Analysis of $PM_{2.5}$ Cement Dust Levels, Temperature and Humidity in Limestone Burning Home Industry Tuban Regency, East Java, Indonesia

Ariska Midya Fahmita, R. Azizah*, Mohamad Edi Kurniadi and Juliana Jalaludin

Abstract--- *Background of this research is one of the parameters of air pollution that are harmful to human health is $PM_{2.5}$. The main source of $PM_{2.5}$ is in the process of limestone burning. In the process of limestone burning, limestone is burned by using wood powdered fuel so that from the burning process, $PM_{2.5}$ dust can be obtained which can affect the health of workers. The purpose of the study was to analyze the exposure of $PM_{2.5}$, temperature and humidity in the limestone burning home industry workers in Tuban Regency, East Java, Indonesia. The research method was a quantitative approach with a total population of 18 people in the burning section. $PM_{2.5}$ cement dust levels were measured using EPAM 5000. Temperature and humidity were measured with a thermohygrometer. The results showed that measurement results of $PM_{2.5}$ cement dust levels is at point I with a value of 12,610 $mg/m^{3,}$ point II was obtained at 4,248 $mg/m^{3.}$ Working environment temperature in the production area on point I and point II were quite high, namely 32.4°C and 31.1°C. Humidity at point I and point II obtained was 42% and 43% with standard of 65%-95%. $PM_{2,5}$ and physical environment has not met the quality standards set on Minister of Manpower of the Republic of Indonesia Regulation No. 5 of 2018 about Safety and Health of the Work Environment in limestone burning so that it can be said limestone burning workers feel uncomfortable. Conclusions and Recommendations of the study was that the amount of dust $PM_{2.5}$ measured mostly in limestone burning place on the first and second location is above the safe category, although none exceeds quality standards. Decent environmental management should be done and management such as the use of appropriate APD such as masks. Water around the burning location and plant trees so that dust is not easily breathed by workers.*

Keywords--- *$PM_{2.5}$ Cement Dust, Temperature, Humidity and Limestone Burning.*

I. BACKGROUND

The health risks posed by inhaled dust particles are influenced by the deposition pattern of the particles in the various regions of the respiratory tract and by the biological responses exerted by the deposited dust particles. Cement dust irritates the skin, the mucous membrane of the eyes and the respiratory system (Zeleke, 2010).

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DOI: 10.37200/IJPR/V24I1/PR200287
Received: 22 Nov 2019 | Revised: 26 Dec 2019 | Accepted: 10 Jan 2020

Industrial activities have an important role in waste contributing, one of them is air waste which can affect ambient air and can also change air quality (*indoor*) (Mukono J, 2010). Ambient air is free air on the surface of earth in troposphere located in the territory of Republic of Indonesia that affects human health, environmental health and other environmental elements (Permen LH 12, 2010). The parameters measured in ambient air pollution are sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide, oxidant (O_3), hydro carbon (HC), particulate <10 (PM_{10}), particulate <2.5 ($PM_{2.5}$), dust particles (TSP), lead (Pb), falling dust, total fluorides, index fluoride, chlorine and chlorine dioxide, and sulphant index (Permen LH 12, 2010). Levels of air pollution can be detected or can be measured and calculated by humans, and can have effects on humans and environment.

The cement industry provides building materials for land-based and off-shore installations. Cement is typically produced by heating a homogenous blend of limestone and clay, which is then adjusted to a suitable content of calcium, silicon, aluminum and iron in a kiln. During its heating to 1,450uC, the clinker is formed, which contains calcium silicates, calcium aluminates and calcium ferrites **(**Nordby, 2011).

Cement dust exposure has previously been associated with airway symptoms and ventilatory impairment **(**Nordby, 2011).

Cement production workers are exposed to airborne particles of raw materials, clinkers, additives and to the final cement product, and their work has been linked to changes in lung function and airway symptoms (Health and Safety Executive, 2004).

Cement is the key ingredient of concrete constructions **(**Nordby, 2016). Workers in cement plants are exposed to airborne particulate matter (dust) generated from cement and raw materials during the production of cement. Employees in the construction industry are also exposed to cement-containing dust, although in lower concentrations (Peters, 2009).

Preventive measures beyond respiratory protection should be implemented to reduce exposure as the most important action to prevent lung function decline **(**Nordby, 2016). The substantial differences between exposure levels in plants suggest that this should be possible (Noto, 2015).

Increased levels of pollutants in a room, especially ambient air caused by two things, namely due to natural causes, for example from volcanic eruptions, wind gusts or from other sources of air pollutants. Other causes of air pollution are from human activities, for example from fossil burns, industrial activities or chemicals usage that are sprayed into the air. Industrial activities that can pollute ambient air are industrial activities, for example limestone burning industry. In limestone burning industry, there are several processes that must be passed from limestone mining as the main raw material, limestone burning, limestone breaking, and packing.

PM is one of the pollutants which consists of a complex mixture of particles such as dust, dirt, soot, smoke, and liquid droplets found in the air with a fairly small size (IDEM, 2015). $PM_{2.5}$ (fine inhalable particles) are particles with a size of ≤2.5 μm with the main sources burning, cigarette smoke, cooking with firewood, and agricultural activities (US EPA, 2016). $PM_{2.5}$ is respirable dust that can be held from terminal bronchiolus to alveoli so that it is among the most dangerous dust (Sumakmur, 2009). Health effects caused by particulates are premature death in

DOI: 10.37200/IJPR/V24I1/PR200287
Received: 22 Nov 2019 | Revised: 26 Dec 2019 | Accepted: 10 Jan 2020

people with heart and lung disease, heart attacks, irregular heartbeat, asthma, decreased lung function, and increased respiratory symptoms such as irritation of the respiratory tract, coughing and breathing difficulties (US EPA, 2016).

The presence of dust particles in limestone burning environment can disrupt the productivity and health of workers and those around them. Under certain conditions, dust causes danger to vision until breathing. According to Minister of Health Regulation No. 70 of 2016 about Standards and Environmental Health Requirements for Industrial Work, the maximum dust content in the air at an average measurement of 8 hours is 10mg/$m^{3.}$ Levels of dust that do not meet the threshold value will certainly pose a risk of health problems.

The effect of $PM_{2,5}$ exposure is more common in respiratory organs, one of which is impaired lung function. Impaired pulmonary function is characterized by a disturbance in ventilation resulting in decreased function. Ventilation disorders consist of restriction disorders, which are impaired lung development, and obstruction, which is a slowing of air flow in the airways due to increased mucus production so that the respiratory tract narrows (MOH, 2008).

The limestone burning industry located in Plumpang District of Tuban Regency is one of the limestone burning industries that has the potential to produce dust in the production process, so workers have the risk of being exposed to dust and experiencing respiratory problems. Therefore it is necessary to conduct a study of air quality, especially regarding $PM_{2.5}$ levels and respiratory complaints in limestone burning workers.

$PM_{2.5}$ exposure in short term results in eyes, nose, throat and lungs irritation, coughing, sneezing and runny nose. The impact of $PM_{2.5}$ in long term can increase the number of sufferers of chronic bronchitis, decreased lung function, deaths from lung cancer and heart disease (Kurnia, 2013).

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Air temperature can affect the concentration of pollutants in the air according to certain weather conditions. High temperature conditions cause the air to become more tenuous so that pollutant concentrations become smaller. Conversely, at low air temperatures the air condition becomes denser so that the concentration of air pollutants is greater. Temperature can also affect the increase in air humidity so that it can cause an increase in the corrosive effects of pollutants in the area (Mukono, 2008).

Humidity is the moisture content in the air. High humidity causes the moisture content in the air to react with air pollutants into other substances that are not harmful or called secondary pollutants (Mukono, 2008). Humidity can

DOI: 10.37200/IJPR/V24I1/PR200287
Received: 22 Nov 2019 | Revised: 26 Dec 2019 | Accepted: 10 Jan 2020

affect the concentration of particulates in the air, because the higher the humidity, the possibility of particulates to react with water will be higher so that the specific gravity of the particulates increases (Salisa, 2011).

II. RESEARCH METHODS

In conducting research data collection, using the following techniques:

Measurement

Measurements conducted directly in the limestone burning industry in District of Plumpang, Tuban Regency one time related to the physical condition of the environment. Physical environment conditions measured include temperature, humidity, wind direction and $PM_{2.5}$ levels. All measurements were carried out by a laboratory assistant from the Environmental Health Laboratory, Faculty of Public Health, Airlangga University, Surabaya. Measurement of temperature and humidity parameters using a thermohygrometer, measuring $PM_{2.5}$ levels using EPAM 5000.

PM $_{2.5}$ levels were measured using EPAM 5000

The location for sampling $PM_{2.5}$ levels in the work environment was conducted in burning area in the limestone burning industry, which was conducted once during the production process. The instrument used to measure $PM_{2.5}$ was EPAM 5000 which was carried out by the Environmental Health Laboratory of the Faculty of Public Health, Airlangga University, Surabaya and accompanied by researchers.

The working procedures of this tool include:

1. Prepare measurement tool (EPAM 5000)
2. Install a vacuum cleaner with a PM head size of 2.5
3. Turn on the appliance by pressing the *power* button
4. Do *the settings* on devices with pressing *enter-special-function-system options extended-size option select-2.5 mm*
5. Then select the special *function-system options-simple rate-* 1 *min-run*
6. To see the minimum, maximum and average results can be done by pressing *the* data *-statistics-new tag review*.
7. Record the results listed on the monitor

Temperature and Humidity Measurement

Measurement of temperature and humidity in the burning area in the limestone burning industry in Plumpang District of Tuban Regency by using a *thermohygrometer* conducted by the researcher. The *thermohygrometer is* placed at several measurement points when the worker is doing activity.

The measurement time was conducted when there were production activities. The working procedure of this tool include:

1. Prepare the thermohygrometer tool
2. Install the battery in the back of the tool
3. When the battery is installed, the tool will start working automatically
4. The tool will show the temperature and humidity of the burning and packing area

DOI: 10.37200/IJPR/V24I1/PR200287
Received: 22 Nov 2019 | Revised: 26 Dec 2019 | Accepted: 10 Jan 2020

5. Wait for about 15 minutes
6. Record the results showed on the thermohygrometer tool

This research was conducted in the limestone burning industry CV. Indah Lestari is owned by Mr. Nurhadi in Kesamben Village, Plumpang District, Tuban Regency. This research was an observational study. Based on its characteristic and analysis, included as quantitative descriptive research. The research started in December 2018 until August 2019.

III. RESEARCH RESULTS AND DISCUSSION

Overview

Kesamben Village, Plumpang District, Tuban Regency is one of the villages that become the center of $CaCO_3$ (Calcium Carbonate) limestone processing industries. There are several limestone burning industries in Kesamben Village, Plumpang District, Tuban Regency, one of then is CV. Indah Lestari owned by Mr. Nurhadi.

Mr. Nurhadi's limestone burning industry has been established since 2007. The land area of the industry is 200 m^2 with building area of 80 m^2. There are 42 permanent workers consisting of 18 workers in burning section, 15 workers in packing section and 9 porters. These employees are from local residents in Kesamben Village, Plumpang District, Tuban Regency. Every day, this industry could produce dozen tons of done limestone or so-called limestone, which were deposited in several industries such as the paper making, cement making and other building materials industries. Basically, the burning process of limestone carried out by burning the limestone in a furnace or also called tobong. Material layers in tobong were limestone and wood sawdust. Limestone was crushed to a smaller size, then put in a furnace and burned using wood sawdust. In this burning process (calcination) at a temperature of 900-1000°C, $CaCO_3$ was broken down into CaO and CO_2 (CO_2 released into the air). The burning process in this industry was carried out 24 hours non-stop. Fuel was given every 3 hours and the burning stones could be taken every 27 hours. After the limestone was burnt, the next step was watering. If there is a demand for the limestone to be broken down again into smaller sizes, then the workers will break down the limestone that has been burned into smaller sizes and at last, the packaging process will be carried out so the limestone was ready to be deposited to the paper, cement and building materials industries.

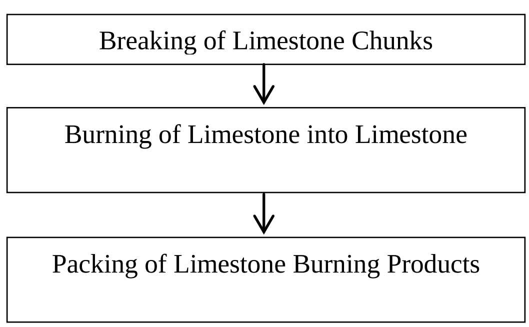

Figure 1: Flowchart of Limestone Burning Production Process

Source: (Processed Results by Researcher, 2019)

The limestone burning process lasted for 24 hours. Workers were divided into 3 work shifts, which were 07.00-03.00 in shift I, 03.00-23.00 in shift II and 23.00-07.00 in shift III. Each worker shift was given one hour to rest, eat and pray. This limestone burning home industry had three furnaces, but only two furnaces could operate. This limestone burning home industry was still using the traditional way, not paying attention to aspects of processing emissions resulted from the burning activity yet. Air emissions resulted from the limestrone burning were directly discharged with a chimney which had approximately 4-5 meters high. This limestone raw material was obtained from the limestone mining industry in Rengel District, Tuban Regency.

IV. MEASUREMENT OF $PM_{2,5}$ CEMENT DUST LEVELS

PM2.5 levels were measured once because the production process lasted 24 hours. Measurement of this PM2.5 levels used the EPAM 5000 tool. EPAM 5000 is a tool used to measure the concentration of dust particles in the ambient air directly. In the PM2,5 measurement results by using EPAM 5000 obtained value of PM2.5 levels every minute. So within 30 minutes, 30 records obtained for PM2.5 levels. From the recording results of PM2.5 levels every minute will be obtained the maximum, minimum, and average values of PM2.5 in the industrial work environment. Based on the measurement results by using EPAM 5000, the results below was the PM2.5 measurement results in the limestone burning industry during the production process. Measurement Location: Limestone burning industry in Plumpang District, Tuban Regency

Measurement Time: Saturday, Auguts 10th 2019

1. Point I : 10.22 – 10.52 WIB
2. Point II: 10.56 – 11.26 WIB

Table 1.1: Measurement Results of $PM_{2,5}$

Time	**$PM_{2,5}$ Levels in Point I**	**Time**	**$PM_{2,5}$ Levels in Point II**
10:22:29	2,287 mg/m^3	10:56:52	1,817 mg/m^3
10:23:29	0,683 mg/m^3	10:57:52	1,416 mg/m^3
10:24:29	11,041 mg/m^3	10:58:52	1,463 mg/m^3
10:25:29	1,538 mg/m^3	10:59:52	2,988 mg/m^3
10:26:29	1,855 mg/m^3	11:00:52	0,769 mg/m^3
10:27:29	2,452 mg/m^3	11:01:52	0,319 mg/m^3
10:28:29	1,524 mg/m^3	11:02:52	0,493 mg/m^3
10:29:29	1,033 mg/m^3	11:03:52	0,471 mg/m^3
10:30:29	0,741 mg/m^3	11:04:52	0,396 mg/m^3
10:31:29	0,557 mg/m^3	11:05:52	0,434 mg/m^3
10:32:29	2,339 mg/m^3	11:06:52	0,811 mg/m^3
10:33:29	3,517 mg/m^3	11:07:52	2,056 mg/m^3
10:34:29	4,666 mg/m^3	11:08:52	0,399 mg/m^3
10:35:29	2,222 mg/m^3	11:09:52	0,357 mg/m^3
10:36:29	1,182 mg/m^3	11:10:52	0,194 mg/m^3
10:37:29	1,203 mg/m^3	11:11:52	0,262 mg/m^3
10:38:29	2,561 mg/m^3	11:12:52	0,132 mg/m^3
10:39:29	1,624 mg/m^3	11:13:52	0,107 mg/m^3
10:40:29	1,650 mg/m^3	11:14:52	0,393 mg/m^3
10:41:29	0,656 mg/m^3	11:15:52	0,376 mg/m^3
10:42:29	3,200 mg/m^3	11:16:52	0,988 mg/m^3
10:43:29	1,373 mg/m^3	11:17:52	0,436 mg/m^3
10:44:29	0,783 mg/m^3	11:18:52	0,238 mg/m^3
10:45:29	0,589 mg/m^3	11:19:52	2,148 mg/m^3
10:46:29	0,614 mg/m^3	11:20:52	1,068 mg/m^3
10:47:29	1,211 mg/m^3	11:21:52	0,405 mg/m^3
10:48:29	0,609 mg/m^3	11:22:52	0,383 mg/m^3
10:49:29	2,270 mg/m^3	11:23:52	0,252 mg/m^3
10:50:29	0,785 mg/m^3	11:24:52	0,553 mg/m^3
10:51:29	12,610 mg/m^3	11:25:52	4,248 mg/m^3
Rata Rata	2,392 mg/m^3	Rata Rata	0,913 mg/m^3
Maximum Levels Measured	**12,610 mg/m^3**	**Maximum Levels Measured**	**4,248 mg/m^3**
Quality Standard **(**Minister of Manpower of the Republic of Indonesia Regulation No. 5 of 2018**)** **5mg/m^3**			

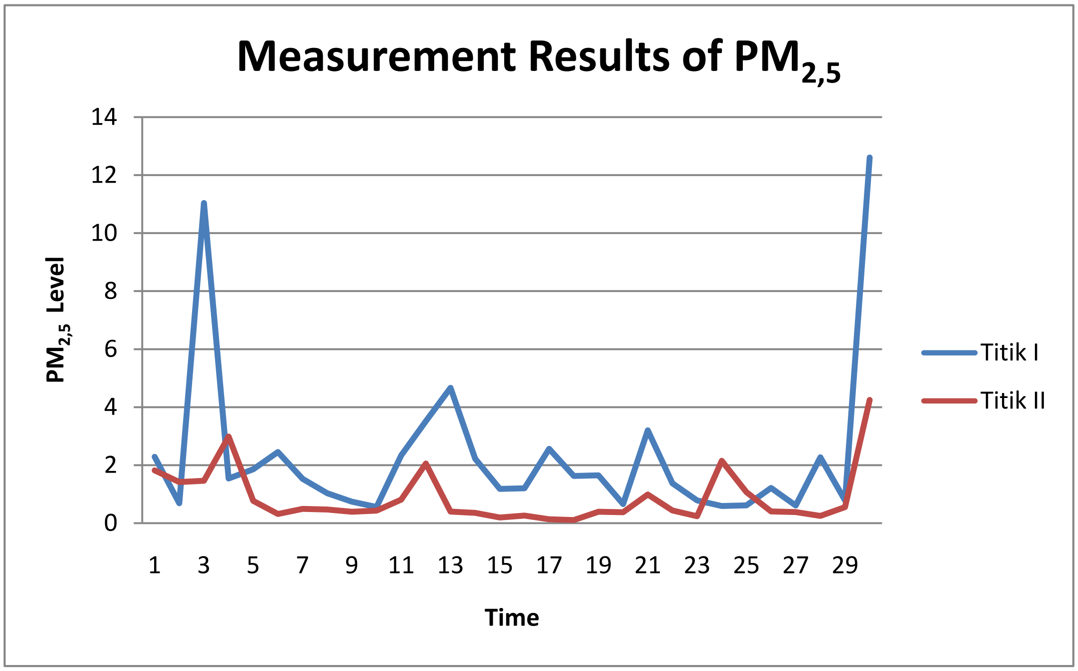

Figure 2: Measurement Results of $PM_{2,5}$

(Source: Processed Results by Researcher, 2019)

Total cement dust exposure was related to acute respiratory symptoms and acute ventilatory effects. Implementing measures to control dust and providing adequate personal respiratory protective equipment for theproduction workers are highly recommended (Zeleke, 2010).

Table 1.2: Measurement Results of $PM_{2,5}$ During Production Process

Measurement Points	Kadar Terukur			Quality Standard (Minister of Manpower of the Republic of Indonesia Regulation No. 5 of 2018)
	Maximum	Minimum	Average	
Point I	12,610 mg/m^3	0,557 mg/m^3	2,392 mg/m^3	$5mg/m^3$
Point II	4,248 mg/m^3	0,107 mg/m^3	0,913 mg/m^3	$5mg/m^3$

From table 5.1 above it could be seen that the average levels of PM2.5 at point I with a maximum value of 12,610 mg / m3, a minimum value of 0.557 mg / m3, and an average value of 2,392 mg / m3 then these still met the quality standard set on Minister of Health Regulation No. 70 of 2016 about Standards and Requirements of Industrial Work Environmental Health.

Point II obtained a maximum value of 4.248 mg / m3, a minimum value of 0.107 mg / m3, and an average of 0.913 mg / m3 these met the quality standard on the Minister of Manpower of the Republic of Indonesia Regulatio No. 5 of 2018 about Safety and Health of the Work Environment.

DOI: 10.37200/IJPR/V24I1/PR200287
Received: 22 Nov 2019 | Revised: 26 Dec 2019 | Accepted: 10 Jan 2020

Measurement of $PM_{2,5}$ in Burning Section of Limestone Burning Industry

PM2.5 levels were measured at 2 points where both points were in the burning section. Measurements were conducted at 2 points because in this limestone burning industry there were 2 furnaces, so that each point was taken at each furnace. The measurement conducted once because the production process in the limestone burning industry lasted for 24 hours.

The highest levels of PM2.5 measured at point I was 12,610 mg / m3, while the highest levels of PM2.5 at Point II was 4,248 mg / m3. Both of these values were obtained when PM2.5 levels measured during the production process. This higher PM2.5 levels at point I could be caused by the burning process and the addition of raw limestone and fuel into the furnace. Meanwhile at Point II, it was not too high because when measured, the limestone was done so it did not cause much PM2.5 dust. In addition, semi-open workplace conditions would ease wind to entry and blow dust particles. The limestone burning and mining industry caused major pollutants in the form of particulate matter (Sutra, 2009).

The highest levels of PM2.5 in the burning section when compared to the Minister of Manpower of the Republic of Indonesia Regulation No. 5 of 2018 about Safety and Health of the Work Environment, with a quality standard of 5 mg / m3 at point I no longer met the quality standard while at Point II it still met the quality standard. Levels of dust that did not meet quality standard would be very dangerous for workers who work with high PM2.5 exposure, because particulate dust could cause lung damage if inhaled during continuous work (Hapsari 2009). High PM2.5 levels would be one of the factors that could cause lung damage to workers, therefore during their work, workers must wear a mask to reduce the amount of inhaled dust.

The condition of this burning section had adequate natural ventilation because the place was not a closed room so the air exchange could easily occur but it was not equipped with a dust collector so in the workplace dust did not come out maximally. The high value of PM2.5 levels was caused by the absence of dust collector. Dust collector could be used as one of the factors that can reduce dust levels. In addition, the dust collector functioned as a dust controller in the air room (Prasetya, 2014).

The prevention of dust exposure is very challenging because of the very unstable and transitional settings at construction sites, where the concrete and demolition workers work. The tasks at the construction site changes from day to day, as do the location of the construction site, which means that protection against dust is difficult. Already legal requirements have been made with regard to removal of dangerous materials (Mølgaard, 2013).

V. MEASUREMENT OF TEMPERATURE AND HUMIDITY

Measurement of environmental physical factors was conducted once during the production process. This measurement of environmental physical factors used a thermohygrometer that functioned to measure of temperature and humidity of the air.

The physical quality factors of air that affected air in room were measured at one point in the production section. The physical air factors measured consisted of temperature and humidity. The results of physical air quality measurements could be seen in Table 5.2 below:

DOI: 10.37200/IJPR/V24I1/PR200287
Received: 22 Nov 2019 | Revised: 26 Dec 2019 | Accepted: 10 Jan 2020

Measurement Location: Limestone burning industry in Plumpang District, Tuban Regency

Measurement Time: Saturday, Auguts 10th 2019

1. Point I : 10.21 – 10.51 WIB
2. Point II : 10.56 – 11.26 WIB

Table 1.3: Results of Environmental Physical Quality Measurement in the Limestone Burning Industry

Parameter	Unit	Measurement Location		Quality Standard Peraturan Minister of Manpower of the Republic of Indonesia Regulation No. 5 of 2018
		Point I	Point II	
Temperature	°C	32,4	31,1	18-30
Humidity	%	42	43	65-95

From Table 5.2, the results were obtained that the temperature in the production area at Point I and Point II were quite high at 32.4 ° C and 31.1 ° C so that these still did not meet the quality standard set on Minister of Health Decree No. 1405 of 2002 about Office and Industrial Work Environmental Health Requirements.

Humidity at Point I and Point II obtained at 42% and 43% which were quite low so these did not meet the quality standard set on Minister of Manpower of the Republic of Indonesia Regulatio No. 5 of 2018 about Safety and Health of the Work Environment.

Measurement of environmental physical factors including temperature and humidity was conducted to find out the environmental conditions when dust measurements was conducted. At the time of measurement, namely during the production process, the temperature recorded were 32.4 ° C at Point I and 31.1 ° C at Point II when compared to the Minister of Manpower of the Republic of Indonesia Regulation No. 5 of 2018 about Safety and Health of the Work Environment, the results of temperature measurements on this burning section exceed the Threshold Limit Value set which was between 18 ° C-30 ° C. The higher the air temperature, the particles would become drier and lighter so those particles became more reactive and lasted longer (Siswanto, 1998).

The results of the humidity measurement in burning section precisely at Point I and II obtained values of 42% and 43%. When compared with the standards based on the Minister of Health Decree No. 1405 of 2002 about Office and Industrial Work Environmental Health Requirements, with a humidity requirement of 65% - 95%, the results of the humidity measurement in the burning section did not meet the requirement set. Humidity in the limestone burning industry was still low so it allowed the particulate to react with water would be lower so that the density of particulate was lower and ease the particulate to float in the air and enter the lungs. This was appropriated with the research by Gupta (2006) which stated that humidity could affect the concentration of dust particles in the air because the higher the humidity so the higher the possibility of particulates to react with water then the density of the particulates increased (Salisa, 2011).

VI. CONCLUSION

The highest PM2.5 level measured at point I was 12,610 mg / m3, this showed the result that the value of dust level still exceeds the threshold limit value in the Minister of Manpower of the Republic of Indonesia Regulation No. 5 of 2018 about Safety and Health of the Work Environment a maximum of 5 mg / m3

DOI: 10.37200/IJPR/V24I1/PR200287
Received: 22 Nov 2019 | Revised: 26 Dec 2019 | Accepted: 10 Jan 2020

Measurement of temperature and humidity showed that the temperature in limestone burning was above the temperature and humidity limit still did not meet the TLV of the work environment in the Minister of Manpower of the Republic of Indonesia Regulation No. 5 of 2018 about Safety and Health of the Work Environment.

Based on research that had been done and the results obtained, workers should get used to use disposable masks when working. To make the temperature and humidity around the workplace not too hot, around the limestone burning place, it should watered and given plants to avoid too much dust inhaled by workers.

The Tuban Regency Government can do selective harvest and replant trees around the limestone burning industry so the air around the industry become cooler. Providing information to workers related to the danger of PM2.5 exposure in the body. Providing facilities such as routine medical check ups for workers in the limestone burning industry as a preventive action.

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DOI: 10.37200/IJPR/V24I1/PR200287
Received: 22 Nov 2019 | Revised: 26 Dec 2019 | Accepted: 10 Jan 2020

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