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Characterization of TSP (Si, Pb and Ca) from tropical ambient air during building construction project

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Abstract. Apartment development in urban areas is often proposed as solution to meet the housing needs. However, building construction could contribute air pollutants that have a negative impact on health. This activity could generate Total Suspended Particulate (TSP). This study aimed to quantify the composition of TSP (Si, Pb and Ca) arising from building construction activities and comparing the measurement results with the air quality standard in Indonesia. The sampling method was undertaken according to SNI 19-7119.3-2005. Based on this research, the TSP concentration in samples has exceeded the permissible limit (the highest concentration of TSP was 786,13 $\mu\text{g}/\text{m}^3$). The result of characterization of TSP indicates that the highest Si concentration was found at the point of transportation path, while Pb and Ca.

1. Introduction

In recent years, there is a decrease in air quality caused by various human activities such as fuel combustion, transportation, industrial processes and building construction activities [1,2,3]. The risks posed by construction activity may come from two sources. First, external risk from the environmental impact and second, internal risk is from the uncertainties in the project itself [4]. In addition, the construction activities showed 3.8% of total particulate emission from open source in the US [5] which inevitably contribute to air pollution. Many studies have suggested that Total Suspended Particulate (TSP) is one of the hazardous components that worsens air quality [6,7]. Negative impact of TSP on human health, especially PM_{2.5} (particulate with a diameter less than 2.5 μm) which it is easily enter the lungs and cause serious health problems, such as respiratory disorders and lung diseases [8,9]. PM_{2.5} proved to be more diffuse compared to coarse dust (particulate diameter 2.5-10 μm), affecting workers around the work area and anyone exposed by it [10,11]. Worldwide, it is estimated that air pollution caused by PM_{2.5} in the atmosphere is responsible for about 0.8 million premature infant deaths and 6.4 million human deaths annually [12].

On the other hand, TSP is a very complex pollutant because it consists of various elements. This research characterizes the elements Si, Pb, and Ca because these three elements are often contained in TSP and harmful to human health [13]. According to some sources, silica exposure poses a serious threat to nearly 2 million US workers, including more than 100,000 workers in high-risk jobs such as



abrasive blasting, foundry work, stonecutting, rock drilling, mine work, and tunnelling. Silica crystals have been classified as a carcinogen for human lungs. In addition, crystalline silica causes silicosis which can further lead to fatal paralysis [14]. Kampa and Castanas [15], suggest that heavy metals including lead (Pb) which is often contained in TSP, are natural components of the earth's crust, cannot be degraded or destroyed, can be suspended in the air, and subsequently enter into water or food. Pb enter the environment through various sources including fuel combustion. Meo [16], states that calcium (Ca) is contained in the manufacture of cement in large quantities. The presence of Ca content as one of the materials used in construction allows the occurrence of exposure to the human body. If the human body is exposed by excess Ca elements can cause calcification of blood vessels, cardiovascular, heart disease and stroke, high blood pressure, low stomach acid, muscle or joint pain, depression, fatigue, glaucoma, osteoporosis, osteoarthritis, hardening of lime, dry skin, constipation, increased risk of kidney (hypercalcaemia), resulting in inflammation of the urine [17].

However, the evaluate particulate matter on construction sites from an environmental perspective remains relatively unexplored. Therefore, measuring particulate concentration in different phases of construction activities as well as identifying prevention are urgently to do, in order to reduce the impact of air pollutants and to improve air quality air at work sites as well. This paper is part of a broader investigation that aims to determine TSP concentrations caused by particle emissions then compared TSP concentration with government regulations No. 41 of 1999 as air quality standard in Indonesia, also to characterize the amount of air pollutant concentration (Si, Pb, and Ca) in TSP during the different construction phases.

2. Method

2.1. Site Location and Materials

This research was conducted within seven days. The chosen building construction project as sampling location was in the development project of Apartment Paltrow City, Semarang, Central Java, Indonesia. The number of sampling points were made based on category of construction activities which could be divided into three parts of work i.e. material transportation path, workshop floor, and stirring of cement.

HNO₃ used in this study was purchased from Sigma Aldrich USA, Aluminum foil was obtained from local distributor in Indonesia, Dust Sampler DS 600- MVS with maximum capacity 600 L/min from Mark and Wedell, borosilicate glass microfiber filter Whatman GF/A 1820-110 (0.26-mm thickness, 110-mm diameter; 1.6- μ m pore size) from Sigma Aldrich, and Atomic Absorption Spectrophotometer (AAS) 210 VGP from Buck Scientific USA.

2.2. Method

The sampling method was undertaken according to SNI 19-7119.3-2005. Dust Sampler and filter Whatman were used to take air samples. Prior to the sampling process, in order to remove moisture content, volatile substances and other impurities, the filter papers were firstly heated to 105°C for two hours and then put in a desiccator for 15 minutes. The dust sampler was placed in 2-3 meters from the workers with 1.5 meters height and the sampler was mobilized according to the worker movement in order to measure the TSP inhaled by the worker. Test has been done for 8 hours then the filter is folded and put into aluminum foil. Analysis of elemental TSP concentration was done by cutting the filter into several parts then dissolved with a concentrated HNO₃ solvent $\pm$ 200 ml and heated to 175°C for 12 hours. The test samples were diluted in a 25-mL volumetric flask that would later be analyzed using AAS with wavelengths of 251.6 nm, 217.0 nm and 422,7 nm for Si, Pb and Ca respectively.

Calculation of TSP concentration conducted through three steps (based on SNI 19-7119.3-2005):

- Flow Rate Correction at Standard Conditions

$$Q_s = Q_0 \left[\frac{T_s \times P_0}{T_0 \times P_s} \right]^{\frac{1}{2}} \quad (1)$$

where, Q_s : corrected flow rate Q_s (m^3/min) at normal condition; Q : as measured flow rate (m^3/min); T_0 : measured temperature ($^{\circ}\text{C}$); T_s : standard temperature (25°C); P_0 : measured pressure (mmHg); P_s : standard pressure (760 mmHg). These standard temperature and pressure were based on EPA (1999).

- The volume of air sampled

$$V = \frac{Q_{s1} + Q_{s2}}{2} \times t \quad (2)$$

where V : sampled air volume; Q_{s1} : corrected initial flow rate; Q_{s2} : corrected final flow rate, t : sampling duration (minutes).

- TSP Concentrations in Ambient Air

$$C = \frac{(W_2 - W_1) \times 10^6}{V} \quad (3)$$

where, C : TSP concentration ($\mu\text{g}/\text{Nm}^3$); W_1 : initial filter weight (g); W_2 : final filter weight (g); V : sampled air volume (m^3).

Then, the calculation of Si, Pb, and Ca concentrations were conducted according to SNI 19-7119.4-2005 by using following calculation:

$$C = \frac{C_t - C_b \times V_t \times \frac{S}{S_t}}{V} \quad (4)$$

where, C : the concentration of Si and Pb element in the sample ($\mu\text{g}/\text{m}^3$); C_t : concentration in sample; C_b : concentration in blank; V_t : solution volume; S : exposed filter area (m^2); S_t : total filter area used (m^2); and V : sampled air volume.

3. Result and Discussion

3.1. Analysis of TSP concentration

To determine the status of air quality, the resulted TSP concentration on building-construction activities have been compared to Indonesian Government Regulation number 41 year 1999 regarding the Air Pollution Control regulatory. Based on the air quality assessment, it is found that ambient air quality with respect to concentration of TSP was beyond the regulatory limit for several data. The results are shown in Figure 1.

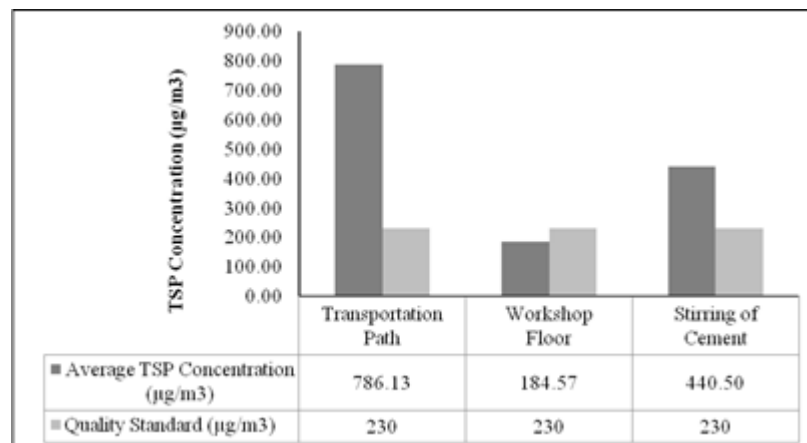


Figure 1. TSP concentrations from three parts of construction activities compared to Quality Standard

As obviously in Figure 1, there were difference between TSP concentrations in each sampling location. The TSP concentrations were 786.13 $\mu\text{g}/\text{Nm}^3$, 440.50 $\mu\text{g}/\text{Nm}^3$, and 184.57 $\mu\text{g}/\text{Nm}^3$ on transportation path, stirring of cement and workshop floor respectively. Only TSP emitted from workshop floor met the standard quality. While in transportation path and stirring of cement were exceeded the quality standard. The difference of TSP concentration was caused by the difference activities at each sampling point. There was also contribution of wind that influenced the measurement results of particulate matter concentrations [13].

At the transportation path, the type of work was transporting materials such as sand and rocks using trucks. This path was also traversed by excavators for soil dredging, pickling of rocks and transporting steel for reinforcement. From the activities that occurred, this was very possible that transportation path was highly prone to produce high levels of TSP, as a proof was the measurement results exceeded the quality standard. At the stirring of cement, the TSP concentration exceeding the quality standard due to mixing activities of sand, cement, and water which was done manually on the open space (by using construction workers, not by grinding machines). This activity generated potential dust which was then emitted into ambient air. While on the workshop floor, activities undertaken were the addition of cement or coating on the work floor, installation of reinforcement cuttings column, and foundry work floor. In this type of work, it did not produce high concentration of TSP. The evidence of this phenomenon was seen from the TSP concentration of measurements that does not exceed the quality standard.

3.2. Analysis of Si, Pb and Ca concentrations

This research characterizes the elements Si, Pb, and Ca in TSP that contained in building construction activity at the various sampling location. The results are shown in Figure 2.

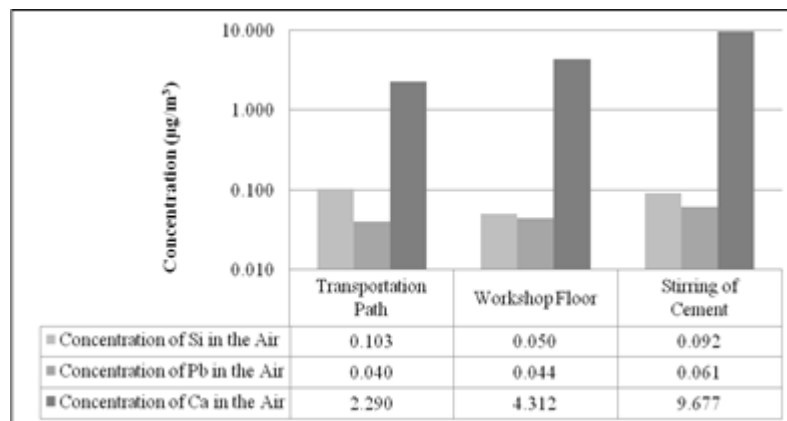


Figure 2. Comparison of Si, Pb, and Ca Compositions

Figure 2 showed that Ca has the greatest content in all three sampling sites. The measured Ca concentrations were 2.290, 4.312 and 9.677 $\mu\text{g}/\text{m}^3$ on transportation path, workshop floor and stirring of cement respectively.

High Ca content in all sampling sites occurs because all sampling location are included in the basic surface category of apartment construction in the form of soil. So that the measurement of elemental content in the ambient air also influenced by the land that flew around the sampling site and from the activity carried out at stirring of cement where Ca element presented in cement mixing [16]. By the Periodic System of Chemical Elements, Ca was one element of alkaline earth metal and the fifth most abundant element in the percentage of the mass of the earth's crust, which means that calcium is also found in soil contents. Kabata-Pendias and Alina[18], also suggests that in solution soils, major ions such as Ca affect the number of soluble elements, Ca elements contain more than 90% of the total cation concentration in the soil and the most important element in regulating the solubility stage of other elements in the soil. This statement was in accordance with result of this research.

The largest concentration of Si in the air is obtained in the transportation path of 0.103 $\mu\text{g}/\text{m}^3$. While in the background test that has been done, it is known that the concentration of Si in TSP was 0.02 $\mu\text{g}/\text{m}^3$. Parker and Raymond [19], found that the percentage of Si element in the soil amounted to 27.72 in the earth's crust, proving that the element of Si is contained in the soil. Based on this research, the second largest concentration of Si found in the activities of stirring cement. This phenomenon can be explained because in the Portland cement hydration process produced a series of silicate hydrate structures at the nanoscale. This form of silicate characterized by a wide surface area and an associated multiphase, inter-connected, and pore system [20,21]. Thus, the Si concentration in this point was high. The results of this comparison chart also proved the theory of Meo [16] and Ontario [22]. They stated that Si element obtained from land, cement building materials, friction or rock and sand transport activities, and stirring of cement.

Usually Pb obtained as byproduct of combustion process in vehicles which used gasoline additive, and Ca element found in stirring of cement activity. Pb results showed that the highest concentration was of 0.061 $\mu\text{g}/\text{m}^3$ from process of cement stirring.

Based on Speciate Data Construction Dust by EPA, the percentage of Si, Pb, and Ca elements in construction dust were 7.1%; 0.0037%; and 14.9% respectively. In this study, the percentage of Si, Pb, and Ca elements in construction dust is 0.15%; 0.12%, and 12.30% respectively. When compared, element of Si and Ca were smaller while Pb was higher than EPA standard. This may be due to differences in activities undertaken in construction, whereas construction dust from Speciate Data Construction Dust does not specify the activities being undertaken at the construction site.

3.3. Impact of TSP, Si, Pb and Ca on health

The results of TSP concentration were 799.87 $\mu\text{g}/\text{m}^3$, 187.79 $\mu\text{g}/\text{m}^3$; and 448.20 $\mu\text{g}/\text{m}^3$ from transportation path, workshop floor, and stirring of cement respectively. There were two points in the development stage that exceed the quality standard i.e., the transportation path and stirring of cement. TSP levels that exceed these quality standards can lead to potential impacts on human health. This particulate, which may also contain PM10 and PM2.5, poses the greatest health concern due to its ability to pass through the nose and throat and get into the lung, thus can affect human health such as respiratory disorder or lung disease [8,9,13].

The threshold of the quality standard of silica established by ISO 7708: 1995 is 3 $\mu\text{g}/\text{m}^3$ [23]. Diseases associated with crystalline silica according to Rees and Murray [24], are pneumoconiosis, chronic silicosis, lung cancer, kidney disease, arthritis and chronic bronchitis. WHO states that the permissible limit of Pb elements is 0.5 $\mu\text{g}/\text{m}^3$ [25] whereas, in this research, three points of samples resulted under quality standard threshold. Although the Pb element does not exceed the quality standard, but daily exposure to dust which is Pb exist inside, has the potential to affect to health such as neuro developmental disorders, suppression of haematological system, renal failure, and immune suppression [26].

Concentrations of Ca in this study were 2.290 $\mu\text{g}/\text{m}^3$, 4.312 $\mu\text{g}/\text{m}^3$, and 9.677 $\mu\text{g}/\text{m}^3$ on transportation path, workshop floor, and stirring of cement respectively. According to Regulation of the Minister of Manpower and Transmigration of Indonesia No. 13 of 2011, when calcium binds to oxygen, the allowed limit is 2,000 $\mu\text{g}/\text{m}^3$. In this case, the concentrations of Ca were below the existing quality standard. But, it does not mean that Ca element does not affect human health, because if humans exposed to Ca dust continuously it can affect human health. Depending on the level of exposure, Ca in particulate pollutants may cause mild to severe illnesses. Cough with phlegm, shortness of breath, impaired lung function; on the digestive system resulted in dental caries, abdominal pain, stomach cancer; while other effects are eye irritation, skin irritation, and skin ulcers are the most prevalent clinical symptoms of disease resulted from air pollution [16].

4. Conclusion

Building construction contribute significantly to environmental contamination with respect to TSP. However, little attention is paid to this activity particularly in developing country such as Indonesia. This study aimed to quantify the composition of TSP (Si, Pb and Ca) arising from building construction activities and comparing the measurement results with the air quality standard in Indonesia. From the results of air monitoring that has been done at three activities of an apartment construction (Paltrow City, Semarang), two points that exceed the quality standard (transportation path and stirring of cement). The highest concentration was found at the transportation path (786.13 $\mu\text{g}/\text{Nm}^3$), and the lowest was found in the workshop floor (184.57 $\mu\text{g}/\text{Nm}^3$). The result of characterization TSP indicates that the highest Si element concentration was found at the point of transportation path 0.103 $\mu\text{g}/\text{Nm}^3$. The highest concentration of Pb was found at the point of stirring of cement 0.061 $\mu\text{g}/\text{Nm}^3$, while the highest concentration of Ca was found at the stirring of cement 9.677 $\mu\text{g}/\text{Nm}^3$. These three elements were still below the quality standards.

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