Modelling of Carbon Monoxide and Carbon Dioxide in an Enclosed Car Park.

By

Mohd Shearhan Bin Mahtar

12241

Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

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Universiti Teknologi PETRONAS

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CERTIFICATION OF APPROVAL

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Approved by,

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(Dr. Nurul Izma Binti Mohammed)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

MAY 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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MOHD SHEARHAN BIN MAHTAR

ABSTRACT

The number of vehicles in Malaysia is increasing and so does the number of underground parking spaces. However, with the increasing number of vehicles using the car park, the air pollution inside the enclosed car park also increases. Therefore, this study is aiming in monitoring the level of air pollutants, namely carbon monoxide and carbon dioxide, inside the enclosed car park, the relationship between the temperature and the concentration of carbon monoxide and carbon dioxide, the effects of the level of carbon monoxide and carbon dioxide on the human health inside the enclosed car park and to suggest possible mitigation measures to reduce the air pollution inside the car park. Using a custom built environmental station, a study was done for a period of 14 days to gather the concentration of carbon monoxide and carbon dioxide inside the enclosed car park. The study was done in the underground Kuala Lumpur City Centre (KLCC) car park from 9th June to 22nd June 2014. The collected data was done averaged for every thirty minutes every day from 0800 to 1700. From the study done, the level of carbon monoxide and carbon dioxide are higher in the weekday compared to in the weekend. Furthermore, the concentration of carbon monoxide and carbon dioxide are higher in the afternoon compared to in the morning. Temperature has minimal impact on the concentration of carbon monoxide and carbon dioxide inside the car park. The level of carbon monoxide surpassed the acceptable limit advised by the Industry Code of Practice on Indoor Air Quality 2010, while the level carbon dioxide exceeded the advised limit too, suggesting the inadequacy of ventilation inside the car park. Therefore, there is a valid health concern for the users and employees of the car park. Among the suggested mitigation measures are to construct localised ventilation at critical area inside the car park and to properly manage the traffic movement inside the car park to minimise the level of pollutants released by the vehicles.

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.

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND OF STUDY

The number of motor vehicles in Malaysia is increasing rapidly in the past decade. The number of registered motor vehicles, as stated by the Department of Statistics Malaysia, is 22,702,221 in 2012 (Department of Statistics, 2013). To compare, 20,188,565 and 21,401,269 vehicles are registered in 2010 and 2011 respectively, an increase of over two million vehicles between 2010 and 2012. In addition, the statistics given by the World Bank shows that the number of motor vehicles per 1000 peoples in Malaysia is 377.7 in 2011(World Bank, 2014). In comparison, our South East Asian neighbours, Indonesia, has 26.12 motor vehicles per 1000 people in the same year. Among the factors that encourage these numbers to increase are well connected road networks, poor public transports, cheaper cars and increased income of the public populations (Dargay et. al., 2007).

Air pollution is one of the main environmental concerns at the moment. The sources of air pollution may come from natural sources or anthropogenic sources. According to the World Health Organization (WHO) 2014 report, in 2012, the number of death caused by air pollution is around 7 million worldwide (World Health Organization, 2014). Furthermore, in 2008, World's Worst Polluted Places report by Blacksmith Institute, an international non-profit organisation, lists indoor air pollution and urban air quality as two of the world's worst toxic problems (Blacksmith Institute, 2008). Mobile air pollution, especially from motor vehicles, are one of the man-made air pollution sources. Vehicles releases many sources of air pollution into the atmosphere such as carbon dioxide, carbon monoxide, nitrogen oxides and air particulates. According to United States Environmental Protection Agency (US EPA), motor vehicles accounted up to 75 % of carbon monoxide pollution in that country (US EPA, 2009). In a country which holds 30 % of automobiles in the world, this shows how much carbon monoxide released by motor vehicles.

The enormous number of vehicles requires a large area of parking spaces. In Kuala Lumpur, the number of vehicles per square kilometre is 20,427 recorded in 2011 (Department of Road Transport Malaysia, 2012). This number shows the demand for many parking lots. However, to provide a large area for car parks, especially in urban areas are highly difficult. For example, Kuala Lumpur has 20, 427 vehicles per square kilometre (Department of Road Transport Malaysia, 2012). Thus, the local councils and property developers constructed multi-level parking lots to solve this problem. Multi stories parking lots can be found in residential buildings such as apartments and residential complexes and also in commercial buildings such as offices, shopping complexes and hotels. These parking spaces can be constructed above the ground or by excavating deep into the ground to build multi-level basements.

Motor vehicles produced various gases and particulate matter due to the combustion of hydrocarbon and released them into the air. Several of them are very harmful to the people and to the environment. Among the gases known to be dangerous are carbon monoxide (CO), carbon dioxide (CO_2), nitrogen monoxide (NO), nitrogen dioxide (NO_2), air particulates and others. Carbon monoxide are the most dangerous to human as it is an unstable molecule. Prolonged exposure of low level carbon monoxide can cause headache, depression, confusion, nausea, vomiting and memory loss. Exposure to carbon monoxide also can cause or worsen people with heart disease and also harmful to pregnant women (Anderson et. al., 1973; Townsend et. al., 2002). Carbon dioxide, a greenhouse gas, is known to be major player in the global climate change. On the other hand, nitrogen oxides, namely nitrogen oxide and nitrogen dioxide, can react with ammonia vapour to form nitric acid particles. These particles, if inhaled, may worsen or cause respiratory diseases such as bronchitis and emphysema (Morris and Naumova, 1998).

The gases released by the vehicles inside enclosed parking spaces will be trapped. Over time, this will accumulate and can be considered dangerous both to the vehicle passengers and the workers. For the workers, this can be classified as occupational hazard. The French Agency for Food, Environmental and Occupational Health &

Safety, ANSES, in its 2007 report, suggested that the health risks inside car parks cannot be regarded as negligible given the concentrations of pollutants measured in their investigations, plus the known acute and chronic effects of the toxics (ANSES, 2013). However, in Malaysia, this is not in the attention of the responsible agencies. Even though the number of vehicles and parking spaces surges, there are no particular guidelines given by the government to help developers especially to build parking spaces which are safe for the occupants over time.

1.2 PROBLEM STATEMENT

In an enclosed parking space, it is believed that the effect of air pollution may worsen. This is because, when pollutants are released into the air, it is trapped inside the parking lot. Without proper ventilation system, these pollutants will accumulate and over time, will become dangerous to the users and workers of the car parks (Duci et. al., 2003; Bariyah, 2013). Low concentration of carbon monoxide, if exposed for a long period of time, may cause confusion, depression, memory loss, vomiting, nausea and many more (US EPA, 2009). In addition, carbon monoxide poisoning also may worsen one’s cardiovascular diseases (Anderson et. al., 1973). It is hard to identify carbon monoxide as it is a colourless, odourless and tasteless gas. Plus, it is highly toxic. Therefore, the danger of carbon monoxide poisoning in enclosed car parks exists. On the other hand, carbon dioxide is also released by motor vehicles. A greenhouse gas (GHG), carbon dioxide is capable of absorbing and emitting radiation within the thermal infrared range. This particular characteristic is suggested by the academic circle as the main culprit for the global warming problem. However, it is unclear the effect of carbon dioxide inside an enclosed parking lots. Thus, it is important for such investigation to be taken.

The effect of air quality inside an enclosed car parks to its occupants is not deeply investigated, in Malaysia particularly. There are several studies done in other countries such as France, Hong Kong and Greece. However, it is difficult to generalise these research to Malaysia’s condition as this country has difference in climate, number of vehicles, building designs and others. Additionally, government agencies do not have a particular law in ensuring the safety of parking lot users and workers under both Environment Quality Act (EQA) 1974 and Occupational Safety and Health Act

(OSHA) 1994. Therefore, a comprehensive study must be done to investigate the air quality inside enclosed car parks so the effect of pollution on human can be determined.

1.3 OBJECTIVES

The aim of this study is to investigate the quality of air inside an enclosed car park. In order to achieve the aim stated, the following objectives must be accomplished:-

i. Investigate the level of carbon monoxide and carbon dioxide inside the enclosed car park based on the number of vehicles using the car park.
ii. Analyse the concentration of carbon monoxide and carbon dioxide inside the car park by using time series model.
iii. Study the relationship between the concentration of carbon monoxide and carbon dioxide inside the enclosed car park with the temperature recorded inside the car park.
iv. Benchmark the findings with the Industry Code of Practice on Indoor Air Quality 2010.
v. Propose proper mitigation measures on reducing the concentration of pollutants.

1.4 SCOPE OF STUDY

The study of the air quality inside an enclosed car park will be based on the level of carbon monoxide and carbon dioxide inside the car park. The reason for choosing carbon monoxide and carbon dioxide as the indicator for air quality inside the car park is because of carbon monoxide is highly toxic to human health, while carbon dioxide is a major contributor for the increase of temperature. The study will be carried out at an enclosed underground parking lot in the Kuala Lumpur City Centre (KLCC) building. KLCC car park is chosen because KLCC is not only the headquarters and offices to many companies, it is also the home to one of the most popular shopping mall in Malaysia. Thus, the study can be related to the number of vehicles using the car park during weekdays and weekends. The car park will be monitored 24 hours for a duration of two weeks. This is to see the effects of certain timeframes towards the level of air quality inside the car park.

CHAPTER 2

LITERATURE REVIEW

2.1 AIR POLLUTION

Air pollution is the pollution of harmful substances into the atmosphere which can be dangerous to the environment and to human beings. In 2014, the World Health Organization (WHO) reported that air pollution had caused death to around 7 million people worldwide (WHO, 2014). Furthermore, indoor air quality and urban air pollution are recognised as among the worst toxic pollution problems in 2008, according to a report entitled World's Worst Polluted Places by Blacksmith Institute (Blacksmith Institute, 2008). There are many pollutants that are released to the atmosphere by various means. Among them are carbon monoxide (CO), nitrogen oxides (NO_x), sulphur oxides (SO_x), and volatile organic compounds (VOC), air particulates, ground level ozone (O_3), ammonia (NH_3), chlorofluorocarbons (CFC) and others. In Malaysia, the Department of Environment Malaysia (DOE) listed 5 major air pollutants which are CO, O_3, sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and air particulate with the diameter below 10 microns (PM_{10}) (Zawiyah, et al., 2009). These pollutants are the parameters which subsequently be used to calculate the air quality index (API).

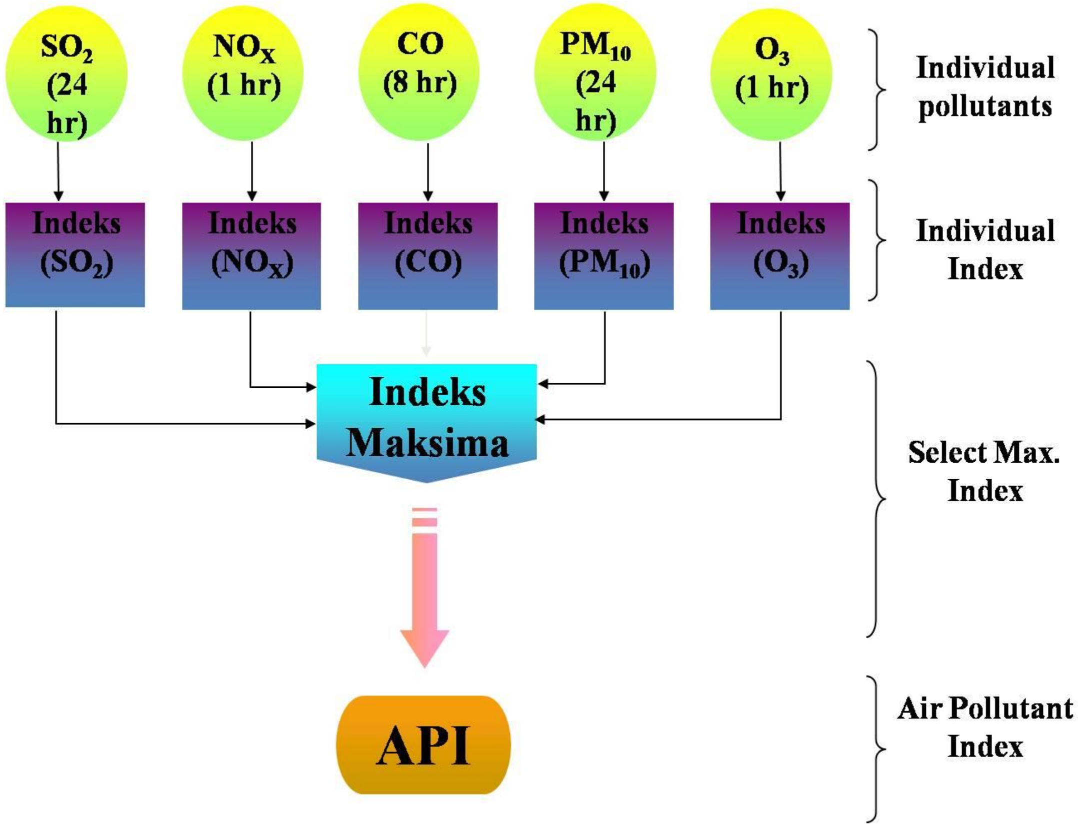

Figure 2.1: Calculation of API in Malaysia.

These pollutants can be generally divided into two types, primary pollutants and secondary pollutants (Holgate et al., 1999). Primary pollutants are pollutants that are directly released to the atmosphere. On the other hand, secondary pollutants are pollutants that are formed in the air as a result of chemical reaction with other pollutants and gases. However, there are certain pollutants that can be categorised both as primary and secondary pollutants.

Air pollution can come from various sources, either from man-made sources or natural sources. The combustion of fossil fuels are generally considered as the single most important source of air pollution (Holgate et al., 1999). Anthropogenic sources can further be divided into stationary sources, mobile sources, area sources, evaporative sources, controlled burns and waste disposal landfills (Beychok, 2011). An example of stationary sources of air pollution is the emission of pollutants to the air at industrial factories. Mobile sources are usually associated to the emission from motor vehicles.

Area sources are usually related with the emission of methane from livestock operations. Natural sources, on the other hand, are air pollution sources that are not of the result from human activities. Volcano eruptions which releases SO_2, CO_2, air particulates and other air pollutants can be considered as natural sources of air pollution.

Air pollution has caused death to almost 7 million people worldwide in 2012, according to a report released by WHO (WHO, 2014). Air pollution not also present health risks to human beings, but also can be dangerous to other living organisms and to the natural and build environment. According to a report by European Commission, the life expectancy across the European Union can decreases up to nine months due to air pollution ("Air pollution causes early deaths", 2005). Among diseases that are caused by air pollution are ischaemic heart diseases, stroke, chronic obstructive pulmonary disease (COPD), lung cancer, acute lower respiratory infection for children and others (WHO, 2014).

Many efforts have been taken to control the emission of pollutants into the atmosphere domestically and globally. Kyoto Protocol, for example, is an internationally recognised treaty signed by many countries to curb the excessive emission of greenhouse gases (GHG) into the air. In Malaysia, the government introduced the Malaysia Environmental Quality Act 1974 (EQA) as the primary regulations for pollution control in Malaysia. EQA 1974 is an act relating to the prevention, abatement, control of pollution and enhancement of environment (Environmental Quality Act, 1974). Other than that, WHO also offers its own guidelines for air pollution. Other than using laws to reduce air pollution, many innovations have been invented to help improving the quality of atmosphere.

2.2 AIR POLLUTION IN ENCLOSED CAR PARK

Motor vehicles are the primary mode of transport, especially in Malaysia. In 2012, the Malaysia Department of Statistics reported that 22,702,221 motor vehicles were registered in Malaysia (Department of Statistics, 2013). Plus, the report given by the

World Bank stated that the number of motor vehicles in Malaysia per 1000 persons is 377.7 in 2011. To compare, Indonesia has 69.17 motor vehicles per 1000 persons while Singapore has 151.07 motor vehicles per 1000 persons (World Bank, 2014). As the number of motor vehicles in Malaysia increases, so does the demand for parking spaces, especially in the urban areas. The number of vehicles registered in Kuala Lumpur in 2011 is 4,963,646 while the total area of Kuala Lumpur is 243 square kilometres (JPJ, 2012). Therefore, the number of vehicles per square kilometre in Kuala Lumpur is 20426.53. However, it is difficult to provide a huge area for parking spaces in urban area because it is usually will be used for residential, commercial and industrial zones. Thus, parking spaces are within the apartments or offices.

Air pollution in enclosed car park are mainly related with the emission of motor vehicles inside the car park. These emissions are the result of fossil fuel combustion inside the vehicles. There are two types of fuel combustion, which are complete combustion and incomplete combustion. Complete combustion is the burning of hydrocarbon in an excess of air at stoichiometric condition, in which the product of the combustion will be CO_2 and water vapour (H_2O) only (Ronney, n.d.). However, complete combustion can only be achieved in the ideal condition in which sufficient oxygen is supplied and enough time is given for the fuel to be burn completely.

$$Fuel + O_2 \longrightarrow CO_2 + H_2O$$

Figure 2.2: Complete combustion of hydrocarbon

On the other hand, incomplete combustion happens when there are inadequate supply of oxygen during combustion. The product from incomplete combustion of fuel are usually CO2, CO, H2O and unburned hydrocarbons (UHC). If nitrogen is present during the combustion, NOX also will be produced (Ronney, n.d.). Incomplete combustion is always happening in vehicle engines as the time to burn the fuel is limited. Furthermore, due to different usage of fuel during different mode of driving such as idling, accelerating, cruising, decelerating and stopping, incomplete combustion will continuously occur inside the engine.

$$Fuel + O_2 \longrightarrow H_2O + CO_2 + CO + UHC$$

Figure 2.3: Incomplete combustion of hydrocarbon

The pollutants associated with the emission of motor vehicles inside the car park are CO, CO2, NOX, SOX, air particulates, UHCs, VOCs and others. Due to the high traffic density, the human exposure to the harmful substances is expected to increase (Farhan et. al., 2003). In a report released by French Agency for Food, Environmental and Occupational Health & Safety in 2007, due to the quality of air inside indoor car parks, the health risks present cannot be neglected (ANSES, 2013). A study in Hong Kong revealed that the level of CO and PM_{10} of indoor car parks are relatively higher compared to outdoor car parks (Wong Y.C et. al., 2002). Plus, high level of CO released by the vehicles is detected inside enclosed car parks due to improper or malfunctioning ventilation (Duci et. al., 2003; Bariyah, 2013). Thus, it is believed that prolonged exposure to the pollutants can be dangerous to the occupants of the car park, especially to the workers.

2.3 CARBON MONOXIDE (CO)

CO is the product from the incomplete combustion of hydrocarbon, usually from the vehicle engines. According to a study, practically 70 % of carbon monoxide are released from motor vehicles (Farhan et. al., 2003; Kiely, 1997). In United States, 60 % of carbon monoxide emission came from mobile vehicles in 2011 (US EPA, 2014). In urban area, where the traffic density is high, human exposure to carbon monoxide is suggested to be increased (Farhan et. al., 2003). Referring to the standard given United States Department of Labour, the Occupational Safety and Health Association (OSHA) permissible exposure limit (PEL) is 55 mg/m^3 in eight hours (USA Department of Labour, n.d.). In Malaysia, the concentration of CO allowed indoor is below 10 ppm TWA, as instructed by the Department of Occupational Safety and Health (DOSH) Malaysia (Industry Code of Practice on Indoor Air Quality, 2010).

CO is a colourless, odourless and tasteless gas, yet highly toxic. Because of its characteristics, it is hard to detect CO (Prockop et. al., 2007). CO is the most common type of fatal air poisoning in many countries (Omaye, 2002). CO poisoning is hardly identifiable because its clinical symptoms are nonspecific (Prockop et. al., 2007). CO is dangerous to human because when inhaled, CO will combine with haemoglobin in the red blood cells to form carboxyhaemoglobin (COHb). This will reduce the level of oxygen (O_2) delivered throughout the body. The affinity of haemoglobin towards CO is 210 times higher than O_2 (Prockop et. al., 2007). The brain and heart can be severely affected after exposure of CO with COHb surpassed 20 % (Prockop et. al., 2007). Among the symptoms of CO poisoning are headache, dizziness, vomiting, nausea and fatigue. These symptoms are alike with viral flu symptoms, causing misunderstand to the victim (Khandelwal et. al., 2007). At CO concentration of 1600 ppm, CO poisoning can be fatal to the victim in less than 2 hours (Goldstein, 2008).

2.4 CARBON DIOXIDE (CO_2)

CO_2 is important in the environment. It is directly used by the plants for photosynthesis which subsequently produce O_2, which in turn essential for human beings. CO_2 is one of the greenhouse gases (GHG). GHG are gases that can absorb and emits radiation within the thermal infrared range. In 2012, the concentration of CO_2 in the atmosphere is 392.6 ppm (Blasing, 2014). In 2002, CO_2 amounted up to 75.1 % of the total GHG in Malaysia (“Second National Communication to the UNFCCC”, n.d.). From the data from the Second National Communication to the UNFCCC, 21 % of CO_2 come from transportation (“Second National Communication to the UNFCCC”, n. d.). In United States, the OSHA PEL is 5000 ppm TWA (USA Department of Labour, n. d.). For Malaysia, the ceiling limit for CO_2 concentration indoor is 1000 ppm, which also indicate the inadequacy of ventilation (Industry Code of Practice on Indoor Air Quality, 2010).

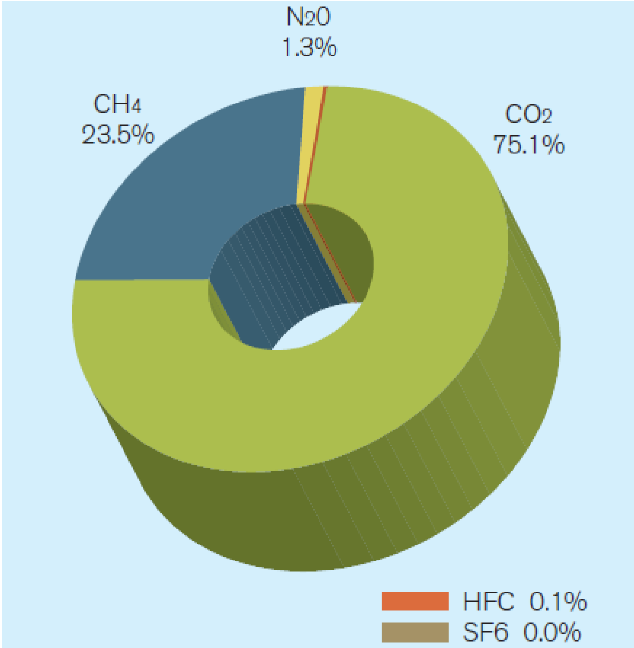

Figure 2.4: Percentage emissions according to GHG in Malaysia year 2000

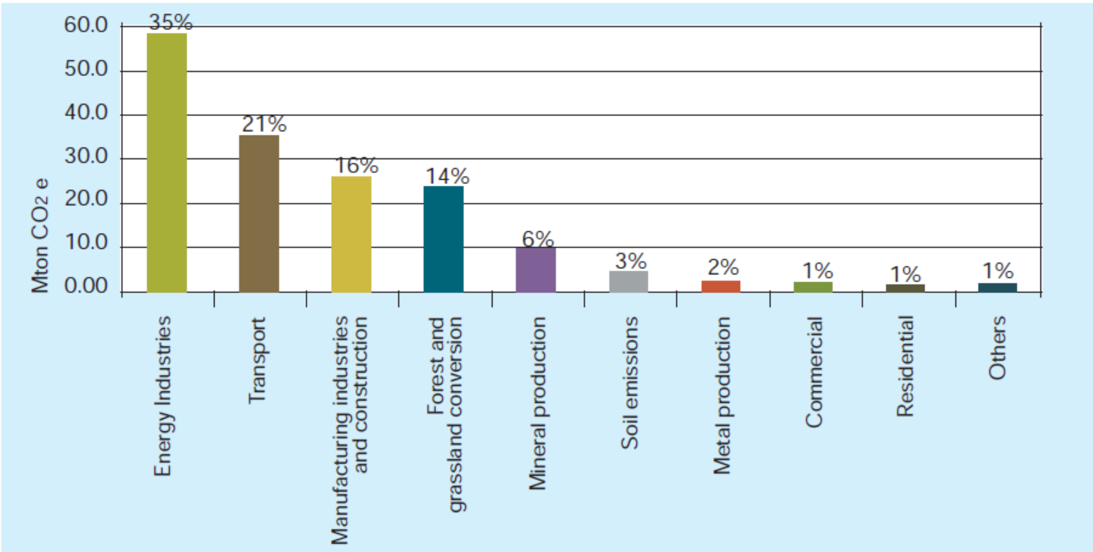

Figure 2.5: Major sources of CO_2 emissions in Malaysia year 2000

CO_2 poisoning is known as hypercapnia. This happens when there is an elevated level of CO_2 in the blood. Early symptoms of hypercapnia are flushed skin, muscle twitches, possible increase in blood pressure and others. In the cases of severe CO_2 poisoning, the victim may experience panic, hyperventilation, convulsion, unconsciousness and eventually death (Lambertsen, 1971). The effects of CO_2 on human health varies with the duration and the concentration of CO_2. Prolonged exposure to low level CO_2 may not be life threatening, but it may have health consequences on healthy individuals (Rice, 2004).

CO_2 is widely associated with the global greenhouse effect. CO_2 accounts up to 20 % to the world's greenhouse effect (Schmidt et. al., 2010). Greenhouse effect is essential in regulating the Earth's temperature. Naturally, CO_2 in the atmosphere is continuously exchanged with land and water as it is produced and absorbed by microorganisms, animals and plants (USA EPA, 2012). This is called carbon cycle. However, the increase of CO_2 concentration in the atmosphere due to human activities has caused the temperature to increase annually, a process known as global warming.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter will be explaining about the research flow, scope of research, type of analysis and the equipment used to conduct the study. The observation and results then will be carefully analysed to achieve the main objective. The main objective of the research is to investigate the air quality inside an enclosed car park.

To investigate the air quality inside the car park, the level of carbon monoxide (CO) and carbon dioxide (CO_2) will be measured. From there, the data collected will be analysed by time series model analysis. After that, the analysed data will be further studied to investigate the relationship between concentration of CO and CO_2 inside the enclosed car park with the number of vehicles entering the car park.

3.2 SITE DESCRIPTION

The investigation site is located within the most iconic location in Kuala Lumpur. The car park chosen for this research is situated inside Kuala Lumpur City Centre (KLCC) which consists of Petronas Twin Towers, the headquarters of the national oil company, and Suria KLCC, one of the most popular shopping complexes in Klang Valley. KLCC itself is located at the heart of Kuala Lumpur. The coordinate for the site is 3.15785 °N, 101.71165 °E.

Petronas Twin Towers is currently the tallest twin towers in the world. Standing at 451.9 m high, Petronas Twin Towers, the highest building in the world from 1998 to 2004, has 88 levels for each tower. As the most iconic building in Malaysia, Petronas Twin Towers is one of the main tourist attraction in Kuala Lumpur.

Suria KLCC is a shopping complex that is located below the towers. Suria KLCC houses many popular and high-end retail brands and world class attraction such as Dewan Filharmonik, Petrosains and Petronas Arts Gallery. With easy access to Light Rapid Transit (LRT) via KLCC station, the six-floors shopping complex is serves not only to Malaysians, but to the visitors alike.

Figure 3.1: Kuala Lumpur City Centre (KLCC) and its surroundings.

Kuala Lumpur is located in the west coast of peninsular Malaysia. Enclosed within Selangor, Kuala Lumpur is the capital of Malaysia. The total population of Kuala Lumpur, according to the 2010 Malaysian Census, is 1,627,172 (Department of Statistics Malaysia, 2010).

Kuala Lumpur has a tropical rainforest climate. As Kuala Lumpur is located near to the earth’s equator, the temperature recorded varies a little every year. The maximum temperature logged usually fluctuates between 32 °C to 34 °C, while the minimum temperature are between 23 °C to 25 ° (World Meteorological Organization).

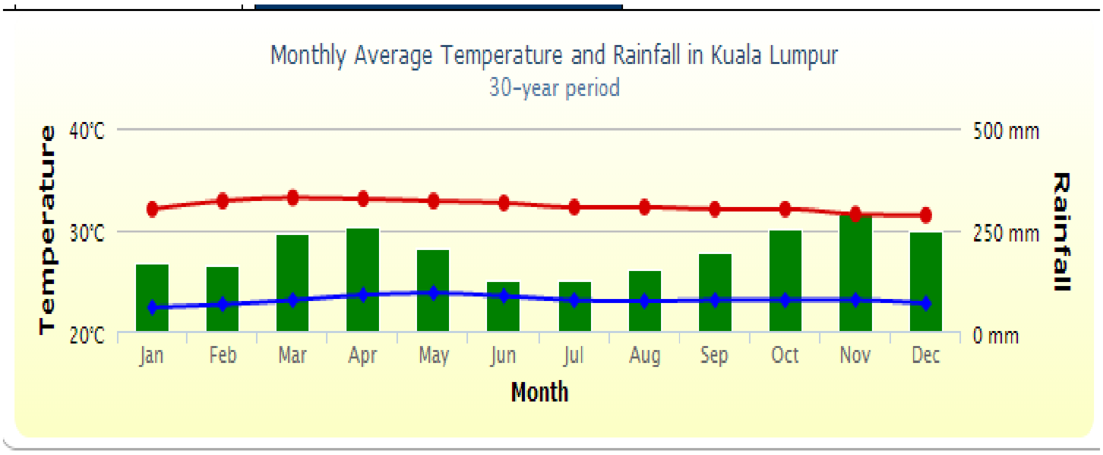

Figure 3.2: Average temperature (°C) for Kuala Lumpur (World Meteorological Organization)

Kuala Lumpur receives a great amount of precipitation throughout the year. The average rainfall monthly in Kuala Lumpur always exceeds 100 mm, even during the dry period between May and July. Weather in Kuala Lumpur is hot and humid. The relative humidity in Kuala Lumpur during the day is between 95 % and 97 %, while the relative humidity during the night is between 58 % and 66 % (BBC, 2014).

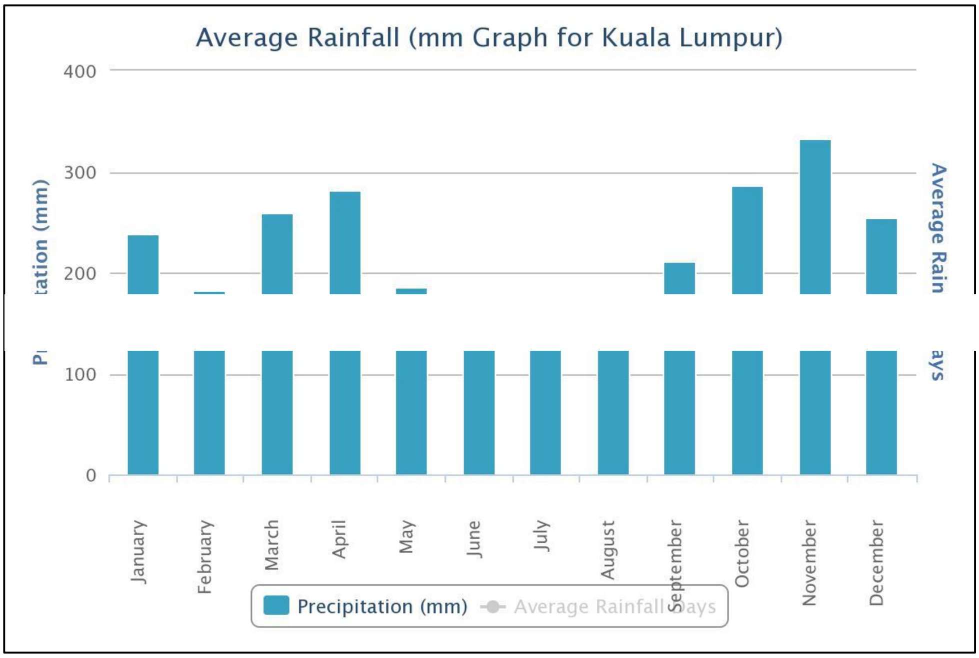

Figure 3.3: Average rainfall (mm) for Kuala Lumpur (BBC)

3.3 DATA SAMPLING

The data that are collected are the concentration of CO_2 and CO. The sampling process was taken from 9th June 2014 to 22nd June 2014, an investigation period of two weeks. The data was taken continuously for two weeks in order to record the data during the weekdays and weekends.

3.4 EQUIPMENT

The equipment used in this study is Aeroqual AQM60 Environmental Station (AQM60). AQM60, according to its manual, can be defined as a custom-built ambient air quality instrument (AQM60, 2013). AQM60 is capable to measure common air pollutants such as CO, O_3, NO_X, SO_X, CO_2, and particulate matter (PM_{10} and $PM_{2.5}$). Other than that, AQM60 also can measure meteorological data such as temperature, humidity, wind speed and direction (AQM, 2013). One AQM60 station is placed at B1 level of the KLCC underground car park, which is located near to the KLCC parking management office.

Figure 3.4: Aeroqual AQM60 Environmental Station (AQM60 User Guide)

The dimension of AQM60 is 900 x 555 x 400 mm, while it weighs approximately 50 to 60 kg. There are many different modules inside AQM60 that serves different purposes. Among the modules inside AQM60 are control module, power module, thermal management system, gas treatment module, gas sensor modules, a relative humidity/temperature (RH/T) sensor and associated cabling and plumbing (AQM60 user guide version 7.0, 2013).

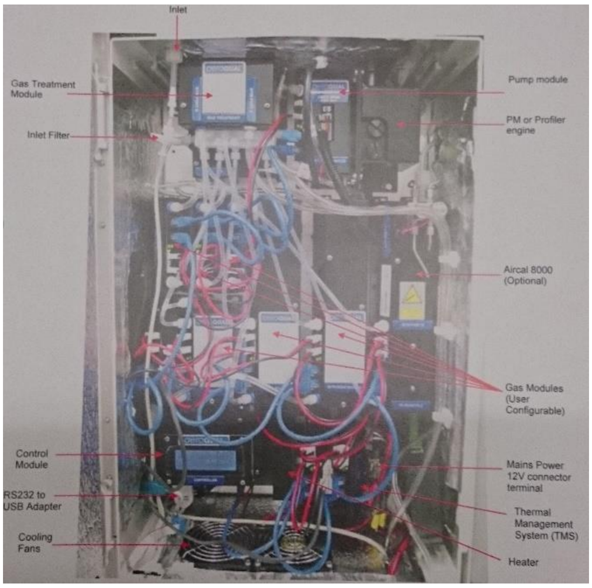

Figure 3.5: Modules inside AQM60 (AQM60 User Guide)

Figure 3.6: the dimension of AQM60 (AQM60 User Guide)

In AQM60, the gas sensor modules are the modules which detect the air pollutants. The minimum detection limit of pollutants varies with the types of pollutants detected. Since the study focuses on CO and CO_2, more details on these gases are given. The range of CO concentration level that can be detected by AQM60 is between 0 to 25 ppm. On the other hand, the range of concentration level of CO_2 that can be detected by AQM60 is between 0 to 2000 ppm. AQM60 can detect the minimum concentration level CO at less than 0.04 ppm while the minimum concentration level of CO_2 that can be detected by AQM60 is less than 10 ppm.

3.5 DATA ANALYSIS

The data collected from AQM60 will be then analysed by using time series analysis. Time series data, by definition, is a sequence of data points, measured typically at successive points in time spaced at uniform time intervals. The time series analysis is used in this study so that the fluctuations of CO and CO_2 can be clearly examined. Thus, the relationship between the concentration of CO and CO_2 with the temperature inside the car park can be observed.

3.6 PROJECT MILESTONES

In order to complete the study, a Gantt chart and milestones has been followed, according to the guidelines given. The following are the key milestones throughout Final Year Project II.

Key milestone	Week
Submission of progress report	7
Pre-SEDEX	10
Submission of draft final report	11
Submission of dissertation (soft bound)	12
Submission of technical paper	12
Viva	13
Submission of project dissertation (hard bound)	15

Table 3.1: Key milestones for FYP II

The following are Gantt chart for FYP II as provided by the guidelines.

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Project Work Continues	■	■	■	■	■	■	■								
2	Submission of Progress Report							●								
3	Project Work Continues								■	■	■	■	■			
4	Pre-SEDEX										●					
5	Submission of Draft Final Report											●				
6	Submission of Dissertation (soft bound)												●			
7	Submission of Technical Paper												●			
8	Viva													●		
9	Submission of Project Dissertation (Hard Bound)															●

Figure 3.7: FYP II Gantt chart

CHAPTER 4
RESULT AND DISCUSSION

4.1 INTRODUCTION

The concentration of carbon monoxide (CO) and carbon dioxide (CO_2) inside the Kuala Lumpur City Centre (KLCC) underground car park was taken for 14 days from 9th June 2014 until 22nd June 2014. The data is collected 24 hours a day. However, the data presented in this chapter will only shows the data from 8 am until 5 pm. The Aeroqual AQM60 environmental station was placed at level P2, where the parking management office is located.

The data was recorded every 30 seconds. From there, the data collected will be averaged for every 30 minutes before the corresponding graphs were plotted. Among the 14 days of data collection, 5 days of critical data collection will be discussed, 3 weekdays and 2 weekends. The discussion will be done according to the objectives which are to investigate the level of CO and CO_2 inside the enclosed car park, to analyse the concentration of CO and CO_2 using basic time series model, to study the relationship between the level of CO and CO_2 with the temperature inside the car park, to benchmark the findings with the Industry Code of Practice on Indoor Air Quality 2010 by Department of Occupational Safety and Health (DOSH) Malaysia, and to propose mitigation measures inside the enclosed car park.

4.2 CONCENTRATION OF CARBON MONOXIDE ON WEEKDAYS

The data used for discussion for weekdays are from Friday, Monday and Tuesday of 13th, 16th and 17th June 2014 respectively. Figure 4.1 below presented the concentration level of CO on Friday, 13th June. The concentration of CO at 0830 is 5.79 ppm, and continues to decrease to its lowest point of the day to 4.57 ppm at 1000. However, the concentration of CO drastically to increase at 1030 to 6.8 ppm and continue increasing to 9.59 at 1300, with a slight decrease at 1130. The data once again significantly fell at 1330 to 6.35 ppm. Nevertheless, the CO concentration continued to increase back until its highest recorded concentration of 9.97 ppm at 1630. The last recorded concentration of CO of the day is 8.86 ppm at 1700. In terms of the temperature, there were no noteworthy fluctuations throughout the discussed period, with the lowest temperature of 30.1 °C at 0800 and the highest temperature of 34.5 °C at 1330.

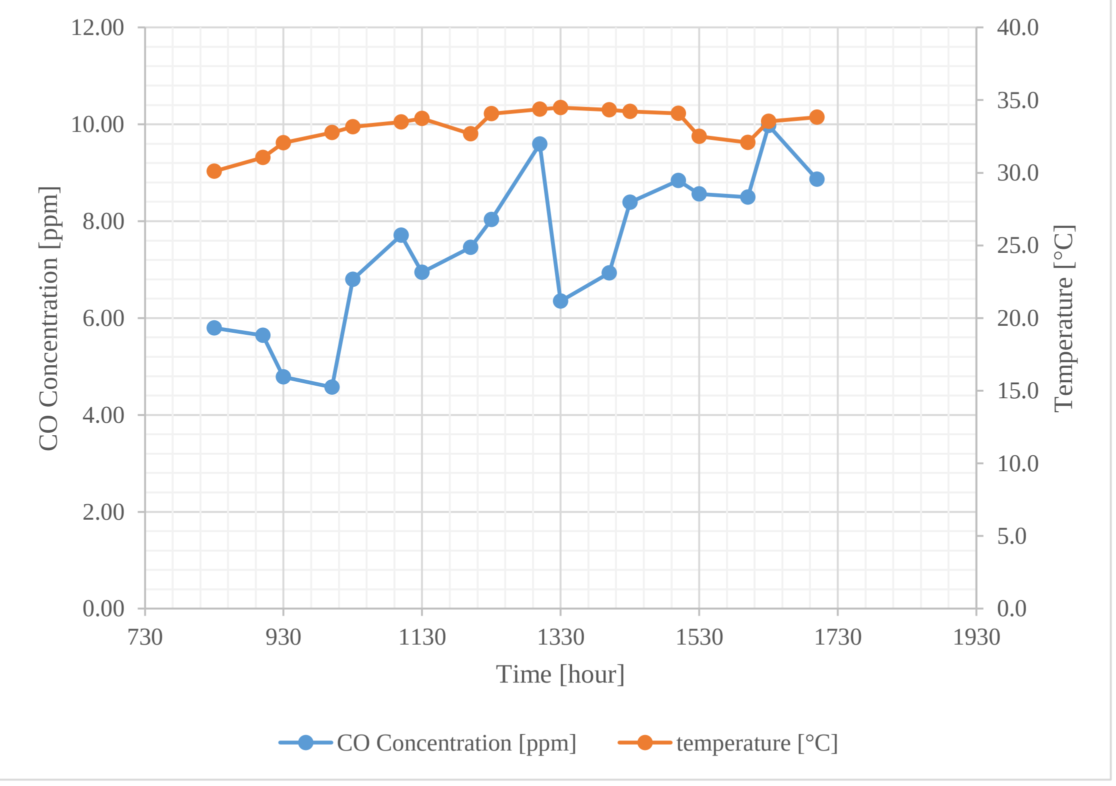

Figure 4.1: The concentration of carbon monoxide (CO) and the temperature versus time on 13th June 2014

Figure 4.2 portrayed the concentration of CO on Monday, 16th June 2014. The data collected throughout this day was the most critical compared with the data collected from 13th June and 17th June. The concentration of CO at 0830 was 8.6 ppm and increases to 10.05 ppm at 0900. However, from that point, data shows a decreasing trend until the lowest concentration of CO of the day, 5.32 ppm at 1030. Then, the concentration increased with a slight decrease at 1230, until its highest point of the day of 15.75 ppm at 1400. From there, the concentration was decreased until the last recorded data of 11.27 ppm. Similar with the temperature on 13th June, the temperature on 16th June also did not show any noticeable changes, as the lowest and highest temperature recorded were 30.12 °C and 34.69 °C respectively.

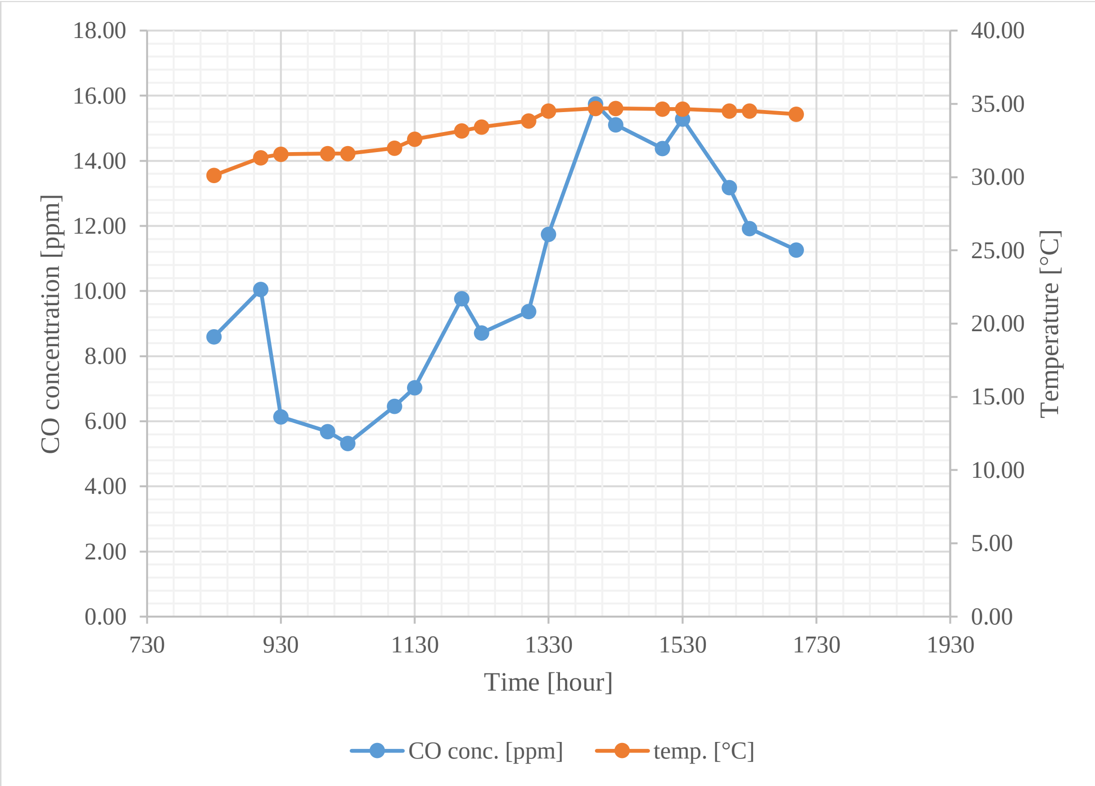

Figure 4.2: The concentration of carbon monoxide (CO) and the temperature versus the time on 16th June 2014

The concentration of CO on Tuesday, 17th June 2014, was presented in the figure 4.3 below. From the figure, the concentration of CO recorded at 0830 was 5.79 ppm and decreased to its lowest concentration of the day of 3.28 ppm at 0930. Then, it showed an increasing trend until its highest recorded concentration of 16.60 ppm at 1600. The last recorded concentration of CO at 1700 was 11.62 ppm. The temperature recorded throughout this day also showed no significant changes, as the temperature fluctuates between 29.96 °C at its lowest and 34.68 °C at its highest.

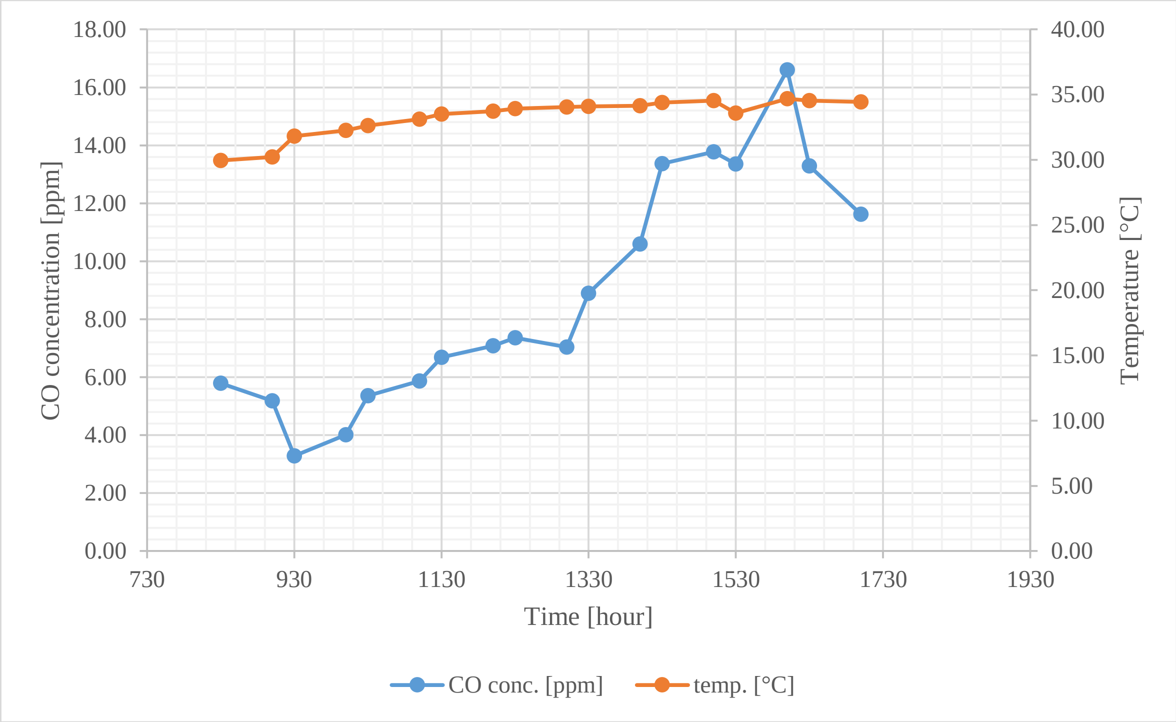

Figure 4.3: The concentration of carbon monoxide (CO) and the temperature versus the time on 17th June 2014

4.3 CONCENTRATION OF CARBON MONOXIDE ON WEEKENDS

The concentration of CO during weekends did not have significant difference with the concentration of CO recorded on weekdays. Figure 4.4 presented the concentration of CO recorded on Saturday, 14th June 2014. The concentration of CO at 0830 was 3.50 ppm and continued to increase steadily to 14.79 ppm at 1330. However, it decreased to 10.28 ppm at 1430, before increased to its highest concentration of the day, 16.06 ppm at 1500. Then, the CO concentration showed a decreasing trend until 11.67 ppm at 1600. The last recorded data of CO concentration at 1700 was 14.29 ppm. Temperature wise, there were minimal fluctuations of temperature throughout the day, with the lowest recorded temperature of the day was 30.22 °C, while the highest recorded temperature was 34.83 °C.

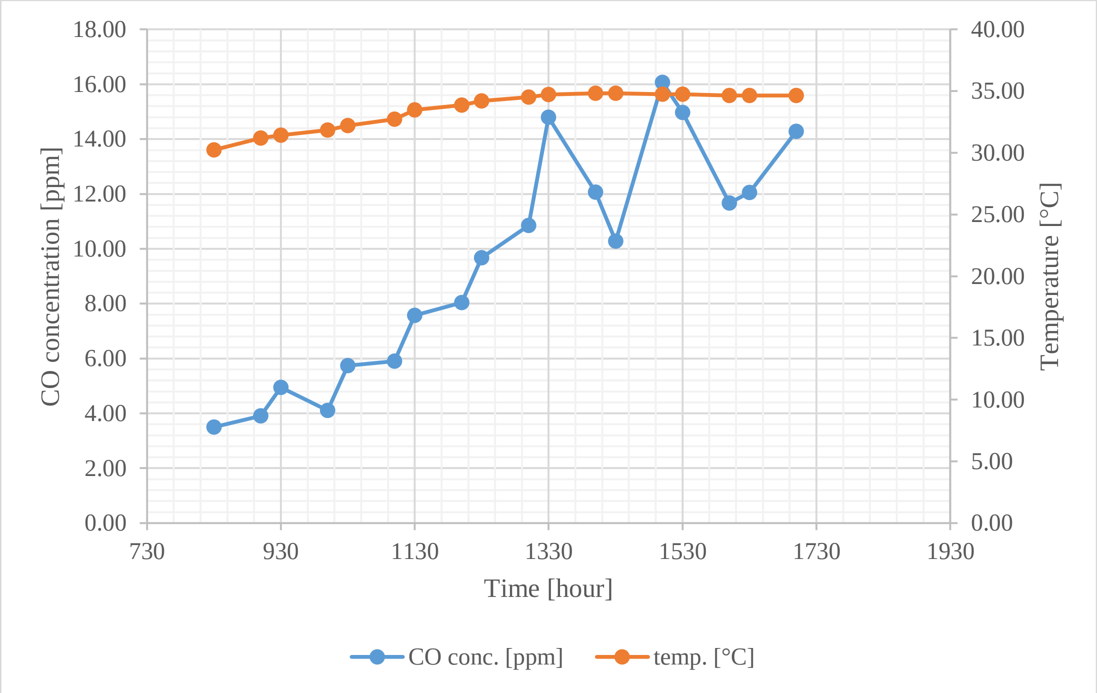

Figure 4.4: The concentration of carbon monoxide (CO) and the temperature versus time on 14th June 2014

The data collected throughout Sunday of 15th June 2014 was relatively higher compared to the data from the before. Thus, the CO concentration on this day is regarded as the critical data for weekends. Figure 4.5 showed the visible trends recorded on that day. The first recorded level of CO at 0830 was 5.28 ppm, before it plunged to its lowest level of 3.42 ppm at 0900. The next few half hourly data showed the CO concentration fluctuated between 3.88 ppm and 5.09 ppm before significantly increased to 8.61 ppm at 1230. Then, the level of CO increased to 12.00 ppm at 1430, decreased to 8.37 ppm at 1500 and increased to its highest level of the day of 13.65 ppm at 1600. The level of CO at the end recorded period, 1700, was 8.37 ppm.

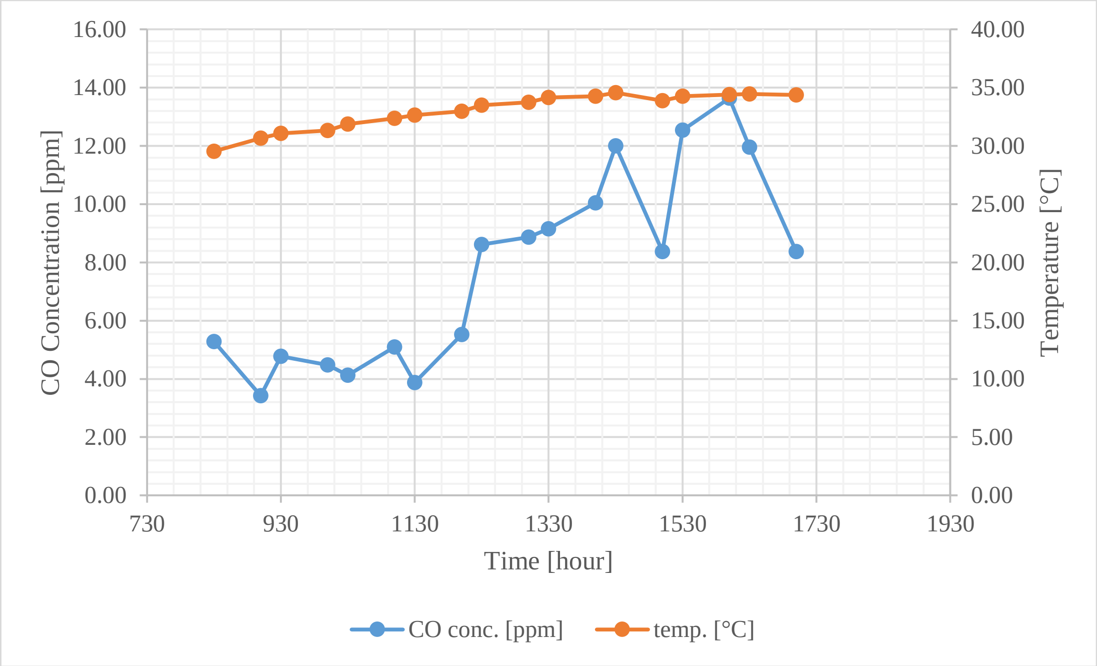

Figure 4.5: The concentration of carbon monoxide (CO) and the temperature versus the time on 15th June 2014

4.4 CONCENTRATION OF CARBON DIOXIDE ON WEEKDAYS

The level of CO_2 recorded throughout the study is significantly higher to the concentration of CO. figure 4.6 shows the level of CO_2 on Friday, 13th June 2014. The concentration of CO_2 at 0830 was 557.28 ppm and it decreased to the lowest point of 525.40 ppm at 0930. Then, it increased to 707.00 ppm at 1030 before decreased to 619.50 ppm at 1130. The concentration of CO_2 then increased to the highest recorded point of 774.20 at 1300, and fluctuated between 651.85 ppm and 717.90 ppm afterwards. The last recorded data of the day was 678.38 ppm at 1700. The temperature recorded on this day varied between 30.1 °C and 34.5 °C.

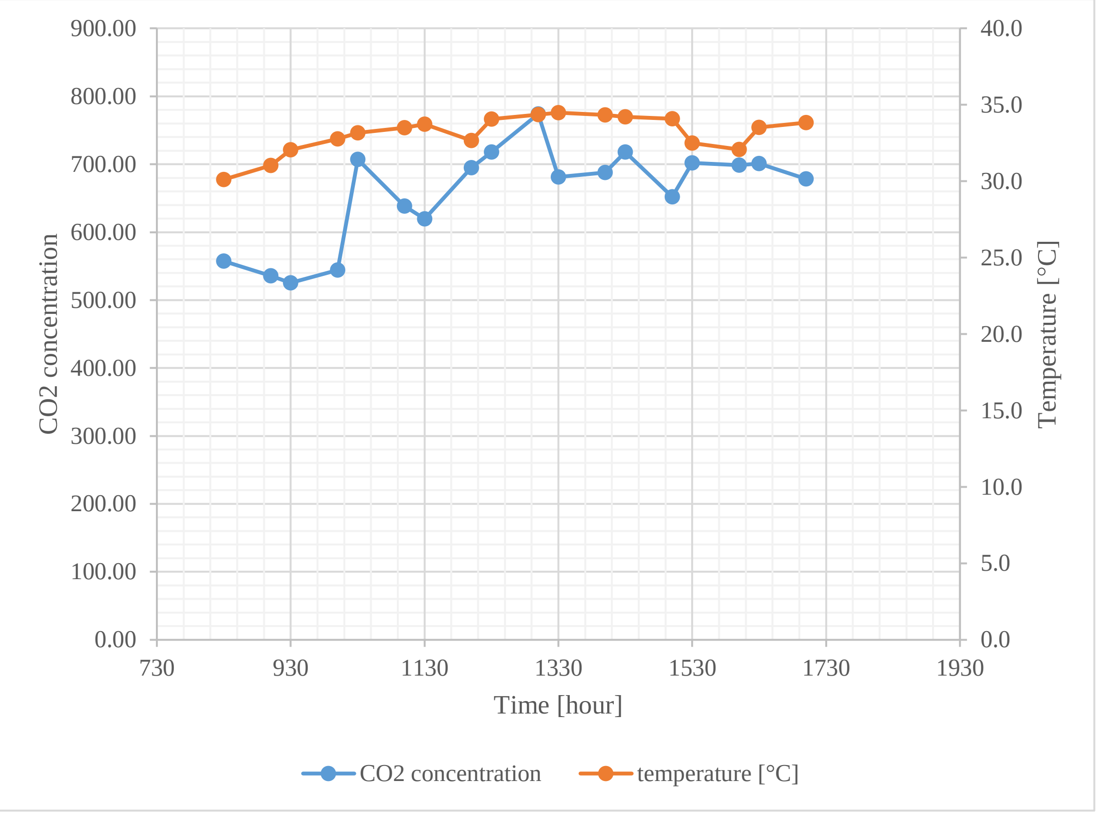

Figure 4.6: the concentration of carbon dioxide (CO_2) and the temperature versus the time on 13th June 2014

Figure 4.7 showed the concentrations of CO_2 on Monday, 16th June 2014. Similar with the data collected for CO, the data collected on this day comparatively critical for discussion compared to the data from 13th June and 17th June. The level of CO_2 at 0830 was 681.79 ppm and it decreased to the lowest recorded level of CO_2 of 572.86 ppm at 1030. Onwards, the level of CO_2 increased until its highest concentration of 1000.37 ppm at 1400. Then, the concentration decreased until the final recorded data at 1700 of 809.76 ppm. In term of the temperature, the lowest recorded temperature was 30.12 °C while the highest temperature was 34.69 °C.

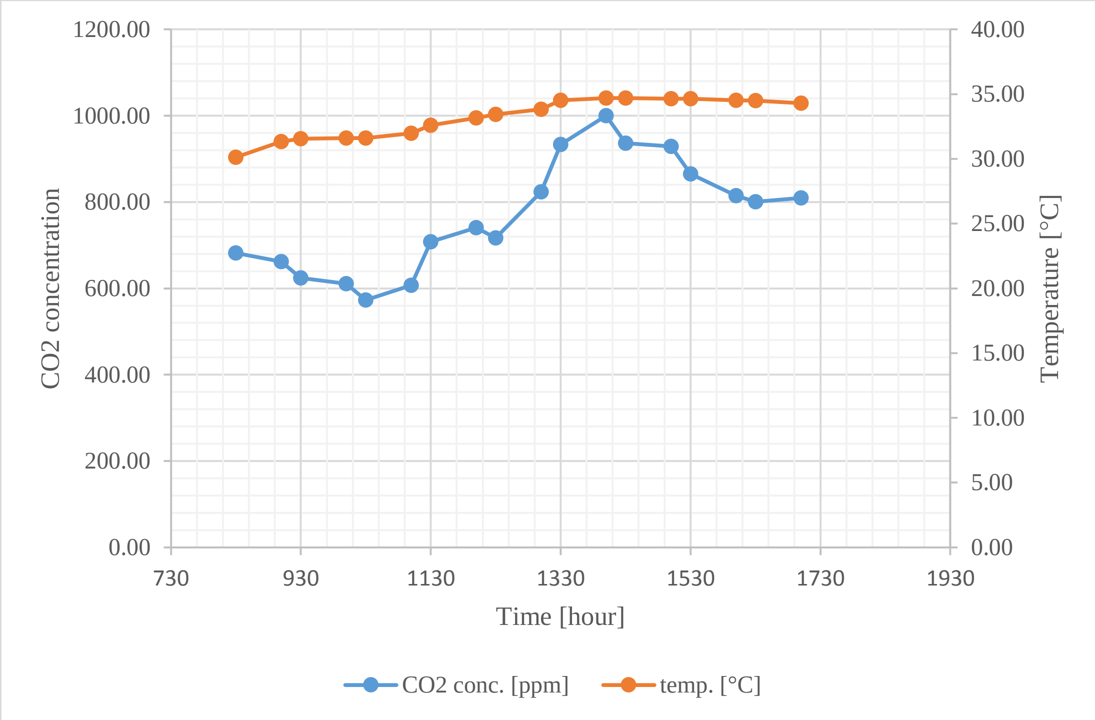

Figure 4.7: The concentration of carbon dioxide (CO_2) and the temperature versus the time on 16th June 2014

Figure 4.8 below portrayed the concentration of CO_2 recorded on Tuesday, 17th June 2014. The relatively similar trend between the concentration of CO_2 on this day and the concentration of CO_2 on the day before can be seen. The level of CO_2 at 0830 was 557.28 ppm before it decreased to the lowest point of the day of 493.86 ppm at 0930. Afterwards, the concentration of CO_2 inside the car park gradually increased to its highest level of 943.74 ppm at 1530. Then, it decreased until at 1700, the recorded concentration of CO_2 was 789.37 ppm. The temperature logged on this day also did not showed any drastic fluctuations as the recorded temperature varied between 29.96 °C and 34.86 °C.

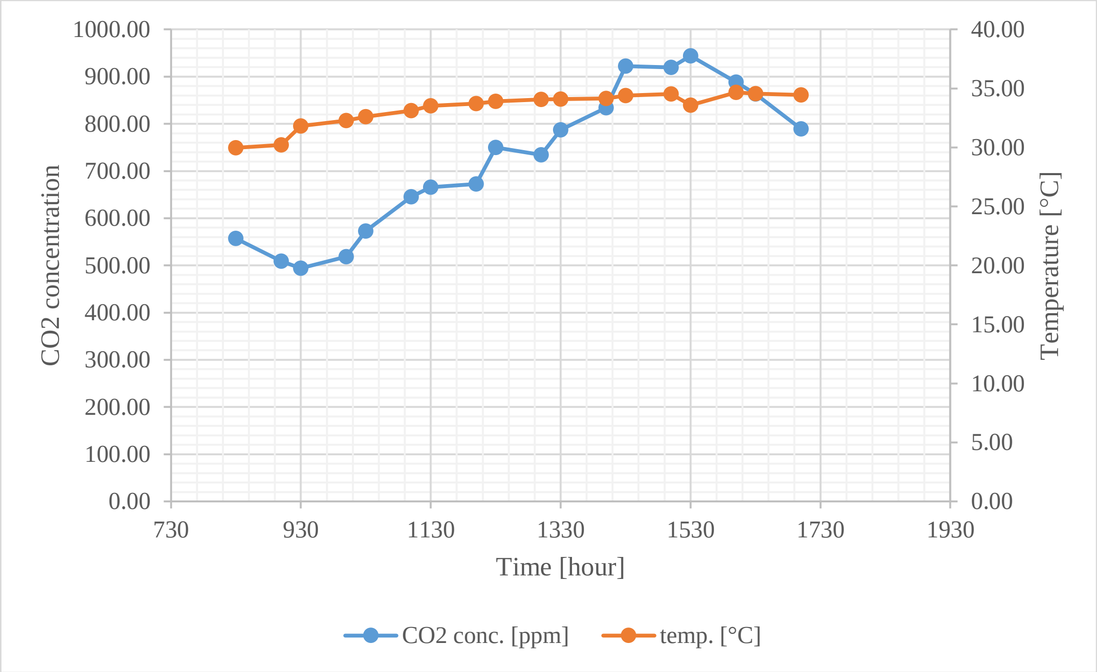

Figure 4.8: The concentration of carbon dioxide (CO_2) and the temperature versus the time on 17th June 2014

4.5 CONCENTRATION OF CARBON DIOXIDE ON WEEKENDS

Figure 4.9 displayed the concentration of CO_2 on Saturday, 14th June 2014. The concentration of CO_2 recorded at 0830 was 485.70 ppm and it increased progressively throughout the day up to the highest recorded level of 1006.64 ppm at 1500. The CO_2 concentration decreased to 881.70 ppm 1630, and the level of CO_2 recorded at 1700 was 953.14 ppm. The temperature logged on this day showed insignificant variations with the temperature fluctuated between 30.22 °C and 34.82 °C.

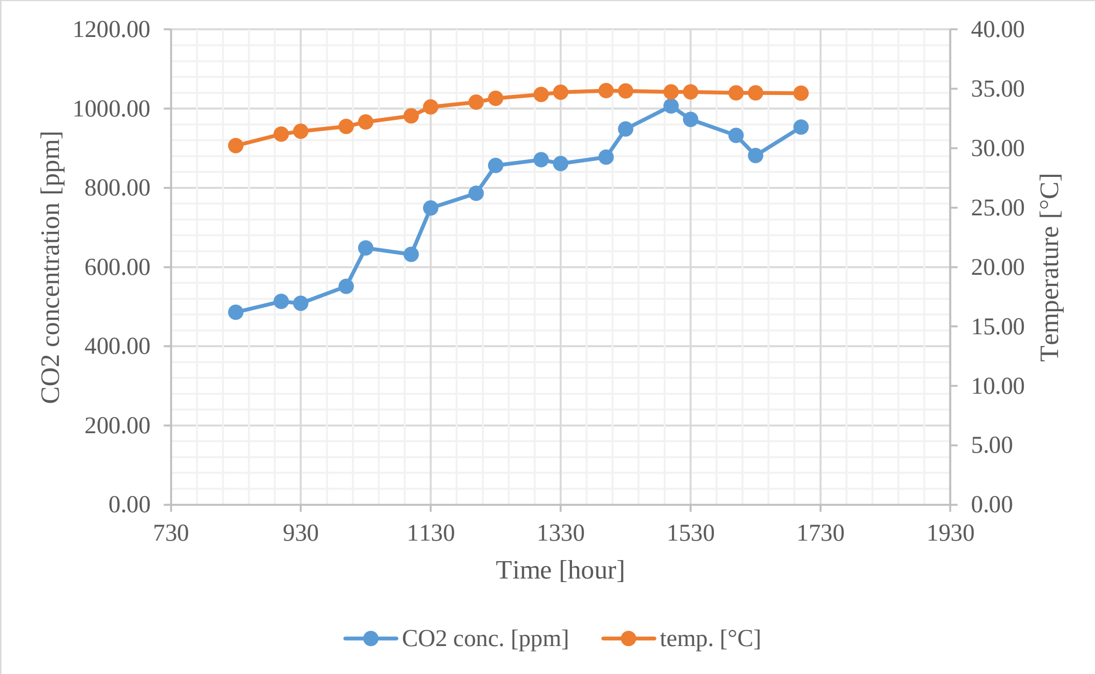

Figure 4.9: The concentration of carbon dioxide (CO_2) and the temperature versus time on 14th June 2014

The concentration of CO_2 on Sunday, 15th June 2014, can be seen in figure 4.10. The data recorded is more critical compared to the data collected on 14th June. The concentration of CO_2 at 0830 was 504.36 ppm, then the CO_2 level decreased to the lowest data recorded of 459.08 ppm at 0900. Then, the level of CO_2 displayed an increasing trend until it peaked at 1430, with the CO_2 level recorded of 951.30 ppm. Then, the CO_2 level fluctuated between 724.95 ppm and 905.53 ppm, and at the end of the recorded period at 1700, the level of CO_2 was 664.03 ppm. The temperature on this day did not varied significantly, as it fluctuated between 29.54 °C and 34.57 °C.

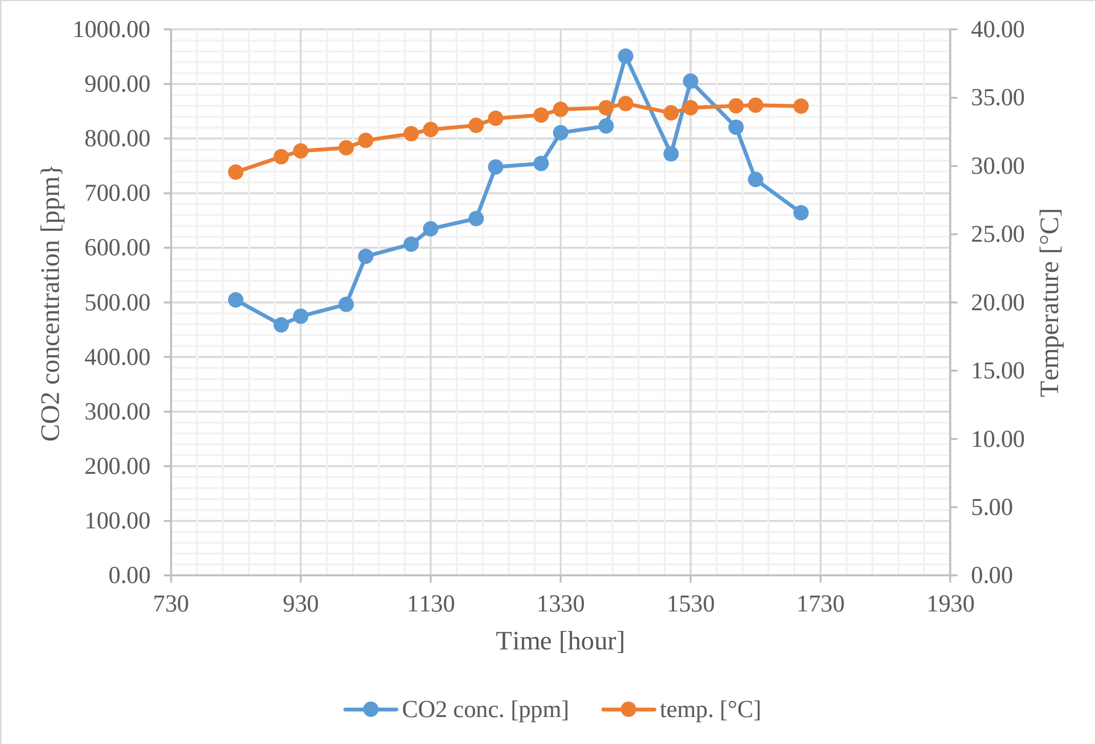

Figure 4.10: The concentration of carbon dioxide (CO_2) and the temperature versus the time on 15th June 2014

4.6 DISCUSSION

In this section, a comparative discussion will be made between the concentration of CO and CO_2 on weekdays and the concentrations of CO and CO_2 on weekends. In the previous discussion, the data from 16th June will represent the data for weekdays while the data from 15th June will represent the weekend's data. Then, these data will be benchmarked with limit stipulated by the Department of Occupational Safety and Health (DOSH) Malaysia in its Industry Code of Practice on Indoor Air Quality 2010 (COPIAQ). As specified by the code of practice, the acceptable limit for the indoor concentration of CO is 10.0 ppm for 8 hours while the ceiling limit for the indoor concentration of CO_2 is 1000 ppm. When the concentration of CO_2 surpass the ceiling limit, this indicates inadequate ventilation.

Indoor Air Contaminants	Acceptable limits		
	ppm	mg/m³	cfu/m³
<u>Chemical contaminants</u>			
(a) Carbon monoxide	10	-	-
(b) Formaldehyde	0.1	-	-
(c) Ozone	0.05	-	-
(d) Respirable particulates	-	0.15	-
(e) Total volatile organic compounds (TVOC)	3	-	-
<u>Biological contaminants</u>			
(a) Total bacterial counts	-	-	500*
(b) Total fungal counts	-	-	1000*
<u>Ventilation performance indicator</u>			
(a) Carbon dioxide	C1000	-	-

Figure 4.11: List of Indoor air contaminants and the acceptable limits (Industry Code of Practice on Indoor Air Quality, 2010)

Figure 4.12 displayed the concentration of CO in weekend and weekday against time. From the figure, firstly, a comparatively similar trend can be seen. The concentration of CO is lower in the morning compared to in the evening. However, an unanticipated findings is made. From the graphs, the level of CO in weekday is higher compared to the level of CO in weekend. At first, it was expected that the level of CO will be higher in the weekend compared to the weekday, however, this supposition has been proved wrong. The reason that weekday recorded higher level of CO is because KLCC not only a major tourist attraction in Kuala Lumpur, it also houses the headquarter of PETRONAS and also many companies in the twin towers. Therefore, the number of users using the car park increases.

From the graph, the relationship between the temperature and the level of CO inside the car park also can be discussed. The temperatures for both days shows minimal fluctuations. However, the concentrations of CO in weekend and weekday varied significantly. Therefore, from the figure, it is proven that temperature has minimal effect on the concentration of CO inside the enclosed car park.

Another significant discovery from the figure is that both CO concentration in weekend and weekday exceeded the COPIAQ limit, especially in the afternoon. This is because, the tourists and visitors who came to KLCC usually came in the afternoon. Plus, the CO level from the morning accumulated together with CO level in the afternoon, thus increasing the concentration. Furthermore, there are many movements of vehicles, especially during office break which contributed to the increase of CO level inside the car park. This is important as it presented a significant health issue to the occupants and users of the car park. CO is very dangerous to human health, and if this problem is overlooked, especially by the car park management, it will affect the health of employees, visitors, tourists and many others in the future. Since the level of CO exceeded the COPIAQ limit, it is advisable to the users, especially visitors and tourists, to avoid this period, in order to reduce the effect from CO.

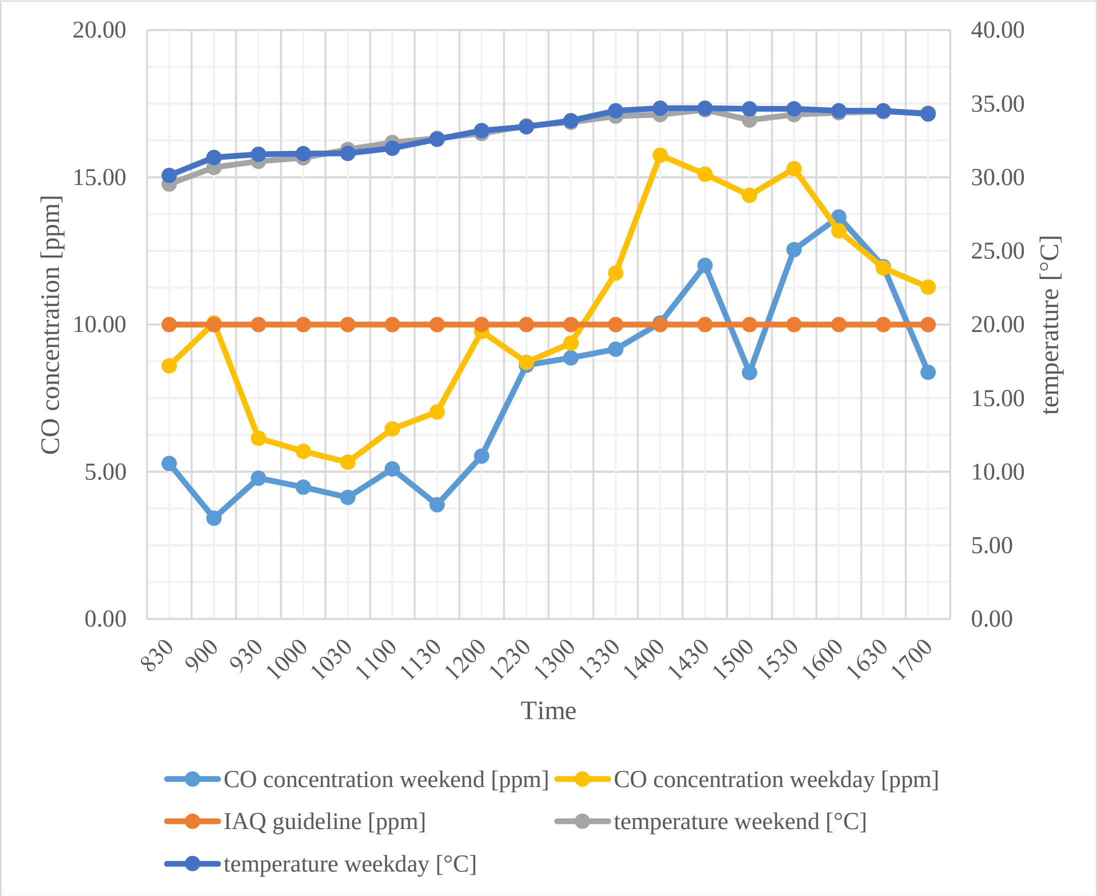

Figure 4.12: Concentration of carbon monoxide and the temperature versus time

The concentration of CO_2 also shows similar trends, in which the level of CO_2 for both days were higher in the afternoon compared to in the morning, as showed in figure 4.13. The figure also showed that the level of CO_2 during weekday is relatively higher compared with the concentration of CO_2 during weekend. Since it resemble with the findings in figure 4.12, it can be argued that the reasons presented earlier is valid.

These graphs also shows that temperature effect on the concentration of CO_2 inside the enclosed car park is very little. However, it is advisable to give more emphasis on this particular parameter in future study, to validate the results found here.

From the graph, it also showed that throughout the day, the level of CO_2 inside the car park is below the acceptable limit. This shows that, the ventilation system, especially at the level where the study was being done, is adequate. However, the highest level of CO_2 inside the car park did slightly exceeded the limit. This showed that even though for the time being, the ventilation system can be regarded as satisfactory, it is advisable for the parking management to review back their ventilation system to cater for the future.

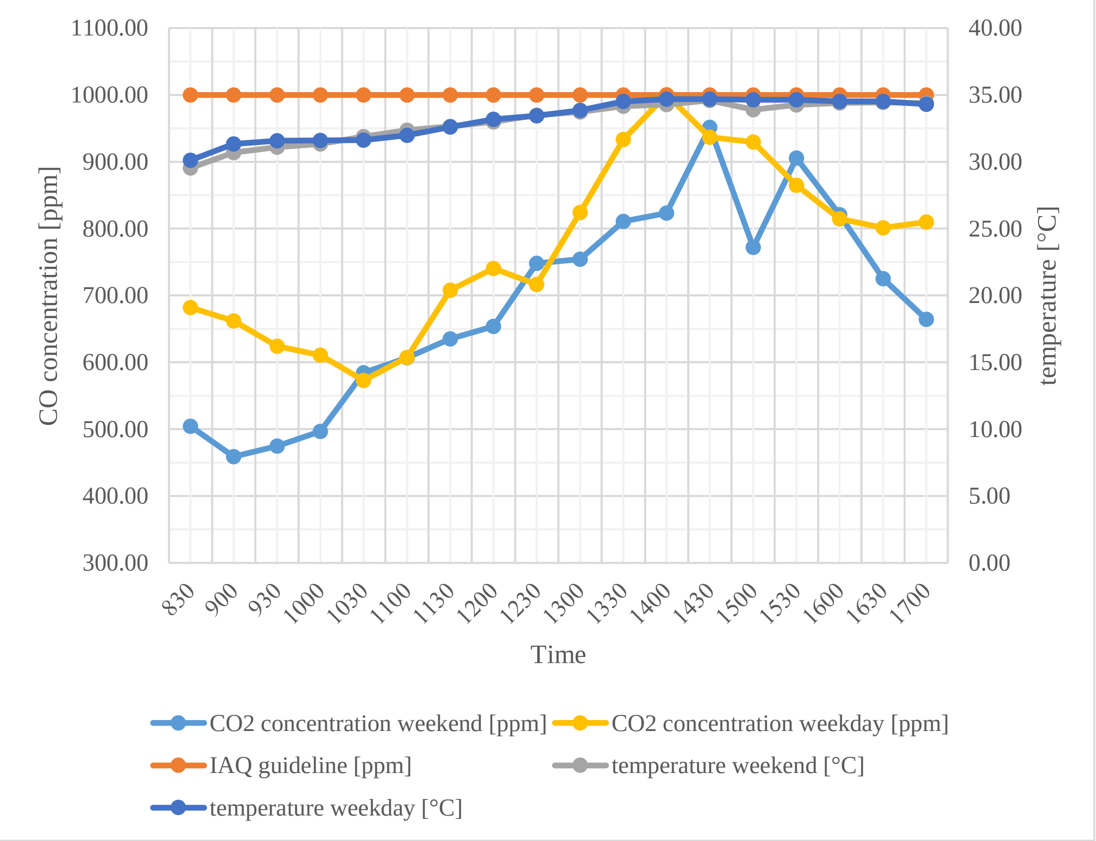

Figure 4.13: concentration of carbon dioxide and the temperature versus the time

In order to reduce the impact of air pollution, especially CO and CO_2, inside the enclosed car park, several recommendations are suggested. First, it is recommended for localised ventilation system to be implemented. It has been proven that the ventilation system is inadequate to keep the level of CO under the permitted limit. Furthermore, this has been verified by the fact that the level of CO_2 surpassed the ceiling limit at one point throughout the day. As suggested by the COPIAQ, when the level of CO_2 exceeded the ceiling limit, this demonstrated that the ventilation system is inadequate. Thus, the parking management should consider building localised ventilation at critical points inside the car park. Among the suggested places where these localised ventilation system is to be built are at the entry and exit points throughout the car park. This is because, these entry and exit points are where high pollution level are found (Burnett, et al., 1997). Another suggestion that can be implemented to reduce the effect of air pollution on human health inside the KLCC underground car park is to properly manage the movements of vehicles inside the car park. Proper traffic management inside the car park can helps the vehicles to produce less CO, thus lowering the level of CO inside the car park. Plus, with proper traffic management, it can avoid accumulation of pollutants at certain areas inside the car park, such as the entry and exit points, and at the ramps leading to other levels.

CHAPTER 5
CONCLUSION

The conclusion of this study will be based on the objectives presented in Chapter 1, which are to investigate the level of CO and CO_2 inside the enclosed car park, to analyse the concentration of CO and CO_2 using basic time series model., to study the relationship between the level of CO and CO_2 with the temperature inside the underground car park, to benchmark the findings with DOSH's Industry Code of Practice on Indoor Air Quality 2010 (COPIAQ), and to propose feasible mitigation measures to reduce the air pollution inside the car park.

The level of CO and CO_2 inside the enclosed car park during weekday is proven to be higher than the level of CO and CO_2 inside the car park during weekend. By looking at the graphs, the level of CO and CO_2 is significantly higher in the afternoon, compared to the level of CO and CO_2 in the morning. The temperature inside the enclosed car park has minimal effect on the concentration of CO and CO_2 inside the enclosed car park. The level of CO exceeded the permissible limit suggested by COPIAQ in the afternoon. Plus, the level of CO_2 surpassed the ceiling limit advised by the COPIAQ, and thus showed the car park has an inadequate ventilation system.
Last but not least, localised ventilation system and proper traffic management are among many feasible recommendations that can be proposed to the parking management to reduce the air pollution inside the enclosed car park, and thus, minimising the effect on the human health.

More study are needed to prove that the air pollution inside car park, especially in Malaysia, is at an alarming level. Further research in the future probably can proposed a standard guideline that can be used by the authority as well as the developers to construct and built enclosed parking spaces that have minimal effect on human health, especially the users and employees of the car park. On a particular note, this research can be further proven, by studying the level of CO and CO_2 at the other levels inside the KLCC underground car park.

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