



**THE PROTOTYPE DESIGN OF VEHICLE CARBON MONOXIDE  
DETECTOR (VECOD) WITH A LOW-COST SENSOR USING  
ARDUINO UNO AS A PLATFORM**




**BACHELOR OF MECHANICAL AND MANUFACTURING  
ENGINEERING TECHNOLOGY (AIR CONDITIONING AND  
REFRIGERATION SYSTEM) WITH HONOURS**

**2022**



**Faculty of Mechanical and Manufacturing Engineering  
Technology**



**THE PROTOTYPE DESIGN OF VEHICLE CARBON MONOXIDE  
DETECTOR (VECOD) WITH A LOW-COST SENSOR USING  
ARDUINO UNO AS A PLATFORM**

**Muhammad Firdaus Bin Yusdianto**

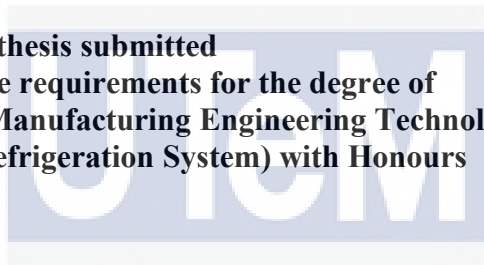
**Bachelor of Mechanical And Manufacturing Engineering Technology (Air  
Conditioning And Refrigeration System) with Honours**

**2022**

**THE PROTOTYPE DESIGN OF VEHICLE CARBON MONOXIDE DETECTOR  
(VECOD) WITH A LOW-COST SENSOR USING ARDUINO UNO AS A  
PLATFORM**

**MUHAMMAD FIRDAUS BIN YUSDIANTO**

A thesis submitted  
in fulfillment of the requirements for the degree of  
**Bachelor of Mechanical And Manufacturing Engineering Technology (Air  
Conditioning And Refrigeration System) with Honours**



اونيورسيتي تيكنيكل مليسيا ملاك

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**Faculty of Mechanical and Manufacturing Engineering Technology**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2022**

## DECLARATION

I declare that this choose an item entitled “Vehicle Carbon Monoxide Detector (VeCOD)” is the result of my own research except as cited in the references. The choose an item has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature



Name

: Muhammad Firdaus Bin Yusdianto

Date

: 25/01/2022

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical And Manufacturing Engineering Technology (Air Conditioning And Refrigeration System) with Honours.

Signature :



25 Januari 2022  
Ts. Azwan Bin Aziz  
Senior Lecturer (D551)  
Department of Industrial Technology  
Faculty of Mechanical & Manufacturing Engineering Technology  
Universiti Teknikal Malaysia Melaka (UTeM)

Supervisor Name :

Ts. Azwan Bin Aziz

Date :

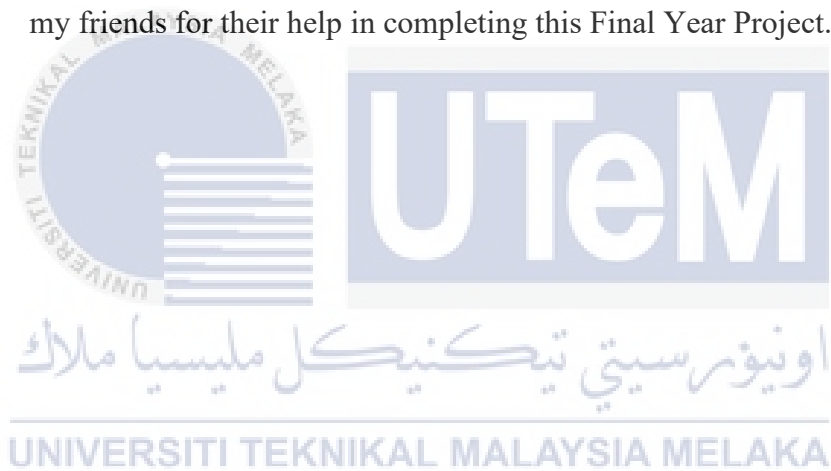
25/01/2022

اونيورسيتي تيكنيكل مليسيا ملاك

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## DEDICATION

I would like to dedicate the success of this research to my parents, Yusdianto Bin Mohd Yunus and Saadiah Binti Abdul Hamid. This dedication is then made to my siblings, who helped me complete this report by providing advice, financial support, and encouragement. Then, I'd want to express my heartfelt gratitude to Ts. Azwan Bin Aziz, my supervisor, and my friends for their help in completing this Final Year Project.



## ABSTRACT

Carbon monoxide (CO) is a toxic, colorless, and odorless gas that is difficult to detect. Carbon monoxide is produced in large quantities by automobile exhaust emissions. Carbon monoxide can get into the vehicle through holes in the exhaust system. Inhaling an excessive amount of carbon monoxide for an extended period has a direct influence on human health and can result in lethal carbon monoxide poisoning. To ensure that the level of carbon monoxide in the vehicle is safe, the air quality must be monitored. Drivers who must endure long drives and must rest in their automobiles will be particularly affected. When the car's air conditioner (AC) is turned on during hot weather, the engine is simultaneously turned on, generating CO leakage into the vehicle. Many people perished as a result of carbon monoxide poisoning in cars. As a result, incorporating a low-cost "Vehicle Carbon Monoxide Detector (VeCOD)" into a carbon monoxide monitoring system minimizes similar incidents. Using an MQ-7 CO gas sensor, this research intends to construct a CO gas warning system for detecting CO in cars. To make the system more realistic, an Arduino Uno is utilized as a microcontroller to control the entire system. In addition, the LCDs the CO concentration within the car in ppm units and warns of leaks at the exhaust-to-engine connection, using an alert system consisting of an LED and a buzzer. CO concentration is divided into two levels in this project based on the output voltage of the sensor. This system would automatically warn the driver or user if a leak connection between the exhaust connection and the engine is detected, or if a dangerous level of CO in the car cabin is detected, by activating signals via LCD, LED, and buzzer to alert the driver or user to avoid carbon monoxide poisoning.

اونيورسيتي تيكنيكل مليسيا ملاك

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## ***ABSTRAK***

Karbon monoksida (CO) adalah gas beracun, tidak berwarna dan tidak berbau yang sukar dikesan. Karbon monoksida dihasilkan dalam jumlah besar oleh pelepasan ekzos kenderaan. Karbon monoksida dapat masuk ke dalam kenderaan melalui lubang pada sistem ekzos. Menghirup sejumlah besar karbon monoksida untuk jangka masa yang panjang mempunyai pengaruh langsung terhadap kesihatan manusia dan dapat mengakibatkan keracunan karbon monoksida yang mematikan. Untuk memastikan tahap karbon monoksida di dalam kenderaan selamat, kualiti udara mesti dipantau. Pemandu yang mesti menempuh perjalanan panjang dan mesti berehat di dalam kenderaan mereka akan sangat terjejas. Apabila penghawa dingin kereta (AC) dihidupkan semasa cuaca panas, mesin dihidupkan secara serentak, menyebabkan kebocoran CO ke dalam kenderaan. Banyak orang mati akibat keracunan karbon monoksida di dalam kereta. Akibatnya, memasukkan "Vehicle Carbon Monoxide Detector (VeCOD)" kos rendah ke dalam sistem pemantauan karbon monoksida meminimumkan kejadian serupa. Dengan menggunakan sensor gas MQ-7 CO, penyelidikan ini bermaksud membina sistem amaran gas CO untuk mengesan CO di dalam kereta. Untuk menjadikan sistem lebih realistik, Arduino Uno digunakan sebagai mikrokontroler untuk mengawal keseluruhan sistem. Selain itu, LCD memaparkan kepekatan CO di dalam kereta dalam unit ppm dan memberi amaran akan kebocoran pada sambungan ekzos ke mesin, menggunakan sistem amaran yang terdiri dari LED dan buzzer. Kepekatan CO dibahagikan kepada dua tahap dalam projek ini berdasarkan voltan output sensor. Sistem ini secara automatik akan memberi amaran kepada pemandu atau pengguna jika hubungan bocor antara sambungan ekzos dan mesin dikesan, atau jika tahap bahaya CO di kabin kereta dikesan, dengan mengaktifkan isyarat melalui LCD, LED, dan buzzer untuk mengingatkan pemandu atau pengguna untuk mengelakkan keracunan karbon monoksida.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA



## ACKNOWLEDGEMENTS

In the Name of Allah, the Most Gracious, the Most Merciful

Firstly, I would like to thank my supervisor, Ts. Azwan bin Azizi, for his excellent guidance, encouragement, constant support, suggestions, patience, and help to complete my project. He has contributed towards my understanding and I have learnt a lot from him. He motivated and inspired me to work on this report. A special thanks to UTeM for providing a small financial allocation towards the completion of this project.

A special thanks to my parents, Yusdianto Mohd Yunus and Saadiah Abdul Hamid, and also my siblings, for giving me support and tolerance all these years.

I also wish to express my deepest appreciation to my friends for their moral support and lending me their hands in completing this project. Lastly, thank you to all of you who have been crucial parts of the realization of this project and have read my thesis.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## TABLE OF CONTENTS

	PAGE
DECLARATION	
APPROVAL	
DEDICATION	
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	vi
LIST OF FIGURES	vii
LIST OF SYMBOLS AND ABBREVIATIONS	x
LIST OF APPENDICES	xi
<b>CHAPTER 1 INTRODUCTION</b>	<b>1</b>
1.1 Background of the study	1
1.2 Problem Statement	3
1.3 Objectives	4
1.3.1 General Objective	4
1.3.2 Specific Objectives	4
1.4 Scope of Project	4
<b>CHAPTER 2 LITERATURE REVIEW</b>	<b>5</b>
2.1 Introduction	5
2.2 Carbon Monoxide (CO)	5
2.3 Effect of Carbon Monoxide on the Human Body	6
2.4 Source of Carbon Monoxide from Vehicle	9
2.5 Catalytic Converter	10
2.6 Carbon Monoxide Sensor Technologies	13
2.6.1 Metal Oxide Semiconductors Based CO Sensing	13
2.6.2 Electrochemical Gas Sensors	15
2.6.3 Cyber-Physical System Framework for CO Monitoring	16
2.7 Overview of Existing Systems	17
2.7.1 Computer based carbon monoxide monitoring systems	18
2.7.2 Microcontroller based carbon monoxide monitoring	19
2.8 Summary	20

<b>CHAPTER 3</b>	<b>METHODOLOGY</b>	<b>22</b>
3.1	Introduction	22
3.2	Overall Flow Chart	22
3.3	Hardware Implementation	24
3.3.1	Carbon Monoxide Sensor (MQ7)	24
3.3.2	Arduino Uno R3 Board	25
3.3.3	Power Bank / USB Port	26
3.3.4	Output system	27
3.3.4.1	Light Emitting Diode (LED)	27
3.3.4.2	Buzzer	28
3.3.4.3	Liquid Crystal Display (LCD)	29
3.4	Project Development	29
3.5	Software Development (Arduino IDE)	32
3.6	Hardware Development	35
3.7	Project Circuit Design	36
3.8	Project Design	37
3.9	Costing of the Project	40
3.10	Summary	41
<b>CHAPTER 4</b>	<b>RESULTS AND DISCUSSION</b>	<b>42</b>
4.1	Introduction	42
4.2	Prototype	42
4.3	Software Testing (Arduino IDE)	44
4.4	Hardware Testing	47
4.5	Data Analysis in Perodua Viva and Proton Wira	49
4.6	Discussion	55
4.7	Summary	56
<b>CHAPTER 5</b>	<b>CONCLUSION AND RECOMMENDATION</b>	<b>57</b>
5.1	Introduction	57
5.2	Conclusion	57
5.3	Recommendation	58
<b>REFERENCES</b>		<b>59</b>
<b>APPENDICES</b>		<b>63</b>

## LIST OF TABLES

TABLE	TITLE	PAGE
Table 2.1	Concentration of carbon monoxide and signs after inhalation (Flashsbart, 2007)	7
Table 2.2	Levels of COHb and clinical manifestations (Rajiah et al., 2011)	8
Table 3.1	Specifications of Arduino Uno	26
Table 3.2	The estimated cost of VeCOD Prototype	40
Table 4.1	The CO gas concentration in Viva and Wira cars	51



## LIST OF FIGURES

FIGURE	TITLE	PAGE
Figure 1.1	Average Annual Number of Deaths and Mortality Rates Due to CO Poisoning in the United States (1999-2010). (Source: Centers for Disease Control and Prevention (CDC), 2014)	2
Figure 2.1	Schematic vehicle sampling site (Miller, 2014)	10
Figure 2.2	The exhaust systems	11
Figure 2.3	Exhaust system on the car (Dr. Kamarul Ariffin Nor Sadan,2020)	12
Figure 2.4	Basic block diagram of MOS thin film-based CO gas detection system	15
Figure 2.5	(a) Amperometric cell sensor and (b) Potentiostatic cell sensor (Igor Cretescu, Doina Lutic, and Liliana Rosemarie Manea, 2017)	15
Figure 2.6	Basic cyber-physical system (CPS) structure (Nandy et al, 2018)	17
Figure 3.1	The procedures for the production of the VeCOD prototype	23
Figure 3.2	Sensor of Carbon Monoxide (MQ-7)	25
Figure 3.3	Arduino Uno R3	26
Figure 3.4	A power bank with a voltage of 5V and a USB port with a voltage of 12V	27
Figure 3.5	Light Emitting Diode (LED)-Yellow, Red and Green	28
Figure 3.6	Buzzer (sound)	28
Figure 3.7	Liquid Crystal Display (LCD)	29
Figure 3.8	The flowchart of development of the project	31
Figure 3.9	The main page of the Arduino IDE software	33
Figure 3.10	The flow chart of the VeCOD system	34

Figure 3.11 Block diagram of VeCOD system	36
Figure 3.12 The circuit overview for the VeCOD system	37
Figure 3.13 Top view of VeCOD Prototype	38
Figure 3.14 Front view of VeCOD Prototype	38
Figure 3.15 Side view (Right) of VeCOD Prototype	39
Figure 3.16 Side view (Left) of VeCOD Prototype	39
Figure 4.1 The circuit built into the project system	43
Figure 4.2 Vehicle Carbon Monoxide Detector (VeCOD) Prototype	44
Figure 4.3 The Arduino IDE software's main page and a label for the serial monitor port	45
Figure 4.4 Readings of CO gas in a stable state inside the laboratory	46
Figure 4.5 CO gas readings increasing after being tested with a lighter	46
Figure 4.6 The green LED on the VeCOD prototype lights up, indicating the environment is in a safe state	47
Figure 4.7 The LED turns yellow, alerting the user to the presence of a gas CO leak	48
Figure 4.8 A red LED illuminates, indicating that CO gas has entered the vehicle's cabin compartment and is posing a threat to the user	49
Figure 4.9 A VeCOD Prototype tested to detect carbon monoxide gas in a Perodua Viva car	50
Figure 4.10 A VeCOD prototype was tested in a Proton Wira car to detect carbon monoxide gas concentrations	50
Figure 4.11 The readings of Carbon Monoxide (CO) concentration against time on Viva car	52

Figure 4.12 The readings of Carbon Monoxide (CO) concentration against time on

Wira car

53

Figure 4.13 The difference between readings of Carbon Monoxide (CO)

concentration against time on Viva and Wira cars

54



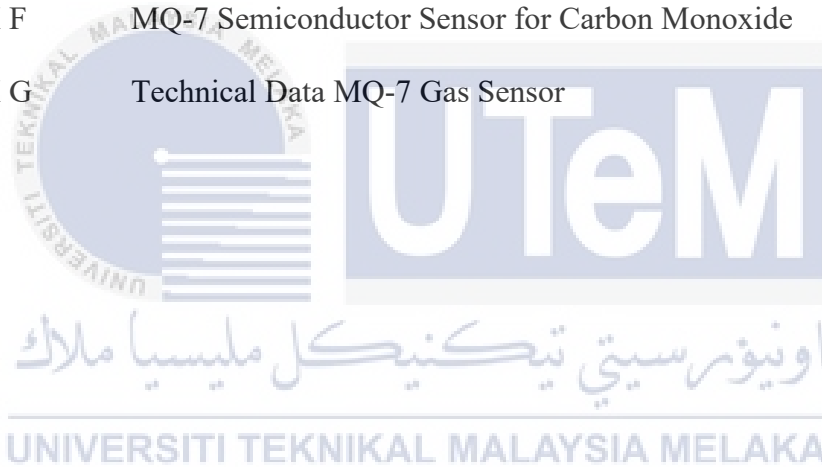
## LIST OF SYMBOLS AND ABBREVIATIONS

CO	-	Carbon Monoxide
COHb	-	Carboxyhemoglobin
O <sub>2</sub>	-	Oxygen
SnO <sub>2</sub>	-	Tin oxide
Hb	-	Hemoglobin
US	-	United States
VeCOD	-	Vehicle Carbon Monoxide Detector
IDE	-	Integrated Development Environment
PEL	-	Permissible Exposure Limit
ppm	-	Parts per million
OSHA	-	Occupational Safety and Health Association
DOSH	-	Department of Occupational Safety and Health
NIOSH	-	National Institute for Occupational Safety and Health
MOS	-	Metal-Oxide-Semiconductor
MEMS	-	Micro-Electro-Mechanical Systems
GPS	-	Global Positioning System
CPS	-	Cyber-Physical System
GMS	-	Google Mobile Services
MQ-7	-	Carbon Monoxide Sensor
LED	-	Light Emitting Diode
LCD	-	Liquid Crystal Display



## LIST OF APPENDICES

APPENDIX	TITLE	PAGE
APPENDIX A	Gantt Chart of PSM 1	63
APPENDIX B	Gantt Chart of PSM 2	65
APPENDIX C	Coding of VeCOD system	67
APPENDIX D	Data of Wira car	69
APPENDIX E	Data of Viva car	72
APPENDIX F	MQ-7 Semiconductor Sensor for Carbon Monoxide	75
APPENDIX G	Technical Data MQ-7 Gas Sensor	79



# CHAPTER 1

## INTRODUCTION

### 1.1 Background of the study

One of the pollutants that pollute the air is carbon monoxide (CO). Carbon monoxide is commonly found on highways because it is formed when incomplete combustion occurs, such as in a car engine. Carbon monoxide can also be created through the high-heat-pressure combustion of fuels such as natural gas, firewood, solar, coal, and gasoline. Malaysia is seeing an increase in the number of vehicles on the road. As a result, gas pollution rises. Toxic and unhealthy gases will be produced by the exhaust of vehicles such as cars, buses, and others. Poor ventilation systems or leakage problems in the car's air ducts can give way to toxic gases entering the spacecraft slowly. A more dangerous situation can be created when dozens of vehicles stop waiting for a green light on the road.

Staying or sleeping in a vehicle with the engine running, driving a vehicle with exhaust damage, or driving a vehicle with holes in the car body are the most common causes of carbon monoxide poisoning. Carbon monoxide can enter the car through cracks in the exhaust system, windows, or doors. Inhaling carbon monoxide gas over some time and being in an enclosed place can cause serious health problems as well as will be deaths against the driver and also passengers inside the vehicle due to carbon monoxide poisoning. Carbon monoxide affects people by replacing oxygen with carboxyhemoglobin in the blood, reducing the amount of oxygen available to the body. According to death and fatality rates

attributable to CO poisoning in the United States (US) from 1999 to 2010, as shown in Figure 1.1, there has been a significant increase in concern each year.

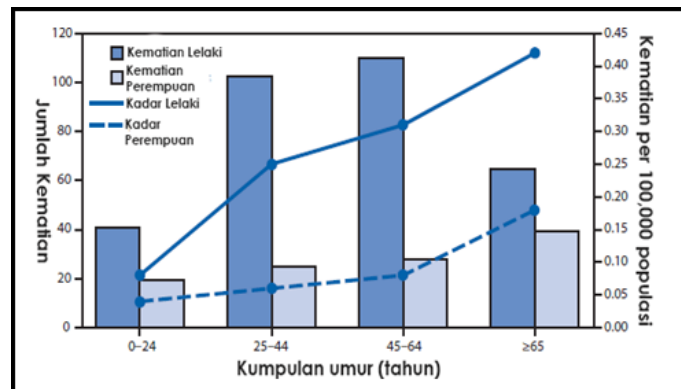


Figure 1.1 Average Annual Number of Deaths and Mortality Rates Due to CO Poisoning in the United States (1999-2010). (Source: Centers for Disease Control and Prevention (CDC), 2014)

CO is one of the hardest gases to detect with the human senses. A project called "Vehicle Carbon Monoxide Detector (VeCOD)" is being proposed to solve the problem of excessive CO inhalation in vehicles by generating alarm signals when CO concentrations in vehicles exceed harmful levels. The Arduino Uno acts as the project's main component, controlling all VeCOD inputs and outputs for CO detection in vehicles. The MQ-7 sensor is used in the project, and it has a detection range of up to 2000 parts per million, making it suitable for use in a CO detection system. The CO content in the automobile is displayed on the LCD, showing whether it would be high or low. When the CO concentration in the vehicle exceeds the predetermined limit, the LED and buzzer outputs will be triggered, notifying the people in the car to avoid carbon monoxide poisoning in the vehicle.

## 1.2 Problem Statement

The case of a sudden death while sleeping in a car has worried the Malaysian community and the authorities. Especially for car drivers and passengers who normally stop at a certain place (e.g., on the side of the road) to rest, but are unfortunately poisoned by carbon monoxide during sleep. Exhaust gas leaks have contaminated car passenger space, especially for poorly maintained cars. Previous reports showed sudden deaths due to gas poisoning during sleep due to inhaled carbon monoxide gas in the density range of more than 800 ppm. The latest case took place in Seberang Jaya, Penang, where four friends were unconscious in a Honda Odyssey multi-purpose vehicle (MPV) due to inhalation of carbon monoxide (CO), and it was found that three students died while the other survived the incident. In another case, two teenage boys died in a Perodua Myvi car in Kampung Jaya Baru believed to be carbon monoxide poisoning.

The average case that happened was that they slept in the car without stopping the engine or shutting off the air conditioning system. The fact about carbon monoxide (CO) gas is that it is a colorless, tasteless, and toxic gas that is difficult to detect, making it even more harmful. The absence of additional devices to detect the presence of carbon monoxide gas is a major problem, and its application is seen as insignificant. Therefore, this paper proposes a prototype of an automated carbon monoxide detector using Arduino that can benefit car drivers and passengers. A project entitled "Vehicle Carbon Monoxide Detector (VeCOD)" should be developed through study and design to detect carbon monoxide gas. It can directly assist drivers in detecting carbon monoxide gas leaks.

### **1.3 Objectives**

#### **1.3.1 General Objective**

To design the prototype of a carbon monoxide detection system with a low cost for average car owners.

#### **1.3.2 Specific Objectives**

- i. To analysis the level of carbon monoxide on the vehicles.
- ii. To develop a carbon monoxide detection system to prevent carbon monoxide poisoning in vehicles.

### **1.4 Scope of Project**

This device is specially made to be installed for road users who use motor vehicles such as cars, buses, lorries, and so on. Then, this research is a first step in developing low-cost carbon monoxide detection equipment that will be available to all consumers to avoid deaths caused by carbon monoxide gas in vehicles. The hardware and software of the project can be separated into two categories. Both hardware and software are used to execute this project. In the circuit design, components such as an Arduino microcontroller, a CO gas sensor, a buzzer, an LCD, and an LED are used. The Arduino microcontroller's work is used to monitor the entire detection system's operation. The CO sensor detects the presence of CO, and when CO is detected, the buzzer will sound. LED indicators are used to show the state of the device to the user. After CO is measured, the sensor reading will be shown on the LCD panel. The Arduino integrated development environment (IDE) is used to program the system in the software phase, which is simple to read and understand.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Introduction

Carbon monoxide (CO) is a colorless, odorless, tasteless, invisible, and poisonous gas that can be fatal when inhaled into the human body (Masek et al., 2019). The incomplete combustion of fossil fuels produces this toxic gas. These fuels (coal, gasoline, kerosene, natural gas, oil, propane, and wood) are used by many people all over the world (Vacanti et al., 2011). CO is described as the "silent killer" because it leaves no visible signs of its existence (Long & Flaherty, 2017). In many places, especially vehicles, carbon monoxide poisoning has become the most common type of lethal air poisoning. As the number of vehicles on the road rises, so does the degree of pollution from carbon monoxide fumes (Chamberlain, 2016).

#### 2.2 Carbon Monoxide (CO)

CO is a product of incomplete hydrocarbon combustion, which occurs most commonly in vehicle engines. According to a study, motor vehicles emit over 70% carbon monoxide (Farhan et al., 2003). In 2011, mobile vehicles accounted for 60% of carbon monoxide emissions in the United States (US EPA, 2014). Carbon monoxide exposure is assumed to be higher in urban areas with heavy traffic congestion (Farhan et al., 2003). According to the regulations set by the United States Department of Labor (USA Department of Labor, n.d.), the Occupational Safety and Health Association (OSHA) permitted exposure limit (PEL) is 55 mg/m<sup>3</sup> for eight hours.

According to the Department of Occupational Safety and Health (DOSH) Malaysia, the maximum CO concentration allowed indoors is less than 10 ppm TWA (Industry Code of Practice on Indoor Air Quality, 2010). CO is a colorless, odorless, and tasteless gas, yet highly toxic. CO is difficult to detect due to its properties (Prockop et al., 2007). CO poisoning is the most common cause of death in several countries (Omaye, 2002). CO poisoning is difficult to diagnose due to the lack of clear clinical symptoms (Prockop et al., 2007).

CO is dangerous to humans because when inhaled, CO will combine with hemoglobin in the red blood cells to form carboxyhemoglobin (COHb). This will reduce the level of oxygen (O<sub>2</sub>) delivered throughout the body. The affinity of hemoglobin towards CO is 210 times higher than that of O<sub>2</sub> (Prockop et al., 2007). The brain and heart can be severely affected after exposure to CO with COHb surpassing 20% (Prockop et al., 2007). Among the symptoms of CO poisoning are headaches, dizziness, vomiting, nausea, and fatigue. These symptoms are similar to viral flu symptoms, causing misunderstandings for the victim (Khandelwal et al., 2007). At a CO concentration of 1600 ppm, CO poisoning can be fatal to the victim in less than 2 hours (Goldstein, 2008).

### **2.3 Effect of Carbon Monoxide on the Human Body**

Every aerobic form of life is killed by carbon monoxide (CO). Through the lungs, it was simply absorbed into the bloodstream (U.S. Environmental Protection Agency, 2000). Because CO has a 240-fold higher affinity for hemoglobin than oxygen, oxygen cannot bind to hemoglobin. Carboxyhemoglobin lowers the blood's ability to carry oxygen and interferes with oxygen delivery to tissues. Continuous oxygen supply can cause tissue hypoxia by interfering with cellular respiration (Q. Liu et al., 2012). Increased blood levels of

carboxyhemoglobin (COHb) reduced the quantity of oxygen transferred across the body by the hemoglobin in red blood cells.

Carbon monoxide is a toxic gas with harmful effects on the human body. CO combines with hemoglobin (Hb) in the blood during inhalation to generate carboxyhemoglobin (COHb). This reduces the amount of oxygen available to the human heart and brain. Carbon monoxide is absorbed faster by red blood cells than oxygen. As a result, higher CO inhalation can harm one's health by cutting off oxygen delivery to the body's organs. As a result, high levels of carbon monoxide can be lethal. Table 2.1 shows the health effects of long-term exposure to various carbon monoxide concentrations in parts per million (ppm) (Flachsbart, 2007).

Table 2.1 Concentration of carbon monoxide and signs after inhalation (Flachsbart, 2007)

Concentration	Effects and Symptoms
0 ppm	Fresh air
9 ppm	Maximum indoor air quality level
10-34 ppm	Possible health effects with long-term exposure
35 ppm	Headache and dizziness within 6-8 hours of constant exposure
100 ppm	Slight headache after 2-3 hours
200 ppm	Slight headache within 2-3 hours ; loss of judgment
400 ppm	Serious headache within 1-2 hours
800 ppm	Dizziness, nausea and convulsions with 45 min Continued exposure: Death within 2-3 hours
1,600 ppm	Headache, increased heart rate, dizziness, and nausea within 20 min Continued exposure: Death in less than 2 hours
3,200 ppm	Headache, dizziness and nausea in 5-10 min Continued exposure: Death within 1 hour