GREENHOUSE GASES ANALYSIS IN OIL AND GAS INDUSTRY

By

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

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Approved by,

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TRONOH, PERAK

May 2014

CERTIFICATION OF ORIGINALITY

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

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(HAZIERUL HAZIQ BIN YAHYA)

ABSTRACT

Air pollution is a presence of one or more air pollutant inventory in the atmosphere within a certain time that can give harmful to the environment. Some of the air pollutants can also be classified as greenhouse gases, which are carbon dioxide, sulphur dioxide, methane, nitrous oxide and CFCs. The emission of greenhouse gases to the atmosphere can contribute to global warming through greenhouse effects. The concern of people about air pollution is low so lack of researches and information about air pollution in this country.

The aim of this study is to evaluate the emissions of greenhouse gases such as carbon dioxide, carbon monoxide, sulphur dioxide and non-methane hydrocarbon, released at oil and gas industrial area. For this study, oil and gas industrial areas were selected since industrial areas can be classified as a bigger contributor to air pollution and lack of study has been done in oil and gas industrial area regarding to air pollution

The sample of air pollutants are collected in 24 hours per day for every month in 2008, 2009 and 2010. The following air pollutants; carbon dioxide, carbon monoxide, sulphur dioxide and non-methane hydrocarbon were measured by using Aeroqual AQM60 Environmental Station equipment. The data collected was analyzed by using time series analysis method. . In this study, Kerteh was selected due to the production of air pollutants is higher for a number of months in a year compared to Paka, Bintulu, Miri and Jerantut. The results of these stations were compared to the air quality guidelines by Department of Environment for standard limit and relate to the report by Ministry of Health to determine the consequences of these gases to human health.

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CHAPTER 1

PROJECT BACKROUND

1.1 Background of study

1.1.1 Air Pollution and Department of Environment, Malaysia

Air pollution is a presence of excess air pollutants, such as carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), methane and non-methane hydrocarbon, in the atmosphere gives a problem to living things (Mongillo and Mongillo, 2004; Bert and Stephen, 2000). Excessive air pollutants in the ambient air lead to the major health problem in this country and others throughout the world. Medical researchers found the connection of high level air pollution to illness and diseases, such as asthma, allergies, emphysema, chronic bronchitis, lung cancer, and heart attacks (Mongillo and Mongillo, 2004; Bert and Stephen, 2000).

In the 1990's, the air pollution is not a main concern in Malaysia since the rain depth exceeded 2000 mm per year and it is enough to clean the polluted air (Ujang, 1997). However, this statement is not valid based on a complaint by people about air pollution in Malaysia (Ujang, 1997). Department of Environment, also known as DOE, is an organization in Malaysia that responsible to ensure the advancement in sustainability of the development in Malaysia, also responsible to make sure the environment is always clean, health and safe for the people in this country. Department of Environment have done two approaches to detect the changes in ambient of air that may cause harm to human health as well as the environment; Continuous Air Quality Monitoring (CAQM) and Manually Air Quality Monitoring (MAQM) (Department Of Environment, 2014). Figure 1.1 illustrates that for CAQM, there are 52 stations located around the country and strategically being place in industrial area, residential and traffic area (Department of Environment, 2014). The CAQM function is to detect any changes in air quality around the specific area. For MAQM, DOE used High Volume Sampler that are located at 19 stations at different sites including at industrial area, residential and traffic area. The equipment used is to measure total suspended particulates, which is a small airborne particles, such as dust, with a diameter less than 100 micrometers, PM_{10}, a smaller airborne particles such as, fume or smoke with the diameter less than 10 micrometers, and several heavy metals such as lead mercury, iron, sodium, and copper (Department of Environment, 2014).

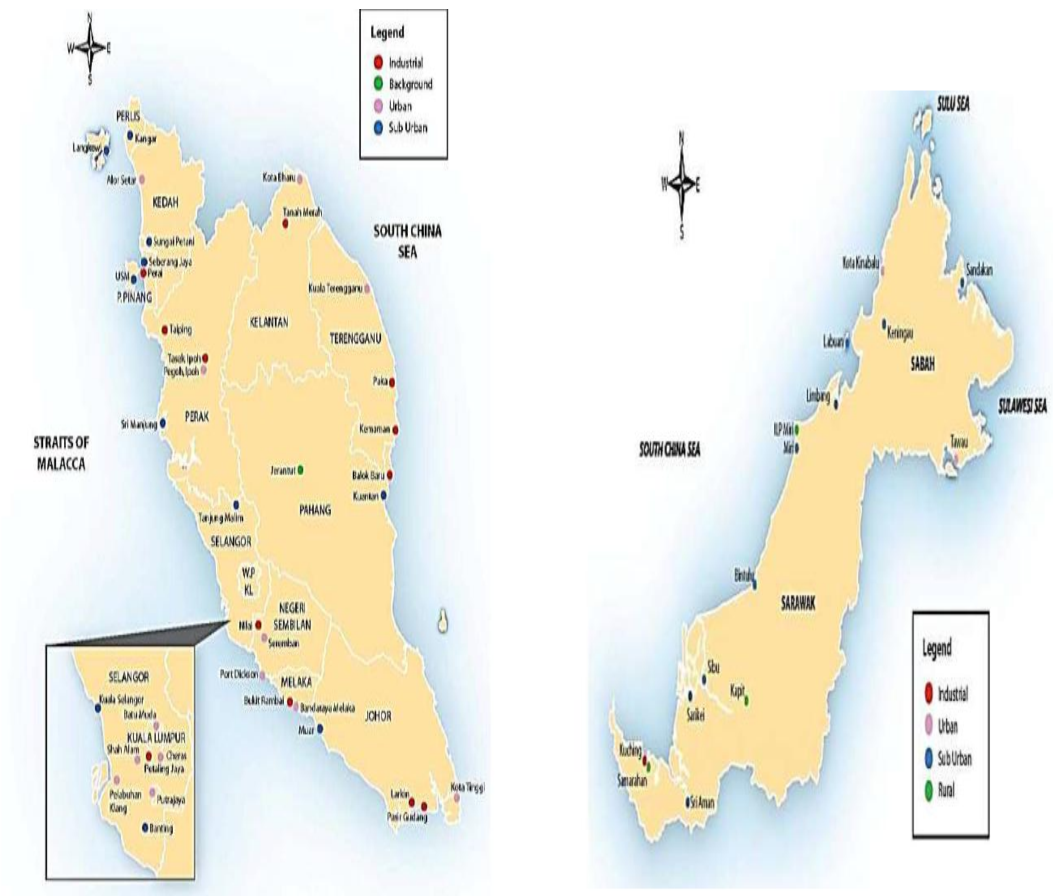

Figure 1.1: Location of Continuous Air Quality Monitoring Stations in Malaysia (Department of Environment, 2014).

Table 1 portrays the data obtained from all CAQM stations and the result is used to calculate Air Pollutant Index (API) values. Air Pollutant Index (API) is an indicator for the air quality at specific area. The air pollutants that being measured for API are ground level ozone (O_3), carbon monoxide (CO), nitrogen dioxides (NO_2), sulphur dioxide (SO_2) and particulate matter (PM_{10}). The dominant air pollutant with the highest concentration considered as pollutants that will determine the API (Department of Environment, 2014). The category presented in the table shows a place where CAQM station is located, which at industrial, residential, traffic and background. For background category, the CAQM is placed at Jerantut, Pahang because it has a clean air compared to other places. It has been used to measure the level of parameters in a clean air condition to compare clean air area to the polluted air area (Othman, 2014).

Table 1.1: Data collected from CAQM stations to calculate Air Pollutant Index (API) (Department of Environment, 2014).

Category	Sulphur Dioxide	Nitrogen Dioxide	Carbon Monoxide	Ozone	Hydrocarbon	PM_{10}	UV
Industrial	X	X	-	-	X	X	-
Residential	X	X	X	X	X	X	X
Traffic	X	X	-	X	X	X	-
Background	X	X	X	X	X	X	X
PM_{10}	-	-	-	-	-	X	-

1.1.2 Global Warming and Greenhouse Effect

Global warming is the observed increase in the average temperature of the earth's atmosphere and ocean in recent decades. The earth's surface temperature has risen by about 0.6 °C in the past century (Banerjee and Md. Yusof, 2005; Tiwari, 2007). The earth has a natural greenhouse parameters; carbon dioxide, water vapour and dust particles, which keeps the earth's temperature warmer. However, man-made activities such as land clearing, burning of fossil fuels and agriculture, lead to an increase in the greenhouse effect. Human activities have been releasing extra greenhouse gases to the atmosphere during the last 200 years. (Banerjee and Md. Yusof, 2005; Tiwari, 2007).

Figure 1.2 describes the process of global warming affected by greenhouse gases. The radiation of heat from the sun is absorbed by the earth. The radiant heat reflects back from Earth's surface to the atmosphere. However, due to the existence of greenhouse parameters such as carbon dioxide, methane, water vapour and CFC's that trap heat, the reflected radiant heat retains and warms up the earth. This greenhouse parameters make the earth become warm and habitable (Mongillo and Mongillo, 2004). The emission of greenhouse gases which lead to the greenhouse effect can be classified into two categories; natural resources such as volcanic activities, forest fires, changes in the photosynthesis and respiration rate in various ecosystem, and man-made activities such as burning of fossil fuels, transportation and industrial development (Banerjee and Md. Yusof, 2005).

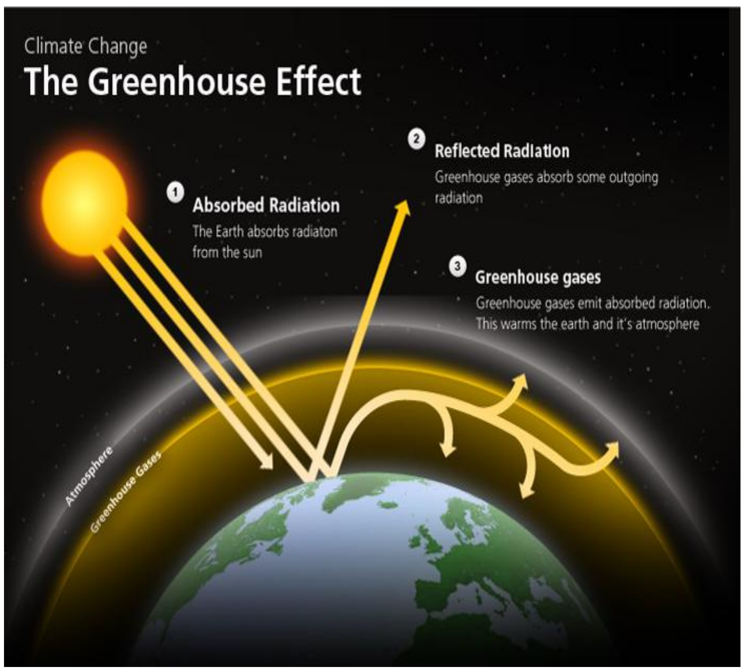

Figure 1.2: Process of greenhouse effect

1.2 Problem Statement

A developed country such as USA and China are the country that contributing, mostly in releasing greenhouse gases to the atmosphere, compared to other countries. The increase of energy consumptions and CO_2 emissions is taking places in cities, where rapidly expanding populations enjoy higher living standards and material affluence (Ho. et. al., 2012). Most people have been negligent in taking care of environment while concentrating on developing a country and living in a good life. Other than residential and traffic area, the primarily result of outdoor pollution is from the combustion of fossil fuels at industrial area including oil and gas industry. Increasing of industrial activities in the country throughout the years causing rise in greenhouse gases in the atmosphere, and contribute to global warming. Global warming has become an environmental threat and excess of greenhouse gases, resulting from air pollution to the atmosphere leads to the problem of human health. (Tengku Ismail, 2005).

The research about air pollution has been done in Malaysia is lack, thus the data and case studies about this problem are very limited (Afroz. et. al., 2002; Wai. et. al., 2005). There is no research had been done for oil and gas industry in Malaysia. In order to have a mutual understanding and concern on global warming and effect on human health with other countries, the research about air pollution at oil and gas industry in Malaysia must be obtained.

1.3 Objective of the Project

The objectives of this project are identified as follows:

i. To measure the level of the pollutants (CO_2, CO, SO_2, Non-methane hydrocarbon) at oil and gas industrial area.
ii. To analyze the air pollutants (CO_2, CO, SO_2, Non-Methane hydrocarbon) by using time-series model.
iii. To identify the consequences and effect this gases to the human health.

1.4 Scope of Study

This research focused on the releasing of greenhouse gases at oil and gas industry in Malaysia. PETRONAS Company has been selected and it is one of the biggest oil and Gas Company in Malaysia. PETRONAS was incorporated on 17 August 1974 as the national oil company of Malaysia, vested with the entire ownership and control of the petroleum resources in the country (PETRONAS, 2014). PETRONAS business activities include the exploration, development and production of crude oil and natural gas in Malaysia and overseas, the liquefaction, sale and transportation of LNG, the processing and transmission of natural gas and the sale of natural gas products, the refining and marketing of petroleum products, the manufacture and sale of petrochemical products, the trading of crude oil, petroleum products and petrochemical products; and shipping and logistics relating to LNG, crude oil and petroleum products (PETRONAS, 2014). PETRONAS Carigali Sdn. Bhd. is responsible to manage exploration and production business in Malaysia and around the world (PETRONAS, 2014).

The study of this project will take place at oil and gas industry in Kerteh, Paka, Bintulu and Miri, and the type of operation at this industry is normal basis. The sample of carbon dioxide, carbon monoxide, sulphur dioxide and non-methane hydrocarbon will be collected 24 hours per day in 3 years; 2008, 2009, and 2010. The sample will be collected by using the Aeroqual AQM60 Environmental Station equipment. The results of the sample of air pollutants will be analyzed by using time series analysis.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Malaysia is a developing country which has transformed itself from more on producer of raw materials to an emerging multi-sector economy in a span of 40 years (Saidur et. al., 2007). Energy is one of the crucial factors for continuous improvement and economic growth, and it is important for automation and modernization. The energy demands in Malaysia are rapidly increase day by day in the industrial area (Mohamed and Lee, 2006; Saidur et. al., 2007). The industrial activities emitted greenhouse gases like carbon dioxide, sulphur dioxide and non-methane hydrocarbon. So, by increasing the industrial activities, the greenhouse gases released to the atmosphere is also increase (Mohamed and Lee, 2006).

The ambient air quality in Malaysia is monitored by Department of Environment (DOE). Table 1 describes the major pollutants including ground level ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, total suspended particle (TSP), particulate matter below 10 microns (PM_{10}) and lead, varies with specific time. The averaging time represents the period of time over which measurements is monitored and reported for the assessment of human health impacts of specific air pollutants (DOE, 2014).

The greenhouse gases emitted by industrial activities to the atmosphere divided into two category; direct emissions and indirect emissions (USEPA, 2014; Shah, 2013). Direct emissions are produced by burning fuel for power or heat, through chemical reactions, and from leaks at industrial processes or equipment, but mostly come from the consumption of fossil fuels for energy (USEPA, 2014; Greenhouse Gas Protocol, 2014). Indirect emissions are the consequences of the activities of the reporting entity, but being controlled by another entity. For example, burning of fossil fuels at a power plant to make electricity, and then used by an industrial facility to power industrial machinery (USEPA, 2014; Greenhouse Gas Protocol, 2014).

Table 2.1: Malaysian Air Ambient Quality Guideline (MAAQG) (DOE, 2014).

Pollutant	**Averaging** Time	**Malaysian Guidelines (Concentration)**	
		ppm	(µg/m^3)
Ozone (O_3)	1 Hour	0.10	200
	8 Hour	0.06	120
Carbon Monoxide(CO)	1 Hour	30.0	35*
	8 Hour	9.0	10*
Nitrogen Dioxide (NO_2)	1 Hour	0.17	320
	24 hour	0.04	10
Sulphur Dioxide (SO_2)	1 hour	0.13	350
	24 Hour	0.04	105
Particulate Matter (PM_{10})	24 Hour		150
	12 Month		50
Total Suspended Particulate (TSP)	24 Hour		260
	12 Month		90
Lead (Pb)	3 Month		1.5

Note:
* (mg/m^3)

2.2 Carbon Dioxide (CO_2)

Carbon dioxide (CO_2) is one of the gases in the atmosphere that are uniformly distributed over the earth's surface at a concentration of about 0.033 % or 330 ppm (Shakhashiri, 2008). It is colorless, odorless, non-flammable gas and it has a molecular weight of 44.01 g/mol (NIOSH, 1976; Bureau of Land Management, 2014; Union Engineering, 2014). It is produced and emitted naturally to the atmosphere by aerobic biological processes, combustion, and weathering of carbonates in rock and soil (Godish, 2004). Carbon dioxide also used by plants for the process of photosynthesis. This process will convert carbon dioxide and water into oxygen and oxygen will be used by human and animal for breathing process (Dickson, 2000). Carbon dioxide can be dangerous to mankind when the concentration of carbon dioxide in the atmosphere increase to the toxic levels (Ndoke, 2006).

2.2.1 Behavior of Carbon Dioxide (CO_2) in industrial area

Carbon dioxide is the major greenhouse gas emitted through industrial activities, such as combustion of fossil fuels (coal, natural gas, and oil) (USEPA, 2014). A major contributor of carbon dioxide in Malaysia is through transportation, followed by industrial and power station (Salahudin et. al., 2013). When fossil fuels undergo a complete combustion burning in the air, the only products are carbon dioxide and water (Brown, 2014; Weston, 2014). Eq. 1 demonstrates the combustion of fossil fuels into carbon dioxide and water.

$$\text{Methane + Oxygen} \longrightarrow \text{water + carbon dioxide}$$

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_20_{(l)} \quad \text{(Eq. 1)}$$

2.2.2 Effects of Carbon Dioxide (CO_2)

The major concern on excessive contribution of carbon dioxide in the atmosphere is greenhouse effect. From man-made activities, carbon dioxide is released to the atmosphere in the process of carbon-containing fossil fuels such as oil, natural gas and coal (Shakhashiri, 2008). The rising concentration of carbon dioxide in the atmosphere trapped the radiant heat from escaping too quickly back to the space (Mongillo and Mongillo, 2004; Nave, 2014). The trapped radiant heat will increase the earth's temperature time by time and resulting in global warming.

Other than effect on climate changes, inhaling immediate air from breathing will increase the concentrations of carbon dioxide in human' blood may cause several diseases such as sweating, headache, muscular tremor, unconsciousness and death (Cizewski, 2009).

2.3 Carbon Monoxide (CO)

Carbon monoxide (CO) is a colorless, odorless, and tasteless gas emitted from incomplete combustion processes and the emission mostly comes from mobile sources (Schwela, 2000; USEPA, 2014; OSHA, 2002). Carbon monoxide consists of a carbon atom and an oxygen atom linked together, is lighter than air with relative density of 1.25, flammable and highly toxic gas (UCC, 2000). Sources of carbon monoxide mostly come from transportation such as road, rail, air and marine (Colvile et. al., 2001; EC, 2012; USEPA, 2014) but it also considered as on important industrial gas, which is widely used as a fuel and reducing agent in chemical industry (UCC, 2000). Carbon monoxide is considered as a very weak direct greenhouse gases, but it gives an indirect effects on global warming and human health (Lashof and Ahuja, 1990; GHG, 2014)

2.3.1 Behavior of Carbon Monoxide (CO) in industrial area

Carbon monoxide is a common industrial hazard emitted from the process of incomplete combustion of natural gas and any other material containing carbon such as gasoline, kerosene, oil, propane, coal or wood (Lewtas, 2007; OSHA, 2002). Carbon monoxide is used as a raw material and also produced by certain industrial processes. Majority of industry used carbon monoxide as fuel gas mixtures includes water gas with 44% of carbon monoxide, blast furnace gas with 30% of carbon monoxide, producer gas with 34% of carbon monoxide and illuminating gas with 7.4% of carbon monoxide (IAPA, 2008). Eq. 2 demonstrates the reaction of carbon with carbon dioxide as described by Boudouard reaction:

$$\text{Carbon dioxide + Carbon} \longrightarrow \text{Carbon monoxide}$$

$$CO_2 + C \longrightarrow CO \qquad \text{(Eq. 2)}$$

2.3.2 Effects on Carbon Monoxide

Carbon monoxide is a poisonous gas and harmful to human health by reduced the amount of oxygen delivery to the body's organ such as heart and brain (Kampa and Castanas, 2008; USEPA, 2014; OSHA, 2002). The effects is varies depends on the amount of concentration exposed and time exposure to the human which divided into two, acute for short-term exposure and chronic for long-term exposure (HSA; 2008; IAPA, 2008). Expose to carbon monoxide can cause tightness at the chest, headache, fatigue, dizziness and nausea (Prockop and Chichkova, 2007; OSHA, 2002). In addition, people with heart diseases is already have a reduced capacity for transporting blood to the heart, and exposure to CO can give them myocardial ischemia accompanied by increased stress and chest pain (Kampa and Castanas, 2008; USEPA, 2014; OSHA, 2002).

2.4 Sulphur Dioxide (SO_2)

Sulphur compounds are emitted from a variety of natural and anthropogenic sources and produced as a result of atmospheric chemical processes (Godish, 2004). The major atmospheric sulphur compounds are sulphur dioxide (SO_2). Sulphur dioxide (SO_2) is colorless, nonflammable and liquefied gas with penetrating odor. This odor is acceptable at different levels depend on individual's sensitivity, but it is generally perceived between 0.3 - 1.4 ppm and easily noticeable at 3 ppm (IVHHN, 2014; Baxter, 2000; Welburn, 1994). Sulphur dioxide is a reducing agent and is used for bleaching and as a fumigant and food preservative (O'Leary, 2000).

2.4.1 Behavior of Sulphur Dioxide (SO_2) in industrial area.

Sulphur dioxide (SO_2) is the most dispersed air pollutants in the atmosphere (Ujang, 1997; USEPA, 2014). More than 8 % of sulphur oxides are produced through fuel combustion, 85 % produced from power plant, only 2 % from fuel combustion in transportation and 13 % from the production of sulphur related to industrial activities such as petroleum refining, cement manufacturing and copper smelting (Ujang, 1997; Pereira, et. al., 2007). Eq. 3 demonstrates the combustion of fossil fuels that contain sulphur reacts with air to produce SO_2:

$$\text{Fuels} + \text{Oxygen} \longrightarrow \text{Sulphur dioxide} + \text{Carbon dioxide} + \text{Water}$$

$$CH_4S + 3O_2 \longrightarrow SO_2 + CO_2 + 2H_2O \qquad \text{(Eq. 3)}$$

The emission of sulphur dioxide into the atmosphere may react with water vapour to produce sulfuric acid (Ujang, 1997; Godish, 2004). Eq. 4, 5 and 6 demonstrates the production of sulfuric acid:

$$SO_2 + OH \longrightarrow HOSO_2 \qquad \text{(Eq. 4)}$$

$$HOSO_2 + O_2 \longrightarrow HO_2 + SO_3 \qquad \text{(Eq. 5)}$$

$$SO_3 + H_2O \longrightarrow H_2SO_4 \qquad \text{(Eq. 6)}$$

2.4.2 Effect of Sulphur Dioxide (SO_2)

The emission of sulphur dioxide into the atmosphere comes from man-mad activities such as burning coal and other fossil fuels, and natural sources such as volcanoes eruptions and forest fires (ESSEA, 2011). Sulphur dioxide can be easily form sulfate ions when it is disperse in the atmosphere. Thus, this negative charge ion will combine with water vapour and form sulfuric acid, which is acidic and dangerous to the environment and human health (ESSEA, 2011).

At industrial areas, most of worker or people surrounding are exposed to sulphur dioxide through breathing. Higher concentration levels of sulphur dioxide will give a lot of negative effects to human health. It can cause severe irritation of the nose and throat. Inhalation of air contained sulphur dioxide can cause coughing, shortness of breath, difficult breathing and leads to tightness in the chest (OSH, 2014; USEPA, 2014; Miller, 2004).

2.5 Non-methane Hydrocarbons (NMHC)

Nonmethane hydrocarbons (NMHC) refer to the total air borne hydrocarbons and other organic compounds excluding methane (CH_4) (DEC, 2014; CASLAB, 2014). NMHC plays a vital role in the formation process of ozone in urban environment, where vehicle emissions are dominant (Yahya, et. al.,2011). Many developed countries regulate the emission of NMHC, where major human activities contribution are in combustion, petroleum refining, industrial and biomass burning (Godish, 2004).

2.5.1 Behavior of Non-methane Hydrocarbons (NMHC) in industrial area

The nonmethane hydrocarbons gaseous emissions in industrial area resulting from combustion of natural gas and which are of environmental concern such as oxides of nitrogen, carbon dioxide and carbon monoxide (Sonibare and Akeredolu, 2004). There are two types of combustion from natural gas that always dictates the nature of the product and the nonmethane gaseous emission; complete and incomplete. In complete combustion, the hydrocarbon natural gas produced carbon and hydrogen atoms react with oxygen from air to form CO_2 and water. Nitrogen from the same air is released as one of the products without taking part in reaction (Sonibare and Akeredolu, 2004). Incomplete combustion leads to formation of several products resulting from various reactions taking place (Sonibare and Akeredolu, 2004). Eq. 7 demonstrates the reaction of complete combustion while Eq. 8 demonstrates the reaction of incomplete combustion:

$$C_XH_Y + M_S(O_2 + 3.76N_2) \longrightarrow n_1CO_2 + n_2H_2O + n_3N_2 \qquad \text{(Eq. 7)}$$

$$C_XH_Y + M_S(O_2 + 3.76N_2) \longrightarrow n_1CO_2 + n_2H_2O + n_3N_2 + n_4CO + n_5NO + n_6NO_2 \qquad \text{(Eq. 8)}$$

2.5.2 Effect of Non-methane Hydrocarbons (NMHC)

Nonmethane hydrocarbons, such as aldehydes and acrolein are potent irritants. A person who being exposed to these substances may affect eyes, nose, throat and sinus irritation (Somerville, 2013; Godish, 2004). A person who exposed to benzene, one of the seven pollutants of NMHC, that hazardous to human health may get critical effects in blood, immunotoxicity, kidney and liver (Godish, 2004; Choi, et. al., 2011).

2.6 Greenhouse Gases Emission in USA

The effect from emission of greenhouse gases being taken seriously by many developed countries such as USA and China. The emission of greenhouse gases such as carbon dioxide, sulphur dioxide, and methane, especially from fossil fuels combustion, give a result of changing of global climate (McMichael and Haines, 1997). In 1990, the emission of greenhouse gases through human activities mostly from fuel combustion, where the rest are; 5.8 % of fuel consumed in the production and transport of fuel, 5.2 % from industrial processes, excluding fuel combustion and 3.3 % from agriculture (Tiwari, 2007).

In USA, an organization that responsible to monitor the environment in the USA is United States Environmental Protection Agency or US EPA. US EPA will collect the data from various types of greenhouse gases emissions at industries to identify opportunities to reduce the emission of greenhouse gases and increase the efficiency of the product (USEPA, 2014). Table 2 shows the main industry sectors in USA and the amount of emissions from each sector, where the oil and gas industry contribute the greenhouse gases emission at second place under power plants sector.

Table 2.2: Top five sectors in USA contribute in greenhouse gases emission (USEPA, 2013; Plagakis, 2013).

Rank	Source Categories	Emissions (Million Metric Tons CO2 equivalent)
1	Power Plant	2221
2	Oil and Gas	225
3	Refineries	182
4	Chemicals	180
5	Other (electronics, food manufacturing)	126

The greenhouse gases emissions through oil and gas industry can be divided into two; direct emissions and indirect emissions (USEPA, 2014). Direct emissions produced from burning of fuel for power through chemical reactions, and from the leak of industrial processes or equipments (USEPA, 2014). Indirect emissions produced from burning of fuel for power plant to make electricity (USEPA, 2014). Figure 1 illustrates the trend of greenhouse gas emissions from industry in USA for both direct and indirect emissions.

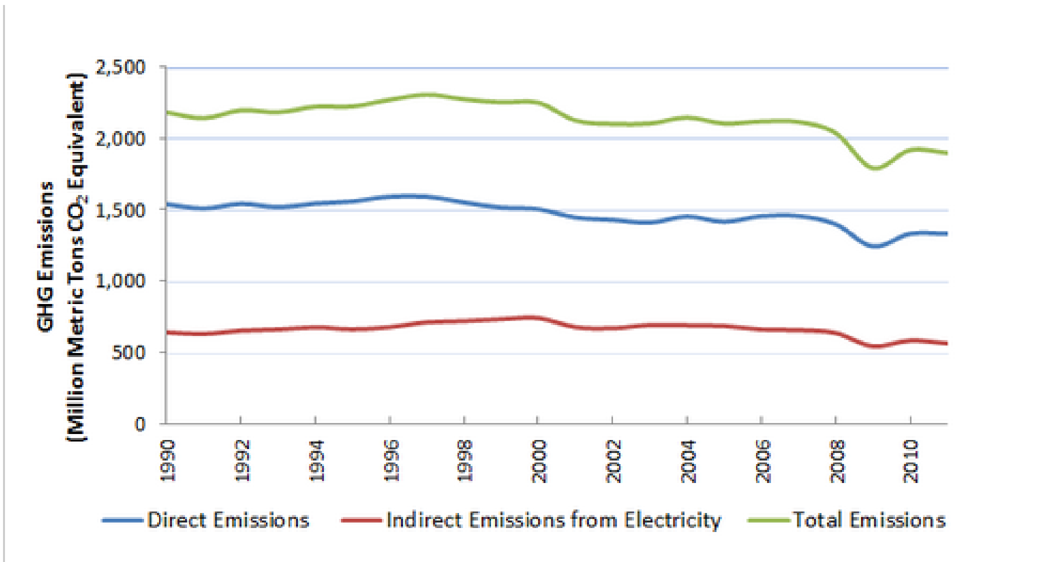

Figure 2.1: Greenhouse Gas Emissions from industry (USEPA, 2014)

2.7 Trend of Temperature Changes in Malaysia

Long time ago, the attention given by the citizen of Malaysia to the environmental issue is low due to minimal development and least industrial activities (Afroz, et., al., 2002; Ujang, 1997). Malaysia's goal to become a developed, industrial country by the year of 2020 resulting in the growth of various industrial with a lot of job offered to citizens (Mohmad, 2003). Along with it, many environmental issues has been discussed such as reduction of fisheries, air and water pollution, and contamination by industrial wastes, which has become a serious issue in Malaysia (Mohmad, 2003; Afroz, et., al., 2002). The emissions of greenhouse gases through human activities remain in the atmosphere for long periods and contribute to global warming (Md. Yusoff and

Banerjee, 2005). Figure 2 describes the trend of global temperature rise in Malaysia from the year of 1880 to 2008.

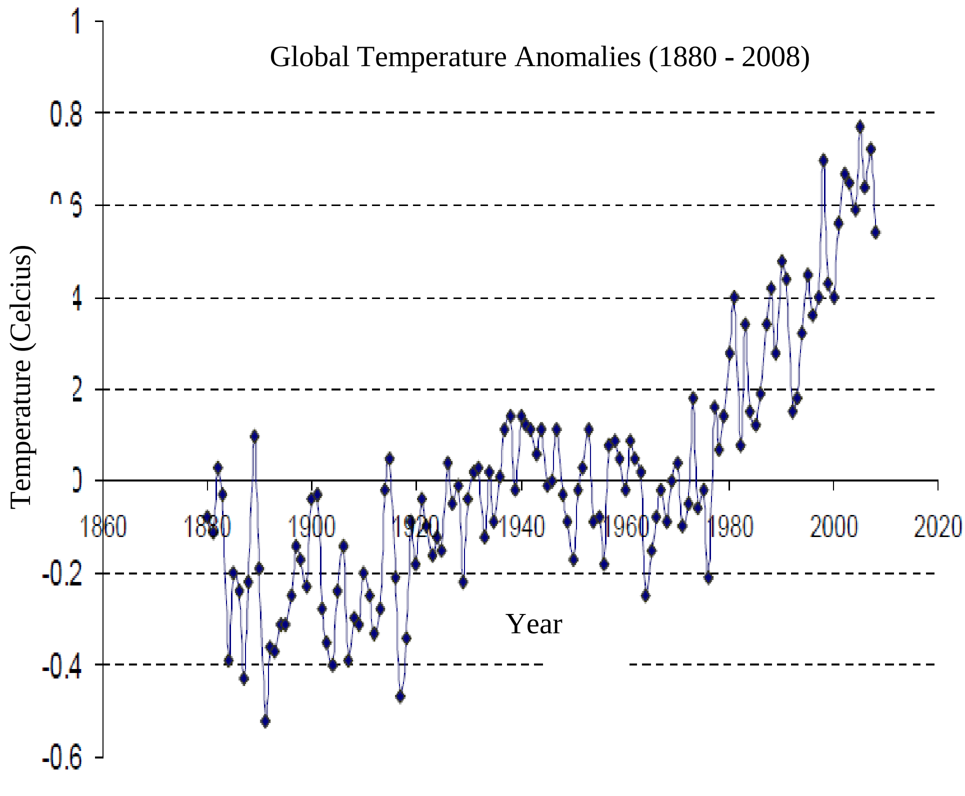

Figure 2.2: The trend of global temperature anomalies (Md Hashim, 2010).

CHAPTER 3

METHODOLOGY

3.1 Introduction

The locations selected for this study are Jerantut, Paka, Miri, Bintulu and Kerteh. The sample that will be collected at the study area are carbon dioxide, carbon monoxide, sulphur dioxide and non-methane hydrocarbon. However, due to the limitation of time and permission problem, the secondary data can be obtained from the Department of Environment for the year of 2008, 2009 and 2010 to be used for this study.

3.2 Key Milestone

A progression of a project usually illustrate by using Gantt chart. In Gantt chart, every works need to be done from start to finish are listed and the time proposed is set up to make sure the project is done within the time given. Key milestone is used as a project checkpoint to certify how the project is progressing. Table 3.1 and Table 3.2 illustrate the progress of work need to be done within time given for Final Year Project 1 and Final Year Project 2 respectively.

Table 3.1: Gantt chart for FYP I

No.	Detail Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection Project Topic	■	■												
2	Preliminary Research Work		■	■	■	■									
3	Submission of Extended Proposal						●								
4	Proposal Defence								■	■					
5	Project work continues										■	■	■		
6	Submission of Interim Draft Report													●	
7	Submission of interim report														●

● suggested milestone

■ process

Table 3.2: Gantt chart for FYP 2

No.	Detail Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project work continues	■	■	■	■	■	■	■							
2	Submission of progress report							●							
3	Project work continues								■	■	■	■	■		
4	Pre-SEDEX										●				
5	Submission of draft final report											●			
6	Submission of Dissertation												●		
7	Submission of technical paper												●		
8	Viva													●	
9	Submission of project dissertation														●

● suggested milestone

■ process

3.3 The Aeroqual AQM60 Environmental Station.

The Aeroqual AQM60 Environmental Station is a custom-built ambient air quality instrument. AQM instrument can measure common air pollutants such as ozone (O_3), nitrogen dioxide (NO_2), carbon monoxide (CO), and sulphur dioxide (SO_2) as well as particulate matter (PM_{10}, $PM_{2.5}$) and meteorological parameters such as temperature, humidity, wind speed and direction (Aeroqual, 2014). The Department of Environment used this instrument as CAQM to collect the data of the gases at particular area. Figure 1 describes the components used to measure the air pollutants placed inside the AQM.

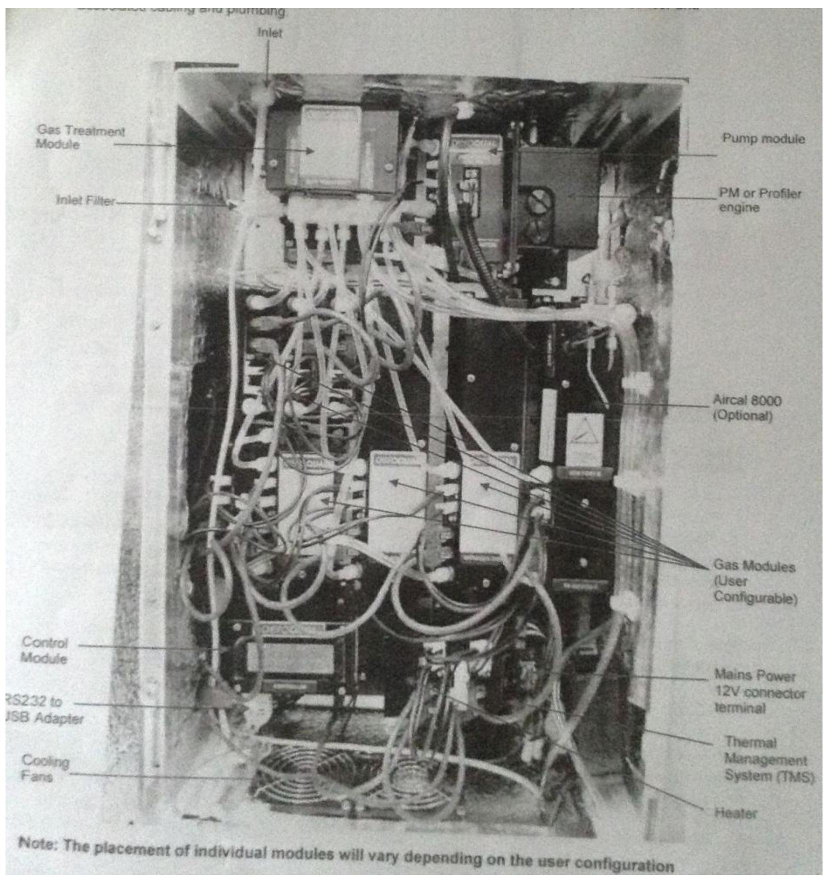

Figure 3.1: The placement of individual modules in AQM60 (Aeroqual, 2014)

3.4 Description of Gas Modules (Carbon dioxide, Sulfur Dioxide, Nonmethane Hydrocarbon).

All modules are mounted onto the base plate using 4 or 2 bolts. They can be either full size or half size modules depending on the gas. Inlet and outlet tubes are connected to the gas distribution manifold and exhaust respectively (Aeroqual, 2014). Figure 2 shows the sample of gas sensor module and table 3.3 illustrates the specifications of each gas sensor module.

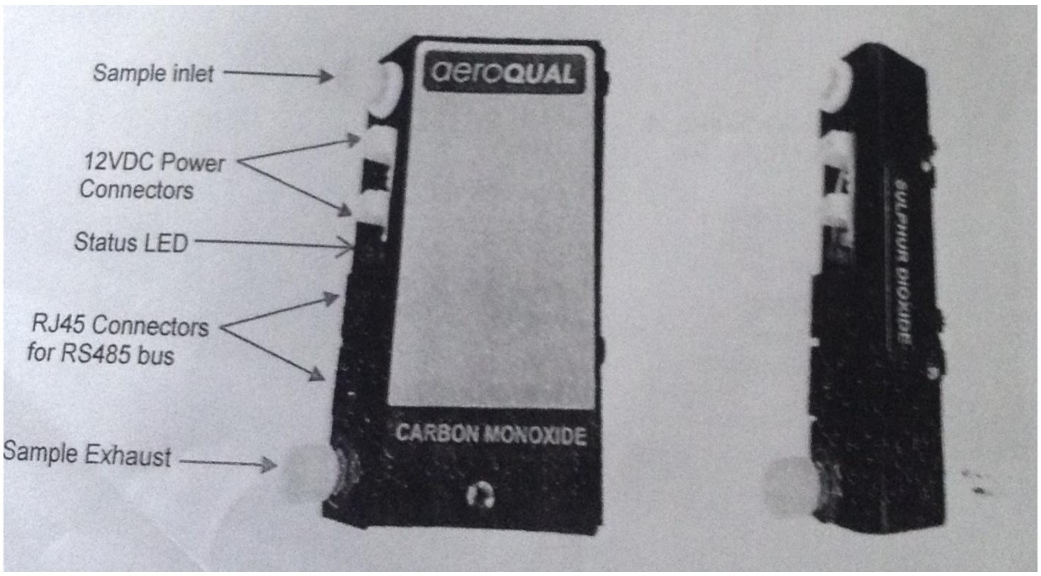

Figure 3.2: Example of Gas Sensor Module installed inside AQM60 (Aeroqual, 2014)

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Table 3.3: Gas Sensor Module Specifications (Aeroqual, 2014).

Gas Modules	Calibrated Range	Lowest detection	Accuracy	Precision
Carbon dioxide	0 – 2000 ppm	6 ppm	< 40 ppm +3%	6 ppm
Carbon monoxide	0 – 25 ppm	0.1 ppm	< ± 1 ppm	0.2 ppm
Sulphur dioxide	0 – 10 ppm	0.2 ppm	< ± 0.5 ppm	0.2 ppm
Non-methane hydrocarbon	0 – 25 ppm	0.1 ppm	< ± 0.5 ppm	0.2 ppm

3.5 Time - Series Analysis

This study will be analyzed by using time series analysis. Time series analysis seeks to link in changing of time, for example day-to-day, variations in ambient pollutants concentrations with time changes (Hester and Harrison, 2009). The concern to analyze the data collected over time is to discern whether there is some pattern in the values collected to date.

In this study, time series analysis is used to see the trend of greenhouse gases in oil and gas industry. The concentration of these gases is monitored in hourly basis per day throughout the year of 2008, 2009 and 2010.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

The concentration of air pollutants for carbon monoxide, sulphur dioxide and non-methane hydrocarbons were analyzed and the result is obtained for each month in the year of 2008, 2009 and 2010. The samplings are recorded for 24 hours per day for 3 years and the data are collected from Continuous Air Quality Monitoring (CAQM) stations located at Jerantut, Paka, Bintulu, Miri, Station A and Station B. Table 4.1 illustrates the coordinates for each location for this analysis.

Table 4.1: The coordinate of selected CAQM station

Station ID	Station Name	Longitude	Latitude
CA0007	Pej. Kajicuaca Batu Embun, Jerantut	N03°58.238	E102°20.863
CA0024	Kaw. Industri Paka	N04°35.880	E103°26.096
CA0027	Balai Polis Pusat Bintulu, Sarawak	N03°10.587	E113°02.433
CA0028	Sek. Men. Dato Permaisuri Miri, Sarawak	N04°25.456	E114°00.731

Figure 4.1 shows a CAQM station at Jerantut where Jerantut is chosen because Jerantut is set as the least polluted area compared to other places where the CAQM stations are located (DOE, 2014). The distance of the CAQM station to

the PETRONAS Oil and Gas industry is measured by using Google Earth software and described in the Figure 4.2, 4.3 and 4.4 respectively. The distance from Paka CAQM station to the PETRONAS Kerteh Oil and Gas industry is 2.23 kilometer, Bintulu CAQM station to the PETRONAS LNG Bintulu is 12.63 kilometer, and Miri CAQM station to the PETRONAS Carigali Miri is 4.85 kilometer.

Figure 4.1: Continuous Air Quality Monitoring station at Jerantut, Pahang

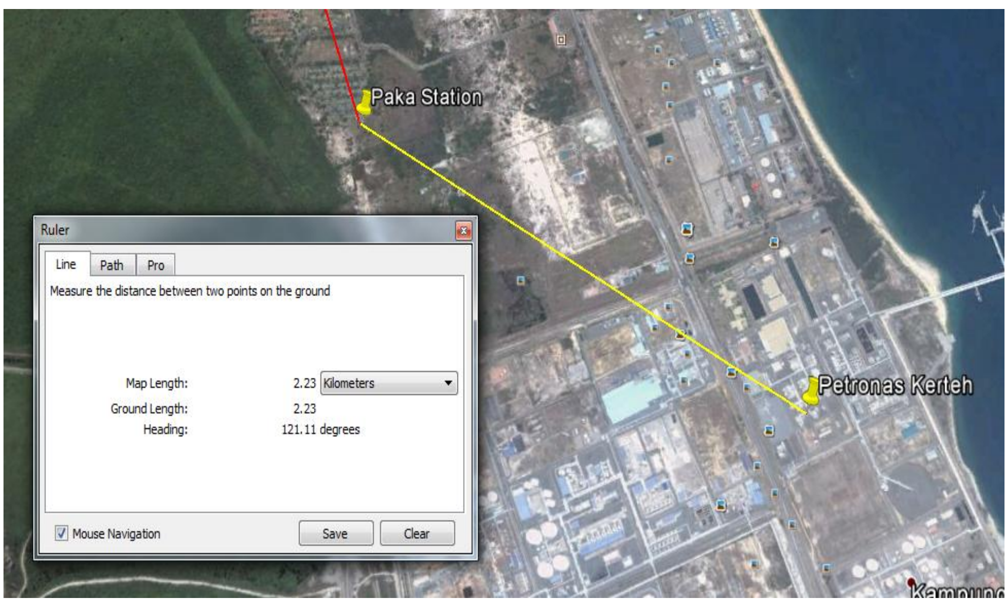

Figure 4.2: Continuous Air Quality Monitoring station at Paka, Terengganu

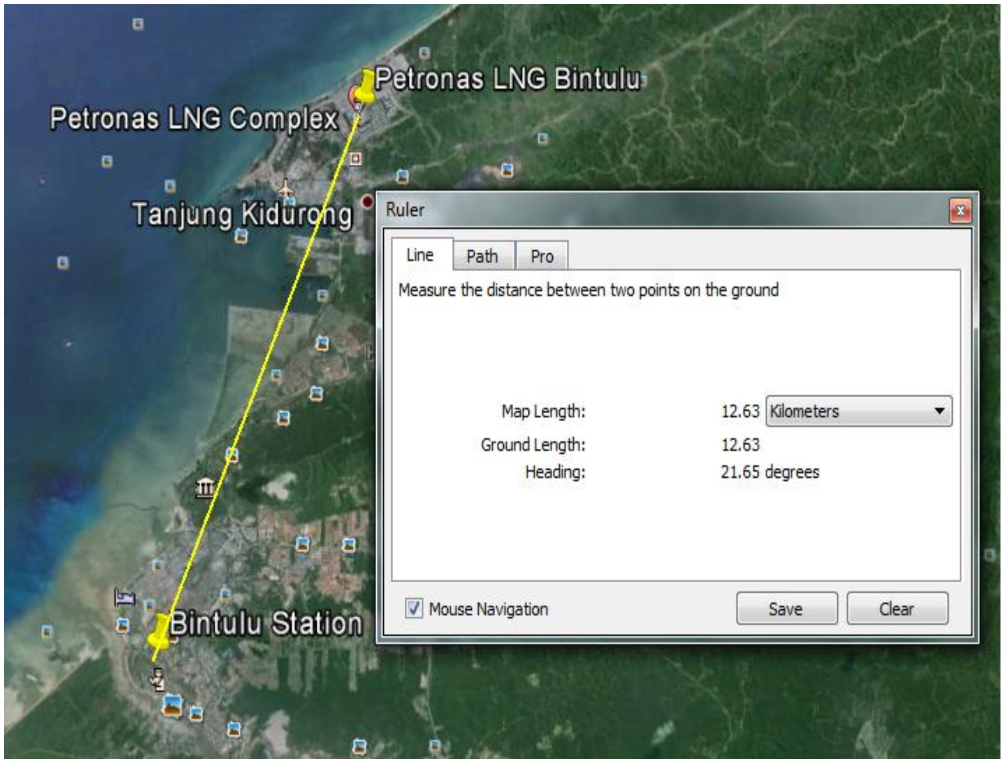

Figure 4.3: Continuous Air Quality Monitoring station at Bintulu, Sarawak

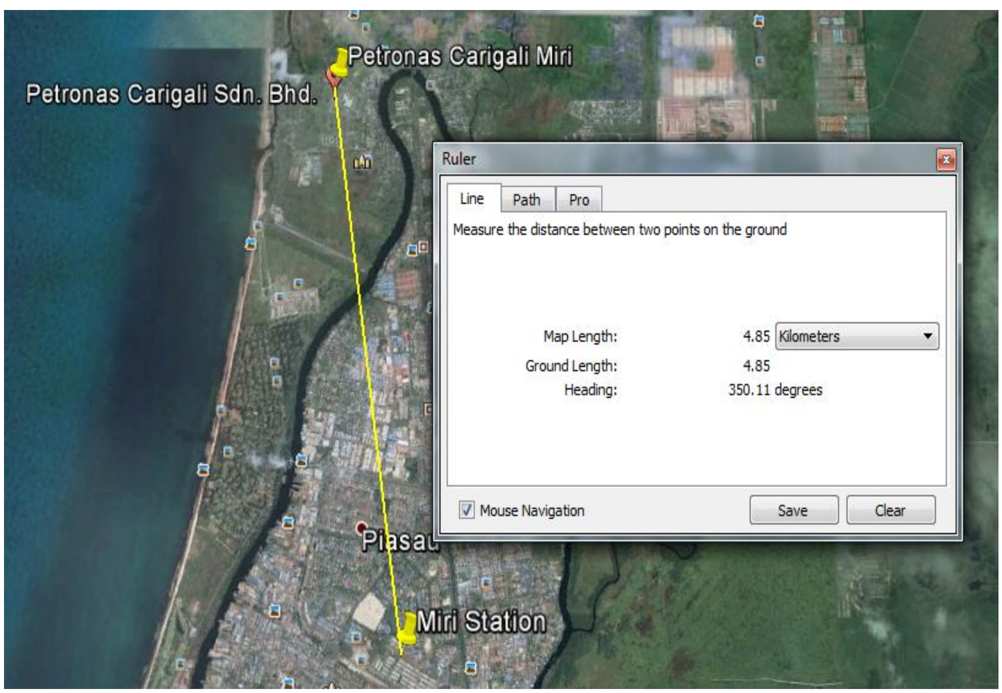

Figure 4.4: Continuous Air Quality Monitoring station at Miri, Sarawak

From the beginning, the study is proposed to analyze carbon dioxide since carbon dioxide is the most polluted and emitted gases in the ambient air. However, since the research is based on secondary data, there is no data on the concentration of carbon dioxide due to permission problem by the authorities. Since the concern of this study is to cater on the emission of carbon, carbon monoxide is selected to replace the carbon dioxide. Even though carbon dioxide is different with carbon monoxide, both of them have similarities at the effect on human health, depending on the concentration of each of the gases.

The data of each concentration of air pollutants are presented in a graph, with an interval time of 1 hour per day for each month and 1 month for each year. From five locations, only Station A and Station B will be discussed and divided into three parts; average daily for each month, daily max for each month, and the highest recorded concentration for particular month in a year. The rest of the sampling will be presented in Appendix.

4.2 CONCENTRATION OF AIR POLLUTANTS AT STATION A

Figure 4.5 illustrates the average daily concentration of air pollutants carbon monoxide in a year of 2010 for each month. The data for each concentration starts in April because of missing data in month of January, February and March. The concentration of carbon monoxide is 1.62 ppm in April, which is the highest concentration of a year. The concentration of carbon monoxide in the next month is drop to 1.18 ppm and then it varies each month from June till December with the reading of 1.23 ppm, 1.09 ppm, 1.12 ppm, 1.18 ppm, 1.04 ppm, 1.30 ppm and 1.20 ppm respectively. The lowest concentration of carbon monoxide for Station A is in October, with a reading of 1.04 ppm.

Figure 4.5 also demonstrates the average daily concentration of sulphur dioxide in a year of 2010 for each month. The concentration of sulphur dioxide in April is 0.0042 ppm and increased to 0.0047 ppm at the next month. The readings are then varies with the reading of 0.0046 ppm, 0.0038 ppm, 0.0040 ppm, 0.0048 ppm, 0.0038 ppm, 0.0045 ppm and 0.0041 ppm for each month from June to

December. The lowest concentration of sulphur dioxide at Station A is 0.0038 ppm in July while the highest is 0.0048 ppm in September.

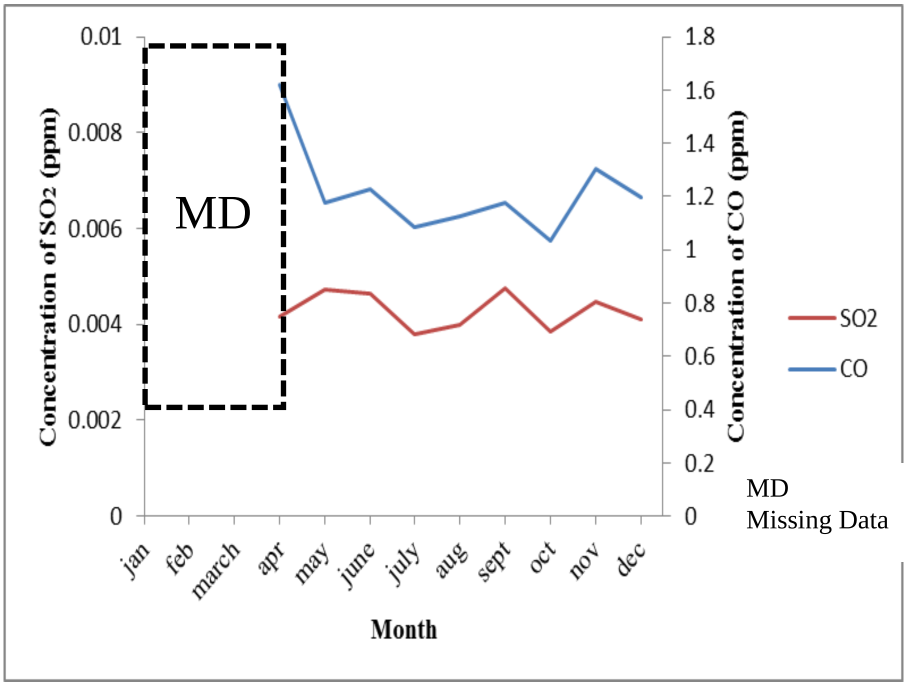

Figure 4.5: Concentration of carbon monoxide and sulphur dioxide vs month at Station A

From the discussion above, the highest reading of the concentration of carbon monoxide is in a month of April. Figure 4.6a describes the average daily of the concentration of carbon monoxide in April. The reading is 2.07 ppm at day 1 and continuously increased to 2.53 ppm from day 2 to day 4. The results are varying from day to day and the highest reading is 2.98 ppm at day 7 and then continuously decreased to 0.92 ppm from day 7 to day 11. The highest reading is 2.98 ppm at day 7 while the lowest reading is 0.89 ppm at day 19.

Figure 4.7 and Figure 4.9 describes the meteorological factors that being recorded at Station A. The concentration of carbon monoxide and sulphur dioxide are found to be gradually high due to high ambient temperature with low humidity. Another possible cause is the excess production of the particular gases in particular month.

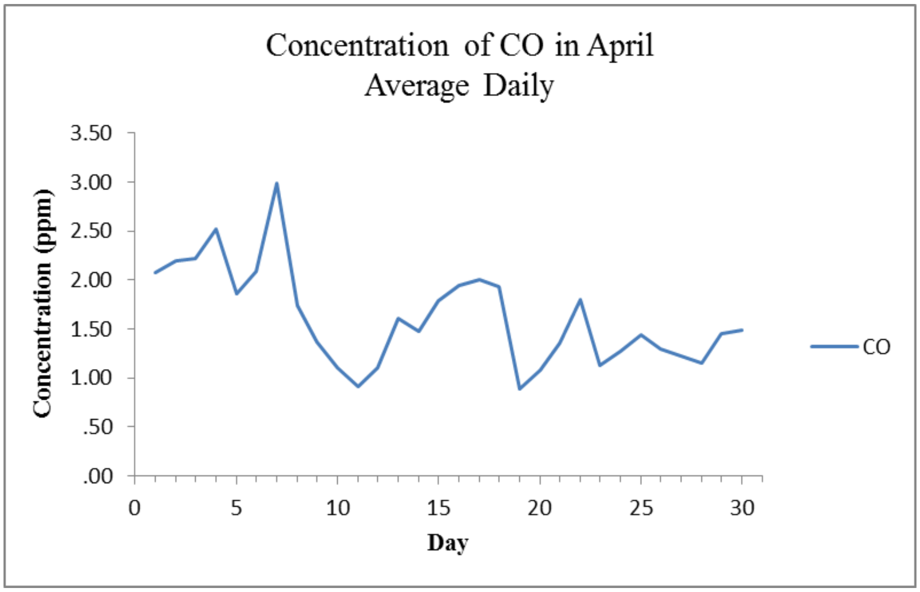

Figure 4.6a: Concentration of carbon monoxide in April

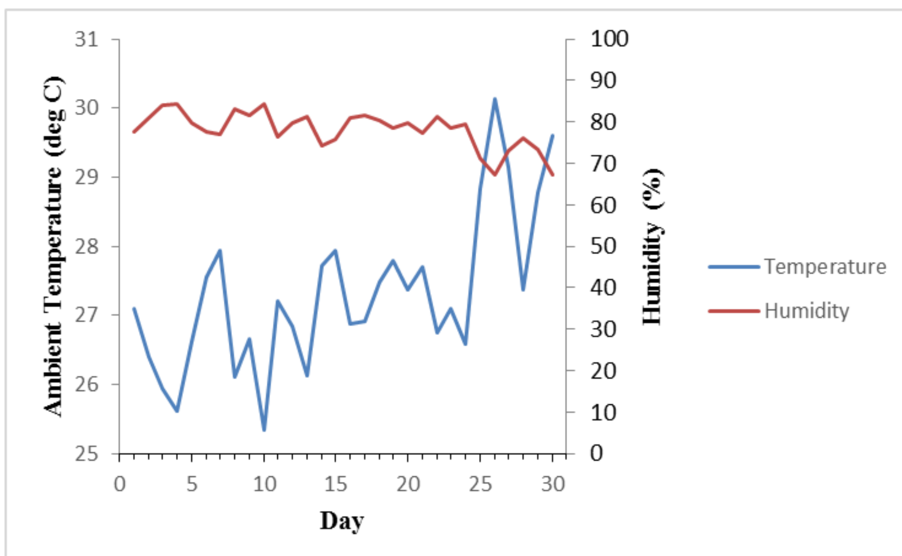

Figure 4.7: The average daily of ambient temperature and humidity in April

The highest reading of the concentration of sulphur dioxide is in a month of September. Figure 4.8a illustrates the average daily of the concentration of sulphur dioxide in September. The highest reading is 0.008 ppm at day 5 then decreased to 0.004 ppm at day 7. At day 14, the reading is 0.003 ppm and continuously increased 0.006 ppm at day 17. The lowest reading of the concentration is 0.002 ppm at day 28 and day 30.

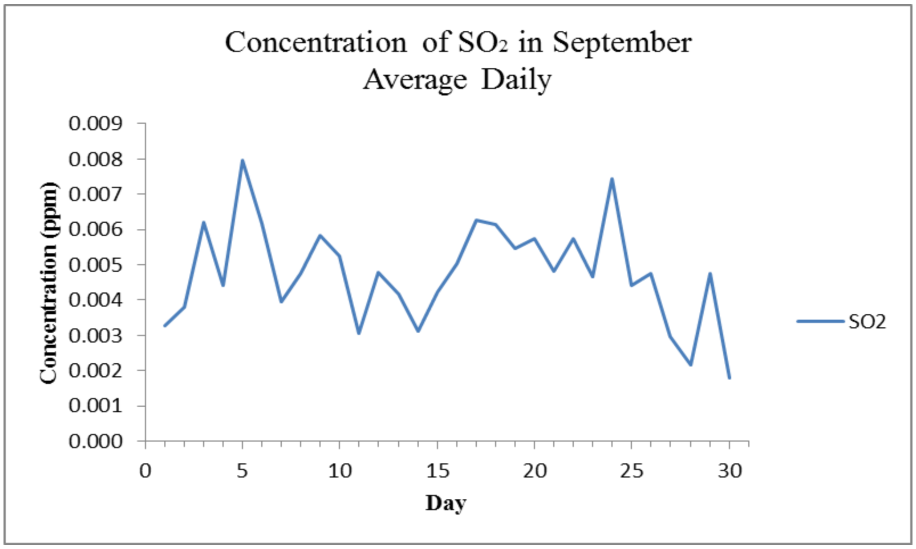

Figure 4.8a: Concentration of sulphur dioxide in September

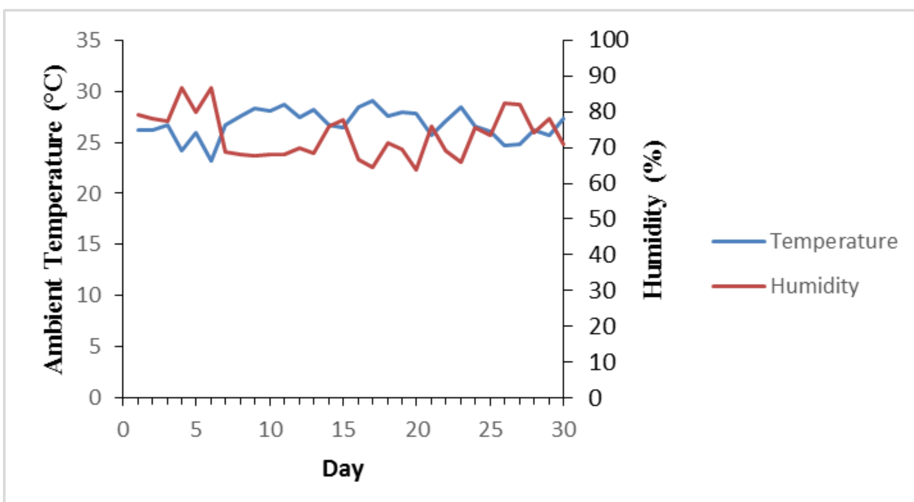

Figure 4.9: The daily average of ambient temperature and humidity in September

Figure 4.6b and Figure 4.6c represent the average daily of the concentration of carbon monoxide for all months, while Figure 4.7b to Figure 4.7c represented the average daily of the concentration of sulphur dioxide for all months.

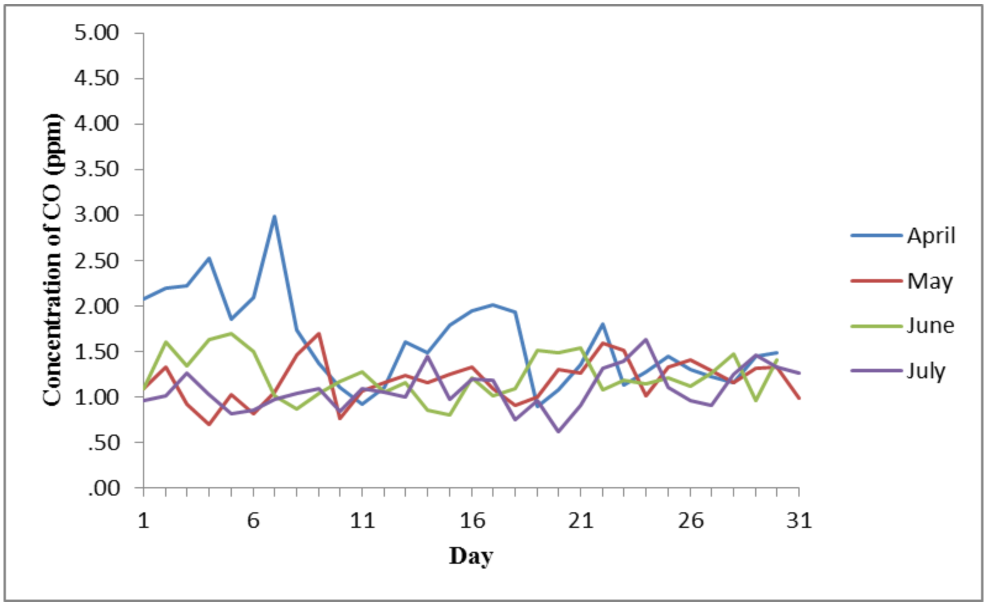

Figure 4.6b: Concentration of carbon monoxide for April, May June and July

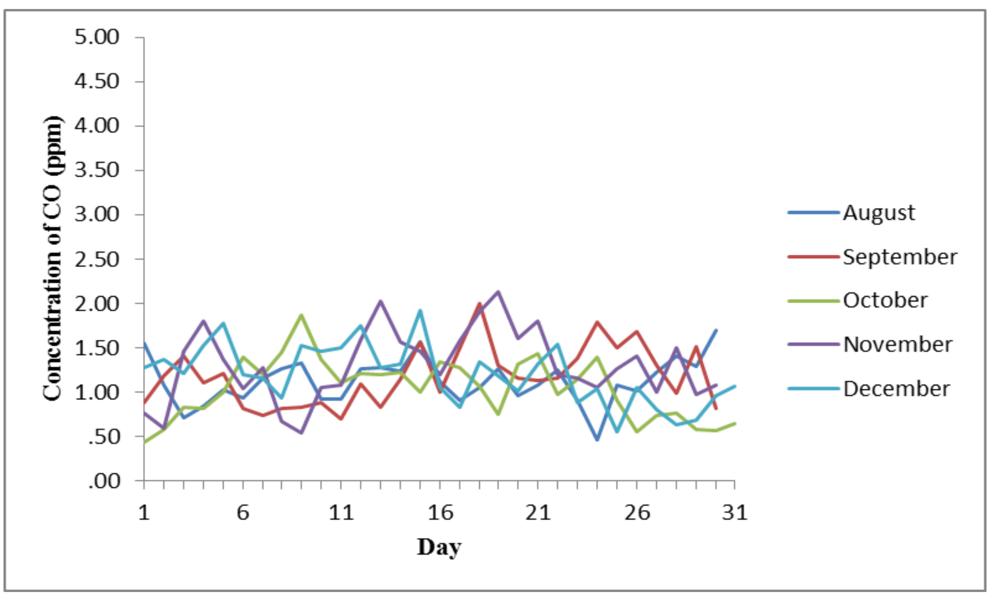

Figure 4.6c: Concentration of carbon monoxide for August, September, October, November and December

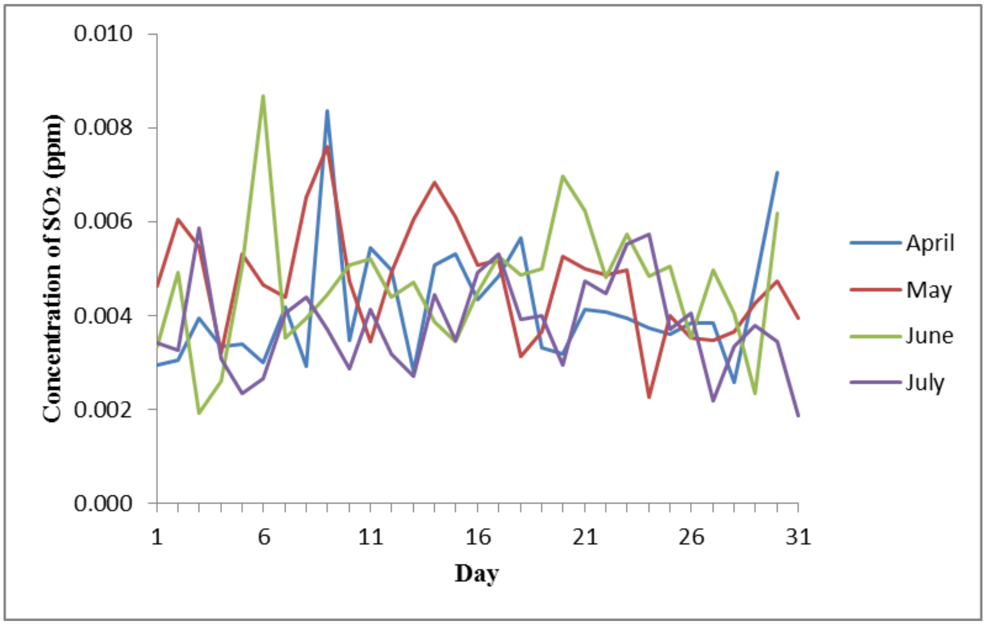

Figure 4.8b: Concentration of sulphur dioxide for April, May June and July

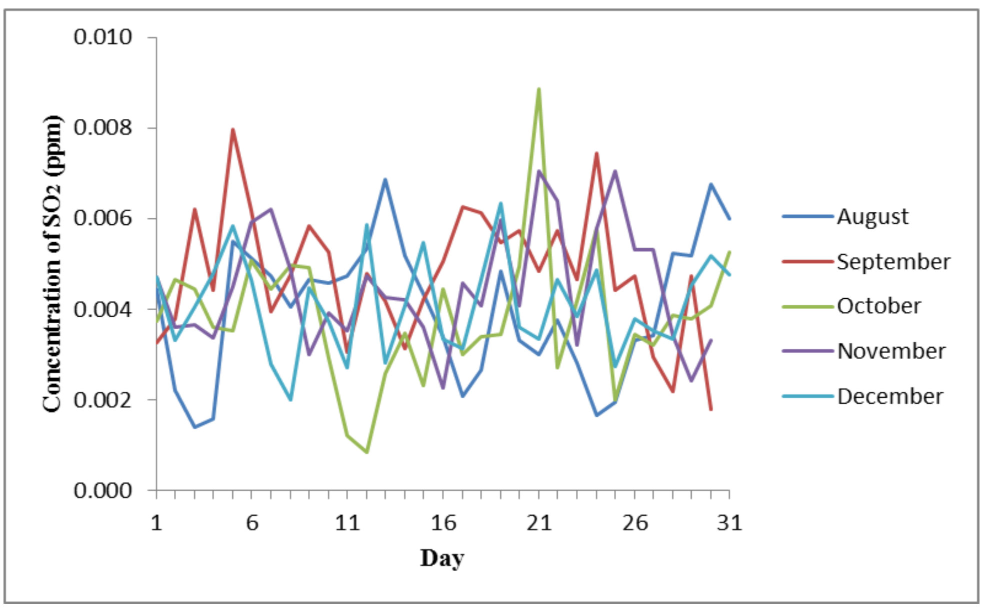

Figure 4.8c: Concentration of sulphur dioxide for August, September, October, November and December

4.3 CONCENTRATION OF AIR POLLUTANTS AT STATION B

Figure 4.9 indicates the data of the average daily of the concentration of carbon monoxide, sulphur dioxide and non-methane hydrocarbons in a year of 2010. Early in the year, the concentration of carbon monoxide is 0.82 ppm. In February, the concentration of carbon monoxide is increased to 1.30 ppm. The concentration of carbon monoxide starts to drop continuously between March and July at 0.97 ppm to 0.62 ppm. The highest concentration recorded for carbon monoxide at Station B is 1.30 ppm in February and the lowest concentration is 0.59 ppm in October.

Figure 4.9 also describes the average daily of the concentration of sulphur dioxide for each month in a year of 2010. From the graph, the concentration of sulphur dioxide in January is 0.005 ppm, and then slightly increased to 0.006 ppm in the next month. The concentration of sulphur dioxide continuously decreased from 0.006 ppm to 0.003 ppm between months of February and August. The highest concentration recorded for sulphur dioxide is 0.006 ppm in February and the lowest concentration is 0.0029 ppm in December.

The concentration of non-methane hydrocarbons for average daily in each month can be illustrated in the Figure 4.9. The highest concentration of non-methane hydrocarbons is 0.553 ppm in April and the lowest concentration is 0.307 ppm in July. The concentration of non-methane hydrocarbon in January is 0.541 ppm, and then slightly increased at 0.548 ppm in February. It continuously decreased between months of April to July at 0.553 ppm to 0.307 ppm.

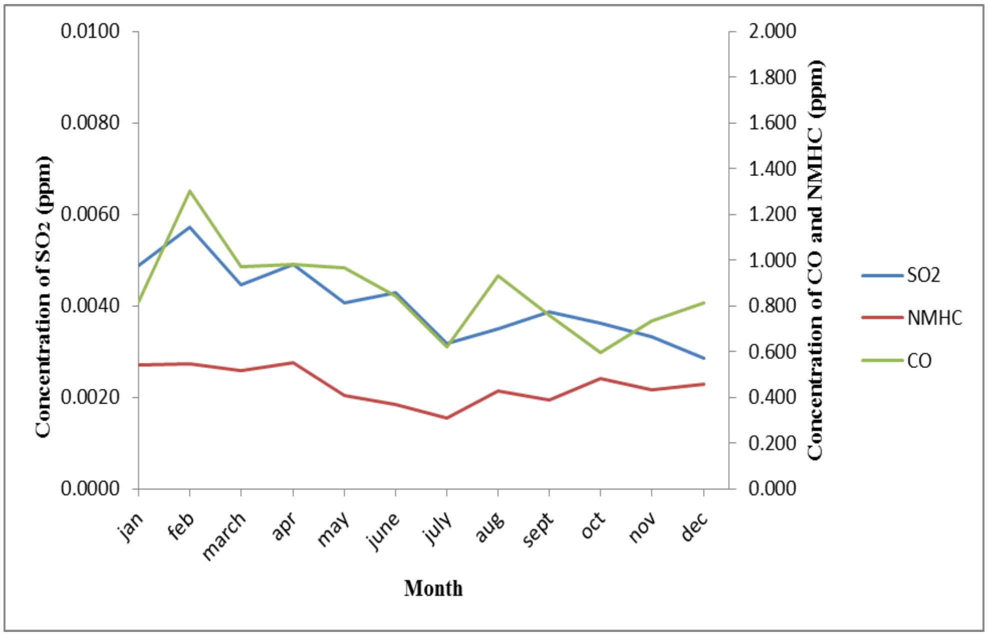

Figure 4.9: Concentration of carbon monoxide, sulphur dioxide and non-methane hydrocarbon vs month at Station B

Figure 4.10a describes the average daily of the concentration of carbon monoxide in the month of February, which is the highest concentration recorded in the year of 2010. The concentration of carbon monoxide at day 1 is 0.72 ppm and it decreased to 0.47 ppm at day 3. At day 12, the concentration is lower, which is 0.89 ppm, and then it continuously increased up to 5.15 ppm at day 15. At day 16, the concentration drastically decreased to 1.39 ppm. The highest concentration of carbon monoxide in this month is 5.15 ppm at day 15 and the lowest concentration is 0.47 ppm at day 3.

Figure 4.11a illustrates the average daily of the concentration of sulphur dioxide in the month of February, which is the highest concentration recorded in a year. The highest concentration of sulphur dioxide in this month is 0.01 ppm at day 24 and the lowest concentration is at 0.003 ppm at day 3. At day 1, the concentration is at 0.005 ppm, and then increased 0.006 ppm at day 2 before it decreased back at 0.003 ppm at day 3. The concentration recorded are varies day by day and for day 7 till day 10, the concentration of sulphur dioxide is the same which at 0.004 ppm.

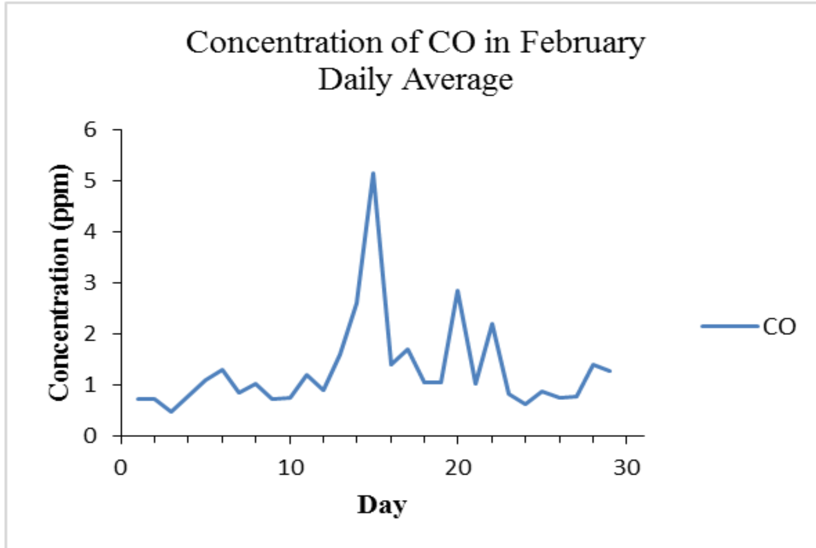

Figure 4.10a: Concentration of carbon monoxide in February

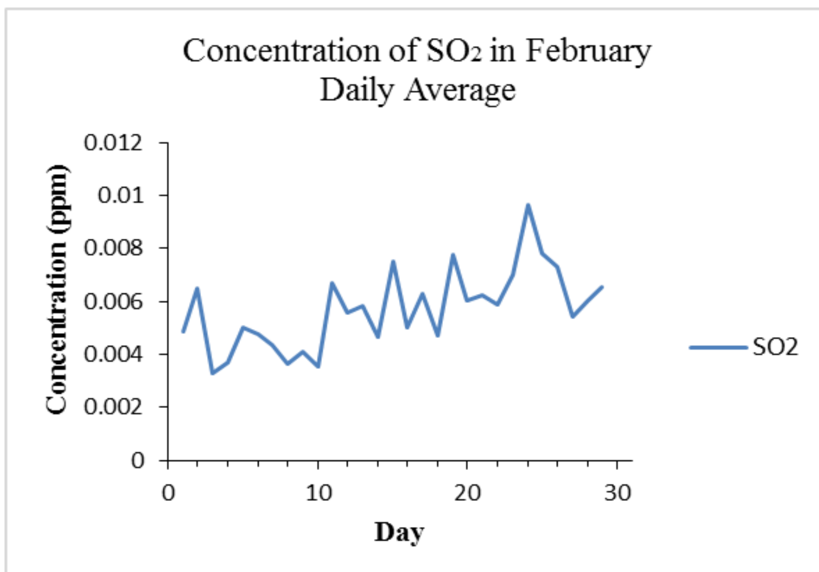

Figure 4.11a: Concentration of sulphur dioxide in February

Figure 4.12 describe the meteorological factors such as ambient temperature and humidity at Station B. High ambient temperature with low humidity affects the concentration of carbon monoxide and sulphur dioxide. The readings of ambient temperature and humidity at day 15 are 30 °C and 60 % affects the concentration of carbon monoxide and sulphur dioxide where both are at higher reading compared to other days. However, the possible production of sulphur dioxide is more at day 24 which make it the highest concentration recorded for sulphur dioxide in month of February.

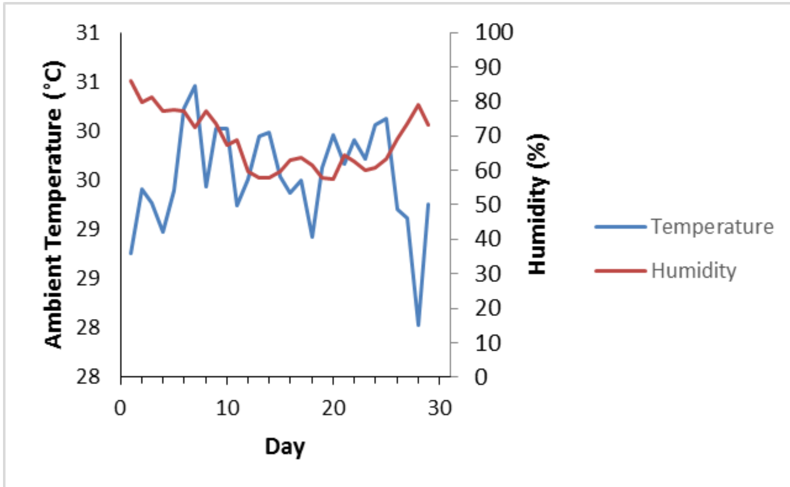

Figure 4.12: The average daily of ambient temperature and humidity in February

Figure 4.13a describes the average daily of the concentration of non-methane hydrocarbon in the month of April, which is the highest concentration recorded in the year of 2010. The highest concentration recorded is 0.90 ppm at day 4 while the lowest concentration is 0.31 ppm at day 25. The concentration of sulphur dioxide at day 23 and day 24 are the same which is 0.39 ppm.

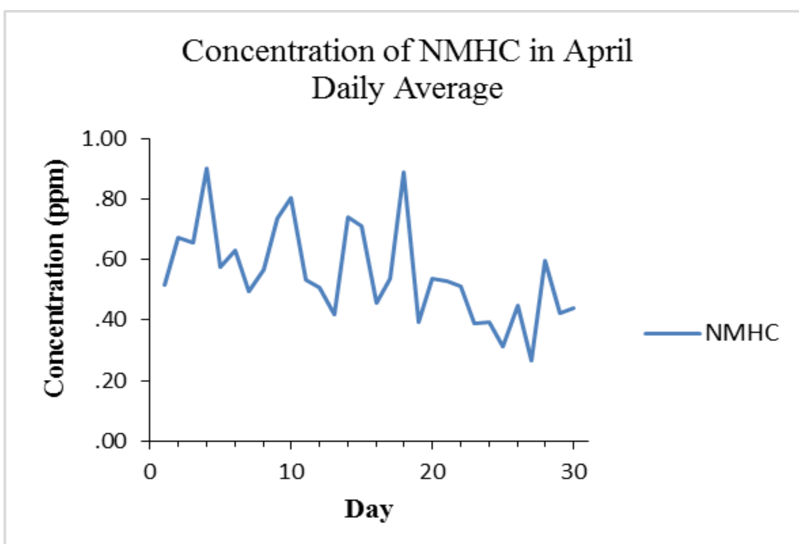

Figure 4.13a: Concentration of non-methane hydrocarbons in April

Figure 4.14 illustrate the meteorological factors such as ambient temperature and humidity at Station B in April. At the highest concentration of non-methane hydrocarbons, the ambient temperature recorded is 29 °C and the humidity recorded is 84 %. The highest humidity recorded is 96 % at day 24 and the highest ambient temperature recorded is 30 °C.

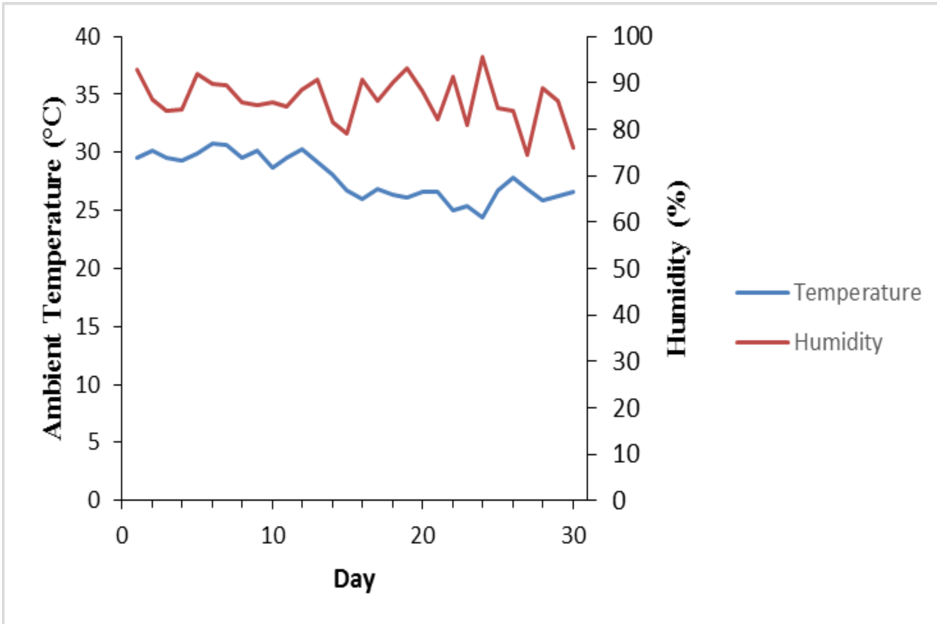

Figure 4.14: The daily average of ambient temperature and humidity in September

Figure 4.10b and Figure 4.10c represent the average daily of the concentration of carbon monoxide for other months in the same year, Figure 4.11b and Figure 4.11c represented the average daily of the concentration of sulphur dioxide, and Figure 4.13b and Figure 4.13c represented the average daily of the concentration of non-methane hydrocarbons.

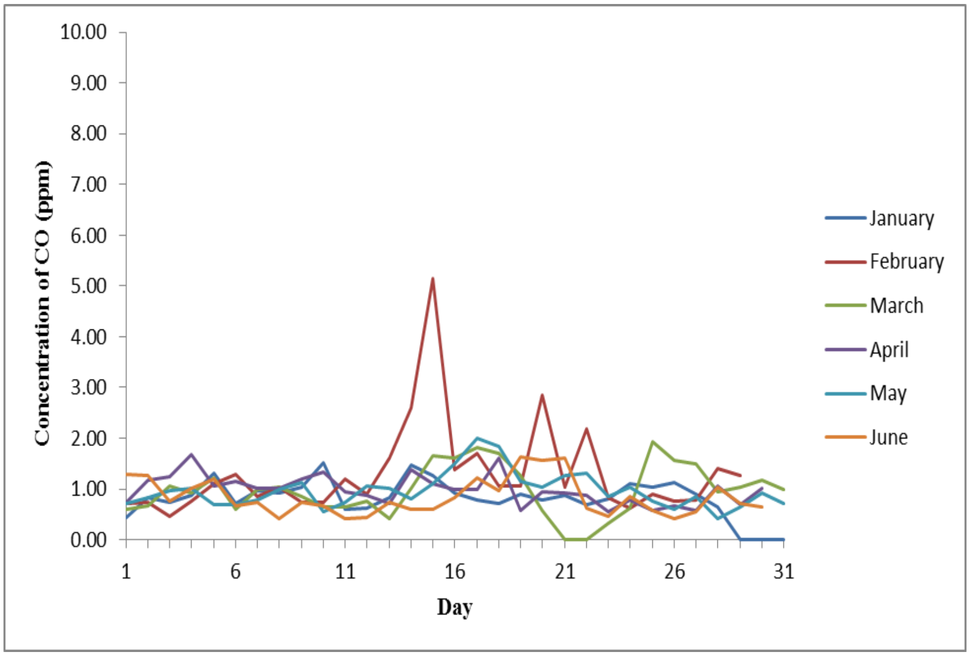

Figure 4.10b: Concentration of carbon monoxide for January, February, March, April, May and June

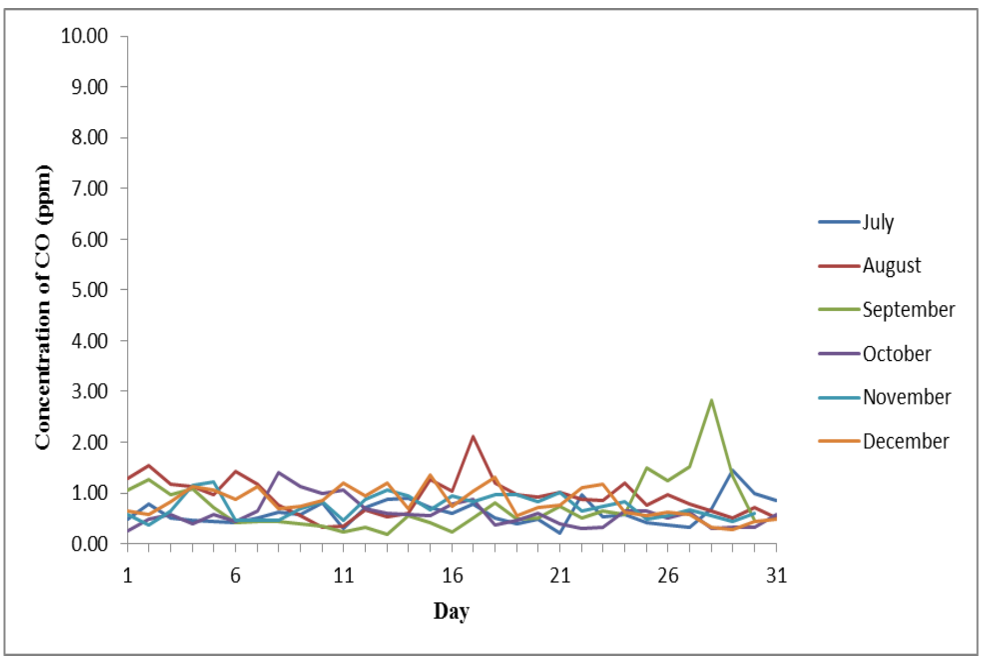

Figure 4.10c: Concentration of carbon monoxide for July, August, September, October, November and December

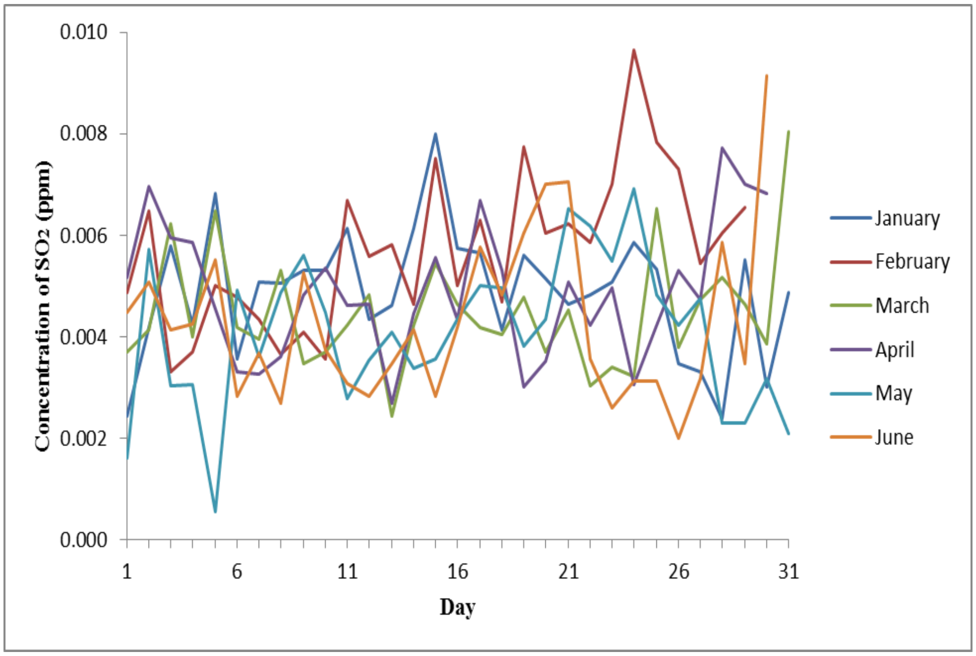

Figure 4.11b: Concentration of sulphur dioxide for January, February, March, April, May and June

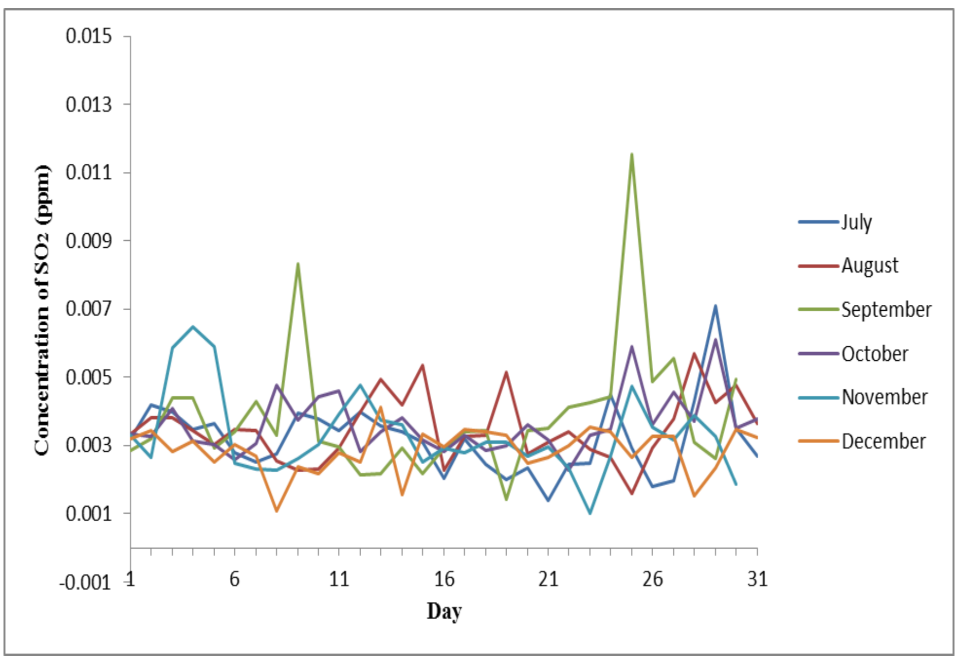

Figure 4.11c: Concentration of sulphur dioxide for July, August, September, October, November and December

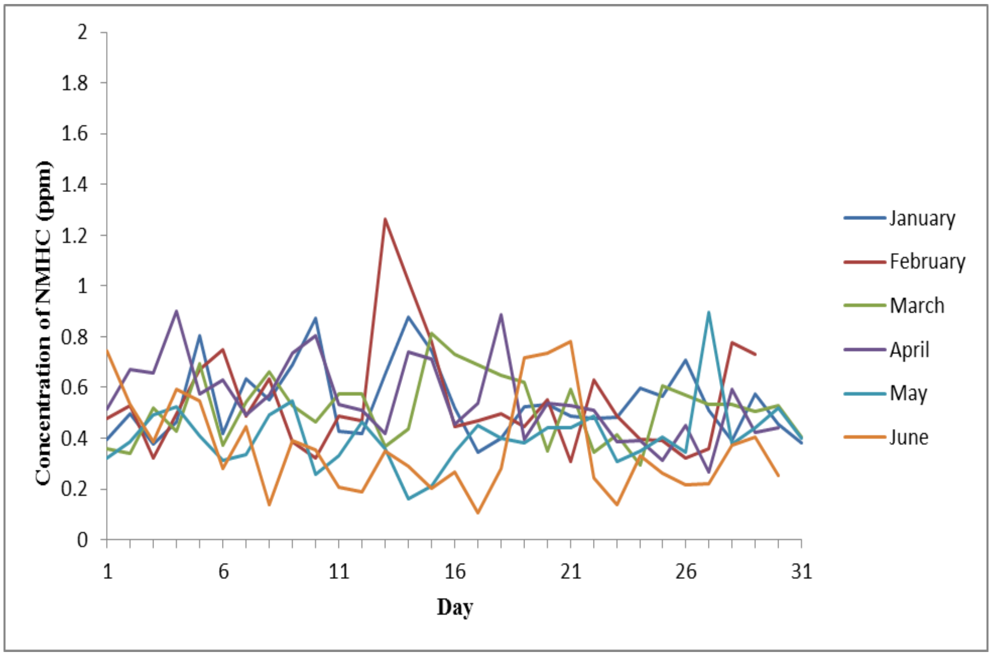

Figure 4.13b: Concentration of non-methane hydrocarbons for January, February, March, April, May and June

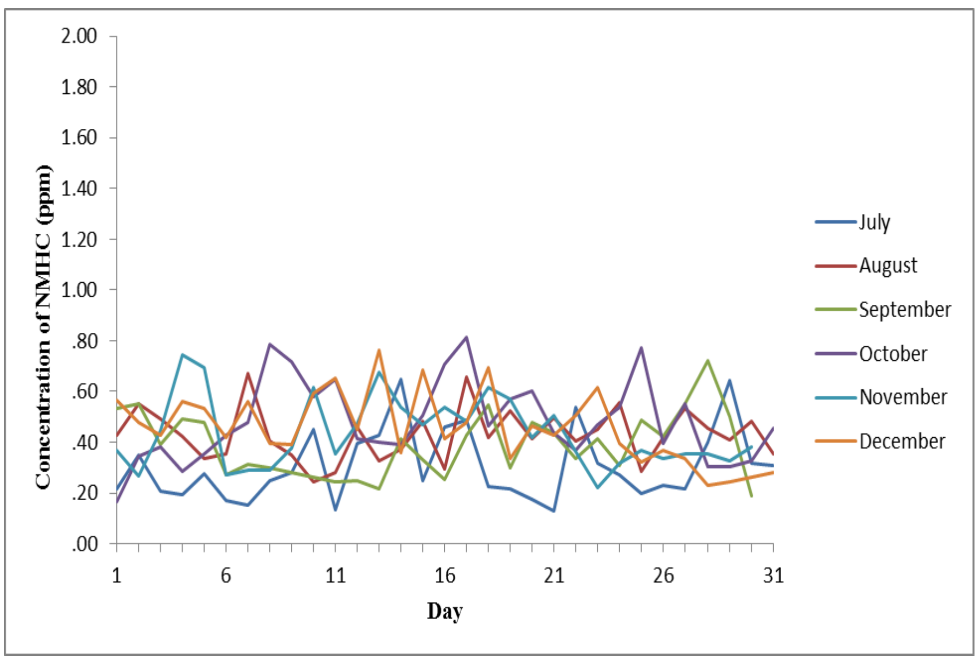

Figure 4.13c: Concentration of non-methane hydrocarbons for July, August, September, October, November and December

4.4 DISCUSSION ON STANDARD LIMIT OF AIR POLLUTANTS

In 1989, Department of Environment has set the guidelines of ambient air for each air pollutants such as carbon monoxide, sulphur dioxide, nitrogen dioxide, particulate matter, and ground level ozone (DOE, 2014; ADB, 2006). For this Final Year project, carbon monoxide and sulphur dioxide are the selected gases to be analyzed at Station A and Station B.

Throughout the year, the concentration of carbon monoxide that exceeded standard limit by DOE is in the month of February. Figure 4.15 illustrate the 8 hour average for carbon monoxide in February. The standard limit set by DOE for carbon monoxide in 8 hour average is at 9.0 ppm. From the figure, the concentration of carbon monoxide is under the standard limit line except at day 15 where the concentration recorded is 9.67 ppm which is 0.67 ppm higher than the standard limit. The reading is increased drastically from 3.31 ppm at day 14 and decreased drastically to 1.52 ppm at day 16. The possible reason is that the carbon monoxide at day 15 in this industry is produced more than other days. Low temperature with higher humidity makes the air become denser; hence the movement of the air particle is limited. Thus, the reading of the concentration becomes higher. The explanation describe based on Figure 4.16.

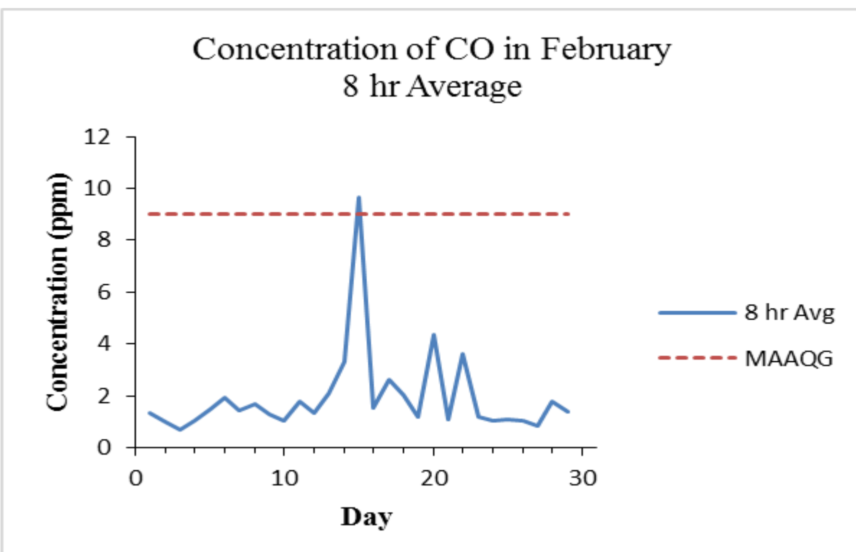

Figure 4.15: Concentration of 8 hour average of carbon monoxide

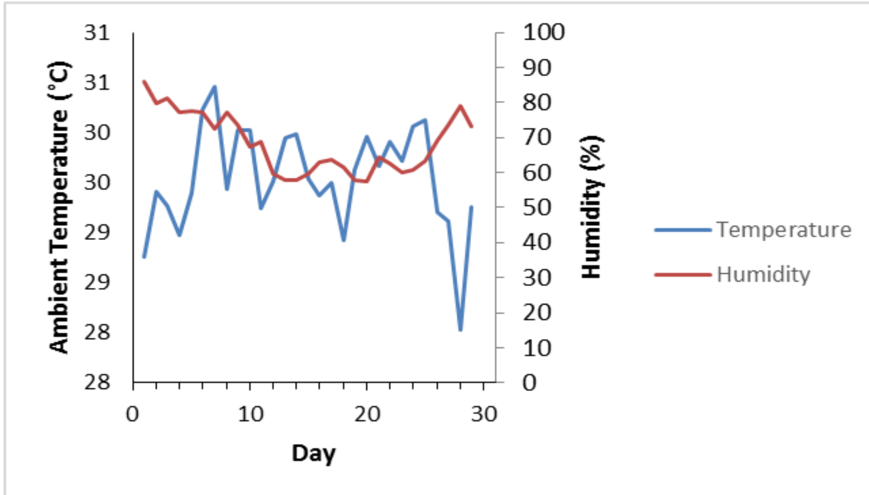

Figure 4.16: The daily average of ambient temperature and humidity in February

Figure 4.17 describe the concentration of sulphur dioxide in particular months that excess the standard limit set by DOE. The standard limit set by DOE for sulphur dioxide is at 0.04 ppm in 24 hours (DOE, 2014). In February, there are 3 days that recorded to be higher than the standard limit; 0.046 ppm at day 23, 0.084 ppm at day 24 and 0.042 ppm at day 25. The possible reason is that the production of sulphur dioxide at these sequential days is more compared to other days in February. Figure 4.16 describe that higher humidity with lower temperature also be one of the reasons the higher concentration of sulphur dioxide at that day is recorded.

The concentration of sulphur dioxide in early June is exceeded standard limit for 5 days. The concentrations recorded are 0.110 ppm, 0.080 ppm, 0.070 ppm, 0.070 ppm and 0.080 ppm. At day 6, the concentration is dropped to 0.005 ppm which is under the standard limit and it continues for the rest of days in June. From Figure 4.18, the temperature is lower while the humidity is higher affects the movement of air particle movement due to the denser air. There is also the possibility that the production of sulphur dioxide is more at the beginning of June compared to other days.

In September, the concentration of sulphur dioxide is exceeded the standard limit at day 25 where the concentration recorded is 0.012 ppm. The concentration of sulphur dioxide is gradually increased from 0.008 ppm at day 24 and the dropped at 0.009 ppm at day 26. The rest of the day in this month is under the standard limit level which is 0.04 ppm. The possible reason is at day 25, the production of sulphur dioxide to the air is more than other days in the month. The temperature is quite high and humidity is quite low which can be another factor that affected the concentration of sulphur dioxide in the air based on the graph in Figure 4.19.

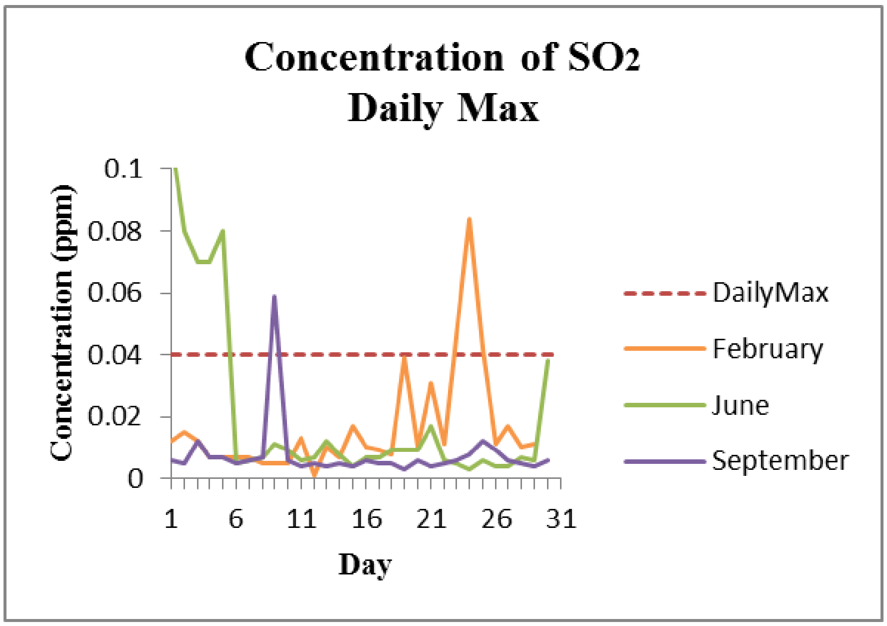

Figure 4.17: Concentration of daily max average of sulphur dioxide

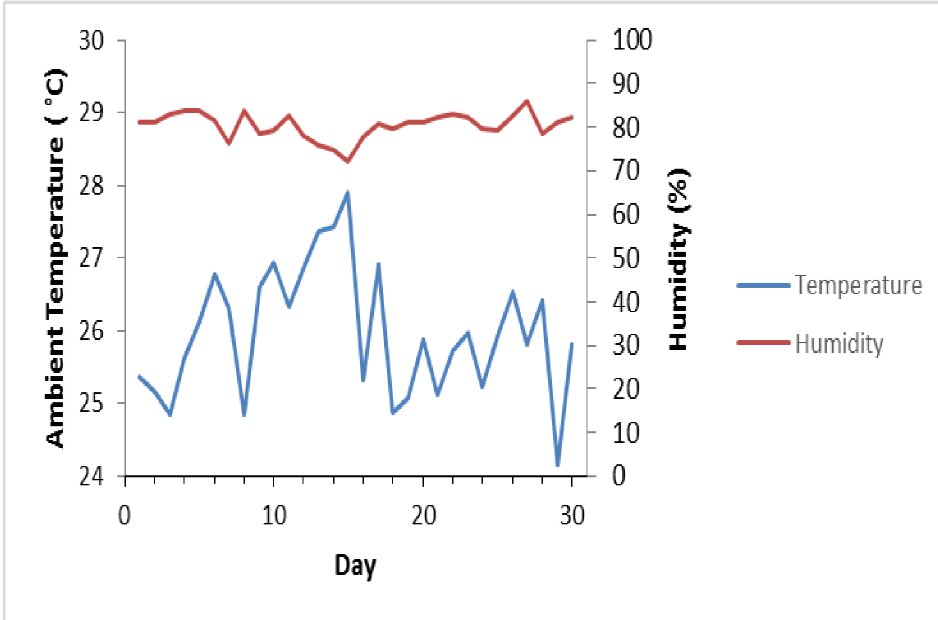

Figure 4.18: The daily average of ambient temperature and humidity in June

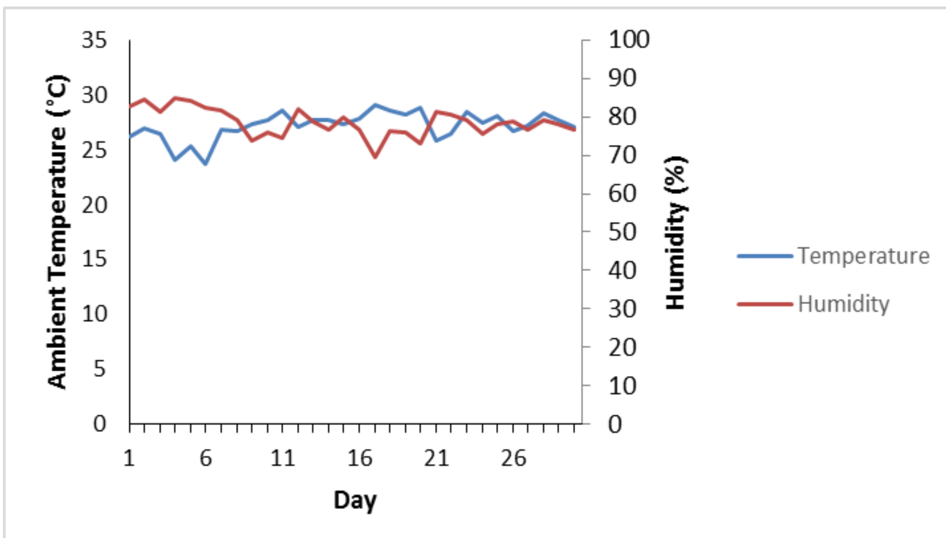

Figure 4.19: The daily average of ambient temperature and humidity in September

4.5 HEALTH STATISTICS RELATED TO AIR POLLUTION

Air pollutants can be very harmful to human's health. The effect's level is frequently depends on the length of time for human to expose at that particular air pollutant, the toxicity of the particle and the concentration of that particle in the air ambient. In Malaysia, The Ministry of Health, or MOH, is responsible to facilitate and support people on health, ensure the high quality of health system and professionalism with regards to the citizen's health (MOH, 2014).

Department of Environment has set the guidelines for air, called Malaysia Air Ambient Quality Guidelines (MAAQG) to make sure that the level of air pollutants are not exceeded the standard limit by the guideline. However, in 2010, the Ministry of Health has published the report of Health Indicator in 2010 that can be related to air pollution.

PETUNJUK KESIHATAN NO: 4.4.
Health Indicator No: 4.4.

JADUAL 4.4. : 10 SEBAB UTAMA KEMASUKAN KE HOSPITAL KEMENTERIAN KESIHATAN MALAYSIA, 2010
Table 4.4. : 10 Principal Causes of Hospitalisation in Ministry of Health Hospitals, Malaysia 2010

NO. *Rank*	SEBAB UTAMA *Principal Causes*	BILANGAN DISCAJ *Number of Discharges*	% KEPADA JUMLAH DISCAJ *% To Total Discharges*
1	Pregnancy, childbirth and the puerperium	540,291	25.72
2	Diseases of the respiratory system	200,693	9.56
3	Injury, poisoning and certain other consequences of external causes	188,522	8.98
4	Certain infectious and parasitic diseases	174,051	8.29
5	Certain conditions originating in the perinatal period	154,328	7.35
6	Diseases of the circulatory system	144,459	6.88
7	Diseases of the digestive system	107,012	5.09
8	Diseases of the genitourinary system	103,972	4.95
9	Neoplasms	76,080	3.62
10	Factors influencing health status and contact with health services	74,250	3.54
	ALL CAUSES (Admissions)	**2,100,375***	**100.00**

NOTA: Berdasarkan: "3 Digit Code Grouping - ICD 10"
* Tidak Termasuk Hospital Umum Sarawak

Note: Based on actual 3 Digit Code Grouping - ICD 10
** Excluding Sarawak General Hospital*

PUNCA : PUSAT INFORMATIK KESIHATAN, KEMENTERIAN KESIHATAN MALAYSIA.
Source : Health Informatics Centre, Ministry of Health Malaysia

Figure 4.20: List of principal causes of hospitalization in 2010

Figure 4.20 illustrated the ranking of principal causes of hospitalization in 2010. From the figure, the diseases of the respiratory system and circulatory system have been listed as a top 10 rank, which both of these diseases can be related to the effects of air pollution. In this project, the effects of carbon monoxide and sulphur dioxide are discussed based on the standard limit graph that has been discussed in section 4.4.

People that expose to the carbon monoxide in the air will be having the circulatory problem where the capacity of oxygen carried in the blood is reduced (USEPA, 2012). People that already have these problems will be having a difficulty to breath, accompanied with chest pain and also death if the level of exposure is high (USEPA, 2012). The presence of sulphur dioxide in the air can cause respiratory problem to human health, including bronchoconstriction and increased asthma symptoms (USEPA, 2012). Other effects include breathing difficulty, eye irritation, heart failure and circulatory collapse (MMA, 2014). Figure 4.21 shows the list principal cause of death in 2010 which Rank 1 and 2 can be related to the effects of carbon monoxide and sulphur dioxide to human health.

PETUNJUK KESIHATAN NO: 4.5.
Health Indicator No: 4.5.

JADUAL 4.5. : 10 SEBAB UTAMA KEMATIAN KE HOSPITAL KEMENTERIAN KESIHATAN MALAYSIA, 2010
Table 4.5. : 10 Principal Causes of Death in Ministry of Health Hospitals, Malaysia, 2010

NO. *Rank*	SEBAB UTAMA *Principal Causes*	BILANGAN KEMATIAN *Number of Deaths*	% KEPADA JUMLAH KEMATIAN *% To Total Deaths*
1	Diseases of the circulatory system	11,812	25.35
2	Diseases of the respiratory system	8,599	18.46
3	Certain infectious and parasitic diseases	8,297	17.81
4	Neoplasms	5,532	11.87
5	Injury, poisoning and certain other consequences of external causes	2,492	5.35
6	Diseases of the digestive system	2,218	4.76
7	Diseases of the genitourinary system	2,177	4.67
8	Certain Conditions Oroginating in the Perinatal Period	1,801	3.87
9	Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	856	1.84
10	Endocrine, nutritional and metabolic diseases	801	1.72
	ALL CAUSES	**46,594***	**100.00**

Figure 4.21: List of principal cause of death in 2010.

CHAPTER 5

CONCLUSION

The result obtained for impacts of climate changes on regional air quality are presented in this study by using time series analysis. From the result, it shows that the level of the concentration of carbon monoxide, sulphur dioxide and non-methane hydrocarbons are all below the standard limit and six oil and gas stations are selected for this analysis. The level of these gases is then being compared with the level of each gas from the guidelines prepared by Department of Environment. From the result, it shows that even though the concentration of these gases is below the standard limit, still the consequences of this gases to the human health is higher based on the health report by Ministry of Health. Thus, the suggestion is made from this study for Department of Environment to review back the standard limit for each particular gases so that the number of human that affected by these gases can be reduced.

There is lack of research have been done on air pollution at oil and gas industry thus this study can be used as a references for future researchers to continue the research about air pollution at oil and gas industry. The guidelines about air pollution specifically for oil and gas industry should be made for safety of workers health and for sustainability development of this country. A few suggestions need to be considered so that this study can achieved more accurate result:

1. Include more meteorological data such as wind speed and direction
2. Obtain the sample in oil and gas industry
3. Usage of suitable software to obtain more accurate result, modeling and analysis.

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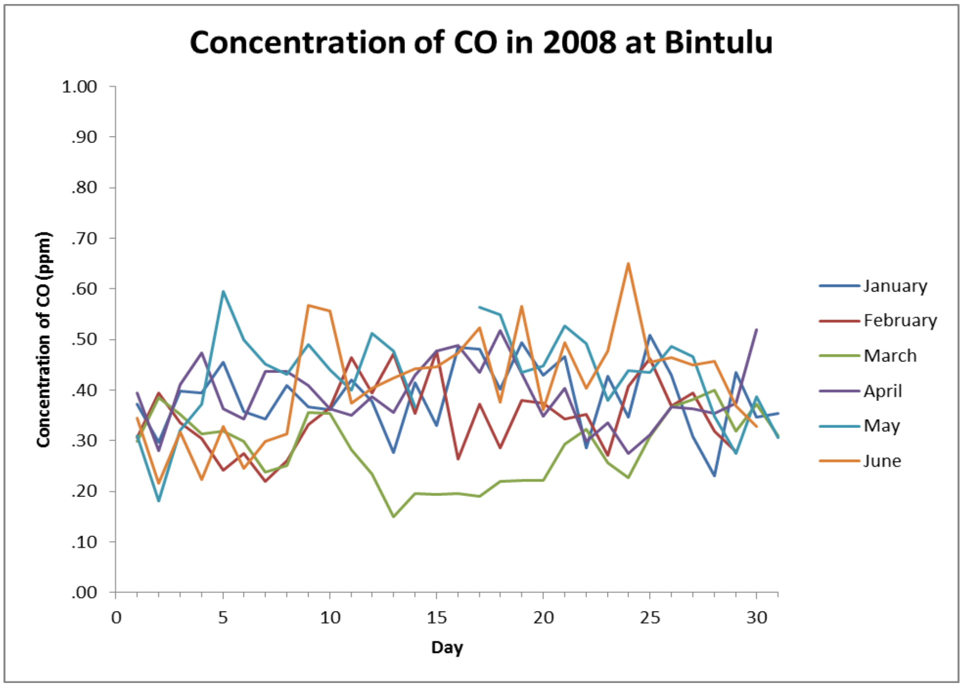
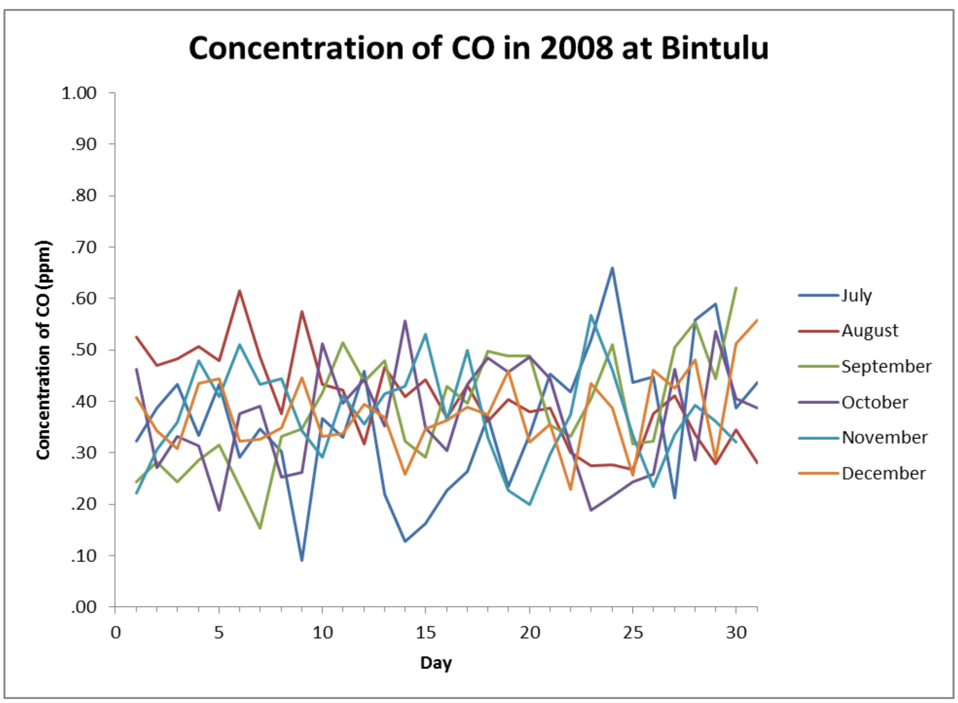
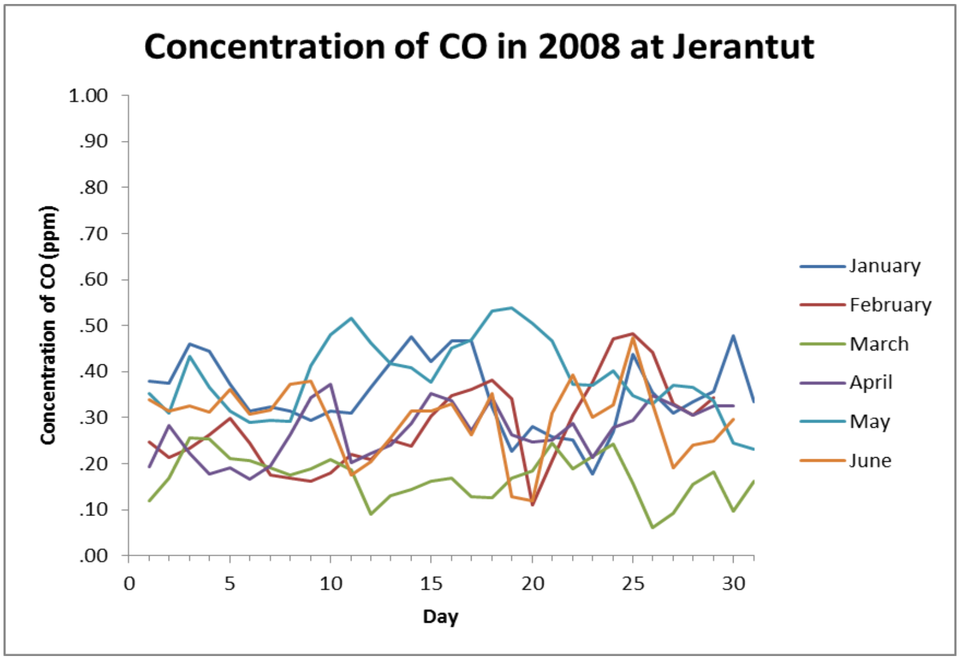
APPENDIX

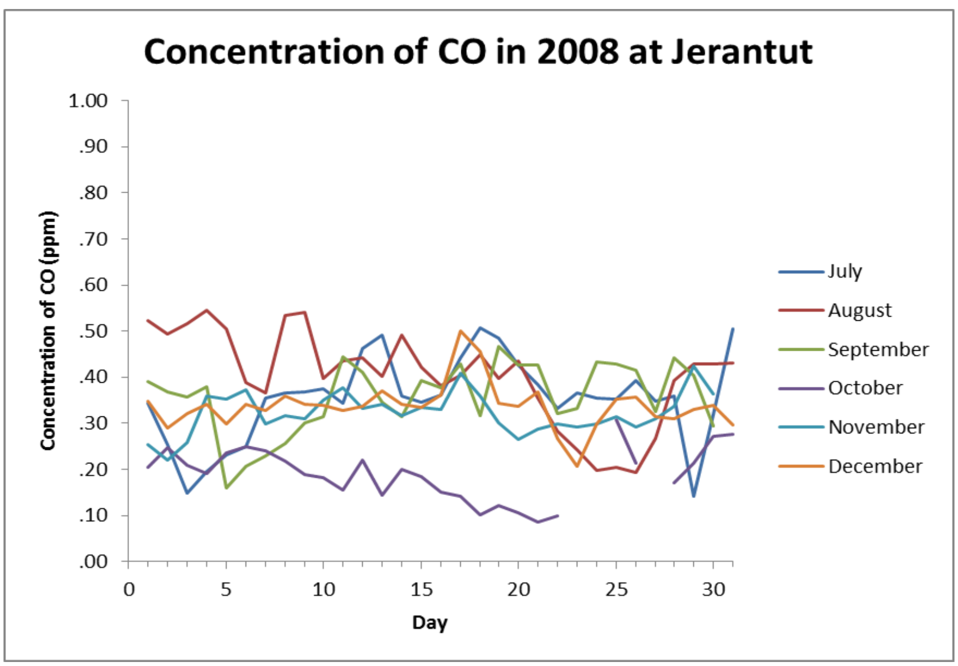
Concentration of carbon monoxide at Bintulu in 2008





Concentration of carbon monoxide at Jerantut in 2008





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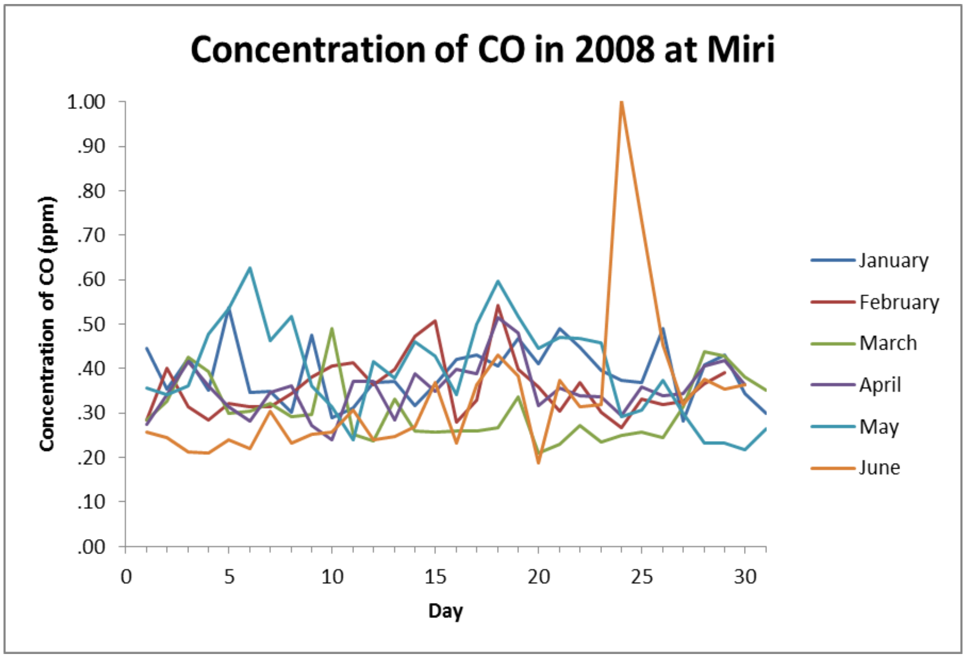

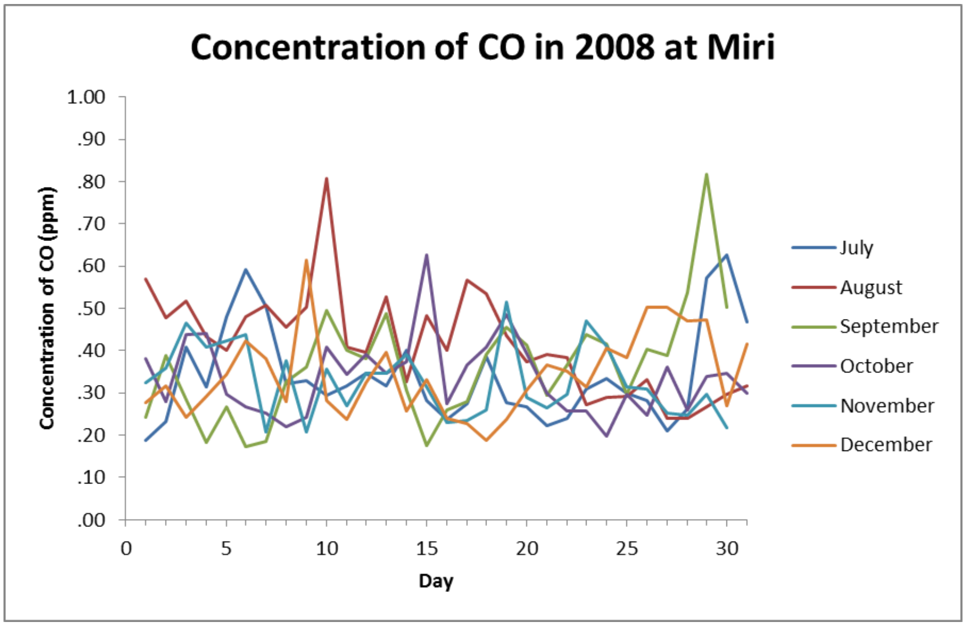

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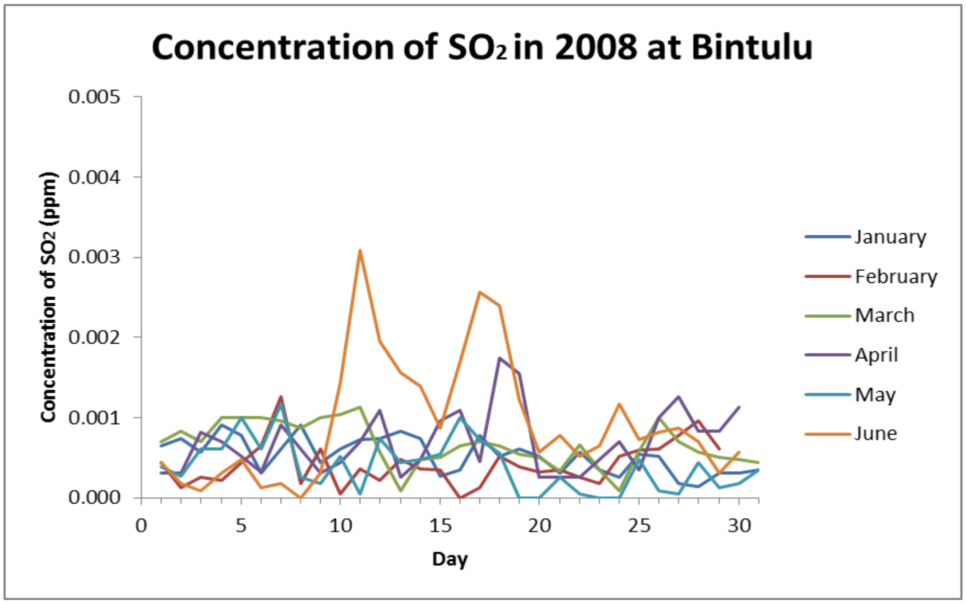

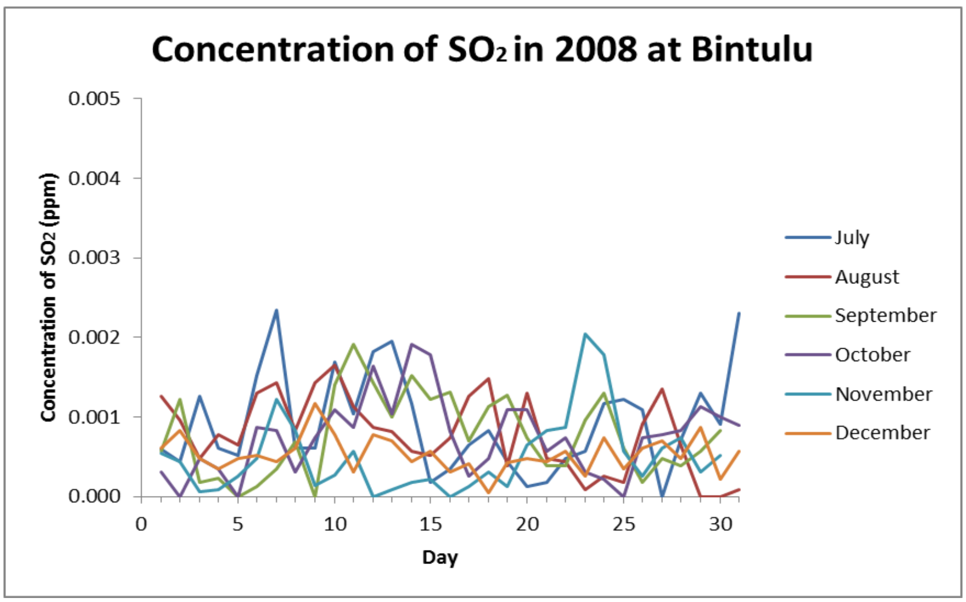

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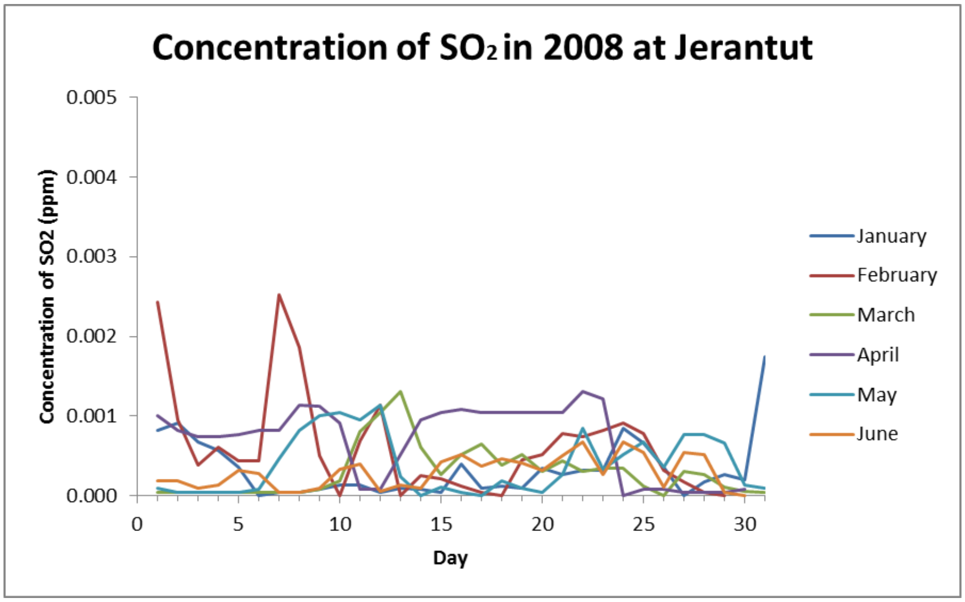

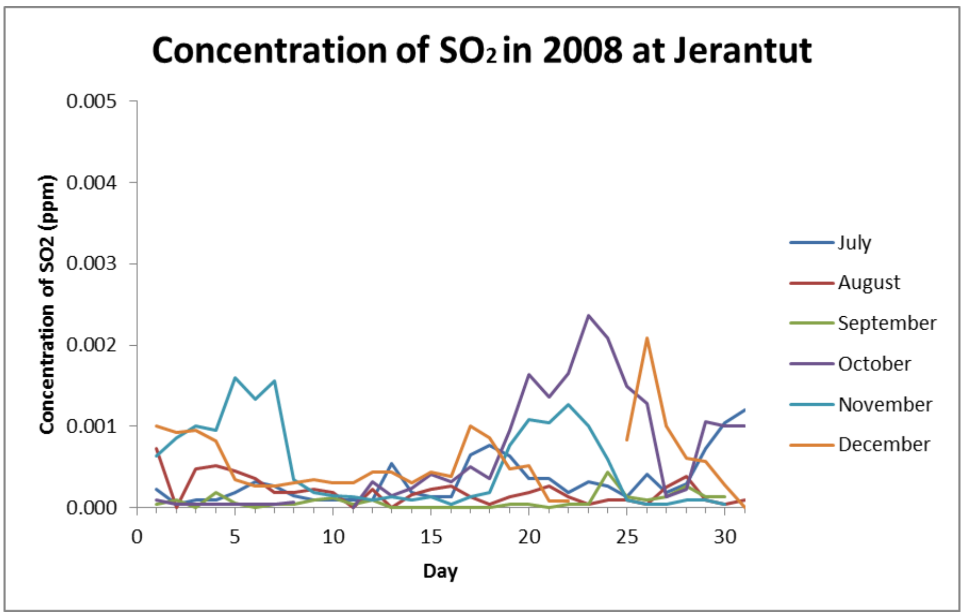

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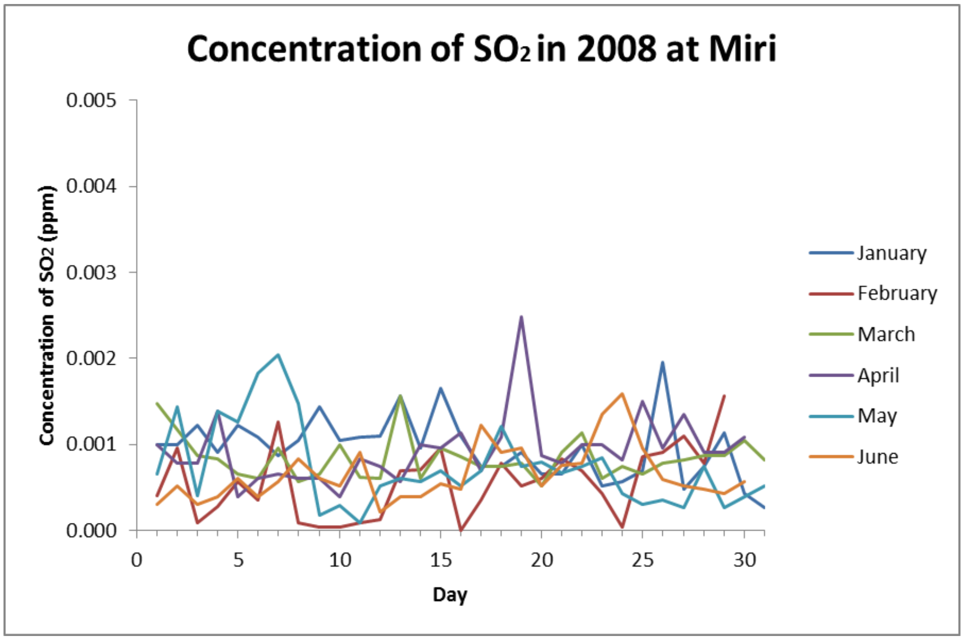

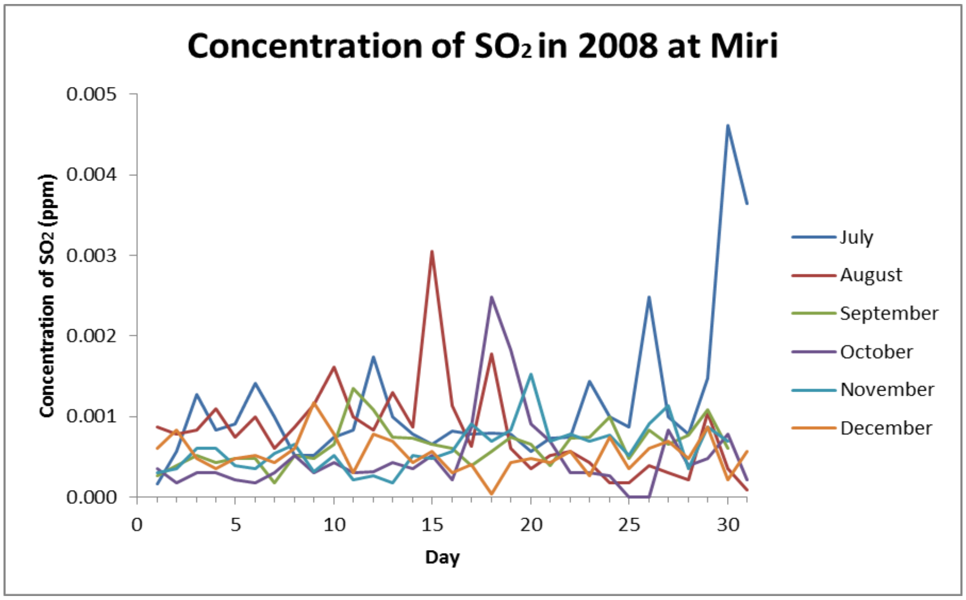

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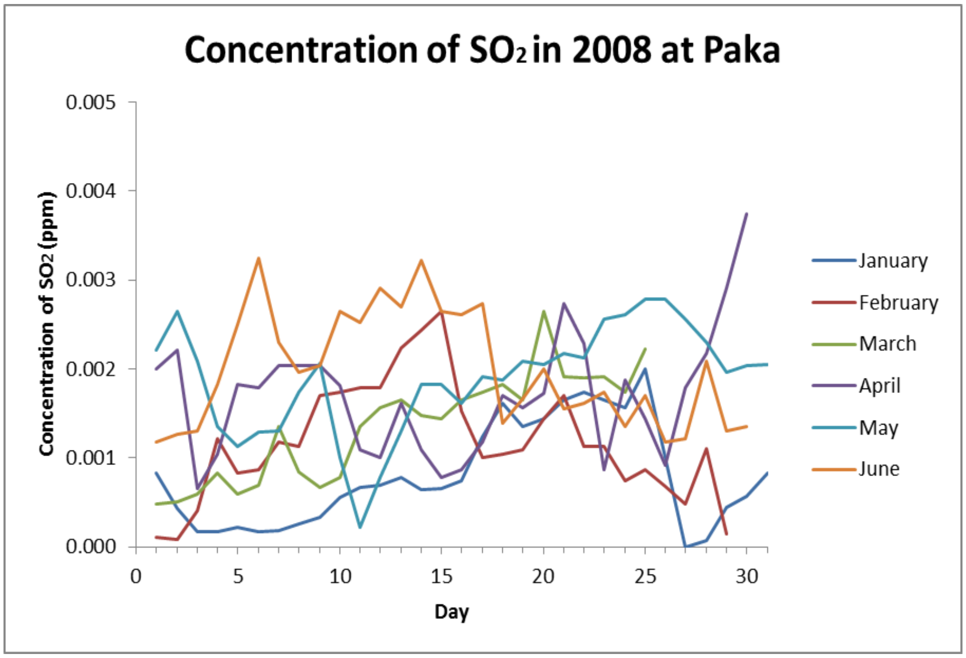

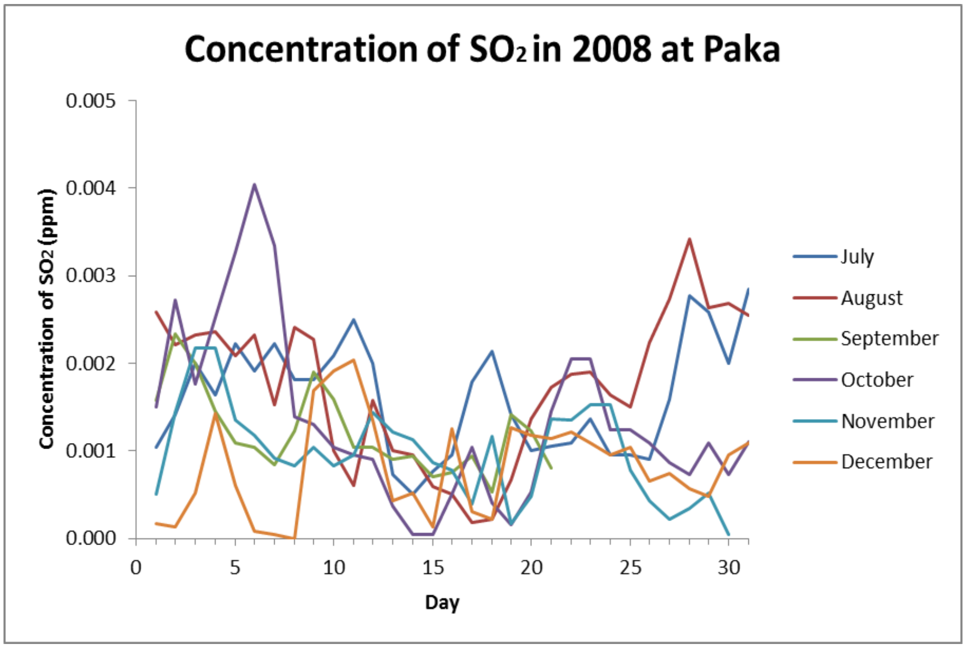

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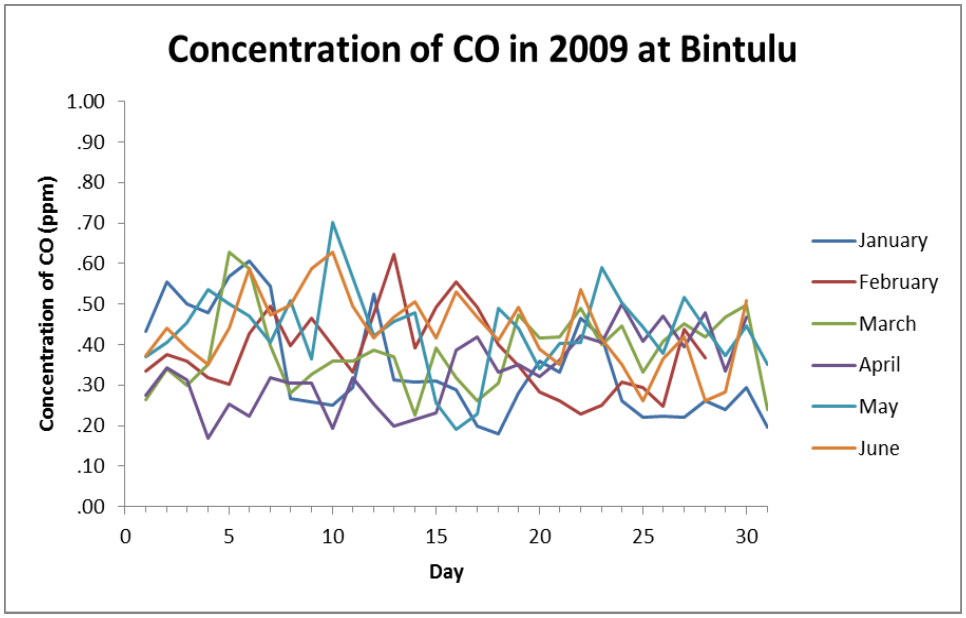

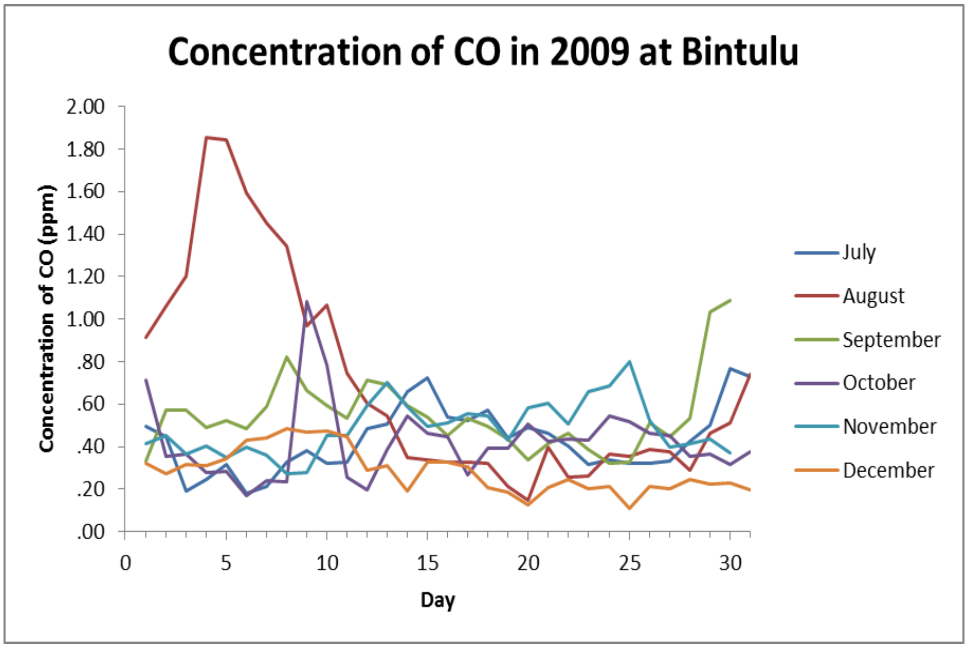

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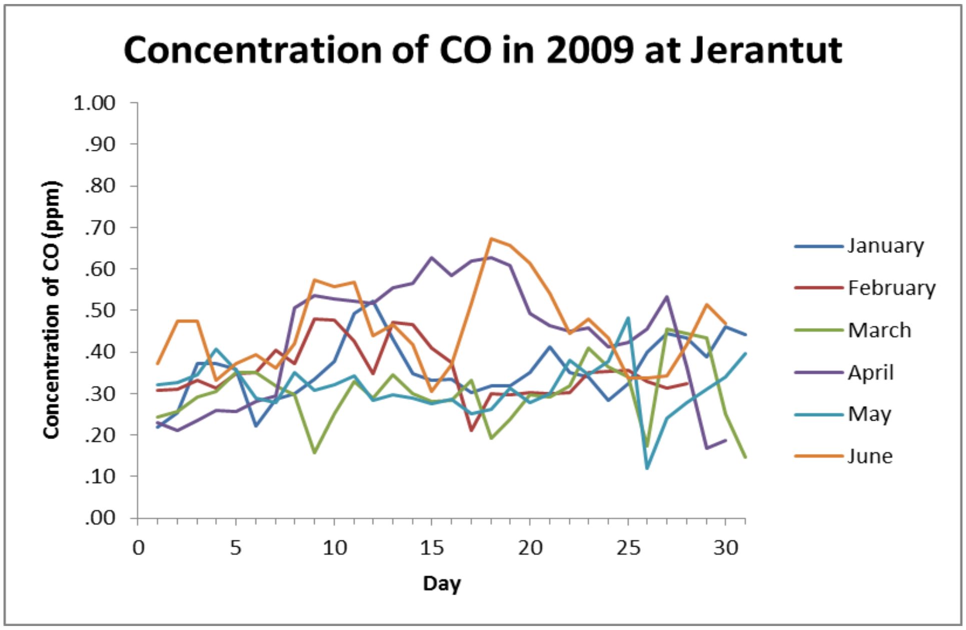

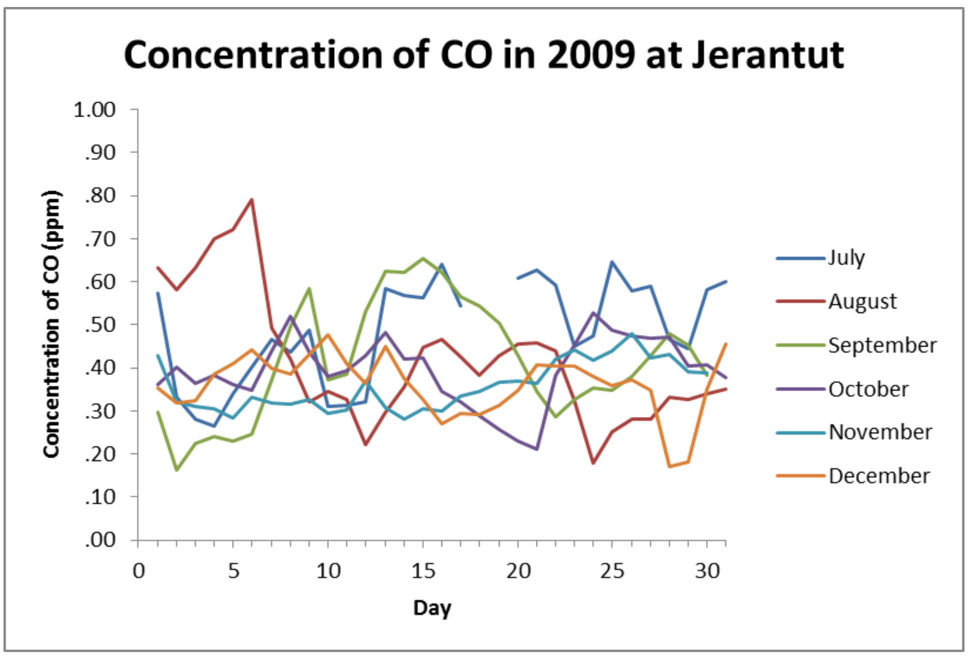

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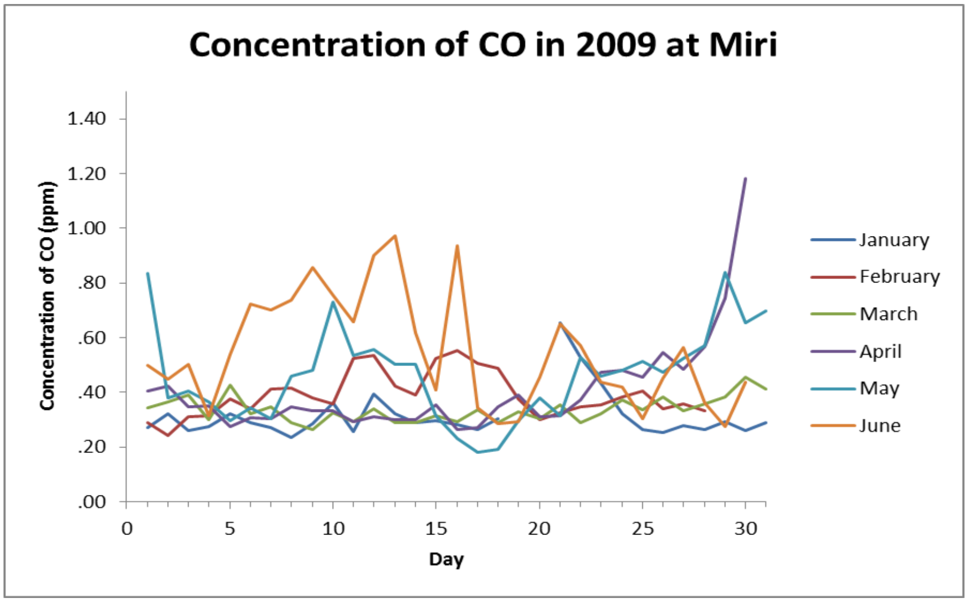

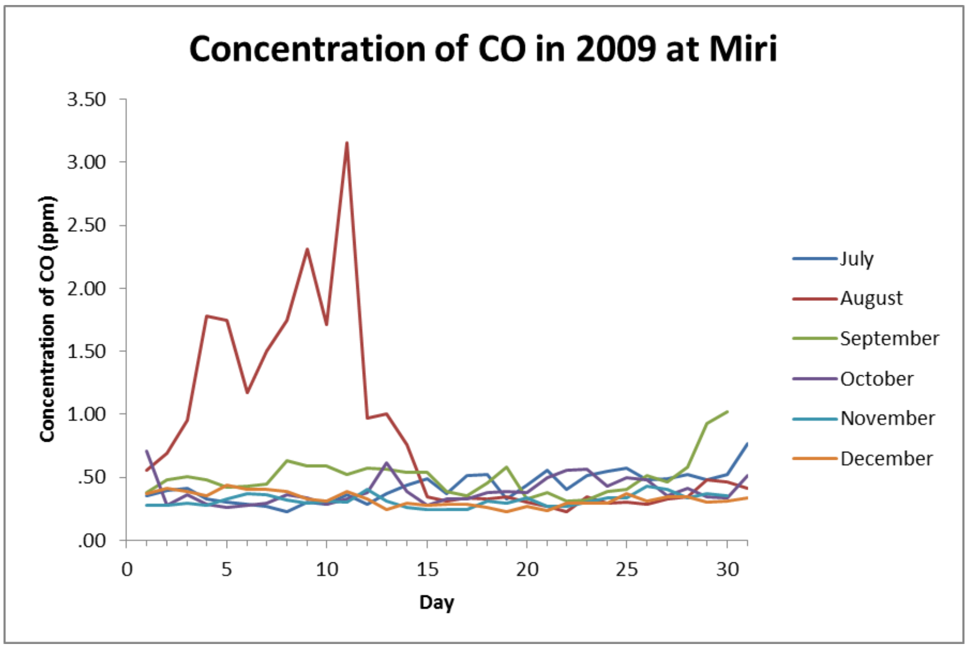

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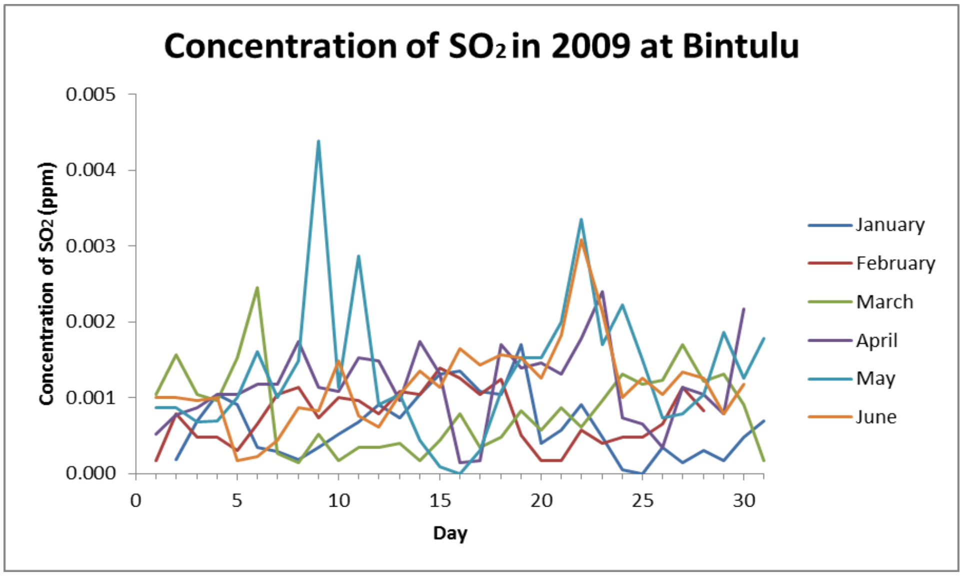

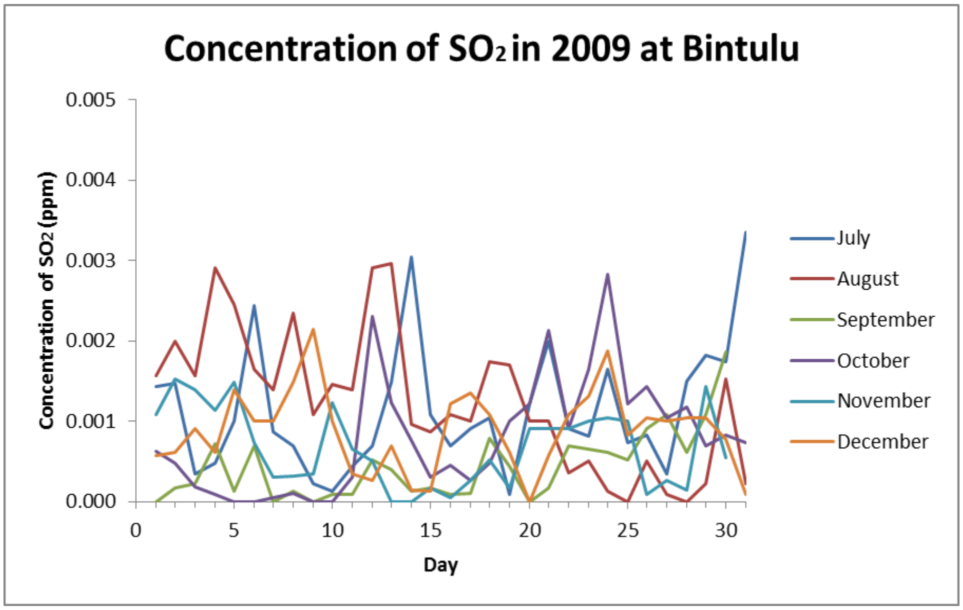

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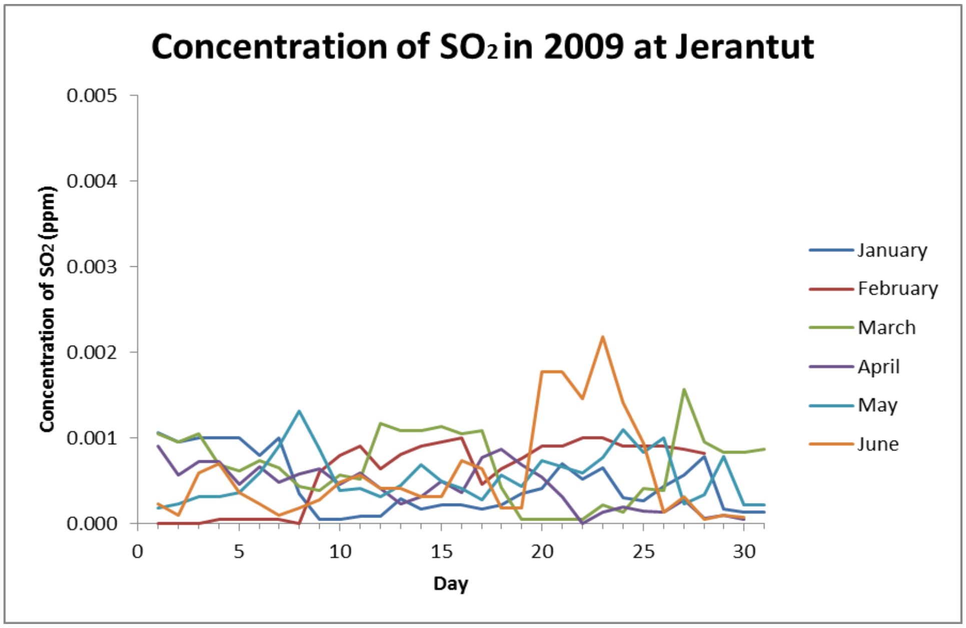

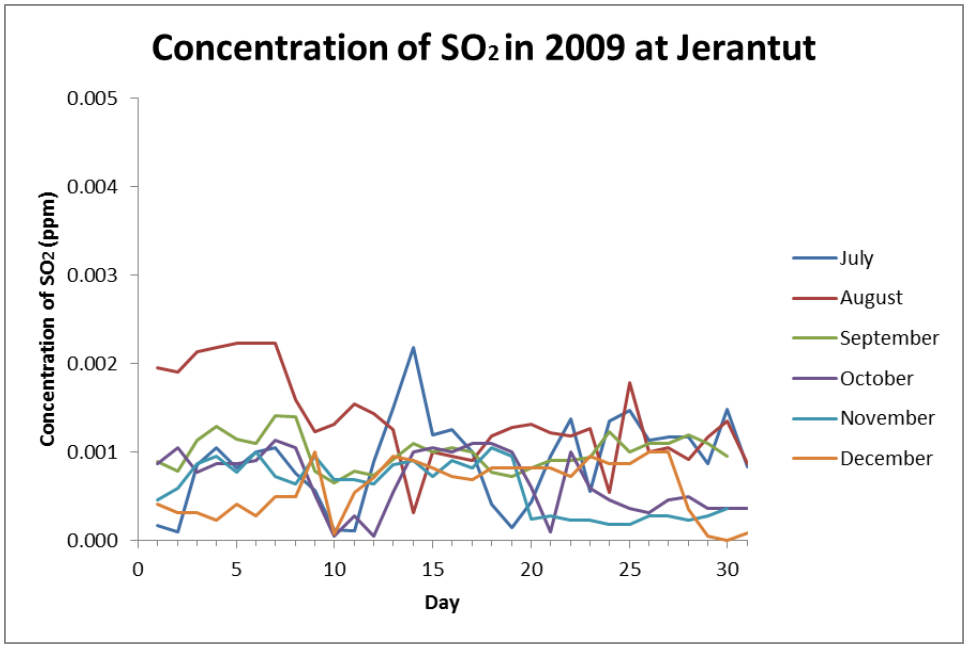

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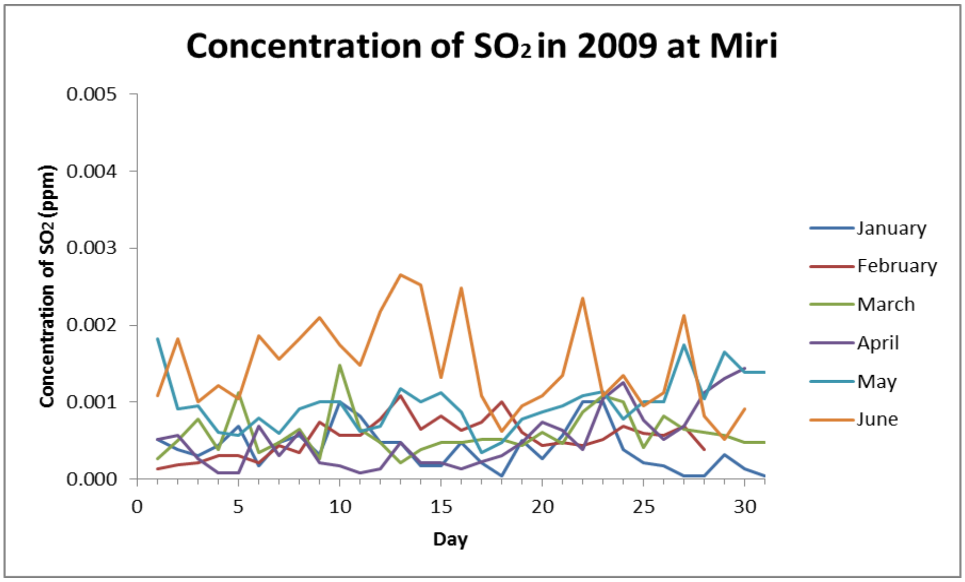
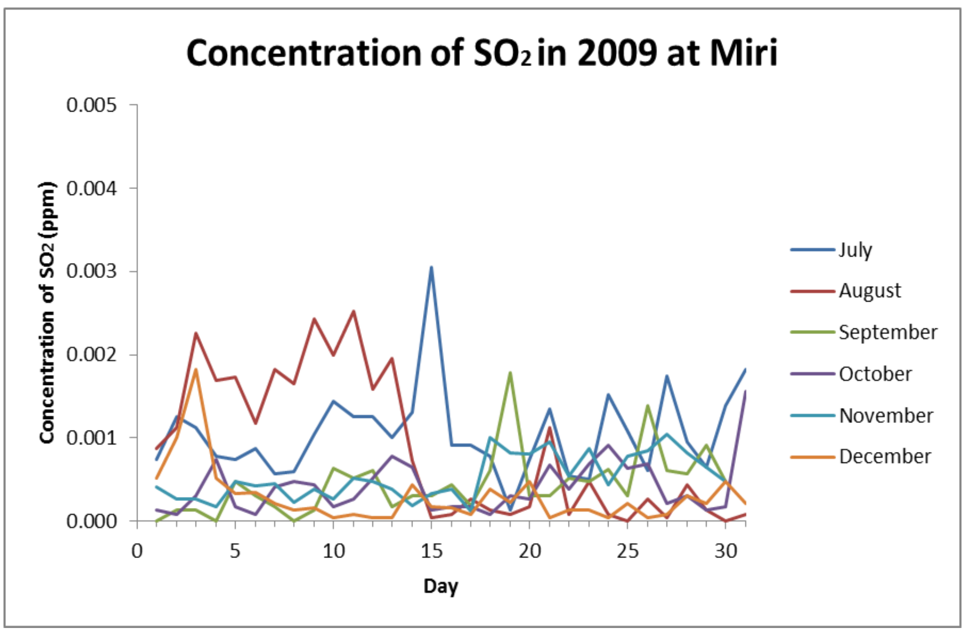
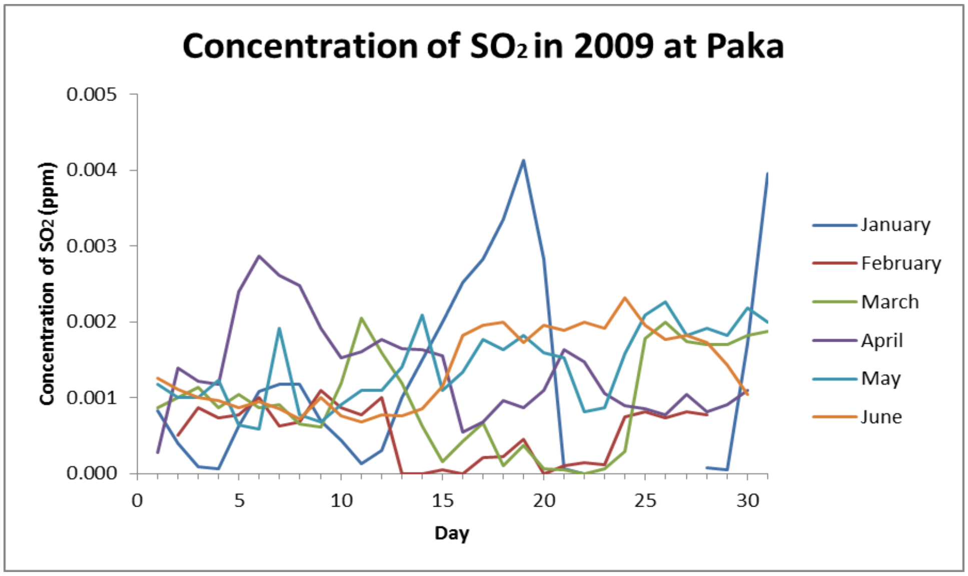
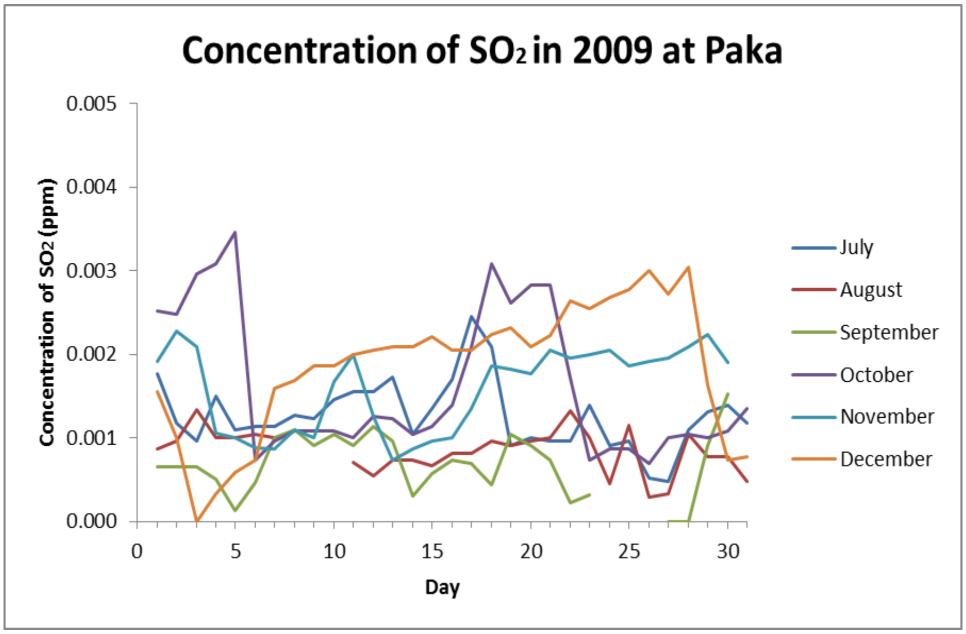




Concentration of sulphur dioxide at Paka in 2009





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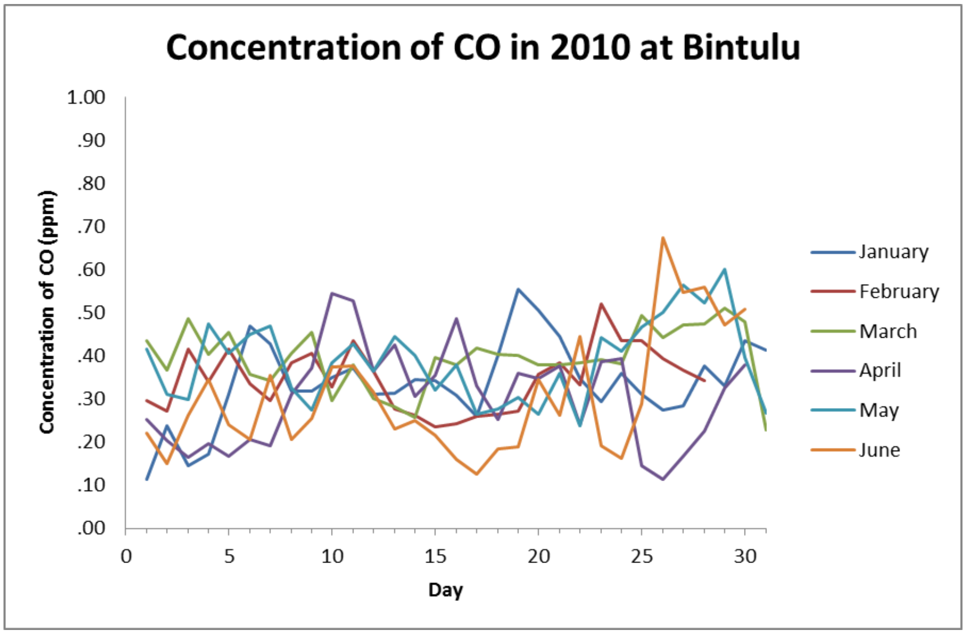

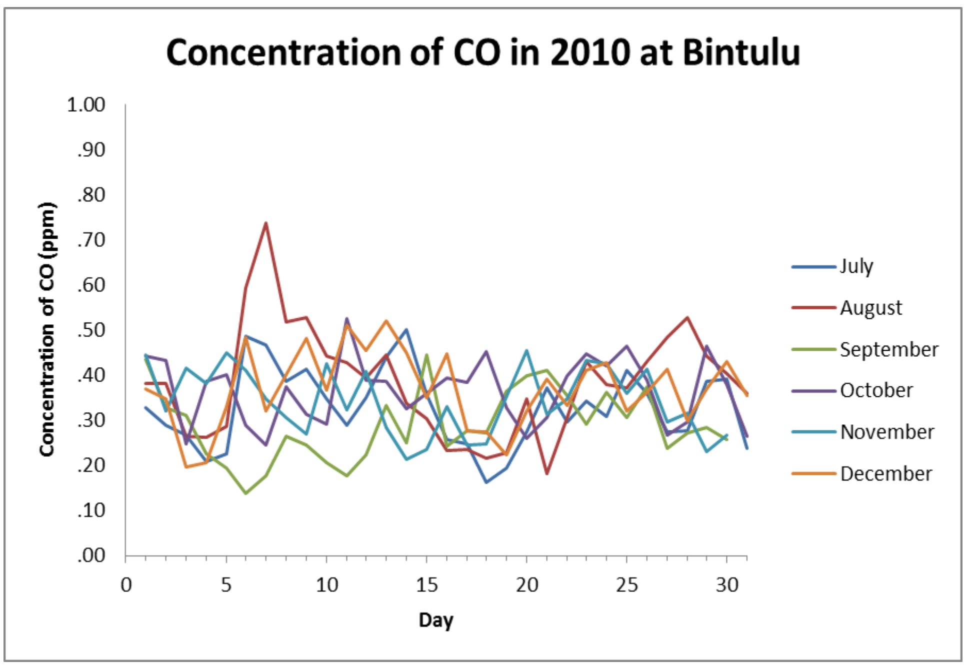

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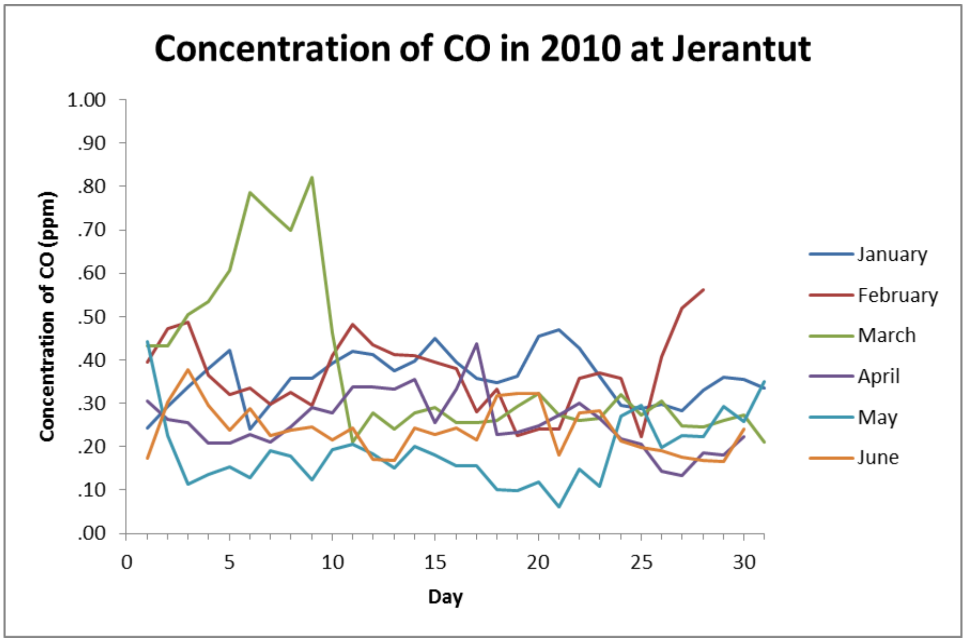

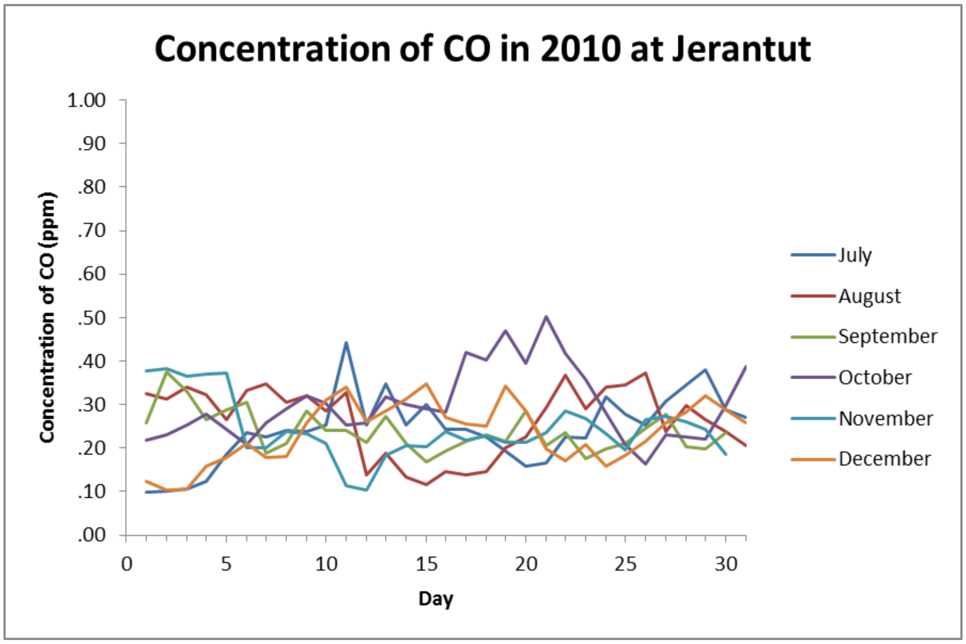

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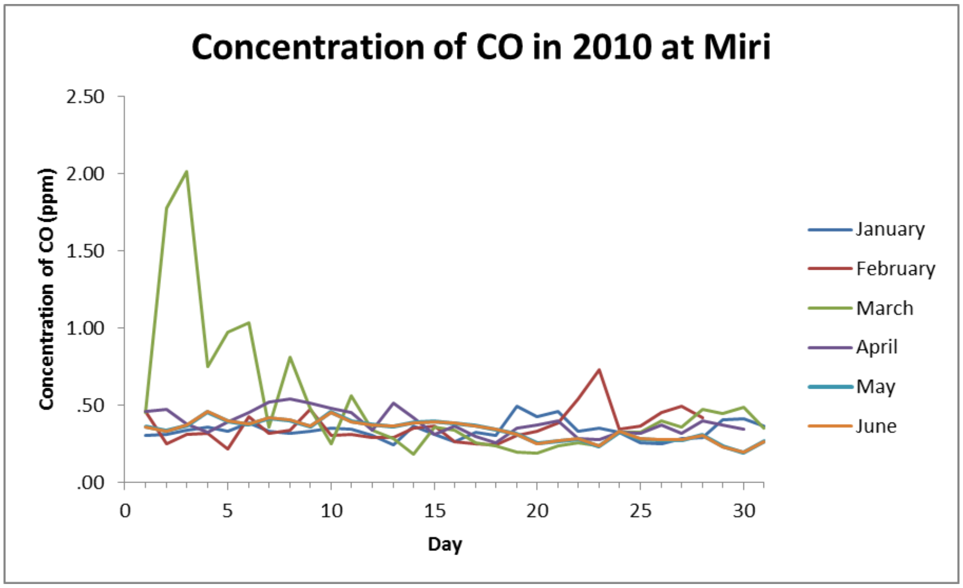

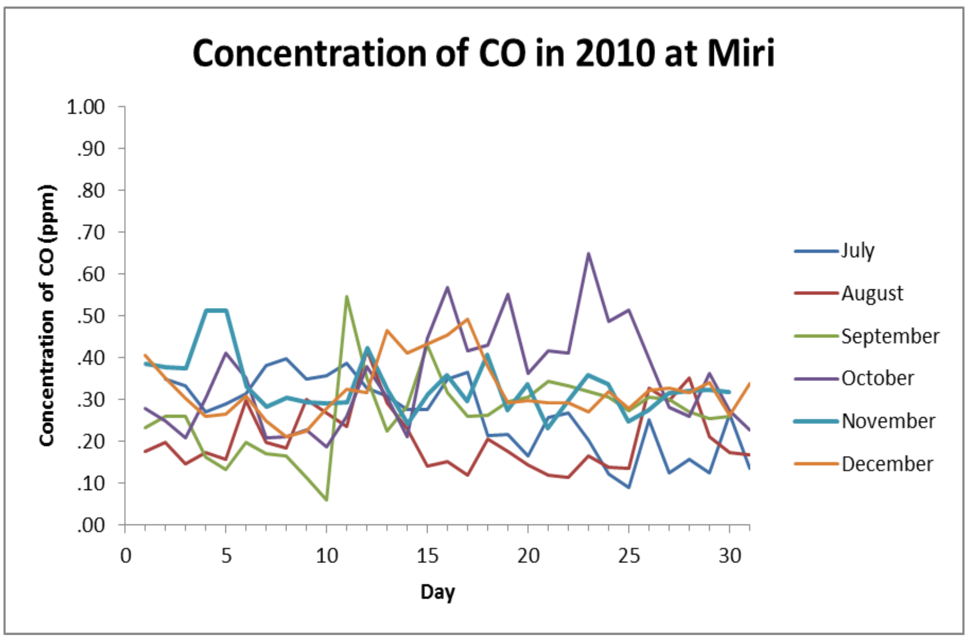

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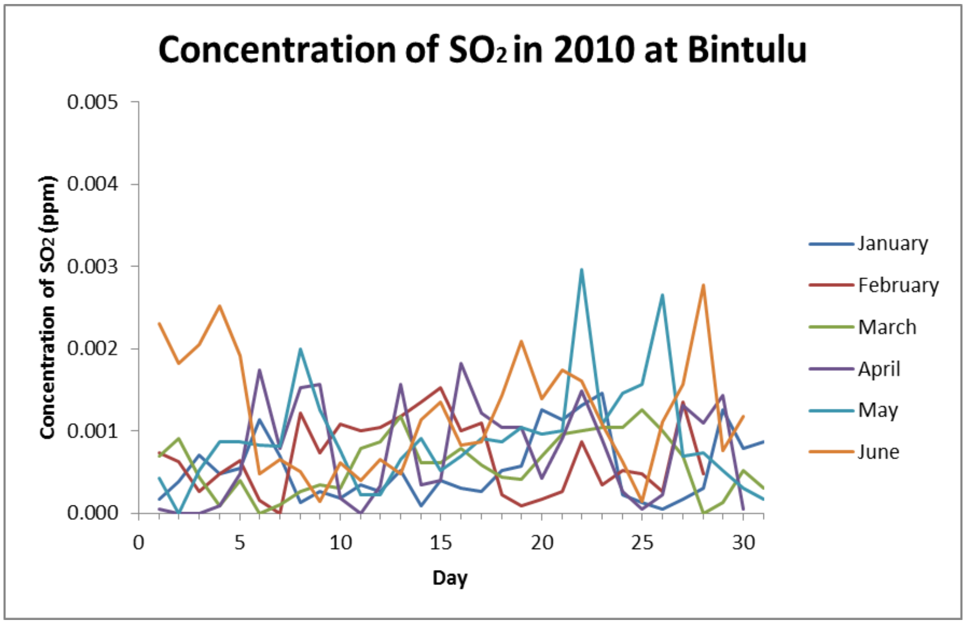

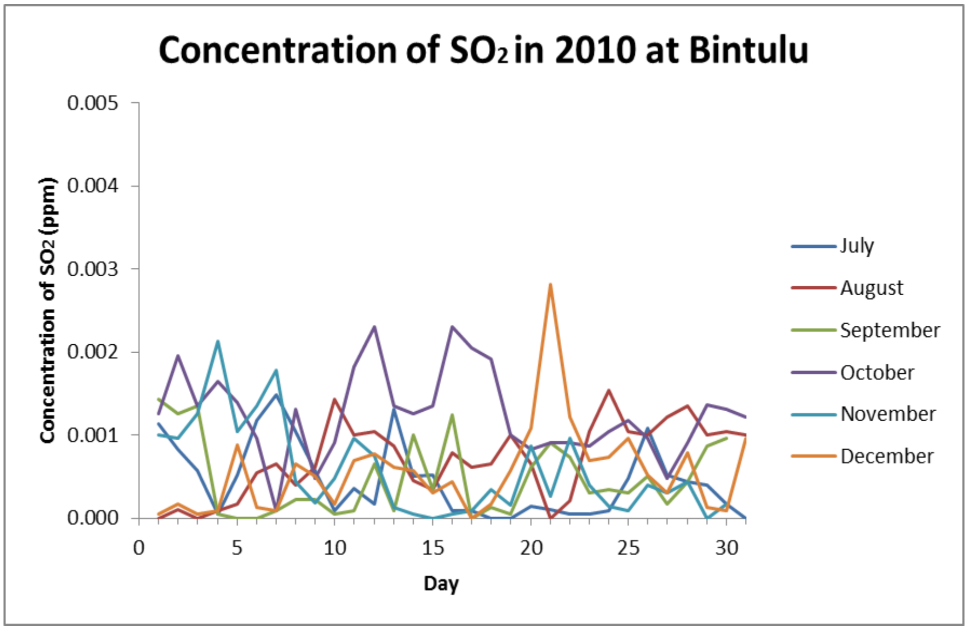

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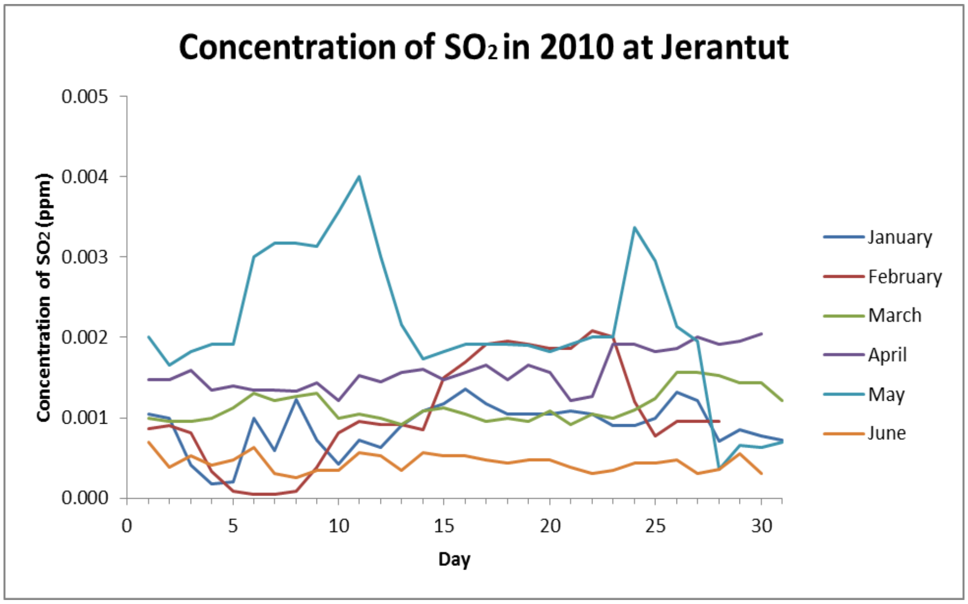

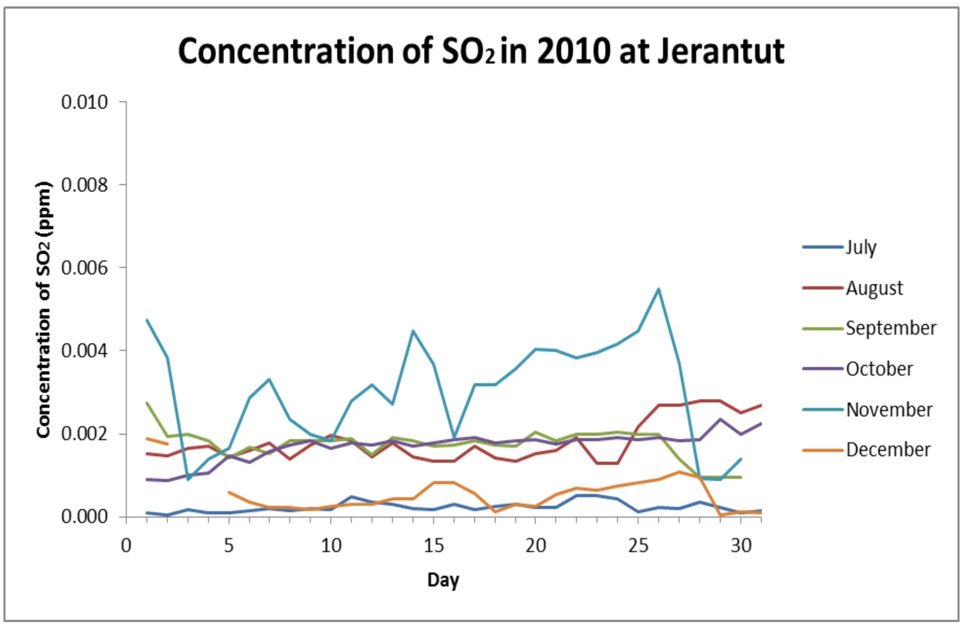

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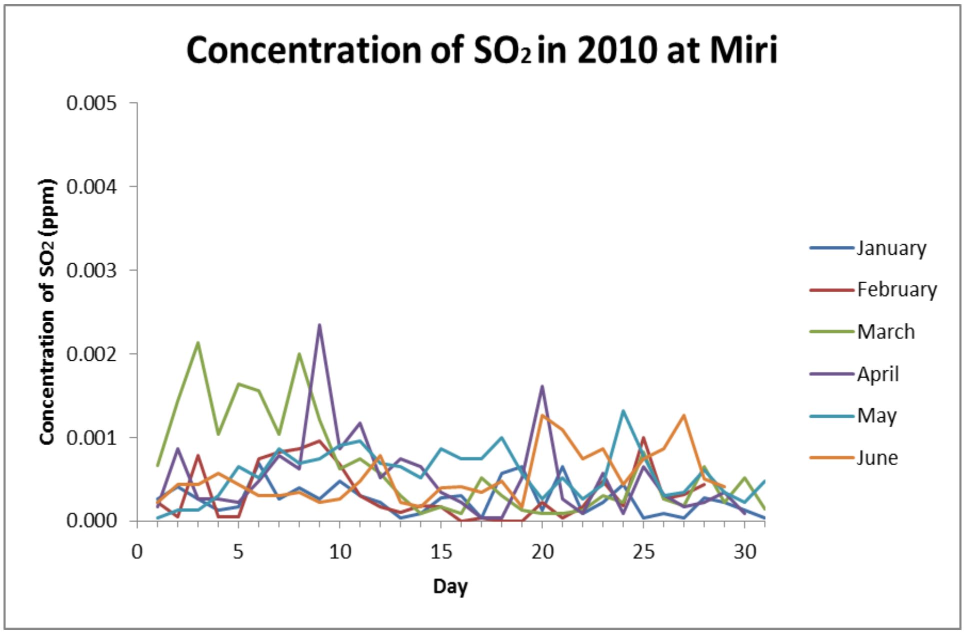
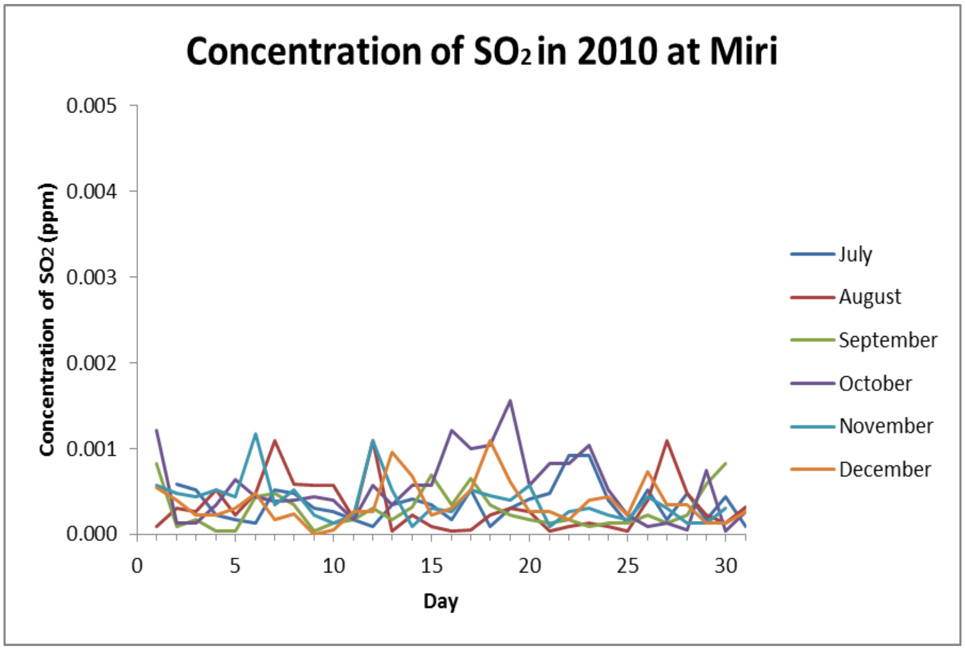
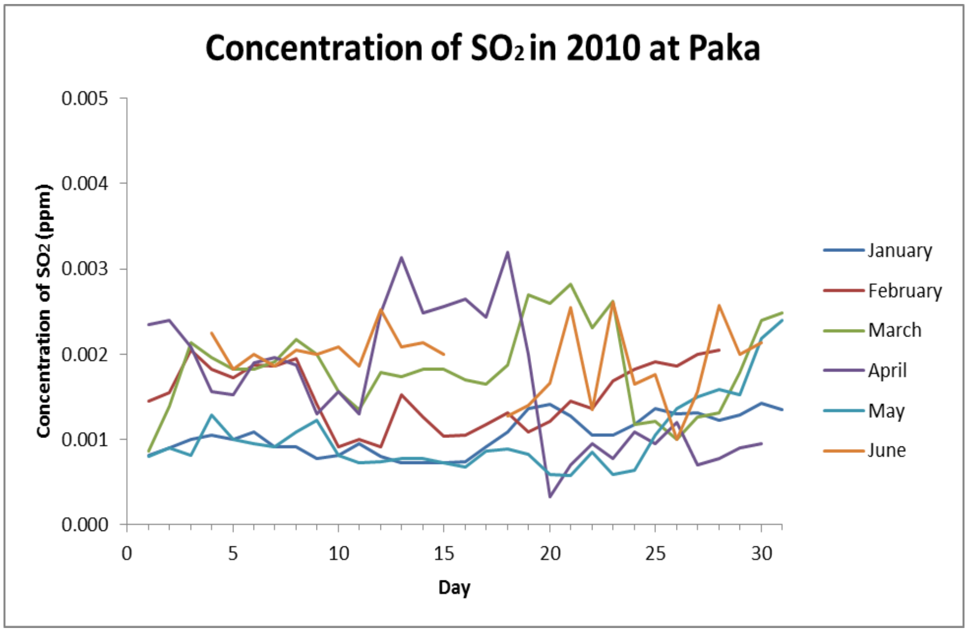
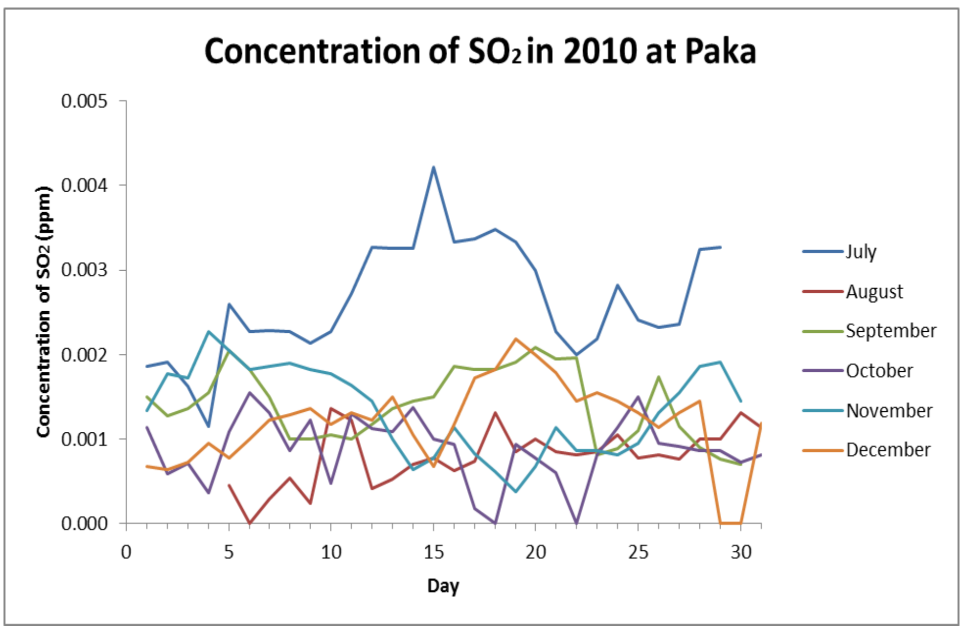


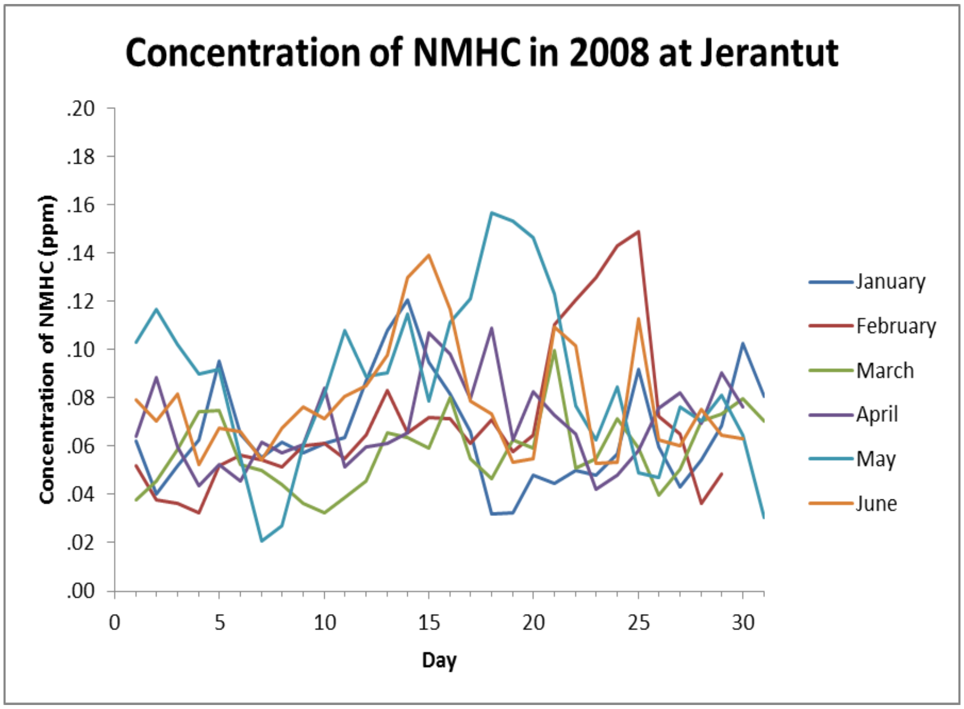


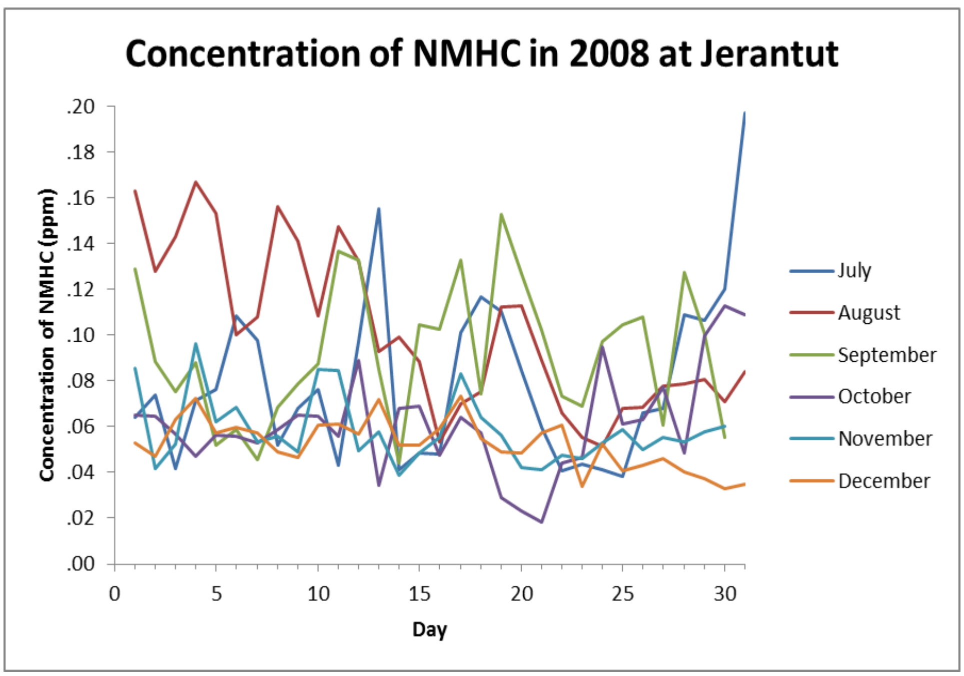
Concentration of sulphur dioxide at Paka in 2010



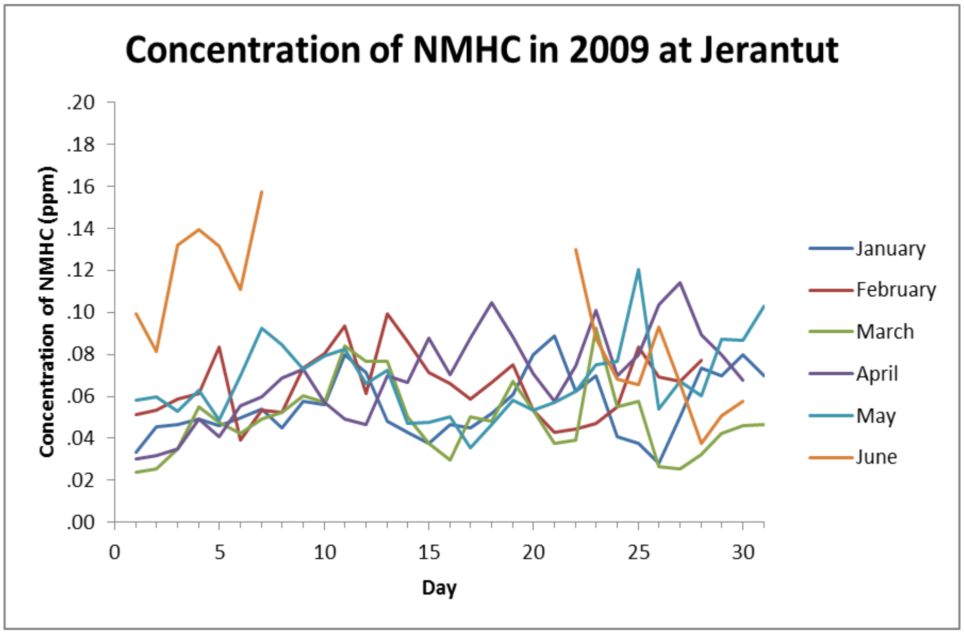


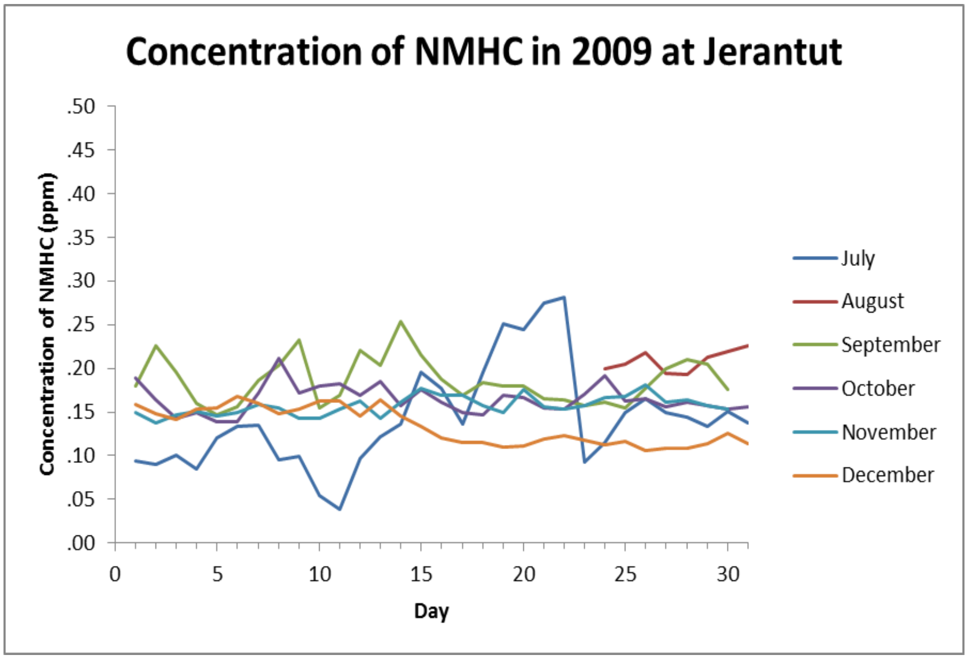
Concentration of non-methane hydrocarbon at Jerantut in 2008





Concentration of non-methane hydrocarbon at Jerantut in 2009





Concentration of non-methane hydrocarbon at Jerantut in 2010