



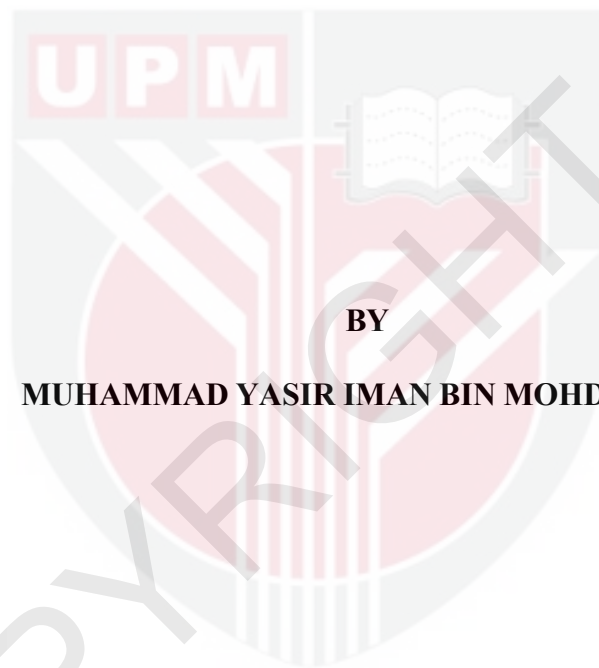
UNIVERSITI PUTRA MALAYSIA

***ASSESSMENT OF INDOOR PM_{2.5} AND CO₂ IN SELECTED
KITCHENS OF HOME-BASED COOKING BUSINESS IN KLANG
VALLEY***

MUHAMMAD YASIR IMAN BIN MOHD YUSRI

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HOME-BASED COOKING BUSINESS IN KLANG VALLEY**



BY

MUHAMMAD YASIR IMAN BIN MOHD YUSRI

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Science in Environmental and Occupational Health with Honours from the
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ABSTRACT

ASSESSMENT OF INDOOR PM_{2.5} AND CO₂ IN SELECTED KITCHENS OF HOME-BASED COOKING BUSINESS IN KLANG VALLEY

MUHAMMAD YASIR IMAN BIN MOHD YUSRI

Introduction: Indoor air pollution is a major health risk, especially for people who spend a lot of time indoors, like home cooks and people who does home-based food businesses. Cooking is proven to be a big source of indoor air pollution, releasing harmful particles and chemicals like particulate matters 2.5 and carbon dioxide. This could lead to many respiratory health problems, heart disease, and even cancer which is concerning. Measurement of the pollutants towards the home-based food handlers (HBFHs) shall be studied to determine the exposure levels towards them which can be obtained from the calculation of inhalation dose as well as the average daily dose of the pollutants. **Objective:** This study aims to assess the levels of indoor PM_{2.5} and CO₂ in selected home-based food business in Klang Valley, Selangor, Malaysia. **Methodology:** The study was conducted at six selected houses that operated home-based cooking (namely H1,H2,H3,H4,H5, and H6) which undergone a convenience sampling located in Klang Valley, Malaysia. These houses were then categorised according to their food business which includes Bakery (H1, H2), Malay cuisine (H3, H4, H5), and Western cuisine (H6). The MILESEEEY Laser Distance Meter was used to obtain the volume of kitchen space of the selected location. PM_{2.5} concentrations were measured using TSI DustTrak II Aerosol Monitor 8532. CO₂, relative humidity and temperature were recorded using HOBO CO₂ Logger (MX1102). In addition, mass concentrations of PM_{2.5} were quantified from collected 37-mm PTFE filter fitted in Gilair Plus Personal Air Sampling Pump at 1.8 min/l flow rate. All measurements were conducted for 6 hours during the day operation of home cooking business. Time-activity diary was also utilised in recording different types of cooking activity used in different time span across the operating business. The decay rate, inhalation dose, and average daily dose of PM_{2.5} and CO₂ were also quantified. **Result:** PM_{2.5} levels were observed the highest in houses that operated for Malay cuisine (median: 72.4, IQR: 59.1-98.0), followed by Bakery (median: 64.8, IQR: 54.9-76.5) and Western cuisine (median: 52.0, IQR: 50.0-53.5). The levels of PM_{2.5} were influenced by the size of the kitchen, the type of ventilation system used, and the cooking methods employed. CO₂ levels were found to the highest at Bakery (median: 903.8, IQR: 607.9-1409.4), followed by Western cuisine and Malay cuisine (median: 769.5, IQR: 695.0-874.0; median: 663.2, IQR: 605.6-727.1). For relative humidity (RH), Malay cuisine had the highest value followed by Western cuisine and Bakery (median: 68.1, IQR: 65.6-70.5; median: 66.9, IQR: 66.5-67.2; median: 61.9, IQR: 60.5-63.1). As for the temperature (T), the highest recorded value was by Western cuisine (median: 31.9, IQR: 31.8-31.9). The second highest was Malay cuisine (median: 31.5, IQR: 30.8-31.8) followed with Bakery (median: 29.6, IQR: 28.9-29.8). This study found a fair positive correlation between PM_{2.5} and CO₂ in all businesses which were Bakery, Malay cuisine, and Western cuisine ($p = 0.645$; $p = 0.425$; $p = 0.534$). The decay rate was found lowest in Western cuisine (0.1 h^{-1}), followed by Bakery (1.4 h^{-1}), and the highest was Malay cuisine (1.7 h^{-1}). Houses that operated for Malay cuisine businesses resulted the highest inhalation dose of PM_{2.5} ($318 \mu\text{g}$) and average daily dose ($85.9 \text{ m}^3/\text{kg-day}$), followed by Bakery and Western cuisine ($221.6 \mu\text{g}$ and $48.6 \text{ m}^3/\text{kg-day}$; $177.8 \mu\text{g}$ and $37.1 \text{ m}^3/\text{kg-day}$). This finding indicates that when the inhalation dose of PM_{2.5} is high, the

ADD of PM_{2.5} towards the food handlers are also high. For CO₂, the inhalation dose was the highest in Malay cuisine ($6.68 \times 10^6 \mu\text{g}$), and the highest ADD was by Malay cuisine ($1.45 \times 10^6 \text{ m}^3/\text{kg-day}$). The lowest inhalation dose and ADD of CO₂ was by Western cuisine with value of $4.82 \times 10^6 \mu\text{g}$ and $0.78 \times 10^6 \text{ m}^3/\text{kg-day}$ respectively. Further analysis was conducted to find significant between different types of businesses and the inhalation dose. ANOVA analysis test was conducted and found no significant between them, thus similar pattern of PM_{2.5} was generated throughout the cooking activities in all of the kitchen. Finally, inhalation dose of PM_{2.5} was also calculated across different types of cooking methods in each business. For the inhalation dose of PM_{2.5}, it was discovered that baking from Bakery generated the highest amount of PM_{2.5} across all of the businesses (median: 90.9). For Malay cuisine, the highest inhaled dose for PM_{2.5} was during the frying and stirring activity while for Western cuisine, the highest was during stir frying (median: 28.9; median: 42). No previous studies were conducted to support the findings, and this could act as a baseline for compare and a further study. **Conclusion:** Overall, the study found that home-based food businesses in Malaysia have poor indoor air quality due to high PM_{2.5} and CO₂ levels. The levels of PM_{2.5} were influenced by the size of the kitchen, the type of ventilation system used, and the cooking methods employed. At the same time, the food handlers were also exposed to the pollutants via inhalation which make them susceptible to develop a long-term or chronic pulmonary disorders. The study recommends that home-based food businesses shall improve their indoor air quality by using proper ventilation systems and by adopting cooking methods that generate less PM_{2.5} such as using less oil in the cooking methods. A change of behaviour towards health is also recommended such as turning on available hood, open windows, and regular cleaning of the kitchen. It is also suggested to utilise ventilation system such as air purifier with good maintenance to filter the particulates thus reducing the exposure towards the food handlers. These findings highlight the need for further research into specific cooking practices and ventilation strategies to develop targeted PM_{2.5} mitigation strategies to improve indoor air quality towards the food handlers as well as the occupants in diverse food businesses.

Keywords: Indoor Air Quality, home-based food businesses, average daily dose, PM_{2.5}, types of cooking

ABSTRAK

PENILAIAN PM_{2.5} DAN CO₂ DALAMAN DI DAPUR TERPILIH BAGI PERNIAGAAN MEMASAK BERASASKAN RUMAH DI LEMBAH KLANG

MUHAMMAD YASIR IMAN BIN MOHD YUSRI

Pengenalan: Bagi banyak pengendali makanan berasaskan rumah (HBFH) di seluruh dunia, memasak, tindakan memudahkan orang lain, menjadi suatu sumber yang bahaya secara tidak kelihatan. Tindakan menyediakan makanan mendedahkan mereka kepada zarah halus (PM_{2.5}) dan karbon dioksida (CO₂), yang dihasilkan daripada aktiviti memasak. Bahan pencemar ini boleh melepasi pertahanan semula jadi dan membawa kesan kepada kesihatan. Daripada isu pernafasan seperti asma dan bronkitis kepada penyakit kardiovaskular dan juga penurunan sistem kognitif, pendedahan jangka panjang kepada PM_{2.5} dan CO₂ boleh membawa kesan yang teruk bagi HBFH. **Objektif:** Kajian ini bertujuan untuk menilai tahap PM_{2.5} dan CO₂ dalam dapur rumah bagi perniagaan makanan berasaskan rumah terpilih di Lembah Klang, Selangor, Malaysia. **Metodologi:** Kajian dijalankan di enam buah rumah terpilih yang mengendalikan masakan berasaskan rumah (iaitu H1, H2, H3, H4, H5, dan H6) yang menjalani persampelan mudah di Lembah Klang, Malaysia. Rumah-rumah ini kemudiannya dikategorikan mengikut perniagaan makanan mereka yang merangkumi Bakeri (H1, H2), masakan Melayu (H3, H4, H5), dan masakan Barat (H6). Meter Jarak Laser MILESEYY digunakan untuk mendapatkan isipadu ruang dapur lokasi yang dipilih. Tahap PM_{2.5} diukur menggunakan TSI DustTrak II Aerosol Monitor 8532. CO₂, kelembapan relatif dan suhu direkodkan menggunakan HOBO CO₂ Logger (MX1102). Di samping itu, kepekatan jisim PM_{2.5} dikira daripada penapis PTFE 37-mm terkumpul yang dipasang dalam Pam Pensampelan Udara Peribadi Gilair Plus pada kadar aliran 1.8 min/l. Semua pengukuran telah dijalankan selama 6 jam semasa operasi hari perniagaan masakan rumah. Diari aktiviti dan masa juga digunakan dalam merekodkan pelbagai jenis aktiviti memasak yang digunakan dalam jangka masa yang berbeza di seluruh perniagaan sepanjang operasi. Kadar pereputan, dos penyedutan dan purata dos harian (ADD) PM_{2.5} dan CO₂ juga dikira. **Keputusan:** Tahap PM_{2.5} diperhatikan tertinggi di rumah yang beroperasi untuk masakan Melayu (median: 72.4, IQR: 59.1-98.0), diikuti oleh Bakeri (median: 64.8, IQR: 54.9-76.5) dan masakan Barat (median): 52.0, IQR: 50.0-53.5). Tahap PM_{2.5} dipengaruhi oleh saiz dapur, jenis sistem pengudaraan yang digunakan, dan kaedah memasak yang digunakan. Paras CO₂ didapati paling tinggi di Bakeri (median: 903.8, IQR: 607.9-1409.4), diikuti oleh masakan Barat dan masakan Melayu (median: 769.5, IQR: 695.0-874.0; median: 663.2, IQR: 605.6-7). Untuk kelembapan relatif (RH), masakan Melayu mempunyai nilai tertinggi diikuti oleh masakan Barat dan Bakeri (median: 68.1, IQR: 65.6-70.5; median: 66.9, IQR: 66.5-67.2; median: 61.9, IQR: 60.5-63.1). Bagi suhu (T), nilai tertinggi dicatatkan oleh masakan Barat (median: 31.9, IQR: 31.8-31.9). Kedua tertinggi ialah masakan Melayu (median: 31.5, IQR: 30.8-31.8) diikuti dengan Bakeri (median: 29.6, IQR: 28.9-29.8). Kajian ini mendapati korelasi positif yang sederhana antara PM_{2.5} dan CO₂ dalam semua perniagaan iaitu Bakeri, masakan Melayu, dan masakan Barat ($p = 0.645$; $p = 0.425$; $p = 0.534$). Kadar pereputan didapati paling rendah dalam masakan Barat (0.1 h^{-1}), diikuti oleh Bakery (1.4 h^{-1}), dan yang tertinggi ialah masakan Melayu (1.7 h^{-1}). Rumah yang beroperasi untuk perniagaan masakan Melayu menghasilkan dos penyedutan tertinggi sebanyak PM_{2.5} ($318 \mu\text{g}$) dan purata

dos harian ($85.9 \text{ m}^3/\text{kg-hari}$), diikuti oleh Bakeri dan masakan Barat ($221.6 \mu\text{g}$ dan $48.6 \text{ m}^3/\text{kg-hari}$; $177.8 \mu\text{g}$ dan $37.1 \text{ m}^3/\text{kg-hari}$). Dapatan ini menunjukkan bahawa apabila dos penyedutan $\text{PM}_{2.5}$ adalah tinggi, ADD $\text{PM}_{2.5}$ terhadap pengendali makanan juga tinggi. Bagi CO_2 , dos penyedutan adalah tertinggi di masakan Melayu ($6.68 \times 10^6 \mu\text{g}$), ADD tertinggi adalah juga oleh masakan Melayu ($1.45 \times 10^6 \text{ m}^3/\text{kg-hari}$). Dos penyedutan dan ADD CO_2 terendah adalah masakan Barat dengan nilai $4.82 \times 10^6 \mu\text{g}$ dan $0.78 \times 10^6 \text{ m}^3/\text{kg-hari}$ masing-masing. Analisis lanjut telah dijalankan untuk mencari signifikan antara jenis perniagaan yang berbeza dan dos penyedutan. Ujian analisis ANOVA telah dijalankan dan didapati tidak signifikan antara mereka, justeru corak $\text{PM}_{2.5}$ yang serupa telah dijana sepanjang aktiviti memasak di semua dapur. Akhir sekali, dos penyedutan $\text{PM}_{2.5}$ juga dikira merentas pelbagai jenis kaedah memasak dalam setiap perniagaan. Untuk dos penyedutan, didapati bahawa Bakeri menjana jumlah tertinggi (median: 90.9). Bagi masakan Melayu, dos sedutan tertinggi bagi adalah semasa aktiviti menggoreng dan mengacau manakala bagi masakan Barat, tertinggi adalah semasa menggoreng (median: 28.9; median: 42). Tiada kajian terdahulu dijalankan untuk menyokong penemuan, dan ini boleh bertindak sebagai garis dasar untuk perbandingan dan kajian lanjut. **Kesimpulan:** Secara keseluruhannya, kajian mendapati perniagaan makanan berasaskan rumah di Malaysia mempunyai kualiti udara dalaman yang lemah disebabkan paras dan CO_2 yang tinggi. Tahap dipengaruhi oleh saiz dapur, jenis sistem pengudaraan yang digunakan, dan kaedah memasak yang digunakan. Pada masa yang sama, pengendali makanan juga terdedah kepada bahan pencemar melalui penyedutan yang menyebabkan mereka terdedah kepada gangguan pulmonari jangka panjang atau kronik. Kajian itu mengesyorkan bahawa perniagaan makanan di rumah hendaklah meningkatkan kualiti udara dalaman mereka dengan menggunakan sistem pengudaraan yang betul dan dengan menggunakan kaedah memasak yang menghasilkan kurang seperti menggunakan kurang minyak dalam kaedah memasak. Perubahan tingkah laku terhadap kesihatan juga disyorkan seperti menghidupkan tudung yang tersedia, membuka tingkap, dan membersihkan dapur secara berkala. Ia juga dicadangkan untuk menggunakan sistem pengudaraan seperti penulen udara dengan penyelenggaraan yang baik untuk menapis zarah sekali gus mengurangkan pendedahan kepada pengendali makanan. Penemuan ini menyerlahkan keperluan untuk penyelidikan lanjut ke dalam amalan memasak khusus dan strategi pengudaraan untuk membangunkan strategi mitigasi yang disasarkan untuk meningkatkan kualiti udara dalaman terhadap pengendali makanan serta penghuni dalam perniagaan makanan yang pelbagai.

Kata kunci: Kualiti Udara Dalaman, perniagaan makanan berasaskan rumah, purata dos harian, , jenis masakan

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LIST OF ABBREVIATIONS

PM _{2.5}	Particulate matter 2.5
CO ₂	Carbon dioxide
US EPA	United State Environmental Protection Agency
HBFHs	HBFHs
WHO	World Health Organization
IAP	Indoor air pollution
IAQ	Indoor air quality
LPG	Liquified petroleum gas
PM	Particulate matter
SDG	Sustainable Development Goals
HEPA	High efficiency particulate air

CHAPTER 1

INTRODUCTION

This chapter will discuss about the background of the study, problem statement, study justification, research question, research objectives, research hypothesis, definition of terms, and conceptual framework.

1.1 Background study

The World Health Organization (WHO) reported that around 4.3 million individuals die annually due to the presence of indoor air pollutants (WHO, 2014). Since outdoor air is easier to observe and therefore more widely monitored, exposure to airborne fine particulate matter with a diameter of less than 2.5 μg ($\text{PM}_{2.5}$) has been linked to a number of detrimental health effects, including cardiovascular and respiratory disease. However, since majority of people spend up to 70% of their time in their homes, exposure to indoor air pollutants may have a greater impact on health (O'Leary & Jones, 2017). According to Van Tran et al. (2020), millions of people die each year as a result of indoor air pollution (IAP), which is a major threat to human health. A wide range of pollutants can cause IAP, so it's critical to pinpoint their primary sources and concentrations as well as develop control and improvement plans for indoor air quality (IAQ) (Van Tran et al., 2020).

Each of the many gaseous and particle components that make up air pollution is harmful to the respiratory and cardiovascular systems whereby the source, the rate of emissions, the amount of sunlight and wind, and other factors all affect the composition of air pollution (Hamanaka & Mutlu, 2018). IAP can be produced by individuals' activities inside of houses or buildings, including cooking, smoking, using electronics, using consumer goods, and emitting emissions from building materials (Van Tran et al., 2020). Since women in developing nations typically handle the majority of the cooking, they are more likely than men to be exposed to indoor air pollution (Kurmi et al., 2012).

The use of cleaner fuels (like liquefied petroleum gas, electricity, and natural gas) for cooking and heating, as well as advancements in technology for everyday household tasks, are largely responsible for the significantly lower indoor particle levels in developed countries than in developing ones, yet there are still known health risks for those who are exposed to indoor air in these places (Abdullahi et al., 2013). Due to the large amounts of particulate matter (ultrafine, fine, and coarse) and numerous potentially hazardous chemicals released during the heating of oil, fat, and other food ingredients, cooking has a significant effect on indoor air quality (IAQ) (Sun & Singer, 2023). Cooking effluent is a major contributor to pollution both indoors and outdoors, and exposure to cooking oil fumes can heighten the risk of various illnesses, necessitating the immediate need for a healthy indoor environment and energy-efficient kitchen ventilation (Zhao et al., 2019).

The primary causes of PM distribution inside buildings are cooking, smoking, using fossil fuels for energy, operating machinery, and engaging in recreational

activities at home and it was shown that these activities are the biggest contributors of indoor air PM (Van Tran et al., 2020). Zhao et al. (2019) has found that cooking has been found to release large amounts of particulate matter (PM), of which a large portion are inhalable particles, whereas these particles have the potential to seriously harm human health, and effluents are among the main sources of pollution in both indoor and outdoor environments, as a result, there is an urgent need for energy-efficient ventilation systems in kitchens and a healthy indoor environment because cooking oil fumes (COFs) increase the risk of numerous diseases.

The quality of indoor air within such environments is influenced by various factors, including cooking methods, ventilation systems, and the presence of contaminants. For instance, cooking activities involving frying, grilling, or using gas stoves can release particulate matter, volatile organic compounds (VOCs), and other potentially harmful substances into the air (Zhang, Smith, & Kerry, 2016). Considering these concerns, exploring strategies to improve indoor air quality for HBFHs becomes imperative. This might involve adopting better ventilation systems, using alternative cooking methods, or employing air purifiers to mitigate indoor air pollutants (Zhong et al., 2018).

1.2 Problem statement

In non-smoking households, cooking has been found to be a major source of PM_{2.5} (O’Leary & Jones, 2017). According to a study, when people searched for alternate means of income during the COVID-19 pandemic, the number of home-based food businesses in Bangladesh spiked considerably (Ishra et al., 2023). Ezani et al. (2021) described in a study that during the COVID-19 lockdown in Malaysia, cooking increased the exposure significantly due to rising PM_{2.5} concentrations. Their study found that indoor air quality was probably more important to health during COVID-19 restrictions than usual because cooking, home repairs, and hobbies were probably more common in packed interiors where daily activity is considerably more restricted (Ezani et al., 2021).

The transformation from restaurants to home-based cooking business are becoming a hot topic these days considering its own benefits economically towards the handlers. In Malaysia, Lee et al. (2017) found that the number of home-based food businesses has increased recently because of expanding variables including the appeal of home-cooked meals and the emergence of online food delivery platforms. A significant move from a traditional to an online strategy was made, and employing contemporary technologies like food applications was enlightening because, in addition to financial assistance from the Malaysian government, the online platform offers excellent prospects for food enterprises in the current crisis (Abdul Majid et al., 2022).

Looking from a healthcare view, this activity would raise concerns as cooking has always been known as one of the sources of indoor air pollutants, and HBHFs will

utilise a massive-continuous cooking throughout the day as their source of income like any other occupations. The quality of the air they breathe will directly impacts their health and the safety of the food they prepare. According to the US Environmental Protection Agency (USEPA), indoor air can be two to five times more polluted than outdoor air, primarily due to various factors such as inadequate ventilation, cooking emissions, and the presence of pollutants from different sources within homes (EPA, 2020).

Due to the emergence and also increasing of home-based cooking business, studies relating to the health status and the exposure towards any possible harmful pollutants shall be conducted to help in assessing the early steps in mitigating any health issues that may arise from this matter.

1.3 Study justification

The World Bank et al. (2023) highlight that Sustainable Development Goal (SDG) 3, which emphasizes ensuring healthy lives and promoting well-being for all at all ages, calls for additional measures to prevent people from breathing contaminated air in their homes. This is particularly relevant to home-based food handlers (HBFHs) in developing countries, who are often exposed to harmful pollutants due to cooking activities. The transformation from restaurants to HBFHs are also becoming more and bigger these days. This occurrence is also supported by many parties, from organisers, customers, and other related parties as it helps the economy and boosts the citizen's chances to work independently. For instance, the Malaysian government has announced an RM250 billion PRIHATIN package to aid small businesses in surviving, while RM40 million has been designated for small businesses involved in agriculture and food production (Abdul Majid et al., 2022). The study aims to investigate the occupational exposure to indoor air pollution among HBFHs and propose mitigation strategies. This aligns with SDG 3's focus on promoting well-being and reducing health risks.

Inadequate ventilation in HBFHs kitchens is a silent threat to the health and well-being of HBFHs, which will exacerbates the build-up of pollutants. Indoor smoke in inadequately ventilated homes can contain fine particle levels that exceed acceptable limits by a factor of 100 (Household Air Pollution, 2022). Furthermore, health of individuals is seriously threatened by the higher concentrations of indoor PM_{2.5} and CO₂ in these particular kitchens, specifically those who work in the kitchen. Long-term and frequent exposure to high concentrations of carbon dioxide and small particulates can contribute to cardiovascular disease, respiratory disorders, and other

health concerns towards the cook and their families who lives inside the same building. This study investigates the characteristics of the air inside the kitchen and the decay rate of PM_{2.5} in HBFHs kitchens, calculating inhalation dose and average daily dose (ADD) to assess pollutant exposure risk for home-based food handlers. This study intends to investigate into the specific causes and patterns of indoor air pollution inside the home-based cooking businesses, giving important insights for implementing optimal ventilation systems and decreasing health risks linked with poor indoor air quality. Furthermore, establishing specific interventions and policies to support a safer and healthier environment for the residents as well as workers requires a knowledge of the dynamics of indoor pollutants in these settings.

Although the widely recognised health hazards related to indoor air pollution, HBFHs lack access to efficient mitigating techniques. Improved cookstoves and ventilation systems are two current interventions that have shown potential, yet they might not be easily available or inexpensive for this community. However, looking at the perspective of healthcare, homes are not built for a heavy smoke or airflow with open spaces to allow the particulate matter as well as other components to smoothly come out the house. Eventually, this will become a bigger issue for the public as the cook in the house, as well as the occupants of the house would be affected from poor indoor air quality as a result of the poor ventilation and improper cooking activities indoors.

Therefore, this study provides an overview for creating a comprehensive understanding of the indoor air quality in the kitchen of HBFHs in Klang Valley. This study will serve as a baseline to identify and quantify the levels of PM_{2.5} and CO₂,

providing an in-depth analysis on the issues encountered by this particular business. The results will not only increase the knowledge of indoor air pollution, but will also offer focused, situation-specific advice on how to raise air quality regulations and encourage sustainable behaviours in HBFHs. This research is very crucial for creating awareness, guiding regulatory measures, and fostering a healthier environment for both the workers and the communities where these home-based cooking businesses operate.



1.4 Research question

Research question 1 : What is the physical state of the house of the HBFHs?

Research question 2 : What is the state of indoor $PM_{2.5}$ and CO_2 of the house of the HBFHs?

Research question 3 : What is the mass concentration of the $PM_{2.5}$ of the home of the HBFHs?

Research question 4 :What is the air exchange rate and decay rate of pollutants among HBFHs?

Research question 5 :What is the inhalation dose and the average daily dose (ADD) of pollutants among HBFHs?

1.5 Objectives

1.5.1 General objective

To assess the exposure level of pollutants towards HBFHs in Klang Valley, Selangor, Malaysia.

1.5.2 Specific objectives

Objective 1: To determine the physical state of the kitchen of the house of the HBFHs.

Objective 2: To assess the indoor air quality pollutants levels (PM_{2.5} and CO₂) in the kitchen of house of the HBFHs.

Objective 3: To determine the mass concentration of PM_{2.5} of the kitchen in the home of the HBFHs.

Objective 4: To determine the air exchange rate and the decay rate of PM_{2.5} in the kitchen of the HBFHs.

Objective 5: To assess the inhalation dose and the average daily dose of PM_{2.5} and CO₂ among the HBFHs.

1.6 Study hypothesis

N_0 hypothesis: There is no significant exposure of indoor $PM_{2.5}$ and CO_2 among the HBFHs in Klang Valley.

N_a hypothesis: There is significant exposure of indoor $PM_{2.5}$ and CO_2 among the HBFHs in Klang Valley.

1.7 Definition

1.7.1 Indoor air quality

According to DOSH, the term "indoor air quality" refers to how indoor air might impact someone's health, comfort, and productivity. Temperature, humidity, mould, bacteria, inadequate ventilation, and exposure to other chemicals are only a few examples. While poor indoor air quality can cause discomfort, ill health, and, in the workplace, absenteeism and poorer productivity, good indoor air quality protects the health of building inhabitants and adds to their comfort and well-being.

The United States Environmental Protection Agency (US EPA) claims that since people spend so much time inside, especially in industrialised nations where the typical individual may spend up to 90% of their time indoors, indoor air quality can have a substantial impact on human health. A number of health problems, such as respiratory problems, allergies, asthma, and other acute or chronic ailments, can be brought on by poor indoor air quality.

1.7.2 Liquefied petroleum gas

According to Energypedia, Liquefied petroleum gas (LPG) is a mixture of light hydrocarbon molecules with propane (C_3H_8), butane (C_4H_{10}), or a combination of both which make up the majority of it and the gases are colourless as well as odourless at normal temperature (Energypedia, 2020). LPG cooking on the other hand, refers to the use of LPG as a fuel source for cooking appliances, such as stoves, ovens, and grills (Energypedia, 2020). LPG is flammable and obtained through the processing of natural gas and petroleum refining and commonly used for residential and commercial cooking due to its convenience, efficiency, and clean-burning properties (Energypedia, 2020). LPG is stored in pressurised containers and is delivered to homes and businesses in portable cylinders or through a centralised supply system (U.S. Energy Information Administration (EIA), 2023)

1.7.3 Exposure from indoor air pollutants

Occupational exposure and unsuitable working conditions are the most frequent causes of mild obstructive sickness and changes in lung function measures (Habybabady et al., 2018). There is ample evidence linking several common indoor air contaminants to adverse health outcomes (US EPA, 2023). These effects can range from mild irritation to serious respiratory diseases and disorders (US EPA, 2023). A prolonged period of exposure to the pollutant will raise the likelihood of long-term health impacts (Manisalidis et al., 2020).

Manisalidis et al also found that different pollutants have different physical and chemical characteristics, which explains why they might have different levels of toxicity. For instance, because of their small size in the atmosphere, aerosol chemicals have a higher toxicity than gaseous compounds and a larger capability for penetration through lungs (Manisalidis et al., 2020).



1.8 Conceptual framework

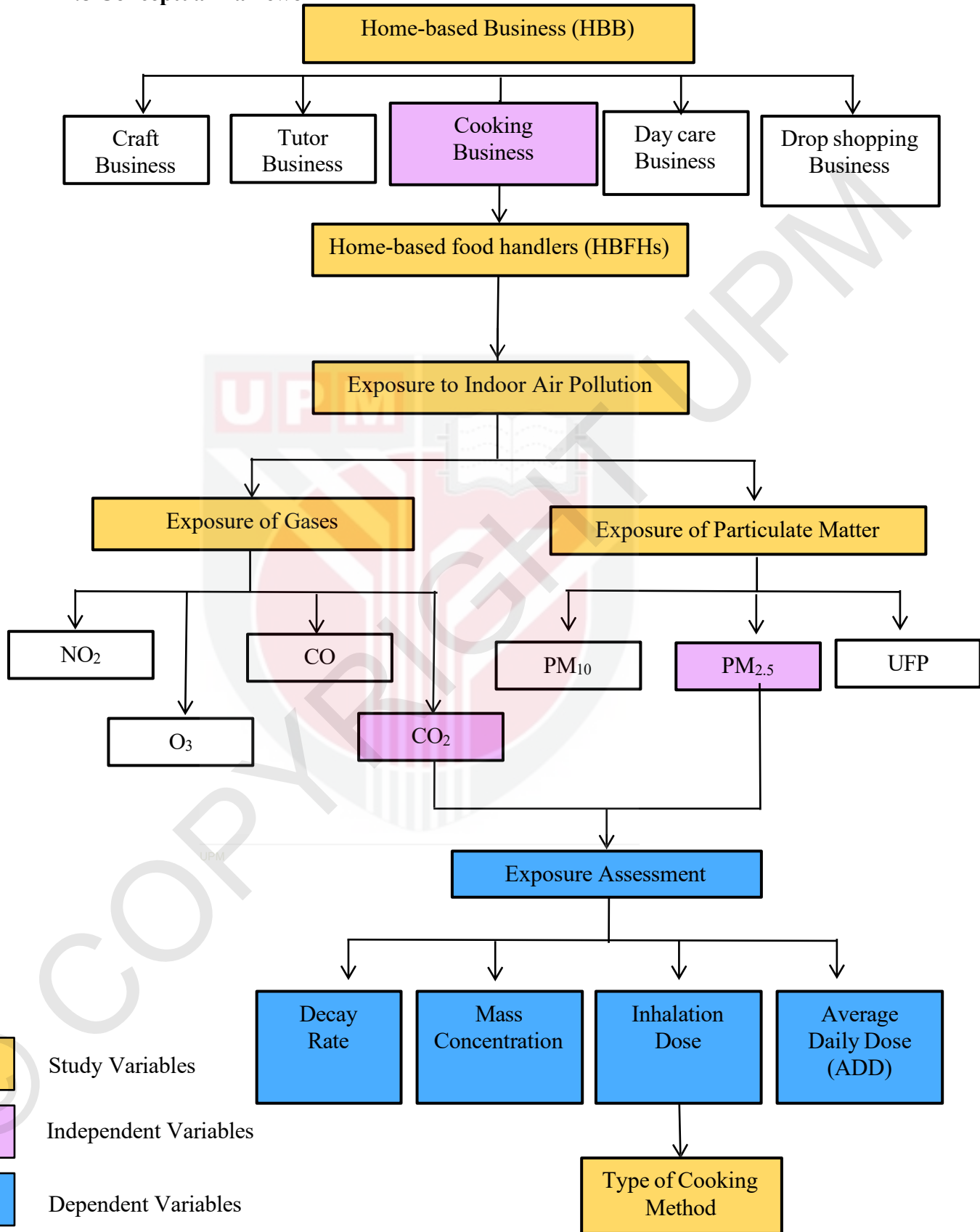


Figure 1.1 Conceptual Framework of the study

CHAPTER 2

LITERATURE REVIEW

This chapter will discuss about the overview of previous studies on the topic of interest. The purpose of the literature review was to get further insight into the problems related to IAP and its relationship to cooking. This chapter's subsequent sections will provide further details on air ventilation, cooking emissions, and exposure of polluted air towards HBFHs.

2.1 Indoor air quality at home

According to US EPA, the term "indoor air quality" refers to the state of the air within enclosed buildings, such as residences, offices, schools, and similar spaces, concerning its effects on occupants' well-being and comfort. It encompasses various elements, such as the presence of pollutants, temperature, humidity, ventilation, and overall indoor cleanliness (US EPA, 2024). The US EPA also states that indoor air quality significantly influences human health, given the substantial amount of time individuals spend indoors, particularly in developed nations where the average person may spend up to 90% of their time indoors. Inadequate indoor air quality can lead to a range of health consequences, including respiratory problems, allergies, asthma, and various acute or chronic illnesses.

IAP can be produced by individuals' activities inside of houses or buildings, including from cooking, smoking, using electronic appliances, using consumer goods,

and emitting emissions from building materials where particulate matter (PM), aerosol, volatile organic compounds (VOCs), carbon monoxide (CO), biological contaminants, and others make up some of the harmful pollutants found within buildings (Van Tran et al., 2020). The accumulation of these pollutants indoors has a direct impact on the quality of the air occupants inhale. Crucially, ventilation system functioning and design have major effects on indoor air quality (Van Tran et al., 2020). To maintain optimal indoor air quality, proper ventilation plays a critical role (US EPA, 2024). It involves ensuring sufficient airflow and the exchange of outdoor air to effectively dilute and eliminate pollutants, thereby creating a healthier indoor environment. Ventilation and filtering may assist in managing indoor temperatures, and also helps eliminate or reduce indoor airborne pollutants generated from indoor environments which will reduce the amount of contaminants and enhances indoor air quality (IAQ) (US EPA, 2024).

The Environmental Protection Agency (EPA) advocates the use of mechanical ventilation systems, like exhaust fans and air purifiers, alongside natural ventilation through open windows and doors whenever possible. Additionally, regular cleaning and maintenance of indoor spaces, including adequate filtration of HVAC systems, can aid in enhancing indoor air quality by minimising the build-up of allergens, dust, and other contaminants. Moreover, controlling indoor humidity levels within the recommended range of 30-50% proves beneficial in preventing the growth of mould and the spread of bacteria or viruses. Numerous techniques, such as the use of indoor air quality sensors and expert evaluations, can be used to measure and evaluate indoor air quality. Regular testing can help identify particular contaminants and direct the application of effective mitigation techniques.

2.1.1 Air ventilation indoor

Ventilation is the process of bringing fresh air from the outside into a structure and circulating it inside a room or structure while eliminating stale air to enhance the quality of the air. This can be accomplished via mechanical, natural, or a combination of both methods (Health and Safety Authority). An increasing body of literature underscores the significance of ventilation within indoor environments. Several studies have demonstrated that inadequate ventilation can give rise to a range of health issues, including respiratory infections, headaches, and fatigue. Conversely, proper ventilation has been shown to enhance cognitive performance and productivity.

For instance, a study published in the journal *Environmental Health Perspectives* revealed that children attending schools with subpar ventilation were more susceptible to respiratory infections compared to those in schools with adequate ventilation. Moreover, the research found that the children suffering from respiratory infections exhibited lower academic achievement scores. Similarly, another study by (Hou et al., 2018) discovered that ventilation reduces indoor generated air pollutant concentrations.

2.1.1.1 Natural ventilation

The outdoor air circulated through purpose-built openings in the building envelope, such as windows, doors, solar chimneys, and wind towers, by natural forces like winds and thermal buoyancy pressure caused by differences in the relative densities of the

indoor and outdoor air and these openings are dependent on factors like climate, building design, and human behaviour (Atkinson, 2009).

2.1.1.2 Mechanical ventilation

Mechanical ventilation is facilitated by fans that may be built into airways to supply or exhaust air from a space, or it can be installed directly in windows or walls (Atkinson, 2009).

2.1.2 Air exchange rate (AER)

Estimating the air exchange rate (AER) for various buildings where people spend time is a crucial part of air pollution exposure evaluations as AER is an essential factor in determining the admission of outdoor air pollutants and the removal of interior air pollutants that are released is the air exchange rate, or AER (Breen et al., 2013). Carlton et al. (2019) found in their study that when compared to previous studies, air exchange rates were high in a lot of houses. Their study also found that greater AER households had a greater likelihood of chronic cough, asthma, and asthma-like symptoms, such as medication-assisted wheezing, activity-limiting wheeze, and night time dry cough (Carlton et al., 2019). On the contrary, lower AER without making up for it with air cleaning will lead to higher indoor pollution concentrations (National Academies Press (US), 1981).

The air exchange rate refers to the frequency at which the air within the kitchen is completely replaced with fresh air from outside. It is measured in air changes per hour (ACH) and indicates how many times the entire volume of air in the kitchen is exchanged with new, outdoor air in an hour. For this study, two types of ventilations were considered which were mechanical and natural ventilation system.

2.1.3 Decay rates of pollutants

Some studies have reported PM removal efficiency based on PM decay rates, whereby the percentage drop in PM concentration for PM_{2.5} after a few hours (Budaniya & Aakash, 2022). The room ventilation rate was determined by measuring the CO₂ decay at the conclusion of the measurement, which also served as an indicator for the other parameters' responsiveness (Tichenor et al., 1990). The decay rate of particulate matter (PM) 2.5 is a measure of how quickly PM_{2.5} levels decrease in the air. The decay rate is measured to determine the rate at which pollutants break down or dissipate over time. Understanding the decay rate helps determine how long pollutants persist in the indoor environment. This information is crucial for assessing the potential risks associated with exposure to specific pollutants, whereby when a pollutant has a long decay rate, it may accumulate over time and pose a greater health risk.

2.1.4 Inhalation dose of pollutants

Inhalation dose is the quantity of contaminant that enters the bloodstream through the lung's exchange border, or the amount that may interact with organs and tissues to produce biological consequences (US EPA, 2024). The pulmonary tract may potentially partly dissolve and deposited with PM_{2.5}, thus the deposition fraction (DF) and the bio-accessibility of PM_{2.5} need to be taken into consideration immediately to be compatible with the reality of the pulmonary area and prevent overestimating the

risk of inhalation for human health (Sun et al., 2022). Particulate matter (PM) inhalation dose and respiratory deposition must be accurately assessed to better understand the potential hazards associated with PM exposure and, as consequently, implement appropriate risk-control measures (Madureira et al., 2020).

The amount of PM_{2.5} that a person inhales, however, is closer to the actual dose that endangers their health (US EPA National Centre for Environmental Assessment and Moya, 2011). Individual's inhaled dosage of pollutants may be derived by multiplying their exposure concentrations found through measurements (Tan et al., 2017).

2.1.5 Average daily dose of pollutants

In general terms, Average Daily Dose (ADD) is defined as the mass of pollutant per unit body weight over time (US EPA, 2024). The average daily dosage is a combination of many doses taken over several days or throughout the day, as opposed to the inhaled dose, which is derived from once daily and demonstrates value for a single dose of the pollutants exposed in a day (BADBIR, 2022).

2.2 Home-based food handlers (HBFHs)

According to Mason, Carter, and Tagg (2011), a home-based business (HBB) refers to any business enterprise that sells products or services and operates primarily from the owner's residence. In addition to the home-based location, an HBB is typically managed by a self-employed individual, either independently or with the involvement of workers (Razak et al., 2022).

There is limited studies on home-based businesses (HBBs), however there are few that stated that rural locations have higher number of home-based businesses (Kapasi & Galloway, 2016). According to statistics from the Scottish Government, 56% of enterprises in Scotland are home-based (Mason & Reuschke, 2015). It was also found that from the report, the primary reasons for running a home-based business are cost-cutting (56%), easy access (61%) and the nature of the enterprise (65%). The high expense of commercial buildings (31%), maintaining a work-life balance (31%), as well as preventing travelling (27%), are secondary considerations (Mason & Reuschke, 2015).

When the MCO began in Malaysia during COVID-19, the majority of business activity ceased, and 44% of employees surveyed by the Department of Statistics (DOSM) in Malaysia said they worked from home (DOSM, 2020). Making changes to their regular jobs by earning an income from home, also known as a Home-Based Business (HBB), is a step towards recovering family ties and achieve work-life balance especially during a difficult economic period, many people found it necessary to find alternative ways to boost income and to protect their livelihood (Arif et al., 2021). Mohamad Fauzi & Abdul-Mutalib mentioned that due to the COVID-19 pandemic, there is a growth in online food businesses where they will operate from home.

2.3 Cooking emissions

Cooking, especially at high temperatures, releases unhealthy pollutants from oils, fats, and food residue, worsening existing health conditions like asthma and heart problems especially towards young children and to tackle this, it is suggested by ensuring proper kitchen ventilation such as using a high-efficiency range hood with powerful exhaust and low noise, and for gas stoves, schedule annual inspections for leaks and carbon monoxide (California Air Resources Board, 2021).

The term "cooking emissions" refers generally to the gas and air fumes released during cooking activities (Gokhale et al., 2019). There are two primary sources of cooking emissions which are the emissions from the stove that is used for cooking and the releases produced during the cooking process itself (Gokhale et al., 2019). The type and concentration of cooking emissions are influenced by the characteristics of the stove and the food being cooked, and the emissions from the cooker might differ greatly based on the fuel source (Gokhale et al., 2019).

2.3.1 Particulate matter 2.5 (PM_{2.5})

Particles with diameters of 2.5 μg or less, including ultra-fine particles and nanoparticles that typically have diameters below 0.1 μg , are part of this category of particles (US EPA).

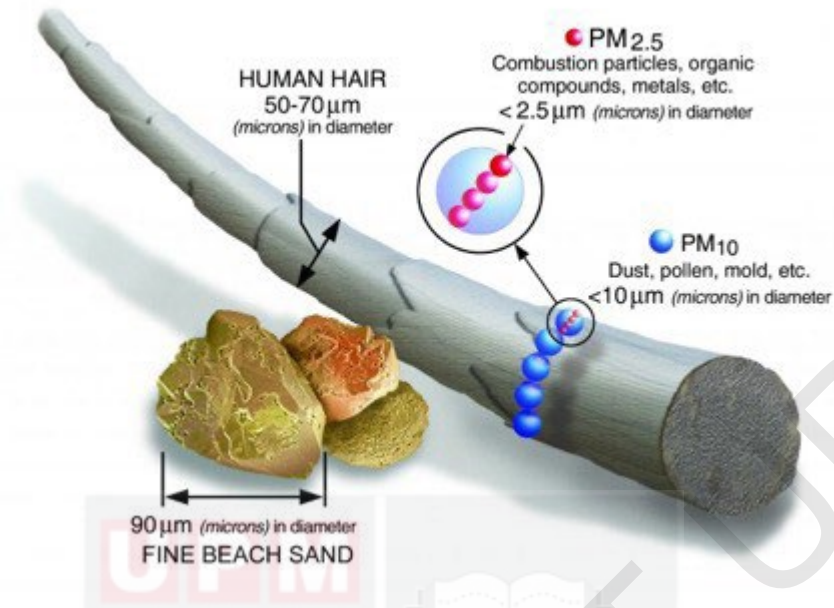


Figure 2.1: Size comparisons for PM particles (US EPA, 2010)

2.3.2 Carbon dioxide (CO₂)

Gas naturally present in the atmosphere and released through human activities like combustion, acting as the primary greenhouse gas that drives the greenhouse effect (USEPA).

CHAPTER 3

METHODOLOGY

This chapter demonstrates the study design, study location, study duration, study population, study sample, sampling method, study instrumentation, data analysis research flowchart, and limitations of the study

3.1 Study design

In this research, an observational cross sectional study was applied to investigate the exposure to indoor air pollutants and the average daily pollutant dose in the residences of food handlers who use their homes for food preparation and cooking. The selection of houses was from a convenience sampling approach, adhering to specific inclusion and exclusion criteria. A real-time 6-hour continuous monitoring of various parameters of interest (including PM_{2.5}, carbon dioxide, , relative humidity, and indoor temperature) for two days within the indoor areas of the selected houses in the Klang Valley region was conducted. The monitoring took place during specific working hours, spanning from 8:00 a.m. to 5:00 p.m.

3.2 Study location

The study location for this research was Klang Valley, and the choice was based on several reasons. In Malaysia, the state of Selangor houses an estimated total of 828 food and beverage-related small businesses that are officially registered and

actively operating (Abdul Majid et al., 2022). This bustling region is known for its vibrant food industry and numerous establishments engaged in food preparation and beverage services. Additionally, it is worth noting that Klang Valley has been identified as having the highest number of households in previous studies (Azmi et al., 2012). Therefore, conducting the research in this dynamic and populous area is highly relevant and essential in understanding the indoor air quality and potential exposure to pollutants in home-based food businesses.

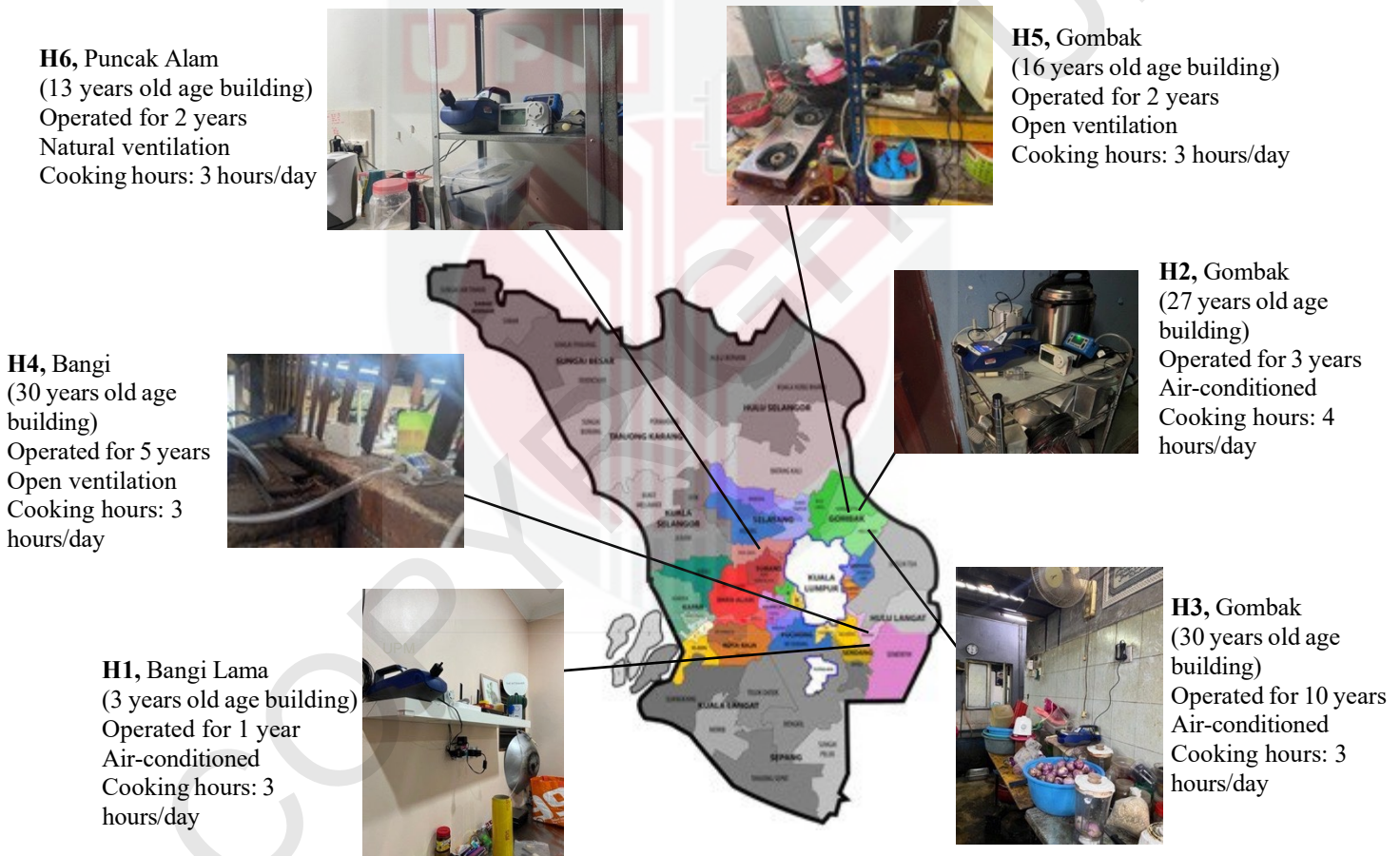


Figure 3.1 The distribution of study location in Klang Valley area including Gombak, Bangi, and Puncak Alam area.

3.3 Selection criteria

3.2.1 Selection criteria of houses

Houses were selected based on the variety of year it was built, utilised as a cooking place for the food business, and types of ventilation used.

3.3.2 Selection criteria of participants

Inclusive criteria

1. Operating business for at least a year
2. Cooking is made in indoor setting

Exclusion criteria

1. Cook with respiratory health problems
2. Cook who smokes
3. Cook who also work various kind of job
4. Cook who do not utilise the indoor setting for the cooking activities.

3.4 Duration of the study

The study encompassed a data collection period of up to 4 months, commencing on the 1st of August 2023 and concluding in November 2023. Within this timeframe, each house was allocated a maximum of two days for data collection. During these sessions, an uninterrupted 6-hour measurement of the parameters of interest (PM_{2.5}, CO₂, relative humidity, and indoor temperature) was conducted at each location, spanning from 8:00 a.m. to 3:00 p.m.

3.5 Data collection and instrumentation

3.5.1 Walkthrough assessment

A walkthrough assessment was carried out to evaluate the overall conditions of the study locations, identifying potential sources of pollutants, and examined the ventilation and air-conditioning systems in use. The assessment was performed following the checklist for walkthrough inspection by the Industrial Code of Practice of Indoor Air Quality, 2010 (ICOP of IAQ 2010) issued by the Department of Safety and Health (DOSH), which is attached in **Appendix 1**.

3.5.2 Indoor air quality monitoring

a. TSI DustTrak II Aerosol Monitor 8532

The TSI DustTrak II Aerosol Monitor 8532 was employed to assess the concentration of PM_{2.5} in the study locations. The instrument utilised a 90° light scattering sensor, offering a measurement range from 0.001 mg/m³ to 150 mg/m³. It operated at a flow rate of 3.0 L/min, the instrument maintained a flow accuracy of ±5% as per factory settings. Calibration of the instrument involved performing a zero calibration with a zero filter attached before initiating the measurement process. The instrument's capability was to detecting particle sizes ranging from 0.1 to 10 µg.

In order to precisely measure the concentration of particulate matter with a size of 2.5 µg, this equipment was used in conjunction with a PM_{2.5} filter for the suggested

research. Throughout the 6-hour measurement period, data were gathered at 1-minute intervals at each kitchen. The equipment was placed at a sampling location at least three metres away from any entry doors and windows in order to reduce potential influence. Additionally, to reflect the cook's breathing zone, the instrument was placed at four feet from the ground.



Figure 3.2 TSI DustTrak II Aerosol Monitor 8532

b. HOBO CO₂ Logger (MX1102)

The HOBO CO₂ Logger (MX1102) was used to measure real-time temperature, relative humidity, and CO₂ levels in the indoor environment where the study was conducted. The logger's temperature sensing range is from 0° to 50°C with an accuracy of $\pm 0.21^{\circ}\text{C}$. The relative humidity sensor detects levels from 1% to 70% when the CO₂ sensor is enabled (in a non-condensing environment) and from 1% to 90% when the CO₂ sensor is disabled (in a condensing environment). The response time for temperature is 12 minutes to reach 90% in an airflow of 1 m/s. The relative humidity sensor has an accuracy of $\pm 2\%$ for relative humidity levels between 20% and 80%, with a maximum accuracy of $\pm 4.5\%$, including hysteresis, at 25°C. For relative

humidity below 20% and above 80%, the accuracy is $\pm 6\%$. The response time for relative humidity is 1 minute to reach 90% in an airflow of 1 m/s. The logger also detects CO₂ levels within the range of 0 to 5000 ppm with an accuracy of ± 50 ppm or $\pm 5\%$ of the reading at 25°C and at relative humidity less than 70%. To monitor carbon dioxide, a warm-up time of 15 seconds and manual or automatic calibration to 400 ppm is required.

The HOBO CO₂ Logger also features a built-in Bluetooth mode, provided a convenient monitoring display to check the measured parameters. The instrument was positioned at a distance of a maintained distance of three metres from any opened doors and windows to avoid influence from the outside. Additionally, the instrument was placed at a height approximating the breathing zone of the cook, which was approximately four feet from the floor. During the entire 6-hour measurement period at each location, the data was recorded at one-minute intervals.



Figure 3.3 HOBO CO₂ Logger (MX1102)

c. GilAir Plus Personal Air Sampling Pump (1 - 5,100 cc/min)

The GilAir® Plus has a broad range of flow and pressure settings, covering all personal air sampling techniques from 20 to 5,100 cc/min. Using its innovative QuadModeSM technology, this device can handle high-flow and low-flow sampling (450-5,100 cc/min and 20-499 cc/min) without needing extra parts. The GilAir Plus was connected to the probe which was attached with a 37mm PTFE filter to collect the particulate matter from cooking. The probe was put at breathing level of the cook in the kitchen for 6 hours on every measurement day.



Figure 3.4 GilAir Plus Personal Air Sampling Pump

3.5.3 Gravimetric analysis

Gravimetric analysis of PM_{2.5} to obtain the mass concentrations was performed by weighing 37-mm Polytetrafluoroethylene (PTFE) filters before and after a 6-hour sample period. Ahead of weighing, all filters were equilibrated in a chamber with a temperature of 20-23°C and a relative humidity (RH) of 30%-35% for at least 24 hours. The sampling was fitted in the Gilair Plus Personal Air Sampling Pump at 1.8 min/l flow rate.

3.6 Calculation of quantitative analysis

3.6.1 Air exchange rate (AER)

The equation used to find the AER was via Equation (3.1) (Vaniman Manufacturing Co., 2023).

$$ACH = \frac{Q}{V} \quad \text{Eq. 3.1}$$

Where,

ACH = air exchange rate under ventilation

Q = to the volumetric flow rate of air in cubic feet per minute (CFM)

V = is volume in cubic feet.

3.6.2 Decay rate of PM_{2.5}

Pollutant concentration decay rate (R) was calculated according to the following equation (Liu et al., 2019).

$$R = \frac{\ln(C_i/C_a)}{t} \quad \text{Eq. 3.2}$$

Where,

R = the decay rate

V = volume of the kitchen in m³

C_i = concentration at initial measurement

C_a = concentration after a measurement

Ln = natural logarithm.

3.6.3 Inhalation dose of pollutants

The amount of a PM_{2.5} absorbed into the body through inhalation (ID) can be estimated with the equation (Borghi et al., 2021).

$$ID = C \times BR \times ED \quad \text{Eq. 3.3}$$

Where,

ID = inhalation dose in μg

C = concentration of pollutant which is PM_{2.5}

BR = breathing rate in m^3/min and

ED = exposure duration of the monitoring

3.6.4 Average daily dose of pollutants (ADD)

The PM_{2.5} doses inhaled by the HBFHs on the monitoring days, were determined using Equation, adopted from the average daily dose (ADD) calculation from U.S. Environmental Protection Agency (USEPA, 2021).

$$ADD = \frac{C \times IR \times ET \times EF \times ED}{BW} \quad \text{Eq. 3.4}$$

Where,

C = concentration of PM_{2.5} in air (mg/m^3)

IR = inhalation rate (m^3/min)

ET = exposure time in hours

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = Body weight (kg).

3.7 Data analysis

The descriptive analytical approach will be used to analyse all the study data. Univariate analysis, which examines demographic information, frequencies, percentages, means, and standard deviations, will be used to analyse the levels of PM_{2.5} and CO₂ during stationary monitoring. The formula derived will be used to calculate the air pollutants' decay rate, air exchange rate of the HBFHs, mass concentrations, inhalation dose, and ADD of pollutants among the HBFHs, and more.

Table 3.1 The specific objectives and the type of analysis used for the study.

Specific objectives	Types of variables	Statistical analysis
To determine the physical state of the kitchen of the house of the HBFHs.	1) Physical characteristics Categorical	Descriptive
To assess the indoor air quality pollutants levels (PM _{2.5} and CO ₂) in the kitchen of house of the HBFHs.	2) Indoor air quality pollutants levels- Numerical	Descriptive - Frequency - Mean - Median - IQR

To determine the mass concentration of PM _{2.5} of the kitchen in the home of the HBFHs.	1) Mass concentration -numerical	Descriptive - Calculation
To determine the air exchange rate and the decay rate of PM _{2.5} in the kitchen of the HBFHs.	1) AER – numerical 2) Decay rate - numerical	Descriptive - Calculation
To assess the inhalation dose and the ADD of PM _{2.5} and CO ₂ among the HBFHs.	1) Inhalation dose – numerical 2) ADD - numerical	Descriptive - Calculation

CHAPTER 4

RESULT

4.1 Sampling locations characteristics of HBFHs' kitchen

The results in Table 4.1 show the characteristics of sampling locations conducted within the residences of food handlers' business owners situated in the Klang Valley area from August 2023 to November 2023. The selected study locations encompassed Gombak, Bangi, and Puncak Alam. In Gombak, three houses—identified as H2, H4, and H5—were included. The study included two houses labelled as H1 and H3 in the Bangi area. Lastly, one house in Puncak Alam, designated as H6, was chosen as a study location.

H1 and H2 were clustered into Bakery category which utilised baking and frying cooking methods. H3, H4, and H5 were clustered into Malay cuisine business which practiced stir frying, frying, and stewing cooking methods. H6 was clustered into frying and deep-frying cooking method which were categorised as Western cuisine business. At these locations, a detailed walkthrough inspection was conducted to assess the overall physical state, human exposure, and indoor air quality of the houses and the areas. The walkthrough findings are presented in Table 4.1

Table 4.1 Sampling location characteristics of selected home-based food business of Bakery (H1,H2), Malay cuisine (H3,H4,H5), and Western cuisine (H6) in Klang Valley area

Variables	Bakery		Malay cuisine			Western cuisine
	H1	H2	H3	H4	H5	H6
Number of households	4	4	5	6	5	2
Types of houses	Terrace	Terrace	Terrace	Terrace	Townhouse	Twin-terrace house
Age of building (years)	3	27	30	33	16	13
Distance from main road (m)	20	18	14	115	520	35
Volume of kitchen (m ³)	52.9	41.2	106.2	79.0	84.3	66.6
Ventilation system	Mechanical Ventilation (Air condition)	Mechanical Ventilation (Air condition)	Natural/Mechanical Ventilation (Exhaust and ceiling fan)	Natural Ventilation (Open space)	Natural/Mechanical Ventilation (Ceiling fan)	Natural/Mechanical Ventilation (ceiling fan)
Types of mechanical ventilation	Daikin FTKF-C Series	Daikin Eco King 1.5hp, Whirlpool (AKR628IXM) Slim Cooker Hood 60cm 450m ³ /HR	-	-	-	-
Number of fans in kitchen	1	1	2	1	1	1
Number of doors at kitchen	1	1	2	1	1	1

Kitchen window type	Louvre window	Louvre window	Louvre window	Transom window	Casement window	Louvre window
Kitchen floor type	Tiles	Carpet	Cement	Cement	Tiles	Tiles
Types of cuisines	Bakery	Bakery	Malay dishes	Malay dishes	Malay dishes	Fried chicken, Malay dishes
Types of cooking method	Baking, Stirring	Baking, frying	Stir frying, frying, stewing, shallow frying	Stir frying, frying, stewing, deep frying	Stir frying, frying, stewing	Stir frying, stewing, frying, deep frying
Types of cooking devices	LPG Stove, Oven, Grill, Mixer	LPG Stove, Oven	LPG Stove, Grill	LPG Stove, Grill	LPG Stove	LPG Stove
Hood	No	Yes	No	No	No	No

The results found that only one house fully utilised a natural ventilation system which was open space. Meanwhile, the other five houses used a combination of natural ventilation which was opening windows and mechanical ventilation systems which were using exhaust fan, ceiling fan, and air conditioner. H2 had two number of fans while the other houses had one number of fans. For the number of households, H1, H5 each contained four households; H2, H4 each had five households; H3 had six households; and H6 had two households.

The age of the house also differs from the range of new to old buildings. H1 and H6 are considered as new buildings with the age of 3 years and 13 years respectively. H2, H3, H4, H5 were old buildings with the age of 30 years, 33 years, 16 years, and 27 years respectively. For type of houses, four houses (H1, H2, H3, and H5) were terrace house, one townhouse (H4), and one twin terrace house (H6). There were three types of kitchen windows which were louvre window for H1, H2, H5, and H6; transom window for H3; and casement window for H4.

Three selected houses, namely H1, H4, and H6, featured tile flooring in their kitchens, while H2 and H3 had cement flooring, and H5 had a carpeted kitchen floor. Most of the house kitchen had one door but H2 had two doors. All the houses are located very near to the main road. This study found that all of the houses utilised liquified petroleum gas (LPG) cooking device which were stove. Both of H1 and H5 were using oven for their cooking methods. The usage of grill was utilised by H1, H2, and H3.

4.2 Indoor air quality pollutants levels (PM_{2.5}, and CO₂) in the house of the HBFHs

All type of businesses recorded exceeding value of PM_{2.5} that is allowed indoor which is supposed to be kept at 15 µg/m³ during the 6-hour monitoring of working duration according to the National Ambient Air Quality Standards (NAAQS). The highest median value of PM_{2.5} is recorded by bakery business which was at 342 µg/m³ while the lowest reading of PM_{2.5} was charted by Western cuisine business with a value of 40 µg/m³. For CO₂ levels, it was found that two of the businesses which were Malay cuisine and Western cuisine businesses recorded acceptable value within the range of 605 ppm to 875 ppm. The highest level of CO₂ was 2167.3 ppm at Malay cuisine business. The results also found that the lowest CO₂ level recorded was at Malay cuisine business. The distribution of indoor air parameters (PM_{2.5} and CO₂) at Bakery, Malay cuisine and Western cuisine businesses is shown in Figure 2. Distribution of indoor air pollutants for (A) PM_{2.5} and (B) CO₂ levels at Bakery (H1, H2), Malay cuisine (H3, H4, H5), and Western cuisine (H6). The horizontal line at each box shows the median value while the box span shows the 25th percentile (Q1) and 75th percentile (Q3) for each house according to its type of business. The upper line of the box shows the maximum value, and the lower line indicates the minimum value recorded.

The box plot diagrams show, each with one for PM_{2.5} measurements and one for carbon dioxide values. For the bakery, the PM_{2.5} measurements have a median value of 300 µg/m³, with a range from about 100 µg/m³ to 500 µg/m³. The carbon dioxide values for the bakery have a median value of around 800 µg/m³, with a range

from about 400 $\mu\text{g}/\text{m}^3$ to 1200 $\mu\text{g}/\text{m}^3$. For Malay cuisine, the $\text{PM}_{2.5}$ measurements have a median value of around 200 $\mu\text{g}/\text{m}^3$, with a range from about 50 $\mu\text{g}/\text{m}^3$ to 400 $\mu\text{g}/\text{m}^3$. The carbon dioxide values for Malay cuisine have a median value of around 600 $\mu\text{g}/\text{m}^3$, with a range from about 200 $\mu\text{g}/\text{m}^3$ to 1000 $\mu\text{g}/\text{m}^3$. For Western cuisine, the $\text{PM}_{2.5}$ measurements have a median value of around 150 $\mu\text{g}/\text{m}^3$, with a range from about 0 $\mu\text{g}/\text{m}^3$ to 350 $\mu\text{g}/\text{m}^3$. The carbon dioxide values for Western cuisine have a median value of around 400 $\mu\text{g}/\text{m}^3$, with a range from about 0 $\mu\text{g}/\text{m}^3$ to 800 $\mu\text{g}/\text{m}^3$. It is important to note that these are just median values and ranges, and the actual data for each measurement may vary. The box plots also show the quartiles of the data, which can give you a better sense of the distribution of the values. Overall, the $\text{PM}_{2.5}$ measurements appear to be highest for the Bakery, followed by Malay cuisine and then Western cuisine. The carbon dioxide values also appear to be highest for the Bakery, followed by Malay cuisine and then Western cuisine

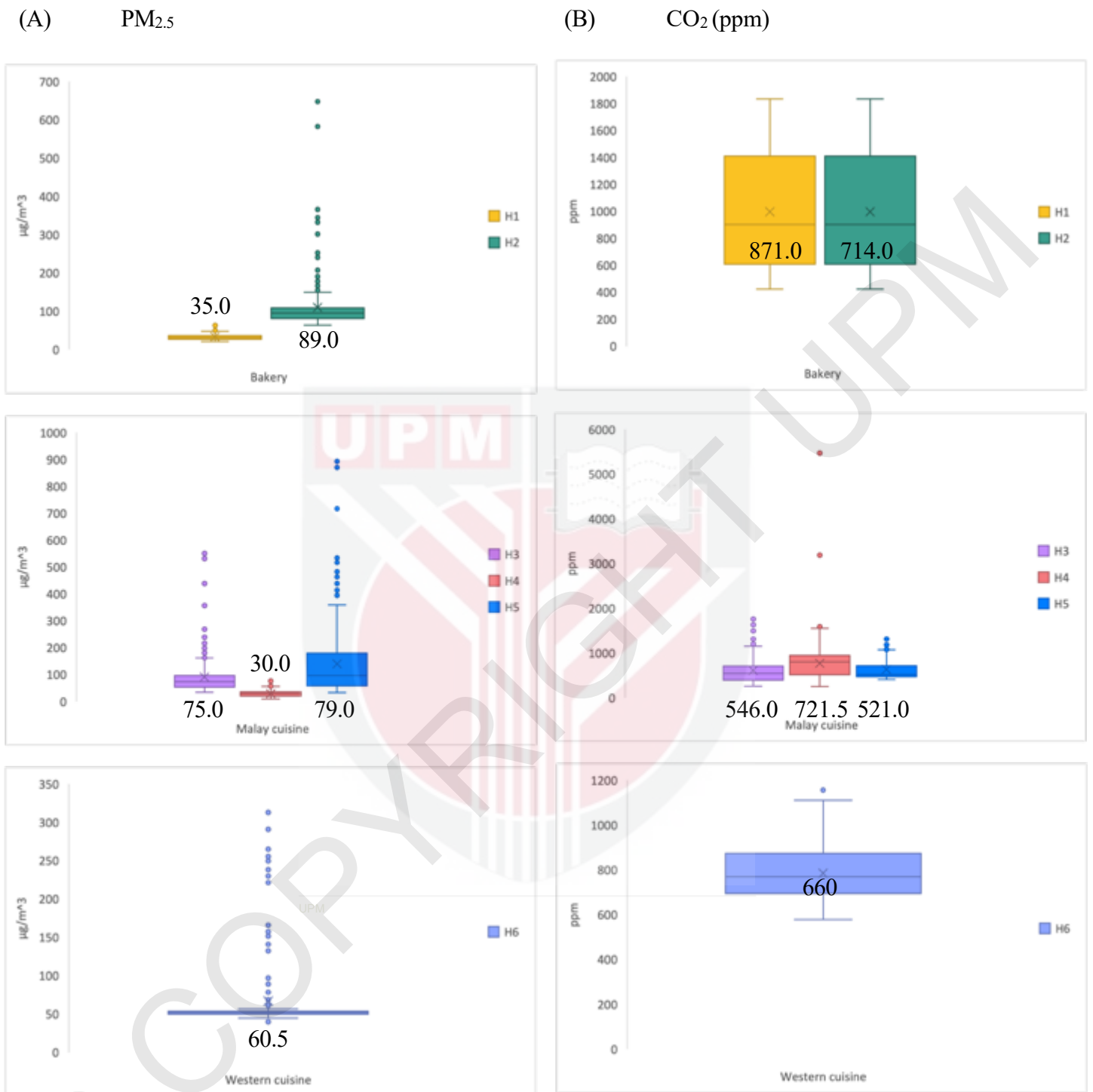


Figure 4.1 Box plot measurement of (A) PM_{2.5} (µg/m³) and (B) CO₂ (ppm) at different home-based cooking premises of Bakery (H1,H2), Malay cuisine (H3,H4,H5), and Western cuisine (H6).

The data obtained was shown in Figure 3. It shows the distribution of different span time of cooking methods and the pattern of the pollutants for each business. All type of businesses recorded exceeding value of PM_{2.5} that is allowed indoor which is supposed to be kept at 15 µg/m³ during the 6-hour monitoring of working duration. For (A) Bakery, the PM_{2.5} levels started relatively low at around 87.3 µg/m³ and remain stable for the first 77 minutes. There was a sharp increase in PM_{2.5} levels at minute 78, reaching a peak of 342 µg/m³. This coincided with the stirring then baking time span, suggesting that these activities generate the most PM_{2.5} emissions from the bakery. After the peak concentration, the PM_{2.5} levels gradually decrease but remain elevated above the baseline level for the rest of the baking cycle. There was also another slight increase in PM_{2.5} levels around minute 235, which was also the time span of baking and stirring after the HBFHs were finishing with home cooking. For the CO₂ levels, it started off high and remain stable for the first 50 minutes, with the value recorded reaching its peak at 1339 ppm. Then, it gradually decreases over time and the lowest recorded value for CO₂ was at 470 ppm during minute 327. There was a steady increase in CO₂ levels throughout the stirring and baking time span, where it was found out that it was a significantly higher than the safe CO₂ emission limit of 1000 ppm.

For the (B) Malay cuisine business, the PM_{2.5} levels started at 31.8 µg/m³ and went increasing rapidly reaching 167.7 µg/m³ on minute 12. This was found to be on the duration span while doing stir fry activity which was involved in the food preparation time. The PM_{2.5} then gradually decreased but remain above the standard limit until the next cooking activity which was the main cooking styles used for Malay dishes which were frying, stewing, and shallow frying. The increase in PM_{2.5} level can

be seen from the figure that it reached up to $341.4 \mu\text{g}/\text{m}^3$ at minute 90. It described that the cooking methods involved for this business time span generate the most $\text{PM}_{2.5}$ emissions from the Malay cuisine business. After the maximum concentration, the $\text{PM}_{2.5}$ levels gradually decrease but also had an increase during the food serving and cleaning time span. The CO_2 levels on the other hand, showed similar pattern distribution with $\text{PM}_{2.5}$ increasement. It started low at 427 ppm and increased during stir fry activity at minute 9 up to minute 12 reaching peak level of stir-frying activity with value recorded at 906.7 ppm. At minute 37, the CO_2 level spiked during the listed main cooking methods for the business with the value of 1515 ppm. It then decreased to a safe level and remain stable during food serving time span where no one was in the kitchen. As for (C) Western cuisine, the $\text{PM}_{2.5}$ levels started low at $42.5 \mu\text{g}/\text{m}^3$ and remain stable for the stir fry and frying activity time span. It went reaching its peak at $315 \mu\text{g}/\text{m}^3$ on minute 338 during deep frying activity. At around minute 311, the CO_2 level of the Western cuisine business also rosed up reaching its peak of 1157 ppm for deep frying activity.

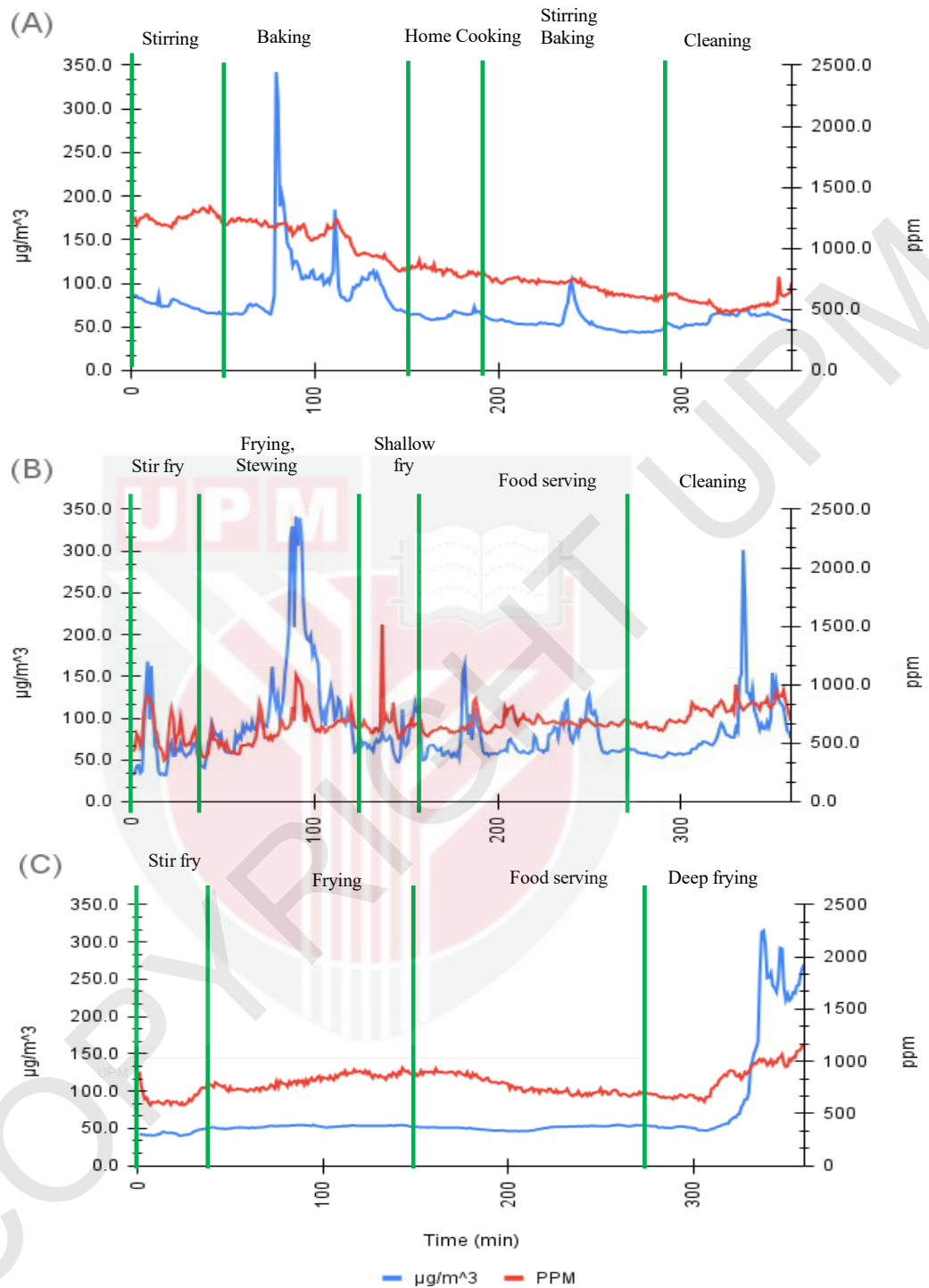


Figure 4.2 The distribution of indoor pollutants (PM_{2.5} and CO₂) measurements for (A) Bakery, (B) Malay cuisine, and (C) Western cuisine businesses against time (min), CO₂ standard limit and the cooking activities involved at each business location

Table 4.2 represents the Spearman correlation between indoor air pollutants in every type of business. For Bakery, it was found that the p-value between PM_{2.5} and CO₂ was 0.645 indicating a moderate and positive correlation. This means as PM_{2.5} increases in bakeries, CO₂ levels tend to increase. As for the PM_{2.5} and temperature, it was found that a moderate negative correlation exist ($p = -0.605$) whereby as the PM_{2.5} increases in bakeries, temperature levels tend to decrease.

For the relation between CO₂ and relative humidity, a fair negative correlation was found ($p = -0.394$). Between CO₂ and temperature on the other hand, a negative strong correlation was shown from the study data with a $p = -0.909$, indicating that when CO₂ increases, the temperature decreases.

Lastly in Bakery, a positive fair correlation between relative humidity and temperature was found ($p = 0.439$). For Malay cuisine business, the first correlation found was between PM_{2.5} and CO₂ with a p-value of 0.425 which shows a fair positive correlation. Unlike Bakery, Malay cuisine found a weak positive correlation between PM_{2.5} and relative humidity with $p = 0.134$. It also discovered a fair negative correlation between relative humidity and temperature ($p = -0.376$).

For Western cuisine business, few Spearman correlations between indoor air pollutants were also determined. It was ascertained that all the correlations from Western cuisine business were a fair positive correlation which were between; PM_{2.5} and CO₂; CO₂ and relative humidity; CO₂ and temperature; and relative humidity and temperature ($p = 0.534$; $p = 0.477$; $p = 0.209$; $p = 0.493$). It concluded that the variables that had correlations stated would increase slightly when the other one increased.

Table 4.2 Shows the Median, IQR, and result of Spearman correlation for Bakery, Malay cuisine, and Western cuisine in Klang Valley area for the indoor air quality factors

Type of business	Variables	Median	IQR	PM _{2.5}	CO ₂	Relative humidity
Bakery	PM _{2.5}	64.8	(54.9 - 76.5)			
	CO ₂	903.8	(607.9 - 1409.4)	0.645**		
	Relative humidity	61.9	(60.5 - 63.1)	-0.092	-0.394**	
	Temperature	29.6	(28.9 - 29.8)	-0.605**	-0.909**	0.439**
Malay Cuisine	PM _{2.5}	72.4	(59.1 - 98.0)			
	CO ₂	663.2	(605.6 - 727.1)	0.425**		
	Relative humidity	68.1	(65.6 - 70.5)	0.134*	-0.432	
	Temperature	31.5	(30.8 - 31.8)	-0.72	0.082	-0.376**

Western cuisine	PM _{2.5}	52.0	(50.0 - 53.5)			
	CO ₂	769.5	(695.0 - 874.0)	0.534**		
	Relative					
	humidity	66.9	(66.5 - 67.2)	0.091	0.477**	
	Temperature	31.9	(31.8 - 31.9)	0.524	0.209**	0.493**

**p < 0.001 (2 tailed); *p < 0.05; N= 360

4.3 Calculation of personal air sampler values, volume of air sampled, and mass concentration of the PM_{2.5} in HBFHs' kitchens

From the results shown in Table 4.3, the highest mass concentration of PM_{2.5} was recorded by Malay cuisine business which was at 111.7 µg/m³, followed by Bakery with 100 µg/m³. The lowest mass concentration recorded was by Western cuisine business with the calculated value of 80.2 µg/m³. The mass concentration calculated for each type of business is compared to average real-time measurement of PM_{2.5} (µg/m³).

Table 4.3 The value of personal air sampler, volume of air sampled, and mass concentration for all three types of businesses which are bakery, Malay cuisine, and Western cuisine businesses

Type of business	Personal Air Sampler (Average) (mg)		Value difference (mg)	Volume of air sampled	Mass concentration	Average real-time measurements (µg/m ³)
	Initial Weight, i	Final Weight, f				
Bakery	178.2	178.5	1.0	0.6	100.0 ± 30.5	64.8 ± 30.5
Malay cuisine	131.3	131.8	3.4	0.6	111.7 ± 47.4	72.4 ± 47.4
Western cuisine	207.6	208.0	0.9	0.6	80.2 ± 53.4	52 ± 53.4

4.4 Decay rate and air exchange rate of the HBFHs' kitchen

Table 4.4 shows the kitchen volumes, airflow rate, air exchange rate in the kitchen and the decay rate of PM_{2.5} for every type of business. Bakery had the smallest kitchen volume of 1660.7 ft³ among the three types of businesses. The largest volume of kitchen was Malay cuisine business with a size of 3173.3 ft³. Western cuisine on the other hand had 2353.4 ft³. For the air flow rate, houses in Bakery utilised air conditioning as their mechanical ventilation system with both air flow rate range from 340 CFM to 355 CFM and was averaged into 347.5 CFM. The other houses which utilised natural ventilation of opening window were using constant of 100 CFM referring to the ASHRAE standard.

The air exchange rate was calculated and differ significantly across the type of businesses. It is shown in table that Bakery had the highest amount of air changes per hour with value of 12.6 h⁻¹ while Malay cuisine had the lowest with 1.9 h⁻¹, and Western cuisine had 2.5 h⁻¹ air change per hour. The decay rate of PM_{2.5} were also calculated and presented in the Table 3. From the finding, it was found that the Western cuisine business had the lowest rate of PM_{2.5} decay with the value of 0.1 h⁻¹. The other businesses also had small value of decay rates which were 1.4 h⁻¹ and 1.7 h⁻¹ for Bakery and Malay cuisine business.

Table 4.4 The value of volume for kitchen, calculated air exchange rate, average air flow rate, and decay rate for every type of business

Pollutants	Type of business	Volume of kitchen (ft³)	Average air flow rate (CFM)	Air exchange rate in kitchen (h⁻¹)	Decay rate of PM_{2.5} (h⁻¹)
PM _{2.5}	Bakery	1660.7	347.5 ^a	12.6	1.4
	Malay cuisine	3173.3	100.0 ^b	1.9	1.7
	Western cuisine	2353.4	100.0 ^b	2.5	0.1

a is the average air flow rate from two sources of air condition utilised by HBFHs

b is the average air flow rate obtained from ASHRAE standard of kitchen

4.5 Inhalation dose and average daily dose (ADD) of PM_{2.5} of HBFHs.

The inhalation dose of PM_{2.5} was found to be the highest from Malay cuisine which were at 318.0 µg, while bakery recorded the value of 221.6 µg. The lowest inhalation dose of PM_{2.5} was from Western cuisine business which was at 177.8 µg. The results show that the lowest average daily dose (ADD) of PM_{2.5} was calculated from Western cuisine business with the value of 37.1 m³/kg/day. The highest ADD for PM_{2.5} calculated from the study was found at Malay cuisine business with value of 48.6 m³/kg/day. In addition, the lowest inhalation dose of CO₂ was from Western cuisine business which was at 4.82 x 10⁶ µg. It was also found that the lowest ADD of CO₂ was calculated from Western cuisine business with the value of 0.78 x 10⁶ m³/kg/day. The highest inhalation dose and ADD for CO₂ on the other hand, was found to be the Malay cuisine business with value of 6.88 x 10⁶ µg 1.45 x 10⁶ m³/kg/day.

Table 4.5 The value for inhalation dose and average daily dose (ADD) of PM_{2.5} for every type of business

Pollutants	Type of business	Inhalation rate (l/min)	Inhalation dose (µg)	Average	Average
				body weight (kg)	Daily Dose (m ³ /kg-day)
PM _{2.5}	Bakery	9.5 ^a	221.6	76.00	48.6
	Malay cuisine	12.2 ^a	318.0	61.70	85.9
	Western cuisine	9.5 ^a	177.8	80.00	37.1
CO ₂	Bakery	9.5 ^a	6.44 × 10 ⁶	76.00	1.10 x 10 ⁶
	Malay cuisine	12.2 ^a	6.88 × 10 ⁶	61.70	1.45 x 10 ⁶
	Western cuisine	9.5 ^a	4.82 × 10 ⁶	80.00	0.78 x 10 ⁶

a is the inhalation rate refers to gender of male and female obtained via USEPA, 2021

The inhalation dose of PM_{2.5} for every type of businesses was discovered to be normally distributed, thus one-way ANOVA test was used to compare the means of three different type of businesses and the inhalation dose. Levene test was used to determine the homogeneity of variances and based on the mean, the p-value is 0.75 which is larger than 0.05 ($p > 0.05$) indicating that the assumption of homogeneity of variance is not violated. Figure 4 shows the distribution of the mean between different types of businesses (Bakery, Malay cuisine, Western cuisine) and it is revealed that the p-value was 0.074 ($p > 0.05$), which indicates that there was no significant difference between the inhalation dose and type of business. Further post-hoc analysis was not necessary to perform. This test found to prove that the distribution of inhalation dose across the different types of businesses were similar.

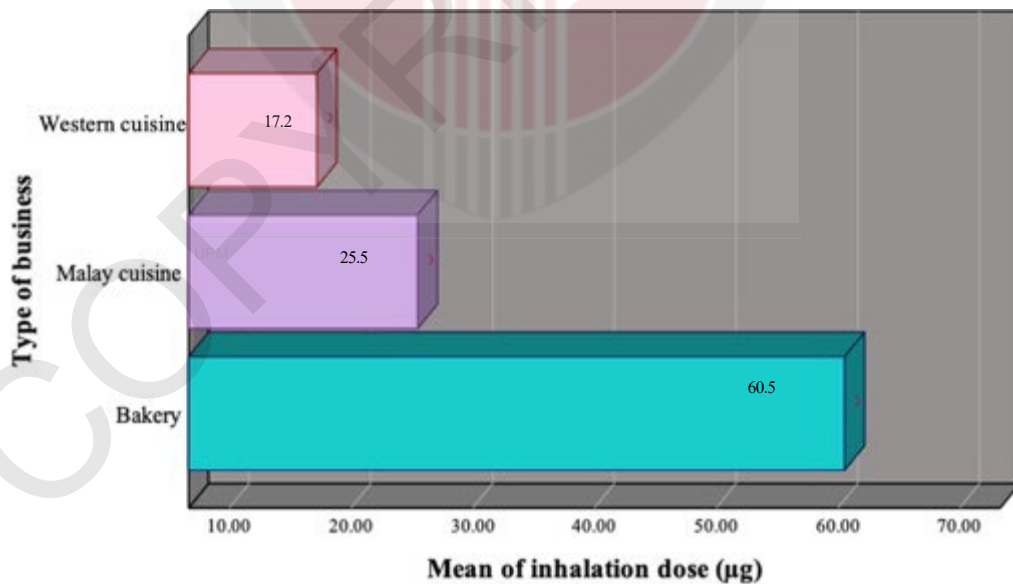


Figure 4.3 Bar graph representing the one-way ANOVA test to determine the mean distribution of inhalation dose (μg) and different type of business (Bakery, Malay cuisine, and Western cuisine)

It was found that the inhalation of PM_{2.5} from every cooking method utilised by different businesses were not normally distributed. The Kruskal-Wallis Test was conducted to examine the significance on inhalation dose according to the types of cooking method used in (A) Bakery, (B) Malay cuisine, and (C) Western cuisine. It was found that there were significant differences among the three categories of cooking methods and their respective inhalation dose. For Bakery, significant differences (Chi square = 204.8, $p < 0.001$, $df = 2$) were found among the three methods of cooking (Stirring, Baking, and, Stirring and Baking). The post-hoc analysis showed results where all the cooking methods in bakery were significantly affecting on inhalation doses for their respective cooking methods.

On the other hand, Malay cuisine also had significant differences (Chi square = 34.1, $p < 0.001$, $df = 2$) across three methods of cooking of Stir-frying, Frying and Stewing, and Shallow frying). However, the pairwise comparison analysed that only two of the cooking methods are significant among each other which were Frying and Stewing with Stir frying and Frying and Stewing with Shallow frying. There is no significant upon inhalation dose between Shallow frying and Stir-frying activity from the Malay cuisine business data.

Lastly, there was also significant difference (Chi square = 59.1, $p < 0.001$, $df = 2$) between inhalation dose and three cooking methods utilised by Western cuisine business which were Stir-frying, Frying, and Deep frying. Post-hoc analysis using pairwise comparison was conducted and the significant was found in all the cooking methods against each other. The bar graph in Figure 5 shows the differences in distribution of each type of business with their respective inhalation dose and cooking methods.

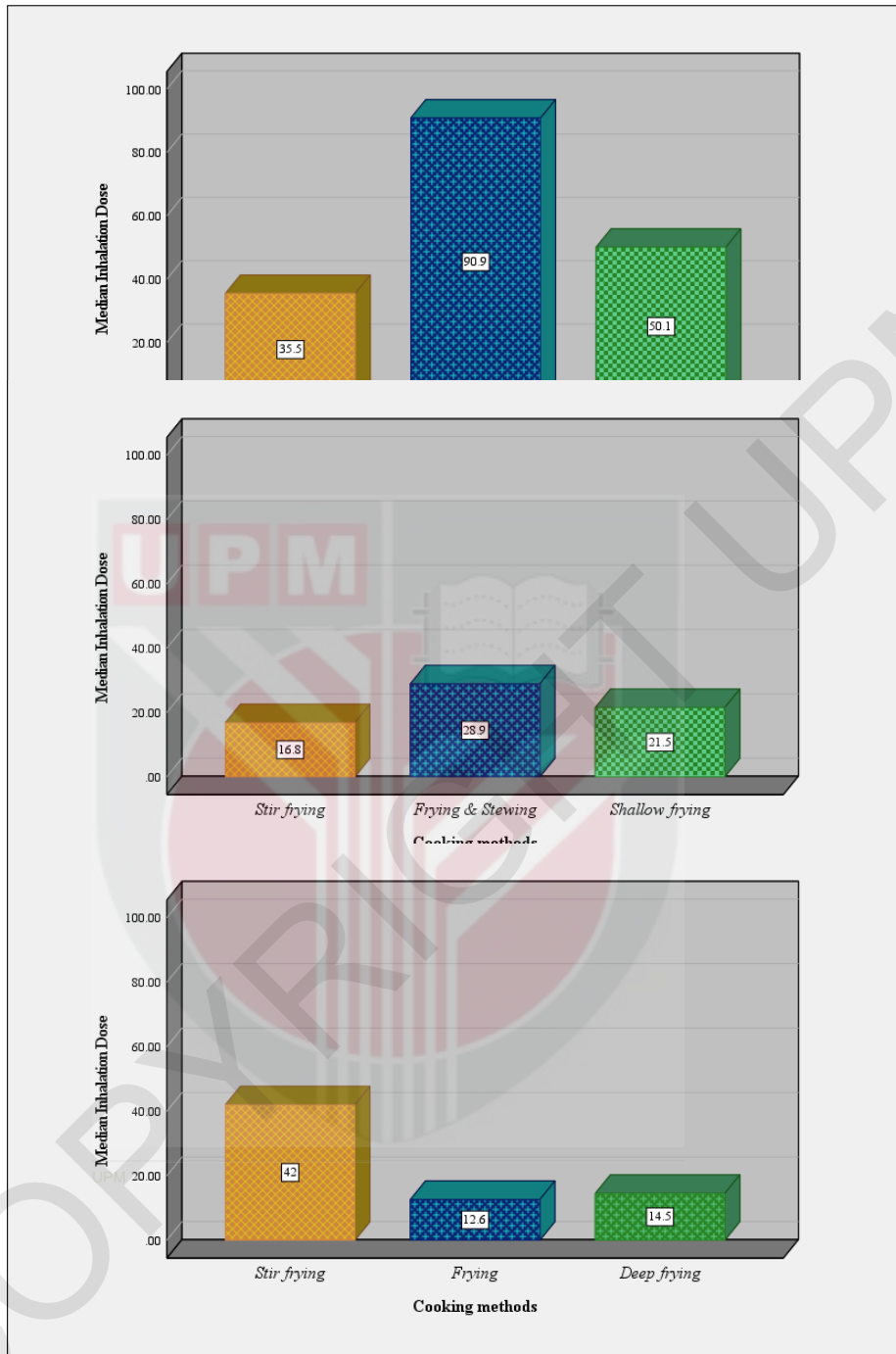


Figure 4.4 Bar graph indicating the result from Kruskal Wallis test of the mean distribution of inhalation dose (μg) with different cooking methods in (A) Bakery, (B) Malay cuisine, and (C) Western cuisine

CHAPTER 5

DISCUSSION

The study on cooking emissions indoors and in restaurant setting have been conducted before to display the data relating to how this particular activity can build up a significant health effects towards breathing system especially. However, this is the first study that conducted to focus on this study group which utilises cooking as part of daily life responsibility and source of income. This chapter will discuss about the findings and relate with previously available studies.

5.1 Physical characteristics of HBFHs' kitchens

The study discovered various sources of particulate matter could be considered that might influence the reading from the kitchen of HBFHs in Klang Valley area. All the houses are located near with the main road which were within the range of 500 meters which might influence the air quality parameters that enters the house. However, excluding H1 and H5 which did not use natural ventilation for their ventilation system, this study excluded the factor of doors opening when people came and get their orders through main door which were connected from living rooms towards the kitchen as well. Study has found that homes situated near main roads often exhibit elevated levels of particulate matter 2.5 in their readings (Huang et al., 2018).

All the houses are built on different range years, five of them were found to be

described as old buildings which were H2 until H6 ranging from 13 to 33 years old. H3 and H4 was found to be refurbishing their kitchen into more commercial-like kitchen even though it is still a part of their house. Batterman et al. (2014) conducted a study comparing indoor air quality between older and newer homes, exploring the correlation between building age and PM_{2.5} levels, it founds those older buildings showed higher PM_{2.5} concentrations due to factors like outdated ventilation systems or materials more prone to degradation. However, this study found that both old and new buildings included in the research had high value of PM_{2.5} regardless their age of building which is due to the activities they do at indoors. From this study, several numbers of households ranging from two to six people were presence in all selected house. All the number of households were found to be the occupants of the house and only help in the kitchen for the businesses in certain time during peak hours or filled with many orders. H6 which was the only one selected house with two number of households had shown data of lowest PM_{2.5} values in the house compared to other houses. Vardoulakis et al. (2020) discovered in his study that, the number of people living in the home as well as domestic and personal activities like cooking, smoking, using a stove, fireplace, candles, incense, or vacuum cleaners, as well as interior reconstruction or restoration, were all positively correlated with indoor pollution levels.

According to the findings, only one house made full use of its open-space natural ventilation system for its kitchen. The other five homes combined mechanical ventilation devices, such as ceiling fans, exhaust fans, and air conditioners, with natural ventilation techniques, such as opening windows at their designated kitchens. Due to fundamental limitations, natural ventilation using windows and doors may not

be sufficient to respond appropriately to the complex and instantaneous ambient environment (Yin et al., 2022).

This study also found that different types of flooring were utilised in every house ranging from carpet, tiles, and cement. H2 which was the only house that utilised carpet had the second highest value of PM_{2.5} reading compared to other houses. According to Becher et al. (2018), carpets may serve as an absorbent or repository for particles, allergens, and other biological contaminants found in indoor air. All the houses also utilised LPG as their cooking devices. When compared to biomass fuels, studies have shown that LPG fuels may significantly lower HAP, yet only a few studies have looked at the relationship between direct measures of HAP and health outcomes when LPG stoves are used as an intervention to replace biomass stoves (Fandiño-Del-Río et al., 2017).

5.2 Indoor air quality pollutant levels in HBFHs' kitchens

From the findings, it was found that all types of businesses recorded exceeding value of PM_{2.5} while handling their cooking activity business according to NAAQS (15 µg/m³). However, the value recorded were compared with a standard of 24 hours' time-weightage while this study is measured only during cooking operating time (6-hours). The details of the distribution can be seen through the observation and diary taken during the monitoring campaign. For Bakery, it can be observed that stirring cooking method produce a substantial amount of PM_{2.5} as well as CO₂. It has been discovered that when food is stirred, the action of ingredients mixing together

produces a lot aerosols (Long et al., 2000). During baking activity, it can be seen that the trend for both PM_{2.5} and CO₂ were similar which was higher than the previous stirring activity. It was found that while baking, the PM_{2.5} and CO₂ levels were increasing and showed similar trend. The usage of three ovens while baking contributed to the high production of PM_{2.5}. Study from Ielpo et al. (2020) concluded that baking was responsible for the emission of fine particles in bakeries. However, during the next time span of cooking activity, Bakery did stirring and baking simultaneously but the findings found a decrease in PM_{2.5} reading. This was due to the amount of orders taken and cook by the food handlers were found to be lesser than during the separate cooking activity time.

For Malay cuisine business, the preparing methods utilised by the food handlers were stir frying. It generated a high value of PM_{2.5} and CO₂ which also exceeded the standard value suggested (15 µg/m³ and 1000 ppm). Abdullahi et al., (2013) discovered that, in general, the methods (stir frying) that used the most oil showed the highest concentrations. The next cooking methods that were used in the Malay cuisine business were frying and stewing. The PM_{2.5} and CO₂ values were recorded from the accumulation from both cooking activities as they were carried out at the same time. The result showed a rapid increase of both PM_{2.5} and CO₂ levels while these activities were used reaching the peak level of the measurement for the whole business category which was at 341.1 µg/m³. In a controlled experiment, Buonanno et al. (2011) evaluated the emission rates of frying and grilling fatty foods and veggies and discovered that the frying had greater emission rates. Study from Zhang et al., (2010) shows that frying activity from residential cooking can emit up to 220 µg/m³ while Wan et al., (2011) found from his research that mixed cooking could

produce 190 $\mu\text{g}/\text{m}^3$ amount of $\text{PM}_{2.5}$ concentration.

There was a study that found a peak level of 573 $\mu\text{g}/\text{m}^3$ was reached from stewing activity in a Chinese home cooking activity (Lu et al., 2019). However, both two studies refer to a normal home cooking behaviour and a non-commercial kitchen type. Thus, no study has found the findings of HBFHs' $\text{PM}_{2.5}$ concentration for different cooking activities. In Malay cuisine business, the next time span was also utilising shallow frying cooking method. The data showed increasing level of both $\text{PM}_{2.5}$ and CO_2 but not as high compared to frying and stewing combined. Shallow frying contributed to high amount of $\text{PM}_{2.5}$ during normal cooking activities with the mean of 498 $\mu\text{g}/\text{m}^3$ (Kaul et al., 2020). It signifies that these activities which were stir frying, frying, stewing, and shallow frying were all contributed to a high amount of $\text{PM}_{2.5}$ and CO_2 release from cooking business activities in Malay cuisine sector.

Cooking methods that were involved in Western cuisine were stir frying, frying, and deep frying. The first preparation methods that was used from the business were stir frying activity which also recorded emission of $\text{PM}_{2.5}$ that exceeded the standard limit suggested. However, as the premise focused more on their fried chicken production and less orders from other types of food unlike the Malay cuisine business, they tend to have less spiking up level of $\text{PM}_{2.5}$ and CO_2 levels during stir frying and frying activities. On the other hand, during the deep-frying activity, the $\text{PM}_{2.5}$ and CO_2 reached its maximum level of 315 $\mu\text{g}/\text{m}^3$ and 1157 ppm. This is supported by a study from Zhao et al. (2019) that heavy-load cooking techniques including stir-frying, pan-frying, and deep-frying release more particulate matters. The correlation was also found between few of the study variables available in this research, whereby when $\text{PM}_{2.5}$ increases, the CO_2 level will also increase and the correlation was fair for all type

of businesses.

5.3 Mass concentration of PM_{2.5} in HBFHs' kitchens

This study has found that Malay cuisine business had the highest mass concentration of PM_{2.5} compared to Bakery and Western cuisine businesses with concentration of 111.7 µg/m³. Its difference with Western cuisine business's mass concentration was significant by 31.5 µg/m³. The reason being was due to the emission of particulate matter from intensive cooking methods that was utilised by the Malay cuisine business which all were contributing to high value of PM_{2.5} concentration compared to the Western cuisine business which practiced only three cooking methods. In a research, comparison of the emissions from Chinese, Indian, and Malay food stands were carried out and discovered that the Malay stall had the highest mass concentrations of PM_{2.5} with the value of 245.3 µg/m³, while the Indian stall had the lowest with 186.9 µg/m³ (See et al. 2006). This study however found that the highest value of mass concentration from the findings of home-based food business were still below the mass concentration from Malay cuisine from commercialized kitchens.

5.4 Decay rate, and air exchange rate of PM_{2.5} in kitchens

Decay rate of PM_{2.5} were found to be very different for each type of business. The highest decay rate of PM_{2.5} would be from Malay cuisine with 1.7 h⁻¹. PM_{2.5} levels at Malay cuisine business may be higher and more concentrated than in other

businesses which were Bakery or Western cuisine due to gravity, these bigger particles leave the air more quickly, which causes the total amount of PM_{2.5} to drop more quickly. Most cooking methods produce particulates that have different characteristic of mass concentrations, size distributions, and chemical compositions (Ielpo et al., 2020). Malay cooking used ceiling fans to efficiently remove heat and steam compared to other businesses, this ventilation system may remove airborne PM_{2.5} particles more quickly, hastening the rate of the decay. In contrast to the continuous cooking found in Bakery and Western cuisine, Malay cuisine involved short emissions of PM_{2.5} during certain steps such as stir frying, frying, stewing, and shallow frying which only operates for a total of 150 minutes while other businesses operate for 300 - 360 minutes. There may also be an impact from the time of PM_{2.5} measurements. It was also found that the Malay cuisine had the biggest volume of kitchen (3173.3 ft³) which might distribute the PM_{2.5} evenly. For Bakery, it had the second highest decay rate of PM_{2.5} of 1.4 h⁻¹.

Even though the air exchange rate for Bakery was the highest as they utilised air conditioning system that helps to change the air indoor for 12 times per hour compared to other two businesses with average of 3 times per hour, it still had lower decay rate value than Malay cuisine because ACH is not directly proportional to decay rate. Çetin et al. (2019) conducted to test the differences in decay rate using different ACH and found that there is a nonlinear relationship between the rate of drop in particle concentration and the increase in air change per hour; as air change per hour rises, the rate of concentration decline. At increased air velocities, particle concentration will yet decrease in essentially the same manner (Çetin et al., 2019). When Bakery experience their peak PM_{2.5} levels immediately following intense

cooking operations, the rate of decay that follows may appear significantly faster than that of establishments where PM_{2.5} generation is more consistent throughout the day.

5.5 Inhalation dose and average daily dose (ADD) of PM_{2.5} on HBFHs

This study found that inhalation dose of PM_{2.5} was the highest from Malay cuisine business with a dose of 318 µg which means that throughout the cooking business the food handlers in Malay cuisine business were more exposed with PM_{2.5} for approximately more than 50% of doses of particulate matter, compared by Bakery and Western cuisine with 221.6 µg and 177.8 µg respectively. This was likely because Malay cuisine business tend to use more cooking oil, which can release PM_{2.5} into the air. Important considerations for evaluating the hazards associated with inhalation exposures include age-related variations in lung structure and function, breathing patterns, and how these impact the inhaled dose and the deposition of particles in the lung (Foos et al., 2008). From this study also, ADD were found to be the highest from Malay cuisine business with value of 85.9 m³/kg-day which was two times higher than both Bakery and Western cuisine businesses. A study from S. Lee et al. (2017) found that the likelihood of inhaling indoor PM_{2.5} would exposed more ADDs compared than breathing in PM_{2.5} from outdoor sources from a roadside. However, studies that suggested ADD from different type of cooking businesses are still currently limited.

5.5.1 Inhalation dose of PM_{2.5} for every cooking method on HBFHs

This study also showed that different cooking style methods are influencing the PM_{2.5} emission distribution. A study has proven that a very high levels of several pollutants in indoor air are due to different types of cooking activities (California Environmental Protection Agency, 2020). From the study, it was found that different

cooking activities imposed different inhalation dose towards the HBFHs. The businesses covered few types of cooking methods which were also known for their emissions of particulate matter namely stir fry, frying, stirring, baking, and deep frying. For Bakery, there were significant difference across all the cooking methods used with inhalation dose. There is no consistent quantity of PM_{2.5} inhaled from two different methods. In Malay cuisine however, it showed significant on two of the cooking methods which were Frying and Stewing with Stir frying and Frying and Stewing with Shallow frying. Lastly, for Western cuisine business, the inhalation dose was also found to be significant across all the cooking methods with each other, meaning that each of the cooking method generated their own PM_{2.5} concentration dose towards the food handlers. The study's findings suggested that exposure to organic pollutants in indoor air might put people at risk for developing oxidative stress, particularly those who work in kitchens (Bilici et al., 2022). However, limited study is available to determine the normal or the pattern for inhalation dose according to different types of cooking in different business setting.

Table 5.1 Comparison study of inhalation dose in kitchen

Study	Location	Activity	Inhalation dose value
Current study: Mohd Yusri et al., (2024)	Home-based food business in Klang Valley, Selangor, Malaysia	Cooking business A) Bakery B) Malay	A) Bakery (PM _{2.5} : 221.6 µg, CO ₂ : 6.44 × 10 ⁶ µg) B) Malay cuisine (PM _{2.5} : 318.0µg, CO ₂ : 6.88 × 10 ⁶ µg)

		cuisine C) Western cuisine	C) Western cuisine (PM _{2.5} : 177.8µg, CO ₂ : 4.82 × 10 ⁶ µg)
Song et al. (2021)	Guangzhou, China	Light activity for residence at home (i.e: Cleaning, buying food and cooking, accompanying, taking care of and picking up family members)	Proportion of inhaled dose (PM _{2.5} : 14.4%)
P. Kumar et al.	Twelve cities across the globe (60 low-income countries)	Daily inhaled dose for Asian household	Highest inhaled dose of PM _{2.5} : 26.3 µg kg ⁻¹ day ⁻¹

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In conclusion, our research showed numerical evidence that suggest in the Klang Valley area, there is a higher chance of getting a high amount of indoor PM_{2.5} and CO₂ when cooking during operation of business. All houses were located near major roads, potentially influencing air quality. Older buildings had higher PM_{2.5} levels compared to newer ones, likely due to outdated ventilation systems. More occupants and cooking activities led to increased PM_{2.5} levels Only one house relied solely on natural ventilation, while others combined it with mechanical methods. Different flooring materials were used, with carpet potentially contributing to higher PM_{2.5} levels.

All houses used LPG for cooking, which may emit fewer harmful pollutants than traditional fuels however due to the norm of the business, the long time running of cooking activity, the production of indoor air pollutants still remain high. All businesses exceeded PM_{2.5} standards during cooking activities. Bakery had the highest PM_{2.5} and CO₂ levels due to multiple ovens and stirring activities. Malay cuisine businesses had the highest overall PM_{2.5} and CO₂ levels due to diverse cooking methods like stir-frying, frying, stewing, and shallow frying. Western cuisine

businesses had lower PM_{2.5} and CO₂ levels compared to the others but deep-frying still caused significant spikes. PM_{2.5} and CO₂ levels were positively correlated across all businesses. Malay cuisine businesses had the highest PM_{2.5} mass concentration due to their varied cooking methods. This finding aligns with previous research comparing emissions from different food stalls. Malay cuisine businesses also had the highest decay rate for PM_{2.5}, possibly due to larger particles settling faster, efficient ventilation, shorter bursts of PM_{2.5} emissions, and a larger kitchen volume.

Bakery had the second highest decay rate despite the highest air exchange rate, highlighting the non-linear relationship between decay rate and air changes. Malay cuisine food handlers had the highest inhalation dose and average daily dose (ADD) of PM_{2.5}. This is likely due to their use of more cooking oil, releasing more PM_{2.5}, and longer exposure times compared to other businesses. The study suggests that food handlers ADD from cooking activities likely exceeds exposure from outdoor sources like roadsides. Different cooking methods significantly impacted inhalation dose across all businesses. Bakery, Malay cuisine, and Western cuisine each showed variations in dose depending on the specific methods used. These findings highlight the significant impact of cooking activities on indoor air quality and the potential health risks faced by HBFHs. Improving ventilation systems, adopting cleaner cooking methods, and reducing cooking oil usage could help mitigate PM_{2.5} exposure and protect the health of these individuals.

6.2 Limitation of studies

While the study provides valuable insights into the indoor air quality of home-based food businesses, it has some limitations that should be considered when interpreting the finding. The study included a limited number of houses and businesses, potentially limiting the generalizability of the results. A larger sample size would be needed to draw more conclusive inferences about the broader population of home-based food businesses. The study categorized houses by age and businesses by type (Bakery, Malay cuisine, Western cuisine), but these categories likely encompass significant internal variability. Age-related differences in ventilation systems may not be uniform, and cooking methods and oil usage within each business type might vary, impacting PM_{2.5} levels.

The study monitored air quality for a limited time frame, capturing only a snapshot of exposure levels. Long-term monitoring across different seasons and times of day would provide a more comprehensive understanding of PM_{2.5} exposure variations. While PM_{2.5} is a significant pollutant, the study did not assess other harmful air contaminants, such as volatile organic compounds (VOCs) or nitrogen oxides (NO_x), which might also be generated during cooking activities. A more comprehensive analysis of different pollutants would provide a more complete picture of air quality risks. By acknowledging these limitations and future research directions, the study can contribute to a more comprehensive understanding of indoor air quality challenges faced by HBFHs and inform efforts to improve their health and well-being.

6.3 Future research

In future studies related to indoor air pollutants in home-based food businesses, a comprehensive approach should be adopted to enhance the understanding of potential health risks and devise effective interventions. First and foremost, expanding the range of pollutants under investigation is crucial. This involves focusing on key gaseous pollutants such as volatile organic compounds (VOCs), nitrogen oxides (NO_x), carbon monoxide (CO), and ozone (O_3). Additionally, attention should be directed towards identifying unique pollutant profiles generated by different cooking methods, assessing their impact on air quality, and analysing seasonal variations.

Expanding exposure evaluation is essential to a more complex comprehension of the problem. This means measuring combined exposure from indoor and outdoor sources as well as analysing individual exposure using wearable monitors for the duration of the work shift. By analysing biological samples, biomonitoring can provide insights on indoor pollution levels and possible health risks for cooks.

Intervention studies play a crucial role in implementing practical solutions. These studies should evaluate the effectiveness of ventilation strategies, such as exhaust fans and increased air exchange rates, in reducing pollutants and cook exposure. Similarly, investigating filtration efficiency of various air filtration systems, along with assessing the impact of source control measures such as alternative fuels and cooking methods, is essential.

Additional suggestions include incorporating sensory evaluations by cooks and residents, exploring potential health outcomes associated with pollutant exposure, and conducting cost-benefit analyses for different air quality improvement strategies. It is essential to consider and align the study with relevant regulations, involve the home-

based food business community in research design, and adhere to ethical research protocols to ensure informed consent from all participants.

Lastly, effective policies for HBFHs are crucial to ensure the safety of both handlers and consumers. To achieve this, a comprehensive approach can be adopted. Mandatory training programs should be implemented, covering essential aspects of hygiene and safe cooking practices. Additionally, a certification process can be established to verify that HBFHs possess the necessary skills and knowledge. Clear guidelines on recommended cooking methods and equipment can be provided to minimize indoor air pollutants. Encouraging the use of low-emission appliances and alternative cooking fuels contributes to environmental sustainability.

Setting standards for kitchen ventilation is imperative, emphasizing the importance of proper exhaust systems and effective ventilation equipment. Education efforts should focus on highlighting the significance of adequate ventilation in reducing indoor air pollutants. A systematic monitoring system for indoor air quality in home-based food businesses can be established. Food handlers should be required to promptly report any equipment malfunctions or ventilation issues to ensure a timely response. Incentives can be introduced to encourage HBFHs to adopt environmentally friendly cooking practices, such as the use of energy-efficient appliances.

Fostering a sense of community among HBFHs through workshops and support networks is essential. This approach encourages the sharing of best practices and raises awareness about indoor air quality. Alignment of home-based food business policies with existing local regulations on food safety, indoor air quality, and environmental impact is crucial. Collaboration with relevant authorities ensures a cohesive regulatory approach. Allocating funds for research grants can encourage

innovation in cooking practices, equipment, and ventilation systems that promote both food safety and indoor air quality.

Public awareness campaigns can play a significant role in educating consumers about the importance of choosing home-based food businesses adhering to safe cooking practices and maintaining good indoor air quality. Further regular reviews of policies that shall be established are necessary to ensure their effectiveness and relevance to evolving technologies. Updating policies based on emerging research findings and advancements in sustainable cooking practices ensures continuous improvement. By adopting these comprehensive policies, authorities can create a regulatory framework that supports the health and well-being of HBFHs while promoting sustainable and safe cooking practices.

6.4 Recommendation

Improving ventilation in the kitchen is crucial for the health and well-being of home-based food handlers exposed to indoor air pollutants. Having a good understanding of the importance of ventilation is the first step. Recognizing potential indoor air pollutants generated during cooking, such as fumes, smoke, and gases, is essential for informed decision-making. Identifying common sources of indoor air pollution in the kitchen, like gas stoves and high-temperature cooking, allows HBFHs to target specific areas for improvement. Regular use of existing exhaust fans is a practical measure by turning on the exhaust fan before and during cooking which helps remove cooking fumes and pollutants from lingering too long inside the kitchen. It is important to ensure the exhaust fan is adequately sized for the kitchen and is in good

working condition. Opening windows and doors promotes natural ventilation, bringing in fresh outdoor air and expelling indoor pollutants. Strategic coordination of windows and doors can create effective cross-ventilation. Developing a positive attitude towards maintaining good indoor air quality is crucial. Prioritizing ventilation practices as part of safe and healthy cooking habits reinforces the importance of this aspect such as with a regular cleaning and maintenance of appliances, including exhaust fans, air filters, and cook hoods, contribute to optimal performance, and improved indoor air quality.

Monitoring indoor air quality and adjusting ventilation practices based on cooking activities and observations are essential. The use of indoor air quality monitors can provide valuable insights into pollutant levels. By incorporating these knowledge, attitudes, and practices into daily routines, individuals can create a healthier and more comfortable kitchen environment, reducing exposure to indoor air pollutants.



Figure 6.1 Prana air PM_{2.5} Monitor

Considering the significant impact of PM_{2.5} particles on HBFHs and their well-being, further implication using the comprehensive applications of the Prana Air PM_{2.5} monitor is highly recommended. This portable and accurate device offers a unique opportunity to empower individuals with real-time air quality data, potentially leading to diverse and valuable research avenues. The Prana Air PM_{2.5} monitor can be

positioned as a transformative tool for promoting public health, personalized air quality management, and environmental awareness. Further research has the potential to unlock the full potential of this innovative technology and significantly improve the well-being of individuals and communities.



Figure 6.2 Philips PM_{2.5} Air Purifier

To enhance indoor air quality in home-based food businesses, the incorporation of air purifiers is recommended. Exploring air purification options, such as using air purifiers with high efficiency particulate air (HEPA) filters and incorporating air-purifying plants, adds an extra layer of protection against indoor pollutants. This initiative seeks to reduce the concentration of indoor air pollutants, providing a healthier working environment for both food handlers and residents. Guidelines should be established for selecting suitable air purifiers, focusing on their ability to target common cooking-related pollutants like volatile organic compounds (VOCs), smoke, and odours. It is encouraged to strategically place these air purifiers within the kitchen to maximize their effectiveness.

It is important to coordinate the use of air purifiers with existing ventilation systems, ensuring they work in tandem to improve overall air quality. Regular maintenance schedules for air purifiers, including filter replacements and system checks, should be implemented to ensure optimal performance. To promote widespread adoption, consider offering incentives for HBFHs who voluntarily integrate air purifiers into their kitchens. This not only encourages positive change but also contributes to the broader improvement of indoor air quality within the community.

Education and awareness initiatives should be implemented to inform HBFHs about the benefits of air purifiers. Providing information on how these devices contribute to a healthier indoor environment and help mitigate potential health risks associated with cooking-related pollutants is essential. By seamlessly integrating air purifiers into the overall policy framework, authorities can strengthen measures aimed at protecting the health and well-being of food handlers and residents in home-based food businesses.

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APPENDIX

Appendix 1 Walkthrough Inspection (ICOP IAQ 2010)

House 1

Department of Occupational Safety and Health (DOSH)

CHECKLIST FOR WALKTHROUGH INSPECTION

APPENDIX 3-A

Date of inspection : 9/08/2015 Time: 8:00 AM
 Location: House 1, Bangi lama, Selangor
 Name of inspector: Yasir Man

1.0 General
 Check whether there is any -

	YES	NO	REMARK
1.1 Odour	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.2 Dirty or unsanitary conditions (e.g. excessive dust)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	- no foul odour, just baking ingredients smell, i.e. flour, cocoa powder
1.3 Visible fungal growth or mouldy odour (often associated with problem of excessive moisture)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.4 Staining or discolouration of building materials	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.5 Unsanitary conditions in equipment such as drain pans and cooling towers	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.6 Inadequate ventilation (e.g stuffy, stale air)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.7 Blocked vents	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.8 Uneven temperature	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.9 Overcrowding	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.10 Poorly-maintained filters	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.11 Air cleaners e.g. ionisers etc specify type:	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.12 Presence of hazardous substances	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.13 Unsanitary mechanical room, or trash or stored chemicals in mechanical room	<input type="checkbox"/>	<input checked="" type="checkbox"/>	

Industry Code Of Practice On Indoor Air Quality 2010



2.0 Human exposure and comfort levels

2.1 How many occupants are there in the work area?

2.2 How long are the occupants in the work area?

2.3 Is the indoor temperature regulated by thermostats? If yes
2.3.1 Where are they located?

2.3.2 Have they been correctly positioned following building alterations?

2.3.3 Are they set to the correct temperature?

2.4 Is there discomfort from heat radiation from visual display units?

2.5 Is there discomfort due to radiant heat from warm window surfaces?

2.6 Are temperature, relative humidity and air flow rates checked regularly during working hours?

2.7 Does air reach all parts of the office? Are there any dead spaces?

2.8 Is the building still being used for the purpose it was intended?

2.9 Have partitions/walls been added or removed?

2.10 Have occupancy levels changed?

YES NO REMARK

4

S- hovv,

CJ [Z]

B B

CJ [ZJ]

CJ CJ

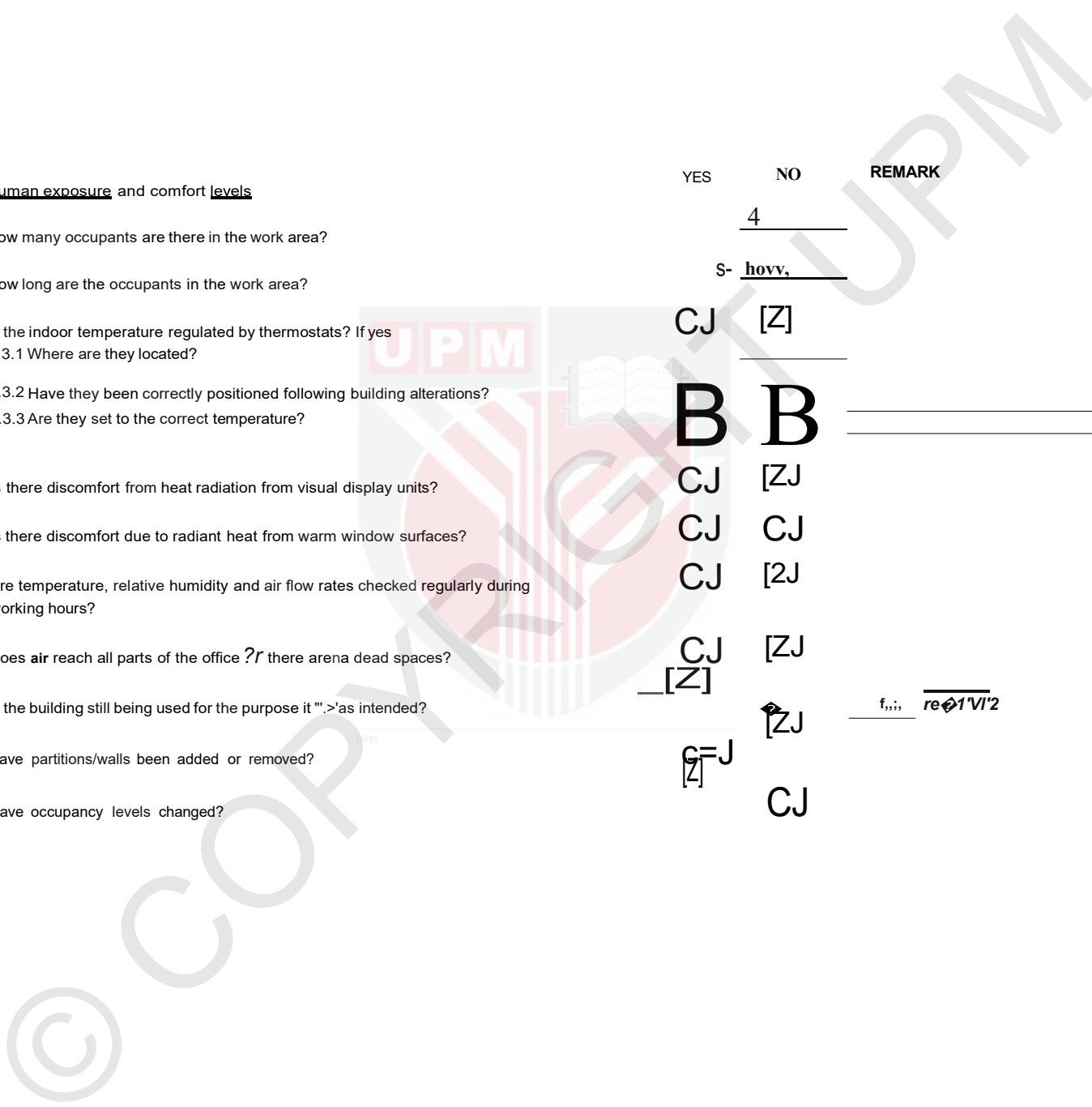
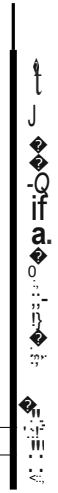
CJ [2J]

CJ [ZJ]
-[Z]

C=J
[Z]

[ZJ] f,,, re 1'VI'2

CJ



w

For use only

	YES	NO	REMARK
3.8 Are the carpets vacuum-cleaned regularly?	D		
3.9 Are there any office equipment giving off gases or fumes such as copying machines, blueprint machines and other office machines?	[Z]	D	tel v> - VIY1' M U(N^Vt / t" t/V I''''
4.0 Ventilation and air-conditioning			
4.1 Is there at least one supply air and extract air vents in every room or area? If Yes, how many supply air and extract air vents are there in each room or area?	[2]	D	
4.2 Are supply air or extract air vents blocked in any way by partitions, files or other structures that obstruct air flow?	D	[2J]	
4.3 Has dust collected around the air vents?	[Z]	CJ	
4.4 Is the air-conditioning system turned off-			
4.4.1 Any time during the day?			
4.4.2 After office hours?			
4.4.3 Are there still occupants in the building after office hours?			
4.5 Where is the outdoor air intake duct located?			
4.5.1 Near the cooling tower in this building			
4.5.2 Near adjacent buildings?			
4.5.3 At street level			

f



4.5.4 Near a car park

4.5.5 Is it obstructed?

4.5.6 Others, please specify:

4.6 Are heavy industries located nearby?

4.7 Are there any construction work going on nearby?

4.8 Is outdoor air actually getting into the building?

4.9 Is there a regular schedule for cleaning and maintenance of the air-conditioning system in the building?

4.10 Are all the components of the air-conditioning system regularly inspected for leaks, breaches etc.?

BB

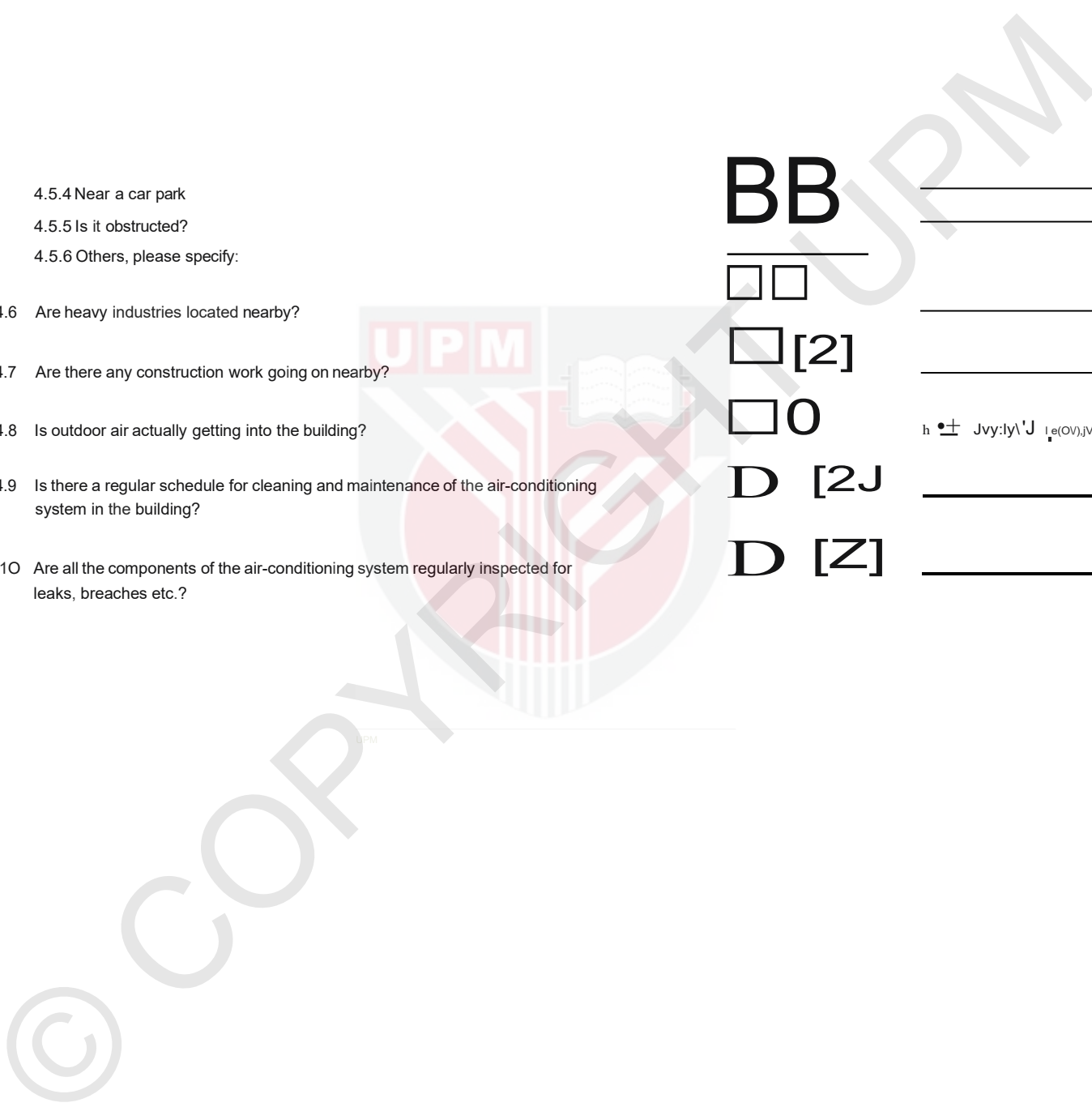
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D [2J]

D [Z]

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APPENDIX 3-B

QUESTIONNAIRE FOR BUILDING OCCUPANTS

This short questionnaire has been given to you to facilitate the identification of potential sources of indoor air quality (IAQ) pollutants and to identify adverse health effects that may be associated with exposure to these pollutants. Your answers will remain confidential. Please complete the form as accurately as possible before returning to us.

Date: di / o' o' / 2011

General information

- 1. Building/Company name _____
- 2. Department/Division _____
- 3. Has your Company carried out any assessment related to IAQ?

Yes No In progress Not sure

Background factor

- 4. Sex: Male Female
- 5. Age: < 25 yrs 25-39 yrs 40-55 yrs > 55 yrs
- 6. Do you smoke? Yes No Sometimes

Nature of Occupation

- 7. Occupation/Position _____
- 8. How long you have been at your present place of work? 3 yr(s) _____ mth(s)
- 9. No. of hours spent per day at your main workstation 4 hr(s)
- 10. Brief description of your work:
working mainly baking to achieve daily target orders if
pastries such as kek batik, and tarts.

Environmental Conditions

- 11. Type of workstation : Enclosed room
 Open concept
- 12. No. of people sharing your workstation: 1
- 13. How is your area air-conditioned? Central unit
 Local unit (split unit)

14. Please indicate if you work with or near the following equipment:

	Everyday	2-3 times weekly	Never
a) Typewriter	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
b) Video display unit/computer	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
c) Photocopier	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
d) Fax machine	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>

15. Have you been bothered during the last three (3) months by any of the following factors at your workstation/workplace?

	Yes, often (every week)	Yes, sometimes	No, never
a) Draught	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
b) Room temperature too high	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
c) Varying room temperature	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
d) Room temperature too low	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
e) Stuffy "bad" air	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
f) Dry air	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
g) Unpleasant odour	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
h) Passive smoking	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
i) Dust and dirt	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

Past/Present Diseases/Symptoms

	Yes	No
16. Have you ever had asthmatic problems? If yes, during last year?	<input type="checkbox"/>	<input checked="" type="checkbox"/>
17. Have you ever suffered from sinusitis? If yes, during last year?	<input type="checkbox"/>	<input checked="" type="checkbox"/>
19. Have you ever suffered from eczema? If yes, during last year?	<input type="checkbox"/>	<input checked="" type="checkbox"/>

Present Symptoms

20. During the last three (3) months, have you had any of the following symptoms at work (Answer every question even if you have not had any symptoms)

	Yes, often (every week)	Yes, sometimes (2-3 times/week)	No, never	If yes, do you believe that is due to your work environment?	
				Yes	No
a) Headache		/			
b) Feeling heavy-headed			/		
c) Fatigue/ lethargy			/		
d) Drowsiness			/		
e) Dizziness			/		
f) Nausea/vomiting			I		
g) Cough			J		
h) Irritated, stuffy nose		I			
i) Hoarse, dry throat			I		
j) Skin rash/ itchiness			/		
k) Irritation of the eyes			/		
l) Scaling/itching scalp or ears			I		

21. No. of days in the past one (1) month that you had to take on work because at these complaints:

___ 0 ___ day(s)

22. When do these complaints occur?

<input type="checkbox"/>	Mornings
<input type="checkbox"/>	Afternoons
<input checked="" type="checkbox"/>	No noticeable trend

23. When do you experience relief from these complaints?

<input type="checkbox"/>	After I leave my workstation
<input type="checkbox"/>	After I leave the building
<input checked="" type="checkbox"/>	No noticeable trend

24. If female, are you currently pregnant?

<input type="checkbox"/>	Yes
<input type="checkbox"/>	No
<input type="checkbox"/>	Not sure

CHECKLIST FOR WALKTHROUGH INSPECTION

Date of inspection : 24/08/2023 Time: 8:00 AM

Location: House 2, Gombak, Selangor

Name of inspector: Yasv Man

1.0 General

Check whether there is any -

	YES	NO	REMARK
1.1 Odour	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.2 Dirty or unsanitary conditions (e.g. excessive dust)	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
1.3 Visible fungal growth or mouldy odour (often associated with problem of excessive moisture)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	* newby air cond
1.4 Staining or discolouration of building materials	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.5 Unsanitary conditions in equipment such as drain pans and cooling towers	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.6 Inadequate ventilation (e.g stuffy, stale air)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.7 Blocked vents	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.8 Uneven temperature	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.9 Overcrowding	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.10 Poorly-maintained filters	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.11 Air cleaners e.g. ionisers etc specify type:	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.12 Presence of hazardous substances	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
1.13 Unsanitary mechanical room, or trash or stored chemicals in mechanical room	<input type="checkbox"/>	<input checked="" type="checkbox"/>	

air-conditioner



2.0 Human exposure and comfort levels

2.1 How many occupants are there in the work area?

2.2 How long are the occupants in the work area?

2.3 Is the indoor temperature regulated by thermostats? If yes

2.3.1 Where are they located?

2.3.2 Have they been correctly positioned following building alterations?

2.3.3 Are they set to the correct temperature?

2.4 Is there discomfort from heat radiation from visual display units?

2.5 Is there discomfort due to radiant heat from warm window surfaces?

2.6 Are temperature, relative humidity and air flow rates checked regularly during working hours?

2.7 Does air reach all parts of the office or there are no dead spaces?

2.8 Is the building still being used for the purpose it was intended?

2.9 Have partitions/walls been added or removed?

2.10 Have occupancy levels changed?

YES NO REMARK

1. boV

U. 1, -00

CJ [Z]

B Ea

CJ [ZJ]

CJ [Z]

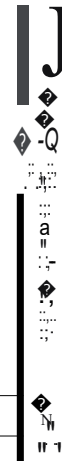
CJ [ZJ]

[Z]

[ZJ] CJ

CJ [ZJ]

D [ZJ]



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3.0 Potential sources of contaminants

YES NO REMARK

3.1 Are there any occupants smoking?
If Yes, indicate where and If No, indicate the designated areas for smoking?

D [ZJ _____

3.2 Are there furniture, furnishings, carpets, etc. that emit noticeable odours?

[Z] D _____

3.3 Have detergents, pesticides or other chemicals been used in the building?

[Z] D _____

3.4 Has there been any recent renovation or maintenance in any part of the building-

8 E3 _____

3.4.1 Done during working hours

3.4.2 That can be a source of contaminants, such as painting, carpet installation, air conditioning repairs, use of acid drain cleaners, carpet cleaning, disinfecting of HVAC system, pesticide application

D [2J _____

3.4.3 That can alter air flow patterns such as installation of partitions or relocation of air intake or exhaust?

3.5 Is there a kitchen or pantry where cooking is done?
If Yes, is exhaust ventilation provided there?

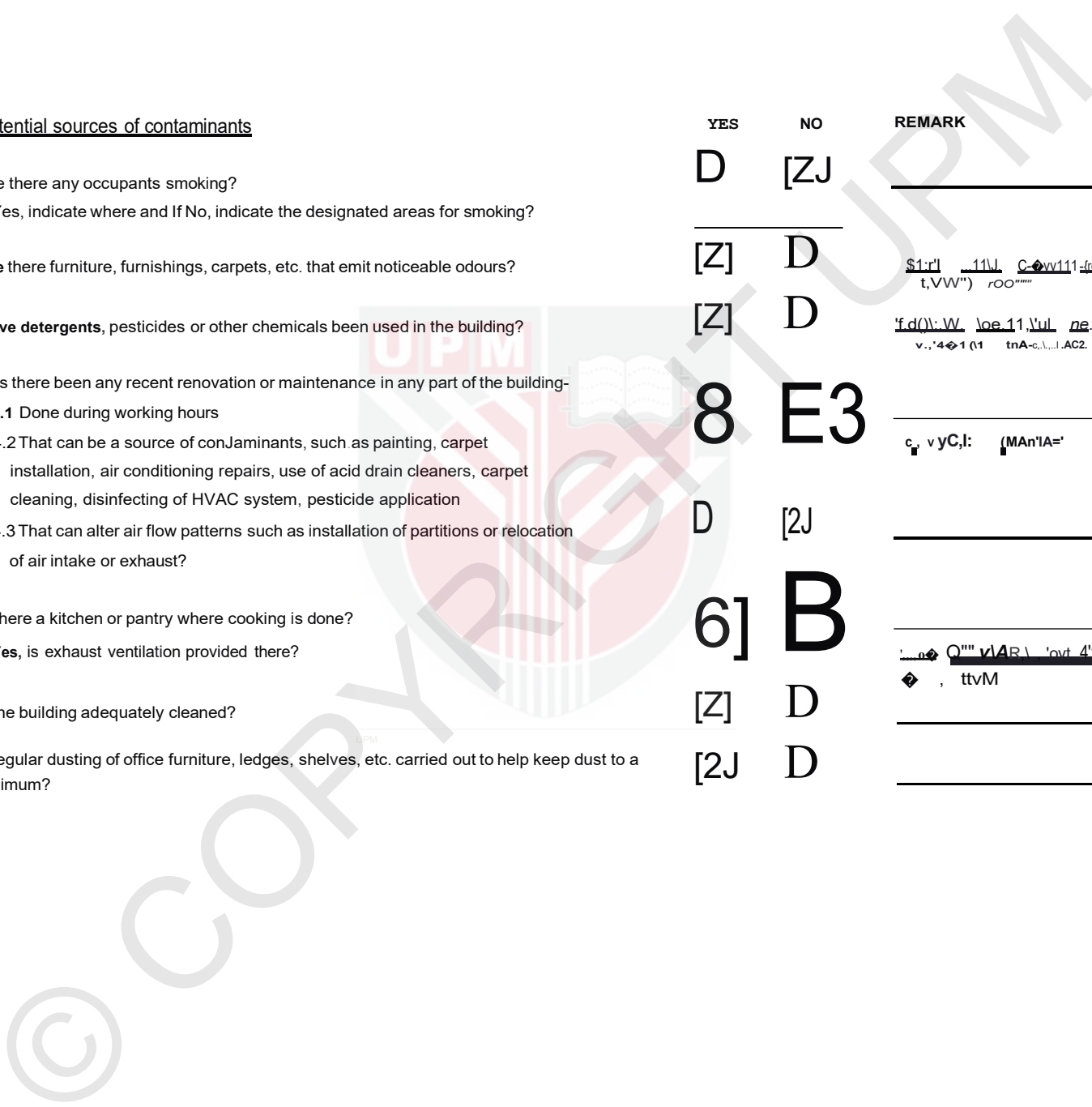
6] B _____

3.6 Is the building adequately cleaned?

[Z] D _____

3.7 Is regular dusting of office furniture, ledges, shelves, etc. carried out to help keep dust to a minimum?

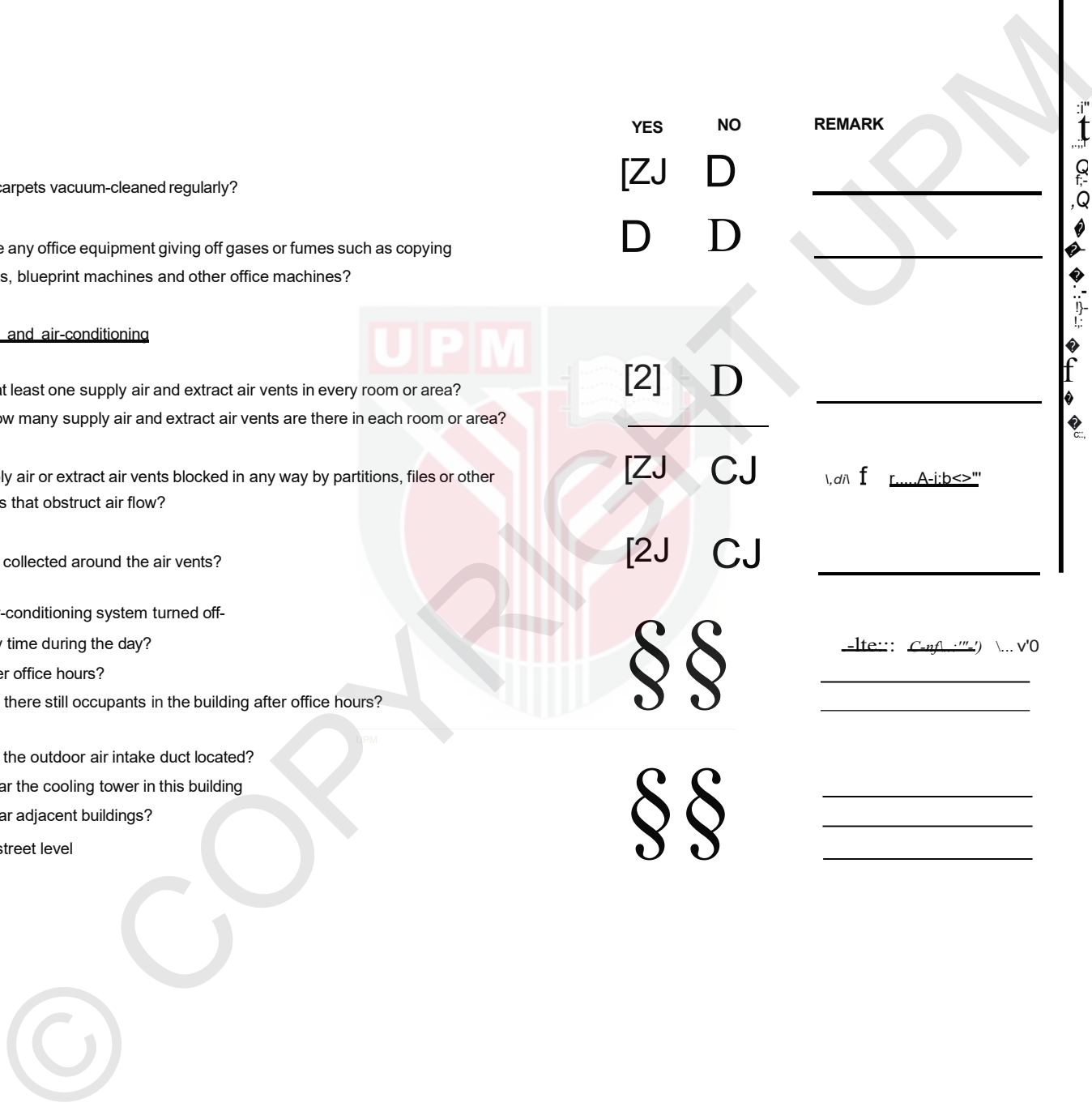
[2J] D _____



W
W



	YES	NO	REMARK
3.8 Are the carpets vacuum-cleaned regularly?	[ZJ	D	_____
3.9 Are there any office equipment giving off gases or fumes such as copying machines, blueprint machines and other office machines?	D	D	_____
4.0 <u>Ventilation and air-conditioning</u>			
4.1 Is there at least one supply air and extract air vents in every room or area? If Yes, how many supply air and extract air vents are there in each room or area?	[2]	D	_____
4.2 Are supply air or extract air vents blocked in any way by partitions, files or other structures that obstruct air flow?	[ZJ	CJ	_____
4.3 Has dust collected around the air vents?	[2J	CJ	_____
4.4 Is the air-conditioning system turned off- 4.4.1 Any time during the day? 4.4.2 After office hours? 4.4.3 Are there still occupants in the building after office hours?	§	§	_____
4.5 Where is the outdoor air intake duct located? 4.5.1 Near the cooling tower in this building 4.5.2 Near adjacent buildings? 4.5.3 At street level	§	§	_____



QUESTIONNAIRE FOR BUILDING OCCUPANTS

This short questionnaire has been given to you to facilitate the identification of potential sources of indoor air quality (IAQ) pollutants and to identify adverse health effects that may be associated with exposure to these pollutants. Your answers will remain confidential. Please complete the form as accurately as possible before returning to us.

Date: 15/07/14

General Information

1. Building/Company name _____
2. Department/Division _____
3. Has your Company carried out any assessment related to IAQ?

Yes No In progress Not sure

Background factor

4. Sex: Male Female
5. Age: < 25 yrs 25-39 yrs 40-55 yrs > 55 yrs

6. Do you smoke? Yes No Sometimes

Nature of Occupation

7. Occupation/Position _____
8. How long you have been at your present place of work? yr(s) 5 mth(s)
9. No. of hours spent per day at your main workstation _____ hr(s)
10. Brief description of your work:

Software developer

Environmental Conditions

11. Type of workstation : Enclosed room
 Open concept

12. No. of people sharing your workstation: 1

13. How is your area air-conditioned? Central unit
 Local unit (split unit)

14. Please Indicate **If** you work with or near the following equipment:

- a) Typewriter **Ei-Y 2-Jtl, kly**
- b) Video display unit/computer
- c) Photocopier
- d) Fax machine

15. Have you been bothered during the last three (3) months by any of the following factors at your workstation/workplace?

	Yes, often (every week)	Yes, sometimes	No, never
a) Draught			I
b) Room temperature too high			I
c) Varying room temperature		/	I
d) Room temperature too low		/	
e) Stuffy "bad" air		I	
f) Dry air			/
g) Unpleasant odour			/
h) Passive smoking			/
i) Dust and dirt		I	

Past/Present Diseases/Symptoms

	Yes	No
16. Have you ever had asthmatic problems? If yes, during last year?	B	EI
17. Have you ever suffered from sinusitis? If yes, during last year?	B	EI
19. Have you ever suffered from eczema? If yes, during last year?	B	EI

Present Symptoms

20. During the last three (3) months, have you had any of the following symptoms at work (Answer every question even if you have not had any symptoms)

	Yes, often (every week)	Yes, sometimes (2-3 times/week)	No, never	If yes, do you believe that is due to your work environment?	
				Yes	No
a) Headache		/			
b) Feeling heavy-headed			/		
c) Fatigue/ lethargy			/		
d) Drowsiness			/		
e) Dizziness			/		
f) Nausea/vomiting			/		
g) Cough					I
h) Irritated, stuffy nose					
i) Hoarse, dry throat			/		
j) Skin rash/ itchiness			/		
k) Irritation of the eyes			/		
l) Scaling/itching scalp or ears			/		

21. No. of days in the past one (1) month that you had to take off work because at these complaints:

0 day(s)

22. When do these complaints occur?

- Mornings
- Afternoons
- No noticeable trend

23. When do you experience relief from these complaints?

- After I leave my workstation
- After I leave the building
- No noticeable trend

24. If female, are you currently pregnant?

- Yes
- No
- Not sure

APPENDIX 3-A

CHECKLIST FOR WALKTHROUGH INSPECTION

Date of inspection : n!o'l{-wJ..1

Time: '6-1: MY

Location: \!py1e 1 6.g.M.W. / 2...loA n!O-

Name of inspector: 'u.i.v ''''''v

1.0

Check whether there is any -

- 1.1 Odour
- 1.2 Dirty or unsanitary conditions (e.g. excessive dust)
- 1.3 Visible fungal growth or mouldy odour (often associated with problem of excessive moisture)
- 1.4 Staining or discolouration of building materials
- 1.5 Unsanitary conditions in equipment such as drain pans and cooling towers
- 1.6 Inadequate ventilation (e.g stuffy, stale air)
- 1.7 Blocked vents
- 1.8 Uneven temperature
- 1.9 Overcrowding
- 1.10 Poorly-maintained filters
- 1.11 Air cleaners e.g. ionisers etc specify type:
- 1.12 Presence of hazardous substances
- 1.13 Unsanitary mechanical room, or trash or stored chemicals in mechanical room

YES

NO

REMARK

§

?

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a

2.0 Human exposure and comfort levels

2.1 How many occupants are there in the work area?

YES NO REMARK

,3

2.2 How long are the occupants in the work area?

2

2.3 Is the indoor temperature regulated by thermostats? If yes

CI [2J

2..3.1 Where are they located?

2.3.2 Have they been correctly positioned following building alterations?

2.3.3 Are they set to the correct temperature?

EI B

2.4 Is there discomfort from heat radiation from visual display units?

CI CJ

2..5 Is there discomfort due to radiant heat from warm window surfaces?

CI [ZJ

2.6 Are temperature, relative humidity and air flow rates checked regularly during working hours?

CI [Z]

2.7 Does air reach all parts of the office or there are no dead spaces?

[2J CJ

2.8 Is the building still being used for the purpose it was intended?

[2J CJ

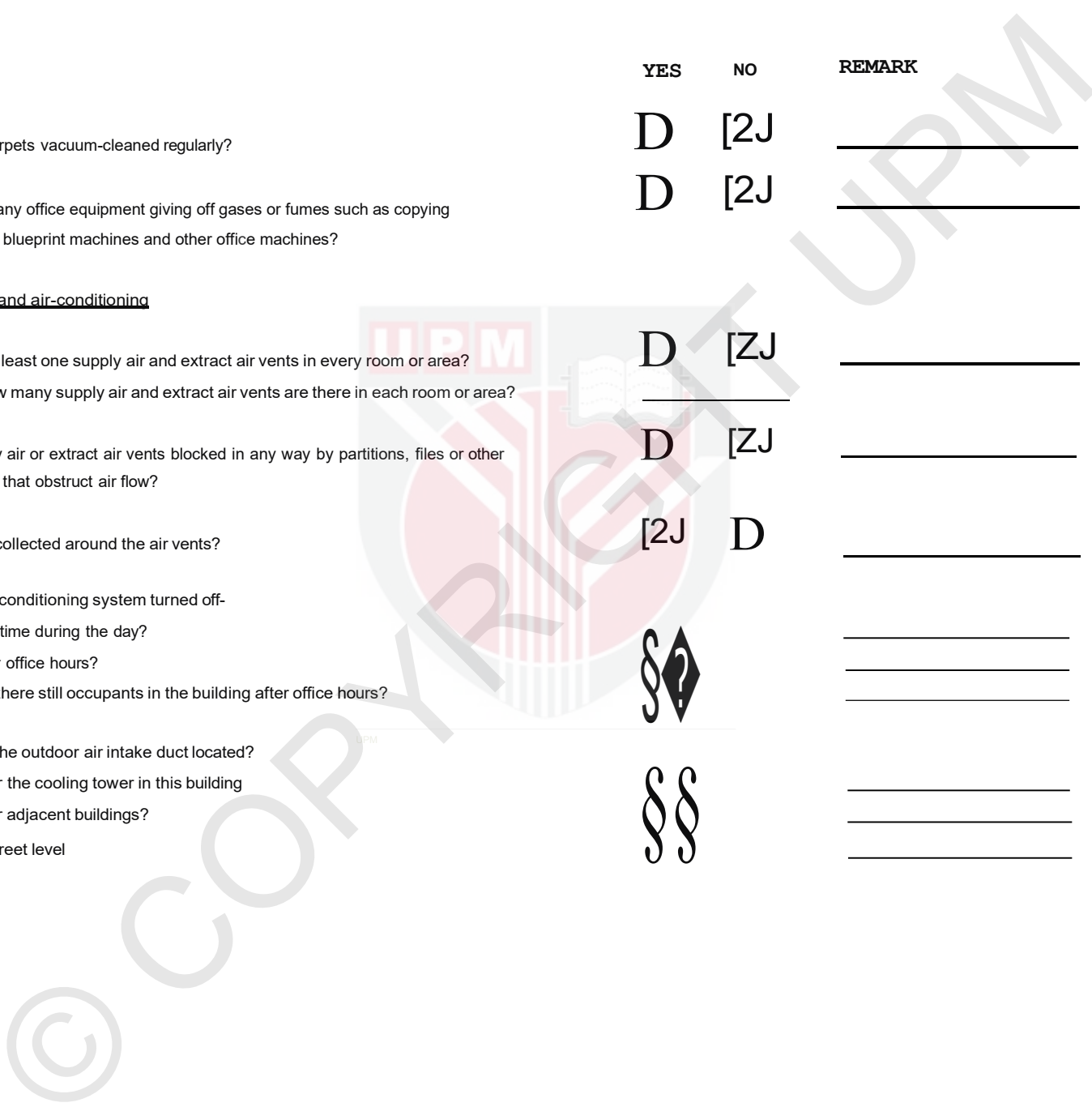
2.9 Have partitions/walls been added or removed?

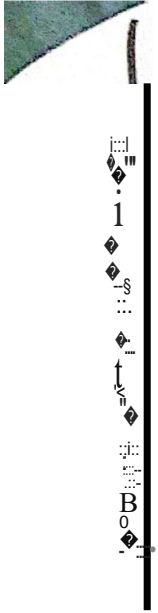
[ZJ CJ

2.10 Have occupancy levels changed?

CJ [2J

	YES	NO	REMARK
3.8 Are the carpets vacuum-cleaned regularly?	D	[2J	_____
3.9 Are there any office equipment giving off gases or fumes such as copying machines, blueprint machines and other office machines?	D	[2J	_____
4.0 Ventilation and air-conditioning			
4.1 Is there at least one supply air and extract air vents in every room or area? If Yes, how many supply air and extract air vents are there in each room or area?	D	[ZJ	_____
4.2 Are supply air or extract air vents blocked in any way by partitions, files or other structures that obstruct air flow?	D	[ZJ	_____
4.3 Has dust collected around the air vents?	[2J	D	_____
4.4 Is the air-conditioning system turned off-			
4.4.1 Any time during the day?			_____
4.4.2 After office hours?			_____
4.4.3 Are there still occupants in the building after office hours?			_____
4.5 Where is the outdoor air intake duct located?			
4.5.1 Near the cooling tower in this building			_____
4.5.2 Near adjacent buildings?			_____
4.5.3 At street level			_____





- 4.5.4 Near a car park
- 4.5.5 Is it obstructed?
- 4.5.6 Others, please specify:
- 4.6 Are heavy industries located nearby?
- 4.7 Are there any construction work going on nearby?
- 4.8 Is outdoor air actually getting into the building?
- 4.9 Is there a regular schedule for cleaning and maintenance of the air-conditioning system in the building?
- 4.10 Are all the components of the air-conditioning system regularly inspected for leaks, breaches etc.?

BtE

[2]

D [Z]

[2J D

D [ZJ

D [2]



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APPENDIX 3-8

QUESTIONNAIRE FOR BUILDING OCCUPANTS

This short questionnaire has been given to you to facilitate the identification of potential sources of indoor air quality (IAQ) pollutants and to identify adverse health effects that may be associated with exposure to these pollutants. Your answers will remain confidential. Please complete the form as accurately as possible before returning to us.

Date : 14/08/2023

General information

1. Building/Company name _____
2. DepartmenVDivision _____
3. Has your Company carried out any assessment related to IAQ?
 D Yes [Z] No D In progress D Notsure

Background factor

4. Sex: 8 Male Female
5. Age: B < 25 yrs 40-55 yrs
 25-39 yrs > 55 yrs
6. Do you smoke? Yes [2f] No Sometimes

Nature of Occupation

7. Occupation/Position _____
8. How long you have been at your present place of work? 1.5 yr(s) _____ mth(s)
9. No. of hours spent per day at your main workstation _____ hr(s)
10. Brief description of your work:
Morning cooking activities involving preparation of nasi lemak, normal malay dishes for breakfast and be sent to warung.

Environmental Conditions

11. Type of workstation : Enclosed room
 Open concept
12. No. of people sharing your workstation: J
13. How is your area air-conditioned? B Central unit
 Local unit (split unit)

14. Please Indicate If you work with or near the following equipment:

	Everyday	2-3 times weekly	Never
a) Typewriter	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
b) Video display unit/computer	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
c) Photocopier	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
d) Fax machine	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>

15. Have you been bothered during the last three (3) months by any of the following factors at your workstation/workplace?

	Yes, often (every week)	Yes, sometimes	No, never
a) Draught	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
b) Room temperature too high	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
c) Varying room temperature	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
d) Room temperature too low	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
e) Stuffy "bad" air	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
f) Dry air	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
g) Unpleasant odour	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
h) Passive smoking	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
i) Dust and dirt	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>

Past/Present Diseases/Symptoms

	Yes	No
16. Have you ever had asthmatic problems? If yes, during last year?	B	
17. Have you ever suffered from sinusitis? If yes, during last year?	B	E
19. Have you ever suffered from eczema? If yes, during last year?	B	

Present Symptoms

20. During the last three (3) months, have you had any of the following symptoms at work (Answer every question even if you have not had any symptoms)

	Yes, often (every week)	Yes, sometimes (2-3 times/week)	No, never	If yes, do you believe that is due to your work environment?	
				Yes	No
a) Headache			<input checked="" type="checkbox"/>		
b) Feeling heavy-headed			<input checked="" type="checkbox"/>		
c) Fatigue/ lethargy			<input checked="" type="checkbox"/>		
d) Drowsiness			<input checked="" type="checkbox"/>		
e) Dizziness			<input checked="" type="checkbox"/>		
f) Nausea/vomiting			<input checked="" type="checkbox"/>		
g) Cough			<input type="checkbox"/>		
h) Irritated, stuffy nose			<input checked="" type="checkbox"/>		
i) Hoarse, dry throat			<input checked="" type="checkbox"/>		
j) Skin rash/ itchininess			<input checked="" type="checkbox"/>		
k) Irritation of the eyes			<input checked="" type="checkbox"/>		
l) Scaling/itching scalp or ears			<input checked="" type="checkbox"/>		

21. No. of days in the past one (1) month that you had to take off work because of these complaints:

— 0 day(s)

22. When do these complaints occur?

- Mornings
- Afternoons
- No noticeable trend

23. When do you experience relief from these complaints?

- After I leave my workstation
- After I leave the building
- No noticeable trend

24. If female, are you currently pregnant?

- Yes
- No
- Not sure

CHECKLIST FOR WALKTHROUGH INSPECTION

Date of inspection : 1.k& :p.) Time: 8' 15 frf/\

Location: \\... \, ?... "r , Se.\''\''1<ty

Name of inspector. '<-\& \& e.111

1.0 **General**

Check whether there is any -

- 1.1 Odour
- 1.2 Dirty or unsanitary conditions (e.g. excessiv♦ dust)
- 1.3 Visible fungal growth or mouldy odour (often associated with problem of excessive moisture)
- 1.4 Staining or discolouration of building materials
- 1.5 Unsanitary conditions in equipment such as drain pans and cooling towers
- 1.6 Inadequate ventilation (e.g stuffy, stale air)
- 1.7 Blocked vents
- 1.8 Uneven temperature
- 1.9 Overcrowding
- 1.10 Poorly-maintained filters
- 1.11 Air cleaners e.g. ionisers etc specify type:
- 1.12 Presence of hazardous substances
- 1.13 Unsanitary mechanical room, or trash or stored chemicals in mechanical room

YES

NO

REMARK

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B

E:=|

YES	NO	REMARK
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§	§	
;i	/	
/	/	
/	/	
//	171	
B	E:=	

2.0 Human **exposure and comfort levels**

2.1 How many occupants are there in the work area?

YES NO REMARK

2.2 How long are the occupants in the work area?

3, _____
k

2.3 Is the indoor temperature regulated by thermostats? If yes

CJ [Z] _____

2.3.1 Where are they located?

2.3.2 Have they been correctly positioned following building alterations?

2.3.3 Are they set to the correct temperature?

B B _____

2.4 Is there discomfort from heat radiation from visual display units?

CJ [2J] _____

2.5 Is there discomfort due to radiant heat from warm window surfaces?

CJ [ZJ] _____

2.6 Are temperature, relative humidity and air flow rates checked regularly during working hours?

CJ [ZJ] _____

2.7 Does air reach all parts of the office or there are no dead spaces?

[2J] c=J _____

2.8 Is the building still being used for the purpose it was intended?

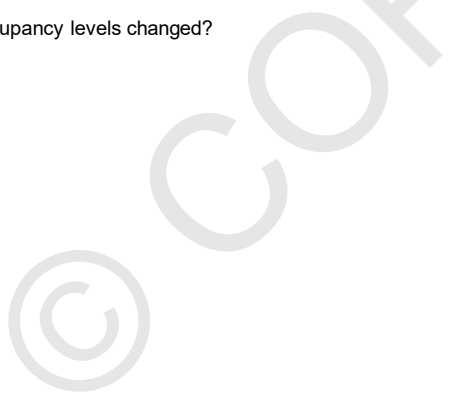
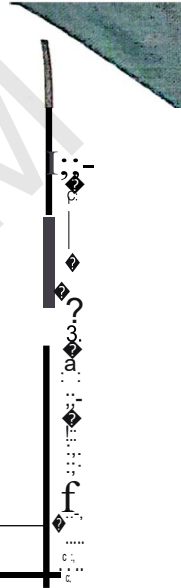
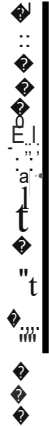
[2] c=J _____

2.9 Have partitions/walls been added or removed?

[2J] c=J _____

2.10 Have occupancy levels changed?

CJ | =Z| _____





3.0 Potential sources Of contaminants

YES NO REMARK

3.1 Are there any occupants smoking?
If Yes, indicate where and If No, indicate the designated areas for smoking?

[Z] D

3.2 Are there furniture, furnishings, carpets, etc. that emit noticeable odours?

D [2J

3.3 Have detergents, pesticides or other chemicals been used in the building?

[2] D

3.4 Has there been any recent renovation or maintenance in any part of the building-

BB

3.4.1 Done during working hours

3.4.2 That can be a source of contaminants, such as painting, carpet installation,
air conditioning repairs, use of acid drain cleaners, carpel cleaning,
disinfecting of HVAC system, pesticide application

DD

3.4.3 That can alter air flow patterns such as installation of partitions or relocation
of air intake or exhaust?

3.5 Is there a kitchen or pantry where cooking is done?

⬢? @

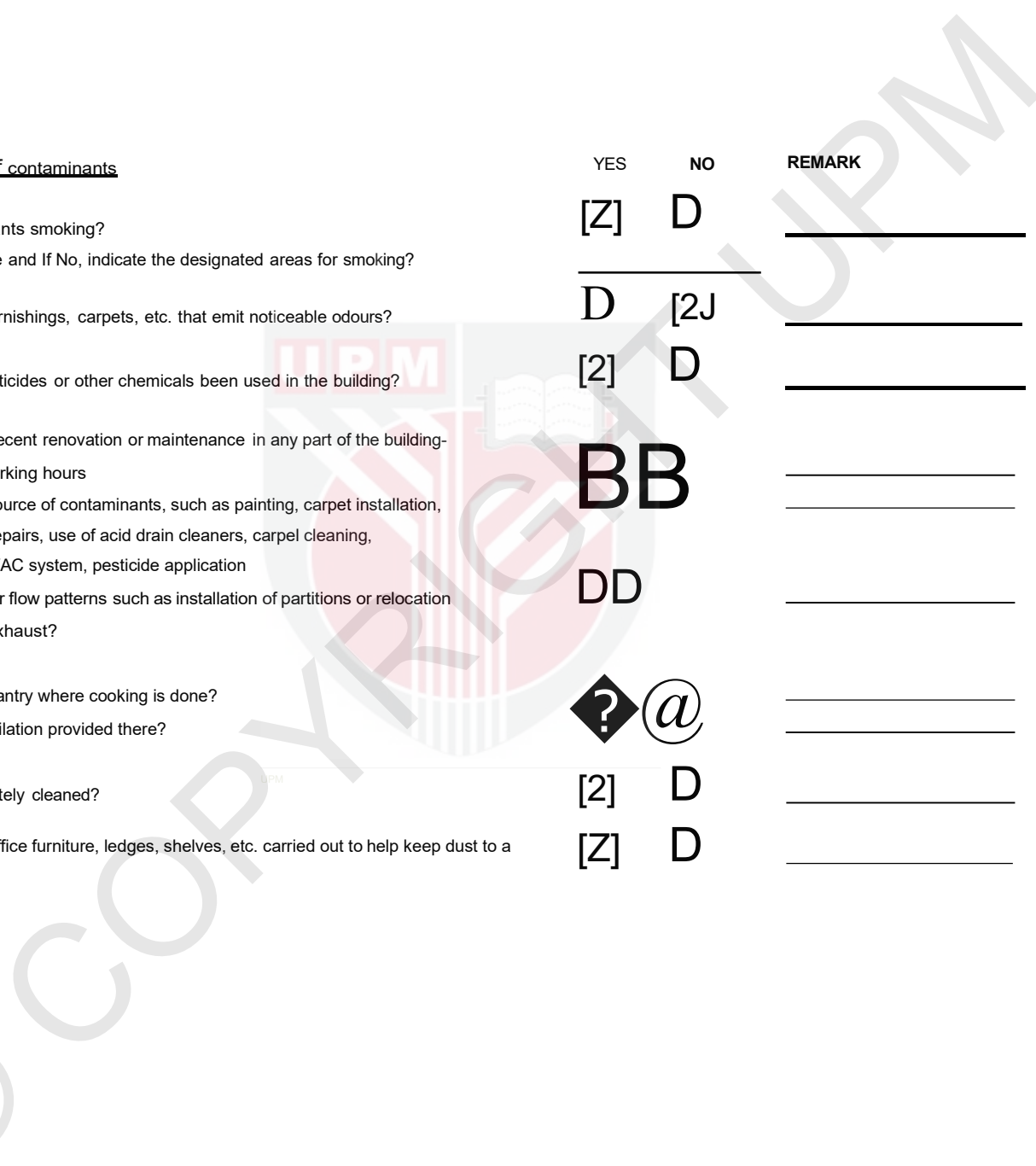
If Yes, is exhaust ventilation provided there?

3.6 Is the building adequately cleaned?

[2] D

3.7 Is regular dusting of office furniture, ledges, shelves, etc. carried out to help keep dust to a
minimum?

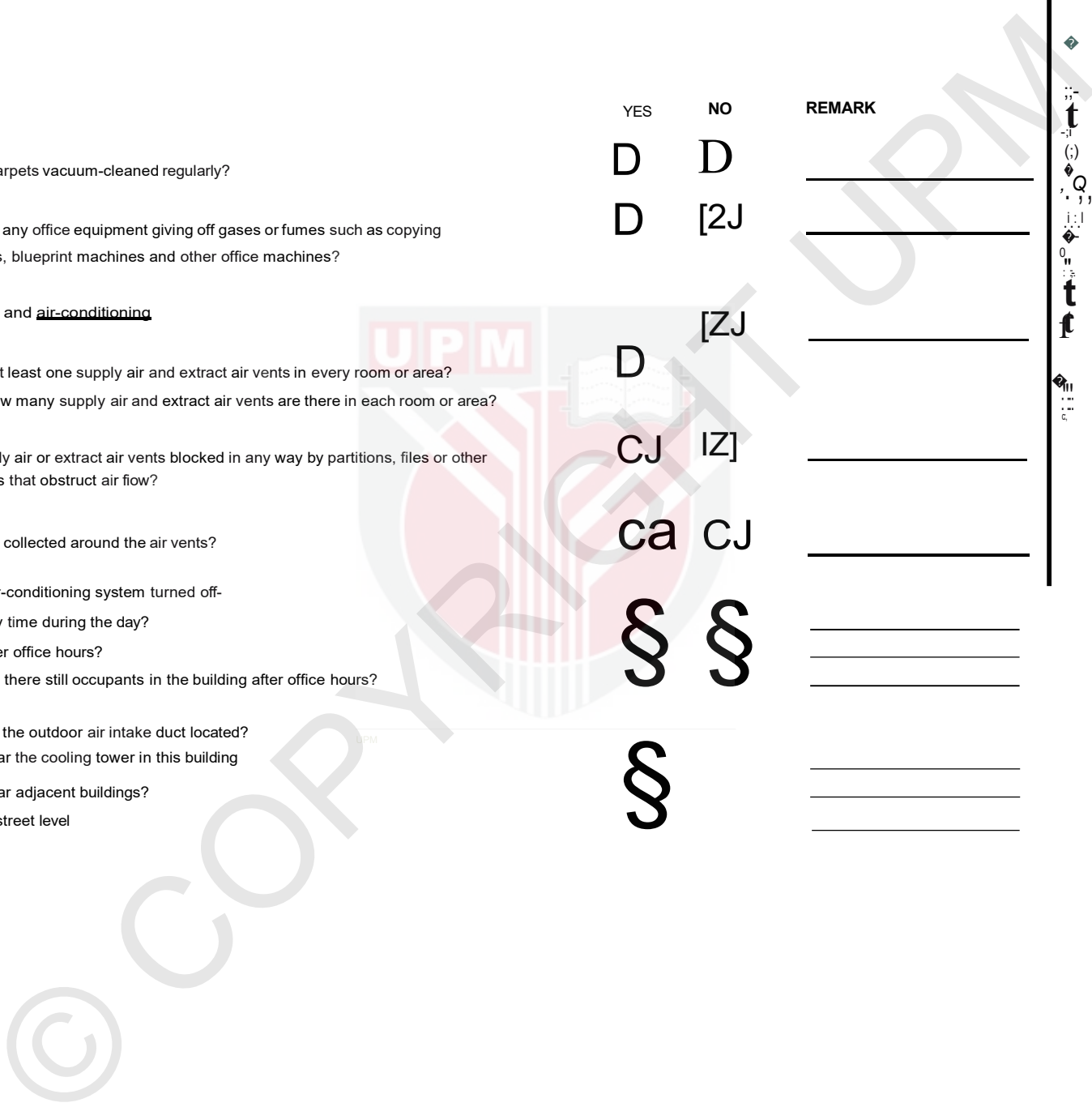
[Z] D





	YES	NO	REMARK
3.8 Are the carpets vacuum-cleaned regularly?	D	D	_____
3.9 Are there any office equipment giving off gases or fumes such as copying machines, blueprint machines and other office machines?	D	[2J	_____
4.0 Ventilation and <u>air-conditioning</u>		[ZJ	_____
4.1 Is there at least one supply air and extract air vents in every room or area? If Yes, how many supply air and extract air vents are there in each room or area?	D		_____
4.2 Are supply air or extract air vents blocked in any way by partitions, files or other structures that obstruct air flow?	CJ	[Z]	_____
4.3 Has dust collected around the air vents?	ca	CJ	_____
4.4 Is the air-conditioning system turned off-			
4.4.1 Any time during the day?	§	§	_____
4.4.2 After office hours?			_____
4.4.3 Are there still occupants in the building after office hours?			_____
4.5 Where is the outdoor air intake duct located?			
4.5.1 Near the cooling tower in this building	§		_____
4.5.2 Near adjacent buildings?			_____
4.5.3 At street level			_____

11
11



- 4.5.4 Near a car park
- 4.5.5 Is it obstructed?
- 4.5.6 Others, please specify:
- 4.6 Are heavy industries located nearby?
- 4.7 Are there any construction work going on nearby?
- 4.8 Is outdoor air actually getting into the building?
- 4.9 Is there a regular schedule for cleaning and maintenance of the air-conditioning system in the building?
- 4.10 Are all the components of the air-conditioning system regularly inspected for leaks, breaches etc.?

BB

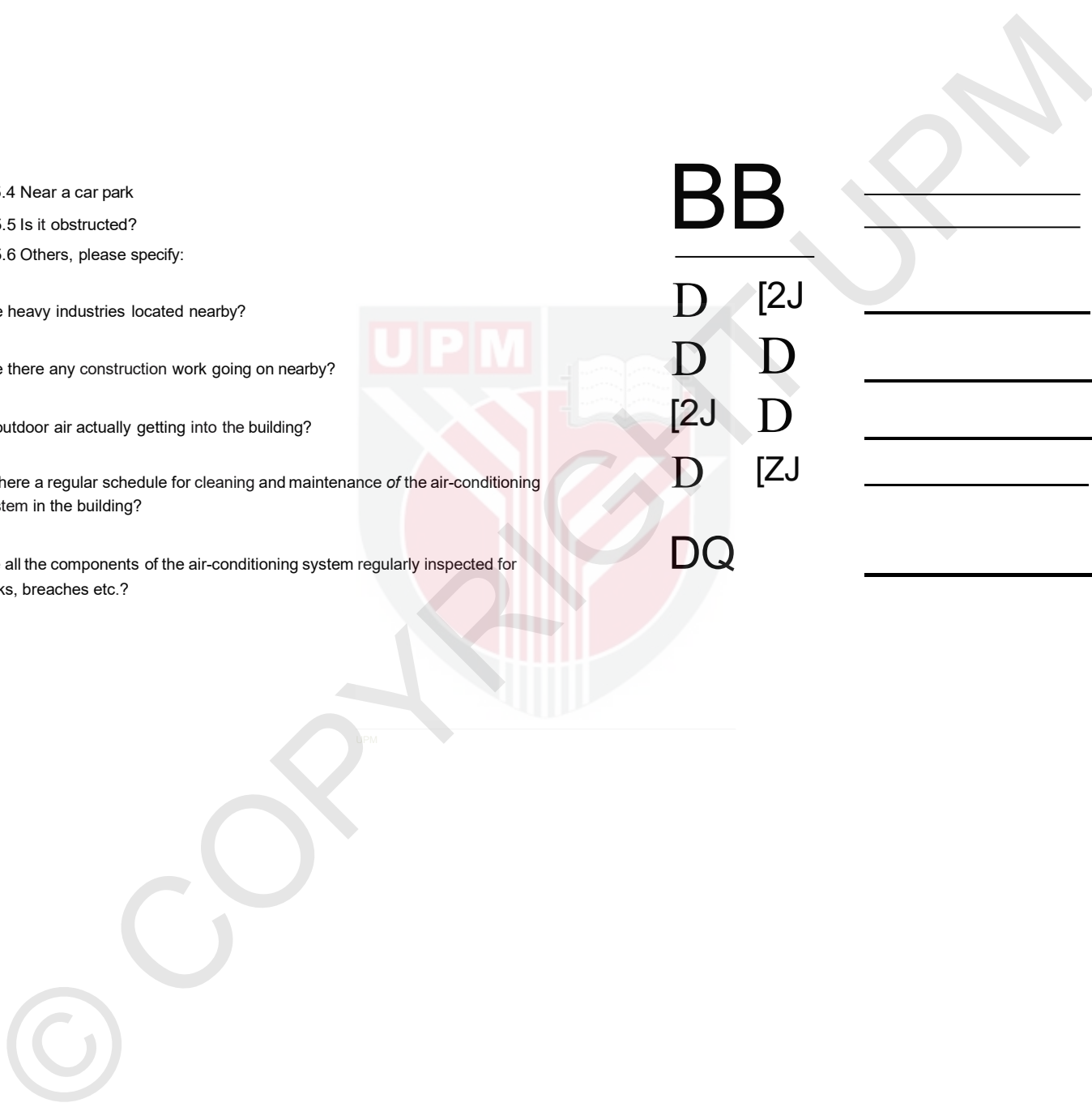
D [2J

D D

[2J D

D [ZJ

DQ



14. Please indicate if you work with or near the following equipment:

- a) Typewriter
- b) Video display terminal/computer
- c) Photocopier
- d) Fax machine

15. Have you been bothered during the last three (3) months by any of the following factors at your workstation/workplace?

	Yes, often (every week)	Yes, sometimes	No, never
a) Draught			/
b) Room temperature too high			I
c) Varying room temperature			I
d) Room temperature too low			I
e) Stuffy "bad" air			/
f) Dry air			/
g) Unpleasant odour			/
h) Passive smoking		I	
i) Dust and dirt			/

Past/Present Diseases/Symptoms

	Yes	No
16. Have you ever had asthmatic problems? If yes, during last year?	B	E
17. Have you ever suffered from sinusitis? If yes, during last year?	B	a
19. Have you ever suffered from eczema? If yes, during last year?	B	a

Present Symptoms

20. During the last three (3) months, have you had any of the following symptoms at work (Answer every question even if you have not had any symptoms)

	Yes, often (every week)	Yes, sometimes (2-3 times/week)	No, never	If yes, do you believe that is due to your work environment?	
				Yes	No
a) Headache			/		
b) Feeling heavy-headed			/		
c) Fatigue/ lethargy			/		
d) Drowsiness			/		
e) Dizziness			/		
f) Nausea/vomiting			/		
g) Cough		J			I
h) Irritated, stuffy nose			/		
i) Hoarse, dry throat					/
j) Skin rash/ itchiness			/		
k) Irritation of the eyes			/		
l) Scaling/itching scalp or ears			/		

21. No. of days in the past one (1) month that you had to take off work because of these complaints:

2 day(s)

22. When do these complaints occur?

- Mornings
- Afternoons
- No noticeable trend

23. What do you experience relief from these complaints?

- After I leave my workstation
- After I leave the building
- No noticeable trend

24. If female, are you pregnant?

- Yes
- No
- Not sure

2.0 Human exposure and comfort levels

2.1 How many occupants are there in the work area?

YES NO REMARK

-3

2.2 How long are the occupants in the work area?

J '1-,c:.

2.3 Is the indoor temperature regulated by thermostats? If yes

CJ [Z]

2.3.1 Where are they located?

2.3.2 Have they been correctly positioned following building alterations?

2.3.3 Are they set to the correct temperature?

B

2.4 Is there discomfort from heat radiation from visual display units?

CJ CZ::J

2.5 Is there discomfort due to radiant heat from warm window surfaces?

2.6 Are temperature, relative humidity and air flow rates checked regularly during working hours?

CJ [Z]

2.7 Does air reach all parts of the office or there are no dead spaces?

[2J CJ

2.8 Is the building still being used for the purpose it was intended?

[Z] C

2.9 Have partitions/walls been added or removed?

CJ J

2.10 Have occupancy levels changed?

[:=J [ZJ

3.0 P9-tential sources of contaminants

YES NO REMARK

3.1. Are there any occupants smoking?
If Yes, indicate where and If No, indicate the designated areas for smoking?

D [Z]

3.2 Are there furniture, furnishings, carpets, etc. that emit noticeable odours?

[Z] D

3.3 Have detergents, pesticides or other chemicals been used in the building?

[Z] D

3.4 Has there been any recent renovation or maintenance in any part of the building-

E] 63

3.4.1 Done during working hours

3.4.2 That can be a source of contaminants, such as painting, carpet installation, air conditioning repairs, use of acid drain cleaners, carpet cleaning, disinfecting of HVAC system, pesticide application

3.4.3 That can alter air flow patterns such as installation of partitions or relocation of air intake or exhaust?

D [Z]

3.5 Is there a kitchen or pantry where cooking is done?

aa

If Yes, is exhaust ventilation provided there?

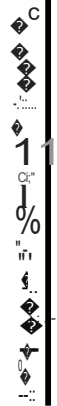
3.6 Is the building adequately cleaned?

D [Z]

3.7 Is regular dusting of office furniture, ledges, shelves, etc. carried out to help keep dust to a minimum?

[Z] D





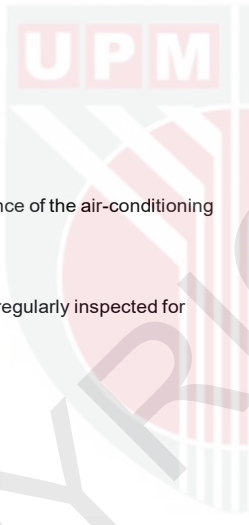
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- 4.5.4 Near a car park
- 4.5.5 Is it obstructed?
- 4.5.6 Others, please specify:

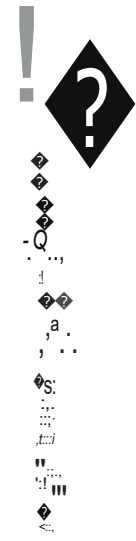
- 4.6 Are heavy industries located nearby?
- 4.7 Are there any construction work going on nearby?
- 4.8 Is outdoor air actually getting into the building?
- 4.9 Is there a regular schedule for cleaning and maintenance of the air-conditioning system in the building?
- 4.10 Are all the components of the air-conditioning system regularly inspected for leaks, breaches etc.?

BB

- [2]
- D [Z]
- [Z] D
- CJ [2J]
- [2]



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QUESTIONNAIRE FOR BUILDING OCCUPANTS

This short questionnaire has been given to you to facilitate the Identification of potential sources of indoor air quality (IAQ) pollutants and to Identify adverse health effects that may be associated with exposure to these pollutants. Your answers will remain confidential. Please complete the form as accurately as possible before returning to us,

Date: 11/11/2013

General information

- 1. Building/Company name _____
- 2. Department/Division _____
- 3. Has your Company carried out any assessment related to IAQ?
 Yes No In progress Not sure

Background factor

- 4. Sex: Male Female
- 5. Age: < 25 yrs 25-39 yrs 40-55 yrs > 55 yrs
- 6. Do you smoke? Yes No Sometimes

Nature of Occupation

- 7. Occupation/Position _____
- 8. How long you have been at your present place of work? _____ yr(s) _____ mth(s)
- 9. No. of hours spent per day at your main workstation _____ hr(s)
- 10. Brief description of your work:
 (a) working on Malay dishes repaired
in morning from 8:30 am to 11:00 am to be sold
at
designated stall.

Environmental Conditions

- 11. Type of workstation Enclosed room Open concept
- 12. No. of people sharing your workstation: _____
- 13. How is your area air-conditioned?
 Central unit
 Local unit (split unit)

14. Please indicate if you work with or near the following equipment:

	Everyday	2-3 times weekly	Never
a) Typewriter	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
b) Video display uniUcomputer	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
c) Photocopier	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
d) Fax machine	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>

15. Have you been bothered during the last three (3) months by any of the following factors at your workstation/workplace?

	Yes, often (every week)	Yes, sometimes	No, never
a) Draught	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
b) Room temperature too high	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
c) Varying room temperature	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
d) Room temperature too low	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
e) Stuffy "bad" air	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
f) Dry air	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
g) Unpleasant odour	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
h) Passive smoking	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
i) Dust and dirt	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>

Past/Present Diseases/Symptoms

	Yes	No
16. Have you ever had asthmatic problems? If yes, during last year?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
17. Have you ever suffered from sinusitis? If yes, during last year?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
19. Have you ever suffered from eczema? If yes, during last year?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Present Symptoms

20. During the last three (3) months, have you had any of the following symptoms at work (Answer every question even if you have not had any symptoms)

	Yes, often (every week)	Yes, sometimes (2-3 times/week)	No, never	If yes, do you believe that is due to your work environment?	
				Yes	No
a) Headache					
b) Feeling heavy-headed			/		
c) Fatigue/ lethargy			/		
d) Drowsiness			I		
e) Dizziness			/		
f) Nausea/vomiting			/		
g) Cough			/		
h) Irritated, stuffy nose			I		
i) Hoarse, dry throat			/		
j) Skin rash/ itchiness			/		
k) Irritation of the eyes			J		
l) Scaling/itching scalp or ears			/		

21. No. of days in the past one (1) month that you had to take off work because of these complaints:

0 day(s)

22. When do these complaints occur?

- Mornings
- Afternoons
- No noticeable trend

23. How do you experience relief from these complaints?

- After I leave my workstation
- After I leave the building
- No noticeable trend

24. If female, are you emotionally exhausted?

- Yes
- No
- Not sure

CHECKLIST FOR WALKTHROUGH INSPECTION

Date of inspection : 12/10/2021 Time: 11:30 AM

Location: Hov.se w f\N(a't. Alono 51-Voniv

Name of inspector: {o.'1' { \'''' t V

1.0 **General**

Check whether there is any -

- 1.1 Odour
- 1.2 Dirty or unsanitary conditions (e.g. excessive dust)
- 1.3 Visible fungal growth or mouldy odour (often associated with problem of excessive moisture)
- 1.4 Staining or discolouration of building materials
- 1.5 Unsanitary conditions in equipment such as drain pans and cooling towers
- 1.6 Inadequate ventilation (e.g stuffy, stale air)
- 1.7 Blocked vents
- 1.8 Uneven temperature
- 1.9 Overcrowding
- 1.10 Poorly-maintained filters
- 1.11 Air cleaners e.g. ionisers etc specify type:
- 1.12 Presence of hazardous substances
- 1.13 Unsanitary mechanical room, or trash or stored chemicals in mechanical room

YES NO

REMARK

§ §

- ..vveJ i C.v.B J m.?

◆ ◆

2.0 Human exposure and comfort levels

2.1 How many occupants are there in the work area?

2.2 How long are the occupants in the work area?

2.3 Is the indoor temperature regulated by thermostats? If yes

2.3.1 Where are they located?

2.3.2 Have they been correctly positioned following building alterations?

2.3.3 Are they set to the correct temperature?

2.4 Is there discomfort from heat radiation from visual display units?

2.5 Is there discomfort due to radiant heat from warm window surfaces?

2.6 Are temperature, relative humidity and air flow rates checked regularly during working hours?

2.7 Does air reach all parts of the office or there are no dead spaces?

2.8 Is the building still being used for the purpose it was intended?

2.9 Have partitions/walls been added or removed?

2.10 Have occupancy levels changed?

YES

NO

REMARK

3 ¥"1"
CJ [2]

B tE

CJ [ZJ]

CJ [ZJ]

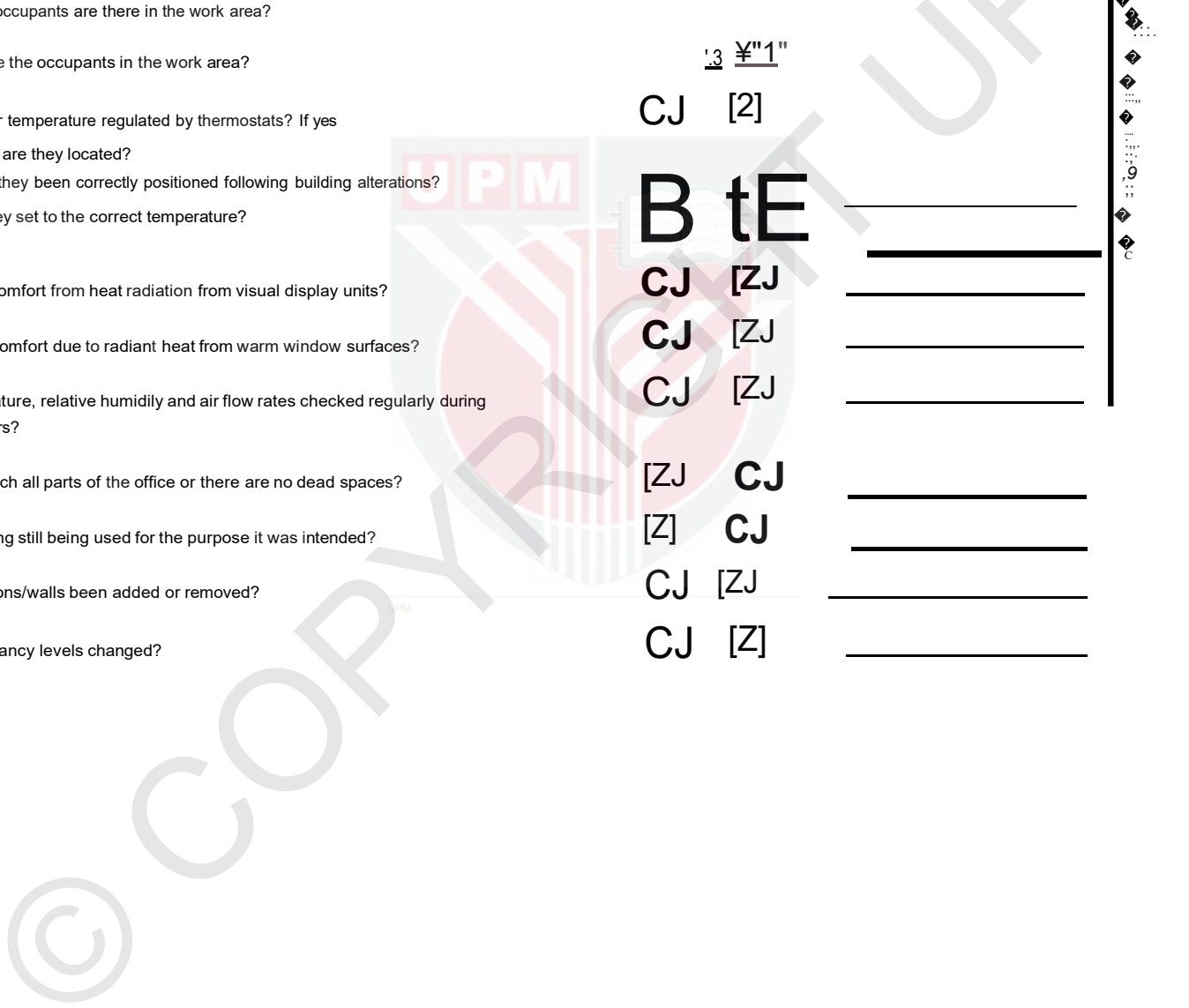
CJ [ZJ]

[ZJ] CJ

[Z] CJ

CJ [ZJ]

CJ [Z]



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B
2;

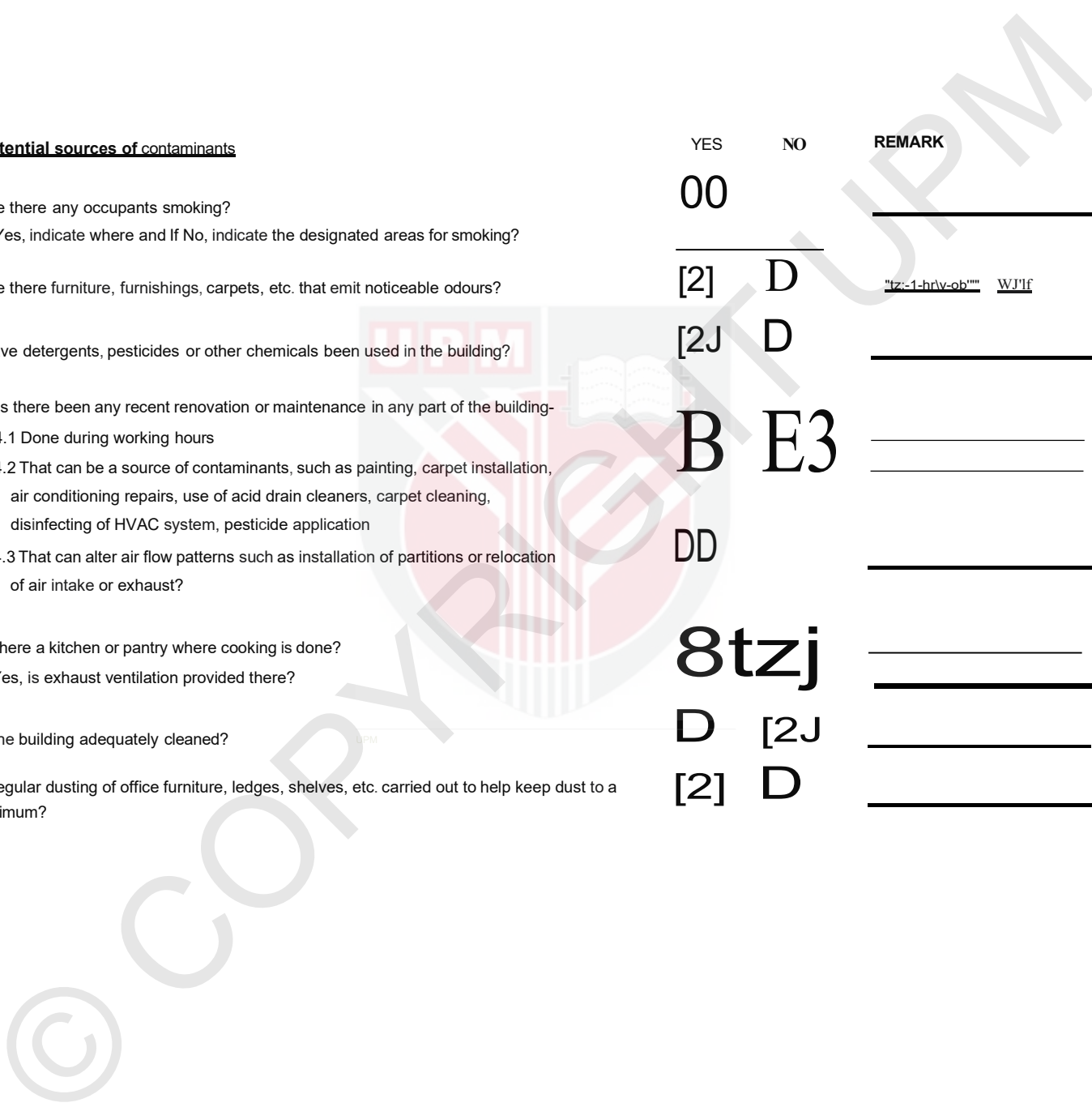
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3.0 Potential sources of contaminants

- 3.1 Are there any occupants smoking?
If Yes, indicate where and If No, indicate the designated areas for smoking?
- 3.2 Are there furniture, furnishings, carpets, etc. that emit noticeable odours?
- 3.3 Have detergents, pesticides or other chemicals been used in the building?
- 3.4 Has there been any recent renovation or maintenance in any part of the building-
 - 3.4.1 Done during working hours
 - 3.4.2 That can be a source of contaminants, such as painting, carpet installation, air conditioning repairs, use of acid drain cleaners, carpet cleaning, disinfecting of HVAC system, pesticide application
 - 3.4.3 That can alter air flow patterns such as installation of partitions or relocation of air intake or exhaust?
- 3.5 Is there a kitchen or pantry where cooking is done?
If Yes, is exhaust ventilation provided there?
- 3.6 Is the building adequately cleaned?
- 3.7 Is regular dusting of office furniture, ledges, shelves, etc. carried out to help keep dust to a minimum?

YES	NO	REMARK
00		
[2]	D	"tz-1-hrv-ob"" WJlf
[2J	D	
B	E3	
DD		
8tzj		
D	[2J	
[2]	D	

if
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III

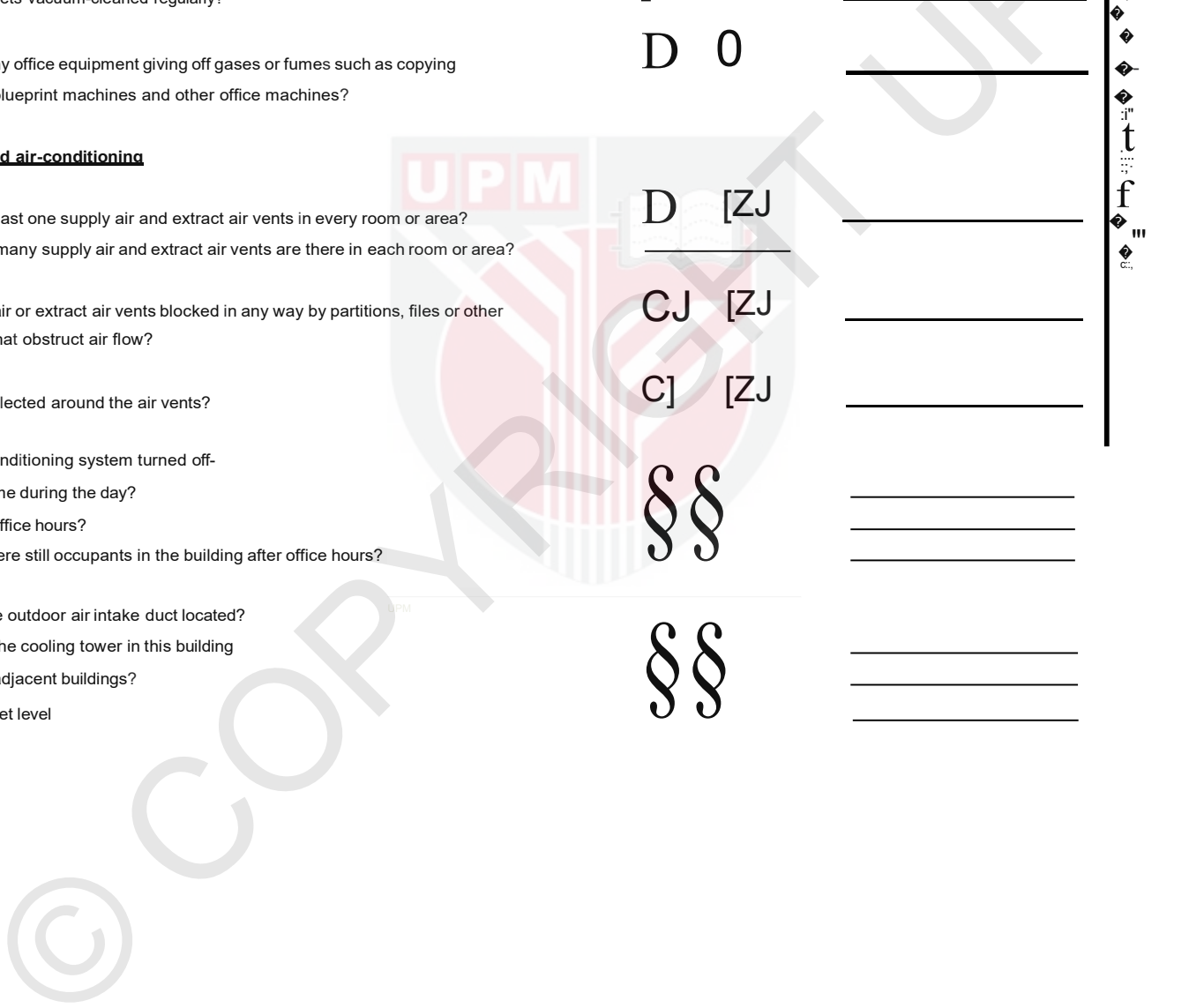




	YES	NO	REMARK
3.8 Are the carpets vacuum-cleaned regularly?	[ZJ	D	_____
3.9 Are there any office equipment giving off gases or fumes such as copying machines, blueprint machines and other office machines?	D	0	_____

4.0 Ventilation and air-conditioning

4.1 Is there at least one supply air and extract air vents in every room or area? If Yes, how many supply air and extract air vents are there in each room or area?	D	[ZJ	_____
4.2 Are supply air or extract air vents blocked in any way by partitions, files or other structures that obstruct air flow?	CJ	[ZJ	_____
4.3 Has dust collected around the air vents?	C]	[ZJ	_____
4.4 Is the air-conditioning system turned off-			
4.4.1 Any time during the day?	§§		_____
4.4.2 After office hours?			_____
4.4.3 Are there still occupants in the building after office hours?			_____
4.5 Where is the outdoor air intake duct located?			
4.5.1 Near the cooling tower in this building	§§		_____
4.5.2 Near adjacent buildings?			_____
4.5.3 At street level			_____





- 4.5.4 Near a car park
- 4.5.5 Is it obstructed?
- 4.5.6 Others, please specify:

- 4.6 Are heavy industries located nearby?
- 4.7 Are there any construction work going on nearby?
- 4.8 Is outdoor air actually getting into the building?
- 4.9 Is there a regular schedule for cleaning and maintenance of the air-conditioning system in the building?
- 4.10 Are all the components of the air-conditioning system regularly inspected for leaks, breaches etc.?

BB

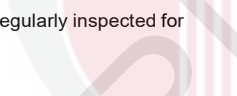
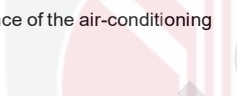
WO

[2] D

[2] D

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U P M



QUESTIONNAIRE FOR BUILDING OCCUPANTS

This short questionnaire has been given to you to facilitate the identification of potential sources of indoor air quality (IAQ) pollutants and to identify adverse health effects that may be associated with exposure to these pollutants. Your answers will remain confidential. Please complete the form as accurately as possible before returning to us.

Date: 30/08/2023

General information

1. Building/Company name _____
2. Department/Division _____
3. Has your Company carried out any assessment related to IAQ?

D Yes **LJ** No **D** In progress **D** Not sure

Background factor

4. Sex: Male Female
5. Age: < 25 yrs 40-55 yrs > 55 yrs
6. Do you smoke? Yes **[2]** No Sometimes

Nature of Occupation

7. Occupation/Position _____
8. How long you have been at your present place of work? _____ yr(s) _____ mth(s)
9. No. of hours spent per day at your main workstation _____ hr(s)
10. Brief description of your work:

Conducting to grill fill activities, mainly using deep frying methods at early morning and by 6 AM finished cooking to sell at stalls.

Environmental Conditions

11. Type of workstation Enclosed room Open concept
12. No. of people sharing your workstation: --◆) _____
13. How is your area air-conditioned? **B** Central unit Local unit (split unit)

14. Please indicate if you work with or near the following equipment:

- a) Typewriter **EBay 2U makli ;**
- b) Video display unit/computer
- c) Photocopier
- d) Fax machine

15. Have you been bothered during the last three (3) months by any of the following factors at your workstation/workplace?

	Yes, often (every week)	Yes, sometimes	No, never
a) Draught			/
b) Room temperature too high			/
c) Varying room temperature		/	
d) Room temperature too low			/
e) Stuffy "bad" air			I
f) Dry air		I	
g) Unpleasant odour			I
h) Passive smoking			
i) Dust and dirt			I

Past/Present Diseases/Symptoms

	Yes	No
16. Have you ever had asthmatic problems? If yes, during last year?	B	?
17. Have you ever suffered from sinusitis? If yes, during last year?	B	?
19. Have you ever suffered from eczema? If yes, during last year?	B	?

Present Symptoms

20. During the last three (3) months, have you had any of the following symptoms at work (Answer every question even if you have not had any symptoms)

	Yes, often (every week)	Yes, sometimes (2-3 times/week)	No, never	If yes, do you believe that is due to your work environment?	
				Yes	No
a) Headache			/		
b) Feeling heavy-headed			/		
c) Fatigue/ lethargy			/		
d) Drowsiness			/		
e) Dizziness			/		
f) Nausea/vomiting			I		
g) Cough		/			
h) Irritated, stuffy nose			/		
i) Hoarse, dry throat			/		
j) Skin rash/ itchiness			/		
k) Irritation of the eyes			/		
l) Scaling/itching scalp or ears			/		

21. No. of days in the past one (1) month that you naa to taKe arr work oecause at these complaints:

0 day(s)

22. When do these complaints occur?

<input type="checkbox"/>	Mornings
<input type="checkbox"/>	Afternoons
<input checked="" type="checkbox"/>	No noticeable trend

23. When do you experience relief from these complaints?

<input type="checkbox"/>	After I leave my workstation
<input type="checkbox"/>	After I leave the building
<input checked="" type="checkbox"/>	No noticeable trend

24. If female, a,e yo, reolly p,egoao?

Yes
No
Not sure

Appendix 2 Data collection

House 1



House 2



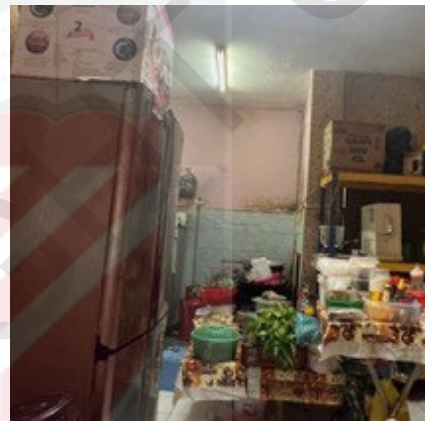
House 3



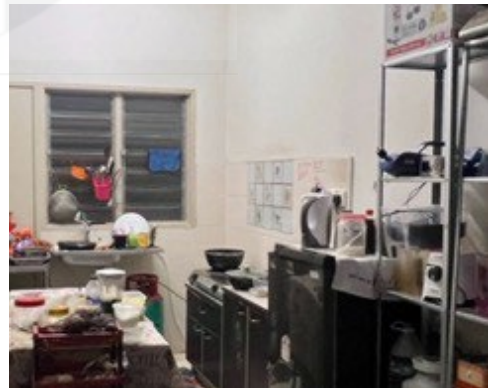
House 4



House 5



House 6



Appendix 3 Lab analysis

PTFE 37mm filter paper preparation

