International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Indoor Air Quality Investigation in Manufacturing and Storing Areas inside a Food Industry

Chiang Ann Wong[1], Mardiana Idayu Ahmad[2]

Environmental Technology Division, School of Industrial Technology, Universiti Sains Malaysia, Penang, Malaysia

Abstract: ***This study was done to investigate the air quality in manufacturing and storing areas inside a food industry. Four locations were chosen within the premises of the food industry which are raw material house, processing area, warehouse and packing department. 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 the locations. 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 the Department of Occupational Safety and Health, Malaysia. The results showed that all parameters measured in four locations were all complied with the standard except for temperature in raw material house, processing area and warehouse, which was 34.85 °C, 35.60 °C and 34.45 °C respectively; air velocity in processing area and warehouse which was 0.14 m s^{-1} and 0.65 m s^{-1} respectively; particulate matter 10 and 2.5 micron in packing department, which the former recorded 2389.3 µg m^{-3} and the latter recorded 182.3 µg m^{-3}. Possible sources were identified in the exceptional cases. This investigation indicates an average performance of the indoor air in manufacturing and storing areas inside the respective food industry.***

Keywords: Indoor air quality, Food industry, Particulate matter

1. Introduction

Few studies show that people tend to spend more than 80% of time in indoor environment [1], [2]. It was also found out that poor indoor air quality is correlated to health-related problems including Sick Building Syndrome [3]. Some other health-related problems like respiratory and cardiovascular problems are also correlated with certain air contaminants [4], [5]. The indoor air quality of an industry can be quite contaminated, depending on the industrial activities. Besides that, certain studies found that indoor pollutant levels are greater than outdoor levels [6]. Failure to maintain good indoor air quality can increase the chance of long-term and short-term health problems, thus reduce the productivity of the building occupants and affect the performance of industry [7].

A respectable number of studies about indoor air quality have been conducted so far in different building categories including museum, printery industry, office, residence, hotel, school, shopping mall, market and restaurant except in the food industry [8], [9], [10], [11]. Different types of buildings recorded different concentrations of various parameters due to varying environmental settings and also different activities being conducted.

This paper investigates the quality of air in few locations in the premises of the food industry by monitoring certain parameters including temperature, relative humidity (RH), air velocity, carbon dioxide (CO_2), carbon monoxide (CO), total volatile organic compound (TVOC), particulate matter 10 and 2.5 micron (PM_{10} and $PM_{2.5}$) and total bacterial counts (TBC). Then the variations of paramaters which exceeded the standard's limits were further investigated in boxplots and line charts.

2. Methodology

Four locations were chosen within the premises of the food industry which are raw material house, processing area, warehouse and packing department. The characteristics of four locations are presented in Table 1.

An indoor air quality sampling was carried out on days chosen within six months (April to September) in 2016. The sampling strategy was mainly referred to Industry Code of Practice on Indoor Air Quality 2010 (ICOPIAQ 2010) by Department of Occupational Safety and Health (DOSH), Malaysia. The sampling equipment was placed about 1 m above floor level at the locations. For the parameters, all were measured for days chosen randomly along the sampling period for 8 hours continuously from 0900 to 1700 which covered the normal working hours except for total bacterial count (TBC). The data logging interval was set to one minute. Physical parameters including temperature, RH, air velocity were measured. The former two parameters were measured using HOBO (Model U12-012, Onset). The latter was measured using Accusense (Model F900, Degree Control Inc). Chemical parameters including CO_2, CO, TVOC, $PM_{2.5}$, PM_{10} were measured. The former four parameters were measured using EVM Environmental Monitors (Model EVM-7, 3M). The latter was measured by Minivol Portable Air Sampler (Airmetrics Inc) using gravimetric method. A <10 µm impactor was used to collect airborne particles on glass microfiber filters (GF/A, Whatman) at a flow rate of 5 L/min. The initial and final weight were measured using analytical balance. Biological parameter which is TBC was measured using Microbial Air Sampler (Model MAS-100 Eco, MBV) at a flow rate of 100 L/min for five minutes. It was sampled and impacted on 90-mm Petri dished containing trypticase soy agar (TSA) twice per day at 1000 and 1500 which covered morning and afternoon sessions respectively. The used TSA plates were incubated at 37°C for two days and the concentrations were determined as colony forming units per cubic meter of air (CFU/m3) using plate count method.

3. Results and Discussion

Table 2 shows the average concentrations of measured parameters in four sampling locations and permitted values set in ICOPIAQ 2010. Figure 3 shows the boxplots of measured parameters in four sampling locations.

Table 1: Main characteristics of the sampling stations

Code	Sampling locations	Number of occupants	Ventilation	Main equipment/ environment	Main activities
S1	Raw material house	0-3	Natural	Bulldozer, piles of raw material	Transporting of raw materials from outside into the processing area
S2	Processing area	-	Natural	Processing machines	Processing of raw materials
S3	Warehouse	10-15	Natural	Forklifts, bulks of end products	Moving and storing of end products
S4	Packing department	10-13	Mechanical	Packing machines and packaging lines	Packaging of products

Table 2: Average concentrations of measured parameters

Sampling locations		Temp, °C	RH, %	Air Velocity m s^{-1}	CO_2, ppm	CO, ppm	TVOC, ppm	PM_{10}, µg m^{-3}	$PM_{2.5}$, µg m^{-3}	TBC, CFU m^{-3}	
										1000	1500
S1	Mean	34.85	60.10	0.48	431.50	0.5	-	123.5	72.5	48	23
S2	Mean	35.60	63.35	0.14	453.00	0.5	-	153.3	95.5	58	179
S3	Mean	34.45	60.15	0.65	443.00	-	-	102.5	35.0	82	13
S4	Mean	25.41	69.26	0.33	585.14	-	1.1	2389.3	182.3	59	65
ICOPIAQ 2010		23-26	40-70	0.15-0.50	< 1000	< 10	< 3	< 150	-	500	500

Note: (-) represents the concentrations below the detectable limit.
ICOPIAQ represents Industry Code of Practice on Indoor Air Quaity (DOSH Malaysia, 2010)

3.1. Temperature

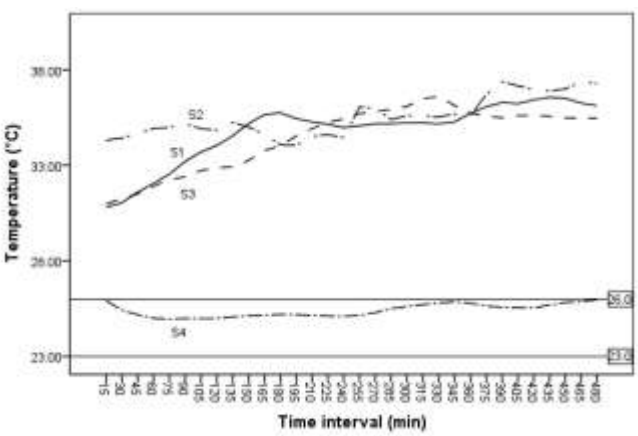


Figure 1: Variation of temperature at S1, S2, S3 and S4

S1, S2 and S3 recorded similar values of temperature which was 34.85 °C, 35.60 °C and 34.45 °C respectively as shown in Table 2. These three values were exceeded the acceptable range which was between 23-26 °C. This occurred due to the three locations were natural ventilated. When natural ventilated, the temperature is greatly depending on the outdoor temperature. This is further supported by the variation of temperature as shown in Figure 1 which the temperature was low in the morning and began to increase when time passed. In Malaysia as a hot and humid country, the outdoor temperature could reach up to 39.3 °C [12]. For S4 which was mechanical ventilated, it recorded mean temperature of 25.41 °C which falls in the acceptable range. As show in Figure 1, the temperature in S4 was quite constant along the sampling period.

3.2. Relative humidity

The RH recorded in the space was 60.10% for S1, 63.35% for S2, 60.15% for S3 and 69.26% for S4 as shown in Table 2. All values were within the recommended range but S4 was found out close to 70% with difference of 0.74%. This could be due to dehumdification of air conditioner was not funtioning at optimum. Problems like growing of bacteria, viruses, fungi, mites could be arised if the RH is greater than 70% [13].

3.3. Air velocity

International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

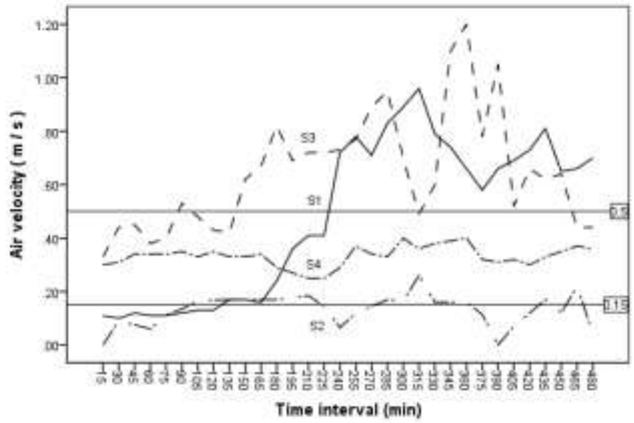
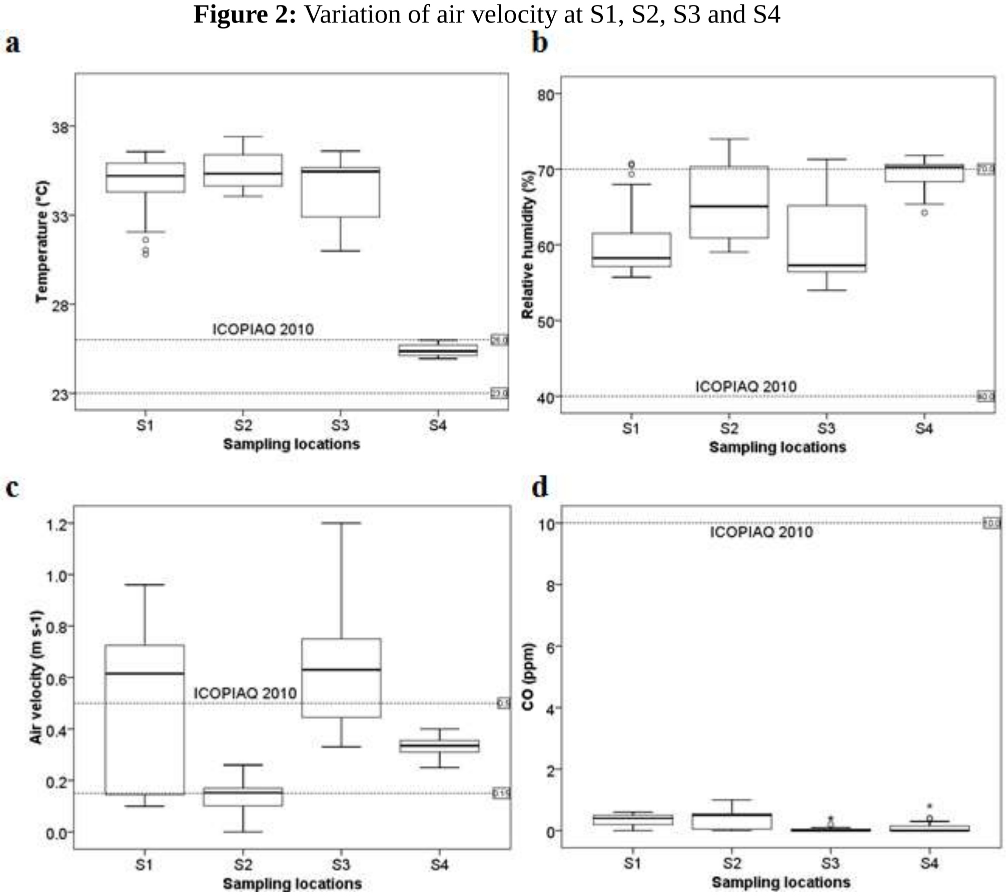


Figure 2: Variation of air velocity at S1, S2, S3 and S4



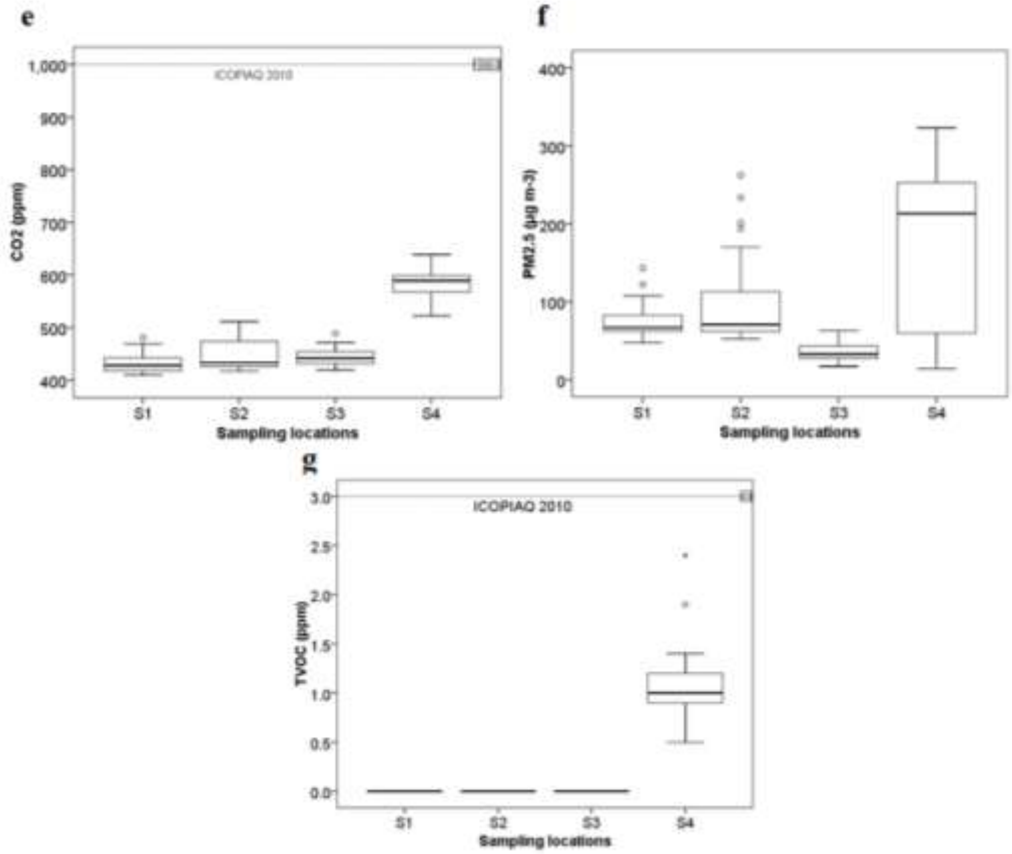


Figure 3: Boxplots of measured parameters at S1, S2, S3 and S4. (a) Temperature; (b) Relative humidity; (c) Air velocity; (d) Carbon monoxide; (e) Carbon dioxide; (f) Particulate matter 2.5 micron; (g) Total volatile organic compound.

The mean air velocity for S1, S2, S3 and S4 was 0.48 m s^{-1}, 0.14 m s^{-1}, 0.65 m s^{-1} and 0.33 m s^{-1} respectively as shown in Table 2. The air flow rate for S2 was slightly lower than than the limit with a difference of 0.1 m s^{-1}. This was due to the processing area was a confined space which solely depending on natural wind to ventilate. Besides, the machineries and compartments inside might further prevent the natural air flow. S3 had mean air velocity which was 0.15 m s^{-1} higher than the limit. Figure 2 shows that air velocity in S1 and S3 were fluctuated alot due to the influence of natural wind and S4 displays a stable trend of air velocity along the sampling period.

3.4. Carbon dioxide

According to ICOPIAQ 2010, the CO_2 concentration is recommended below 1000 ppm for continuous exposure for eight hours. The mean CO_2 for four samping locations was ranged from 431.50 ppm to 585.14 ppm as shown in Table 2. Since the values were complied with the standard, it is considered safe to the building occupants. Besides, the values in natural ventilated locations were found to be similar to ambient CO_2 concentration which is about 400 ppm [14] and also lower than the value in mechanical ventilated location.

3.5. Carbon monoxide

The CO concentration for S1 and S2 was 0.5 ppm for both. For S3 and S4, both were under the detectable limit as shown in Table 2. Usually CO is produced through incomplete combustion of carbonaceous fuels such as petrol, kerosene and others [15]. The source here could be from the bulldozer at S1 and processing machines at S2. Overall, the CO concentration at four locations was low and considered safe.

3.6. Total volatile organic compound

Based on the results obtained, it is observed that TVOC concentration was low at four sampling locations as shown in Table 2. It was under detectable limit for S1, S2 and S3. For S4, this packing department recorded a mean concentration of 1.1 ppm which was also lower than 3 ppm suggested as limit of exposure. During the inspection process, we observed that the scheduled cleaning activity using cleaning agent and also the solvent used to clean the packaging stamp could be the pollutant source. Studies show that cleaning agent and solvent will emit VOC [16], [17].

3.7. Particulate matter 10 micron and 2.5 micron

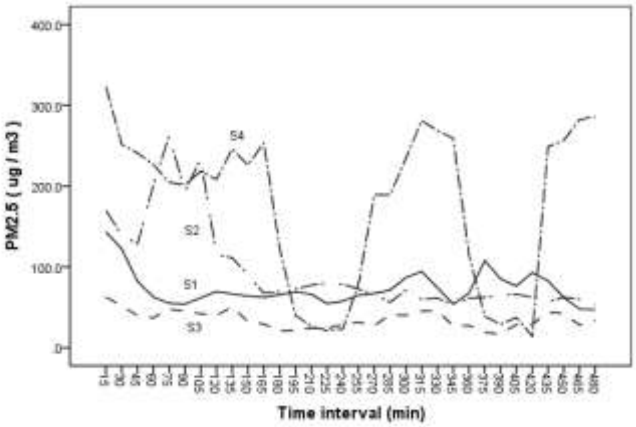


Figure 4: Variation of $PM_{2.5}$ at S1, S2, S3 and S4

As shown in Table 2, the concentration of PM_{10} for S1, S2, S3 and S4 was 123.5 µg m^{-3}, 153.3 µg m^{-3}, 102.5 µg m^{-3}, 2389.3 µg m^{-3} respectively whereas the concentration of $PM_{2.5}$ for S1, S2, S3 and S4 was 72.5 µg m^{-3}, 95.5 µg m^{-3}, 35.0 µg m^{-3}, 182.3 µg m^{-3} respectively. For PM_{10}, S2 slightly exceeded the 150 µg m^{-3} suggested by ICOPIAQ 2010 while S4 was about 16 times of the value suggested by the standard. There is no standard to be compared for $PM_{2.5}$ for indoor air, however the suggested value of $PM_{2.5}$ should be lower than PM_{10} since it is more hazardous due to its smaller size will allow it to penetrate into smallest airways and alveoli [18], [19]. For $PM_{2.5}$, S4 also recorded the highest value as in PM_{10}. As shown in Figure 4, S4 was fluactuated much along the sampling period. During the inspection process, we observed that the low peaks occurred during lunch break and short break whereas the high peaks occured when the packaging process was carrying out. During the packaging process of end product, it released fine food particles into the air and contributed to $PM_{2.5}$. Besides, the high level of PM_{10} was probably due to the packaging process also as we have seen in $PM_{2.5}$.

3.8. Total Bacterial Count

Based on the data, S3 recorded the highest TBC in morning session with 82 CFU m^{-3} whereas S2 recorded the highest TBC in afternoon session with 179 CFU m^{-3}. Both values are considered low if compared with 500 CFU m^{-3} suggested as limit of exposure. Further action is only needed when the value exceeds 500 CFU m^{-3} in order to have better understanding of the bacteria by studying the gram, species and other morphologies.

4. Conclusion

After the investigation of indoor air quality in manufacturing and storing areas inside the food industry, results showed that all parameters measured in four locations were all complied with the standard with some exceptions. The parameters which exceeded the limit suggested in ICOPIAQ 2010 were temperature in raw material house, processing area and warehouse, which was 34.85 °C, 35.60 °C and 34.45 °C respectively; air velocity in processing area and warehouse which was 0.14 m s^{-1} and 0.65 m s^{-1} respectively; particulate matter 10 and 2.5 micron in packing department, which the former recorded 2389.3 µg m^{-3} and the latter recorded 182.3 µg m^{-3}. Possible sources were identified in the exceptional cases including influence by outdoor environment, environmental settings of monitoring spots and the activities being carried out. Overall, this investigation indicates an average performance of the indoor air in manufacturing and storing areas inside the respective food industry.

References

[1] Robinson J, Nelson WC (1995). National human activity pattern survey data base. Research Triangle Park, NC: United States Environmental Protection Agency.

[2] Sharpe M (2004). Safe as houses? Indoor air pollution and health. J. Environmental Monitoring. 6: 46-49.

[3] Jones AP (1999). Indoor air quality and health. Atmospheric Environment. 33, 4535-4564.

[4] Janssen NAH, Schwartz J, Zanobetti A, Suh HH (2002). Air conditioning and source-specific particles as modifiers of the effect of PM on hospital admissions for heart and lung diseases. Environ Health Perspect., 110, 43-9.

[5] Peters A, Dockery DW, Muller JE, Mittleman MA (2001). Increased particulate air pollution and the triggering of myocardial infarction. Circulation, 103:2810-5.

[6] Montgomery DD, Kalman DA (1989). Indoor/outdoor air quality: Reference concentrations in complaint free residences. Appl. Ind. Hyg. 4, 17-20.

[7] Birnbaun HG, Morley M, Greenberg PE, Colice GL (2002). Economic burden of respiratory infections in an employed population. Chest, 122, 2, 603-611.

[8] Lee S, Guo H, Li W, Chan L (2002). Inter comparison of air pollutant concentrations in different indoor environments in Hong Kong. Atmospheric Environment, 36, 1929-1940.

[9] Chan W, Lee SC, Chen Y, Mak B, Wong K, Chan C, Zheng C, Guo X (2009). Indoor air quality in new hotel' guest rooms of the major world factory region. Internatonal Journal of Hospitality Management, 28, 26-32.

[10] Saraga D, Pateraki S, Papadopoulos A, Vasilakos C, Maggos T (2011). Studying on the indoor air quality in three non-residential environments of different use: A museum, a printery industry and an office. Building and environment, 46, 2333-2341.

[11] Muhamad-Darus F, Zain-Ahmed A, Latif MT (2011). Preliminary assessment of indoor air quality in terrace houses. Health and the Environmental Journal, 2, 8-14.

[12] Malaysian Meteorological Department (2016). Monthly Weather Bulletin, April 2016.

[13] Alsmo T, Alsmo C (2014). Ventilation and relative humidity in Swedish buildings. Journal of Environmental Protection, 5, 1022-1036.

[14] Kumar U, Quick WP, Barrios M, Cruz PCS, Dingkuhn M (2017). Atmospheric CO_2 concentration effects on rice water use and biomass production. PLOS ONE, 1-17.

[15] WHO (2010). WHO guidelines for indoor air quality:

Selected pollutants.

[16] Franklin PJ (2007). Indoor air quality and respiratory health of children. Paediatric Repiratory Reviews, 8, 281-286.

[17] Zhang J, Smith KR (2003). Indoor air pollution: a global health concern. British Medical Bulletin, 68, 209-225.

[18] Du Y, Xu X, Chu M, Guo Y, Wang J (2016). Air particulate matter and cardiovascular disease: the epidemiological, biomedical and clinical evidence. Journal of Thoracic Disease, 8(1), E9-E9.

[19] Xing Y, Xu Y, Shi M, Lian Y (2016). The impact of PM2.5 on the human respiratory system. Journal of Thoracic Disease, 8(1), E69-E74.