Malaysian Journal Of Applied Sciences 2024, Vol 9(1): 28-36
E-ISSN:0127-9246 (Online)
http://dx.doi.org/10.37231/myjas.2024.9.1.382
https://journal.unisza.edu.my/myjas

PENERBIT
Universiti Sultan Zainal Abidin

MALAYSIAN JOURNAL OF APPLIED SCIENCES
eISSN:0127-9246

ORIGINAL ARTICLE

Simple and Low-Cost Visual Inspection of Engineering Control in Science Laboratories

Ahmad Nazib Alias[1], Rosmawati Abdul Aziz[1], Nurul Amni Abdullah[1], M. Syukri Suhaimi[1], Zubainun Mohamed Zabidi[1]

[1]Faculty of Applied Sciences, Universiti Teknologi MARA, Perak Branch, Tapah Campus, 35400 Tapah, Malaysia

*Corresponding author: ahmadnazib111@uitm.edu.my

Received: 31/10/2023, Accepted: 29/04/2024, Available Online: 30/04/2024

Abstract

To control chemical hazard, engineering control is one of the Hierarchy of Controls that protects workers from chemical hazard. Engineering control is accomplished by removing hazardous conditions by placing a barrier between the worker and the hazard. Local ventilation system is widely used in laboratories to remove any chemical agents that are released from any chemical reactions. The importance of these ventilation systems is to prevent any health complications to persons in the laboratory due to chemical exposure. İn this paper, the effects and effectiveness of sash height to vapor source position to effectiveness of local exhaust ventilation (LEV) system were studied and identified using vapor flow from the stimulated carbon dioxide (CO_2) and water vapor. Eight LEVs were inspected. The stimulated vapor as a tracer was produced by mixing dry ice into hot-boiled water (100 ºC). The dispersion stimulated CO_2 and water vapor inside and outside the LEV system, and this can predict the efficiency of LEV systems based on visual inspection. The results revealed that each LEV showed a different time taken to draw out the vapor from the inside of the fume hood box

Keywords: Engineering control, Local Exhaust Ventilation (LEV), Maintenance, Safety and health

Introduction

Chemical laboratory is designed to ensure a safe condition for users who are working in the laboratory. Therefore, controlling exposures to chemical hazards and toxic substances is an essential method to protect users in the laboratory. In occupational health and safety, hierarchy of controls is a system used to minimize or eliminate exposure to hazards as far as practicable(Bai et al., 2022). If a hazard cannot be eliminated or substituted, the next approach is to use engineering control to keep the hazards off a laboratory. Engineering control is one of the hierarchy of controls that protects workers from chemical hazards. It is used to reduce or remove the exposure to chemical hazards through equipment or devices. The best engineering control approach is to use a minimum user input which does not rely on the skills or vigilance of individuals(Samaranayake et al., 2022). The example of engineering control is the use of general ventilation, local exhaust ventilation (LEV), glove box, biosafety cabinet, chemical storage cabinet, gas cabinet, laminar beach flow, and shielding for radiation(Mehmood et al., 2022; Zdilla, 2021).

The safety operation on engineering control depends on designing a safe experiment, setting up the right instrument for a safe operation inside the laboratory hood, and maintaining a schedule for engineering control(Chen et al., 2020; Huang et al., 2018). In Malaysia, the Occupational Safety and Health Act (OSHA) 1994 stipulates that the employer shall take action to control health-hazardous chemicals as far as practicable. Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) 2000 requires the employers to inspect or maintain the engineering control for each interval, not exceedingly more than one month ((DOSH), 2000). The registered Hygiene Technician (II) under the Department of Occupational Safety and Health (DOSH) shall examine and test the effectiveness of engineering control in each interval, not exceedingly more than one year. The problem is within a month, what should the laboratory or Hygiene assistance needs to do to ensure that the engineering control is working properly? Within a year, if the engineering control is not maintained properly, there might be a failure of engineering control which can harm the laboratory users.

Immediate action must be informed to the employer to ensure that the chemical exposure to the employees can be controlled. Therefore, this paper emphasizes that there is a need to organize a systematic, simple, and effective inspection within the interval not exceedingly more than one (1) month. The visual observation and inspection of the Local Exhaust Ventilation (LEV) was conducted using dry ice vapour, whereby the flow of the dry ice vapour gets sucked by the fume hood and the chemical storage cabinet fan. This technique is simple and cost effective for the purpose of inspecting any engineering control defects.

Methods

Fume Hood Design

The fume hood equipment was designed and installed by professional engineers and contractors by Wajalab Laboratory system. The fume hoods were expected to mandatorily satisfy the size and requirement to conduct the experiment in the teaching and learning process in the institution. Fig. 1(a) shows the dimensions and design of the fume hood in the location under investigation. While Fig. 1(b) shows the dimensions for the fume hood's sash. The minimum opening sash area is 0.10 m x 1.24 m. According to Hygiene Technical Report, the maximum safe limit of sash opening is 0.34 m x 1.24 m(Ramli, 2016).

Every fume hood is connected to the ducting system, draft fan and stack. The fume hoods are labelled H1 – H8, indicated by the location in the chemical and biological laboratories in Universiti Teknologi MARA Tapah Campus, in different building blocks, as tabulated in table 1. In biological laboratories, the usage of chemicals during experiments involving acids and alcohol require fume hood placements.

Table 1. Location of Fume Hood

Location	Biologi Am 1	Biologi Am 2	Biologi Haiwan 1	Biologi Haiwan 2	Biologi Molekul	Biologi Tumbuhan	Kimia Organik 1	Kimia Analisis 2
Label	H1	H2	H3	H4	H5	H6	H7	H8

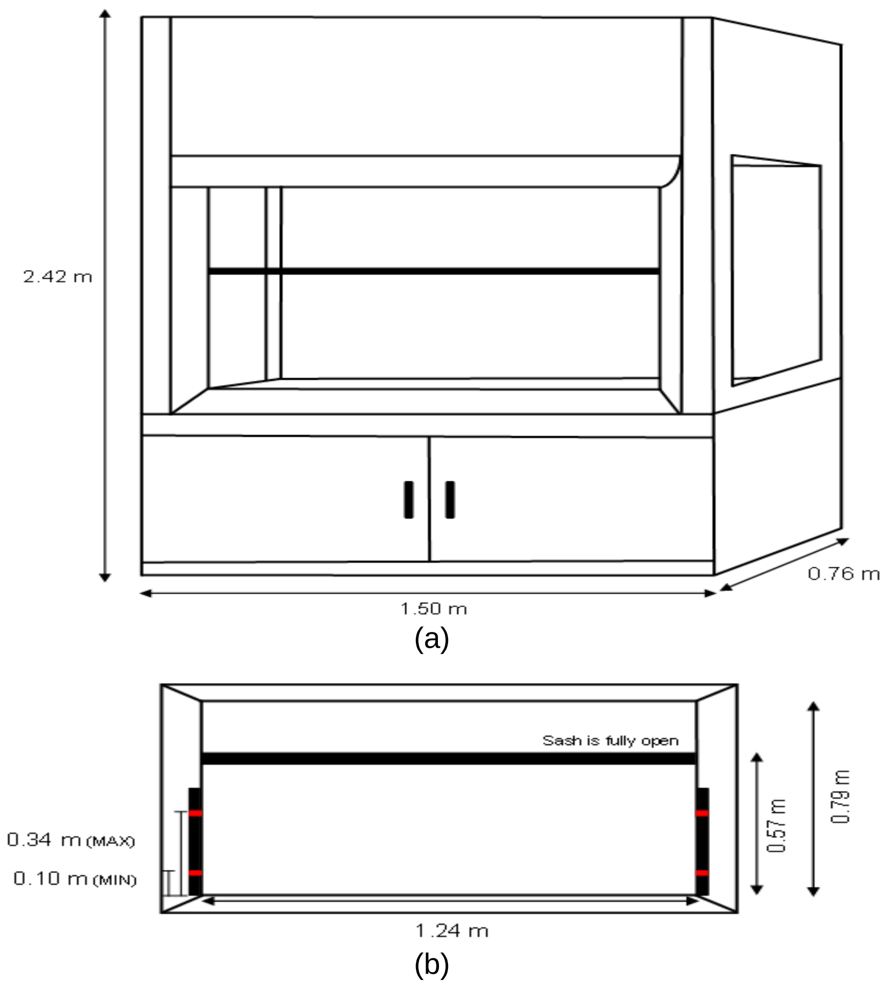


Figure 1. (a) The Dimension of Fume Hood, (b) The Opening of Fume Hood Sash (Side View)

Visual Inspection from Stimulated Fog

Eight (8) fume hoods were involved in this inspection. Each fume hood was located at different laboratory locations. Three (3) petri dishes were set up with the same distance (0.30 m) in the fume hood. Hot boiled water (100ºC) was poured into each petri dish. Then, dry ice (15±0.2g) was poured simultaneously in the three petri dishes. The fog motion and time taken was recorded using digital stopwatch and smartphone camera.

The dry ice was poured into the hot water to stimulate CO_2 and water vapor in the fume hood(Ahn et al., 2016). The method was repeated with different maximum and minimum sash height of the fume hood, and in different conditions of the fume hood being turned on or turned off. The same procedure was repeated outside the fume hood. The observation was done when the fume hood fan was turned off. Similarly, the petri dishes containing dry ice were also placed outside the fume hood at the same level of the minimum sash opening.

Result and Discussion

Stimulated Fog from the Inside of Fume Hood

Table 2 shows the time taken by the dry ice to start vaporizing when it was put into the hot boiled water at different locations. This was proceeded simultaneously inside the fume hood until the vapor was completely vaporized by the surroundings or sucked in by LEV hood. The results show that the time taken for the maximum opening took a longer time compared to the sash's minimum opening for all fume hoods.

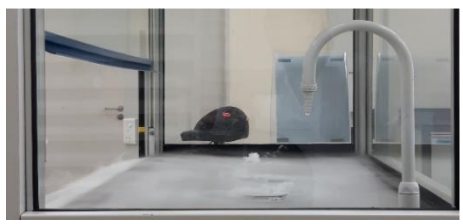
Table 2. The Time Taken for the Dry Ice to Completely Vaporized at Different Locations

Laboratory / Fume hood		Time Taken (min)							
		H1	H2	H3	H4	H5	H6	H7	H8
Condition	**Level of Sash(cm)**								
On	**10.0 Minimum**	5.18	4.57	4.42	4.45	6.47	6.13	4.47	5.00
	34.2 Maximum	8.57	5.37	7.35	8.17	6.57	6.28	7.12	5.44
Off	**10.0 Minimum**	5.48	5.40	4.26	9.55	4.21	5.19	6.31	5.06
	34.2 Maximum	7.45	4.55	3.58	3.26	4.17	4.39	5.21	4.56

Table 3 shows the visual observation for fume hood in H6 with maximum and minimum sash opening. As the fume hood was turned on, the vapor suction was faster for the minimum opening compared to the maximum opening. The vapors spread upward into the ducting system.

Table 3. Visual Observation of Fume Hood for H6

Condition of the Fume Hood	Level of Sash (cm)	Visual Observation	Explanation
ON	10.0 Minimum	 	• The vapors were sucked into the duct system. • For the middle petri dish, the vapors were seen to be spreading at the fume hood's front and side areas. The vapors also moved upwards into the ducting system. The vapors from the other petri dishes were spreading to the fume hood's edge (left and right).

	34.2 Maximum	 	• The vapors sucked into the duct pipe were slower compared to the height of the sash at minimum level. • The vapors from all petri dishes were spreading to the side and front areas of the fume hood. The vapors were also seen to be spreading around the petri dishes. The vapors did not spread evenly.
OFF	10.0 Minimum		• The vapors immediately moved out from the fume hood.
	34.2 Maximum		• The vapors were seen to be spreading all over the fume hood's platform before moving out from the fume hood.

Stimulated Fog from the Outside of Fume Hood

Table 4 tabulates the time taken by the dry ice to start vaporizing as it was put into the hot water simultaneously outside the fume hood. The vapor spread out into the surrounding and into the fume hood. Table 5 shows the visual observation for H6 with maximum and minimum sash opening.

Table 4. Time Taken for the Dry Ice to Vaporize from the Outside of Fume Hood at Different Locations

Laboratory / Fume hood		Time Taken (min)							
		H1	H2	H3	H4	H5	H6	H7	H8
Condition	Level of Sash(cm)								
On	10.0 Minimum	6.00	5.43	6.03	5.27	5.16	6.09	4.48	4.42
	34.2 Maximum	7.46	4.55	5.24	3.38	4.22	4.13	5.17	5.46

In this research, the stimulated CO_2 and water vapor were used to observe the efficiency of Local Exhaust Ventilation (LEV) system at laboratories. The efficiency of LEV was determined based on the visualization inspection of the flow of the stimulated CO_2 and water vapors. The time taken for the vapors to disperse completely was observed using a digital stopwatch. Based on the results, when the source was placed inside the fume hood under ON condition and the sash at the lowest height, the fume hood at H3 recorded the shortest time for the vapors to completely disperse (4.42 minutes). H3 recorded the longest time of 6.47 minutes. As for the sash at maximum height of the same condition, fume hood for H2 Laboratory recorded the shortest time of 5.37 minutes. However, H1 Laboratory recorded ther longest time of 8.57 minutes for the vapors to completely disperse.

Table 5. Visual Observation of Fume Hood for H6

Condition of the Fume Hood	Level of Sash(cm)	Visual Observation	Explanation
ON	10.0 Minimum		• The vapors took 18 seconds to flow into the fume hood. • More vapors spread into the surroundings. Only a few vapors were observed to be flowing into the fume hood.
	34.2 Maximum		• The vapors took 6 seconds to flow into the fume hood. • The vapors were observed to be clearly flowing into the fume hood and ducting system.

Based on the visualization of the flow of the dry ice vapors, the vapors sucked by the ducting pipe were faster compared to the sash at minimum level (Omar et al., 2014). Meanwhile, it was a bit slower for when the sash at maximum level. The vapors did not spread evenly. Some of the vapors were seen to be spreading around the petri dishes and moving outside of the fume hood. The vapors were also observed to be sucked into the ducting system. Based on these inspections, the most efficient LEV took place when the sash was placed at its minimum level.

However, the vapor flows for both sash levels were considered unusual as they dispersed towards the side and front screen of the fume hood, instead of going straight into the ducting pipe – showing that both fume hoods were not in good condition. This could have happened because of the lack of maintenance, resulting to dust accumulation on the fan's top area, or the presence of reverse flow region that depends on sash level(Shu et al., 2022; Zhao & You, 2020).

The fume hood under OFF condition with the sash at the lowest height showed the fume hood in H5 recording the shortest time taken, which was 4.21 minutes. H4 recorded the longest time of 8.55 minutes – perhaps due to the general ventilation effect in the laboratory that created pressure into the fume hood, making H4 to take the longest time(Kee-Chiang et al., 2008). These results match with the stimulated fog from the outside of the fume hood, which H4 had a faster vaporization at maximum sash level. The visual inspection shows that for the minimum level of sash, the vapors were immediately being sucked out into the ducting system.

At the maximum level, the vapors were seen to be spreading and accumulating in the fume hood before flowing into the ducting system. This could be due to the outer pressure that was lower than the fume hood's inner pressure. This observation shows that any chemicals that are volatile and hazardous must be used under excellent-performing fume hoods to avoid accidents or chemical exposures to the users. The accumulation of highly reactive and volatile materials can also cause a worse scenario like fume hood explosion(Al-Dahhan et al., 2016).

When the stimulated CO_2 and water vapor were placed outside the fume hood sash, the minimum height at H8 recorded the shortest time of 4.42 minutes. Whereas H6 recorded the longest time of 6.09 minutes for the vapors to completely disperse. The maximum height sash at H4 recorded the shortest time of 3.38 minutes. While the longest time was recorded for H1 at 7.46 minutes for the vapors to disperse completely. For the visual inspection of sash at minimum level, some of the vapors flowed inside the fume hood and dispersed into the surrounding. The suction of vapors into the fume hood was generally fast. A visual inspection alone will not suffice, as there is a need for further study in other technical aspects to indicate whether the vapor-sucking periods followed the current fume hood standard.

Contrarywise for sash at maximum level, the suction of vapors into the fume hood was slower and weaker – perhaps due to the efficiency of the fan used being interrupted by the low suction pressure that occurred, due to the big opening of the sash(Pinelli & Suman, 2014). This made the air flow at different sash opening levels to be different. Besides that, the amount of vapors that dispersed into the surrounding were greater compared to the vapor flowing into the fume hood at the minimum level of sash. Therefore, it can be said the LEV worked more efficiently when the sash was at the minimum level.

Conclusion

In conclusion, the effect and effectiveness of sash height to vapor source position, to the effectiveness of local exhaust ventilation system was investigated in this study. Besides, the stimulated CO_2 and water vapor in the local exhaust ventilation were identified using the dispersion and the vapor flow via smartphone visualization.

At the minimum sash opening, H3 showed a faster vapor suction when the fan was turned on and off. However, there is a need for a further study in the technical aspects, to indicate whether the vapor-sucking periods were compliant to the current fume hood standard.

Acknowledgments

The authors would like to thank Faculty of Applied Sciences, UiTM Perak Branch (Tapah Campus) for supporting this project financially and technically. Appreciation to Maisarah, Nur Farah Dini, Fatin Najwa and Nabila for their assistance in recording the vapor flow in the fume hood.

References

Ahn, K., Ellenbecker, M. J., Woskie, S. R., & DiBerardinis, L. J. (2016). A new quantitative method for testing performance of in-use laboratory chemical fume hoods. *Journal of Chemical Health & Safety*, *23*(4), 32-37. https://doi.org/10.1016/j.jchas.2015.10.021

Al-Dahhan, W. H., Al-Zuhairi, A. J., Hussein, F. H., Rodda, K. E., & Yousif, E. (2016). Laboratory biological safety cabinet (BSC) explosion. *Karbala International Journal of Modern Science*, *2*(4), 276-279. https://doi.org/https://doi.org/10.1016/j.kijoms.2016.11.001

Bai, M., Liu, Y., Qi, M., Roy, N., Shu, C.-M., Khan, F., & Zhao, D. (2022). Current status, challenges, and future directions of university laboratory safety in China. *Journal of Loss Prevention in the Process Industries*, *74*, 104671. https://doi.org/https://doi.org/10.1016/j.jlp.2021.104671

Chen, K., Wang, W., & Zhang, W. (2020). Investigation of influential factors on laboratory fume hood containment performance. *Science and Technology for the Built Environment*, *26*(3), 387-399. https://doi.org/10.1080/23744731.2019.1637192

DOSH (2000). *Occupational Safety and Health (Use and Standard of Exposure of Chemicals Hazardous to Health) Regulations*. `

Huang, R. F., Hsu, C. M., & Lin, K. L. (2018). Influence of high heat load on flow and containment of an inclined air-curtain (IAC) fume hood. *Journal of Occupational and Environmental Hygiene*, *15*(4), 322-333. https://doi.org/10.1080/15459624.2018.1428330

Kee-Chiang, C., Kuo-Pao, T., & You-Hsuan, W. (2008). Performance of Local Ventilated Hood in a General Ventilation Working Environment. *ASHRAE Transactions*, *114*(1).

Mehmood, T., Liu, C., Gaurav, G. K., Haider, F. U., Bibi, R., Usman, M., Mustafa, B., Liu, J., Ejaz, M., & Arslan, F. (2022). Chapter 8 - Toxicity and related engineering and biological controls. In D. Yadav, P. Kumar, P. Singh, & D. A. Vallero (Eds.), *Hazardous Waste Management* (pp. 185-215). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-12-824344-2.00018-5

Omar, M. A. A., Wisnoe, W., & Bakri, A. (2014). Effect of Baffle Openings to the Flow Distribution in a SERVCO Fume Cupboard. *Applied Mechanics and Materials*, *660*, 719-723. https://doi.org/10.4028/www.scientific.net/AMM.660.719

Pinelli, M., & Suman, A. (2014). A numerical method for the efficient design of free opening hoods in industrial and domestic applications. *Energy*, *74*, 484-493. https://doi.org/https://doi.org/10.1016/j.energy.2014.07.014

Ramli, M. N. (2016). *Report on Hygiene Technician II, JKKP HIE 127/171-2 (161)*.

Samaranayake, A. I., Nishadya, S., & Jayasundara, U. K. (2022). Analyzing Safety Culture in Sri Lankan Industrial Chemical Laboratories. *Safety and Health at Work*, *13*(1), 86-92. https://doi.org/https://doi.org/10.1016/j.shaw.2021.11.001

Shu, L., Fang, L., Grønbæk, H., Bendtsen, J., & Olesen, B. W. (2022). Measurement of particle removal performance for a novel design of range hood. E3S Web of Conferences,

Zdilla, M. J. (2021). Local exhaust ventilation systems for the gross anatomy laboratory. *Morphologie*, *105*(350), 237-246. https://doi.org/https://doi.org/10.1016/j.morpho.2020.11.002

Zhao, D., & You, X.-y. (2020). Inverse design optimisation of a novel range hood based on intelligent algorithms and computational fluid dynamics simulations. *Advanced Powder Technology*, *31*(2), 730-745. https://doi.org/https://doi.org/10.1016/j.apt.2019.11.028

How to cite this paper:
Alias, A. N., Abdul Aziz, R., Abdullah, N. A., Suhaimi, M. S., Mohamed Zabidi, Z. (2024). Simple and Low-Cost Visual Inspection of Engineering Control in Science Laboratories. *Malaysian Journal of Applied Sciences, 9(*1), 28-36.