highest exposure concentration of $PM_{2.5}$in Magnum machine 1 and 2 could be found in the bundling paper area (0.209 mg/m^3) which exposed to 11 operators in total. Measurement of exposure concentration $PM_{2.5}$ in the HT machine area included the HT 1, HT 2 and HT 3, the highest exposure concentration was found in the field of near to the quiet room and folding process with 0.034 mg/m^3 of concentration which exposed to 14 operators in total.

TABLE 2: measurement results of Concentration $TWA_{(15minutes)}$ of $PM_{2.5}$ in the Measurement Points.

Types of Machine	Measurement Point	TWA (Time Weighted Average) during 15 minutes in (mg/m^3)	Working Process
Solna 4	Point 1 (near of desk operator/team leader)	0.470	Replacing the paper roll through the connection process, cutting and folding newspaper, stacking and counting the number of publications
Solna 4	Point 2 (cutting or folding paper/folder area)	0.077	
Solna 4	Point 3 (paper bundling area)	0.085	
Solna 1	Point 1(cutting or folding paper/folder area)	0.407	
Solna 1	Point 2 (near mail room)	0.519	
Magnum 1	Point 1 (cutting process and folding paper area)	0.039	Cutting and folding newspaper
Magnum 1	Point 2 (paper bundling area)	0.209	Replacing the paper roll through the connection process
HT2	Point 1 (paper bundling area)	0.021	Replacing the paper roll through the connection process
HT2	Point 2 (near to the quiet room, besides the machine, folding process area)	0.034	Receiving the newspapers that have cut and folded from the folding process area in the unit area and send to the mail room area
HT2	Point 3 (mail room area)	0.029	Receiving, counting, giving bundle, giving label/address, and wrap newspapers that come out of the folding process

4. Discussions

The Associated with the concentration of $PM_{2.5}$ exposure, it was known that there was no government regulation for the $PM_{2.5}$ exposure limits in the workplace base on 8 hours but regulation about the limits concentration of $PM_{2.5}$exposure for 24 hours exposure period was established. Indonesia had set limits on concentrations of $PM_{2.5}$ exposure in the form of Ambient Air Quality Standards with the issuance Government Regulation No. 41 of 1999 which limited exposure to $PM_{2.5}$ per 24 hours was 65 $\mu g/m^3$(0.065 mg/m^3) and the average exposure per year was 15 $\mu g/m^3$(0.015mg/m^3).

This study hada limitation related to the duration of exposure concentration measurements of $PM_{2.5}$. Exposure concentration measurement was only performed for 15 minutes at any point, while the exposure standards were available for an average exposure concentration within 24 hours. It implied that it was difficult to state the reality if the exposure concentration exceeded the regulations or did not.

Table 3: Distribution of Operator Based on Type of Machine and Work Location.

Types of Machine	Work Location	n
Solna 4	Near of desk operator/team leader, cutting area or folding paper/folder, and paper bundling area	8
Solna 1	Cutting or folding paper/folder area and near mail room	7
Magnum 1	Cutting process and folding paper area	6
	Paper bundling area	1
Magnum 2	Cutting process and folding paper area	5
	Paper bundling area	1
HT 1	Paper bundling area	2
	Near to the quiet room, besides the machine, folding process area	5
	Mailroom area	1
HT2	Paper bundling area	2
	Near to the quiet room, besides the machine, folding process area	5
	Mailroom area	1
HT 3	Paper bundling area	2
	Near to the quiet room, besides the machine, folding process area	4
	Mailroom area	1
Total		51

The exposure concentrations of $PM_{2.5}$ in Solna machines were higher than Magnum machines and HT machines. Exposure concentration of $PM_{2.5}$ in Solna machines also exceeded the Government Regulation. The number of a worker who were exposed with the concentration was 15 people. The locations that also had higher concentrations of $PM_{2.5}$ than the government regulation were the paper bundling areas, both Magnum machine 1 and Magnum machine 2, with a concentration of $PM_{2.5}$exposure 0.209 mg/m^3. The number of workers who were exposed to 0.209 mg/$m^3$of $PM_{2.5}$ in the bundling area of both Magnum machine 1 and Magnum machine 2 was two people. Based on the observations that had been made, the concentration of $PM_{2.5}$exposure in the area of Solna machines that was higher compared with Magnum machines and HT machines was caused by two things: 1) the Solna machines was still operated manually and 2) The age of Solna machines were older than the other two types of printing machines.

The exposure concentration of $PM_{2.5}$ in all of HT machines (HT 1, HT 2, and HT 3) area were still relatively lower than other machines because the HT machines had installed a dust extractor which could reduce the particulate from spreading. On the other side, the characteristics of Solna 1 machine environment was a closed environment, causing a poor air circulation and more particulates. The paper bundle area of both Magnum machine 1 and 2 were also in a closed environment which causef poor air circulation.

Table 4: Distribution of Operator Based on Type of Machine and Work Location.

Types of Machine	Work Location	n	Exposure Concentration $PM_{2.5}$ (mg/m^3)
Solna 4	Near of desk operator/team leader, cutting area or folding paper/folder, and paper bundling area	8	0.211*
Solna 1	Cutting or folding paper/folder area and near mail room	7	0.463**
Magnum 1	Cutting process and folding paper area	6	0.039
	Paper bundling area	1	0.209
Magnum 2	Cutting process and folding paper area	5	0.039
	Paper bundling area	1	0.209
HT 1	Paper bundling area	2	0.021
	Near to the quiet room, besides the machine, folding process area	5	0.034
	Mailroom area	1	0.029
HT2	Paper bundling area	2	0.021
	Near to the quiet room, besides the machine, folding process area	5	0.034
	Mailroom area	1	0.029
HT 3	Paper bundling area	2	0.021
	Near to the quiet room, besides the machine, folding process area	4	0.034
	Mailroom area	1	0.029
Total		51	

Note: * Average of concentration from three points, ** Average of concentration from two points

The machines that were in the closed environment could increase the concentration of $PM_{2.5}$ significantly if compared to other machines which were not in it. In additions, the environmental conditions of Solna 1 and two machines were much different from the HT 1,2, and 3 and Magnum 1 and two machines. All processed in Solna 1 machines were done in one room as same as with Solna 4 machine. However, operation in the HT 1,2, and three machines had their room according to the type of processes as well as Magnum 1 and two machines.

$PM_{2.5}$ found in the printing industry was particulate from the paper and printing inks. In general, the raw material of newspaper used typically in newspaper printing process consistied of mechanical wood pulp. The flesh was the result of separating process of cellulose fibers from mixing the ingredients (lignin and pentose). The paste were obtain from an extract of the fruit, roots, stems, seeds, and skins or the results of processing plants or fruits, while the paper was the result from the fiber compression process sourced from the pulp. The raw materials in the papermaking process were a material that had cellulose, such as bamboo, wood, hay, straw, etc. (Rohimah et al., 2010).

Ink components generally consisted of three groups, including pigment (organic pigment, inorganic, and carbon black), a binder or carrier pigment consists of a solvent (solvent), resin and drying oil, and substance as additives composed from fillers, drying agents, anti-dry materials, waxes, diluents, materials relaxants, and the dispersing agent (Adhi and Susanto, 2013). A review article about the research report earlier in 1995 showed that the health effects in industry of paper and wood (pulp) where workers were exposed to paper dust, chlorine compounds in high concentrations could increase the damage lung function, respiratory diseases that are allergic, and even led to death (Thoren et al, 1996a in Korhonen et al, 2004). Black carbon in ink was included in the $PM_{2.5}$, components that could disrupt the respiratory system (Salonen in WHO, 2012).

5. Conclusions

The highest concentration of $PM_{2.5}$ exposure was derived from the Solna 1 machine (0.463 mg/m^3 or 463 µg/m^3), exceeding the quality of the $PM_{2.5}$ 24 hours standards (65 µg/m^3). It was followed by the average concentrations of Solna 4 machine (0.211 mg/m^3 or 211 µg/m^3), exceeding the quality standards of $PM_{2.5}$ 24 hours (65 µg/m^3). The exposure concentration of $PM_{2.5}$ in HT 1, HT 2, and HT 3 machine were still lower than Solna 1 and two engines. The exposure concentration of $PM_{2.5}$ in Magnum 1 and two machines especially paper bundle area was above the regulation of $PM_{2.5}$ for 24 hours exposure.

Based on the distribution operators, the number of operators or workers at risk of exposure to $PM_{2.5}$ with high concentrations (above 65 µg/m^3) were:

1. 4 of 8 people in the engine area Solna
2. 1 of 7 people in the engine area Solna
3. 2 people in in the area on the Magnum machine 1 and 2.

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