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Indoor Environmental Quality in Mara Vocational Workshops

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Abstract—*This study is to evaluate the Indoor Environmental Quality (IEQ) of MARA vocational training workshops particularly welding, fabrication, foundry and machine shops. The study was conducted in twenty eight workshops at Institute Kemahiran MARA (IKM) Kuala Lumpur, Lumut Perak and Tan Sri Yahya Ahmed (TSYA) Pekan Pahang. The measurements collected are inclusive of temperature, relative humidity, carbon monoxide, carbon dioxide, dust, air velocity, sound pressure and lighting level. Results showed the temperatures measured were exceeding the recommended level by ASHRAE. The relative humidity for twenty four workshops was not complies the recommended range, while carbon dioxide of two workshops also exceeds the ASHRAE required level which is 650ppm. Twenty six workshops have air velocity below 0.25m/s the recommended by World Health Organization (WHO). Finally the lighting levels of twelve workshops were below 160Lux the Australian Standard (AS) recommended level. From the study made, it is concluded that the IEQ in MARA Vocational training workshops is unhealthy and comfortable for occupancy.*

Keywords— *Thermal Comfort; IEQ; Workshop Environment; Mara Workshops*

I. INTRODUCTION

Indoor Environmental Quality (IEQ) has become a hot topic of the late. Many investigators have found that environmental quality may be influenced by a number of factors such as comfort, noise, lighting, ergonomic stressors (poorly designed work stations and tasks). Environment Protection Agency (EPA) studies have found that pollutant levels indoor can be two to five times higher than outdoors. After some activities, indoor air pollution levels can be 100 times higher than outdoors. According to David (2002), the diagnosis of indoor air quality problems is complicated by the fact that air pollutants affect people in different ways. A certain contaminant at a certain concentration might cause headache in one person, dizziness in another, skin irritation in another and have no effect on still another person. Changing the concentration of the same contaminant could changes its effects among the same individuals. Alexander (1991) said that lighting could also affect occupants' perceptions of buildings. Strauss (1984) and Steadman (1975) report that, there is a significant relationship between poor lighting and reported building illness. Office workers having poor building lighting were found to be more likely to think of their buildings as contributing to poor health. Noise has also been identified as a potential cause of Sick Building Syndrome (SBS) symptoms.

The National Institute for Occupational Safety and Health (NIOSH) (1995), found that the primary source of indoor air quality problems are due to several factors namely 52% of problems are due to inadequate ventilations, 16% due to contamination from inside the building, 10% due to contamination from outside the building, 5% as a result of microbial contamination, 4% contamination from building fabrics and 13% from unknown sources.

In Malaysia, there are guidelines such as Uniform Building By Law (UBBL) 1984, Occupational Safety and Health Act 1994, and the Factory and Machinery Act 1967 for building owners to ensure that air quality in workshop be within acceptable conditions. Institute Kemahiran MARA (IKM) provides vocational training on 40 skills such as mechanical, electrical, electronic, civil, building, etc. mainly at 13 training centers. Due to the little attention given by the management and MARA Building Standard Committee, most of the MARA vocational training workshops are not designed to provide adequate natural ventilation. As a result, the occupants of the workshop may have been exposed to hazards and risks to their health. Therefore, the objective of this manuscript is to determine the indoor environmental quality of MARA vocational training workshop by measuring the indoor pollutants and stressors so that the Indoor Environmental Quality (IEQ) of MARA Vocational Training Workshops can be known as baseline information.

II. METHODOLOGY

There are four methods that were used in the process of gathering information, which are preliminary study, questionnaires, field measurement and observations

1. Preliminary study

Preliminary study was conducted in dinning halls at IKM Kuala Lumpur on August 7, 2002 and IKM Johor Bahru on Agust 9, 2002. The test was involved determining the temperature, relative humidity, carbon dioxide and sound pressure level at twelve pre-determined locations. A total of 3960 measurements were recorded from each of the dinning hall evaluated. The measurements were taken at an average of 15 to 30 minutes. The results of the study are tabulated in Table 1 and 2.

Table 1: Results on Indoor

No	Center	Indoor (Mean)				
		Temp. (°C)	**RH (%)**	**CO (PPM)**	**CO_2 (PPM)**	**Sound (dBA)**
1	IKL Johor Bahru	30.3	64.3	3.9	584.5	67.0
2	IKM Kuala Lumpur	31.0	63.7	3.6	601.0	66.8
Standard		22-27 (ASHRAE)	30-60 (ASHRAE)	9 (WHO)	650 (ASHRAE)	90 (FMA)

Table 2: Results on Outdoor

No	Center	Outdoor (Mean)				
		Temp. (°C)	**RH (%)**	**CO (PPM)**	**CO_2 (PPM)**	**Sound (dBA)**
1	IKL Johor Bahru	31.5	65.8	4.4	537.1	66.3
2	IKM Kuala Lumpur	31.8	65.5	4.0	511.0	66.7
Standard		22-27 (ASHRAE)	30-60 (ASHRAE)	9 (WHO)	650 (ASHRAE)	90 (FMA)

2. **Questionnaires**
   The questionnaires were designed to focus on personal background, pollution exposure, safety background, health background and recommendation. Two sets of questions had been distributed to lectures and students.
3. **Field Measurements**
   The measurement is taken in three chosen center; IKM Kuala Lumpur, Lumut and Tan Sri Yahya Ahmed (TSYA) Pekan. Measurements were taken from twenty-eight workshops to determine the temperature, relative humidity, carbon monoxide, carbon dioxide, dust, air velocity, sound and light level at the ten selected workshops.
4. **Observations**
   During field measurement, the observation was focus on the building design together with its orientation to find out whether the building has a good ventilation system.

III. RESULTS AND DISCUSSIONS

1- Result on the Preliminary Study

Table 3 is the overall reading recorded on the measurement made in each of the dining hall evaluated. The mean score indoor temperatures were 30.3°C in IKM Johor Bahru and 31.0°C in IKM Kuala Lumpur, with outside temperatures 31°C in both places. The contents of indoor temperatures are lower compared to the measurement made in outdoor. These temperatures exceed the ASHRAE recommendations of 22-27°C. The mean score of indoor relative humidity were 64.3% in IKM Johor Bahru and 63.7% in IKM Kuala Lumpur, outdoor was 65.8% and 65.5%, respectively these relative humidity exceeded within the ASHRAE recommendations of 30-60%.

Results for mean score of carbon monoxide measurements are 3.9ppm in IKM Johor Bahru and 3.8ppm in IKM Kuala Lumpur, outdoor were 4.4ppm and 4.0ppm, respectively these values are fall bellow the recommended level of 9ppm (WHO). Results for mean score carbon dioxide measurements are 5384.5ppm in IKM Johor Bahru and 601.0ppm in IKM Kuala Lumpur, outdoor was 537.1ppm and 511.0ppm, respectively these results are fall bellow the recommended level of 650ppm (WHO).

The mean score sound pressure level measurements are 67.0dBA in IKM Johor Bahru and 66.8dBA in IKM Kuala Lumpur, outdoor was 66.3dBA and 66.8dBA, respectively these values are fall below the recommended level of 90dBA (FMA, 1967)

Table 3: Overall result indoor and outdoor measurement

No	Center	Outdoor (Mean)					Indoor (Mean)				
		Temp. (°C)	**RH (%)**	**CO (PPM)**	**CO_2 (PPM)**	**Sound (dBA)**	**Temp. (°C)**	**RH (%)**	**CO (PPM)**	**CO_2 (PPM)**	**Sound (dBA)**
1	IKL Johor Bahru	31.5	65.8	4.4	537.1	66.3	30.3	64.3	3.9	584.5	67.0
2	IKM Kuala Lumpur	31.8	65.5	4.0	511.0	66.7	31.0	63.7	3.6	601.0	66.8

2- Results on the Questionnaires

A percentage of 93.6% of the distributed questionnaires were returned and analyzed by descriptive test with SPSS and MS excel program.

2-1 Respondent Personal Background

The results show that 25% of the lectures have 1 to 5 years working experience. Meanwhile 34% respondents have 6 to 10 years and another 14.9% have 11 to 15 years working experience. There are also 25.5% respondents who have 16 years working experience. Generally more of the respondents have 6 to 10 years working experience and took up to 5 to 6 hours per day continuously in the workshop.

The majority of the students (42.1%) have 1 to 6 months studying experience, another 3% have 7 to 12 months and 37.1% have 13 to 18 months. There are also 16.8% respondents who have 19 to 24 months and only 1% has 31 to 36 months. In general the results show that more respondents have 1 to 6 months studying experience and spent 5 to 6 hours continuously in the workshop.

2-2 Pollution Exposure

From the study conducted 72.3% of the lecture feel uncomfortable and the majority felt that the temperature in the workshop was too high. Only 19.1% of the respondents admitted that they feel the temperature was suit to their body, and it is just a matter of time before the respondents get themselves used to the environment. While 52.0% of the student feel uncomfortable and 46.9% said that the temperature was too high in the workshop.

The majority of the lectures and 88.5% of the student felt that the workshop environment was not too humid. 77.8% of the lectures and 80.1% of the students admitted that they do not feel breezy during their working in the workshop. 83.0% respondent of the lecturer found that the workshop environment was too dusty and 57.1% of the students agree with them, only 17.0% and 42.9% of the lectures and students respectively claimed that the workshop environment free from dust.

The study shows that, the workshop environment affects 74.5% of the lecturers and 57.2% of the students hearing.

2-3 Safety Background

Analysis of this study shows that 70.2% of the lecturer said that Personal Protective Equipment (PPE) was supply in the workshop and 44.7% always wear the PPE. 92.6% of the student said that the PPE was supply in the workshop and nearly 94.6% are always wearing the PPE. 60.0% of the lecturer stated that dustcoat is the appropriate clothes to wear in the workshop. On the other hand, 22.2% respondents felt that jacket is the right clothes to wear and another 17.8% find that overall is the best clothes to wear in the workshop and the majority found that safety boot is the appropriate shoes to be use in the workshop. For the student 72.9% stated that jacket is the appropriate clothes to wear in the workshop and 27.1% felt that the overall is the right clothes to wear but 100% found that safety boot is the appropriate shoe to be used.

2.4 Health Background

In the lecturer group 30% to 60% of the respondents are suffering from cold, sore throat and headache. Meanwhile, more than 2.1% up to 4.3% are suffering from vomiting, asthma and dizzy. For medical leave 34.1% of the lecturer had their latest medical leave above one year ago. Another 54.5% respondents had their medical leave in 7-11 months ago. Only 11.4% got their medical leave in 2-6 months ago.

For students group, 20% to 50% of the respondents are suffering from sore throat, headache and cold. The other 1.0% of the respondents has asthma and 2.0% are suffering from dizzy. On the other hand, 40.6% of the students had their latest medical leave one year ago. Another 46.2% had their medical leave in 7-11 months ago. The other 11.3% got their medical leave in 2-6 months ago. Only 1.9% respondents have their medical leave in this month. Both lecturer and students stated that the management does not provide routine medical check-up.

2.5 Recommendations

More than 34.0% of the lecturer stated that in order to improve the comfort level, all of the workshop must have enough space, good lighting and good ventilation. 8.5% respondents felt that the workshop layout itself also will help the improvement of the comfort level. The other 2.1% respondents also suggest that cleanliness of the workshop will help the situation. In order to improve the comfort level, 31.2 of the students stated that all of the workshop must have good ventilation. Another 16.3% respondents felt that the workshop lighting system should be upgrade to improve the comfort level. More than 4.0% respondents also suggest that cleanliness, enough PPE and workshop space of the workshop will help the situation. 2.5% of respondents agreed that the workshop layout also continue to the comfortable of the workshop environment.

3- Results on field measurements

The standard measurements use for the purpose of the analysis is based on Table 4.

Table 4: Guidelines for standard parameter

No	Parameter	Limit/Range	Reference
1	Temperature level	22^oC - 27^oC	ASHRAE
2	Relative humidity level	30% - 60%	ASHRAE
3	Carbon monoxide level	< 9 ppm	WHO / ASHRAE
4	Carbon Dioxide level	< 650 ppm	ASHRAE
5	Dust level	< 10 mg/m^3	FMA
6	Air velocity level	> 0.25 m/s	WHO
7	Sound pressure level	< 90 dBA	FMA
8	Lighting level	> 160 Lux	AS

Note:

ASHRAE American Society of Heating, Refrigeration and Air Conditioning Engineers
WHO World Health Organization
FMA Factory and Machinery Act. Malaysia
AS Australian Standard

Result on table 5 and 6 shows that the temperature level for all workshops are exceeds the ASHRAE recommendations of 22^{o}C-27^{o}C, except the air-conditioned workshop in Kuala Lumpur. Results on relative humidity of twenty four workshops are also exceeding the ASHRAE recommendation. The air velocity levels of twenty six workshops are below the ASHRAE recommendation 0.25 m/s. Although mean score for overall workshops are above the 160Lux as the AS recommendations, there are twelve workshops below the AS recommendations. From the analysis, CO_2, CO and dust level are complying with ASHRAE and FMA standard.

Table 5: Mean score overall result

Parameter	IKM KL	IKM LMT	IKM TSYA	Results
Temperature level (^{o}C)				[ASHRAE; 22 ^{o}C -27 ^{o}C]
Minimum	26.2	28.6	28.1	
Maximum	35.6	31.8	33.6	
Mean	**31.5**	**30.8**	**31.4**	**Not Comply**
Relative humidity level (%)				[ASHRAE; 30-60%]
Minimum	55.4	64.2	59.5	
Maximum	83.6	79.8	82.6	
Mean	**66.3**	**70.0**	**68.7**	**Not Comply**
Carbon Dioxide level (ppm)				[ASHRAE; <650ppm]
Minimum	330	396	377	
Maximum	3342	1166	594	
Mean	**467**	**498**	**427**	**Comply**
Carbon Monoxide level (ppm)				[ASHRAE; <9ppm]
Minimum	0.0	0.1	0.8	
Maximum	2.8	4.5	2.8	
Mean	1.2	1.5	1.5	Comply
Dust level (mg/m^3)				[FMA; < 10mg/m^3]
Minimum	0.002	0.119	0.000	
Maximum	0.217	1.380	0.041	
Mean	**0.011**	**0.477**	**0.007**	**Comply**
Air velocity level (m/s)				[WHO; >0.25m/s]
Minimum	0.00	0.00	0.00	
Maximum	0.60	0.46	0.73	
Mean	**0.14**	**0.04**	**0.14**	**Not Comply**
Sound Pressure level (dBA)				[FMA; <90dBA]
Minimum	56.3	54.6	53.4	
Maximum	106.0	109.4	108.1	
Mean	**77.2**	**78.9**	**75.7**	**Comply**
Lighting level (lux)				[AS; > 160 lux]
Minimum	50.1	70.3	92.6	
Maximum	231.0	962.0	996.0	
Mean	**129.1**	**250.2**	**560.3**	**IKM KL Not Comply**

Note:

ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
WHO	World Health Organization
FMA	Factory and Machinery Act. Malaysia
AS	Australian Standard

Table 6: Mean score for every workshop

Test ID	Workshops	Temp. (^{o}C)	Humid. (%)	CO_2 (ppm)	CO (ppm)	Dust (mg/m^3)	Air Vel. (m/s)	Sound (dBA)	Light (Lux)
Center : IKM Kuala Lumpur									
1	Air- Condition	27.3	60.0	801	0.9	0.032	0.12	68.3	157.3
2	EDI I	29.5	80.5	456	1.3	0.003	0.17	71.8	107.6
3	KMPM I	31.8	65.7	632	1.4	0.003	0.14	84.0	129.3
6	KMPM II	31.9	65.3	406	1.5	0.003	0.14	71.6	167.7
7	Welding	35.1	58.8	352	1.5	0.021	0.20	81.8	101.0
8	EDI II	32.0	64.6	399	1.4	0.032	0.11	81.1	113.0
9	PJE	28.8	81.6	411	1.1	0.004	0.08	78.3	110.0
10	EDI III	32.3	63.4	399	0.2	0.003	0.16	83.6	113.9
11	Sheet Metal I	32.7	62.4	410	1.5	0.003	0.11	73.3	149.2
12	Sheet Metal II	33.1	60.7	403	1.4	0.003	0.12	78.7	141.9
		31.5	66.3	467	1.2	0.011	0.14	77.2	129.1
Center : IKM Lumut									
1	Arc I	29.8	77.0	857	4.1	1.090	0.01	74.2	176.5

2	Spray Painting	29.4	76.6	587	1.3	0.848	0.08	77.1	862.2
3	Foundry	30.9	67.5	462	1.1	0.656	0.03	78.4	239.8
6	Pattern	30.7	66.7	439	0.7	0.545	0.03	72.8	228.5
7	Machine I	31.0	65.5	419	0.6	0.434	0.02	81.0	225.5
8	Machine II	31.4	65.0	485	0.4	0.347	0.03	77.7	227.5
9	Electrical I	30.6	74.7	455	2.2	0.308	0.09	80.3	198.3
10	Arc II	31.2	70.6	436	2.0	0.228	0.02	86.0	80.0
11	Arc III	31.4	69.1	428	1.4	0.177	0.02	84.1	77.8
12	Electrical II	31.7	67.6	413	1.4	0.136	0.02	77.7	185.6
		30.8	70.0	498	1.5	0.477	0.04	78.9	250.2
Center : IKM TSYA, Pekan									
1	Petrol (Automobile)	28.7	79.3	448	1.2	0.016	0.13	70.3	929.9
2	Transmission (Automobile)	30.6	74.7	455	2.2	0.004	0.21	74.0	832.3
3	Store (Automobile)	31.4	69.1	428	1.4	0.017	0.27	71.5	95.4
6	Laboratory (Automobile)	31.9	65.3	406	1.5	0.004	0.27	78.5	222.8
7	Petrol (Automotive)	32.0	64.6	399	1.4	0.001	0.13	76.0	919.0
8	Desiel (Automotive	32.3	63.4	399	1.5	0.001	0.06	73.7	921.2
9	Fitting (Spray painting)	31.1	72.7	459	1.3	0.013	0.02	79.6	281.6
12	Machine shop	33.4	60.1	420	1.4	0.003	0.02	81.6	280.4
		31.4	68.7	427	1.5	0.007	0.14	75.7	560.3

4- Result on field observation

There are two main factors that being focusing during the field observations done. The factors are the building design and the building orientation.

4-1 Building design

From the design it can be said that the air inside the workshop will circulate from the left to right or right to left. This will create a fresh air on the floor level and allows cool outside air to enter the workshop through the windows. This continuous ventilation cycle also will promotes ventilation and theoretically cools the floor level. However, there may be possible that the air from the left and right is very strong that it will enter the building through the windows. This will be a disadvantage because the air will be circulating inside the building as shown in Figure 1.

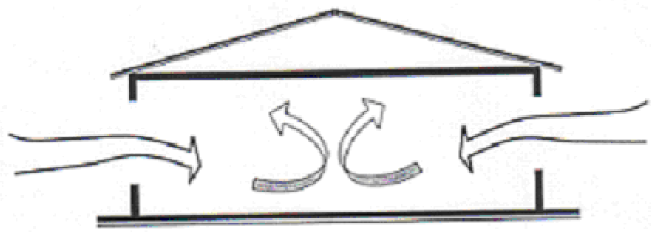

Fig. 1 **The air circulating inside**

For the double roof design it can be said that the hot air inside the workshop will rise to the top and escaped through the opening on the raised roof level. This will create a partial vacuum on the floor level and allows cool outside air to enter the workshop through the windows. This continuous ventilation cycle will promotes ventilation and theoretically cools the floor level. However, there may be possible that the air on the upper level is very strong that will enter the building through the stack. This will be a disadvantage because it will restrict ventilation if the air on the ground level is equally strong. The air will be circulating inside the building as shown in Figure 2.

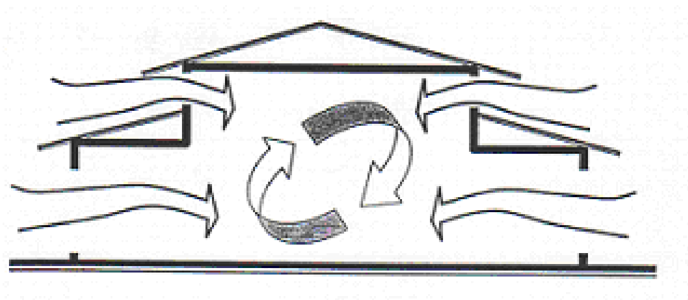

Fig. 2 **The air circulating inside for double roof design**

4-2 Building location

Even through the design of the building is considerably effective to promote ventilation, thus promote cooling inside the building; it is observed that it is extremely hot especially in the afternoon even when all the windows and doors are open. This might be done to the location of the building. The fact that the double storey buildings surrounds the building which may provides shade from direct sunlight; however at the same time it created a wind shadow in the area. The obstacles will reduce the wind speed and create vortices around the building. This will create a negative pressure area. Therefore, even though the building is designed as such, the rate of ventilation is considerably slow. This is noticed due to the lack of sensation of draughts.

IV. CONCLUSIONS

Twenty-eight workshops were evaluated for indoor environmental quality (IEQ). Parameters measured were temperature level, relative humidity level, carbon monoxide contents, carbon dioxide contents, dust level, air velocity level, sound pressure level and lighting level. From the research made, it is established the IEQ in MARA vocational training workshops is unhealthy and is not comfortable for occupancy. The temperatures measured were exceeding the recommended level by ASHRAE. The relative humidity for twenty for workshops was exclusive 30% - 60% of the recommended by ASHRAE while carbon dioxide of two workshops also exceeds the required level at 650ppm (ASHRAE). Air velocity at twenty-six workshops is below the recommended value by WHO. The lighting level for twenty-two workshops were also below the recommended rang by AS.

Majority of the respondents claimed that the workshop environment was uncomfortable for the training activities. From the audit and evaluation conducted, it is ascertained that the operations of workshop in three centers have neglected the safety and health requirements of the occupants. On the other hand due to the unsuitability of location, the design cannot be fully utilized for ventilation.

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