



## An Assessment of Indoor Air Quality (IAQ) in Foundry Laboratory

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# An Assessment of Indoor Air Quality (IAQ) in Foundry Laboratory

**Abstract.** Indoor Air Quality (IAQ) is an important element for a healthy working environment. Working in poor IAQ can lead to sick building syndrome (SBS) with symptoms and troublesome to concentrate in delivering the task. In this study, a preliminary IAQ investigation was carried out at a teaching foundry facility of a higher learning institution in Malaysia. The foundry processes are known to discharge pollutants and gasses. Therefore, this assessment was used to investigate the existence of harmful gasses including Carbon Dioxide (CO<sub>2</sub>), Carbon Monoxide (CO), particulate matter (PM), and Volatile Organic Compound (VOC) throughout the complete foundry process cycle. An advanced environmental monitor kit was used to monitor the air quality at three different locations within the foundry space to get a good distribution of data. The results reveal that only CO<sub>2</sub> and PM10 traces were detected with the reading is still within the allowable range based on guidelines from the Department of Occupational Safety and Health (DOSH), Malaysia. As for thermal comfort result, the Temperature and Relative Humidity (RH) was found to exceeds the benchmark value. Therefore, a more comprehensive and detail thermal comfort study should be conducted to validate the current finding and an appropriate mitigation strategy must be put in place to ensure the thermal comfort of the occupants during the teaching and learning process in the foundry can be improved.

## 1. Introduction

Indoor Air Quality (IAQ) has received increasing public concern in the last few decades. In average, people spend approximately 90 percent of their time indoors [1], where the concentrations of some pollutants are often 2 to 5 times higher than typical outdoor concentrations [2]. Indoor air quality represents how inside air in a specific space such as a home, school, office, or other building environment can affect a person's health, comfort, and ability to work [3]. It can include but not limited to temperature, humidity, mould, bacteria, poor ventilation, or exposure to other chemicals. IAQ problems arise when there is inadequate quantity of fresh air ventilation to diffuse any air contaminants present in the area[4]. The common health problems include allergic reactions, respiratory problems, eye irritation, sinusitis, bronchitis, and pneumonia [5].

IAQ problems are caused by indoor air pollutant that comes from the outdoors, mechanical ventilation and air-conditioning (MVAC), building equipment as well as human activities [6]. The most common indoor air pollutant is Carbon dioxide (CO<sub>2</sub>) as it is being emitted by human beings where the level of CO<sub>2</sub> in an area is dependent to the number of people around and the degree of metabolic activity which is carried out within the area. The National Institute of Occupational Safety and Health (NIOSH) and other studies indicates that death will occur at exposure of 7% CO<sub>2</sub> in only 5 minutes even during the presence of normal concentrations of oxygen [7]. At high level of CO<sub>2</sub>, the performance or decision making may also affect certain important productivity measure. Another type of hazardous gaseous is Carbon monoxide (CO) which is a toxic, colorless, odorless, and tasteless gas. If the concentration of

CO is high within the area, it would be very dangerous for it may cause adverse health effects which include headaches, sore eyes, runny nose, dizziness, vomiting and loss of consciousness [8].

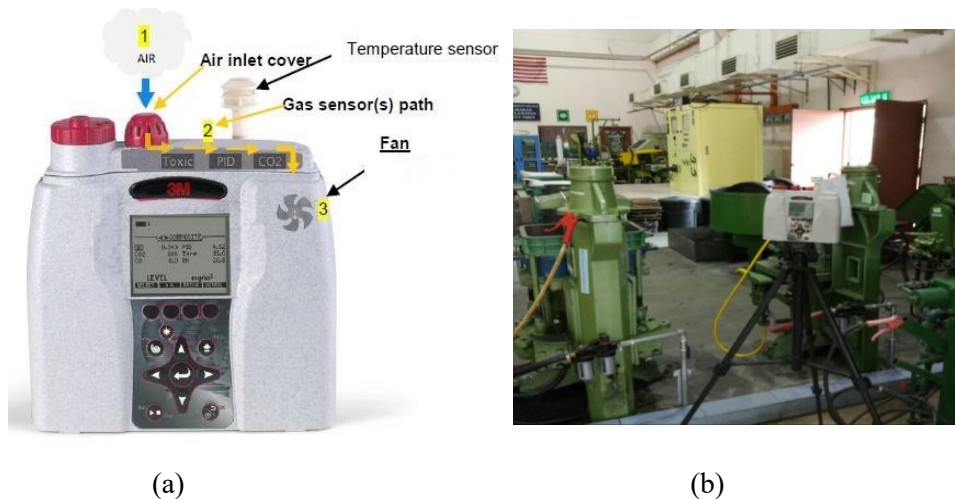
Volatile organic compounds (VOC) however are gaseous contaminants that could be found indoors coming are from building substances, furniture, the foundry furnace and even from the green sands [9]. VOCs exists in the gas phase in the temperature and humidity ranges encountered indoors and may affect the IAQ in terms of sensory reaction such as odor annoyance and irritation to the eye and airway [8]. Also contributing to the effect of IAQ is the particulate matter (PM10) pollution which consists of very small liquid and solid particles floating in the air. These particles are less than 10 microns in diameter and are concerned to the health due to the small particles which are small enough to be inhaled into the deepest parts of the lung. It is a major component to the air pollution where it threatens both health and the environment [10]. The greatest concern of the PM10 is that recent link had linked that exposure to PM10 may lead to death for those who already have lung or heart disease [11].

Having a good ventilation system does not only control the temperature and humidity to provide thermal comfort in an enclosed area but also distribute enough air to the occupants and also remove pollutants [12]. Thermal comfort is usually associated with discomfort in a building which is an effect of a bad IAQ. Although there is usually no serious health implication involved, the productivity and performance of the occupant may be affected, especially the ability to concentrate. Extreme temperature in an area can led to symptoms in building occupants and reduce productivity. While Humidity refers to the amount of moisture in the air, Relative Humidity (RH) on the other hand is the percentage of water vapor in the air at a specific temperature compared to the amount of water it can hold at that temperature. High RH condition may reduce the ability of the body to lose heat through perspiration and evaporation. Besides that, a high RH promotes mold growth, increase dust mites, and musty odors that lead to allergies and asthma [13].

Like other countries in the world, there are regulations and standards developed by the specific government authority with the objective is to promote the awareness and attention regarding IAQ hazards [14]. In the case of Malaysia, Uniform Building by Law (UBBL) 1984, Occupational Safety and Health Act 1994, Factory and Machinery Act 1967, and Department of Occupational Safety and Health (DOSH) provide guidelines and policy to guide building owners and users on IAQ requirements within their responsibility hence adhere and operated within the acceptable condition. Therefore, this study can be considered as an initial assessment to determine the current IAQ condition specifically in the foundry lab. The result form this assessment can be used to establish the baseline and as the input for any initiative or action to improve the IAQ condition to ensure the staff and student will conduct the teaching and learning process in healthy, safe and comfort environment. The influences of the air ventilation to the actual effectiveness of teaching and learning delivery however was not been considered in this study.

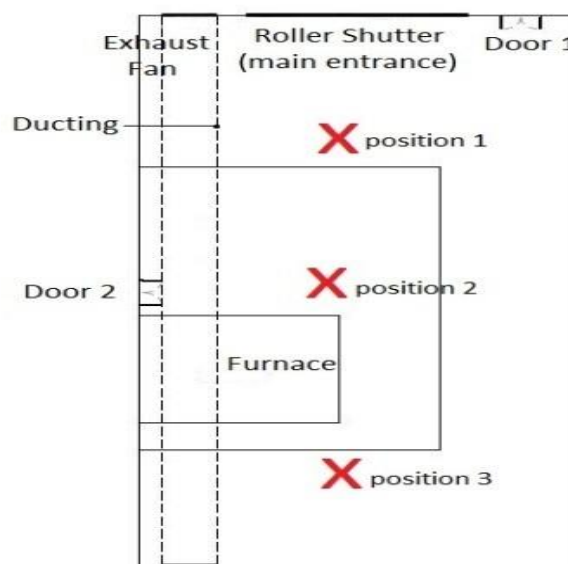
## **2. Methodology**

In this study, a teaching foundry laboratory for one of the public universities in Shah Alam, Malaysia was chosen for the IAQ assessment. The foundry which has the capacity for 100 students at one time was equipped with typical air ventilation system. The indoor air characteristics within the foundry working space area were measured by using an advanced environmental monitor equipment (3M-EVM7) as shown in Figure 1.



**Figure 1** The Advanced Environmental Monitor Equipment (3M model EVM7) to Measure IAQ (a) and Layout Position of Equipment During Assessment (b).

During the data monitoring process, the foundry process was segregated into four stages. The first stage is before any lab activity started followed by the preparation and setup as second stage. Consequently, the melting of aluminum process is the third stage while the actual foundry activity when the aluminum poured into the mold is defined as the final stage. One cycle of the assessment consumes four (4) hours altogether from 2.30 pm to 6.30 pm. The data logging features which is available for this model was programmed to record the data at 15 minutes interval. The same measurement process was repeated for three times before the position of the equipment was moved to the next marked location according to the layout illustrated in Figure 2 until all the assessment completed.



**Figure 2** Equipment Position Layout during IAQ Assessment

Table 1 exhibit the time and condition according to different stages of the measurement planned for this assessment. As such, the IAQ pollutant over the different stages and time can be closely monitored. The environmental equipment kit has been set up to measure six types of pollution elements namely CO<sub>2</sub>, CO, VOC, and PM<sub>10</sub> alongside with temperature and RH.

**Table 1:** The exposure time and the conditions when measurements were taken.

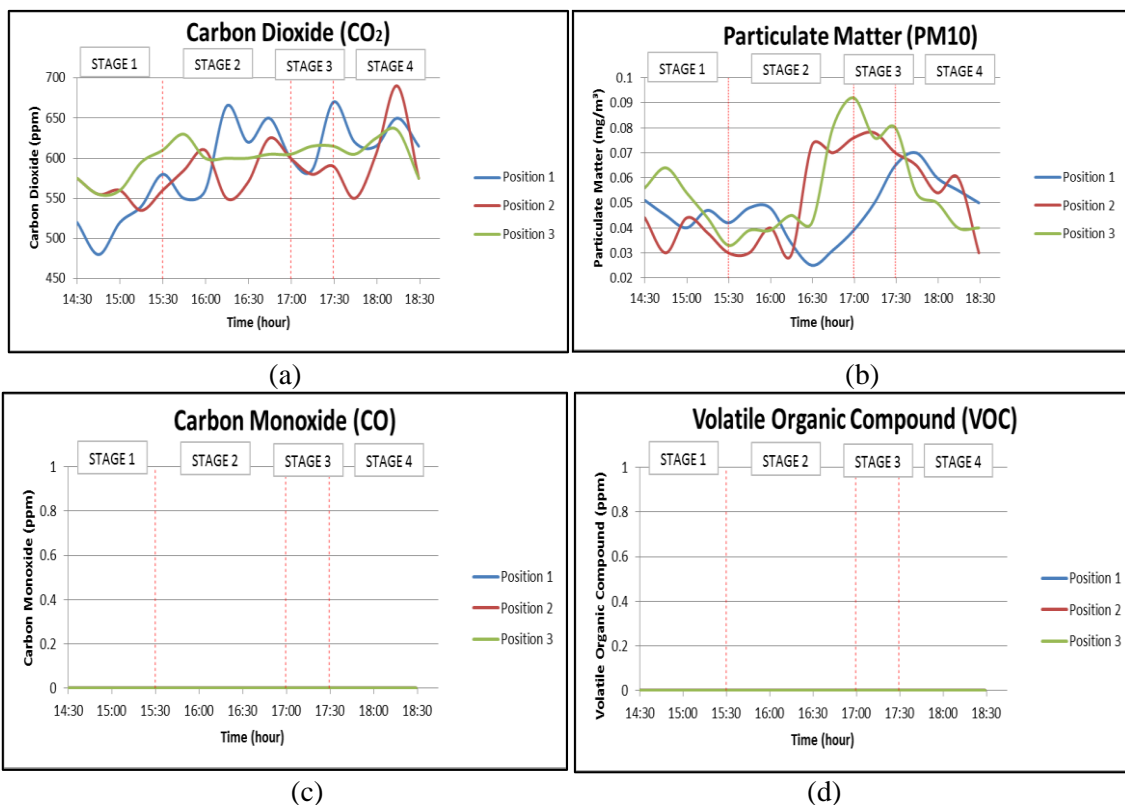
Stage	1	2	3	4
Time	2:30pm – 3:30pm	3:30pm – 4:30pm	4:30pm -5:30pm	5:30pm – 6:30pm
Condition	Before process	Preparation Stage	Melting of Aluminium	Actual Foundry Work

The collected measurement data then were compared to the standards and guidelines established by Department of Occupational Safety and Health (DOSH), Malaysia to access the current IAQ level during the foundry process which can be mapped under Industrial Code of Practice on Indoor Air Quality 2010 requirements.

### 3. Results and Discussions

#### 3.1. Gasses, PM traces and Temperature Comfort Result

Figure 3 (a) to (d) exhibits the level of elements recorded from the IAQ assessment. Out of six elements monitored, only 4 elements have the data available (CO<sub>2</sub>, CO, Temperature and RH) while no reading captured for the CO and VOC.

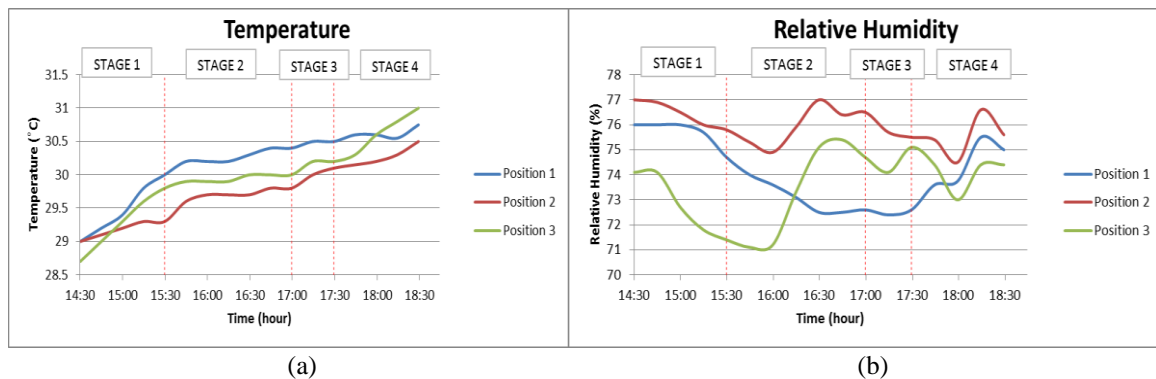


**Figure 3** Result of CO<sub>2</sub> (a), PM10 (b), CO (c) and VOC (d) Detected by Environment Monitoring Equipment

From Figure 3 (a), the CO<sub>2</sub> level is gradually increased from the first stage of the foundry process up to the final stage before a significant drop at end of data collection. This can be explained by the accumulative rate of the occupant respiration when they start entering and doing more activities until they stopped at end of foundry session when the occupants leaving the space. Unlike the gradual increment by stages, PM10 value shows relatively low reading in the beginning of the first two stages and increase suddenly in middle of stage two when the furnace been activated as part of the set-up procedure. The continuity of high PM10 reading at stage four suggest that the current ventilation setup in the foundry may not effective enough to remove the polluted air once the furnace dan melting material

occur which is the peak of the pollution, and it takes sometimes to lower down the reading at stage four. This is when no more particulate matter generated since the pouring of the molten aluminium had been performed and the furnace has been turned off.

Data from the current study did not reveal any trace of CO during the foundry process (Figure 3 (c)). Similarly, VOC which supposed to be the compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, that supposed to participate in atmospheric photochemical reactions also not detected in (Figure 3 (d)). Theoretically, it is either the pollution from these two elements is not exist at all or their concentration were too small that only can be detected using ultra-sensitive and higher precision sensor equipment.



**Figure 4** Data for Temperature (a) and RH (b) Recorded During IAQ Assessment.

Figure 4 (a) shows the trend of temperature reading in the foundry laboratory where it increases in a constant mode from 29.8 °C at beginning of the first stage until maximum of 30.1 °C at stage four. This can be associated with the increased activity of the occupant as well as thermal induction from the furnace during the whole casting process cycle take place. In contrast, the RH level behave in cyclic manner where the value seems to drop from stage one to early part of stage two before it suddenly rises to the maximum before it slightly drops again at early stage four. However, this phenomenon is only valid for position 2 and position 3 where the equipment was placed nearer to the student activity area as well as the furnace as compared to position 1. Therefore, it can be assumed that the level of occupant activities and the equipment used in foundry directly influence the concentration of water vapor in the surrounding air thus dictate the RH level conditions.

### 3.2. Comparing the IAQ result to DOSH Guidelines

Benchmarking is one of the methods can be deployed to access the severity and risk of the IAQ. Using the guidelines from DOSH as references, each of the IAQ element has been compared to the standards and tabulated as shown in Table 2. From the list, the level of CO<sub>2</sub>, CO, VOC and PM10 is clearly well below the recommended range level. However, the temperature and RH exceed the recommended minimum and maximum range thus this should trigger for further investigation to validate the findings and necessary action plan to mitigate this discomfort thermal condition.

**Table 2:** The comparison of data with the acceptable limit from DOSH

Indoor Air Contaminant	Data Obtained		Acceptable Limit	
	Minimum	Maximum	DOSH Minimum	DOSH Maximum
Carbon Dioxide, CO <sub>2</sub> (ppm)	530	643	-	1000
Carbon Monoxide, CO (ppm)	0	0	-	10
Volatile Organic Compound, VOC (ppm)	0	0	-	3
Particulate Matter, PM10 (mg/m <sup>3</sup> )	0.04	0.09	-	0.15

<b>Parameters</b>				
Temperature (°C)	28.5	30.9	23	26
Relative Humidity, RH	73.7	76.3	40	70

Note: DOSH - Department of Safety and Health, Malaysia

Based on Table 2, the CO<sub>2</sub> content of the foundry laboratory is below the maximum acceptable limit of 1000 ppm with a reading of 643 ppm maximum. This is also true for PM10 level where the maximum detected value of 0.09 mg/m<sup>3</sup> is much lower than the maximum standard at 0.15 mg/m<sup>3</sup>. There is no issue can be associated with CO and VOC as there is no reading for those elements present in this study.

The temperature of the foundry laboratory on the other hand is above the maximum acceptable limit set by DOSH of 26 °C. With the minimum RH value of 73.7, it was indeed exceeding the maximum range proposed where the RH must be in the range of 40 to 70. Even though there is no conclusive finding as far as the reason of this high RH value observed, this finding should provide an insight to the management to have deeper understanding on the situation and much thorough thermal comfort study must be carried out to confirm the situation.

#### 4. Conclusions

The IAQ condition of a foundry laboratory had been successfully assessed. The result reveals that the foundry laboratory meets the standards for is at a safe standard for CO<sub>2</sub>, PM10, CO and VOC. Despite of this accepted condition, appropriate personal protective equipment (PPE) should be observed all the time during the foundry process by the occupant to further minimise the health risk related to IAQ. As far as the Temperature and RH result is concern, more comprehensive thermal comfort study should be conducted to validate the discomfort level findings before any corrective action carried out by the management since it will involve huge investment to improve the overall IAQ level of the foundry.

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