Evaluation of the Implementation of the Local Exhaust Ventilation System in the Testing Laboratory

Yudha Andaka Setyawan[1,2], Shintia Yunita Arini[3], Sri Widodo[4]
[1]Master of Occupational Health and Safety, Department of Occupational Safety and Health, Faculty of Public Health, Universitas Airlangga, Indonesia
[3]Department of Occupational Safety and Health, Faculty of Public Health, Universitas Airlangga, Indonesia
Campus C Mulyorejo, Surabaya, East Java 60115 Indonesia
[2,4] Technical Implementation Unit (henceforth-UPT) of Occupational Safety Surabaya, Indonesia,
Departement of Manpower and Transmigration, East Java Provincial Government, Indonesia
Dukuh Menanggal 122, Surabaya, East Java Indonesia

ABSTRACT

Introduction: One of the ways to control hazards with an engineering approach in an effort to reduce hazards due to chemical reactions in the laboratory is to install a ventilation system, especially in the Atomic Absorption Spectrophotometer (AAS). The research objectives of this study are to evaluate the implementation of the Local Exhaust Ventilation System in the AAS room. **Method:** This study used a descriptive observational method with a cross-sectional approach. It was carried out at the Testing Laboratory of the Technical Implementation Unit (henceforth-UPT) of Occupational Safety Surabaya. Data collection was carried out through direct observation in the field to determine the LEV system components and to measure the flow velocity in the inlet and outlet areas of the LEV system. The data obtained were analyzed descriptively by describing the situation systematically and factually. The data were then presented in the form of narration, tabulation, and figures. **Results:** The conditions of the Local Exhaust Ventilation (LEV), in terms of the design, type and material of each component such as the hood, ducting system and pump machine as well as the fan, are already in accordance with the tool specifications and ASHRAE standards. However, the LEV system has not installed an air cleaner. The results of the measurement show that flow velocity in the LEV system has met the standard, which is 10 m/s with the danger of fume contaminants. In fact, its volumetric flow rate has decreased by more than 20%. **Conclusion:** laboratory management is advised to consider installing an air cleaner on the LEV system installed in the Hitachi AAS so that contaminants released in the air are cleaner and more environmentally friendly.

Keywords: hazard control, laboratory, local exhaust ventilation, ventilation

Corresponding Author:
Shintia Yunia Arini
Email: shintia.arini@fkm.uniar.ac.id
Telephone: +6282233031117

INTRODUCTION

The quality of air in the work environment in the last few decades has received increasing attention from researchers, business owners, expert practitioners and especially the government through the implementation of regulations aimed at improving the comfort, health and welfare of workers and protecting workers from the dangers of air pollution in the workplace (Cincinelli and Martellini, 2017). Thus, it is necessary to carry out risk management through hazard identification and determination of comprehensive control with a risk management approach (Ramli, 2010).

Proper risk management is a form of company commitment in ensuring protection of workers, especially against occupational diseases in the work environment. One of the forms of risk management is the effort to identify hazards by conducting regular air quality testing and occupational health checks. This is intended as one of the efforts to prevent occupational diseases and provide added value for companies in developing their business.

Along with the increasing commitment of the company in providing protection for workers from accidents and occupational diseases, it is necessary to have institutions from both the government and the private sector to provide services, especially in terms of air quality testing and occupational health checks. One of the government institutions that provides air quality testing services and occupational health checks in the area of East Java Province is the Technical Implementation Unit (henceforth-UPT) of Occupational Safety Surabaya under the auspices of the Manpower and Transmigration Service of East Java Province. As a testing

Cite this as: Setyawan, Y. A., Arini, A. H., and Widodo, S. (2022) 'Evaluation of the Implementation of the Local Exhaust Ventilation System in the Testing Laboratory', *The Indonesian Journal of Occupational Safety and Health*, 11(1), pp. 83-93.

doi:10.20473/ijosh.v11i1.2022.83-93
Received May 25, 2021, received in revised form December 06, 2021, Accepted December 08, 2021, Published: April 2022

laboratory, in accordance with Article 16 of the Governor Regulation Number 62 of 2018 on the UPT of Manpower and Transmigration Service, it is stated that the main duties and functions of the UPT of Occupational Safety Surabaya are as a public service unit and as laboratory testing to carry out testing, inspection, research and training in the areas of corporate hygiene, occupational health and safety for companies and other agencies using laboratory management, administrative duties and community services (East Java Provincial Government, 2018).

However, in carrying out its main duties and functions, the UPT of Occupational Safety Surabaya certainly faces the risk of hazards, so it needs to take actions to prevent incidents in the laboratory. Thus, it necessary to formulate and implement a management system (Lestari *et al*., 2019). Activities in the laboratory involve the use of hazardous chemicals in liquid, solid or gaseous forms that can cause chronic and acute health problems (Cahyaningrum, Sari and Iswandari, 2019). Health laboratory personnel can be threatened if the performance of ventilation is not in accordance with the standard ventilation rate, which can increase some cancer diseases as well as the possibility of adverse pregnancy outcomes in female laboratory personnel (Liu, Liu and Gao, 2017). Thus, it is necessary to carry out various control efforts in accordance with the hierarchy of hazard control as an attempt to ensure the protection of workers from occupational diseases. The circulation of fresh air into the laboratory and good ventilation system must be considered carefully. The better the air circulation and ventilation system, the healthier the laboratory conditions will be (Rahmantiyoko, Sunarmi and Rahmah, 2019).

The UPT of Occupational Safety Surabaya has a commitment to protect workers in order to avoid occupational diseases caused by direct or indirect exposure to chemicals in the laboratory. This is in accordance with its commitment in implementing the mandate of Law Number 1 of 1970 on Occupational Safety, especially in article 3 paragraph 1 letter g which states that the conditions of occupational safety are preventing and controlling the rise or diffusion of temperature, humidity, dust, dirt, smoke, vapor, gas, wind gusts, weather, rays or radiation, sound and vibration (the President of the Republic of Indonesia, 1970). This commitment is realized by implementing various hazard controls. One of the ways of controlling hazards with an engineering approach in an effort to reduce harmful gases due to chemical reactions in the laboratory is by installing a ventilation system, especially on the Hitachi ZA3000 Atomic Absorption Spectrophotometer (AAS). This tool can emit dangerous gases (especially metal vapors) based on the analysis of the test samples and can emit heat up to 1,600 degrees Celsius (Hitachi, 2013).

Based on an interview with one of the analysts, there was an incident where an analyst forgot to turn on the Local Exhaust Ventilation (LEV), which made the air in the room become warmer and the smell of the analysis solution spread into the room. Accordingly, the use of the Local Exhaust Ventilation is an effort to control hazards in accordance with the source of air contaminants in the AAS room. However, in its implementation, it is necessary to evaluate the performance of the Local Exhaust Ventilation.

Referring to the aforementioned description, the researchers are interested in conducting a study to find out the implementation and effectiveness of Local Exhaust Ventilation in controlling hazards in the AAS room in the Testing Laboratory at the UPT of Occupational Safety Surabaya.

METHODS

Data collection in this study was conducted using a cross-sectional design because data collection was carried out simultaneously at the same time. The nature of this study was observational. Based on the analysis, this study was a descriptive study describing the process without analyzing the relationship between variables (Masturoh, 2018). This study was conducted in the AAS room in the Testing Laboratory at the UPT of Occupational Safety Surabaya from August to October 2020. This study has also received an ethical clearance certificate from Health Research Ethical Clearance Commission, Universitas Airlangga Faculty of Dental Medicine and the number of the ethics certificate is 022/HRECC.FODM/I/2021. Moreover, the data were collected through direct observation at the research location to determine the completeness of the LEV system components and to measure the LEV performance by measuring the cross-sectional area of the Inner Circle Hood and the flow velocity in the inlet and outlet areas of the LEV system.

First of all, before determining the flow velocity, the diameter of the inner circle hood had to be measured first and then the cross-sectional area of the Inner Circle Hood was calculated. The calculation of the cross-sectional area of the Inner Circle Hood was based on the following formula:

$$A=\pi \quad x \quad r^2$$

Note:

A = cross-sectional vector area (m2)

π = constant equal to the ratio of the circumference of a circle to its diameter (can describe with 3,14 or 22/7)

r = the distance between the edge of the circle and the center of the circle (m)

The next step after calculating the cross-sectional area of the Inner Circle Hood was to measure the flow velocity. The flow velocity measurement was done using the Lutron AM-4206 Anemometer.

After knowing the flow velocity, the next step was to calculate the volumetric air flow rate with the following formula:

$$Q=V"avg" \quad x \quad A$$

Note:

Q = volumetric air flow rate (m3/second)

Vavg= air flow velocity (m/second)

A = cross-sectional vector area (m2)

Source: NIH (National Institutes Health)2011)

Data collection was also carried out by interviewing supervisor analysts and analysts, while secondary data collection was carried out by looking for references to tool specifications. The description of equipment condition by taking several photos was also needed to describe the condition of the equipment at the time of data retrieval.

Figure 1. Anemometer

Importantly, the data obtained were analyzed descriptively by describing the situation systematically and factually. The data were then presented in the form of narration, tabulation, and figures, so that a clear representation of the evaluation of the implementation of the LEV system in the testing laboratory would be obtained. After the required data were collected, the data were then presented through the observation results and the measurement table of LEV flow velocity.

RESULTS

Hazard Identification

Atomic Absorption Spectrophotometry (AAS) is one type of spectrophotometric analysis equipment where the mechanism of measurement uses absorption of a ray by an atom, and the light that is not absorbed is transmitted and converted into a measured electrical signal. AAS is a popular method for metal analysis because apart from being simple, it is also sensitive and selective.

This AAS uses the Flame Method to burn the test sample with a flame temperature of up to 2000 °C. This temperature can be reached using hydrogen and acetylene. Meanwhile, when argon-hydrogen is used, the temperature can reach 1600 °C.

The mechanism of action of this tool is to spray the sample solution into the burner. This sprayed solution then burns at high temperature and turns into atoms. The solution that turns into atoms is then forwarded to a detector and read as an electrical signal. The reading results are displayed on a computer screen and then printed. The printout of the readings is then used as an analysis of data recording.

The use of AAS as a tool to analyze metals has the potential to pollute the work environment, especially in the AAS room if there is no hazard control. This is because when the analysis is carried out, there is flame heat up to 2,000 °C and vapor generated by the standard solution when standard operating procedures for metal analysis is performed.

One of the examples of an analysis that has potential hazards is the analysis of the test sample with a parameter of Lead (Pb) in the air. Based on the work instructions, the Lead analysis method uses 6 standard solutions, starting from a solution concentration of 0.1 ppm - 0.3 ppm - 0.5 ppm - 1 ppm - 3 ppm - 5 ppm sequentially. The standard solution of Lead can evaporate when the LEV is not turned on. The AAS room with a room volume of 90 m3 will contain at least 6.05 mg/m3 (0.55 ppm) in the first hour. The concentration of lead due to the analysis of the sample will occur if the room is not well ventilated, or the LEV is not operated.

Local Exhaust Ventilation System Components

Based on the results of observations in the AAS room, could describe the Local Exhaust Ventilation system components as follows.

Hood

Based on observations in the AAS room, the hood used was a hanging receiver canopy hood. The placement of the hanging hood was supported by providing an iron chain at each of the 4 corners so that it did not sway while operating.

The inner hood dimension was used to measure the cross-sectional area of the flow rate in order to determine the actual suction volume. Therefore, the cross-sectional area used was the Cylindrical Inner Hood. The Cylindrical Inner Hood diameter was 0.012 m, so the calculation of the cross-sectional area of the Inner Circle Hood was 0,011304 m2.

The hood was also equipped with a manual valve which functioned to regulate the speed of the flow rate and protect the equipment from dust coming from outside the room when the tool was not in use.

The use of a manual valve was indicated by an arrow which was made using a black marker, so that if it was used in the long term, it had the potential to fade due to rubbing or exposure to liquid or chemical vapors.

Figure 2. A Hood installed on Hitachi ZA3000 of the Testing Laboratory at the UPT of Occupational Safety Surabaya in 2020

Duct

Based on observations in the AAS room, the duct was cylindrical with a flexible duct-type made of stainless steel to be able to withstand heat and metal vapor when the AAS flame and furnace were operating. This flexible duct had 3 elbows/corners with a diameter of 15 cm and a length of approximately 5 meters

Air Cleaner

Based on observations in the AAS room, the LEV system did not use an air cleaner so that the gas and heat resulting from the analysis activities were immediately discharged into the free air through the office roof of the UPT of Occupational Safety Surabaya.

Fan

Based on observations on the building roof of the UPT of Occupational Safety Surabaya, the pump machine used was Hitachi EFOUP, while the fan in the LEV system was GWF. The pump machine used 0.5 HP (Horse Power), 220 Volt and 3.8 Ampere power and was Induction Motor and Condenser

Figure 3. A Duct installed on Hitachi ZA3000 of the Testing Laboratory at the UPT of Occupational Safety Surabaya in 2020

Start. This Hitachi pump machine was capable of driving the fan with an average speed of 1,430 revolutions per minute.

Flow Velocity Measurement

The following are the results of flow velocity measurement of the Local Exhaust Ventilation installed on Hitachi ZA3000 AAS in the AAS room using the Lutron AM-4206 Anemometer.

Maintenance of Local Exhaust Ventilation

Based on secondary data sourced from Work Instructions number IK.A 12-3 concerning Work Instructions for Hitachi Type ZA3000 Atomic Absorption Spectrophotometer (AAS), the maintenance procedure for Local Exhaust Ventilation (LEV) only turns the valve hood from position ← to position ↑ and pressing the switch is ON if LEV will be used to control pollutants from AAS. Meanwhile, when the AAS tool is not used, the valve hood must be in the ← position. This procedure is carried out so that dirt originating from outside the building does not enter the Flame AAS room so as to keep AAS performance precise.

Figure 4. A Fan installed on Hitachi ZA3000 of the Testing Laboratory at the UPT of Occupational Safety Surabaya in 2020

Table 1. Results of Flow Velocity Measurement of the Local Exhaust Ventilation installed on Hitachi ZA3000 of the Testing Laboratory at the UPT of Occupational Safety Surabaya in 2020

Measurement Location	Flow Velocity (m3/hour)
Inlet – Circle Duct	494.75
Outlet	626.59

Based on an interview with one of the analysts, there have been no work instructions or LEV maintenance procedures either routinely or incidentally. Thus, when the tool started operating in June 2016 until now, there has been no LEV maintenance either regularly or incidentally.

Based on interviews with analysts' supervisors, LEV maintenance was carried out by measuring the flow rate velocity at the inlet hood using an anemometer. The maintenance technician would check and measure the flow rate at the outlet if the flow rate was not as expected.

DISCUSSION

Hazard Identification

The working mechanism of the Hitachi ZA3000 type AAS has a fairly complex working mechanism, involving various methods and specific test methods so as to produce precise readings. The working mechanism of this AAS also produces various potential hazards so that workers can be exposed when operating this AAS equipment.

Based on the results of the calculation of lead concentration, high lead concentration will occur if the room is not well ventilated or if the LEV is not operated according to the regulation. According to the Regulation of the Minister of Manpower Number 5 of 2018, the permissible exposure limit for lead in workplace air is 0.15 mg/m3 for 8 hours of work (the Ministry of Manpower, 2018). Opening windows is actually an effective measure to increase infiltration ventilation rates, but this measure is not practical because it can depend of contaminant source characteristics (Zhu *et al*., 2020).

The results of the hazard identification process need to consider the characteristics of the risk to determine how to control it. Determination of control must pay attention to the hierarchy of controls including elimination, substitution, technical control, administrative control and provision of safety equipment adjusted to organizational conditions and types of hazards (Dankis and Mulyono, 2015).

More importantly, control of the work environment as a form of hazard control efforts carried out by the UPT of Occupational Safety Surabaya by using LEV in the AAS room is fairly appropriate. This is consistent with the recommendation of the American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003 Chapter 2.1 mentioning that “Management should establish a Laboratory Ventilation Management Plan to ensure proper selection, operation, use and maintenance of laboratory ventilation equipment” (Gupta, 2013).

In this study, the selection of the use of LEV systems was preferred to general laboratory whole-room ventilation systems with regard to rapid elimination of vapors (Zdilla, 2020). The LEV System can be an effort to control hazards in the AAS room based on tool specifications and management policies in controlling hazards during metal analysis activities. The selected hazard control should be able to reduce the levels of pollutants in the work environment to a predetermined Threshold Limit Value (TLV) (Tarwaka and Bakri, 2004). Thermal Hazard issues from AAS operation must be considered to control indoor thermal workplaces because they can affect the ventilation strategy (Y. Liu *et al*., 2019).

The operation of LEV actually starts in the work instruction document of the tool. Therefore, this tool should be operated fairly easily so the analyst can read and understand the work instructions of the tool. Besides, the use and maintenance of LEV should be regularly monitored and evaluated (Al-dahhan, Ali and Yousif, 2017). This is a manifestation that maintaining air quality that meets occupational health and safety requirements is very necessary, especially for employees working in the AAS room so that they can work with comfortable air quality (Tarwaka and Bakri, 2004).

Local Exhaust Ventilation System Components

LEV system must have at least 5 elements consisting of a source of contaminants and 4 parts/components: Hood, Duct, Air Cleaner, and Fan (Lees, 2012). Based on observations made on LEV in the AAS room, the following are the conditions for each component:

Hood

A hood that uses a canopy-type hanging receiver is basically very effective when workers are not in the area of the AAS flame airflow. The efficiency of hood collection depends on many factors, such as installed hood structure (cover depth, shape and configuration), position, and many more (Li, Zhang and Gao, 2017).

Based on the results, the hood structures and position have already followed recommendations. The cover depth, shape, and position between the hood and contaminant sources have already met the standard that is recommended by the factory (Hitachi, 2013).

Based on observations shown in Figure 4, the analyst who operated the AAS tool was in a safe zone because it was outside the AAS flame airflow. Movement of contaminated air away from workers creates a clean air work zone and later channels contaminated air into the hood (Olander *et al*., 2001).

The hood performance can be improved by using a personal ventilation method. This method potentially improves air quality in the breathing zone by providing comfortable thermal environments and higher local ventilation effectiveness (J. Liu *et al*., 2019). The collection performance of the hood is conducted by minimizing distance from contaminant sources, so the hood can improve its performance (Li, Zhang and Gao, 2017; Y. Liu *et al*., 2019).

The hood output that contains a manual valve mark with a black permanent marker should be replaced with a more permanent mark. Manual valve

Figure 5. . An Analyst was operating the AAS tool of the Testing Laboratory at the UPT of Occupational Safety Surabaya in 2020

signs are caution signs that should use the material that is durable because, as safety signs, they play a vital role in work environments (Reis, Duarte and Rebelo, 2015). This action aims to reduce the potential for missing or faded manual valve signs due to friction or due to reactions with the local environment. The provision of safety signs should, therefore, follow the safety sign recommendations (ANSI, 2011).

In this case, the evaluation is only given to the hood on the four corners of the canopy hood using a chain made of corrosive materials. Consequently, when the observations were made by the researchers, the chain had begun to look corrosive, marked by a change in its color. The impact of the chain that has been corrosive is the reduced durability in holding the canopy hood to maintain its position against the source of contaminants. The hood will not effectively capture the contaminant source if the hood is shifted towards a contaminant source. Therefore, maintenance and monitoring of the material needs to be considered since maintaining the resistance of the material is a necessity to prevent problems in the future (Zhivov *et al*., 2001).

Duct

There is no recommendation for the maximum number of duct elbows from the tool specifications. However, according to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), every LEV Systems must have duct components that comply with the standards and their designations (ASHRAE, 2016). Each duct must have 2 or 2.5 diameters in the center line radius (Gupta, 2013). This is expected to reduce the air turbulence in the duct flow. Of the 3 duct elbows in the LEV system in the AAS room, all elbows have met this requirement.

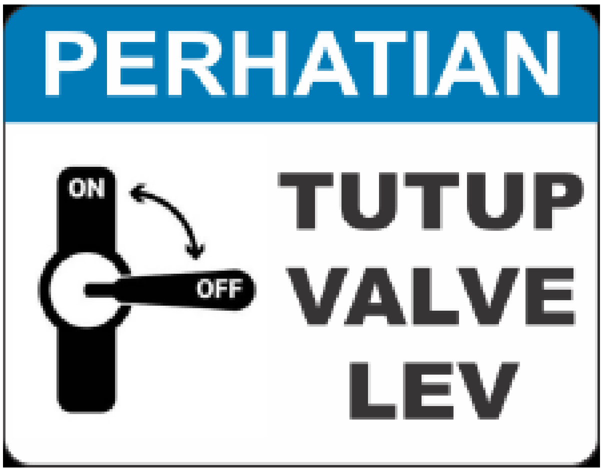

Figure 6. .Recommendation of A Safety Sign (ANSI, 2011)

The shape of the ducting system is in accordance with the tool specifications, namely in the form of a cylinder with a diameter of 15 cm (Hitachi, 2013). Cylindrical ducts can result in better distribution of airflow to the outside of the room than duct in the rectangular shape (Aydin and Ozerdem, 2006). Cylindrical ducts can reduce the turbulence in the duct flow so that airflow does not experience a significant reduction from the hood to the fan output.

Air Cleaner

Based on observations, the LEV system for Hitachi AAS did not install an Air Cleaner. Besides, despite not being included in the recommended tool specifications, laboratory management used the Dillution Ventilation Method, a method of controlling chemical contaminants in air by diluting them in free air. Consequently, the sucked air from the combustion chamber or the flame of the AAS tool was sucked directly into the free air through the ducting system and fan without going through the air cleaner (ACGIH, 1998, 2010).

Based on the recommendation of the American Conference of Governmental Industrial Hygienists (ACGIH) on Manual Industrial Ventilation in 2010, the air cleaner that is often used for chemical contaminants in the air in the form of fume is a wet collector (ACGIH, 2010; NIH (National Institutes Health), 2011). However, if it is installed in an LEV which has hot contaminant characteristics (up to 1,600 °C), there will be potential for evaporation which will cause smoke. Thus, according to ASHRAE (2016), the recommended air cleaner for LEVs which have fume and heat contaminants is a bag filter made of a very fine glass fiber mats. The use of a filter as a tool for air cleaner can reduce air pollution wasted through the fan outlet. In addition, some filter materials are able to withstand the temperature generated by heat due to the activity of the AAS tool (Pei and Ji, 2018; Pei *et al*., 2020).

Fan

The fan used was a forward-curved-blade centrifugal fan. This type of fan is the right choice for fume contaminants, and the fan is relatively quiet when operated (ASHRAE, 2016). The materials used to make the fan are not known. In fact, the fan looks to be in good condition during usage from mid-2016 until now. It proves that the fan uses materials which are heat resistant and not corrosive quickly. Choosing a good fan can increase performance so that the fan can work well for a long time. However, if the selection of the fan is not in accordance with its designation, it can lead to poor work efficiency of the fan and result in increased energy use (Gunner, Afshari and Bergsøe, 2015; Zhou *et al*., 2021).

The fan was placed right under the roof of the building and well protected from rain and direct sunlight, which can extend the life of the pump machine and fan and can increase economic efficiency (ASHRAE, 2016). There was damage to the wire mesh attached to the end of the fan. This is because the temperature and metal vapor resulting from the analysis can damage the wire mesh because the mesh uses a material that is not anti-heat and anti-corrosive. Thus, the wire mesh experiences heat and chemical reactions so that it becomes damaged (ASHRAE, 2016). This must be well-considered because maintaining the resistance of the material is a necessity to prevent problems in the future (Zhivov *et al*., 2001).

Flow Velocity Measurement

Based on the results of measurements using an anemometer, this flow velocity is in accordance with the requirements of the American Conference of Governmental Industrial Hygienists (ACGIH) on Manual Industrial Ventilation in 1998, which asserts that air chemical contaminants in the form of fumes should have a flow velocity of 2,000 – 2,500 fpm (10.16 – 12.7 meter per second) (ACGIH, 1998). Additionally, the results of the measurement of the corrected average flow velocity were 12.158 m/s inlet for inner circle flow velocity, and 11.312 m/s for the average outlet flow velocity. The flow velocity at the inlet is greater than that of the outlet because it has a smaller diameter than the outlet diameter. According to Zhivov *et al*. (2001), the flow velocity must be in accordance with the standard flow velocity based on the type of target contaminant so that the contaminants can enter the hood normally and turbulence does not occur. Here is an illustration of the standard flow velocity:

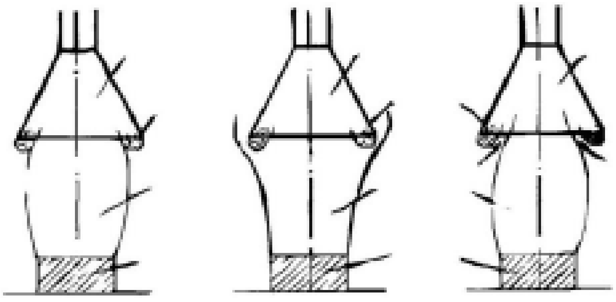

Figure 7. . Hood capability to capture contaminants according to flow velocity; (left figure) according to the standard flow velocity, (middle figure) less than the standard, and (right figure) more than the standard (Zhivov *et al*., 2001)

The LEV volumetric flow rate in the AAS room has met the requirements in accordance with the recommended tool specifications, namely 600 – 1,200 m3/hour especially at the volumetric flow rate at the fan output, which was 626.59 m3/hour (Hitachi, 2013). It was different from inlet volumetric flow rate which was only 494.75 m3/hour since the inlet hole was only 12 cm so that volumetric flow rate does not match tool specifications with a minimum of 600 m3/hour. The inlet volumetric flow rate has decreased into 78.96% (decreased by 21.04%) from the outlet volumetric flow rate. A decrease in the volumetric LEV flow rate can be categorized within a reasonable limit. This decrease in volumetric flow rate is acceptable and is in accordance with previous research which stated that there was a decrease between the inlet volumetric flow rate and the outlet volumetric flow rate with an average of 25% of the fan outlet flow (Aydin and Ozerdem, 2006; Rastani *et al*., 2016).

However, if it is calculated with normal volumetric flow rate in accordance with the tool specifications, the volumetric flow rate is still in line with the standard tool specifications because it only decreased by 17.54% (82.46% from the standard capability) (Hitachi, 2013). The inlet diameter of only 12 cm compared to an outlet diameter of 14 cm can cause disrupted streamline flow. The inlet diameter can be enlarged to minimize the disturbed airflow rate. Changes to the LEV component should still measure the flow velocity so that the objectives of the change are achieved (Ziganshin, Logachev and Batrova, 2021).

In addition, the standard for Ventilation Requirements for Laboratory-Type Hood Operations affirms that there must be an alarm detection instrument if the flow velocity drops to less than 80% (decreased by more than 20%) (OSHA, 2008). Corrective actions must be taken immediately if the flow velocity decreases to less than 80% of the normal flow velocity capacity according to the tool specifications. Volumetric flow rate that drops to less than 80% can have the potential for contaminants to not be properly channeled to the outlet pump. Contaminants that are not properly channeled to the outlet pump can potentially contaminate the air in the workplace because the volumetric flow rate in the LEV system is less than the standard flow rate (Zhivov *et al*., 2001).

The LEV system in the AAS room did not have an indicator for the flow velocity, either using an anemometer or using a manometer (an instrument to measure pressure differences). Therefore, it is expected that there will be an instrument to monitor LEV performance, especially in the flow velocity from the inlet to the outlet of the LEV system (Health and Safety Authority Ireland (HSAI), 2014; Y. Liu *et al*., 2019).

Maintenance of Local Exhaust Ventilation

Based on the results of study of both sources, namely from secondary data and from interviews with one of the analysts, there was no LEV maintenance procedure in the Hitachi ZA3000 type AAS device. Maintenance can be conducted in the form of monitoring, checking and maintaining the LEV system starting from the inlet hood to the outer outlet (Rastani *et al*., 2016; Al-dahhan, Ali and Yousif, 2017).

Evaluation of the quality and quantity of LEV should be evaluated at the time of installation, monitored regularly (at least every 3 months), and re-evaluated whenever there is a change in the LEV system(Gupta, 2013). The maintenance procedure of local exhaust ventilation should be established to prevent any obstructions, abrasions, leaks, imbalance of system ducts and inefficiency in some branches. The maintenance implementation must be scheduled with regular and appropriate maintenance (Rastani *et al*., 2016)

CONCLUSION

The conditions of the Local Exhaust Ventilations (LEVs), in terms of the design, type and material of each component such as the hood, ducting system and pump machine as well as the fan, are already in accordance with the tool specifications and standards. However, the LEV system has not installed an air cleaner. The results of the measurement show that the flow velocity in the LEV system has met the standard of10 m/s with the danger of fume contaminants. In fact, its volumetric flow rate has decreased by more than 20%. Henceforth, laboratory management is advised to consider installing an air cleaner on the LEV system installed in the Hitachi AAS so that contaminants released in the air are cleaner and more environmentally friendly.

ACKNOWLEDGEMENTS

This study was fully funded by the author because this research was conducted independently. The highest form of praise and gratitude is given to the God Almighty, and a very special gratitude is also given to UPT K2 Surabaya which has facilitated the accomplishment of this research.

REFERENCES

ACGIH (1998) Industrial Ventilation 20th Edition of recommended practice, Acgih. Ohio, Amerika Serikat: ACGIH Publisher.

ACGIH (2010) Industrial Ventilation 27th Edition. 27 th. Cincinnati, Ohio: ACGIH.

Al-dahhan, W. H., Ali, A. A. and Yousif, E. (2017) 'Lack of Maintenance in a Chemical Laboratory has Almost Caused an Accident', *Open Access Journal of Chemistry,* 1(1), pp. 63–66.

ANSI (2011) American National Standard Product Safety Signs and Labels. ANSI Publisher.

ASHRAE (2016) ASHRAE Handbook—HVAC Systems and Equipment. Edited by M. S. Owen. ASHRAE.

Aydin, C. and Ozerdem, B. (2006) 'Air Leakage Measurement and Analysis in Duct Systems', *Energy and Buildings*, 38(3), pp. 207–213.

Cahyaningrum, D., Sari, H. and Iswandari, D. (2019) 'Faktor-Faktor yang Berhubungan dengan Kejadian Kecelakaan Kerja di Laboratorium Pendidikan', *Jurnal Pengelolaan Laboratorium Pendidikan*, 1(2), pp. 2654–251.

Cincinelli, A. and Martellini, T. (2017) 'Indoor Air Quality and Health', *International Journal of Environmental Research and Public Health*, 14(11), p. 1286.

Dankis, N. D. V. and Mulyono, M. (2015) 'Risk Assessment Perusahaan Export Sepatu Pada Bagian Line Upper PT. X', *The Indonesian Journal of Occupational Safety and Health*, 4(1), pp. 22-32.

Gunner, A., Afshari, A. and Bergsøe, N. C. (2015) 'Evaluation of Reversed Airflow in A Ventilation System with Multiple Fans', *Energy and Buildings*, 108(2015), pp. 413–419.

Gupta, J. P. (2013) Laboratory Ventilation Codes and Standards. Siemens Industry, Inc.

Health and Safety Authority Ireland (HSAI) (2014) 'Our vision : A country where worker safety , health and welfare', p. 69.

Hitachi (2013) 'Hitachi Polarized Zeeman Atomic Absorption Spectrophotometer ZA3000 Series', pp. 1–16.

Imam Masturoh, N. A. T. (2018) Metodologi Penelitian Kesehatan. First Edit, Kementrian Kesehatan Republik Indonesia. First Edit. Jakarta: Badan Pengembangan dan Pemberdayaan Sumber Daya Manusia Kesehatan, Kementrian Kesehatan RI.

Kementrian Tenaga Kerja (2018) 'Peraturan Menteri Tenaga Kerja Republik Indonesia nomor 5 Tahun 2018 Keselamatan dan Kesehatan Kerja Lingkungan Kerja'. Kementrian Tenaga Kerja, pp. 200–207.

Lees, F. (2012) 'Chapter 25 : Personal Safety', in Mannan, S. (ed.) Lees' Loss Prevention in the Process Industries. Texas: Elsevier, pp. 2108–2144.

Lestari, F. *et al*. (2019) 'Evaluation of the Implementation of Occupational Health, Safety, and environment Management Systems in Higher Education Laboratories', *Journal of Chemical Health and Safety*, 26(4–5), pp. 14–19.

Li, A., Zhang, W. and Gao, M. (2017) 'Field Test and CFD Modeling for Flow Characteristics in Central Cooking Exhaust Shaft of A High-Rise Residential Building', *Energy and Buildings*, 147, pp. 210–223.

Liu, J. *et al*. (2019) 'Performance Analysis of A Ductless Personalized Ventilation Combined with Radiant Floor Cooling System and Displacement Ventilation', *Building Simulation*, 12(5), pp. 905–919.

Liu, W., Liu, D. and Gao, N. (2017) 'CFD Study on Gaseous Pollutant Transmission Characteristics Under Different Ventilation Strategies in A Typical Chemical Laboratory', *Building and Environment*, 126, pp. 238–251.

Liu, Y. *et al*. (2019) 'Ventilation Optimization for Reduction of Indoor Air Temperature of Main Transformer Room in Urban Indoor Substation by the Variational Method', *Journal of Thermal Science*, 28(5), pp. 1089–1101.

NIH (National Institutes Health) (2011) Local Exhaust Ventilation Testing Protocols. Maryland: NIH Publisher.

Olander, L. *et al*. (2001) 'Local Ventilation', *Industrial Ventilation Design Guidebook*, pp. 807–1023.

OSHA (2008) Ventilation Requirements for Laboratory-Type Hood Operations.

Pei, J. *et al*. (2020) 'Laboratory and Field Investigation of Portable Air Cleaners' Long-term Performance for Particle Removal to be Published in: Building and Environment', *Building and Environment*, 181(February).

Pei, J. and Ji, L. (2018) 'Secondary VOCs Emission from used Fibrous Filters in Portable Air Cleaners and Ventilation Systems', *Building and Environment*, 142(March), pp. 464–471.

Pemerintah Provinsi Jawa Timur (2018) 'Peraturan Gubernur 62 Tahun 2018 Tentang Nomenklatur, Susunan Organisasi, Uraian Tugas dan Fungsi serta Tata Kerja Unit Pelaksana Teknis Dinas Tenaga Kerja dan Transmigrasi Provinsi Jawa Timur', Biro Hukum Provinsi Jawa TImur. Surabaya, Jawa Timur: Biro Hukum dan Organisasi Provinsi Jawa Timur.

Rahmantiyoko, A., Sunarmi, S. and Rahmah, F. K. (2019) 'Keselamatan Dan Keamanan Kerja Laboratorium', *IPTEK Journal of Proceedings Series*, 0(4), pp. 36–38.

Ramli, S. (2010) Pedoman praktis manajemen risiko dalam perspektif K3 : OHS risk management. Edited by K. P. Husjain Djajaningrat, Risa Praptono ; Ilustrasi. Jakarta: Dian Rakyat.

Rastani, M. J. *et al*. (2016) 'Evaluation of Local Exhaust Ventilation System Performance for Control of Fe_2O_3 Dust at an Iron making Unit', *Journal of Health and Safety at Work*, 6(2), pp. 43–56.

Reis, L., Duarte, E. and Rebelo, F. (2015) 'Research on Workplace Safety Sign Compliance: Validation of a Virtual Environment Prototype', *Procedia Manufacturing*, 3(Ahfe), pp. 6599–6606.

Republik Indonesia (1970) 'Undang - Undang no. 1 Tahun 1970 Tentang Keselamatan Kerja'. Jakarta: Biro Hukum Sekretaris Jendral, Kementrian Tenaga Kerja, pp. 1689–1699.

Tarwaka and Bakri, S. H. A. (2004) *Ergonomi untuk Keselamatan, Kesehatan Kerja dan Produktivitas*. First. Surakarta: UNIBA Press.

Zdilla, M. J. (2020) 'Local Exhaust Ventilation Systems for the Gross Anatomy Laboratory', *Morphologie*, 105(350), pp. 237-246 .

Zhivov, A. *et al*. (2001) 'Principles of Air and Contaminant Movement Inside and Around

Buildings', *Industrial Ventilation Design Guidebook*, pp. 415–599.

Zhou, S. *et al*. (2021) 'Research on Blade Design Method of Multi-Blade Centrifugal Fan for Building Efficient Ventilation based on Hicks-Henne Function', *Sustainable Energy Technologies and Assessments*, 43(February). pp. 1-13.

Zhu, S. *et al*. (2020) 'Ventilation and Laboratory Confirmed Acute Respiratory Infection (ARI) Rates in College Residence Halls in College Park, Maryland', *Environment International*, 137, pp. 1-15

Ziganshin, A., Logachev, K. and Batrova, K. (2021) 'Reducing the Drag of Midpoint Lateral Orifices of Exhaust Air Ducts by Shaping them along Vortex Zone Outlines', *Building and Environment*, 188, pp. 1-12