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Original Article

Effectiveness of Cadaver Tables with Local Exhaust Ventilation in Reducing Formaldehyde Levels

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Abstract

Formaldehyde, which is exposure in the workplace, is very dangerous for health, especially for students, staff and lecturers in the anatomy laboratory room. Cadaver tables with local exhaust ventilation (LEV) in previous studies were used to reduce formaldehyde levels in the anatomy room. This study aimed to determine the effectiveness of a cadaver table with local exhaust ventilation to reduce formaldehyde exposure. Using a pre-post study, this study showed that a cadaver table with local exhaust ventilation can reduce formaldehyde exposure significantly ($p<0.001$) with a confidence interval of 2.715–2.186. The percentage reduction in formaldehyde levels at each measurement point was 31% - 89% (min-max). This showed that the cadaver table with LEV was effective in reducing formaldehyde levels.

Keywords: *cadaver table, formaldehyde, local exhaust ventilation, anatomy laboratory*

Introduction

Hazardous substances in the workplace can be controlled by considering the hierarchy of control measures. Elimination and substitution should be considered from starting itself. If this option is not possible, exposure which is controlled by technical; and local exhaust ventilation may be an option as an engineering control measure (Health and Safety Authority Ireland (HSAI), 2014) (Zdilla, 2022). Air quality in enclosed work areas is an important issue for workers' health to be able to work 8 hours per day and 40 hours per week (Zdilla, 2021). Eliminating the exposure at the source using local exhaust ventilation is the best option for reducing hazardous substances (Sinnige *et al.*, 2021). Local exhaust ventilation is designed to remove contaminants at the source before they spread throughout the workspace (Allison *et al.*, 2022; Ruschena, 2012; Sinnige *et al.* 2021).

Formaldehyde is a colorless, highly flammable gas that is sold commercially as 30– 50% (by weight) aqueous solutions (Liteplo *et al.*, 2002). The World Health Organization (WHO) set indoor air quality guidelines for short-term and long-term exposure to formaldehyde in 2010 of 0.1 mg/m3 (0.08 ppm) for all 30-minute periods of lifetime exposure (Nielsen, Larsen and Wolkoff, 2013) (Nielsen, Larsen and Wolkoff, 2017). According to Asgharian research, a mechanistic model was developed to study air formaldehyde uptake and transport to surrounding lung tissue at 1 mg/m3 in humans. Ignoring the rubbing effect of the nasal and oral tissues, it was estimated that formaldehyde would be absorbed very rapidly (~97%) by the mucous membrane in the trachea so that no formaldehyde would pass through. Thus, no formaldehyde will reach the lower airways (Asgharian *et al.*, 2012). It enters the

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body through the breath or when it meets the skin. It is easily absorbed from the nose and upper part of the lungs (Nisa *et al.*, 2016).

Anatomy laboratory reports in Medical School, that it needs one drum (200 liters) of formalin every year. Until 2021, there are 64 medical faculties registered in Indonesia (BAN-PT, 2021). If they need an average of one drum of formalin 37% (200 liters) annually, then the total amount of formalin needed for anatomy laboratories from all medical faculties in Indonesia is 12,800 liters per year. Likewise, the use of formalin in hospitals is for embalming, in anatomical pathology laboratories for as a tissue preservative. However, the amount of use is unknown in the faculty of veterinary medicine.

Formalin is a binder solution to preserve cadaver (Azari and Asadi, 2012). Formaldehyde evaporation from cadavers, which is embalming fluid, can have a negative impact on the health of medical students and instructors (Nisa *et al.*, 2016). Students and lecturers are exposed to formaldehyde during anatomy learning (Kunugita *et al.*, 2004) (Abdullahi *et al.*, 2014). A study of Buccal Epithelial Exfoliated Cells (BEC) in students exposed to formaldehyde during anatomy class showed that formaldehyde induces mutagenicity during anatomy class. Efforts should be made to reduce the risk of exposure by improving air quality and reducing exposure during anatomy classes (Lorenzoni *et al.*, 2017).

Short-term exposure to this pungent-smelling formaldehyde causes eye, nose, and throat irritation at levels up to 5 ppm. At levels of 10 to 20 ppm, it causes coughing, chest tightness, and an unusual heartbeat; and from 50 to 100 ppm, fluid in the lungs, is followed by death. Prolonged exposure to formaldehyde can also cause cancer (CDC and NIOSH, 2014).

According to NIOSH, designed and evaluated a local exhaust ventilation [LEV] system that effectively reduces embalming formaldehyde exposure below the OSHA permissible limit of 0.75 ppm, as a time-weighted average exposure of 8 hours (CDC and NIOSH, 2014).

Various approaches have been suggested to control exposure, including good work practices, alternative embalming agents/formulations, personal protective equipment, dilution ventilation, and local exhaust. Of all the proposed methods, only local exhaust ventilation combined with good work practices can show promise in controlling formaldehyde exposure in the laboratory for normal functioning (Adamović *et al.*, 2021; Demer and Notary 1999).

Researchers are very interested in measuring the effectiveness of a cadaver table design with local ventilation that can reduce formaldehyde from the cadaver. The effectiveness of this cadaver table's function in reducing formaldehyde levels to improve health and safety in the laboratory.

Local Exhaust Ventilation (LEV) is primarily intended to capture contaminants at specific points of release into the workspace air through the use of exhaust hoods, covers, or similar assemblies. LEV is suitable for stationary point source control of contaminant release. It is important to ensure proper selection, maintenance, placement and operation of the LEV system to ensure its effectiveness (Ruschena, 2012).

In preventing exposure to hazardous substances in the workplace such as formaldehyde in the anatomy laboratory, there is a hierarchy of control measures that must be considered. The principle of control measures begins with the elimination or replacement of the hazard (substitution), if this option is not possible, the hazard must be controlled by technical means. Local exhaust ventilation (LEV) is one such engineering control measure (HSAI, 2014).

Exposure controls are used to protect workers from potentially hazardous exposure to hazardous workplace chemicals, physical or biological agents. Order of priority in control measures: elimination, substitution, engineering controls, administrative controls and appropriate work practices, and use of protective clothing and equipment (CDC and NIOSH, 2013; HSAI, 2014).

This study aims to determine the effectiveness of a cadaver table with local exhaust ventilation to reduce formaldehyde exposure in the anatomy laboratory of the medical faculty of Y University, Jakarta, Indonesia.

Methods and Variables

The research carried out by the author, in this case, was to determine the effectiveness of a cadaver table with local exhaust ventilation in reducing formaldehyde levels in the anatomy laboratory, Faculty of Medicine, Y University Jakarta, with the aim of reducing the spread of formaldehyde from the source. This research is critical for the safety and health of staff and students, as formaldehyde is a dangerous irritant. Formaldehyde also causes cancer, especially throat cancer.

This study used a pre-post-study experimental design to measure formaldehyde exposure. Measurements were made before the suction of the LEV on the cadaver table was turned on and when the LEV on the cadaver table was turned on. The independent variable in this study was a cadaver table with local exhaust ventilation. The dependent variable in this study was the decreased formaldehyde levels in the cadaver table.

In this study, data on formaldehyde levels taken in the anatomy laboratory were grouped into three, non-suction, suction and non-cadaver data.

'Non-suction' data means this data was taken when the cadaver was placed on the cadaver table, but the suction machine was not turned on. Data 'with suction' means this data was taken when the cadaver was placed on the cadaver table and the suction machine was turned on constantly. 'Non-cadaver' data means this data is taken when the cadaver table is empty (no cadaver).

The cadaver table with local exhaust ventilation used is a table that has been carried out in previous research (see Fig. 1).

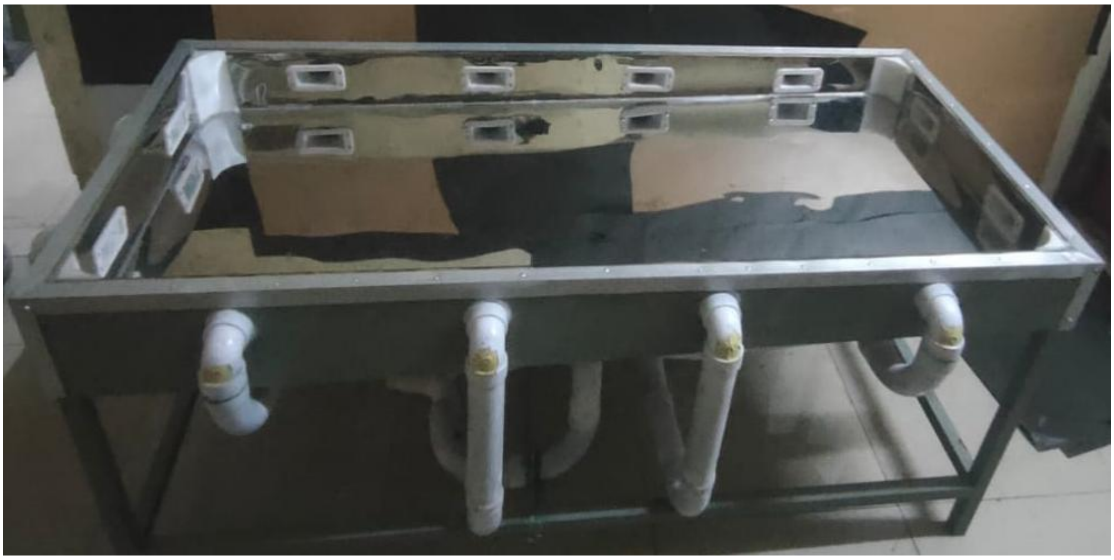

Fig.1 Cadaver Table with Local Exhaust Ventilation

Data Collection Method

This data collection was carried out over two days following the rules in this anatomy laboratory. Where the cadaver will be prepared the day before students' study

First day

At 17.00 the cadaver was placed on the table, at 17.15 the measurements began at 15 points according to the picture. The measuring instrument is placed on the inside of the table at a predetermined point position. Measurements were carried out for 5 minutes and the values were taken according to those listed on the measuring instrument graph using a Temtop measuring instrument.

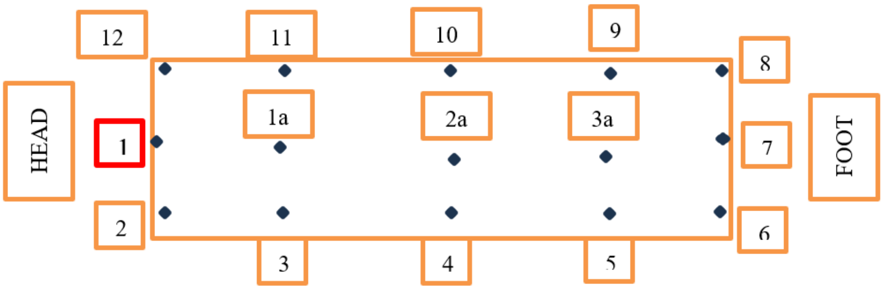

Fig. 2 Measurement point cadaver table

Measurements start from point number 1 to point number 12 (see Fig. 2). Each point stops being measured for 5 minutes to get measurements for minutes 1, 2, 3, 4, and 5. Continue with measurements at points 1a, 2a, and 3a, each taken during 5 minutes (see Fig. 3).

After completing the data collection, the cadaver is closed using a Styrofoam lid and the suction device is turned on for 15 minutes on and 15 minutes off using a timer switch.

The second day

At 07.20 the Styrofoam lid was opened with the suction device still on and the timer was changed to constant (see Fig. 4). At 07.30, measurements were taken again as shown in Figure 3, starting from point 1 to point 12, followed by points 1a to 3a with each point measured for 5 minutes.

After completing the measurements, the cadaver was returned to the formalin pool and the table was rinsed with clean water, wiped, and left to dry. The waste collection pipe is cleaned and the spilled liquid is cleaned up.

At 10.30, measurements were taken for the table without a cadaver, starting from point 1 to point 12, followed by points 1a, 2a and 3a, for 5 minutes for each point.

Fig. 3 Formaldehyde Detector

Fig. 4 Styrofoam lid

Material

Measurement of formaldehyde in this study using the Temtop formaldehyde detector from the Temtop LKC-1000S+ (Elitech Technology, Inc., 1551 McCarthy Blvd, Suite 112, USA; Technology, 2017). The formaldehyde measurement range of this tool is 0-5 mg/m3, with an index parameter of healthy 0-0.1 mg/m3, unhealthy >0.1 mg/m3 (Technology, 2017). To convert from mg/m3 to ppm using a conversion calculator from NIOSH by knowing the molecular mass for formaldehyde is 30.3 g/mol (Debra A. Kaden, Corinne Mandin, Gunnar D. Nielsen, 2010; NIOSH, 2014).

Fig. 5 Formaldehyde detector

The vacuum machine used in this research is branded ROWENTA Vacuum Cleaner with Type RU 05 WET & DRY. This vacuum is often found on the market and is easy to use. The power used is 1200 Watts, with a suction power of 1900 mm/H2O. This tool's noise level is still quite high at 75 db with a tool weight of 6.5 kg.

Statistical Analysis

Descriptive analysis of formaldehyde levels was carried out with a normality test first, if the data was found to be normal, it was continued using the paired t-test using SPSS Statistics for Windows, version 21 (IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY, USA: IBM Corp.).

Results

Descriptive data analysis is displayed using basic data first, then continued with analysis for each data group. There were 15 data collections in total with each data being measured 5 times, from the first minute to the fifth minute.

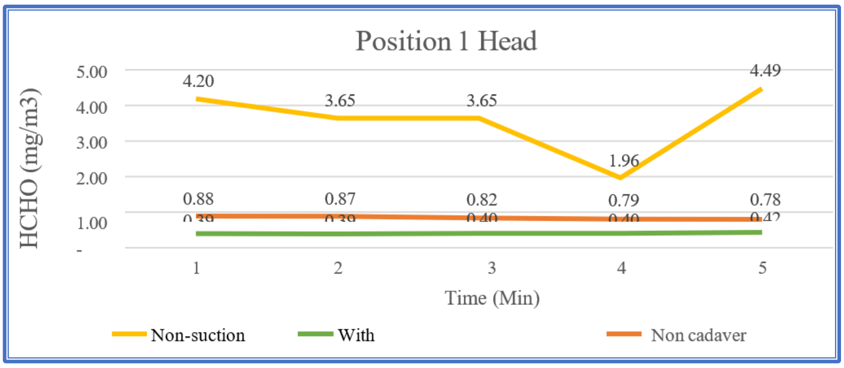

Fig. 6 Measurement at point number 1/ Head

Figure 6 shows the formaldehyde content data on the head of the cadaver was lower when using suction compared to the empty table without the cadaver. The non-suction data showed that formaldehyde levels decreased in the fourth minute, but then rose again in the fifth minute.

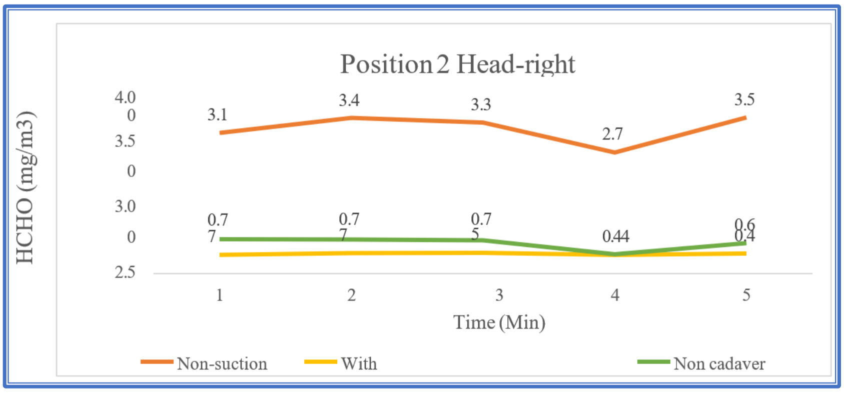

Fig. 7 Measurement at point number 2/ Head-right

Likewise, when measuring point number two, which is located to the right of the head (Figure 7), it appears that the data taken using suction has lower levels of formaldehyde than the table without a cadaver. Meanwhile, table data with non-suction cadavers still has high levels of formaldehyde.

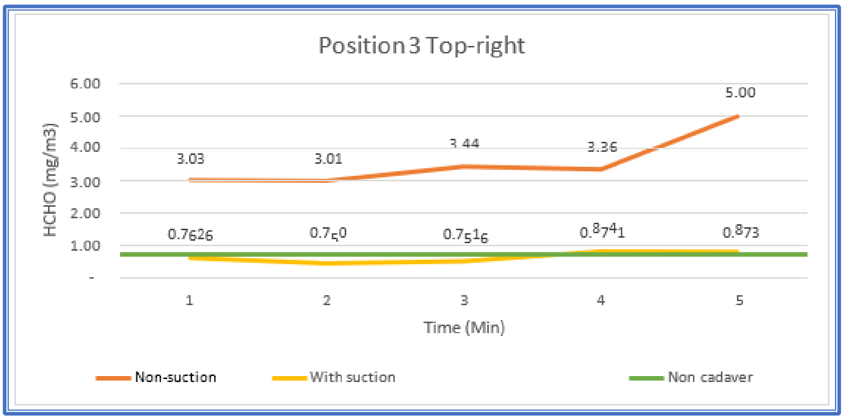

Fig. 8 Measurement at point number 3/ Top-right

The position of data collection at the third point shows that the formaldehyde levels with suction are almost the same as the formaldehyde levels under table conditions without a cadaver (see Fig. 8).

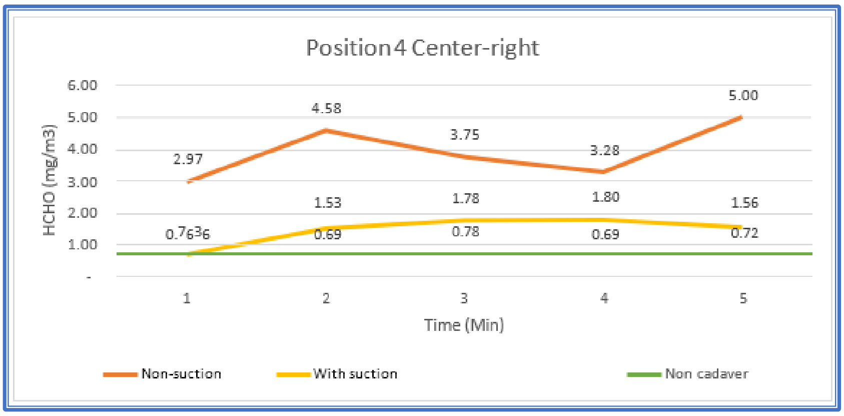

Fig. 9 Measurement at point number 4/ Center-right

At the fourth data collection point, it appeared that the data 'with suction' was starting to be higher than the table data without a cadaver (see Fig. 9).

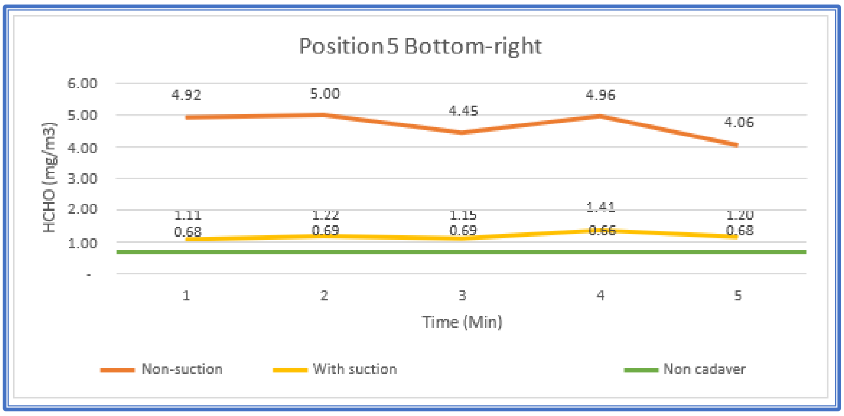

Fig. 10 Measurement at point number 5/ Bottom-right

In the graph in Figure 10, it can be seen that the formaldehyde levels in the 'with suction' data were higher than the 'non-cadaver' data from the first minute of data collection. Meanwhile, the 'non-suction' group remains high.

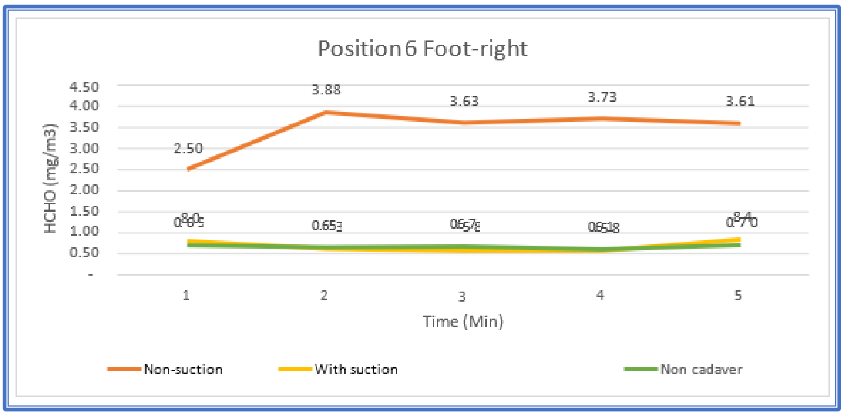

Fig. 11 Measurement at point number 6/ Foot-right

It was found that the formalin levels in the 'with suction' data decreased and were almost the same as in the 'non-cadaver' data (Figure 11)

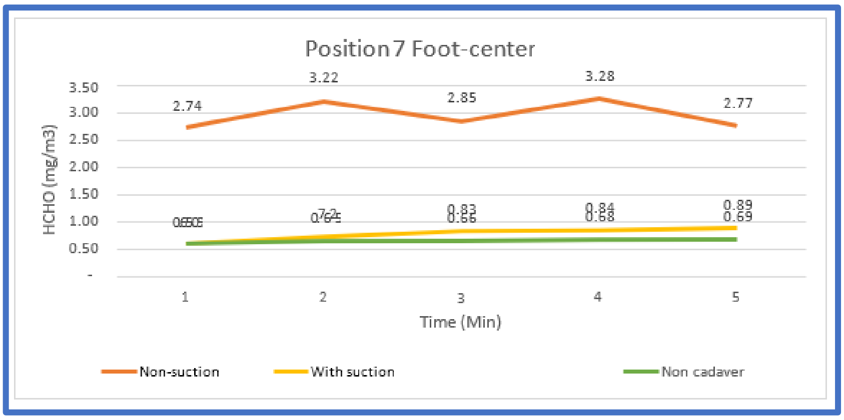

Fig. 12 Measurement at point number 7/ Foot-center

Figure 12 also showed that the formaldehyde levels for 'with suction' data were almost equal to 'non-cadaver' data. The 'non-suction' data fluctuated slightly but was still stable at high levels.

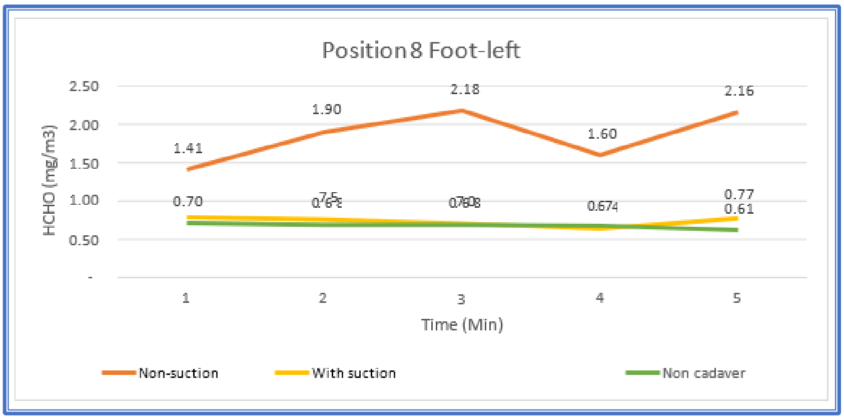

Fig. 13 Measurement at point number 8/ Foot-left

The results of measuring the formaldehyde level at this point were quite interesting because it can be seen that the 'non-suction' data has decreased slightly compared to the previous data, while the 'with suction' data and 'non-cadaver' data were still stable and can be seen from the lines in the graph that are superimposed (see Fig. 13).

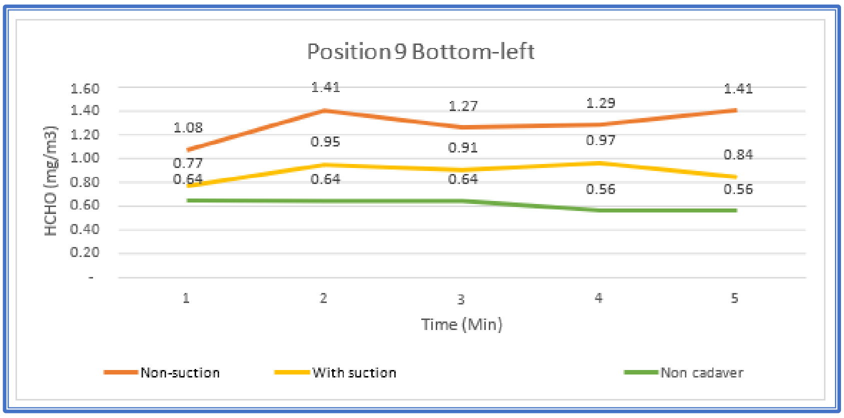

Fig. 14 Measurement at point number 9/ Bottom-left

Figure 14 illustrates that at this point, the formaldehyde levels captured by the formaldehyde detector before turning on the suction have decreased even further compared to Figure 13 with an average of 1.29 mg/m³.

Fig. 15 Measurement at point number 10/ Center-left

Measurements at the point of 10. Center-left, there was a slight increase in the non-suction data taken with the formaldehyde detector. Formaldehyde levels in the 'with suction' data also experienced a slight increase compared to 'non-cadaver' (Figure 15)

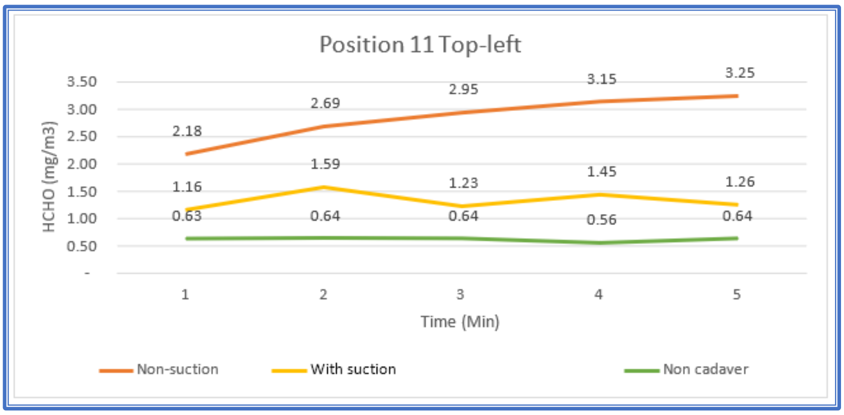

Fig. 16 Measurement at point number 11/ Top-left

Looking at the graph in Figure 16, both 'non-suction' and 'with suction' data are starting to increase again compared to the data in the graph in Figure 15. Meanwhile, non-cadaver data remains stable.

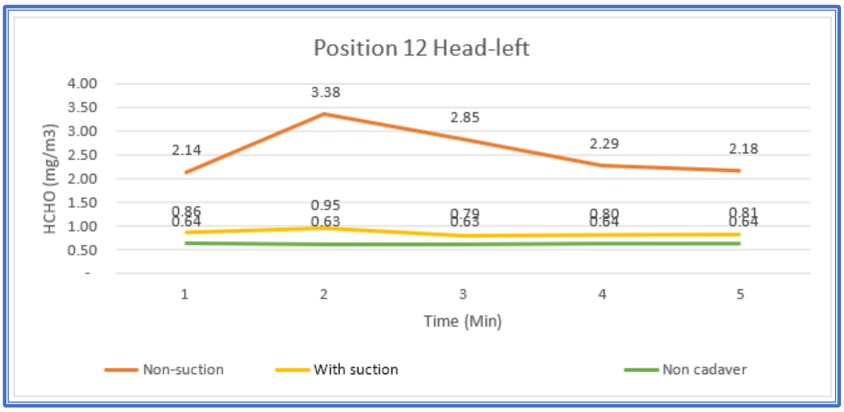

Fig. 17 Measurement at point number 12/ Head-left

The 'with suction' data in this study has decreased slightly and it was back to approaching 'non-cadaver'.

Fig. 18 Measurement at point number 1a Chest

The data in the Figure 18 graph looks interesting, there was data on formaldehyde levels that were constant at 5 mg/m³ for five minutes when the formaldehyde detector was placed on the chest. Meanwhile, the two data 'with suction' and 'non-cadaver' were also more consistently close to each other.

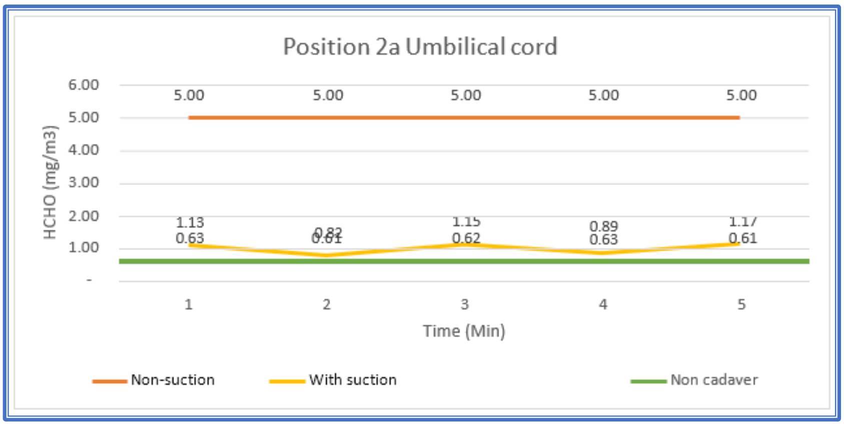

Fig. 19 Measurement at point number 2a Umbilical cord

Taking data on formaldehyde levels in the umbilical cord position also showed that the data was constant at 5mg/m³ for five minutes. For the data 'with suction' there are slight fluctuations up and down, but overall, it looks constant with an average of 1.03mg/m³ (see Fig. 19).

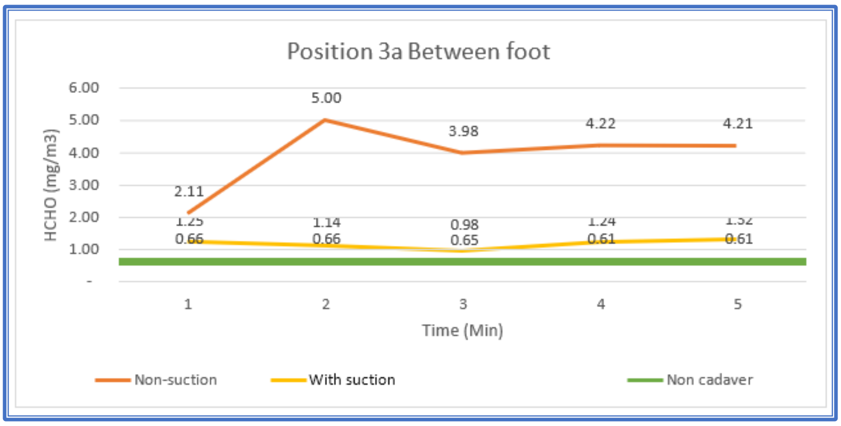

Fig. 20 Measurement at point number 3a between the foot

Data taken from between feet shows an initial low figure in the first minute, then slowly increases in the second to fifth minutes. Even in the second minute, the increase was up to 5mg/m³. Data on formaldehyde levels for 'with suction' is slightly higher than for 'non-cadaver' (see Fig. 20).

Table 1 Descriptive analysis of results table in the anatomy laboratory (n=75)

Variables	Mean (SD)	Min-max
Non-suction (mg/m³)	3.3508 (1.17)	1.08 - 5.00
With suction (mg/m³)	0.8999 (0.33)	0.39 - 1.80
Non-cadaver (mg/m³)	0.6621 (0.07)	0.44 - 0.88

Table 1 shows that the average value of formaldehyde levels in the anatomy laboratory before turning on the suction machine was 3.35 mg/m³, with a minimum value of 1.08 mg/m³. Meanwhile, the average value of formaldehyde levels after turning on the suction machine was 0.9 mg/m³.

Paired T-Test Analysis

In this study, a normality test was carried out first for each group 'non-suction', 'with suction', and 'non-cadaver'. It was found that the three groups of data were normally distributed by looking at the results of the Kolmogorof-Smirnof test with $p>0.07$, $p>0.06$ and $p>0.09$ respectively. Because the three groups of data were normally distributed, a paired t-test was used.

Table 2 Paired t-test for formaldehyde levels between non-suction and suction on the cadaver table in the anatomy laboratory (n=75)

Variables	Mean (SD)	Diff mean (SD)	CI 95%	p-value
Non-suction mg/m³)	3.3508 (1.17)	2.45 (1.15)	2.715 - 2.186	<0.001
With suction (mg/m³)	0.8999 (0.33)			

It is found that the mean difference between the two groups of variables 'non-suction' and 'with suction' was 2.45 mg/m³ with a standard deviation of 1.15 mg/m³ in Table 4.3. A significant difference is found between these two variables with a Confident Interval of 2,715 - 2,186 mg/m³ (table. 2).

Table 3 Paired t-test for formaldehyde levels between cadaver and non-cadaver on the cadaver table in the anatomy laboratory (n=75)

Variables	Mean (SD)	Diff mean (SD)	CI 95%	p-value
With suction (mg/m³)	0.8999 (0.33)	0.24 (0.35)	0.319 - 0.156	<0.001
Non-cadaver (mg/m³)	0.6621 (0.07)			

The results in Table 3 showed that the mean difference between the 'with cadaver' and 'non-cadaver' groups was 0.24 mg/m³ with a standard deviation of 0.35 mg/m³. Statistical analysis showed that there were significant differences in these two groups, which can also be seen in the confidence interval value of 0.319-0.156 mg/m³.

Table 4 Comparison of formaldehyde level reduction between without suction and using suction (LEV)

Position	Non-suction	With suction	Reduction %
1. Head	3,59	0,4	89
2. Head right	3,25	0,44	86
3. Top right	3,57	0,68	81
4. Center right	3,92	1,48	62
5. Bottom right	4,68	1,22	74
6. Foot right	3,47	0,69	80
7. Foot center	2,97	0,78	74
8. Foot left	1,85	0,73	61
9. Bottom left	1,29	0,89	31
10. Center-left	2,36	0,95	60
11. Top left	2,84	1,34	53
12. Head left	2,57	0,84	67
1a_Chest	5	0,86	83
2a_Umbillicus Cord	5	1,03	79
3a_Between foot	3,9	1,19	69

In Table 4, it is found that the lowest formaldehyde level reduction using suction (local exhaust ventilation) is seen at the bottom of the left side at collection point number 9 of 31.01 mg/m³.

Discussion

In this research, equipment testing was carried out in a real environment, an anatomy laboratory. Data measurements start from the first point to the fifteenth point, where each point is measured for 5 minutes. Data collection starts from the first point above the cadaver's head. It was found that at the first and second points, the data results for formaldehyde levels 'with suction' were lower compared to 'tables without cadavers' (Figure 6-7). In the data at the third point, the line graph appears to overlap between the 'with suction' data and the 'table without cadaver' data (Figure 8). Taking data at other points, almost all formaldehyde levels were higher in data 'with suction' compared to 'tables without cadavers'. This was because when collecting data at points one and two the cadaver table had just been opened from the Styrofoam lid after the suction had been turned on overnight.

In the graph at points 6 and 8, the data collection positions are at the right and left corners of the table. It can be seen that the line graph between 'with suction' and 'table without cadaver' coincides because the corner area gets suction from 2 manifolds, so its ability to suck can increase slightly. It can also be seen in Table 4 which showed a decrease in formaldehyde levels at points 6 and 8 by 80% and 61%, especially in the lower right corner area (point 6) where the formaldehyde collection hole is located. The 'no suction' measurement was found to be 3.47 mg/m³ with a decrease of 80% after turning on the suction device (see Fig. 11, 13).

When collecting data in the middle position of the cadaver in the chest, umbilical cord and between the toes, very high levels of formaldehyde were found, especially in the chest and umbilical cord at 5 mg/m³. Because the maximum capability of the formaldehyde detector can only measure up to 5 mg/m³, even though it is possible that the measurement results could be more. At these two points, the suction device can reduce formaldehyde levels quite significantly by 83% and 79%. This is because the last measurement at this point was carried out, so the suction device has been working longer than the previous point.

The ability to reduce formaldehyde levels is lowest at point 9 on the bottom left at 31%, where the formaldehyde level before the suction device is turned on is 1.29 mg/m³, which is the lowest formaldehyde level (see Table 4). The position of the formaldehyde detector is located next to the left leg, which is the furthest area between the cadaver and the formaldehyde detector and the leg is a small part of the cadaver. When compared to the same position on the right at point 5 lower right, the formaldehyde level before suction was turned on was 4.68 mg/m³, which is the third largest after the chest and umbilicus cord. When the suction is turned on, the formaldehyde level decreases by 74% (see table 4). The high level of formaldehyde at this point was because this area is close to the formalin collection hole and a lot of formalin liquid flew due to the tilt of the table. When taking measurements to place the detector, it needed to be cleaned a little to place the detector.

All data on formaldehyde levels taken from the table without a cadaver were quite high compared to the recommended healthy limit value from the formaldehyde detector, 0-0.1 mg/m³. This was due to the anatomy room where data collection was carried out on the second day at the same time as the practicum activities. That day's practicum was the last enrichment practicum before the exam, so almost all the cadavers were taken out for study. Several cadavers had just been taken out of the formalin bath in the morning. The condition of the anatomy room was messy because the anatomy museum room was being renovated so all the items from the anatomy museum were collected in this room. There were many buckets filled with formalin liquid, and there was a formalin drum in the same room. Several buckets without lids and several unused tables had formaldehyde pooling on them. This condition caused table measurements without cadavers to have quite high levels of formaldehyde.

Statistical analysis using SPSS found an average difference between 'non-suction' and 'with suction' data of 2.45 mg/m³ with a standard deviation of 1.15 mg/m³ (table 2). A significance value of 0.000

($p<0.05$) was obtained with a confidence interval of 2,715 – 2,186 mg/m³. Based on statistics, it can be concluded that using a cadaver table with local exhaust ventilation is able to reduce formaldehyde levels originating from the cadaver.

Table 3 showed that the statistical analysis found that the mean difference between the data when the suction was turned on and the table without a cadaver was 0.24 mg/m³ with a standard deviation of 0.35 mg/m³. There was a significant difference between these two data ($p<0.001$) with a Confident Interval of 0.319 – 0.156 mg/m³. Even though the statistical analysis was significant, it was found that the average formaldehyde levels on cadaver tables with suction were still higher than the results of measuring formaldehyde levels on tables without cadaver. It was also found that the results of measuring formaldehyde levels on tables without cadavers were still high. When referring to the standard detector equipment, the healthy category is 0 - 0.1 mg/m³, whereas research found an average of 0.66 mg/m³. So, the category is unhealthy. As has been discussed above, the cause of formaldehyde levels being in the unhealthy category (0.66 mg/m³) in the 'desk without cadaver' data was that the anatomy laboratory room was very messy. Buckets and drums containing formalin liquid are placed in the same room as the student practice room. There is limited storage space, so everything is placed in the anatomy laboratory room where students' study. Even though the buckets and drums were closed, it appeared that some of the buckets were still open. The remaining formaldehyde liquid under the cadaver's table is only stored in a bucket without a lid because almost all the cadavers are placed on the table for students to study. During data collection, formaldehyde exposure also came from the student study area that means more and more storage buckets and no lids. Some unused formalin liquid remaining on the table also pools, which is also a source of high levels of formaldehyde. While the practicum and data collection were taking place, the exhaust fan and fresh air fan were kept, which were located on the wall and in the middle of the room.

Conclusion

The effectiveness of the cadaver table with local exhaust ventilation in the real environment of the anatomy laboratory room showed that there was a significant difference ($p<0.001$) between the cadaver table with the suction device turned off and when the suction device was turned on. In Table 4, the results from 15 data collection points showed a fairly large reduction in formaldehyde levels. This illustrated the contribution of cadaver tables with local exhaust ventilation which played an important role in reducing formaldehyde exposure at the source.

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Conflict of interest:

No conflict of interests.

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