AIR AND NOISE POLLUTION MONITORING SYSTEM OVER INTERNET OF THINGS

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DECLARATION

I declare that this thesis entitled "AIR AND NOISE POLLUTION MONITORING SYSTEM OVER INTERNET OF THINGS" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : ....

Date : ....

APPROVAL

I hereby declare that I have checked this report entitled "Air and Noise Pollution Monitoring System over Internet of Things" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

Signature : ....

Supervisor Name : ....

Date : ....

DEDICATIONS

To my beloved mother and father

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ABSTRACT

The recent scenario of tremendous increase in air and noise pollution is the largest challenge encountered by the public. Air and noise pollution had brought a huge impact to living organism and environment where it could lead to adverse effects on human health. This creates a need of measuring and analysing the air and noise pollution level from the monitoring system in order some actions and solutions can be taken. However, there is unavailable on the combination on air and noise pollution monitoring system for the Department of Environment (DOE) in Malaysia. Besides, the data and the status of the pollutions obtained by the DOE is not shared to the public. Hence, in this project, a real-time air and noise pollution monitoring system with Internet of Things (IoT) was developed in order to store the data collected in the cloud platform. Two gas sensors with model MQ135 and MQ7 were used to detect the level of carbon dioxide (CO2) gas and carbon monoxide (CO) gas in unit of parts per million (ppm) where Gravity Analog Sound Level Meter SKU SEN0232 was used to detect the noise level in decibel (dB). The data collected from the sensors was transferred and saved to an Advanced Reduced Instruction Set Computing Machine (ARM)-based minicomputer Raspberry Pi 3 which then uploaded the data to a cloud platform called ThingSpeak. The data collection time of monitoring system for one cycle was set to a minimum of 15s where the system was set to 17s.in the experiments. The sound level meter in the system had high sensitivity as it compared with a Sound Pressure Level (SPL) meter. The MQ135 and MQ 7 sensor were well functioned and capable to detect the level of CO2 gas and CO gas in the unit of ppm. All of the data collected from the system were successfully stored and uploaded to ThingSpeak which then displayed in the ThingSpeak channel graphically. The air and noise pollution monitoring system over IoT in this project was developed successfully and well functioned.

ABSTRAK

Senario baru-baru ini peningkatan yang besar dalam pencemaran udara dan bunyi adalah cabaran terbesar yang dihadapi oleh orang ramai. Pencemaran udara dan bunyi telah memberi impak besar kepada organisma hidup dan persekitaran di mana ia boleh menyebabkan kesan buruk kepada kesihatan manusia. Ini mewujudkan keperluan untuk mengukur dan menganalisis paras pencemaran udara dan bunyi dari sistem pemantauan agar beberapa tindakan dan penyelesaian dapat diambil. Walau bagaimanapun, tidak terdapat gabungan sistem pemantauan pencemaran udara dan bunyi untuk Jabatan Alam Sekitar (JAS) di Malaysia. Selain itu, data dan status pencemaran yang diperoleh oleh DOE tidak dikongsi dengan orang ramai. Oleh itu, dalam projek ini, sistem pemantauan pencemaran udara dan bunyi masa nyata dengan Internet Perkara (IoT) telah dibangunkan untuk menyimpan data yang dikumpul di platform awan. Dua sensor gas dengan model MQ135 dan MQ7 digunakan untuk mengesan tahap gas karbon dioksida (CO_2) dan gas karbon monoksida (CO) dalam unit per juta (ppm) di mana Gravity Analog Sound Level Meter SKU SEN0232 digunakan untuk mengesan tahap bunyi dalam decibel (dB). Data yang dikumpulkan dari sensor telah dipindahkan dan disimpan ke komputer riba minikomputer berasaskan Setulus Pengurangan Kompaun Lanjutan (ARM) yang kemudian memuat naik data ke platform awan yang disebut ThingSpeak. Waktu pengumpulan data sistem pemantauan untuk satu kitaran ditetapkan setidak-tidaknya 15s di mana sistem ditetapkan ke 17 dalam eksperimen. Tahap bunyi di dalam sistem mempunyai kepekaan yang tinggi kerana dibandingkan dengan meter tekanan tekanan (SPL). Sensor MQ135 dan MQ 7 berfungsi dengan baik dan mampu mengesan tahap gas CO_2 dan gas CO dalam unit ppm. Semua data yang dikumpulkan dari sistem berjaya disimpan dan dimuat naik ke ThingSpeak yang kemudian dipaparkan dalam saluran ThingSpeak secara grafik. Sistem pemantauan pencemaran udara dan bunyi ke atas IoT dalam projek ini dibangunkan dengan jayanya dan berfungsi dengan baik.

TABLE OF CONTENTS

PAGE

DECLARATION

APPROVAL

DEDICATIONS

ACKNOWLEDGEMENTS **1**

ABSTRACT **2**

ABSTRAK **3**

TABLE OF CONTENTS **4**

LIST OF TABLES **6**

LIST OF FIGURES **7**

LIST OF SYMBOLS AND ABBREVIATIONS **9**

LIST OF APPENDICES **11**

CHAPTER 1 INTRODUCTION **12**
1.1 Overview 12
1.2 Motivation 12
1.3 Problem Statement 13
1.4 Objectives 14
1.5 Scope 14
1.6 Report Outline 15

CHAPTER 2 LITERATURE REVIEW **16**
2.1 Overview 16
2.2 Study of Pollution 16
2.2.1 Air Pollution 16
2.2.2 Noise Pollution 19
2.3 Air and Noise Pollution Monitoring System 21
2.3.1 A Components Used in Monitoring Systems 24
2.3.1.1 Type of Sensing Units 24
2.3.1.2 Controller for Monitoring System 26
2.3.2 Software Applied in Monitoring Systems 26
2.3.3 Application of Internet of Things (IoT) 27
2.3.4 Region to Install Monitoring System 30
2.4 Conclusion 30
2.5 Summary 32

CHAPTER 3 METHODOLOGY **33**

3.1 Overview 33
3.2 Air and Noise Monitoring System over IoT 33
3.2.1 Hardware Development 34
3.2.1.1 Sensors 34
3.2.1.2 Microcontroller 36
3.2.1.3 Mini-computer 36
3.2.2 Software Development 37
3.2.2.1 ThingSpeak™ 37
3.3 System Architecture 38
3.3.1 Initial Setup 40
3.4 Experiment Setup 41
3.4.1 Experiment 1: Experimenting on the Difference Between the Data Stored in Raspberry Pi and the Data Uploaded to Cloud Platform 41
3.4.2 Experiment 2: Experimenting on the Difference Between Sound Sensor and Sound Pressure Level (SPL) Meter 42
3.4.3 Experiment 3: Experimenting on the Level of Carbon Monoxide Gas 43
3.4.4 Experiment 4: Experimenting on the Level of Carbon Dioxide Gas 44
3.5 Summary 45

CHAPTER 4 RESULTS AND DISCUSSIONS 46
4.1 Overview 46
4.2 Result of Experiment 1: Experimenting on the Difference Between the Data Stored in Raspberry Pi and the Data Uploaded to Cloud Platform 46
4.2.1 Result on Experimenting the 10 Seconds As One Cycle of the Data Collection Time of the Monitoring System 47
4.2.2 Result on Experimenting the 15 Seconds As One Cycle of the Data Collection Time of the Monitoring System 49
4.2.3 Result on Experimenting the 20 Seconds As One Cycle of the Data Collection Time of the Monitoring System 51
4.2.4 Result on Comparing on the 10s, 15s and 20s As One Cycle of Data Collection Time of the Monitoring System 53
4.3 Result of Experiment 2: Experimenting on the Difference Between Sound Sensor and Sound Pressure Level (SPL) Meter 55
4.3.1 Result on Experimenting the 0% Loudness of Sound Level 56
4.3.2 Result on Experimenting the 10% Loudness of Sound Level 58
4.3.3 Result on Experimenting the 20% Loudness of Sound Level 60
4.3.4 Result on Comparing the 0%, 10% and 20% Loudness of Sound Level 62
4.4 Result of Experiment 3: Experimenting on the Level of Carbon Monoxide Gas 64
4.5 Result of Experiment 4: Experimenting on the Level of Carbon Dioxide Gas 67
4.6 Summary 71

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS 72
5.1 Conclusion 72
5.2 Recommendations 73

REFERENCES 74

APPENDICES 81

LIST OF TABLES

Table 2.1: Health Effects Due to Prolonged Exposure of the Level of Carbon Monoxide (CO) 18

Table 2.2: Level of Carbon Dioxide Gas and Potential Health Problems 19

Table 2.3: Comparison of Monitoring System over IoT from Previous Studied Journals or Papers 22

Table 2.4: Advantages and Disadvantages of IoT 29

Table 4.1: Result from Experiment 1 with 10s As One Cycle of Data Collection Time 48

Table 4.2: Result from Experiment 1 with 15s As One Cycle of Data Collection Time 51

Table 4.3: Result from Experiment 1 with 20s As One Cycle of Data Collection Time 53

Table 4.4: Percentage of Error for 10s, 15s and 20s As One Cycle of Data Collection Time 54

Table 4.5: Result from Experiment 2 with Loudness of Sound Level is 0% 57

Table 4.6: Result from Experiment 2 with Loudness of Sound is 10% 59

Table 4.7: Result from Experiment 2 with Loudness of Sound is 20% 61

Table 4.8: Average of The Loudness of Sound Level and The Differences Between Sound Sensor and SPL Meter 62

Table 4.9: Result from Experiment 3 65

Table 4.10: Result from Experiment 4 69

LIST OF FIGURES

Figure 3.1: System Setup for Air and Noise Pollution Monitoring System over IoT 33

Figure 3.2: MQ135 Semiconductor Sensor 35

Figure 3.3: Semiconductor Sensor for Carbon Monoxide 35

Figure 3.4: Gravity Analog Sound Level Meter SKU SEN0232 35

Figure 3.5: Arduino Nano V3.0 36

Figure 3.6: Raspberry Pi 3 Model B 36

Figure 3.7: Overall Chart of Air and Noise Pollution Monitoring System over IoT 38

Figure 3.8: The Functionality of Each Stage of Air and Noise Monitoring System over IoT 39

Figure 3.9: Flowchart of the Air and Noise Pollution Monitoring System over IoT 39

Figure 3.10: Schematic Diagram of the Air and Noise Pollution Monitoring System 40

Figure 3.11: Hardware Setup of Air and Noise Pollution Monitoring System 40

Figure 4.1: Experiment Setup of Experiment 1 46

Figure 4.2: Text File Stored in Raspberry Pi for 10s As One Cycle Data Collection Time 47

Figure 4.3: Plotted Graph of 10s As One Cycle of Data Collection Time in ThingSpeak Channel 48

Figure 4.4: Text File Stored in Raspberry Pi for 15s As One Cycle Data Collection Time 50

Figure 4.5: Plotted Graph of 15s As One Cycle Data Collection Time in ThingSpeak Channel 50

Figure 4.6: Text File Stored in Raspberry Pi for 20s As One Cycle Data Collection Time 52
Figure 4.7: Plotted Graph of 20s As One Cycle Data Collection Time in ThingSpeak Channel 52
Figure 4.8: Experiment Setup of Experiment 2 55
Figure 4.9: Plotted Graph of Sensor Data at Loudness is 0% 56
Figure 4.10: Compare of Sound Level when Loudness is 0% 57
Figure 4.11: Plotted Graph of Sensor Data at Loudness is 10% 58
Figure 4.12: Compare of Sound Level when Loudness is 10% 59
Figure 4.13: Plotted Graph of Sensor Data at Loudness is 20% 60
Figure 4.14: Compare of Sound Level when Loudness is 20% 61
Figure 4.15: Bar Chart of the Average of the Loudness of Sound Level and the Differences Between Sound Sensor and SPL Meter 63
Figure 4.16: Experiment Setup of Experiment 3 64
Figure 4.17: Result of Experiment 3 65
Figure 4.18: Experiment Setup of Experiment 4 67
Figure 4.19: Plotted Graph of Sensor Data when Dry Ice is 10g 67
Figure 4.20: Plotted Graph of Sensor Data when Dry Ice is 20g 68
Figure 4.21: Plotted Graph of Sensor Data when Dry Ice is 30g 68
Figure 4.22: Plotted Graph of Sensor Data when Dry Ice is 40g 68
Figure 4.23: Level of Carbon Dioxide (CO2) Gas Versus Amount of Dry Ice 69

LIST OF SYMBOLS AND ABBREVIATIONS

ADC	-	Analog-to-Digital Converter
USB	-	Universal Serial Bus
CPU	-	Central Processing Unit
IoT	-	Internet of Things
CO	-	Carbon Monoxide
CO2	-	Carbon Dioxide
dB	-	Decibel
ppm	-	Parts Per Million
WHO	-	World Health Organisation
HEI	-	Health Effect Institute
DOE	-	Department of Environment
API	-	Air Pollutant Index
CES	-	Compendium of Environment Statistics
ARM	-	Advanced Reduced Instruction Set Computing Machine
SPL	-	Sound Pressure Level
JAS	-	Jabatan Alam Sekitar
MPCB	-	Maharashtra Pollution Control Board
AQI	-	Air Quality Index
ACGIH	-	American Conference of Government Industrial Hygienists
OSHA	-	Occupational Safety and Health Administration
ASHRAE	-	American Society of Heating, Refrigerating and Air Conditioning Engineers
Hz	-	Hertz
HCHO	-	Formaldehyde
UV	-	Ultraviolet
SBC	-	Single Board Computer
UART	-	Universal Asynchronous Receiver-Transmitter
AWS	-	Amazon Web Services
I/O	-	Input and Output

CSI	-	Camera Serial Interface
RFID	-	Radio Frequency Identification
O3	-	Ozone
SO2	-	Sulphur Dioxide
NO2	-	Nitrogen Dioxide
PM	-	Particulate Matter

LIST OF APPENDICES

APPENDIX A: Gantt Chart for Final Year Project 1 81

APPENDIX B: Gantt Chart for Final Year Project 2 82

APPENDIX C: Project Flow Chart 83

APPENDIX D: Datasheet of MQ7 Gas Sensor 84

APPENDIX E: Datasheet of MQ135 Gas Sensor 86

APPENDIX F: Datasheet of Analog Sound Level Meter SKU: SEN0232 88

APPENDIX G: Datasheet of Sound Pressure Level (SPL) Meter 89

APPENDIX H: Experiment 1 (Experimenting on the Difference Between the Data Stored in Raspberry Pi and the Data Uploaded to Cloud Platform) 90

APPENDIX I: Experiment 2 (Experimenting on the Difference between Sound Sensor and Sound Pressure Level (SPL) Meter) 91

APPENDIX J: Experiment 3 (Experimenting on the Level of Carbon Monoxide (CO) Gas) 92

APPENDIX K: Experiment 4 (Experimenting on the Level of Carbon Dioxide (CO2) Gas) 93

APPENDIX L: Arduino Coding for Sensors to Detect Data 94

APPENDIX M: Python Script for Saving Data in Raspberry Pi and Uploading Data to ThingSpeak 96

CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter presented the five subtopics which are motivation, problem statement, objective and scope of the proposed project.

1.2 Motivation

The issues of pollution had drawn a lot of concern in terms of research and everyday life as the results in Google search related to “2014 Air Pollution” is about 46 million, which was 19 million more than that of “2014 Nobel Prize” [1]. According to the survey of the environmental concern for 2019, pollution is rated at Top 4 in the survey and clarified the pollution is one of the primary causes of the other environmental concerns [2].

The public concern on the issues of pollution has significantly increased as the serious negative impact brought to human health and the environment. Hence, a large scale on the studies of the exposure of air and noise pollution to human health have been published [3].

Based on the 7 main types of pollution, the major constituents for having adverse and harmful effects on human being and the environment is air pollution and noise pollution [4]. Air pollution is the natural air which is contaminated with different pollutants whereas noise pollution is the loud noise created by human activities [5]. According to the Health Effect Institute (HEI), air pollution has become the Top 4 worldwide death killer which 6.1 million people died due to long-term exposure of air pollution in 2016. Based on the HEI’s report in 2016, China and India had the highest number of death due to air pollution which is 1.58 and 1.61 million respectively [6]. According to World Health Organisation (WHO) exposure to noise can kill people where 3% of people die in heart attack is due to traffic noise in Europe [7].

Exposure of polluted air has a different negative impact on human health including respiratory and cardiovascular diseases, neuropsychiatric complications, the eyes irritation, skin diseases, and long-term chronic diseases [8]. Beside of air pollution, according to World Health Organization (WHO), the underestimated threat of noise pollution harmed human by causing sleep disturbance, cardiovascular effect, hearing impairment and so on [9].

Collecting and sharing the first-hand data of the pollution level to the public by installing an air and noise pollution monitoring system is helpful to raise the awareness among the public as well as inform the public about the surrounding pollution level. Low cost and high efficiency of the monitoring system can be produced with the aid of the Internet of Things (IoT).

1.3 Problem Statement

Research on the pollution monitoring system has received a lot of attention over a few ten years. The air pollution monitoring system had improved in the form of technology from the time-consuming traditional way of the pollution monitoring system [10] to nowadays which the Department of Environment (DOE) of Malaysia monitors the ambient air quality through a network of 51 stations [11]. However, there is unavailable of the air and noise pollution monitoring system for the DOE of Malaysia. It can be seen that the other type of pollution besides of air pollution has been ignored and unconcerned. Hence, combination of different types of the pollution in a monitoring system can increase the awareness of the other types of pollutions to the environment.

In addition, the data and the status of the pollutions obtained by the DOE is not shared to the public. The data collected is held by the DOE to calculate the Air Pollutant Index (API) values. The Department of Statistics Malaysia received the secondary data from the DOE and shared to the public through Compendium of Environment Statistics (CES). However, the daily and detail of the pollution data is not shared by the CES where some of the data is not updated. The incident of the Pasir Gudang happened had caused some people poisoned by the harmful gaseous. This incident can be prevented as the public was able to access the first-hand pollution data collected by the monitoring system. Hence, a real time air and noise pollution monitoring system over Internet of Things (IoT) allows the public to receive the data in a very short time.

In conclusion, a new innovation on the pollution monitoring system is required to address the demand for pollution data availability as well as the performance of the pollution monitoring system. The research will focus on developing a real-time air and noise pollution monitoring system by transferring the data from Air Quality Sensing Module and Sound Detection Module to clouds with the aid Internet of Things (IoT).

1.4 Objectives

The aims of the Final Year Project (FYP) are

i) To develop an air and noise pollution monitoring system

ii) To design an air and noise monitoring system for storing and displaying information collected to the cloud platform

iii) To validate the reliability of the information collected from the air and noise pollution monitoring system

1.5 Scope

The extents of the area of the monitoring system are:

a) The detection of the pollution is focused on the air and noise pollution.

b) The number of sensors used in the monitoring system is three where 2 sensors are used to detect the concentration of carbon dioxide and carbon monoxide respectively whereas another sensor is a sound sensor which is used to detect sound level.

c) The coverage area of the monitoring system is set within 11L which is 360mm x 250mm x 220 mm.

d) The demonstration environment for the monitoring system is focused on the open area.

e) The monitoring system is tested in a storage box which has a size of 11L.

f) The cloud platform is focused on the open source of Internet of Things (IoT) platform.

1.6 Report Outline

Chapter 1 of this report introduced the motivation of this project. Thus, problem statement of this project is explained in details. Besides, the scope and objectives of this project are listed based on the purpose of the project.

Chapter 2 of the report covered the background knowledge of air and noise pollution as well as their monitoring system. Reviews of related works and evaluation of the methods used for monitoring system over IoT are presented.

In Chapter 3, the methodology to achieve the objectives of the proposed project is discussed. Explanation on the selected components used in hardware and the experiments conducted as well as the procedures of the experiments are described.

Chapter 4 illustrated the results obtained from the experiments and presented in the form of graphs, charts, diagrams, and tables. The discussion based on the results obtained for every experiment is done.

Chapter 5 is the last chapter of this report which the overall conclusion of this project is made as well as the recommendations and future work related to this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In this chapter, the theoretical background which is related to the project including theories on pollutions and monitoring system are presented. The research of the journals and conference papers which are related to this project is studied and the evaluation based on a few criteria is done.

2.2 Study of Pollution

Pollution is defined as a harm and poison substance that presents or introduces into the environment [12]. Pollutants could be simple things such as lights, sounds, and temperature as these are introduced into the natural environment [13]. There are some major forms of pollutions such as land pollution, water pollution, light pollution, air pollution, and noise pollution. All kinds of pollutions brought great negative impacts on the environment and wildlife as well as human health and well-being [14].

2.2.1 Air Pollution

The natural form of air is made up of exact chemical composition such as water vapour, oxygen, nitrogen, and inert gases. Air pollution happened as things introduced into it artificially [13]. Atmospheric particulate air pollution came from the sources of both natural and synthetic. Hence, air pollutants can be classified into primary and secondary. A primary air pollutant is the pollutants emitted directly into the atmosphere whereas secondary air pollutant is formed by having chemical reactions involving gas-phase precursors in the atmosphere [15]. A common type of air pollution occurred is the combustion of fossil fuels which in vehicle engines, power station, agricultural activities and mining operation [16].

According to the World Health Organization (WHO), a long exposure to ambient air pollutants increases the risk of causing airborne diseases such as cardiovascular disease, respiratory disease, and lung cancer [17]. Dangerous gas such as sulphur dioxide, carbon monoxide, nitrogen oxide and chemical vapours could create acid rain, smog and greenhouse effects which caused air pollution when they have a chemical reaction with the gases in the atmosphere. Besides, through climate change, the air pollutants of carbon dioxide will affect human health indirectly [13]. According to [18], more than 2.1 million people are died with anthropogenic due to air pollution. The poor air quality in Mumbai reached the Air Quality Index (AQI) of 305 after one day of Diwali [19]. Hence, real-time air quality monitoring system from 13 stations went live on the website of Maharashtra Pollution Control Board (MPCB) for the public to check the air quality in Mumbai [20].

There are 13 cities and towns of India are in the list of top 20 in the world's most polluted places based on WHO's report. Delhi, one of the cities in India is recorded that it had only 3 clean air days in the whole year of 2017 [21]. In order to monitor the environment as well as raise the awareness among people in Delhi, Umesh Chandra and Kamal Jaina created a web-based ambient air quality monitoring system for the public to access the real-time information of air quality in Delhi [22].

Carbon Monoxide (CO) gas is one of the elements in measuring the AQI which is odourless and colourless gas. The main sources of CO gas at outdoor are vehicles, factory or machinery that burn fossil fuels [23]. This dangerous gas is toxic to the human health as it could enter the bloodstream through the lungs and reduce the oxygen gas level in human body. In the view of health, exposure to high level of CO gas can affect mental alertness and vision [24]. There is a case that an adult is dead and a youth injured after getting CO poisoning in Salmon Arm. The source of the emission of CO gas in this case is the fuel from the camp stove. Hence, CO gas sometimes called invisible killer as it may not have warning sign of its presence [25]. The Table 2.1 shows the health effects due to prolonged exposure and government limit on the various level of CO gas.

Table 2.1: Health Effects Due to Prolonged Exposure of the Level of Carbon Monoxide (CO) Gas [26]

Level of CO	**Health Effects, and Other Information**
0 PPM	Normal, fresh air.
9 PPM	Maximum recommended indoor CO level (ASHRAE).
10-24 PPM	Possible health effects with long-term exposure.
25 PPM	Maximum exposure for 8 hours work-day (ACGIH)
50 PPM	Maximum permissible exposure in workplace (OSHA).
100 PPM	Slight headache after 1-2 hours.
200 PPM	Dizziness, nausea, fatigue, headache after 2-3 hours of exposure.
400 PPM	Headache and nausea after 1-2 hours of exposure. Life threatening in 3 hours.
800 PPM	Headache, nausea, and dizziness after 45 minutes; collapse and unconsciousness after 1 hour of exposure. Death within 2-3 hours.
1000 PPM	Loss of consciousness after 1 hour of exposure.
1600 PPM	Headache, nausea, and dizziness after 20 minutes of exposure. Death within 1-2 hours.
3200 PPM	Headache, nausea, and dizziness after 5-10 minutes; collapse and unconsciousness after 30 minutes of exposure. Death within 1 hour.
6400 PPM	Death within 30 minutes.
12,800 PPM	Immediate physiological effects, unconsciousness. Death within 1-3 minutes of exposure.

Besides of carbon monoxide gas, carbon dioxide (CO2) has its effects on air pollution as its concentration increases. carbon dioxide is one of the greenhouse gases as it traps radiation at ground level which creating ground-level ozone. This phenomenon causes the increase of concentration of carbon dioxide gas contributes to air pollution. In addition, increase in the concentration of carbon dioxide gas in our environment will lead to climate change, acid rain and human health impacts. Carbon dioxide emissions will displace the oxygen in atmosphere which will increase the difficulty of human breathing [27]. There are also other impacts of carbon dioxide gas on human health such as headaches, restlessness, drowsiness and so on. The Table 2.2 below shows the different level of carbon dioxide causes different impacts on human health.

Table 2.2: Level of Carbon Dioxide Gas and Potential Health Problems [28]

Level of Carbon Dioxide	**Potential Health Problems**
250 - 350 ppm	Background (normal) outdoor air level.
350 - 1,000 ppm	Typical level found in occupied spaces with good air exchange.
1,000 - 2,000 ppm	Drowsiness and poor air.
2,000 - 5,000 ppm	Headaches, sleepiness, and stagnant, stale, stuffy air, poor concentration, loss of attention, increased heart rate and slight nausea
5,000 ppm	• Unusual air conditions where high levels of other gases could also be present. • Toxicity or oxygen deprivation could occur. This is the permissible exposure limit for daily workplace exposures.
40,000 ppm	Immediately harmful due to oxygen deprivation

2.2.2 Noise Pollution

In general, noise pollution is defined as the exposure of unwanted sound level which may have deleterious effects on human and the environment. Noise pollution is mainly generated from human activities especially in industrial area, construction area, land or air traffic and so on. For instance, the construction sounds from the operation of heavy machines, drilling and pilling [29]. Sound is a noise which described in terms of loudness and pitch. The decibels (dB) is the logarithmic unit used to measure the loudness whereas frequency (Hz) is used to express the pitch of a sound [30].

Noise pollution has brought huge negative impacts to human, wildlife and marine life. There are various ways which noise pollution can be harmful to human health as the diseases could be hypertension, hearing loss, sleep disturbances, cardiovascular dysfunctions, psychological dysfunctions and noise annoyance. Besides, the children development has been affected and the fact in 2001, 12.5% of between 6 to 19 years old American children are estimated to have impaired hearing. Long-term of sleep disturbances could be a serious problem as it will lead to everyday performance and other diseases [29].

The sound from 0dB to 140dB and 20Hz to 20,000Hz is the detection range of the human ear where sound beyond 120dB is the pain threshold for the human ear [30]. The daily exposure of an average of 55dB noise could impact human health in nonauditory such as increases in stress hormones, hypertension, obesity, cardiac disease, and mortality [31]. Being exposed to loud noise level which 140dB and 120dB for adult and children respectively can cause hearing loss. According to [32] , people exposed to traffic noise with a daily average noise level of 65dB would have developed hypertension at a risk of 6% compared to the people exposed to the average 55dB noise level.

The World Health Organization (WHO) stated, regardless of the consistency and the period of exposure, sound levels not exceeding 70dB are harmless to living organisms. However, exposure to a constant noise level that more than 85dB and 8 hours may be dangerous [29]. On the other hand, the National Institute on Deafness and Other Communication Disorders mentioned that hearing loss where people exposed to sound beyond 85dB in long term. However, 85dB is not a safe sound level as exposure time is not considered. Hence, the EPA had done a calculation and stated that the public safe sound level is 70dB for an average of 24 hours in order to prevent hearing loss [31].

In order to maintain the harmony between human's activities and environment, K. Vogiatzis studied the environmental noise and air pollution monitoring in Athens Ring Road [33]. The method used to calculate the noise level in K. Vogiatzis's paper is similar to the Marin Marinov [34] where the basis of the Acoustic measurement is implemented. The Acoustic measurement is a process affected by many variables which only some of them can be controlled and measured, thus, noise constantly changes in time and space domain. Sound level can be measured in sound pressure level (SPL) which is denoted in unit of decibel (dB) and it is defined as a logarithm scale. [35].

2.3 Air and Noise Pollution Monitoring System

A pollution monitoring system is considered as one of the methods to control and predict the pollution level of the region nowadays. There are many studies proved that the increase of pollution level in the world is affecting the living organism including the environments. The pollutants damaged the environments and it showed obviously in the climate change from a few ten years compared to now. Global warming is getting serious as a huge difference of the temperature in summer and winter seasons for two consecutive years in Europe countries indicated the Earth is sick [36]. The impacts on the environment will undoubtedly affect the human being and animals in terms of living quality. The consequences of pollutions on the human health are concerned and many researchers studied the relationship between the type of pollutions and the diseases on human. Solving the pollutions are difficult as well as reducing the pollution level. However, there are some researchers have figured out to control the pollutions by monitoring it using a system. Hence, the information collected from the monitoring system can be used to alert the public and analyse by the analyser in order some actions can be taken by the authorities. The relative pollutions monitoring system done by the researchers are summarized as shown in Table 2.3 below.

Table 2.3: Comparison of Monitoring System over IoT from Previous Studied Journals or Papers

Journal/ Conference Paper with Criteria	**IOT Based Air and Noise Pollution Monitoring System** [37]	**A Raspberry Pi Controlled Cloud Based Air and Sound Pollution Monitoring System with Temperature and Humidity Sensing** [10]	**IoT based air pollution monitoring and predictor system on Beagle Bone Black** [38]	**IoT-Enabled Air Quality Monitoring Device** [39]	**An IoT Based Low Cost Air Pollution Monitoring System** [40]	**IoT Enabled Proactive Indoor Air Quality Monitoring System for Sustainable Health Management** [41]	**Real-time Air Quality Monitoring System for Bangladesh's perspective based on Internet of things** [42]	**IOT based environmental pollution monitoring system** [43]	**Air Pollution and Particulate Matter Detector Using Raspberry Pi with IoT Based Notification** [44]
Sensors Used	1. MQ 135 air sensor 2. FC04 noise sensor	1. MQ135 gas sensor 2. LM393 sound sensor 3. DHT11 temperature and humidity sensor	1. MQ-7 gas sensor 2. MQ-11 gas sensor	1. Light sensor 2. Gas sensor 3. CO2 sensor 4. HCHO sensor 5.Temperature sensor	1. MQ7 gas sensor 2. MQ135 gas sensor	1. Ozone sensor	1. MQ-2 gas sensor 2. MQ-3 gas sensor 3. MQ-7 gas sensor	1. MQ-7 gas sensor 2. M213 noise sensor 3. LM35 temperature sensor 4. SY-HS220 humidity sensor	1. SHARP GP2Y1010 AU0F compact optical dust sensor 2. MQ-7 gas sensor

Contro-ller Used	ARM7 microcontro-ller with nRF24L01 Wi-Fi module	Raspberry Pi Model 3B	Beagle Bone Black	Marvell 88MW302	Raspberr-y Pi 3	Raspberry Pi-3	Microcont-roller Intel® Edison Board	Arduino Uno board with wi-fi module 8266	Raspberry Pi 2B
Hardw-are and/or Softwa-re System	Arduino programmi-ng	Python programm-ing	Python program-ming	1. Marvell C programm-ing language 2. Python programm-ing	Java program-ming	N/A	Python programm-ing	Programm-ing languages C and C++	N/A
Medium Used to Comm-unicate	Internet	Internet	Internet with Azure Cloud	Internet with AWS cloud	Internet	Internet	Internet	Internet	Internet
Region to Install	1.Hospitals 2. highways 3. Schools and campus 4.Streets 5. Parks 6. Homes 7.Mall	N/A	Smart city	1.Crowded auditorium 2. Schools 3.Playgrou-nds 4.Factories 5.High traffic areas	N/A	Near a high volumes photocopy machine	1. House 2. Industry 3. Crowded workplace	Industrial area	Pilot site in Barangay 836 Zone 91

2.3.1 A Components Used in Monitoring Systems

2.3.1.1 Type of Sensing Units

Based on summarized papers shown in Table 2.3, all the papers studied involve the hardware application which used a different type of sensors as sensing units to collect information in order to establish the monitoring system. The sensing unit is dependent on the parameters required by the monitoring system. In this section, the air and noise sensors used by the researchers in Table 2.3 will be discussed as other sensors are not in the scope of the proposed system.

Referring to Table 2.3, both of the MQ135 and MQ7 gas sensors were frequently used in detecting the air pollution and air quality. In the paper [40], the sensors used in hardware was both of that two sensors, MQ135 and MQ7, to monitor the air pollution. The gas sensor of MQ7 has high sensitivity to carbon monoxide which its detection range is between 20ppm to 2000ppm. It can be used in detecting carbon monoxide (CO) in family, industry or car as domestic gas leakage detector, industrial CO detector or a portable gas detector. The simple drive circuit of MQ7 gas sensor has been widely used in the pollution monitoring system and also air quality monitoring system shown in [42]. This indicated that air quality relatively affects the results of air pollution. Hence, the MQ7 gas sensor is one of the important sensors to detect the level of air pollution.

Besides MQ7 gas sensors, MQ135 gas sensor is most often applied in diagnosing the air pollution as out of 9 papers studied, 3 papers [37], [10], [40] chose MQ135 gas sensor in their project, indicating that MQ135 is helpful in monitoring the air pollution. This is due to its wide detecting scope where it is high sensitivity to ammonia, sulphide and benzene. The detecting concentration scope for ammonia, benzene and alcohol are 10ppm-300ppm, 10ppm-1000ppm and 10ppm-300ppm respectively. The low cost of MQ135 gas sensor has a simple drive circuit which can be applied as air quality control equipment for buildings and offices.

Furthermore, the gas sensor of MQ11 applied in the paper [38] is a hydrogen gas sensor which used to measure the hydrogen gas. In the paper of [42], 3 unit of the gas sensor, MQ7, MQ 2 and MQ3 are applied. MQ2 gas sensor has high sensitivity to LPG, propane and hydrogen where it also has good sensitivity to combustible gas in a wide range. The detection concentration of combustible gas is between 300ppm to

10000ppm. Moreover, the MQ3 gas sensor has high sensitivity to alcohol and small sensitivity to Benzine. Hence, it is mostly used for alcohol checker, Breathalyser as the detecting concentration scope for alcohol is 0.05mg/L- 10mg/L. From the paper studied, the implementation has the gas sensor, CO_2 gas sensor and HCHO gas sensor. The selected of HCHO gas sensor is due to Akshata Tapashetti believed that the volatile organic compounds of Formaldehyde (HCHO) gas is the major components that causing respiratory system [39]. The exact type of gas sensor and CO_2 gas sensor are not specified in this paper. Choosing of semiconductor ozone sensor in [41] has many advantages compared with that of electrochemical, optical and UV absorption ozone sensors. The low cost of semiconductor ozone sensor has high sensitivity to the low level of ozone which increases the accuracy of the sensor.

By comparing the gas sensors discussed above, the gas sensor in MQ- series has a wide detection scope, low cost, long life and a simple drive circuit. However, the elements detected by the sensors are different. In order to detect the air pollutants accurately, the gas sensor of MQ7 and MQ135 are chosen as the gas sensors in this project. There are 3 harmful gaseous that could cause air pollution and harm to human health can be detected by MQ135, where another serious pollutant, carbon monoxide can be detected by MQ7. Hence, choosing the MQ135 and MQ7 is sufficient to evaluate the air pollution level.

The papers of [37] [10] [43] included the studies of noise pollution in the monitoring system. FC04 noise sensor, LM393 sound sensor and M213 noise sensor are utilized in detecting the noise level of the papers of [37] [10] [43] respectively. FC04 noise sensor module uses a microphone to obtain the sound input and give the digital output. The LM393 sound sensor is a sensitive adjustable sensor which the sound is detected via microphone and fed into an op-amp of LM393. Both analog and digital output can be given out by this sensor. The M213 noise sensor detects sound and its intensity using the microphone to the maximum 60dB only. However, all the noise sensor discussed above is not chosen to be implemented in the monitoring system. This is due to the noise sensors do not consist of a low noise microphone where unwanted noises can be detected during the data collection.

2.3.1.2 Controller for Monitoring System

There are a microcontroller and single board computer (SBC) used in the studied papers of the monitoring system. The controller in the monitoring system is connected to the sensors and the data collected are transferred to the controller for processing and uploading the data based on the paper studied. A controller is needed to connect with a Wi-Fi module if the controller does not have the built-in Wi-Fi features. An extra Wi-Fi module is needed for the ARM7 microcontroller in [37] and Arduino Uno board in [43] in order to upload the data collected from the sensors.

Moreover, there are some cases that the controller is not directly connected to the sensors. This is due to the unavailable analog inputs pin at the controller which unable to receive the output data of the sensors in analog form. Hence, an analog-to-digital converter (ADC) is required to be connected between sensors and controller. From the paper studied, an analog-to-digital converter (ADC) is not required when the controller used in the system is Marvell 88MW302, Beagle Bone Black and Microcontroller Intel® Edison Board as they consist of a full set of analog and digital I/O interfaces. In the paper [39], Marvell 88MW302 board is attached to a base shield which can connect up to 16 sensors that are of the type need to be connected to the ports analog, digital, I2C, UART on the base shield.

According to the paper in [40], the Raspberry Pi is set as a Base Station in the wireless monitoring system based on the low complexity and affordable price. The high flexible minicomputer which allowed it interfaced with many devices simultaneously encouraged the applying of Raspberry Pi in the wireless monitoring system. There are various models of Raspberry Pi where three different models of Raspberry Pi are shown in Table 2.2. Raspberry Pi 3B and Raspberry Pi 3 are used in the paper of [10] [40] [41] respectively instead of Raspberry Pi 2 in [44]. Although the appearance of Raspberry Pi 2, Raspberry Pi 3 and Raspberry Pi 3B are the same, their performances are slightly different in term of connectivity and compatibility [45] [46].

2.3.2 Software Applied in Monitoring Systems

A programming language is used in controlling the performance of a machine or expressing the algorithms as it is a notation design for connecting a machine or computer with instructions. There are a few types of programming language whereas they can support various programming style [47]. The type of the controller decides the type of the programming language used. It can be clearly seen from Table 2.2 that each hardware or software system applied in the paper studied had different types of the programming languages. Python programming is considered favourable as this programming language is used in 4 out of 9 papers studied. Besides python programming language, Java, C and C++ programming languages are used in other papers studied. C++ is the object-oriented programming language based on the C language. This language is preferable for performance-critical applications which can be audio or video processing [48].C programming language is the subset of C++ programming language. C programming language is unable to support function and operator overloading whereas C++ does [49].

Python programming is simple and its language is readable as it is a high-level language which nearly resembles the English language. Hence, it is easier than other languages [48]. Besides, Python can be embedded in C and C++ in the addition for the users to modify and reuse the open source code. Furthermore, Java is one of the most popular programming languages due to its readability and simplicity. The attraction of Java language is its long-term compatibility where it can bring the older applications to future. Writing, Compiling and debugging is easy in Java language as its platform is independent and the code is reusable [50].

2.3.3 Application of Internet of Things (IoT)

All the paper studied used the internet as the communication medium. This is due to the technology of IoT which can transmit the information directly through the internet. The data collected from the sensors are transferred to clouds over IoT. Cloud is a storage which managed to keep and save the data sent to it. Based on the papers [38] [39]the information is sent to a platform called Azure Cloud and Amazon Web Services (AWS) Cloud. However, other papers have not mentioned the cloud platform used in their system. Both clouds are pay-as-you-go model where AWS cloud is charged per hour whereas Azure cloud is charged per minute. Hence, Azure cloud has the exact pricing compared to AWS cloud [51].

The conventional air pollution monitoring system monitored the air pollution situation using a stationary monitor which capable to measure pollutants in a wide range. This conventional monitoring system is time-consuming as updating of air pollution situation only be done hourly or daily [1]. Applying the IoT in the monitoring system could speed up the updating of the air pollution information. There are some journal and conference papers which IoT system is applied in a monitoring system have been studied. The researchers in [52] [53] proposed an air quality monitoring system with IoT based. In the conference paper [52], the technique of IoT and cloud computing are utilized to manage the data collected from sensors in a better way. Thus, accessing and analysing the data stored at the cloud can be done at any time with ease.

Better management of data increase the simplicity in analysing the scenarios of the pollution and resulted in proposing ideas for controlling the pollutions. According to [53], integration on IoT technology to detect pollution is crucial as transmitting the data collected by the system to a web-page application can be done in a very short time. Hence, monitoring and collecting of real-time data can be accomplished by applying IoT in the system, thus, risk management can be done right away.

IoT is a good platform for introducing the autonomic behaviour to many sectors such as industrial, agriculture, building management, transportation and healthcare. However, everything comes with two sides including the application on IoT. Table 2.4 showed the advantages and disadvantages of IoT system.

Table 2.4: Advantages and Disadvantages of IoT [54] [55] [56]

Advantages	**Disadvantages**
Automation - Minimize human intervention - Maximize the efficiency of services	Privacy and Security - Risk of leakage the confidential information
Cost-effective - Conserve cost and energy as devices communicate in a required way	Complexity - Failure in either single loophole caused disastrous consequences
Communication - Convenience in interacting between machines	Compatibility - Unavailable of international standard caused different manufactured devices difficult in communication
Instant Data Access - Fasten process of making a decision - Controlling devices in real time	Lesser employment - Decrease in the need of the human labour
	Dependability - Reduce human communicating skills

The study and analysis of the bad of the technology of IoT is crucial in order to prevent the failure occurred, at the same time enhance the system. However, it is no doubt that technology of IoT has brought a lot of advantages in the region of technology end engineering as well as business. Transmitting the real-time data collected can be done instantly with the technology of IoT. Applying the IoT in the monitoring system increase effectiveness of the system and hence, the data presented at cloud can be retrieved any time which allow the scenario of pollution can be analyzed more accurately.

2.3.4 Region to Install Monitoring System

The region to install the monitoring system in the paper studied covered a wide range of area. It had the similarity that the system is likely to be installed in an area that mostly would have appeared many noise and air pollutants or a place that need to have a low noise and air pollutants. It is obviously presented in Table 2.3 where the regions suggested installing the monitoring system in the paper [37] are hospitals, schools, streets, homes, parks and mall. There will be various ages of people and different human health level. For instance, patients in the hospital need to have a quiet and clean environment for fast recovery. Homes are the comfort zone for people to rest after the entire working day. Hence, these regions are important to be a place free of pollution.

Other than the region stated in [37], Industry and crowded workplace are suggested as the area to install the system [42]. This is due to the workers in the industrial area are facing long-term air and noise pollution seriously every working day. However, installing the system in residential areas is better as homes are the place where human stay most often.

2.4 Conclusion

There are pros and cons in the air and noise pollution monitoring system based on the comparison from the previous studied papers which summarized in Table 2.3. In order to select the desired setup for the proposed system, the pros and cons of each system are discussed.

The Internet of Things (IoT) is becoming popular as its advantages of instant data access and automation behaviour. The technology of IoT is common to establish communication between machines and human. It has allowed the automation behaviour in the system where transferring of data manually is not needed. Hence, the data can be sent instantly with the technology of IoT. The real-time data collected can be transferred to the cloud and accessed by the authorities just a click of time. The approach of IoT in the proposed system enable to produce a low-cost monitoring system as currently, the IoT is a cost-effective technology. Thus, implementation of IoT technology in the proposed air and noise monitoring system benefits in many ways.

Furthermore, there are various controllers used in a monitoring system which has a microcontroller and single-board computer (SCB). Choosing ARM7 microcontroller or Arduino Uno board as the controller of the monitoring system is not a smart choice as an extra Wi-Fi module is needed. This extra needed of Wi-Fi module has added up to the total cost of the monitoring system. Hence, choosing a controller which have built-in Wi-Fi module is preferable as this allows of sending data over IoT with an unlimited area of coverage. Although some criteria of Beagle Bone Black and Microcontroller Intel® Edison Board are more powerful than that of Raspberry Pi, a low cost of Raspberry Pi is sufficient to fulfil the criteria and condition needed for the proposed monitoring system. Hence, the Raspberry Pi is adequate to support and accomplish the objectives of the proposed monitoring system.

The python program language is preferred in programmed the proposed system due to its high level, easy to read and comprehend as well as applicable in Raspberry Pi. The high flexibility and the embedded C and C++ program language in it save the time and space when running of the scripts. Although the Java program language is more verbose coding style, Python program language is suitable to be used in program the monitoring system.

There are a few types of sensors which used to detect various gas to calculate the air pollution level. Among the system used to detect the air quality and pollution, most frequent used sensors are MQ135 and MQ7. These gas sensors can be connected to the controller and sent the data collected to the Raspberry Pi. Besides, the simple connection of these two sensors to the Raspberry Pi can reduce the possibility of wrong connection circuit in the monitoring system. The two gas sensors are sufficient to monitor the air pollution level as MQ135 can detect various type of harmful gaseous whereas MQ7 gas sensor detects carbon monoxide gas. In selecting the sound sensors, the gravity analog sound level meter SKU SEN0232 is chosen to be implemented in the proposed system due to its low noise microphone. This can prevent the unwanted noise is detected during the data collection from the monitoring system.

2.5 Summary

In overall, the theoretical background related to this project is presented. The pros and cons of the research paper are studied and summarized in this chapter. The next chapter will cover the setup of the project with the hardware description. The designed experiments will be presented in order to accomplish the objectives of this project.

CHAPTER 3

METHODOLOGY

3.1 Overview

This chapter will present the methods used to achieve the objectives stated in Chapter 1. The project flow chart from the initial stage to the final stage is shown in this chapter. Three main parts of this chapter are hardware development, software development and experiment setup. The software and components used in hardware are briefly described. A series of experiments are designed and conducted to evaluate the performance of the proposed monitoring system. The list of equipment needed and the procedure of each experiment are listed in detail in appendices.

3.2 Air and Noise Monitoring System over IoT

The selection of hardware and software applied in the proposed system are done as the pros and cons of each component in the papers studied are discussed in the previous chapter. The system setup of the air and noise pollution monitoring system over IoT is presented as shown in Figure 3.1.

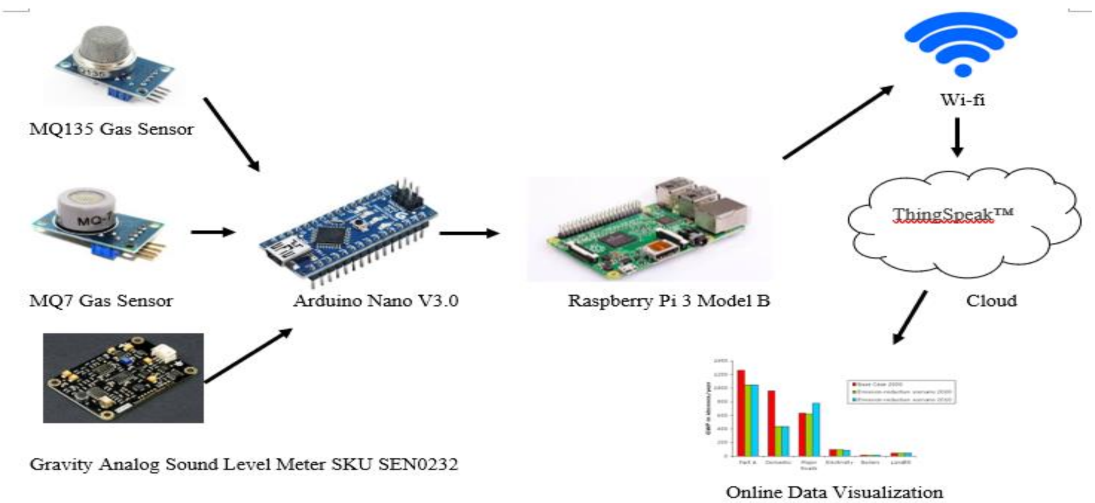


Figure 3.1: System Setup for Air and Noise Pollution Monitoring System over IoT

Based on Figure 3.1, gas sensor with the model of MQ7 and MQ135 are chosen in this project due to its low cost, wide detection range and a simple drive circuit. The Gravity Analog Sound Level Meter SKU SEN0232 is selected as a sound sensor to detect the sound level as it is capable to detect the sound level in the unit of decibel (dB). Arduino Nano V3.0 acts as an Analog-to Digital Converter (ADC) which digitalize the output of the sensors. Raspberry Pi 3 Model B is the controller of the system as it is cost effective and convenience in building IoT model where build in of Wi-fi model is available. ThingSpeak™ is selected as the cloud platform to display and store sensor data which allow analysis and visualization of data in MATLAB.

3.2.1 Hardware Development

The previous chapter has compared the type of controller based on the paper studied. Raspberry Pi is chosen as the controller in the proposed system where it is a commonly used controller in the application of Internet of Things (IoT). Thus, the low cost of Raspberry Pi which fulfil the criteria needed in this project. Arduino Nano V3.0 acts as an analog-to-digital converter (ADC) in this project as it consists of 8 analog input pins and 16 digital I/O pin which can be used to digitalize the sensor data. The low cost of the gas sensor in MQ-series has a simple drive circuit and high sensitivity. The Gravity Analog Sound Level Meter is a noise meter which has low noise microphone.

3.2.1.1 Sensors

MQ135 gas sensor shown in Figure 3.2 is a low-cost semiconductor sensor for air quality control. It has good sensitivity to carbon dioxide (CO2) gas and smoke. The conductivity of the sensor is low in clean air and the conductivity increases as the concentration of the targeted gas increases. The main reason for choosing this sensor is due to its wide detecting scope, fast response, stable and long life, and a simple drive circuit which capable to operate in 5V power supply.

Figure 3.2: MQ135 Semiconductor Sensor

The MQ7 shown in Figure 3.3 is a semiconductor sensor to detect carbon monoxide. The reason of choosing the MQ7 gas sensor in this project is due to its high sensitivity to natural gas, long life, low cost and simple drive circuit [57].

Figure 3.3: Semiconductor Sensor for Carbon Monoxide

The Gravity Analog Sound Level Meter SKU SEN0232 shown in Figure 3.4 below is used as a sound sensor to detect sound level in the unit of decibel (dB) using a low noise microphone. The high measuring range and the plug-and-play which compatible to Arduino become the most suitable component to be used in the monitoring system.

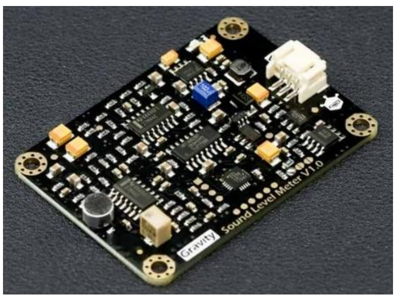


Figure 3.4: Gravity Analog Sound Level Meter SKU SEN0232

3.2.1.2 Microcontroller

In this project, Arduino Nano V3.0 shown in Figure 3.5 acts as an analog-to-digital converter (ADC) which digitalize the analog output sensors and transmit the digital data to the controller.

Figure 3.5: Arduino Nano V3.0

3.2.1.3 Mini-computer

Raspberry Pi shown in Figure 3.6 is created by the Raspberry Pi Foundation, which is an ARM based credit card sized Single Board Computer (SBC) which has a similar function with a computer device. [58]. Although Raspberry Pi is slower than a modern computer, it is a complete Linux computer which can provide the abilities in low power consumption [59].

Figure 3.6: Raspberry Pi 3 Model B

The Raspberry Pi 2B and Raspberry Pi 3 looks similar where both of them consist of four USB ports, 40 GPIO pins, Ethernet port, Camera Serial Interface (CSI), Micro SD card slot and so on. However, the Raspberry Pi 3 is chosen to be used in this project as the Central Processing Unit (CPU) Clock is 1.2GHz which is higher than that of in Raspberry Pi 2 which is 900MHz.

3.2.2 Software Development

In 1999, Kevin Ashton who attributed the phrase “Internet of Things” in the presentation of Proctor and Gamble (P&G) to link the Radio Frequency Identification (RFID) into the internet [60]. Nowadays, IoT is taking the lead in the world of advanced technology as its easy people life. Hence, the concept of IoT is utilized in this project where the data obtained from the system is needed to be uploaded and stored in cloud.

3.2.2.1 ThingSpeak™

ThingSpeak™ is an open data platform providing various services which specially designed for building IoT applications which capable to store, analyze and visualize the data sent to ThingSpeak™. The “Thing speak channel” is the core element of ThingSpeak™ which stores the data sent and it is visualized in the form of charts in ThingSpeak™. [61].

ThingSpeak™ is an open source which can be changed and adapted by users with their needs. Programming languages such as Ruby, Python and Node.js. can be used to communicate between the hardware devices and ThingSpeak™. The integration of ThingSpeak™ with any hardware device such as Arduino, Raspberry Pi and others microcontroller provides flexibility in controlling a user’s project as the connection between them can be run locally. The most important is that the data channel of ThingSpeak™ provides free hosting [62]. Based on the advantages described above, ThingSpeak™ is selected as the cloud service in the air and noise pollution monitoring system.

3.3 System Architecture

The overall chart of air and noise monitoring system over Internet of Things (IoT) is shown in Figure 3.7 below.

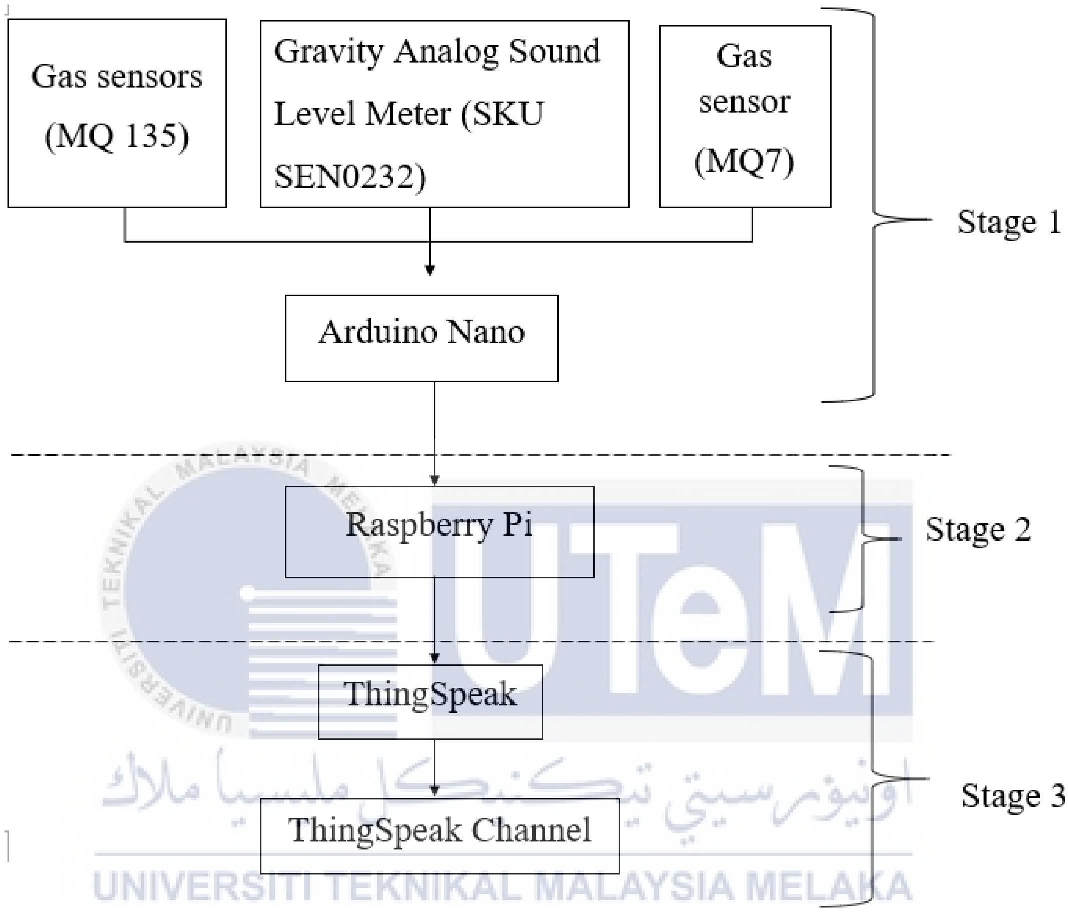


Figure 3.7: Overall Chart of Air and Noise Pollution Monitoring System over IoT

Based on Figure 3.7 shown above, the air and noise pollution monitoring system is divided into 3 stages. The purpose of each stage is explained in Figure 3.8 where the process in the system is presented as a flow chart in Figure 3.9.

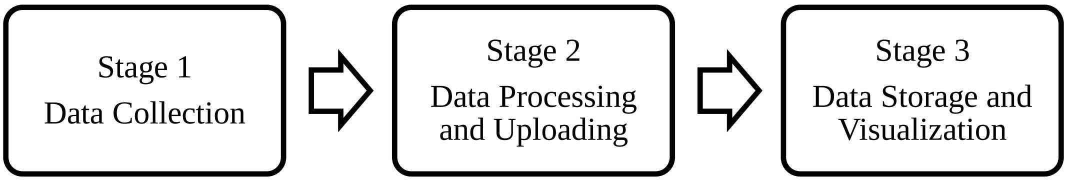


Figure 3.8: The Functionality of Each Stage of Air and Noise Monitoring System over IoT

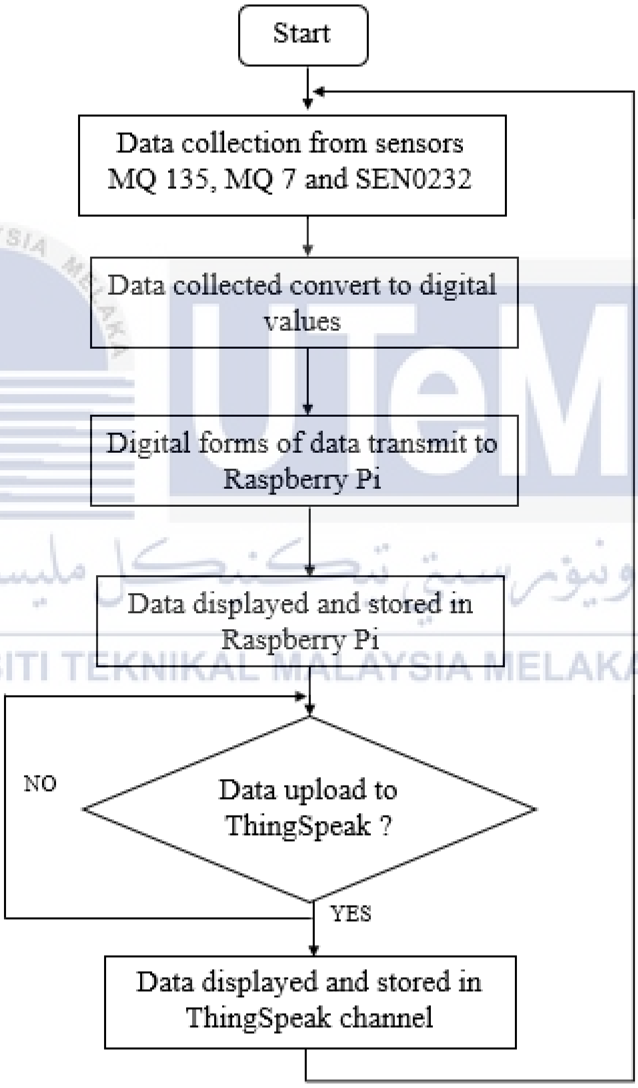


Figure 3.9: Flowchart of the Air and Noise Pollution Monitoring System over IoT

3.3.1 Initial Setup

The installation of each component in the circuit is explained in this section. The schematic diagram of the air and noise pollution monitoring system is shown in Figure 3.10 where the hardware setup of the air and noise pollution monitoring system is shown in Figure 3.11.

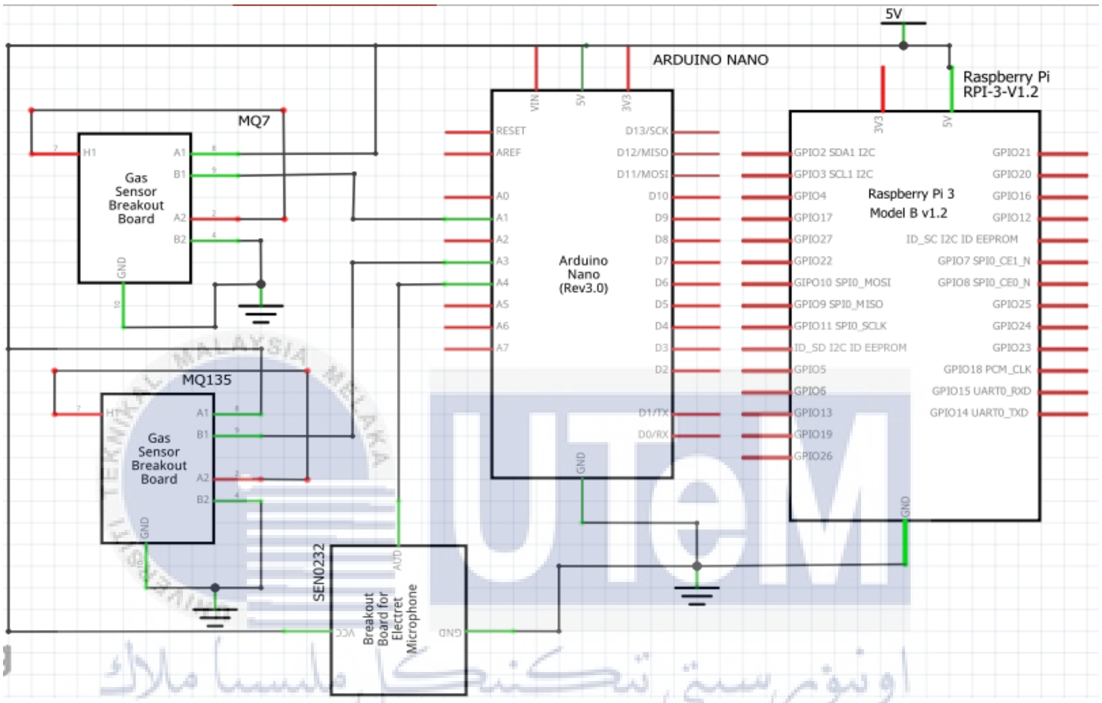


Figure 3.10: Schematic Diagram of the Air and Noise Pollution Monitoring System

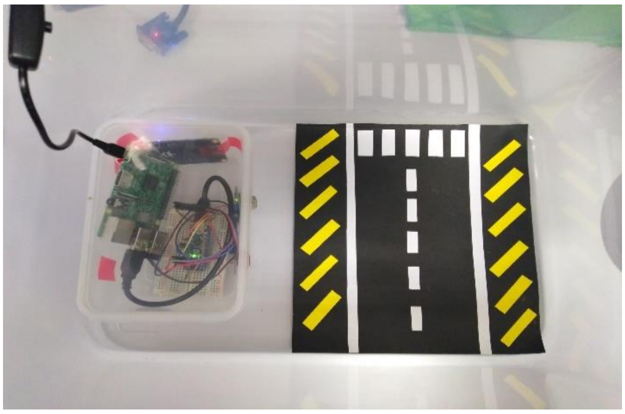


Figure 3.11: Hardware Setup of Air and Noise Pollution Monitoring System

The system in Figure 3.11 above consists of the components listed as above:

- MQ 7 Gas Sensor
- MQ135 Gas Sensor
- SEN 0232 Gravity Analog Sound Level Meter
- Arduino Nano V3.0 as ADC
- Raspberry Pi 3 as controller
- 5V Power Supply for Raspberry Pi 3

The 5V power supply is not shown in the schematic diagram due to the power is supplied to the Raspberry Pi 3 which could not be drawn in the schematic diagram. It is the same for to the connection between Arduino Nano and Raspberry Pi as a USB cable is used to connect the Arduino Nano board with the Raspberry Pi. The power source received from Raspberry Pi provides the electrical energy to the sensors and Arduino board.

3.4 Experiment Setup

A series of experiments were carried out based on the objectives of this project in order to accomplish the objectives mentioned in Chapter 1. The detail of each experiment including the materials and apparatus, hardware needed and procedures were listed in the Appendix H, Appendix I, Appendix J and Appendix K. A brief explanation about the experiments conducted were discussed in this section.

3.4.1 Experiment 1: Experimenting on the Difference Between the Data Stored in Raspberry Pi and the Data Uploaded to Cloud Platform

This experiment was aimed to compare the data stored in Raspberry Pi and the data stored and shown in ThingSpeak channel. The experiment was conducted at the normal condition of the environment which was at outdoor. The monitoring system was placed in the storage box with the size of 11L. All of the data collected from the monitoring system which were sound level, carbon monoxide and carbon dioxide gas level were stored in Raspberry Pi and the ThingSpeak channel in three different fields.

The experiment was repeated with different time for one cycle of data collection time of the monitoring system to investigate whether there was data lost or disordered of data when uploading the data to ThingSpeak channel.

The stored data, collected by the monitoring system, in the Raspberry Pi and ThingSpeak was tabulated in a table for every different time of one cycle of data collection time. Both of the stored data was compared the similarity of the order of the number of data collected and then the percentage of the error in uploading the data according to the order of data stored in Raspberry Pi was calculated using (3.1) and tabulated in the table.

$$\boldsymbol{Percentage\ of\ Error}\ (\%) = \frac{\boldsymbol{X - Y}}{\boldsymbol{X}} \tag{3.1}$$

where X = Number of data collected in Raspberry Pi

Y= Number of data stored in ThingSpeak channel

The (3.1) was used to calculate the percentage of error in uploading the data according to the order of data stored in Raspberry Pi to determine whether the incidents of lost data or unsuccessful upload of data to the ThingSpeak channel occurred. The procedure of the Experiment 1 was listed in the Appendix H.

3.4.2 Experiment 2: Experimenting on the Difference Between Sound Sensor and Sound Pressure Level (SPL) Meter

This experiment was aimed to compare the data collected by the sound sensor from the monitoring system and the SPL meter. The noise level collected from the noise sensor was compared with the noise level shown in the sound meter which had a standard measurement range up to 130dB. In this experiment, the monitoring system and the SPL meter was placed in a box with the size of 11L. A speaker which had Bluetooth connection was connected to the ASUS laptop. A song was chosen to play by the speaker with different loudness of the sound level. The data collected from the monitoring system was uploaded to the ThingSpeak channel where those data was compared with the data collected by the SPL meter in the laptop.

The average of the data collected by the monitoring system and the SPL meter with different loudness of sound level was calculated using the equation shown in (3.2). Besides, the difference of average of the sound level calculated in (3.2) was calculated using (3.3) to compare the data at different loudness of sound level.

$$\boldsymbol{Average\ of\ Sound\ Level\ (dB)} = \frac{\boldsymbol{Summation\ of\ all\ the\ data\ collected}}{\boldsymbol{Total\ number\ of\ data\ collected}} \tag{3.2}$$

Difference of Sound Level between Sound Sensor and SPL Meter

$$\boldsymbol{A = |(B - C)|} \tag{3.3}$$

where A = Difference of Sound Level between Sound Sensor and SPL Meter (dB)
B= Sound Level from Sound Sensor (dB)
C= Sound Level from SPL meter (dB)

The (3.2) and (3.3) were used to calculate the data obtained from the experiment and compare the result of the experiment. The procedure of the Experiment 2 was listed in the Appendix I.

3.4.3 Experiment 3: Experimenting on the Level of Carbon Monoxide Gas

This experiment was aimed to check whether the level of CO gas detected by the MQ7 gas sensors from the monitoring system was well function as it showed 0ppm in the indoor environment. This experiment was a very simple as it had no compare the data with other apparatus. The box with size of 11L which had the monitoring system inside, was placed behind the exhaust pipe of a VIVA car. The experiment was repeated with placing the box at different distance away from the exhaust pipe. The data collected from the monitoring system was stored in the ThingSpeak channel. The average of the level of carbon monoxide (CO) gas was calculated using the formula as shown in (3.4) to define the pattern of the data collected in this experiment.

$$Average\ of\ CO\ gas\ level(ppm) = \frac{Summation\ of\ all\ the\ data\ collected}{Total\ number\ of\ data\ collected} \quad (3.4)$$

The (3.4) was used to calculate the average of level of carbon monoxide gas in the unit of ppm in each repeated test of experiment. The procedure of the Experiment 3 was listed in the Appendix J.

3.4.4 Experiment 4: Experimenting on the Level of Carbon Dioxide Gas

The experiment was aimed to compare the detection of the level of carbon dioxide (CO2) gas with the sources of the CO2 gas which was dry ice. The experiment was conducted in the outdoor environment due to the safety purposes. Before conducting the experiment, the concentration of the CO2 gas will be sublimated from the dry ice was calculated based on the theory shown in (3.5). Then, the monitoring system and the glass bottle which had added weighted dry ice were placed in the box with size 11L. The data obtained from the monitoring system was uploaded to the ThingSpeak channel. The average level of CO2 gas was calculated using the formula shown in (3.6).

$$Level\ of\ CO2\ gas\ in\ theory\ (ppm) = \frac{Amount\ of\ dry\ ice\ (g)}{Volume\ of\ the\ box\ (m^3)} \quad (3.5)$$

$$Average\ level\ of\ CO2\ gas\ (ppm) = \frac{Summation\ of\ all\ the\ data\ collected}{Total\ number\ of\ data\ collected} \quad (3.6)$$

The (3.5) and (3.6) were used to calculate the level of carbon dioxide gas in every repeated test of the experiments. The procedure of the Experiment 4 was listed in the Appendix K.

3.5 Summary

In overall, detail of experiments was provided and explained to ensure the objectives of this project can be achieved. The equipment needed and procedure of each experiment was listed in the Appendices. Most of the test of the experiments were repeated 10 times in order to obtain the a more accurate of the measurement. The average of the data collected was calculated in some of the experiment for comparison purposes with other changing variables of the experiment. The results of the designed experiments and the corresponding analysis were presented in the next chapter.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Overview

This chapter will present the results obtained from the conducted experiments stated in the previous chapter. The results of each experiment were recorded and tabulated in the form of a table, graph or chart for better understanding of the different type of parameters measured from each experiment.

4.2 Result of Experiment 1: Experimenting on the Difference Between the Data Stored in Raspberry Pi and the Data Uploaded to Cloud Platform

The experiment setup of Experiment 1 was shown in Figure 4.1 below where the air and noise pollution monitoring system was place in a storage box with the size of 11L. Then, the storage box was placed at a normal condition of the environment at outdoor.

Figure 4.1: Experiment Setup of Experiment 1

The experiment was conducted with three different time of data collection by the monitoring system which were 10s, 15s and 20s. The data collected was stored in the Raspberry Pi in the monitoring system and hence, the data was uploaded to a cloud platform which was ThingSpeak. The data stored in the Raspberry Pi as text file were shown in Figure 4.2, Figure 4.4 and Figure 4.6 whereas the uploaded data in the ThingSpeak channel were shown in Figure 4.3, Figure 4.5, and Figure 4.7 in below. All the data was tabulated in the Table 4.1, Table 4.2 and Table 4.3 shown as below.

4.2.1 Result on Experimenting the 10 Seconds As One Cycle of the Data Collection Time of the Monitoring System

The data, collected by the monitoring system, stored in Raspberry Pi and the uploaded data in ThingSpeak channel were shown in Figure 4.2 and Figure 4.3 below respectively. The comparison of the data collected in Raspberry Pi and ThingSpeak channel was tabulated in the Table 4.1 below.

File Edit Format View Help

399	0	64
407	0	65
399	0	63
399	0	66
399	0	62
399	0	63
392	0	63
407	0	66
399	0	65
399	0	63
399	0	62
392	0	62
399	0	63
407	0	63
399	0	64
399	0	69
392	0	68
407	0	64
399	0	63
414	0	63
392	0	63
399	0	64
399	0	62
399	0	62
407	0	63

Figure 4.2: Text File Stored in Raspberry Pi for 10s As One Cycle Data Collection Time

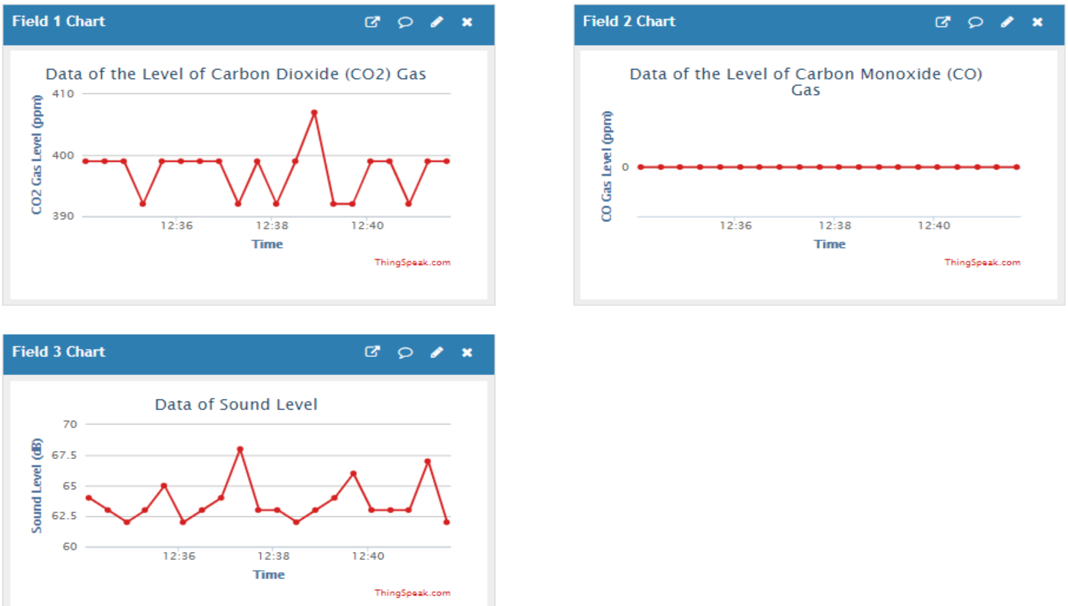


Figure 4.3: Plotted Graph of 10s As One Cycle of Data Collection Time in ThingSpeak Channel

Table 4.1: Result from Experiment 1 with 10s As One Cycle of Data Collection Time

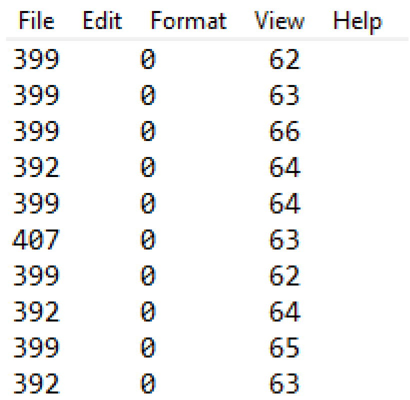
Number of Data Collected	**Data of (CO2 Gas: CO Gas: Sound Level)**		**Data Stored in Raspberry Pi Same As Data Uploaded in ThingSpeak Channel (/)**
	Data Stored in Raspberry Pi	**Data Uploaded in ThingSpeak Channel**	
1	(399:0:64)	(399:0:64)	/
2	(407:0:65)	(399:0:63)	
3	(399:0:63)	(399:0:62)	
4	(399:0:66)	(392:0:63)	
5	(399:0:62)	(399:0:65)	
6	(399:0:63)	(399:0:62)	
7	(392:0:63)	(399:0:63)	
8	(407:0:66)	(399:0:64)	
9	(399:0:65)	(392:0:68)	
10	(399:0:63)	(399:0:64)	

Based on the Table 4.1, it can be seen that there was only one time exactly the same data uploaded to the ThingSpeak channel from the data stored in Raspberry Pi in the monitoring system. The first data stored in Raspberry Pi was successfully uploaded to the ThingSpeak channel. However, the 2nd data stored in the Raspberry Pi which was (407:0:65) was not successfully uploaded to the ThingSpeak channel. The 2nd data stored in Raspberry Pi was replaced by the 3rd data stored in the Raspberry Pi to upload to ThingSpeak channel as 2nd uploaded data. This pattern of the uploading data can be seen from arrow in the Table 4.1 above as 5th, 7th and 9th data stored in Raspberry Pi were uploaded to ThingSpeak channel as the 3rd, 4th and 5th data. It had shown that a total of 5 out of 10 data stored in Raspberry Pi were not successfully uploaded to ThingSpeak channel and considered as data lost.

The occurrence of data lost was due to the process of uploading the data to ThingSpeak channel from the Raspberry Pi was slower than the one cycle of time for the monitoring system to collect the data. In other words, the time to write a data in ThingSpeak is more than 10s, which was one cycle of data collection time. Since the latest stored data in Raspberry Pi was selected to upload to ThingSpeak channel, thus, the previous data stored in Raspberry Pi had lost the chance to be selected to upload to ThingSpeak as the previous process of uploading data was not completed. The data uploaded in the ThingSpeak after the 6th data were the data after 10th data stored in Raspberry Pi. The data after 10th data stored in the Raspberry Pi was not tabulated in the Table 4.1 as the pattern of the process of uploading the data was clearly seen through the first 10 data collected.

4.2.2 Result on Experimenting the 15 Seconds As One Cycle of the Data Collection Time of the Monitoring System

The data, collected by the monitoring system, stored in Raspberry Pi and the uploaded data in ThingSpeak channel were shown in Figure 4.4 and Figure 4.5 respectively.



File Edit Format View Help

399	0	62
399	0	63
399	0	66
392	0	64
399	0	64
407	0	63
399	0	62
392	0	64
399	0	65
392	0	63

Figure 4.4: Text File Stored in Raspberry Pi for 15s As One Cycle Data Collection Time

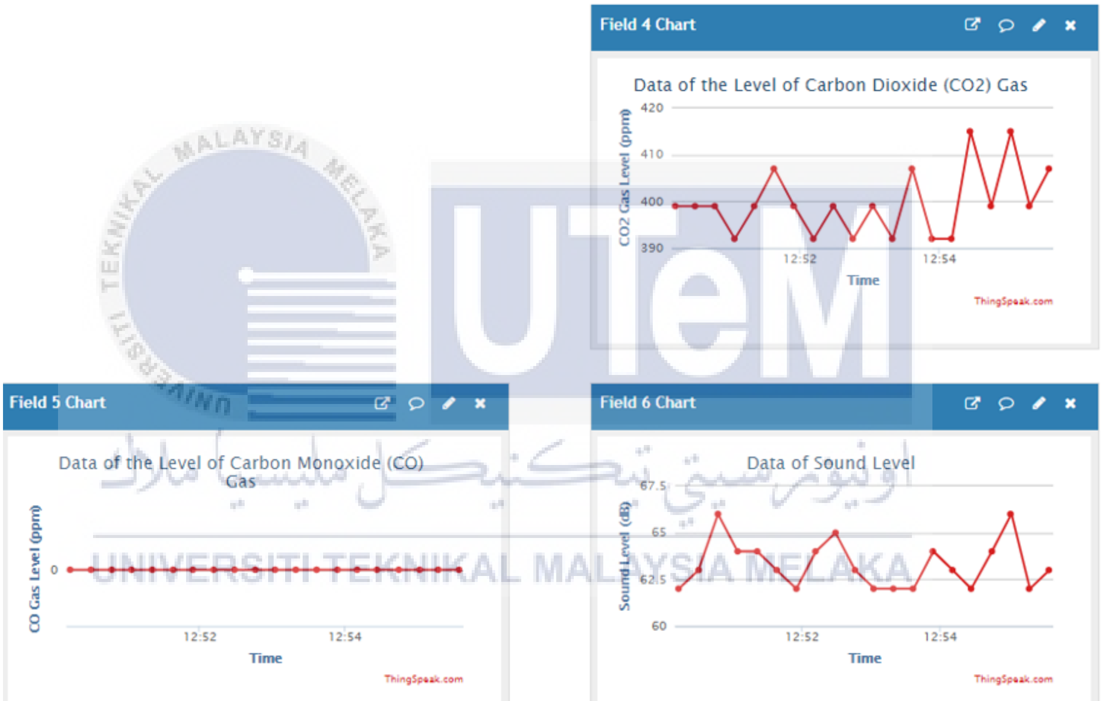


Figure 4.5: Plotted Graph of 15s As One Cycle Data Collection Time in ThingSpeak Channel

Table 4.2: Result from Experiment 1 with 15s As One Cycle of Data Collection Time

Number of Data Collected	Data of (CO2 Gas: CO Gas: Sound Level)		Data Stored in Raspberry Pi Same As Data Uploaded in ThingSpeak Channel (/)
	Data Stored in Raspberry Pi	Data Uploaded in ThingSpeak Channel	
1	(399:0:62)	(399:0:62)	/
2	(399:0:63)	(399:0:63)	/
3	(399:0:66)	(399:0:66)	/
4	(392:0:64)	(392:0:64)	/
5	(399:0:64)	(399:0:64)	/
6	(407:0:63)	(407:0:63)	/
7	(399:0:62)	(399:0:62)	/
8	(392:0:64)	(392:0:64)	/
9	(399:0:65)	(399:0:65)	/
10	(392:0:63)	(392:0:63)	/

Based on the Table 4.2, all the data stored in Raspberry Pi were successfully uploaded to the ThingSpeak channel. It can be clearly seen that 10 out of 10 of the number of data collected by the monitoring system, the uploaded data in the ThingSpeak channel were exactly the same as the data stored in the Raspberry Pi. It had proved that there was no any data lost or replaced in the order of data collected during the uploading process.

4.2.3 Result on Experimenting the 20 Seconds As One Cycle of the Data Collection Time of the Monitoring System

The data, collected by the monitoring system, stored in Raspberry Pi and the uploaded data in ThingSpeak channel were shown in Figure 4.6 and Figure 4.7 respectively.

File Edit Format View Help

393	0	63
393	0	63
399	0	63
393	0	62
393	0	62
393	0	77
393	0	64
393	0	62
399	0	62
406	0	62

Figure 4.6: Text File Stored in Raspberry Pi for 20s As One Cycle Data Collection Time

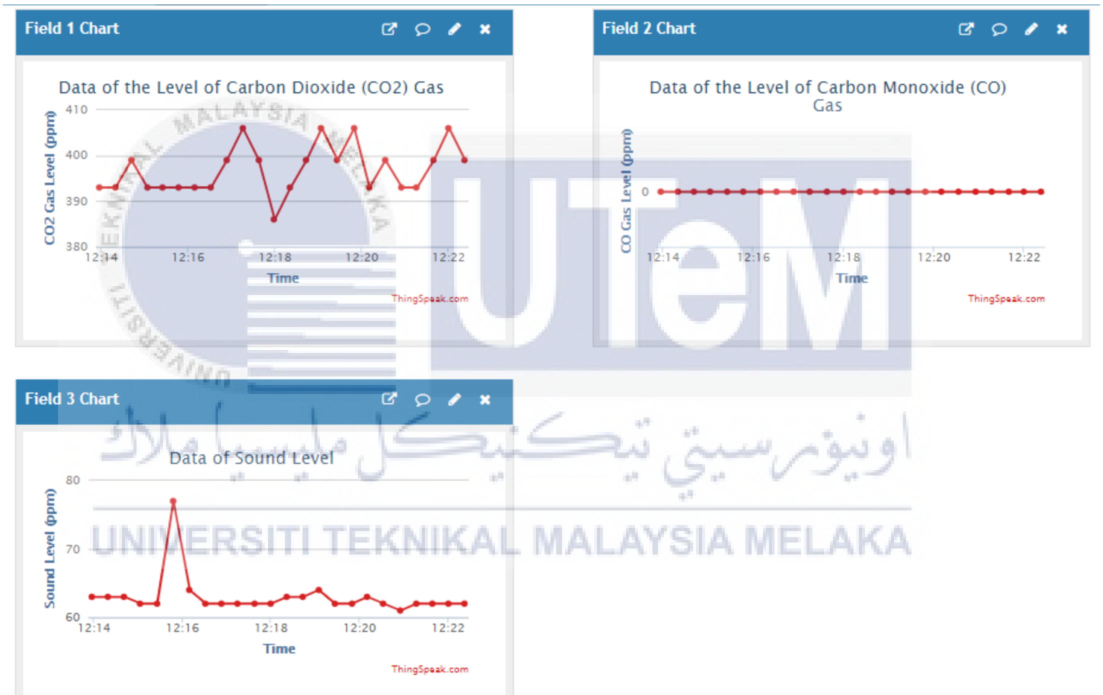


Figure 4.7: Plotted Graph of 20s As One Cycle Data Collection Time in ThingSpeak Channel

Table 4.3: Result from Experiment 1 with 20s As One Cycle of Data Collection Time

Number of Data Collected	**Data of (CO2 Gas: CO Gas: Sound Level)**		**Data Stored in Raspberry Pi Same As Data Uploaded in ThingSpeak Channel (/)**
	Data Stored in Raspberry Pi	**Data Uploaded in ThingSpeak channel**	
1	(393:0:63)	(393:0:63)	/
2	(393:0:63)	(393:0:63)	/
3	(399:0:63)	(399:0:63)	/
4	(393:0:62)	(393:0:62)	/
5	(393:0:62)	(393:0:62)	/
6	(393:0:77)	(393:0:77)	/
7	(393:0:64)	(393:0:64)	/
8	(393:0:62)	(393:0:62)	/
9	(399:0:62)	(399:0:62)	/
10	(406:0:62)	(406:0:62)	/

Based on the Table 4.3, it was obviously shown that 10 out of 10 of the number of data collected by the monitoring system, the uploaded data in the ThingSpeak channel were equivalent to the data stored in the Raspberry Pi. It had undoubted that there was no any data lost or replaced in the order of data collected during the uploading process as all the data stored in Raspberry Pi were successfully uploaded to the ThingSpeak channel according to their order of the number of data collected.

4.2.4 Result on Comparing on the 10s, 15s and 20s As One Cycle of Data Collection Time of the Monitoring System

The number of data collected and the percentage of error in uploading the data according to the order of data stored in Raspberry Pi for this experiment was tabulated as the Table 4.4.

Table 4.4: Percentage of Error for 10s, 15s and 20s As One Cycle of Data Collection Time

One Cycle of Data Collection Time (s)	Number of Data Collected	Number of the Data Stored in Raspberry Pi Same As Data Uploaded in ThingSpeak Channel	Percentage of Error (%)
10	10	1	90
15	10	10	0
20	10	10	0

Based on Table 4.4, it was certainly shown that when the one cycle of data collection time is 10s, the percentage of error in uploading the data to the ThingSpeak channel according to the order of the data collected by the monitoring system was 90%. However, the percentage of error for 15s and 20s as one cycle of data collection time were 0% which was a huge different compared to 10s as one cycle of data collection time.

The reason that caused the high percentage of error when 10s as a cycle of data collection time was the time needed for the uploading process of the ThingSpeak was more than 10s, a cycle of data collection. This was due to the minimum update time was limited to 15s since the ThingSpeak channels used were a free version of cloud. In other words, a minimum of 15s as a cycle time to upload a data to ThingSpeak channel since ThingSpeak need some times to read the next data from the sender. Hence, there was some waiting time for the next data to be uploaded after the previous data was uploaded.

Furthermore, the percentage of the error also caused by the Wi-fi speed for uploading the data to ThingSpeak channel. The slow speed of Wi-fi connected by the monitoring system created some delay of time in uploading the data. This had increased the minimum cycle time for a data being uploaded to ThingSpeak. Hence, some of the data saved in Raspberry Pi was unsuccessfully uploaded as more time was needed for the ThingSpeak to upload a data. When the time needed to upload a data was longer and exceeded the cycle of data collection time of monitoring system, the next data stored in the Raspberry Pi which should be uploaded was not selected to be uploaded. This was because of the “next data” was not the last data stored in Raspberry

Pi anymore where the ThingSpeak read the latest data stored in Raspberry Pi after the minimum cycle time for uploading a data. Thus, the delay of the uploading time also had the effect on the percentage of error in uploading the data according to the order of the data stored in Raspberry Pi.

Throughout this experiment, it was concluded that the minimum of the time for one cycle of data collection was 15s. In order to ensure all the data collected by the monitoring system was successfully uploaded to the ThingSpeak channel in correct order and prevent of the occurrence of data lost or replaced, one cycle of the data collection time of the monitoring system was set to more than 15s.

4.3 Result of Experiment 2: Experimenting on the Difference Between Sound Sensor and Sound Pressure Level (SPL) Meter

The experiment setup of Experiment 1 was shown in Figure 4.8 below where the air and noise pollution monitoring system and the Sound Pressure Level (SPL) Meter as well as a speaker were placed in the box with the size of 11L.

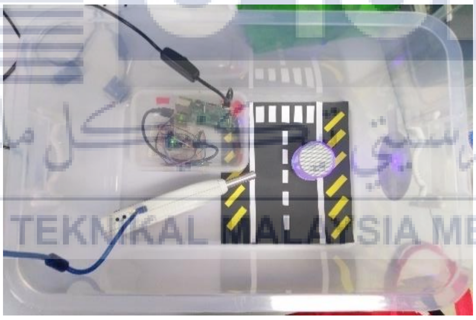


Figure 4.8: Experiment Setup of Experiment 2

The experiment was conducted with 3 different loudness of a sound played by the speaker which were 0%, 10% and 20% of the loudness. The sensor data was recorded and shown in the ThingSpeak channel where the data of the SPL meter was recorded in the laptop.

The sensor data from the monitoring system uploaded in ThingSpeak channel were shown in Figure 4.9, Figure 4.11 and Figure 4.13. Both of the data collected from monitoring system and SPL meter were tabulated in the tables and plotted in graphs. The sensor data from the monitoring system and the data from the SPL meter were tabulated in the Table 4.5, Table 4.6 and Table 4.7 where the Figure 4.10, Figure 4.12 and Figure 4.14 were plotted based on the data in the respective tables as shown below.

4.3.1 Result on Experimenting the 0% Loudness of Sound Level

The data collected by the sound sensor was uploaded to the ThingSpeak channel as shown in Figure 4.9 below.

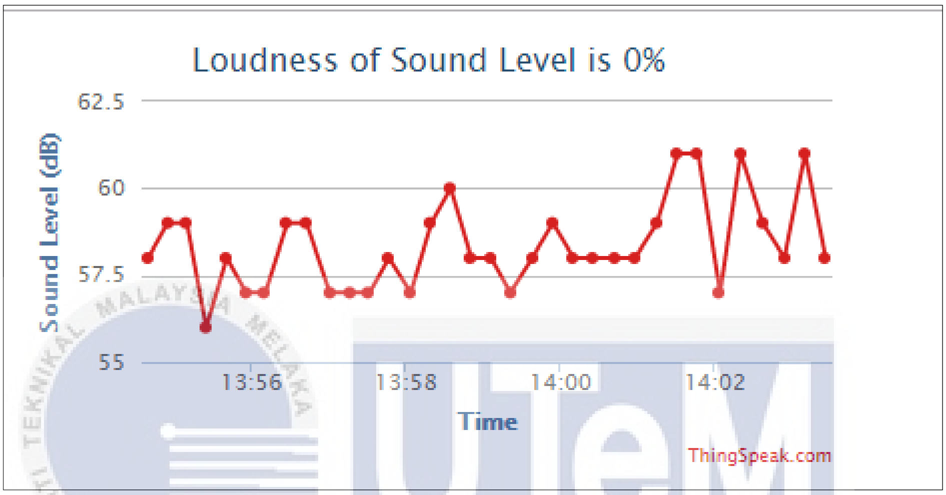


Figure 4.9: Plotted Graph of Sensor Data at Loudness is 0%

Table 4.5: Result from Experiment 2 with Loudness of Sound Level is 0%

Loudness of Sound Level is 0%		
Timestamp (hr:min:sec)	**Sound Level (dB)**	
	Sound Sensor	**Sound Pressure Level (SPL) Meter**
13.58.35	60.0	63.4
13.58.51	58.0	62.5
13.59.06	58.0	61.6
13.59.21	57.0	61.2
13.59.54	59.0	62.3
14.00.10	58.0	61.3
14.00.26	58.0	60.4
14.00.42	58.0	60.9
14.00.58	58.0	61.3
14.01.15	59.0	61.9

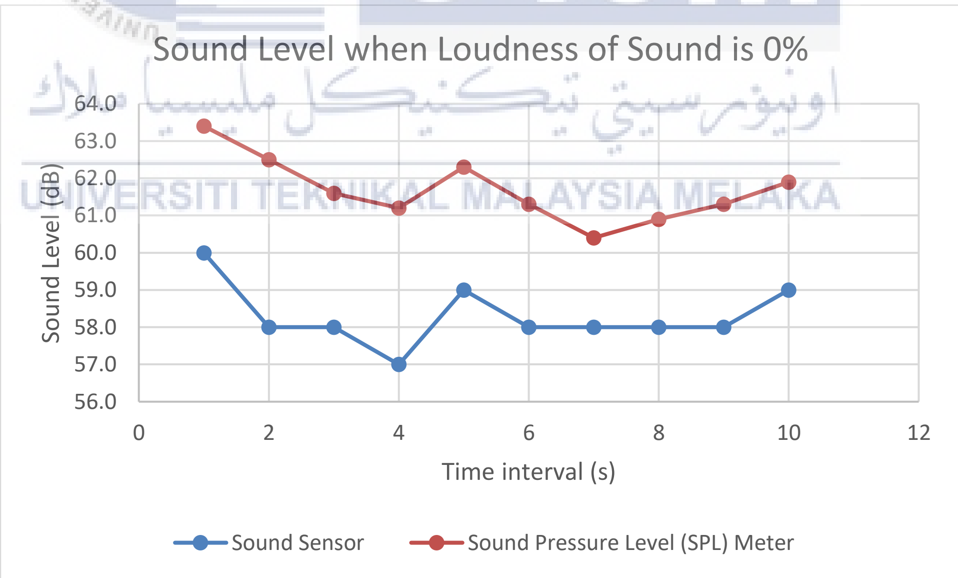


Figure 4.10: Compare of Sound Level when Loudness is 0%

Based on the Figure 4.10, the pattern of both data collected at the 0% loudness of the sound level was almost the same. When the time the sound level detected by the sound sensor increased, the sound level detected by the SPL meter also increased. However, there was a difference of the sound level detected by both sound sensor and the SPL meter. It can be seen from Figure 4.10 that the highest sound level detected from Sound sensor was 59.0dB where the sound level detected by SPL meter was 62.3dB. The lowest sound level detected by the sound sensor was 57.0dB where SPL meter was 60.4dB. It was obvious that the sound level detected by the sound sensor was lower than the SPL meter. It showed that the sensitivity of the sound sensor was lower than that of SPL meter when there was 0% of the sound played from the speaker.

4.3.2 Result on Experimenting the 10% Loudness of Sound Level

The data collected by the sound sensor from monitoring system was uploaded to the ThingSpeak channel as shown in Figure 4.11 below.

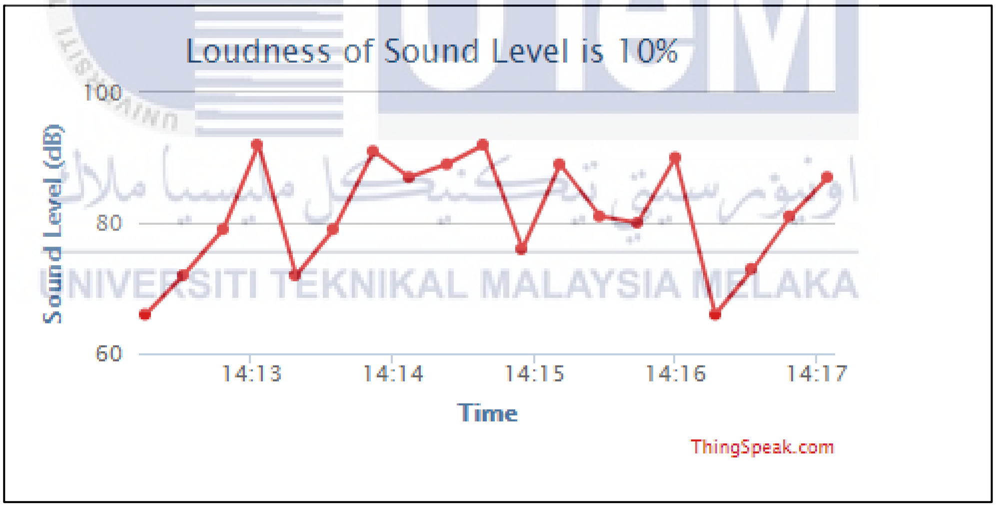


Figure 4.11: Plotted Graph of Sensor Data at Loudness is 10%

Table 4.6: Result from Experiment 2 with Loudness of Sound is 10%

Loudness of Sound Level is 10%		
Timestamp (hr:min:sec)	**Sound Level (dB)**	
	Sound Sensor	**Sound Pressure Level (SPL) Meter**
14.14.39	92.0	73.1
14.14.55	76.0	74.4
14.15.11	89.0	86.3
14.15.28	81.0	75.5
14.15.44	80.0	77.6
14.16.00	90.0	78.9
14.16.17	66.0	78.1
14.16.33	73.0	64.3
14.16.49	81.0	67.0
14.17.05	87.0	70.6

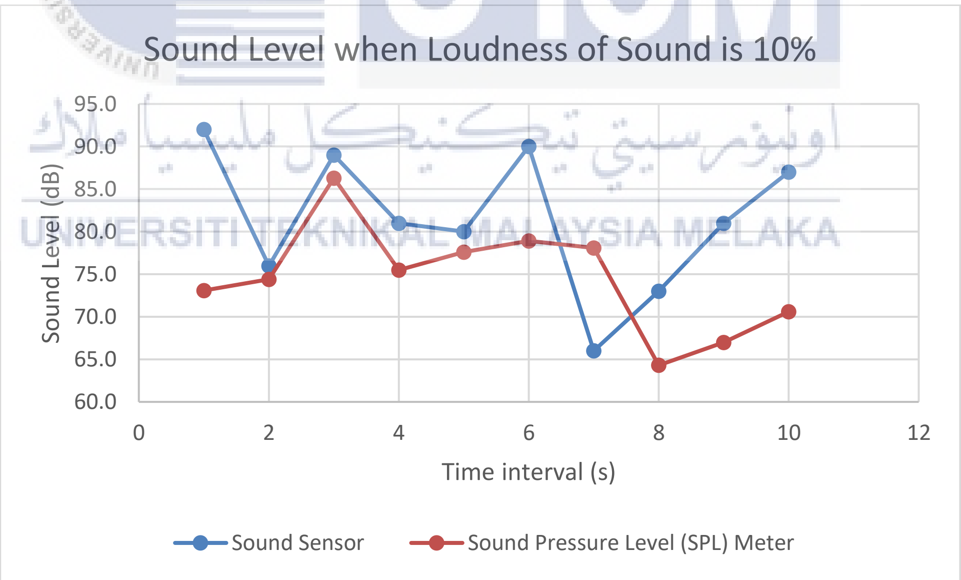


Figure 4.12: Compare of Sound Level when Loudness is 10%

Based on the Figure 4.12, the pattern of both data collected at the 10% loudness of the sound level was different most of the time. It can be clearly seen that at the starting point, the sound level of the sound sensor detected was decreased from 92.0dB to 76.0dB where from the SPL meter, the sound level was increased from 73.1dB to 74.4dB. Besides, at the time interval of 4s, the sound level detected by sound sensor was decreased from 81.0dB to 80.0dB whereas for SPL meter, the sound level was increased from 75.5dB to 77.6dB. This situation was occurred due to the delay of uploading the data collected by sound sensor to the ThingSpeak channel. Hence, it caused the pattern of both data collected is different at some of the time.

4.3.3 Result on Experimenting the 20% Loudness of Sound Level

The data collected by the sound sensor was uploaded to the ThingSpeak channel as shown in Figure 4.13 below.

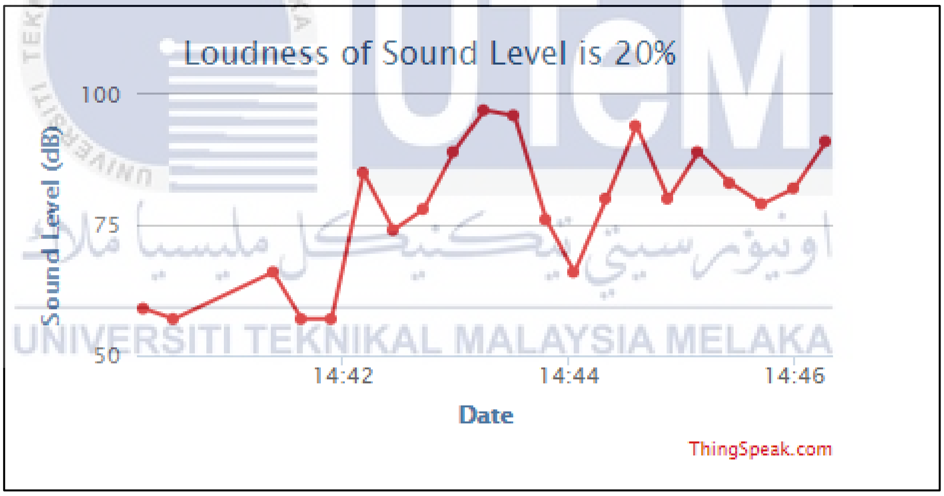


Figure 4.13: Plotted Graph of Sensor Data at Loudness is 20%

Table 4.7: Result from Experiment 2 with Loudness of Sound is 20%

Loudness of Sound Level is 20%		
Timestamp (hr:min:sec)	**Sound Level (dB)**	
	Sound Sensor	**Sound Pressure Level (SPL) Meter**
14.42.59	89.0	76.2
14.43.15	97.0	89.7
14.43.31	96.0	77.1
14.43.48	76.0	73.0
14.44.03	66.0	61.4
14.44.20	80.0	82.9
14.44.36	94.0	83.8
14.44.53	80.0	76.3
14.45.09	89.0	86.6
14.45.26	83.0	82.2

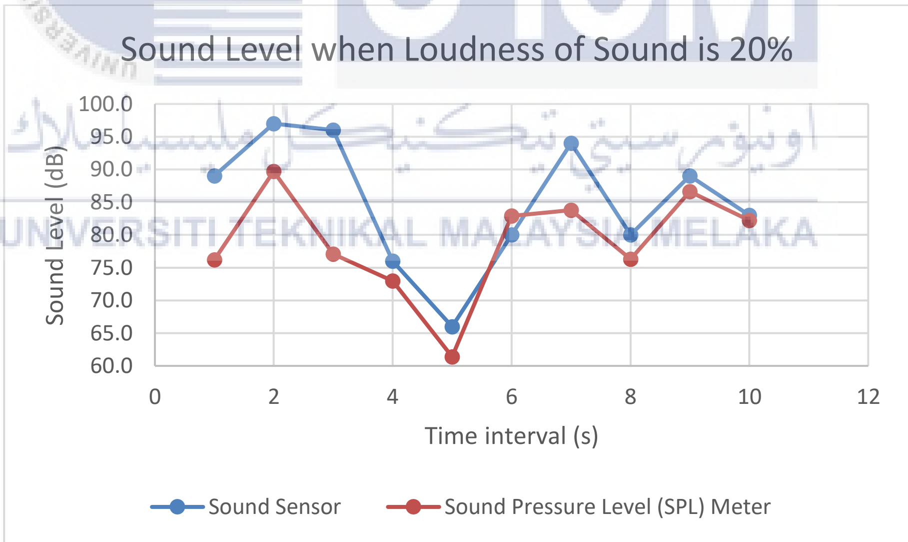


Figure 4.14: Compare of Sound Level when Loudness is 20%

Based on Figure 4.14, the pattern of both data collected at the 20% loudness of the sound level was most likely the same. When the time the sound level detected by the sound sensor increased, the sound level detected by the SPL meter also increased. However, there was a difference of the sound level detected by both sound sensor and the SPL meter. It can be seen that the sound level detected by the sound sensor was higher than that of SPL meter most of the time. There was a time, in time interval of 8s, the sound level detected by the sound sensor is 80.0dB which was lower than that of detected by SPL meter, 82.9dB. However, the last collected sound level from both sound sensor and SPL meter was almost the same which is 83.0dB and 82.2dB respectively.

4.3.4 Result on Comparing the 0%, 10% and 20% Loudness of Sound Level

The Experiment 2 consisted of three experiments which recorded three different loudness of sound level detected by sound sensor and Sound Pressure Level (SPL) meter. The average of the three different loudness of sound level detected by both sound sensor and SPL meter was calculated the difference between them were determined using (3.2) and (3.3) respectively. The calculated data was tabulated in the Table 4.8 and a bar chart was drawn as shown in Figure 4.15.

Table 4.8: Average of The Loudness of Sound Level and The Differences Between Sound Sensor and SPL Meter

Loudness of Sound Level (%)	**Average of Sound Level**		**Difference of Sound Level between Sound Sensor and SPL Meter (dB)**
	Sound Sensor (dB)	**Sound Pressure Level (SPL) Meter (dB)**	
0	52.30	61.68	9.38
10	81.50	74.58	6.92
20	85.00	78.92	6.08

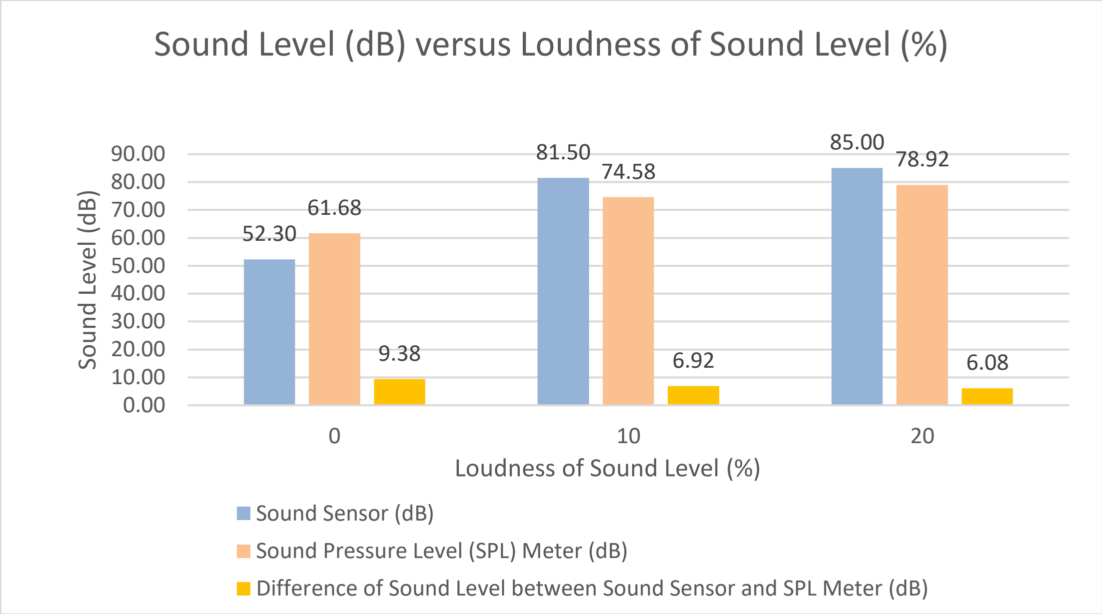


Figure 4.15: Bar Chart of the Average of the Loudness of Sound Level and the Differences Between Sound Sensor and SPL Meter

Based on the Figure 4.15, in 0% loudness of sound level, the average of the sound level detected by sound sensor was lower than the SPL meter. However, in 10% and 20% loudness of sound level, the average of the sound level detected by sound sensor was obviously higher than the SPL meter. Besides, the difference of the average sound level between sound sensor and SPL meter was decreased when the loudness of sound level increased. It showed that the similarity of the sound level detected by the sound sensor and SPL meter increased when the loudness of sound level increased. It can be concluded that the sound sensor from the monitoring system was more sensitive compared to SPL meter when the loudness of the sound level increased. In other word, the sound sensor can detect lower and higher sound level of the environment compared to the SPL meter.

4.4 Result of Experiment 3: Experimenting on the Level of Carbon Monoxide Gas

The experiment setup of Experiment 3 was shown in Figure 4.16 below where the air and noise pollution monitoring system was placed in the box with the size of 11L. The box was then placed at the exhaust pipe of a VIVA car.

Figure 4.16: Experiment Setup of Experiment 3

The experiment was conducted with 4 different distance which were 0cm, 20cm, 40cm and 60cm from the reference point marked behind the exhaust pipe of the car. The data from the monitoring system was recorded and uploaded to the ThingSpeak channel. The data shown in ThingSpeak was tabulated and the average of level of carbon monoxide was calculated using (3.4) as shown in Table 4.9 and a bar chart was drawn as shown in Figure 4.17.

Table 4.9: Result from Experiment 3

Test	**Time Interval (s)**	**Carbon Monoxide (CO) Level (ppm) where Distance from Reference Point is**			
		0 cm	**20cm**	**40cm**	**60cm**
1	0	13	4	2	1
2	5	10	4	2	1
3	10	8	4	2	1
4	15	9	4	2	1
5	20	9	4	2	1
6	25	9	4	2	1
7	30	9	4	2	1
8	35	9	5	2	0
9	40	8	4	2	0
10	45	8	4	2	0
Average of Level of Carbon Monoxide (CO) Gas (ppm)		9.2	4.1	2	0.7

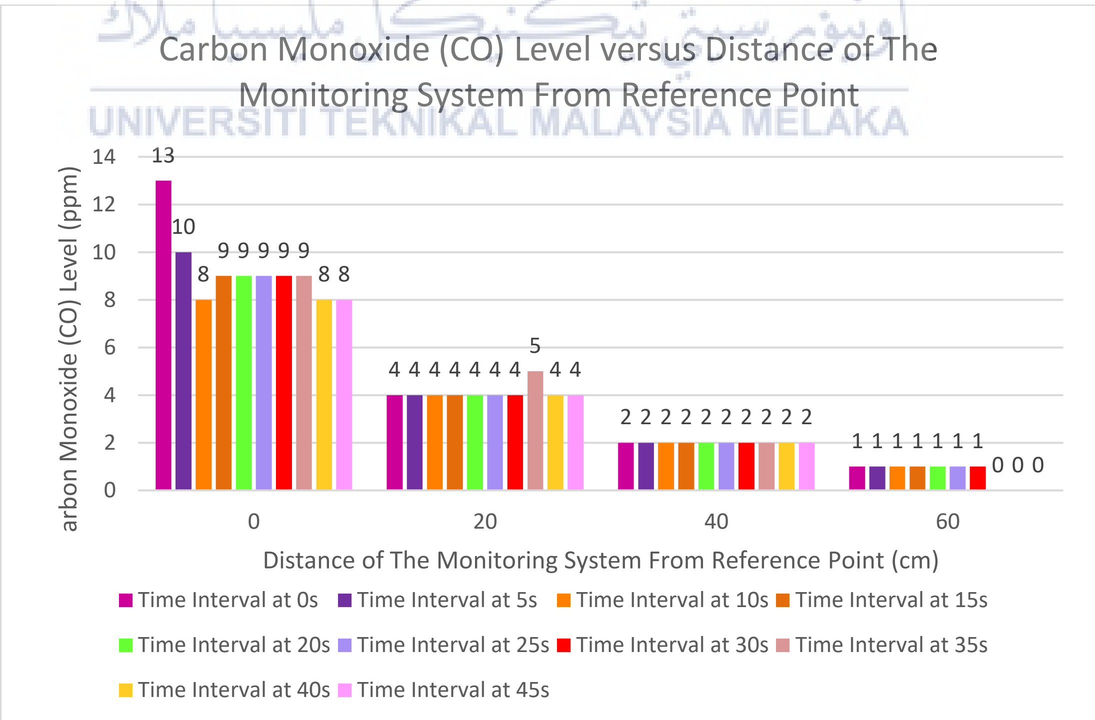


Figure 4.17: Result of Experiment 3

Based on the Figure 4.17, when the distance of the reference point increased, the level of carbon monoxide (CO) decreased. It meant that when the monitoring system was placed further from the exhaust pipe of the car, the level of CO gas detected by the monitoring system dropped. It can be clearly seen that when the monitoring system was placed at 0cm away from the reference point, the level of CO gas detected was very high which was 13ppm at first and then slightly dropped to 10ppm and 8ppm. When the monitoring system was place at 60cm away from the reference point, the monitoring system detected a very low level of CO gas which was 1ppm and lastly 0ppm.

The VIVA car used in experiment was a modern car which had the catalytic converter that can reduce the emission of CO gas. In addition, the CO gas was lighter than air, thus, the monitoring system which placed on the ground during the experiment detected a very low amount of CO gas as it flew up to the sky once it was emitted from the exhaust pipe. Hence, the Graph 4.5 showed that when the monitoring system was placed 60cm away from reference point, 0ppm of CO gas was detected after 35s of the experiment started. The monitoring system only can detect a high level of the CO gas when the monitoring system is placed very close to the exhaust pipe which was 0cm at the reference point. In overall, it can be concluded that the monitoring system can detect the level of CO gas well but not very accurate as the resources of the CO gas used in the experiment was not consistent and concentrated.

4.5 Result of Experiment 4: Experimenting on the Level of Carbon Dioxide Gas

The experiment setup of Experiment 4 was shown in Figure 4.18 below where the air and noise pollution monitoring system and the dry ice were placed in the box with the size of 11L.

Figure 4.18: Experiment Setup of Experiment 4

The experiment was conducted using 4 different weight of dry ice which were 10g, 20g, 30g and 40g. The data collected from the monitoring system was uploaded to the ThingSpeak channel as shown in Figure 4.19, Figure 4.20, Figure 4.21 and Figure 4.22.

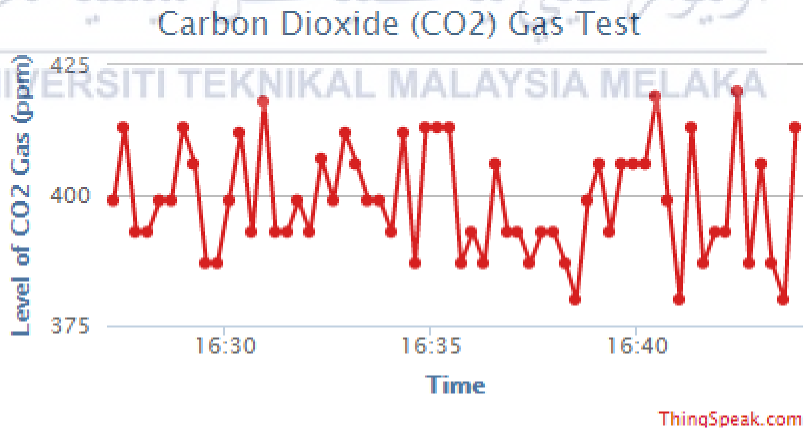


Figure 4.19: Plotted Graph of Sensor Data when Dry Ice is 10g

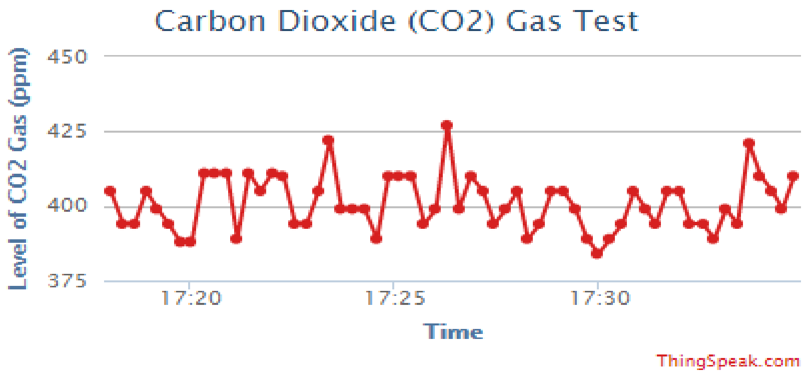


Figure 4.20: Plotted Graph of Sensor Data when Dry Ice is 20g

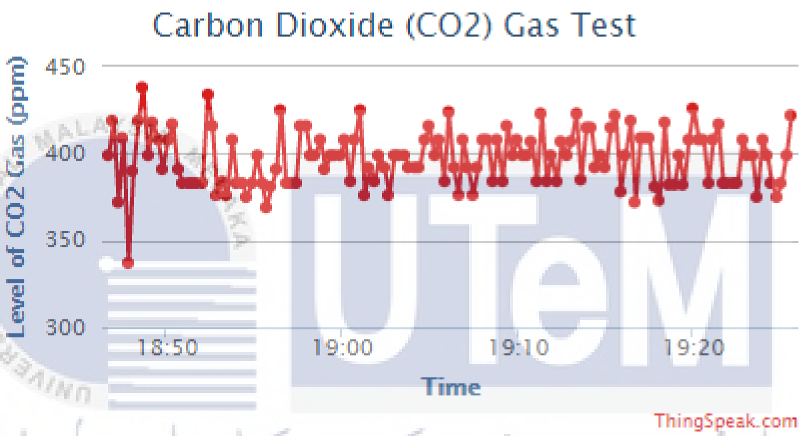


Figure 4.21: Plotted Graph of Sensor Data when Dry Ice is 30g

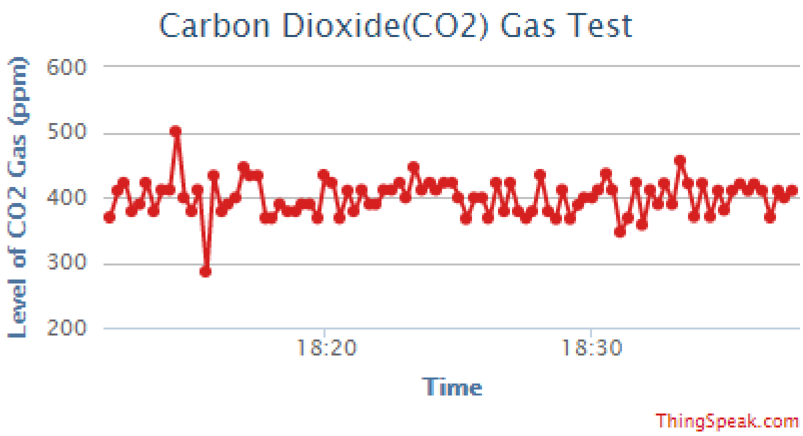


Figure 4.22: Plotted Graph of Sensor Data when Dry Ice is 40g

The data obtained by the monitoring system shown in figures above was used to calculate the average of the level of carbon dioxide (CO2) gas for each amount of dry ice. The different level of CO2 gas in can be released from different amount of the dry ice was calculated using (3.5) whereas the average of the level of carbon dioxide gas from monitoring system was determined using (3.6). The calculated data obtained was tabulated in the Table 4.10 and the level of CO2 gas versus amount of dry ice as shown in Figure 4.23 as below.

Table 4.10: Result from Experiment 4

Weight of Dry Ice (g)	**Highest Level of CO2 Gas Recorded (ppm)**	**Calculated Level of CO2 Gas in Theory (ppm)**	**Average Level of CO2 Gas from Monitoring System (ppm)**
10	418	909.09	398.90
20	427	1818.18	400.72
30	438	2727.27	403.23
40	501	3636.36	405.80

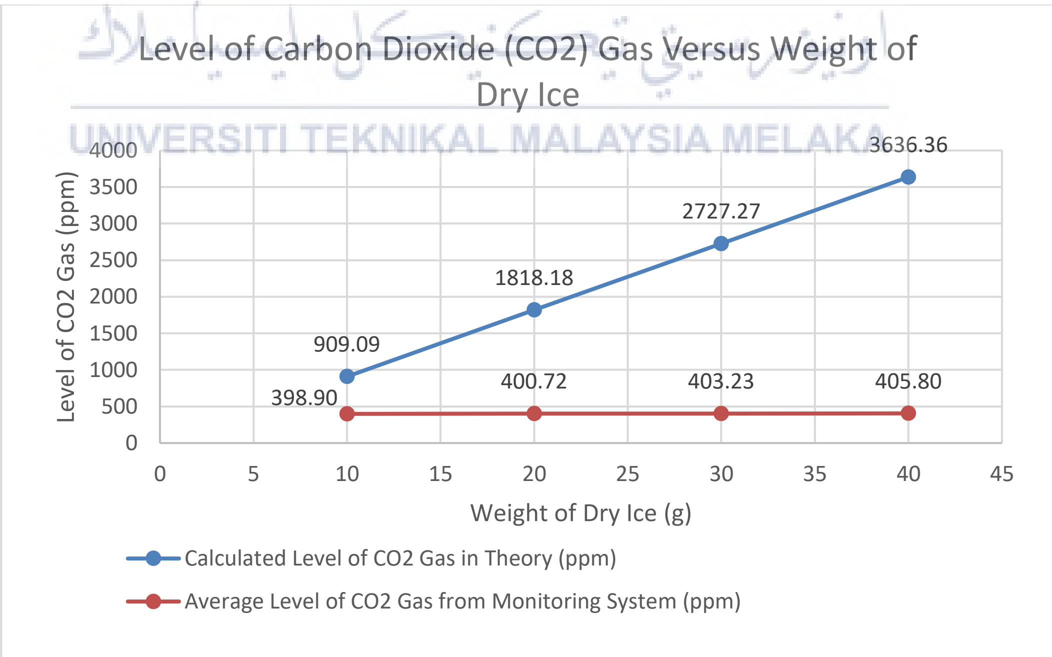


Figure 4.23: Level of Carbon Dioxide (CO2) Gas Versus Amount of Dry Ice

Based on the Figure 4.23, the average level of carbon dioxide (CO2) gas from the monitoring system increased slightly when the amount of dry ice increased. This showed a huge different compared to the calculated level of CO2 gas in theory which increased significantly when the weight of dry ice increased. When the experiment was conducted, the dry ice was not completely sublimated to CO2 gas in a few seconds as it sublimated at an inconsistent rate. Hence, the calculated level of CO2 gas and the average level of CO2 gas detected from the monitoring system was not the same as the concentration of the CO2 gas detected by the monitoring system was not exactly equal to the calculated level of CO2 gas in theory, which was converted from the amount of dry ice into the amount of CO2 gas.

Throughout this experiment, it can be concluded that the monitoring system was well function although it had not proved that it can detect the CO2 gas level accurately. This was due to the lack of a constant resources of CO2 gas which was needed in the experiment. However, the monitoring system can function properly and obtain the level of CO2 gas which can be trusted as the amount of dry ice increased, the highest level of the CO2 gas recorded by the monitoring system also increased.

4.6 Summary

The result of this project had been shown in Chapter 4 and Experiment 1, 2,3 and 4 had been conducted. Analysis and discussion on the outputs obtained from total of 4 conducted experiments were done with proper explanation on presented tables, figures and graphs. Throughout the experiments, there were few issues which can affect the performance and the effectiveness of the system.

Firstly, one cycle of the data collection time of the monitoring system need to be set as the minimum of 15s as the update rate of a free version of ThingSpeak channel used in this project was limited. In order to ensure all the data collected by the monitoring system were uploaded in order without any data lost, the monitoring system was set to 17s as shown in Appendix L.

Furthermore, the detection of the level of carbon dioxide (CO2) gas in Experiment 4 showed an inconsistent of the data. This was due to the air quality sensor MQ135, used in the monitoring system to detect the CO2 gas was respond to other gaseous such as ammonia, benzene, smoke and alcohol. Hence, the detection of the level of CO2 gas might not be very accurate as the sensor gives respond to other type of gas. This issue can be solved by modifying the MQ135 gas sensor.

Besides, both of the gas sensor used in the monitoring system need a different preheat time to obtain a more accurate result. The MQ135 sensor which used to detect the CO2 gas need 24 hours of preheat time where MQ7 gas sensor used to detect Carbon Monoxide (CO) gas need 48 hours of preheat time. Thus, the preheat time of both of the sensor was needed at the first time used of the sensors in order to get an accurate data from the monitoring system. In addition, the data obtained from the monitoring system might be delayed in uploading to the ThingSpeak channel which occurred in the Experiment 2. This issue can be prevented by fasten the data delivery speed using a higher speed of Wi-fi.

In overall, the experiments and the analysis on the prototype of the air and noise pollution monitoring system over Internet of Things (IoT) was done in this chapter. The next chapter concludes the project findings and further improvement suggestion.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the objectives of this project were achieved where an air and noise pollution monitoring system with Internet of Things (IoT) based was successfully developed. All the three sensors, Gravity Analog Sound Level Meter SKU SEN0232, MQ135 and MQ7 gas sensors were well-functioned and capable to obtain accurate data. The sound sensor, Gravity Analog Sound Level Meter SKU SEN0232, was sensitive to different sound level as it can detect a very low and high sound level in decibel (dB). The sound sensor can detect wide range of the sound level which was from 57dB to 97dB as in recorded in chapter 4. Besides, the gas sensors which can detect the carbon dioxide ($CO2$) and carbon monoxide (CO) gas and obtain the level of $CO2$ and CO gas in the unit of parts per million (ppm). The MQ135 gas sensor can detect the highest level of $CO2$ gas which is 501ppm whereas MQ7 sensor can detect 13ppm level of CO gas from the experiments.

In addition, the data obtained from the air and noise pollution monitoring system was successfully uploaded and stored to the cloud platform which is in the ThingSpeak channel according to the order of the data stored in Raspberry Pi as the requirement of the minimum of one cycle of the data collection time for the monitoring system is 15s. The sensor data obtained from the monitoring system can be monitored and stored online for future reference through ThingSpeak channel where the uploaded data was well ordered and convenient for visualization as all the data were presented in the form of graph. In overall, the air and noise pollution monitoring system over IoT was successfully developed as the sensor data can be obtained from the system uploaded to the cloud platform for visual and storage purpose.

5.2 Recommendations

For further improvement, a better and specify Carbon Dioxide (CO_2) gas sensor can be used to replace the MQ135 air quality sensor in detecting the CO_2 gas level in order to get the CO_2 gas level more accurately. Besides, different type of gas sensors can be implemented in the air and noise pollution monitoring system to increase the air pollution detection scope of the monitoring system. The detection of the other gaseous elements such as ozone (O_3), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and particulate matter (PM) can be added so the Air Quality Index (AQI) can be calculated. Moreover, other type of sensors can be added to the monitoring system such as light sensor, radiation sensor and so on in order to detect different type of pollution. In addition, a filter circuit should be added to the monitoring system to reduce the noise from the sensor data for increasing the accuracy of the final data obtained from the monitoring system. Furthermore, the monitoring system is recommended to connect to a high speed of Wi-fi for speed up the process of uploading data. The buying of a ThingSpeak home license is recommended as the update rate and the capacity as well as other features are enhanced. Last but not least, the location of the monitoring system can be displayed together with the data obtained in the ThingSpeak channel and the ThingSpeak app. When the air and noise pollution level exceed the threshold value, notification can be sent to the app users.

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APPENDICES

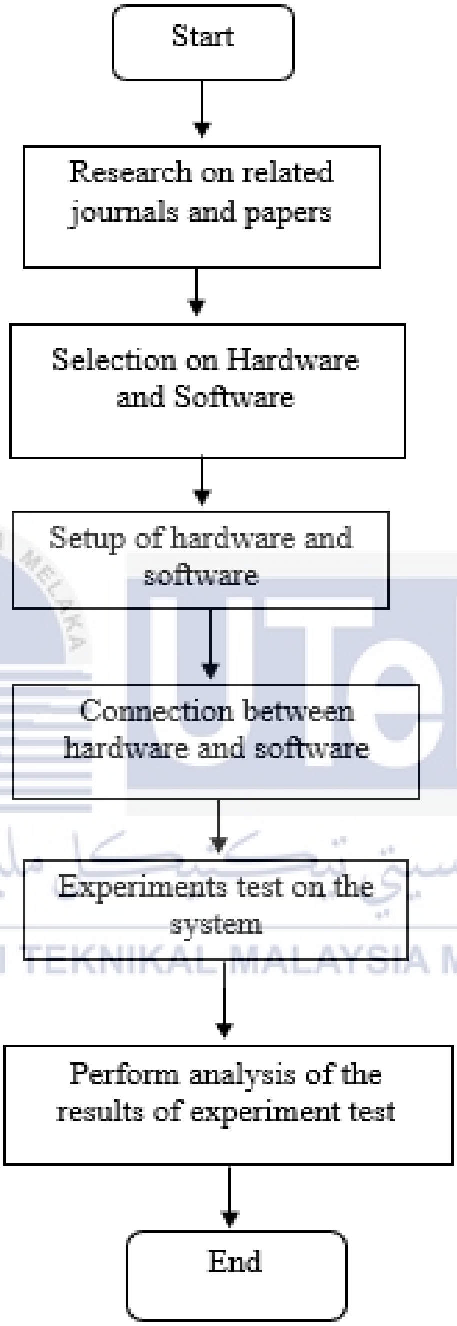
APPENDIX A: Gantt Chart for Final Year Project 1

Project Activities of Final Year Project 1	Week														
	September				October			November				December			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Research Journal and Paper Review															
Selection on Hardware and Software															
Hardware Testing															
Testing Experiment 1															
FYP 1 Presentation															
Submission of FYP 1 Final Report															

APPENDIX B: Gantt Chart for Final Year Project 2

Project Activities of Final Year Project 2	Week														
	February		March				April				May				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Objective 1															
Programming the gas sensors in Arduino	■	■													
Testing the gas sensors in indoor environment		■	■												
Programming the sound level meter										■	■				
Design the cover of the monitoring system								■	■						
Objective 2															
Programming the data transfer from Arduino to Raspberry Pi				■											
Develop a cloud platform					■	■	■	■	■	■	■				
Programming the data transfer from Arduino to Raspberry Pi to cloud					■	■	■	■	■	■	■				
Testing on the process of data transfer from Arduino to cloud									■	■	■	■			
Testing on the accessibility of the cloud												■			
Convert the data stored in cloud to display in graph												■	■	■	■
Objective 3															
Carry out the experiment on the sound level meter											■	■			
Carry out the experiment on the gas sensor											■	■	■	■	■

APPENDIX C: Project Flow Chart



APPENDIX D: Datasheet of MQ7 Gas Sensor

Sensitive material of MQ-7 gas sensor is SnO_2, which with lower conductivity in clean air. It make detection by method of cycle high and low temperature, and detect CO when low temperature (heated by 1.5V). The sensor's conductivity is more higher along with the gas concentration rising. When high temperature (heated by 5.0V), it cleans the other gases adsorbed under low temperature. Please use simple electrocircuit, Convert change of conductivity to correspond output signal of gas concentration.

MQ-7 gas sensor has high sensitity to Carbon Monoxide. The sensor could be used to detect different gases contains CO, it is with low cost and suitable for different application.

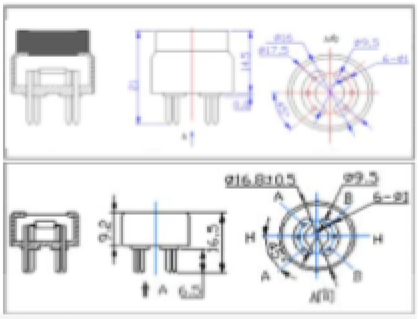
Character

*Good sensitivity to Combustible gas in wide range
* High sensitivity to Natural gas
* Long life and low cost
* Simple drive circuit

Application

* Domestic gas leakage detector
* Industrial CO detector
* Portable gas detector

Configuration



Technical Data

Model No.			MQ-7
Sensor Type			Semiconductor
Standard Encapsulation			Plastic
Detection Gas			Carbon Monoxide
Concentration			10-10000ppm CO
Circuit	Loop Voltage	V_c	≤10V DC
	Heater Voltage	V_H	5.0V±0.2V ACorDC（High） 1.5V±0.1V ACorDC（Low）
	Heater Time	T_L	60±1S（High）90±1S（Low）
	Load Resistance	R_L	Adjustable
Character	Heater Resistance	R_H	31Ω±3Ω（Room Tem.）
	Heater consumption	P_H	≤350mW
	Sensing Resistance	R_s	2KΩ-20KΩ(in 100ppm CO)
	Sensitivity	S	Rs(in air)/Rs(100ppm CO)≥5
	Slope	α	≤0.6 (R_{300ppm}/R_{100ppm} CO)
Condition	Tem. Humidity		20℃±2℃；65%±5%RH
	Standard test circuit		Vc:5.0V±0.1V; V_H (High) : 5.0V±0.1V; V_H (Low) : 1.5V±0.1V
	Preheat time		Over 48 hours

Basic test loop

The above is basic test circuit of the sensor. The sensor need to be put 2 voltage, heater voltage（VH） and test voltage（VC）. VH used to supply certified working temperature to the sensor, while VC used to detect voltage (VRL) on load resistance （RL） whom is in series with sensor. The sensor has light polarity, Vc need DC power. VC and VH could use same power circuit with precondition to assure performance of sensor. In order to make the sensor with better performance, suitable RL value is needed:

Power of Sensitivity body(Ps):

$Ps=Vc^2 \times Rs/(Rs+RL)^2$

Resistance of sensor(Rs): Rs=(Vc/VRL-1)×RL

Sensitivity Characteristics

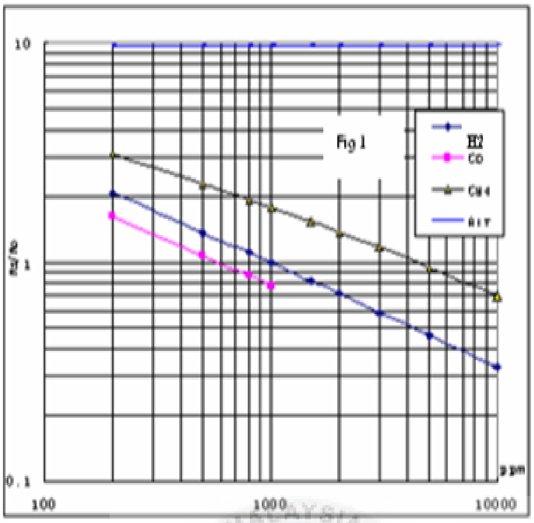


Fig.1 shows the typical sensitivity characteristics of the MQ-7, ordinate means resistance ratio of the sensor (Rs/Ro), abscissa is concentration of gases. Rs means resistance in different gases, Ro means resistance of sensor in 1000ppm Hydrogen. All test are under standard test conditions.

Influence of Temperature/Humidity

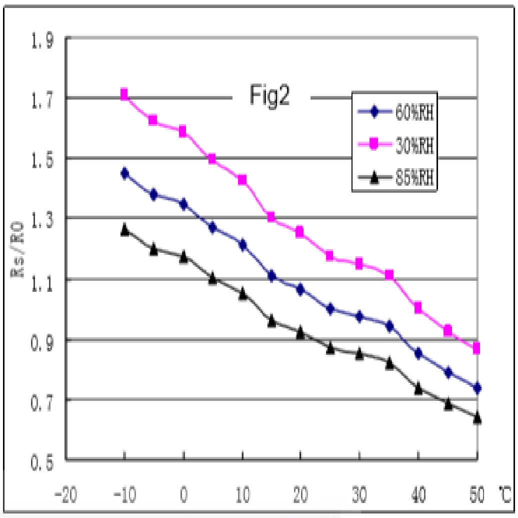


Fig.2 shows the typical temperature and humidity characteristics. Ordinate means resistance ratio of the sensor (Rs/Ro), Rs means resistance of sensor in 100ppm CO under different tem. and humidity. Ro means resistance of the sensor in environment of 100ppm CO, 20℃/65%RH

APPENDIX E: Datasheet of MQ135 Gas Sensor

TECHNICAL DATA MQ-135 GAS SENSOR

FEATURES

Wide detecting scope Fast response and High sensitivity
Stable and long life Simple drive circuit

APPLICATION

They are used in air quality control equipments for buildings/offices, are suitable for detecting of NH3,NOx, alcohol, Benzene, smoke,CO_2 ,etc.

SPECIFICATIONS

A. Standard work condition

Symbol	Parameter name	Technical condition	Remarks
Vc	Circuit voltage	5V±0.1	AC OR DC
V_H	Heating voltage	5V±0.1	ACOR DC
R_L	Load resistance	can adjust	
R_H	Heater resistance	33Ω±5%	Room Tem
P_H	Heating consumption	less than 800mw	

B. Environment condition

Symbol	Parameter name	Technical condition	Remarks
Tao	Using Tem	-10□-45□	
Tas	Storage Tem	-20□-70□	
R_H	Related humidity	less than 95%Rh	
O_2	Oxygen concentration	21%(standard condition)Oxygen concentration can affect sensitivity	minimum value is over 2%

C. Sensitivity characteristic

Symbol	Parameter name	Technical parameter	Ramark 2
Rs	Sensing Resistance	30KΩ-200KΩ (100ppm NH_3)	Detecting concentration scope: 10ppm-300ppm NH_3 10ppm-1000ppm Benzene 10ppm-300ppm Alcohol
α (200/50) NH_3	Concentration Slope rate	≤0.65	
Standard Detecting Condition	Temp: 20□±2□ Vc:5V±0.1 Humidity: 65%±5% Vh: 5V±0.1		
Preheat time	Over 24 hour		

E. Sensitivity characteristic curve

Fig.2 sensitivity characteristics of the MQ-135

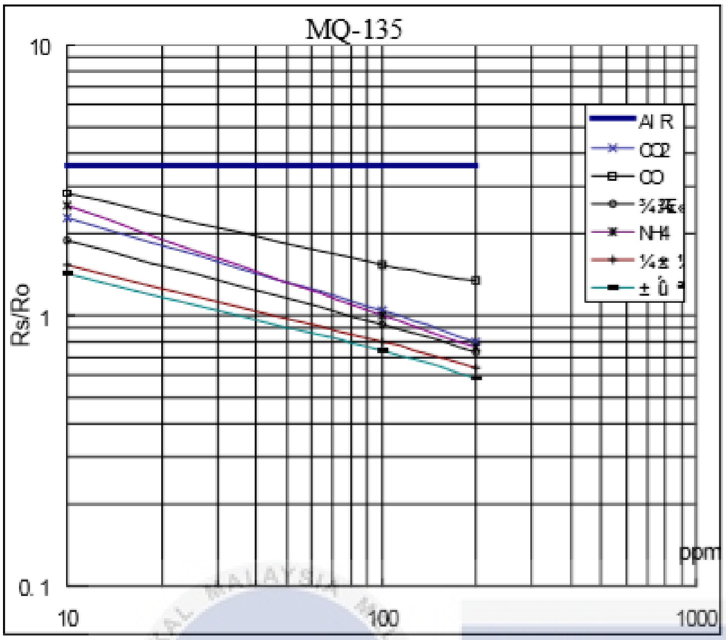


Fig.3 is shows the typical sensitivity characteristics of the MQ-135 for several gases.
in their: Temp: 20℃
Humidity: 65%
O_2 concentration 21%
RL=20kΩ
Ro: sensor resistance at 100ppm of NH_3 in the clean air.
Rs:sensor resistance at various concentrations of gases.

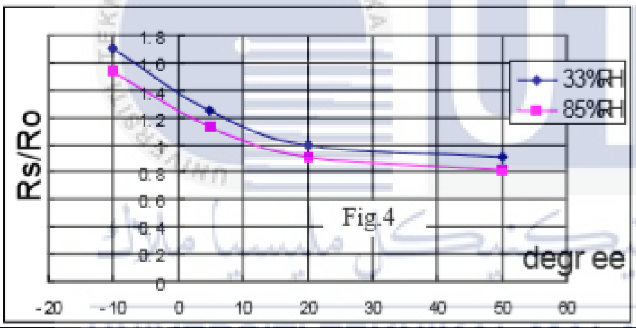


Fig.4 is shows the typical dependence of the MQ-135 on temperature and humidity.
Ro: sensor resistance at 100ppm of NH_3 in air at 33%RH and 20 degree.
Rs: sensor resistance at 100ppm of NH_3 at different temperatures and humidities.

APPENDIX F: Datasheet of Analog Sound Level Meter SKU: SEN0232

Analog Sound Level Meter SKU:SEN0232

In our environment, there are all kinds of sounds, some of which are noise. With the development of human civilization, the quiet environments are less and less, but more and more noisy environments instead. Staying in the noise for long time will have an impact on hearing, which is bad for health.

Sound level meter (also known as the decibel meter, noise meter) is a basic noise measurement instrument.We have launched a sound level meter, which is compatible with Arduino, plug-and-play . It can accurately measure the sound level of the surrounding environment. This product uses instrument circuit, low noise microphone, which makes it highly precious. It supports 3.3~5.0V wide input voltage, 0.6~2.6V voltage output. The decibel value is linear with the output voltage, which leads to a simple conversion, without complex algorithm.The connector is plug-and-play, without welding, so this product can be easily used in your application.

Sound level meter is widely used in environmental noise detection, such as highway noise monitoring station, room noise monitoring and so on. It's time for you to DIY a sound level detector to protect your hearing.

Specification

- Measuring Range: 30dBA ~ 130dBA
- Measurement Error: ±1.5dB
- Frequency Weighted: A Weighted
- Frequency Response: 31.5Hz ~ 8.5KHz
- Time Characteristics: 125ms
- Input Voltage: 3.3 ~ 5.0V
- Input Current: 22mA@3.3V, 14mA@5.0V
- Output Voltage: 0.6 ~ 2.6V
- Module Size: 60mm * 43mm

Board Overview

	Num	Label	Description
Sound Level Meter	1	A	Analog Signal Output(0.6~2.6V)
	2	+	Power VCC(3.3~5.0V)
	3	-	Power GND(0V)

APPENDIX G: Datasheet of Sound Pressure Level (SPL) Meter

Features:
Type:Decibel Meter
Sampling Rate: 2 times / second
Dimensions:256 x 70 x 35mm
Measuring Level: 30 ~ 130 dB(A)
Accuracy: ±1.5 dB
Frequency Response: 31.5 Hz ~ 8.5 kHz

Description:
Plotted graph and recorded data are printable
High accuracy up to ±1.5 dB
With 2 equivalent weighted sound pressure levels A and C Fast/Slow time weighting selection
Automatic power off when idle for 10 minutes
Tested compatible with Microsoft Windows XP / Vista / 7 (32 bit and 64 bits)/8/10

Specifications:
LCD display: 4 digits
Resolution: 0.1 dB
LCD size: 2.2 inch(55mm)
Display: 0.5 secretary
Sound Level:
Level 1: 30 ~ 80 dB
Level 2: 50 ~ 100 dB
Level 3: 60 ~ 110 dB
Level 4: 80 ~ 130 dB
Level 5: 30 ~ 130 dB
Dynamic Range: 50 dB / 100 dB
Frequency Weighting Characteristic: A / C
Analog Bar Graph: 1 dB / 1 bar graph
PWM Signal Output: duty cycle = 0.01 x dB value x 100% / 3.3
Dynamic Characteristic (Time weighting): FAST(high speed) / SLOW(low speed)
Calendar Accuracy: ±30 seconds / day
Microphone: 0.5 inch polarization capacitance microphone
Power Supply: 4 x 1.5V AA battery (not include)or USB Cable
Power Life: about 20 hours continuous use (alkaline battery)
Operating Temperature: 0 ~ 40 °C (32 ~ 104 °F)
Operating Humidity: ≤80 % R.H.

APPENDIX H: Experiment 1 (Experimenting on the Difference Between the Data Stored in Raspberry Pi and the Data Uploaded to Cloud Platform)

Equipment needed

1. A box with the size of 11L
2. Laptop
3. Air and noise pollution monitoring system over IoT

Procedure

1. The monitoring system is placed inside a box with size of 11L.
2. The storage box is placed at the normal condition of the environment in an open area.
3. The time of one cycle of data collection by the monitoring system is set to 10 seconds.
4. The data collected from the monitoring system is stored at the Raspberry Pi and then uploaded to the ThingSpeak channel.
5. The repeatability of the data collection is 10 times.
6. The stored data in the Raspberry Pi is compared with that of in ThingSpeak channel.
7. Step 3 to 6 are repeated by changing the time of one cycle of data collection to 15 and 20 seconds.

APPENDIX I: Experiment 2 (Experimenting on the Difference between Sound Sensor and Sound Pressure Level (SPL) Meter)

Equipment needed

1. A box with the size of 11L
2. Bluetooth Connection Speaker
3. Sound Pressure Level (SPL) meter
4. Laptop
5. Air and noise pollution monitoring system over IoT

Procedure

1. The SPL meter and the monitoring system is placed inside a box with size of 11L.
2. The speaker is placed on the middle of the street in the box.
3. A song is chosen and the speaker level is set to 0% in the laptop.
4. The song is played and the sound level of the song is detected and recorded by the sound sensor from the monitoring system and the SPL meter.
5. The repeatability of the data collection is 10 times.
6. The sound level collected by the monitoring system is compared with that of SPL meter.
7. Step 3 to 7 are repeated by changing the of speaker level to 10% and 20%.

APPENDIX J: Experiment 3 (Experimenting on the Level of Carbon Monoxide (CO) Gas)

Equipment needed:

1. A box with the size of 11L
2. A VIVA car
3. Ruler
4. Marking tape
5. Air and noise pollution monitoring system over IoT

Procedure

1. The monitoring system is placed inside a box with size of 11L.
2. The marking of the distance 0cm, 20cm,40cm and 60cm away from the reference point which is behind the exhaust pipe is done.
3. The box is then placed at the 0cm away from reference point which is marked using a marking tape.
4. The car engine is started and the data is collected.
5. The time interval of the data collection is 5seconds where the repeatability is 10 times.
6. Step 3 and Step 4 are repeated by placing the box 20cm, 40cm and 60cm away from the at the reference point.

APPENDIX K: Experiment 4 (Experimenting on the Level of Carbon Dioxide (CO2) Gas)

<u>Equipment needed:</u>

1. A box with the size of 11L
2. Glass jar
3. Hand gloves
4. Ice tong
5. Dry ice
6. Electronic weighing scale
7. Air and noise pollution monitoring system over IoT

<u>Procedure</u>

1. The monitoring system is placed inside a box with size of 11L.
2. 10g of the dry ice is weighted and placed inside the glass jar.
3. The glass jar is then put in the box and the data is collected by the monitoring system for 30minutes.
4. Step 2 and Step 3 are repeated by changing the amount of the dry ice to 20g, 30g and 40g.

APPENDIX L: Arduino Coding for Sensors to Detect Data

```
#include <MQ7.h>  //MQ7 lib
MQ7 mq7(A1,5.0);  //define MQ7 pin

//this pin read the analog voltage from the sound level meter
#define SoundSensorPin A4
#define VREF  5.0  //voltage on AREF pin,default:operating voltage

void setup() {
Serial.begin(9600);
delay(5000); // activate python

//String heading = "CO2_level(ppm)\tCO_level(ppm)\tSound_level(dBA)\t";
//Serial.println(heading);
}


void loop() {
  delay(2000);

  //for MQ135
  float MQ135_volt;
  float RS_CO2;
  float Slope;
  float Y_intercept;
  float MQ135Value = (analogRead(A3));
  float Y_Value;
  float sensor1_volt;
  float Rs_CO2;
  float R0;
  float sensorValue; //declare MQ135

  sensorValue = (analogRead(A3));    //MQ135 sensor_CO2 level
  sensor1_volt = sensorValue * (5.0 / 1023.0);
  Rs_CO2 = ((5.0 * 32850) / sensor1_volt) - 32850;
  R0 = Rs_CO2 / 0.6230805382;
  MQ135_volt = MQ135Value * (5.0 / 1023.0);
  RS_CO2 = ((5.0 * 32850) / MQ135_volt) - 32850;
  Slope = -0.370955166;
  Y_intercept = 0.7597917824;
  Y_Value = RS_CO2 / R0

//formula for CO2_level
 double ppm =( pow(10, (log10(Y_Value) - Y_intercept) / Slope));
  int CO2 = ppm;

  //FOR CO LEVEL
  int CO = mq7.getPPM();
```

```
//for sound level meter
float voltageValue;
float dbValue;
int soundLevel;
voltageValue = analogRead(SoundSensorPin) / 1024.0 * VREF;
dbValue = voltageValue * 50.0;   //convert voltage to decibel value
soundLevel= dbValue;  //change to int

String data =String(CO2);
data += "\t";
data += String (CO);
data+= "\t";
data += String (soundLevel);
Serial.println(data);
delay (15000); // minimum one cycle of data collection time
```

APPENDIX M: Python Script for Saving Data in Raspberry Pi and Uploading Data to ThingSpeak

```
import serial
import time
import sys
import os
from time import sleep
import urllib

#Setup our API and delay
myAPI = "47RTMTDEX1WN0UQ9"
baseURL = 'https://api.thingspeak.com/update?api_key=%s' % myAPI

ser = serial.Serial('/dev/ttyUSB0', baudrate =9600)
file = open("2.txt","a+")

while 1:
    if(ser.in_waiting > 0):
        file = open("2.txt","a+")
        data = ser.readline()
        print(data)
        file.write(data)
        file.close()
        fields = data.split('\t')
        if(len(fields) is 3):
            f= urllib.urlopen(baseURL + "&field1="+str(fields[0])+
                                        "&field2="+str(fields[1])+"&field3="+str(fields[2]))
        time.sleep(1)
```