

## INDOOR AIR QUALITY INVESTIGATION OF OFFICES IN THE FOOD INDUSTRY

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### ABSTRACT

This paper investigates the quality of air in chosen offices located in the food industry. The parameters including temperature, relative humidity, air velocity, carbon dioxide, carbon monoxide, total volatile organic compound, particulate matter 10 and 2.5 micron and total bacterial counts were measured in three offices within the premises of the industry. The three offices were administrative office, engineer office and screening station. Measurements were carried out for eight hours per day for days chosen in six months. The results were compared with a standard called Industry Code of Practice on Indoor Air Quality 2010 by Department of Occupational Safety and Health, Malaysia. All parameters measured in three offices were complied with the standard except for temperature and air velocity in screening station, which were 27.26 °C and 0.62 m s<sup>-1</sup> respectively and CO<sub>2</sub> concentration in administrative office, which was 1139.71 ppm. This suggests that the processes in this food industry which might emit PM, VOC were not contributing to the pollutant levels in the offices. The exceeded temperature in screening station was due to the air-conditioner setting and the exceeded air velocity was due to the influence of mechanical fan. The CO<sub>2</sub> was due to the poor ventilation rate that provided insufficient fresh air intake which led to the accumulation of CO<sub>2</sub> in administrative office.

**Keywords:** Food industry; indoor air quality; office.

### INTRODUCTION

Few studies show that people tend to spend more than 80% of time in indoor environment [10,12]. Therefore, indoor air environment can be a concern for the people. Indoor air quality study usually measures three types of parameters including physical parameters, chemical parameters and biological parameters. Physical parameters consist of temperature, relative humidity and air velocity. Chemical parameters consist of carbon dioxide (CO<sub>2</sub>), carbon monoxide (CO), total volatile organic compound (TVOC), particulate matter 10 and 2.5 micron (PM<sub>10</sub> and PM<sub>2.5</sub>). Biological parameter consists of total bacterial counts (TBC).

The three physical parameters will determine the thermal comfort condition. The values recommended by Department of Occupational Safety and Health (DOSH) Malaysia in the Industry Code of Practice on Indoor Air Quality 2010 (ICOPIAQ 2010) for physical parameters are 23-26 °C for temperature, 40-70% for RH and 0.15-0.50 m s<sup>-1</sup> for air velocity. When the thermal comfort condition is not favourable, the building occupants might feel discomfort like too hot or too cold thus affecting the working efficiency. Besides, the undesirable temperature and RH will also affect the growth of bacteria [1].

For chemical parameters, CO<sub>2</sub> acts as a ventilation performance indicator. When the CO<sub>2</sub> concentration is beyond 1000 ppm as suggested as limit of exposure, it indicates that more fresh air intake is needed. For CO, it is a by-product of incomplete combustion using fossil fuels. It can be harmful and causes health effects like headaches, dizziness, vomiting and loss of consciousness when the level is too high. The recommended limit of exposure for CO is below 10 ppm as suggested in ICOPIAQ 2010. TVOC can be emitted from different sources like furniture, cleaning agents, office equipments and others and it can cause effects like exacerbation of asthma and fatigue. ICOPIAQ 2010 recommends a maximum limit of below 3ppm for TVOC exposure. PM<sub>10</sub> and PM<sub>2.5</sub> are both small particles exist in the air and can penetrate deeply into our body through respiration. PM<sub>2.5</sub> could be more harmful than PM<sub>10</sub> due to its smaller size which allows it to penetrate in depth into alveoli. ICOPIAQ 2010 recommends maximum of 150 µg m<sup>-3</sup> as limit of exposure for PM<sub>10</sub> but no recommended limit for PM<sub>2.5</sub>.

For biological parameter, a value above 500 TBC CFU m<sup>-3</sup> is not acceptable by the ICOPIAQ 2010. It has to be noted that excess of bacterial counts does not necessarily imply health risk but serve as an indicator for further investigation. It means that some morphological studies like studying on the gram, shapes and species need to be done to have better understanding on the bacteria. For example, a bacteria called *legionella pneumophila* can cause Legionnaires' disease which is a building-related illness.

A respectable number of studies about indoor air quality have been conducted so far in different building categories [6, 2, 9] except with limited studies in the food industry. Food industry involves the production of food and numerous workers are needed during the manufacturing process. The indoor air quality of an industry can be quite contaminated, depending on the industrial activities. For example, a noodle industry was found to record TBC more than 500 CFU m<sup>-3</sup> at its warehouse, crushing site and other processing areas. In this particular food industry inspected, certain air pollutants like particulate matter (PM), combustion products, and volatile organic compound (VOC) were found to be emitted and released to the air during processes like raw material conveying, packaging equipment, bulk loadout operations, boilers, lime kilns and others. Meanwhile, offices in this food industry were occupied by workers thus the air quality in offices would be our concern on whether would it be affected by the industrial activities. Besides,

a displeased atmosphere of an industrial environment can be linked with employees' health because it was found out that poor indoor air quality is correlated to health-related problems including Sick Building Syndrome [5]. Unhealthy employees will present financial burden to employers and reduce the performance of the industry.

Therefore, this study investigates the offices' air quality within the premises of the food industry by monitoring certain parameters including temperature, RH, air velocity, CO<sub>2</sub>, CO, TVOC, PM<sub>10</sub>, PM<sub>2.5</sub> and TBC. Then the variations of parameters which exceeded the suggested limits by ICOPIAQ 2010 are further investigated in line charts.

### METHODOLOGY

Three offices were chosen within the premises of the food industry which were administrative office, engineer office and screening station. During a walkthrough inspection, the characteristics of three offices including number of occupants, type of ventilation, main equipment and activities being carried out were noted down. The characteristics are presented in Table 1.

An indoor air quality sampling was carrying out within six months (April to September) in 2016. For the parameters, all were measured for days chosen along the sampling period for 8 hours continuously from 0900 to 1700 except for total bacterial count (TBC). The parameters measured were divided into physical, chemical and biological parameters. Physical parameters including temperature, RH and air velocity; chemical parameters including CO<sub>2</sub>, CO, TVOC, PM<sub>10</sub> and PM<sub>2.5</sub> and biological parameter including TBC. The sampling instruments were placed about 1 m above floor level in order to align with the breathing level.

Temperature and RH were measured using HOBO (Model U12-012, Onset). Air velocity was measured using Accusense (Model F900, Degree Control Inc). CO<sub>2</sub>, CO, TVOC and PM<sub>2.5</sub> were measured using EVM Environmental Monitors (Model EVM-7, 3M). The three instruments mentioned above were operating based on real-time monitoring method where the data logging interval was set at one minute. After that, the data was imported out using softwares.

PM<sub>10</sub> was measured using Minivol Portable Air Sampler (Airmetrics Inc) using gravimetric method. A <10 µm impactor was used to collect airborne particles on glass microfiber filters with 47 mm diameter (GF/A, Whatman) at a flow rate of 5 L/min. The initial and final weight were measured using analytical balance (Model Discovery, Ohaus). The weight of of the PM<sub>10</sub> was calculated by subtracting the initial weight from the final weight and then further transformed into unit in term of weight per volume.

The biological parameter, TBC was measured by Microbial Air Sampler (Model MAS-100 Eco, MBV) using plate counting method. The air was drawn at a rate of 1.67 L/min and impacted on 90-mm Petri dished containing trypticase soy agar (TSA) twice per day at 10:00 and 15:00 which covered morning and afternoon sessions respectively. The used TSA plates were incubated at 37°C for two days and the concentrations were determined by counting the colony forming units.

**Table 1.** Main characteristics of the sampling stations

Code	Sampling stations	Number of occupants	Type of ventilation	Main equipment/ environment	Main activities
S1	administrative office	4-6	mechanical	computers, printers, furniture	carrying out office work
S2	engineer office	9-12	mechanical	computers, printers, furniture	carrying out office work
S3	screening station	3-5	mechanical	computers	monitoring of screening process

### RESULTS AND DISCUSSION

Table 2 shows the values of nine measured parameters (temperature, RH, air velocity, CO<sub>2</sub>, CO, TVOC, PM<sub>10</sub>, PM<sub>2.5</sub> and TBC) in administrative office (S1), engineer office (S2) and screening station (S3). The Industry Code of Practice on Indoor Air Quality 2010 (ICOPIAQ 2010) by Department of Occupational Safety and Health Malaysia is also shown in Table 2 for comparison between the standard and the measured values.

**Table 2.** Average concentrations of measured parameters

Sampling locations		Temp, °C	RH, %	Air Velocity m s <sup>-1</sup>	CO <sub>2</sub> , ppm	CO, ppm	TVOC, ppm	PM <sub>10</sub> , µg m <sup>-3</sup>	PM <sub>2.5</sub> , µg m <sup>-3</sup>	TBC, CFU m <sup>-3</sup>	
										1000	1500
S1	Min	22.42	51.37	0.09	665.00	-	-	12.5	-	4	8
	Max	26.06	70.15	0.87	1497.00	1.0	1.3	45.4	50.0	40	62
	Mean	24.19	60.34	0.19	1139.71	-	0.2	28.7	13.0	20	30
	SD	0.85	3.10	0.05	78.31	-	0.3	11.7	8.1	14	18
S2	Min	25.26	48.53	0.09	453.00	-	-	42.1	6.0	8	2
	Max	28.99	57.54	0.66	743.00	-	0.5	45.4	72.0	20	14
	Mean	25.90	52.95	0.16	593.00	-	-	43.8	26.0	14	8
	SD	0.28	1.91	0.02	8.49	-	-	2.4	5.7	8	8
S3	Min	24.15	44.36	0.09	447.00	-	-	16.7	-	12	10
	Max	29.02	74.16	3.18	965.00	7.0	3.2	91.3	131.0	178	180
	Mean	27.26	51.20	0.62	623.43	0.1	0.6	50.1	22.3	93	85
	SD	1.11	1.84	0.46	51.61	0.4	0.2	24.6	17.3	63	58
ICOPIAQ		23-26	40-70	0.15-0.50	< 1000	< 10	< 3.0	< 150	-	500	500

Note: (-) represents the concentrations below the detectable limit.

ICOPIAQ represents Industry Code of Practice on Indoor Air Quality (DOSH Malaysia, 2010)

For temperature, the measured values were 24.19 °C, 25.90 °C and 27.26 °C for S1, S2 and S3 respectively. Among the three sampling locations, S3 had the highest average temperature and it slightly exceeded the limit with a difference of 1.26 °C. Since S3 was mechanical ventilated with air-conditioner therefore this might be due to the AC settings. AC settings should be set correctly in order to maintain the temperature in acceptable range and ensure the thermal comfort. For air velocity, the measured values were 0.19 m s<sup>-1</sup>, 0.16 m s<sup>-1</sup>, and 0.62 m s<sup>-1</sup> for S1, S2 and S3 respectively. S3 also recorded the highest air velocity and slightly exceeded the limit with a difference of 0.12 m s<sup>-1</sup>. This was due to the sampling spot was situated nearby a mechanical fan. A mechanical fan supplies high velocity air to its surrounding. For CO<sub>2</sub>, the measured values were 1139.71 ppm, 593.00 ppm and 623.43 ppm for S1, S2 and S3 respectively. Among three sampling locations, S1 recorded the highest CO<sub>2</sub> concentration at 1139.71 ppm and had exceeded the limit with a difference of 139.71 ppm. The poor ventilation might be the cause of the high CO<sub>2</sub> concentration. The other research that measured higher CO<sub>2</sub> levels in other building categories suggested that poor ventilation could be the reason (Ismail et al, 2010; Lee et al, 2000; Li et al, 2001). Poor ventilation occurs when the fresh air intake is insufficient and might further lead to the accumulation of CO<sub>2</sub> in that particular space.

For RH, the measured values were 60.34%, 52.95% and 51.20% for S1, S2 and S3 respectively. For CO, S1 and S2 recorded values under detectable limit whereas S3 recorded 0.4 ppm. For TVOC, S2 recorded value under detectable limit whereas S1 and S3 recorded 0.2 ppm and 0.6 ppm respectively. Low CO and TVOC were recorded due to the absence of combustion process and possible TVOC sources like solvents and cleaning agents in the sampling locations.

For PM<sub>10</sub> and PM<sub>2.5</sub>, S1 recorded 28.7 µg m<sup>-3</sup> and 13.0 µg m<sup>-3</sup> respectively; S2 recorded 43.8 µg m<sup>-3</sup> and 26.0 µg m<sup>-3</sup> respectively and S3 recorded 50.1 µg m<sup>-3</sup> and 22.3 µg m<sup>-3</sup>. Generally, the values for PM<sub>2.5</sub> would usually be lower than PM<sub>10</sub>. Studies suggest that PM<sub>2.5</sub> can post more consequential health effects than PM<sub>10</sub> due to it can penetrate deeper into smallest airways and alveoli (Du et al., 2016). The PM<sub>10</sub> values recorded for three locations were far lower than 150 µg m<sup>-3</sup> suggested as limit of exposure.

For TBC at 10:00 and 15:00, S1 recorded 20 CFU m<sup>-3</sup> and 30 CFU m<sup>-3</sup> respectively; S2 recorded 14 CFU m<sup>-3</sup> and 8 CFU m<sup>-3</sup> respectively and S3 recorded 93 CFU m<sup>-3</sup> and 85 CFU m<sup>-3</sup>. The low levels of TBC recorded can be explained with the low RH recorded. Studies suggest that when RH is maintained between 40-60%, the growth of bacteria can be suppressed better than low or high humidity [1].

Overall, measured values of CO, TVOC, PM<sub>10</sub>, and TBC (10:00 and 15:00) were all within the limits set by ICOPIAQ in all three offices. This suggests that the processes in this food industry like raw material conveying, packaging equipment, bulk loadout operations, boilers, lime kilns and others which might emit PM, VOC were not contributing to the pollutant levels in the offices.

Figure 1, 2 and 3 show the variations of temperature, air velocity and CO<sub>2</sub> respectively over the time. Only these three variations of parameters were shown instead of all parameters because these three parameters were not complied with the standard of ICOPIAQ 2010.

For the temperature, three offices show no obvious fluctuation along the sampling hours as shown in Figure 1 due to they were all mechanical ventilated which the temperature was controlled by the AC. The temperature at S3 was

above 26°C as suggested by standard for the whole eight hours of monitoring.

As shown in Figure 2, air velocity at S1 and S2 shows stable trend along the sampling hours. For S3, air velocity fluctuates due to the influence by mechanical fan.

For CO<sub>2</sub>, S1, S2 and S3 were all mechanical ventilated with AC. As shown in Figure 3, S2 and S3 showed low and stable CO<sub>2</sub> along the sampling hours. However for S1, it was observed that CO<sub>2</sub> increased when workers started occupied the office (from 30 to 270 minutes interval) and decreased when they left for break (from 270 to 330 minutes interval). CO<sub>2</sub> rose again when the workers reoccupied office (from 330 to 480 minutes interval) and reached the maximum at end of working hours (480 minutes interval). When people present in an area, they exhale out CO<sub>2</sub> while they are breathing. The CO<sub>2</sub> tends to accumulate to higher concentration if poor ventilation rate is provided.

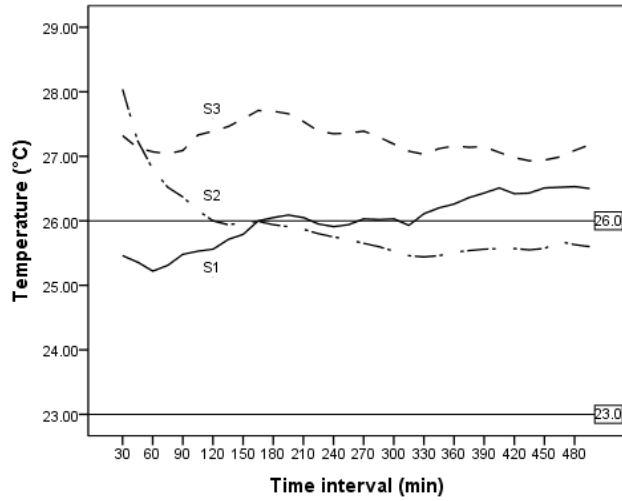


Figure 1. Variation of temperature at S1, S2 and S3

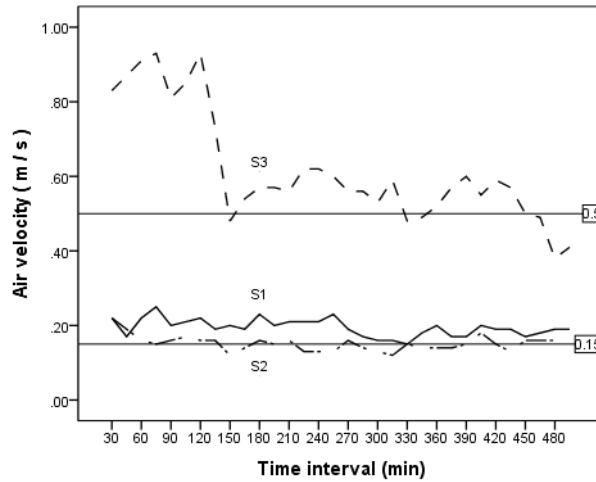


Figure 2. Variation of air velocity at S1, S2 and S3

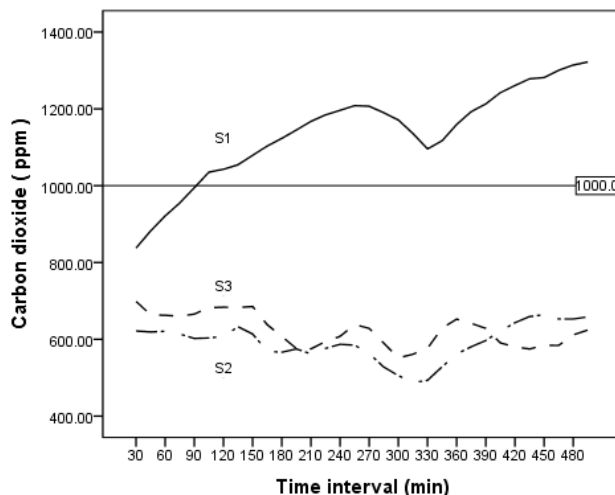


Figure 3. Variation of CO<sub>2</sub> at S1, S2 and S3

## CONCLUSION

Parameters measured like CO, TVOC, PM<sub>10</sub>, and TBC (10:00 and 15:00) in three offices were all complied with the standard (ICOPIAQ 2010) except for temperature and air velocity in screening station (S3), which were 27.26 °C and 0.62 m s<sup>-1</sup> respectively and CO<sub>2</sub> concentration in administrative office (S1), which was 1139.71 ppm. This suggests that the processes in this food industry like raw material conveying, packaging equipment, bulk loadout operations, boilers, lime kilns and others which might emit PM, VOC were not contributing to the pollutant levels in the offices. In screening station, the high temperature was probably due to the AC settings and the high air velocity was due to the influence of nearby mechanical fan. For high CO<sub>2</sub> concentration in administrative office, it happened due to the poor ventilation was provided.

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