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Application of Electrostatic Precipitator with Electrode Distance Variation in Reducing Dust Levels in The Manufacturing Industry

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ABSTRACT

A potential hazard is anything that could potentially cause damage, accident, injury, loss, or even death due to the system or work processes. Hazards in the work environment are due to physical, biological, chemical, and psychosocial factors. One of the chemical factors hazards in the work environment that require control is the level of dust in the air environment at work. High levels of dust can cause health problems for workers. These health problems can cause dust allergies, impaired lung function, and other lung function disorders due to the dust that can eventually reduce worker productivity. Out of all industries, the manufacturing industries are usually high in dust content. During the manufacturing process, it is crucial to maintain efforts in controlling risk factors. This research aims to develop a tool that can reduce the air dust level in the industrial environment. Therefore, this study tries to apply an electrostatic precipitator with electrode distance variations to reduce dust levels in the manufacturing industry. The results of this study are the dust content reduction percentage, an electrode distance of 4 cm resulted in 52.3% to 64.9%, electrode distance of 6 cm is 35.5% to 46.7%, while an electrode distance of 8 cm is 16.6% to 26.7%. There is a difference in the electrodes effect of 4 cm, 6 cm, and 8 cm with a decrease in dust levels in the air. The most effective electrode distance in decreasing the air dust level is a 4 cm distance.

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INTRODUCTION

One of the diseases caused by the working environment is when a person suffers from inhaling compounds or materials used in the industrial environment (Indonesian Minister of Health Regulation, 2016). Dust is one of the materials that could enter the lungs. Dust settles in the lungs and can cause local irritation or other types of irritations (Candra, 2012). Dust is a complex mixture of particles that can pose a serious threat to human health. When inhaled, these particles can settle in the lungs and cause a range of health problems, from minor irritation to serious respiratory illnesses. In particular, dust can cause local irritation in the respiratory tract, leading to symptoms such as coughing, wheezing, and shortness of breath. Additionally, dust exposure has been linked to more serious respiratory problems such as asthma, chronic bronchitis, and even lung cancer (Nel, 2005). Therefore, it is essential to take steps to minimize exposure to dust, especially in occupational settings where workers may be at greater risk of exposure.

According to a study conducted by the World Health Organization (WHO), exposure to dust in the workplace is a significant occupational hazard and can lead to various respiratory

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disorders, such as silicosis, asbestosis, and pneumoconiosis (WHO, 2010). Furthermore, prolonged exposure to high levels of dust can result in chronic obstructive pulmonary disease (COPD), a long-term condition that obstructs airflow and makes it difficult to breathe (Eisen et al., 2019).

Apart from dust, exposure to other harmful compounds in the industrial environment can also have detrimental effects on human health. For instance, exposure to volatile organic compounds (VOCs) can cause respiratory irritation, headaches, dizziness, and nausea (EPA, 2018). Additionally, long-term exposure to these chemicals has been linked to liver and kidney damage, as well as cancer (EPA, 2018). To protect workers from exposure to harmful compounds in the workplace, regulatory bodies and employers must take appropriate measures to mitigate these hazards. Implementing engineering controls, such as installing ventilation systems and using personal protective equipment, can help minimize workers' exposure to dust and other harmful chemicals (NIOSH, 2018). Regular monitoring of air quality and providing workers with adequate training on safe work practices can also go a long way in preventing occupational illnesses caused by exposure to harmful compounds in the industrial environment.

Dust ranging from 5 to 10 micrometer will be retained in the upper respiratory tract, 3 to 5 micrometers will be retained in the middle respiratory tract, which is the bronchioles and trachea, size of 1 micrometer will settle on the surface of the alveoli and a size less than 0.1 μ is not deposited inside the lungs hence it will move back and forth of the alveoli. The smaller the dust particle size, the more harmful it will be to the respiratory system. Disorders of the respiratory tract caused by the dust particles' size are due to the dust deposition in the respiratory tract. Pneumoconiosis is a disease that is generally caused by dust exposure, the pneumoconiosis type depends on the dust type that causes the disease. Some examples of pneumoconiosis types were silicosis due to quartz dust or silica exposure, asbestosis due to asbestos dust, and anthracosilicotic due to the mixture of anthracite and silica, byssinosis due to cotton dust, and siderosis originating from tin ore dust (Salami, 2016).

According to a study by Rosenman et al. (2018), occupational exposure to dust is a significant risk factor for the development of pneumoconiosis. The study found that the risk of developing pneumoconiosis was higher in occupations such as mining, construction, and manufacturing, where workers are exposed to high levels of dust particles. Similarly, a review by Blanc and Annesi-Maesano (2015) highlighted the health risks associated with occupational exposure to dust, including respiratory tract disorders such as pneumoconiosis. The authors emphasized the need for preventive measures, such as the use of personal protective equipment and improved workplace ventilation systems, to reduce the risk of dust-related respiratory diseases.

According to the World Health Organization report, 2 million people worldwide are estimated exposed to wood dust regularly at work (WHO, 1992). Dust exposure in the working environment harms workers because it could be inhaled and accumulated in workers' lungs. Generally, the timber and manufacturing industries were known to be the highest contributor to dust exposure. In particular, wood dust can be inhaled and accumulate in the lungs, leading to respiratory problems such as asthma, bronchitis, and even cancer. Workers in the timber and manufacturing industries are particularly at risk, as they are frequently exposed to high levels of wood dust during the processing and handling of wood products (D'Alessandro et al., 2013). Additionally, workers in other industries such as construction and furniture making may also be at risk of wood dust exposure, depending on the materials they work with.

One of the industries working environments where exposure to dust poses a risk to workers in the manufacturing industry (Mulyati, 2016). The existing manufacturing industries include a manufacturing industry producing tables, study chairs, chairs, nursing beds, as well as other types of furniture. The dust exposure due to the production process can harm the health of workers because it uses materials that produce dust such as metal, wood, and cloth. The production process at risk of dust exposure is the painting, welding, and assembly processes in the warehouse, nailing, painting, frame, polishing, bending (pipe bending), welding, chrome plating section, assembling, and woodworking (Dirgantari, 2019). Dust exposure is a significant occupational hazard for workers in many industries, particularly those involved in the production of metal, wood, and textile products. Workers in these industries may be exposed to harmful dust particles during a variety of production processes, including welding, grinding, cutting, and polishing. For example, workers involved in metalworking and woodworking may be at risk of inhaling metal dust, wood dust, and other hazardous particles, while textile workers may be exposed to cotton dust and other airborne fibers (Antao & Pinheiro, 2012). Dust exposure can cause a range of respiratory problems, from minor irritation to more serious illnesses such as chronic obstructive pulmonary disease (COPD) and lung cancer. In addition to respiratory problems, dust exposure has also been linked to skin irritation and other health issues. Therefore, it is essential for employers to implement effective dust control measures in the workplace, such as ventilation systems, personal protective equipment, and safe work practices.

Efforts to control risk factors have been done by measuring and monitoring the working environment to carry out proper environmental management and prevention (Wichaksana, 2012; Perdana et al., 2012, Okta, 2017). Effective prevention and control of occupational hazards, including those related to dust exposure, require a comprehensive approach that involves measuring and monitoring the working environment, implementing appropriate control measures, and regularly evaluating the effectiveness of these measures. For example, regular air sampling and monitoring can help identify areas where dust levels are high and guide the selection and implementation of appropriate control measures. Engineering controls, such as ventilation systems and dust collection equipment, can be used to reduce dust levels in the workplace, while administrative controls, such as limiting the duration and frequency of dust-producing activities, can help minimize worker exposure (Bisesi et al., 2019). Personal protective equipment, such as respirators and protective clothing, can also be used to help protect workers from dust exposure. However, these measures should be viewed as a last resort and should only be used when other control measures are not feasible or effective.

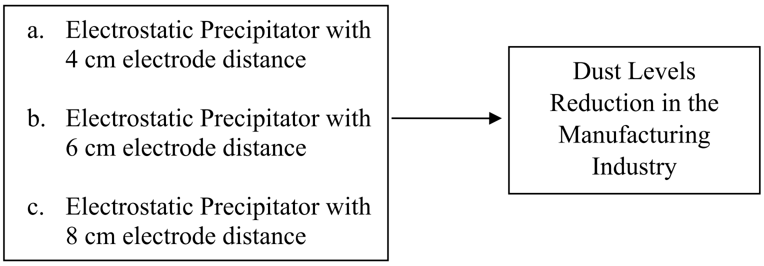
The Risk Control Hierarchy that has been implemented is Engineering Control, Administrative Control, and the use of Personal Protective Equipment (PPE) to create a safe and healthy working environment (Ramdan, 2013). Apart from the use of PPE, another method that can reduce dust levels in the industrial environment to meet the permissible threshold is the electrostatic precipitator method with various electrode distances that can reduce the dust content (Cahyono, 2017). The Risk Control Hierarchy is a framework that is commonly used to manage occupational hazards, including those related to dust exposure. This framework involves three levels of control: engineering controls, administrative controls, and personal protective equipment (PPE). Engineering controls, such as ventilation systems and dust suppression equipment, are typically the most effective way to control dust exposure because they eliminate or reduce the hazard at the source. Administrative controls, such as work practices and training, are often used in conjunction with engineering controls to further reduce worker exposure. Finally, PPE, such as respirators and protective clothing, can be used as a last line of defense to protect workers who are still at risk despite the implementation of engineering and administrative controls (Kumar & Kumar, 2019).

The reduction of airborne dust levels is a crucial concern in the manufacturing industry to ensure a healthy and safe working environment for employees. Electrostatic precipitators have been widely used as a dust control technology. However, determining the optimal electrode distance in an electrostatic precipitator for efficient dust reduction remains a challenge. Therefore, this research aims to investigate and determine the most effective electrode distance for reducing dust levels in an electrostatic precipitator in the manufacturing industry. The findings of this study will provide valuable insights and recommendations for optimizing the performance of electrostatic precipitators in reducing dust levels, thus enhancing workplace safety and health.

MATERIALS AND METHODS

The quasi-experimental with laboratory-scale research was carried out. This study uses a One Group Pretest-Posttest design (Sugiyono, 2017; Hastono, 2017).

The conceptual framework of this research is as follows:



The dependent variable of the research is the various distance of the electrode in the electrostatic precipitator (4, 6, and 8 cm), and the study's independent variable is the effect on dust level reduction in the manufacturing industry.

The research was carried out in the manufacturing industry. The research preparation and implementation took eight months, from March-November 2021.

The population in this study is the level of dust in the manufacturing industry. Meanwhile, the sample is the level of dust in the woodworking area of the manufacturing industry. The number of treatments in this study was three treatments, namely:

a. Electrostatic Precipitator with 4 cm electrode distance
b. Electrostatic Precipitator with 6 cm electrode distance
c. Electrostatic Precipitator with 8 cm electrode distance

Formula in determining the sample size:

$$t\ (r-1) \geq 15$$

Whereas:
t = number of treatments
r = number of repetitions

The calculation based on the formula above:

$t\ (r-3) \geq 15$
$3\ (r-3) \geq 15$
$3r \geq 18$
$r \geq 6$

The data were processed in the univariate and bivariate methods. The Univariate analysis resulted in the percentage and average value of each variable studied. Meanwhile, the effect between each dependent and independent variable were determined using the ANOVA Test as the Bivariate Analysis.

RESULTS AND DISCUSSION

The research was carried out at the Environmental Health Laboratory, using a laboratory-scale electrostatic precipitator with the following results:

Based on Table 1, the results show that the dust levels percentage reduction on 4 cm electrode distance is 52.3% to 64.9%, 6 cm electrode distance is 35.5% to 46.7%, meanwhile, at 8 cm of electrode distance is 16.6% to 26.7%.

Bivariate Analysis Results

The Bivariate analysis used the ANOVA test, with the following result:

Based on Table 2, the ANOVA test result shows a significant effect on the three treatments.

The difference of electrode distances on the electrostatic precipitator aims to determine an optimal distance for dust reduction. The electrode distance of 4 cm was the most optimal in reducing the dust level, which is about 52% to 64.9%, this is because the closer the electrode distances cause a greater fluid resistance which decreases the velocity of fluid and will cause the dust to settle. This is following the previous research conducted by Luthfi which stated that the closer the electrode distance and the greater the electric voltage, the greater it will be in reducing the dust levels in the air (Muttaqim et.al., 2015). According to a study by Sudiro et al. (2018), decreasing the distance between electrodes can increase the efficiency of electrostatic precipitators in reducing the concentration of particulate matter in the air. The study found that reducing the electrode distance from 8 cm to 4 cm increased the collection efficiency of the precipitator by approximately 10%. This is due to the increased electric field strength and turbulence caused by the reduced distance between the electrodes, which promotes the charging and collection of particles.

In a study conducted by Li et al. (2019), it was found that reducing the electrode distance from 7 cm to 5 cm led to an increase in the overall efficiency of an electrostatic precipitator from 80.1% to 88.7%. This increase in efficiency was attributed to the increase in electric field intensity between the electrodes, which enhances the charging of particles and their capture on the collecting plates. In another study by Saeed et al. (2017), it was found that decreasing the electrode distance from 15 cm to 10 cm in an electrostatic precipitator led to a decrease in the concentration of PM2.5 particles in the flue gas by up to 63%. The authors attributed this decrease to the increase in electric field strength and ion density between the electrodes, which

Table 1. ESP Test Result

4 cm Electrode		**%**	**6 cm Electrode**		**%**	**8 cm Electrode**		**%**
Before	**After**		**Before**	**After**		**Before**	**After**	
0,0084	0,0034	59,5	0,0030	0,0016	46,7	0,0144	0,0120	16,7
0,0044	0,0021	52,3	0,0028	0,0017	39,3	0,0164	0,0130	20,7
0,0080	0,0036	55,0	0,003	0,0017	43,3	0,0151	0,0126	16,6
0,0078	0,0032	59,0	0,0033	0,0019	42,4	0,0129	0,0100	22,5
0,0065	0,0031	52,3	0,0031	0,0020	35,5	0,0135	0,0112	17,0
0,0077	0,0027	64,9	0,0029	0,0018	37,9	0,015	0,0110	26,7

Table 2. Bivariate Analysis Result

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	.000	2	.000	23.513	.000
Within Groups	.000	15	.000		
Total	.000	17			

increased the charging and collection efficiency of the particles. A study by Gao et al. (2016) found that reducing the electrode distance from 5 cm to 2 cm in an electrostatic precipitator led to an increase in the overall removal efficiency of PM2.5 particles from 71.4% to 83.5%. The authors attributed this increase to the increase in electric field strength and ion concentration, which enhanced the charging and collection of the particles.

Electrostatic precipitation is a technique commonly used to remove particulate matter from industrial gases. The process involves the ionization of gas molecules by a corona discharge, followed by the attraction of the ionized particles to an oppositely charged electrode. The particles adhere to the electrode and are periodically removed by a mechanical or electrostatic means. The effectiveness of electrostatic precipitation depends on a number of factors, including the size, shape, and electrical properties of the particles, as well as the operating parameters of the system. Factors such as gas flow rate, electrode spacing, and applied voltage can all affect the efficiency of the process. Electrostatic precipitation is widely used in a variety of industrial applications, including power generation, cement manufacturing, and metal smelting (Nguyen et al., 2021).

Excessive ash adhering to the anode and cathode will reduce ash capture efficiency, hence it is necessary to adjust the voltage and current from the control panel manually. The most basic precipitator contains rows of thin vertical wires followed by a stack of large, flat metal plates oriented vertically, with the usual distance of plates at 4 cm, 6 cm, and 8 cm apart. The airstream flows horizontally through the space between the wires and then passes through the stack of plates. A negative voltage passed between the wire and the plates. If the applied voltage is high enough, the electrical discharge ionizes the air around the electrodes and ionizes the particles in the air stream. The ionization occurs due to the transfer of electrostatic forces to the plate. The particles accumulated on the collecting plate and were removed from the airstream. This process can reduce the total air dust levels and eventually reduce the negative impact of dust pollution in the workspace by applying electrostatic precipitation.

Electrostatic precipitators may encounter several problems that require maintenance and repair. The most common issues are related to high-voltage output circuitry, such as open circuits and short circuits between the anode and cathode. The damping network may also overheat, causing sparks to fly. Automatic control systems can fail, resulting in curved indications or ineffective functioning. Ash hopper devices can become blocked due to errors or damage. To prevent these issues, regular maintenance and cleaning are essential. Loose emitting wires, iron attachment to collecting plates and emitting wires, and collecting plate detachment can cause short circuits. These issues can be addressed by regular inspections and cleaning of the precipitator (Sharma et al., 2017). Electrostatic precipitators (ESPs) require regular maintenance to ensure optimal performance. The internal components, such as the discharge electrodes, collecting plates, and rappers, should be inspected and cleaned periodically to prevent ash buildup and short circuits. In addition, the high-voltage power supply should be checked to ensure proper operation (Kothari et al., 2018).

Several disturbances/damages that often occur and cause the ESP operation to stop automatically were: 1. The high-voltage output circuit is open, 2. The damping network has a very excessive temperature/ a spark comes out, 3. The automatic control system has/shows a curved indication, and the control system is not functioning effectively, 4. An error/damage occurred that caused ash blocking on the ash hopper device, 5. A short circuit occurs on the ESP device (usually a short circuit between the anode and cathode), which mainly occurs because -There is a loose emitting wire, -The presence of other materials (iron) attached to the collecting plate and emitting wire, -The collecting plate is off the stopper.

A lower collection efficiency in an electrostatic precipitator would mean that more particles would be released into the air, which could lead to increased air pollution levels. This could have negative impacts on human health, as well as the environment. However, if the electrostatic precipitator was designed to have a lower collection efficiency for a specific application, it could potentially be used in situations where a certain level of particulate matter is desired, such as in the production of some types of materials or chemicals. Overall, it is important to carefully consider the intended application and potential impacts before designing an electrostatic precipitator with a lower collection efficiency.

In order to optimize the performance of an electrostatic precipitator, it is important to consider both the distance between the electrodes and their voltages. While electrode distance plays a role in reducing dust levels by decreasing fluid velocity and causing dust to settle, higher voltages can significantly increase collection efficiency by affecting particulate drift velocity.

CONCLUSION

1. The percentage decrease in dust level on 4 cm electrode distance is 52.3% to 64.9%, 6 cm electrode distance is 35.5% to 46.7%, meanwhile, at 8 cm of electrode distance is 16.6% to 26.7%.
2. There are differences in the effect of 4 cm, 6 cm, and 8 cm electrodes distance with air dust level reduction.
3. The highest effect of the air dust level reduction is at the electrode distance of 4 cm.
4. Based on the findings of this electrode distance research, it is recommended to further investigate the effect of electrode voltage on electrostatic precipitator performance. Specifically, exploring the impact of very low current flow with high voltage, around 35,000-40,000 volts, on particulate drift velocity and collection efficiency, as well as optimizing the collection area on the positive pole, could be valuable areas of focus for future research.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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