MONITORING AIR POLLUTANT INDEX (API) USING AEROQUAL AQM 65 @ UMP, KUALA PAHANG, PEKAN

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MONITORING AIR POLLUTANT INDEX (API) USING AEROQUAL AQM 65 @ UMP, KUALA PAHANG, PEKAN

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ABSTRAK

Dengan pencemaran udara semakin menonjol, orang ramai semakin prihatin terhadap masalah kualiti udara bandar, apabila kebanyakan bandar raya telah mula mengkaji pemantauan kualiti udara dan sistem pengawasan auto kualiti udara yang secara automatik menjadi wujud. Dalam kajian ini, kami akan secara khusus mengkaji pemantauan kualiti udara di kawasan paya gambut sejak pembakaran hutan paya gambut sering menyebabkan pencemaran udara. Tanpa udara, makhluk hidup akan mati. Tanpa udara bersih, makhluk hidup akan mengalami penyakit yang teruk. Status kualiti udara sangat penting dan dimonitor sepanjang hari. Di Malaysia, Jabatan Alam Sekitar (JAS) memantau kualiti udara sekitar negara melalui stesen pemantauan kualiti udara. Stesen-stesen pemantauan ini terletak secara strategik di kawasan-kawasan yang berbeza, biasanya kawasan kediaman, lalu lintas dan perindustrian untuk mengesan sebarang perubahan ketara dalam kualiti udara yang boleh merosakkan kesihatan manusia dan alam sekitar. Objektif kajian ini adalah untuk memantau Indeks Pencemaran Udara menggunakan pemantauan udara masa nyata di kawasan paya gambut. Melalui kajian ini, penilaian pencemaran udara di Kuala Pahang, Pekan untuk strategi kawalan pencemaran masa depan juga boleh ditentukan. Kepekatan pencemar di kawasan paya gambut boleh disiasat dan dikumpulkan juga. Kaedah yang digunakan dalam kajian ini ialah Petunjuk Status API boleh dikira dari data yang diperolehi dari Aeroqual Cloud, perisian dalam talian yang berkaitan dengan Aeroqual AQM 65. API yang dikenali sebagai Indeks Pencemar Udara adalah petunjuk yang dibangunkan berdasarkan penilaian saintifik untuk menunjukkan dalam cara yang mudah difahami, kehadiran pencemaran dan kesannya terhadap kesihatan kepada manusia dan alam sekitar. Panduan untuk Indeks Pencemaran Udara (API) di Malaysia disebut sebagai buku panduan. Data yang diperoleh bermula dari bulan Mac 2018 hingga Mac 2019 yang merangkumi kira-kira 13 bulan. Analisis menunjukkan stesen pemantauan udara di Kuala Pahang, Pekan menunjukkan nilai bacaan API tertinggi dengan 235.2 pada 3 Mac 2019 (tahap yang tidak sihat), di mana pada hari itu Malaysia mungkin menghadapi kualiti udara yang paling teruk akibat episod jerebu. Selama 13 bulan, nilai API mempunyai frekuensi tertinggi pada tahap baik dan sederhana, yang kebanyakannya adalah 83% hingga 100%. Bacaan nilai API adalah penting untuk menentukan status kualiti udara pada hari tersebut. Kualiti udara yang paling teruk boleh merosakkan kesihatan manusia, alam sekitar, dan juga pembangunan ekonomi. Dari bacaan API yang diperoleh, kerajaan boleh mengambil tindakan untuk mengurangkan kualiti udara terburuk dengan mengambil strategi kawalan pencemaran yang sesuai.

ABSTRACT

With air pollution have become increasingly prominent, the public increasingly concerned about urban air quality problems, when most cities have begun to study the air quality monitoring, and air quality auto-monitoring system that automatically came into being. In this research, we will specifically study the ambient air quality monitoring at a peat swamp area since the burning of peat swamp forests often causes air pollution. Without air, living things will die. Without clean air, living things will suffer from severe diseases. The status of air quality is very important and is being monitored all day long. In Malaysia, the Department of Environment (DOE) monitors the country's ambient air quality through air quality monitoring stations. These monitoring stations are strategically located in different areas, typically the residential, traffic and industrial areas to detect any significant change in the air quality which may harm human's health and the environment. The objective of this study is to monitor the Air Pollutant Index using real time air monitoring at a peat swamp area. Through this study, the air pollution assessments in Kuala Pahang, Pekan for future pollution control strategies can also be determined. The pollutant concentrations in the peat swamp area can be investigated and collected too. The method used in this research is API Status Indicator can be calculated from the data obtained from Aeroqual Cloud, an online software specifically connected to the Aeroqual AQM 65. API, known as Air Pollutant Index is an indicator developed based on scientific assessment to indicate in an easily understood manner, the presence of pollutants and its impact on health to human beings and the environment. A Guide to Air Pollutant Index (API) in Malaysia is referred to as handbook. The data obtained starts from March 2018 till March 2019 which spans about 13 months**.** Analysis shows that the air monitoring station at Kuala Pahang, Pekan shows the highest value of API reading with 235.2 on the 3rd March 2019 (very unhealthy level), where on that day Malaysia probably faced its worst air quality due to haze episodes. Over the 13 months, API value has the highest frequency at good and moderate levels, which is mostly at 83% to 100%. API value reading is vital for determining the status of air quality on that particular day. The worst quality of air can harm human health, the environment, and also economic development. From the API reading obtained, the government can take action to reduce the worst air quality by taking suitable pollution control strategies.

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LIST OF SYMBOLS

CO	Carbon Monoxide
NO_2	Nitrogen Dioxide
O_3	Ozone
PM_1	Particulate Matter with 1 micrometers
$PM_{2.5}$	Particulate Matter with 2.5 micrometers
PM_{10}	Particulate Matter with 10 micrometers
PPM	Parts Per Million
RH	Relative Humidity
SO_2	Sulphur Dioxide
VOC	Volatile Organic Compound
$\mu g/m^3$	Micrograms per cubic meter
mL/min	Millilitre per minute
°C	Degree Celsius

LIST OF ABBREVIATIONS

ADB	Annual Development Bank
API	Air Pollutant Index
AQI	Air Quality Index
AQM	Air Quality Monitoring
ASMA	Alam Sekitar Malaysia Sdn. Bhd
CAQM	Continuous Air Quality Monitoring
CAQMS	Compact Air Quality Monitoring System
DOE	Department of Environment
HFMD	Hand, Foot and Mouth Disease
MAAQS	Malaysia Ambient Air Quality Standard
MAQM	Manual Air Quality Monitoring
MPC	Malaysia Performance Category
WHO	World Health Organisation
USEPA	United States Environmental Protection Agency

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Air quality management is receiving attention lately as the air is badly polluted nowadays. The World Health Organization (WHO) has estimated that more than 2 million people per year in developing countries have died due to urban air pollution and indoor air pollution mainly caused by open burning (Davies, 2005). Air pollution levels remain dangerously high in many parts of the world. New data from WHO shows that 9 out of 10 people breathe air containing high levels of pollutants. Updated estimations reveal an alarming death toll of 7 million people every year caused by outdoor and household air pollution. WHO estimates that around 7 million people die every year from exposure to fine particles in polluted air that penetrate deep into the lungs and cardiovascular system, causing diseases including stroke, heart disease, lung cancer, chronic obstructive pulmonary diseases and respiratory infections, including pneumonia, Ambient air pollution alone caused some 4.2 million deaths in 2016, while household air pollution from cooking with polluting fuels and technologies caused an estimated 3.8 million deaths in the same period. More than 90% of air pollution-related deaths occur in low- and middle-income countries, mainly in Asia and Africa, followed by low- and middle-income countries of the Eastern Mediterranean region, Europe and the Americas (WHO, 2018). Malaysia alone contributed 47.4 mortality rate to household and ambient air pollution in 2016 (see Figure 1.1).

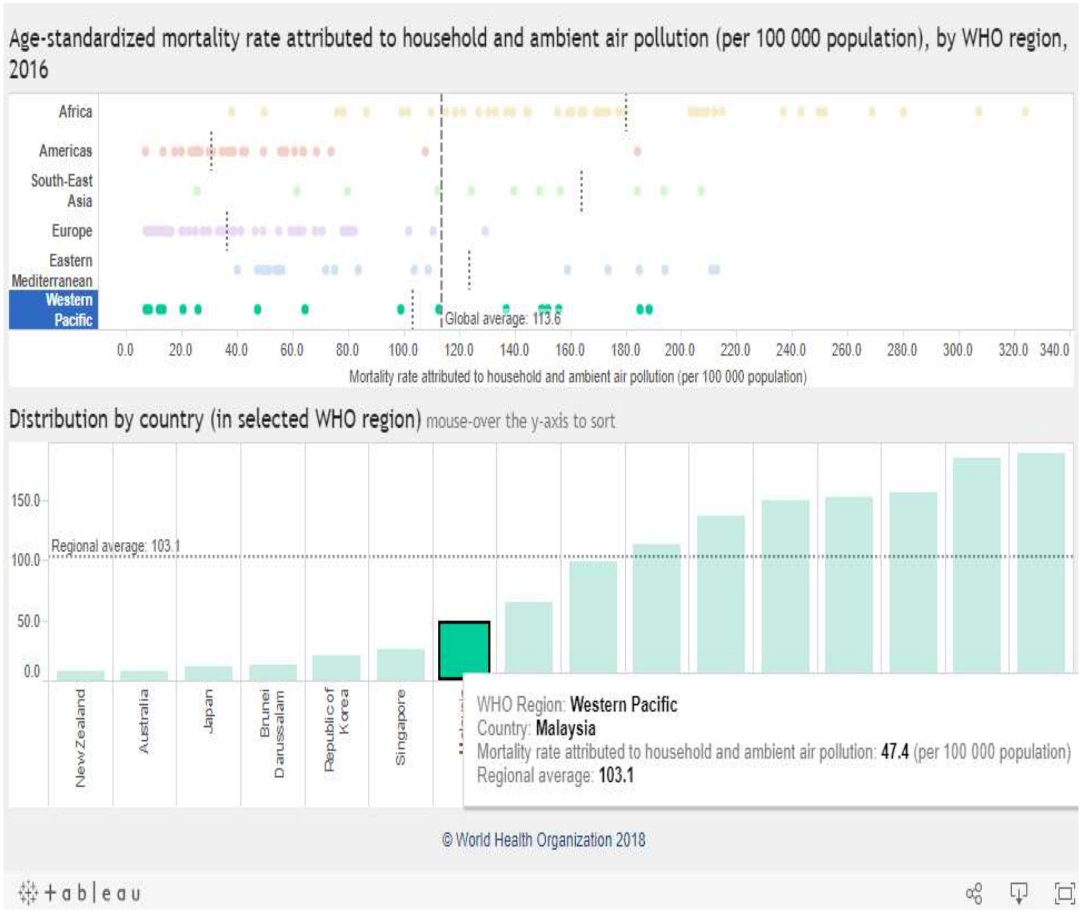

Figure 1.1 Mortality due to air pollution
Source: World Health Organisation (2018)

Air pollution is now considered the world's largest environmental health risk. Among the causes of air pollution, haze problem was faced by Malaysia annually and has largely affected the daily activities of Malaysians. The haze is a result of open burning in Sumatra, Borneo and Peninsular Malaysia – in particular the burning to clear peat swamp forests.

The greatest extent of tropical peat swamp forests in the world occurs in Malaysia and Indonesia (Yule, 2010). These forests are increasingly being drained and cleared for timber and agriculture, particularly the palm oil plantations causing the peat to break down rapidly releasing the carbon that had been stored in the peat into the drains and atmosphere. Once the peat dries out, it is extremely flammable. Peat fires can burn for years and can be extremely difficult to extinguish because they burn underground. The peat swamp forests of Peninsular Malaysia are mostly destroyed or degraded over the past 50 years and have declined to 0.30 million ha in 2005 (UNDP, 2006). Since then there has been further decline and more than half of the remainder is degraded. Only about 100 ha is fully ‘protected’ in Virgin Jungle Reserve, but this is an area too small to ensure preservation of ecosystem functioning, since the water table cannot be maintained in its original state. About 67% is now in Permanent Forest Reserves but these are targeted for sustainable logging (Yule, 2010). The rest is available for conversion to other land uses. The only large tract of pristine peat swamp forest remaining on mainland Asia is the Pekan peat swamp forest, in the state of Pahang on the east coast of the Malaysian peninsula.

Without air, all living things will die; without clean air, living things will suffer from severe diseases as if they are dying. Clean air is considered to be a basic requirement of human health and well-being. The status of air quality is very important and is being monitored all day long. In Malaysia, the Department of Environment (DOE) monitors the country’s ambient air quality through air quality monitoring stations. These monitoring stations are strategically located in different areas, typically the residential, traffic and industrial areas to detect any significant change in the air quality which may harm human’s health and the environment. According the Department of Environment (DOE), the Continuous Air Quality Monitoring stations are divided into five categories. Out of the stations established in Malaysia, 26% are industrial stations, 57% are residential, 2% traffic, 2% background and 13% PM_{10} stations (Department of Environment, 2018). For now, there are only 65 monitoring stations throughout Malaysia. However, the Department is exploring alternatives on mobile equipment to wider the coverage. So, for now, these 65 stations are sufficient enough for the public to know the API readings at their respective states and places near them.

API stands for "Air Pollutant Index". It is an index developed that closely follows the United States Environmental Protection Agency (USEPA) Pollution Standards Index in providing easily comprehensible information about the air pollution level (U.S.EPA, 2005). An Air Pollutant Index allows complicated data to be communicated in a meaningful way to everyone, in a way which everyone can understand easily. Air quality data is often complex and confusing – there are multiple pollutants, several units and all sorts of different standards. All of these factors take professionals a while to get their heads around, and these are people that work with data and instruments every day. The challenge is therefore to convert all this valuable data being collected every minute around the world, into a format that is engaging and understandable for everyone – something which everyone can use to assess the impact of air quality on their day to day activities, their environment, and most critically their health. Traditional monitoring stations are hoped to be replaced by compact air quality monitoring station, Aeroqual AQM 65 to overcome this challenge.

Industry 4.0, an abstract concept that can closely integrate the physical world with the virtual world is already here (Wan, Cai, & Zhou, 2015). The world is already at the fourth stage of industrial revolution which is human machine hand in hand. Malaysia is now onset of adopting and embracing new technologies such as Whatsapp, Facebook and Instagram (Abdullah, Abdullah, & Salleh, 2017). We need to find ways to incorporate the elements of the Fourth Industrial Revolution in our approach to address challenges faced in the bio-based sector. In Industry 4.0, the value of technology is highly emphasised (Revolution, 2017). Industry 4.0 focuses on the environmental and sustainable development to protect public safety and health. Aeroqual AQM 65 is a device that can showcase the elements of Industry 4.0. Building on the success of the forerunning AQM 60, the AQM 65 is targeted at government and industry in rapidly industrialising nations where access to reliable air quality information is sorely needed but often lacking.

1.2 Problem Statement

In Malaysia, Pahang houses the country's most significant peat swamp. In previous year, Pahang has experienced serious peat swamp fires which resulted in the occurrence of haze. Wetlands International reported that there were four blazes in Malaysia in year 2004 where one of the cases happened in Kampung Penadah, Pekan, Pahang (Ramsar, 2004). Another recent case was at Sungai Ular, Gebeng near Kuantan in April 2016 (Rosli Zakaria, 2016). A report shows that in Asia alone, 50% of cities do not have effective air monitoring systems (ADB, 2014). The AQI readings provided by the Department of Environment is indeed readings for each hour, but each hourly value is the average of the past 24 hours for a day. It is very crucial to have high quality air monitoring systems during the period of haze where the Air Quality Index can deteriorate significantly and fast. The published AQI value is most likely lower than the actual Air

Quality which means the air pollution is most likely to be higher than what is published. If this issue is resolved, it will definitely help to reflect the actual conditions in case of haze.

Alam Sekitar Malaysia Sdn. Bhd. (ASMA) is the company providing air quality monitoring for Department of Environment (DOE). ASMA uses Continuous Ambient Air Quality Monitoring (CAQM)) and Manual Air Quality Monitoring (MAQM). For ambient air quality monitoring stations, there may be a detection limit and the response time are not the best. Furthermore, the measurement is manually collected and delivered to a laboratory for analysis for MAQM. Manual air quality monitoring data are obtained monthly from ASMA. The process is time consuming and need manpower. Moreover, the accuracy of the data may be reduced due to personal errors. Aeroqual AQM 65 can help overcome this issue.

Ambient air quality monitoring stations have high initial costs and high running costs. The high cost of managing and maintaining the air quality monitoring stations have become an issue since Malaysia's economy are quite unstable nowadays. This leads to the lack of strong commitment from authorities to continue monitoring efforts since the funding is often inadequate and unsustainable (Quality & Cities, n.d.). The air quality monitoring stations in Malaysia are working continuously non-stop every day. It is always good when we are able to save cost while maintaining the quality of the air management system. Thus, Aeroqual AQM 65 are introduced in order to cut down some costs spent on the air monitoring stations. Aeroqual AQM 65 is easier to install or relocate and does not need a large area for installation. This will help save some costs.

1.3 Research Objectives

i. To monitor the Air Pollutant Index (API) using real time air monitoring at peat swamp area.
ii. To determine air pollution assessments in Kuala Pahang, Pekan for future pollution control strategies.
iii. To investigate pollutant concentrations in peat swamp area at Kuala Pahang, Pekan.

1.4 Scope of Research

The aim of this thesis is to monitor the data API nearby Kuala Pahang, Pekan towards using real time air monitoring via aeroqual. This study will focus on the haze problem, the phenomena of air pollution. As well as examining understandings of air pollution and its potential health effects, the research looks at how AQM 65 functions and what benefits we can get from using it. The impacts of this particular air quality monitoring equipment also will be determined through this research. This study will also demonstrate the steps in obtaining the real time online data. The data produced by the Aeroqual AQM 65 will also be clearly shown. We can also see how it can improve the overall management of air quality in Malaysia.

1.5 Significance of Research

People seems to be indifferent towards air pollution issues although there are horrifying statistics that show that the outdoor air quality is deteriorating gradually. In order to raise mindfulness of air pollution in Malaysia, API readings are published to the public so people will be well informed and prepare themselves if the air quality worsens. To view the API readings, the public can go to the DOE website. This research is done to increase public awareness. This increasing public awareness is putting more scrutiny on air quality monitoring, accurate reporting, and air pollution control measures.

A compact air quality monitoring station, or CAQMS, like the Aeroqual AQM 65, is a complete air monitoring station in a box the size of a large suitcase. It is ten times smaller than a traditional air quality monitoring station. It uses less cost, manpower and space but have strong data correlation. It is calibrated against standard reference materials with maximum traceability. Despite it is affordable and simple, the data obtained is more accurate compared to the traditional monitoring station. Aeroqual AQM 65. It was awarded Most Innovative Hardware Product at 2016 Hi-Tech Awards (Environmental Source Samplers Inc, 2016). This study introduces the impact and usage of Aeroqual AQM 65 which can help the government and industry in terms of environmental health. Other than that, this study aims to expand the usage of Aeroqual AQM 65 in Malaysia to enhance the air quality.

Every country will be ranked based on their overall environmental performance on high priority environmental issues annually. According to the Environmental Performance Index Report, Malaysia was ranked 117 out of 180 countries (MPC, 2016) in terms of air quality which is quite disappointing. Hopefully Aeroqual AQM 65 can help us to improve the environment and also to help achieve sustainable development. This study is set to have access to real time data from Kuala Pahang in Pekan to make better informed decisions about the environment, air quality and current pollution levels beforehand.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This section presents information from an extensive literature review on air pollutant index, air pollution and the five main pollutants. The main objective of this study is to monitor the air pollutant index at a peat swamp area towards using real time air monitoring via Aeroqual. In addition, the emerge of industrial revolution 4.0 and the health effects that air pollution causes are also discussed.

2.2 Air Pollutant Index (API)

An air pollution index system normally includes the major air pollutants which could cause potential harm to human health should they reach unsafe levels. The air pollutants included in Malaysia's API are ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and suspended particulate matter of less than l0 microns in size (PM_{l0}) (Environment, 2000).

Generally, an air pollution index system is developed in easily understood ranges of values, instead of using the actual concentrations of air pollutants, as a means for reporting the quality of air or level of air pollution. To reflect the status of the air quality and its effects on human health, the ranges of index values could then be categorised as follows: good, moderate, unhealthy, very unhealthy and hazardous. The index values may also be categorised according to episode or action criteria, such as air pollutant levels within stipulated standards, or levels signifying conditions for alert, warming, emergency and significant harm. The key reference point in these air pollution index systems is the index value of 100 (the "safe" limit), which is based on the National Air Quality Standards or Guidelines for the specific air pollutants concerned (Environment, 2000).

Before interpreting the results of the air pollution studies in Malaysia, it is important to know about the standard of air quality applied. Generally there are two standards being used to gauge air quality and pollution in Malaysia, namely the Malaysian Ambient Air Quality Standard and the Air Pollution Index (Salahuddin & Ashaari, 2017). The MAAQS is a more specific standard of known parameters that are hazardous to human health and is measured from one to 24 hours for different air pollutants. The MAAQS is shown in Table 2.1. The Air Pollutant Index (API) on the other hand is a simple index to indicate air quality by taking considerations of all the parameters in the MAAQS except for TSP and lead.

Table 2.1: Malaysian Ambient Air Quality Standard (MAAQS)

Pollutant	Averaging Time	Malaysian Ambient Air Quality Standard (MAAQS)	
		ppm	µg/m^3
Ozone	1 Hour	0.10	200
	8 Hour	0.06	120
Carbon Monoxide	1 Hour	30.0	35**
	8 Hour	9.0	10**
Nitrogen Dioxide	1 Hour	0.07	320
	24 Hour	0.04	
Sulphur Dioxide	1 Hour	0.13	350
	24 Hour	0.04	105
Particulate Matter (PM_{10})	24 Hour		150
	12 Month		50
Total Suspension Particulate (TSP)	24 Hour		260
	12 Month		90
Lead	3 Month		1.5

Source: Salahuddin and Ashaari (2017)

2.3 Particulate Matter (PM)

Particle pollution, which is also called particulate matter (PM) is made up of particles of solids or liquids that are in the air. These particles may include:

i. Dust
ii. Dirt
iii. Soot
iv. Smoke
v. Drops of liquid

Some particles are big enough or appear dark enough to see. For example, you can often see smoke in the air. Others are so small that you cannot see them in the air.

The major air pollutants are particulate matter (PM), sulphur dioxide, nitrogen oxides, and carbon monoxide. Within these air pollutants, particulate matter (PM) are the primary air pollutants of health concerns and are significantly associated with adverse health effects (Wu et al., 2018). PM is composed of various chemical components, and can profoundly affect people's living environment in terms of air quality and visibility. PM_{10} are particles with aerodynamic diameters less than or equal to 10 micrometers, consisting mainly of smoke, road dust, and pollen. It is 30 times smaller than the width of a hair and can easily be inhaled into our lungs.

$PM_{2.5}$ are particles with aerodynamic diameters less than or equal to 2.5 micrometers, and are more likely to be linked to respiratory diseases than PM_{10}. $PM_{2.5}$ can only be seen with and electron microscope. It is known as the "invisible killer". $PM_{2.5}$ can pass from our lungs into our blood supply and be carried throughout our body. Numerous studies have demonstrated that long-term or even short-term exposure to ambient air with high PM concentrations, especially high $PM_{2.5}$ concentrations, can increase the risk of morbidity and mortality (Chen, Wang, Xiao, Wu, & Zhang, 2015).

A recent study suggested that ambient fine particulate matter $PM_{2.5}$ accounted for 15.5% which is 1.7 million of all cause deaths in China in 2015 (Motta, Kajava, Śanchez-Ferńandez, Giustini, & Kuulkers, 2017). In China, fine particulate matter is believed to affect the health of adults and children, and long-term exposure to both $PM_{2.5}$ and PM_{10} has adverse effects on human health. Moreover, many diseases such as atopic asthma, cardiovascular disease, and sudden mortality could be associated with the increase of particulate matter in ambient air (Chen et al., 2015).

2.4 Ozone

Ozone is a gas composed of three atoms of oxygen (O_3). Ozone occurs both in the Earth's upper atmosphere and at ground level. Ozone can be good or bad, depending on where it is found. Stratospheric ozone, the good ozone occurs naturally in the upper atmosphere, where it forms a protective layer that shields us from the sun's harmful ultraviolet rays. This beneficial ozone has been partially destroyed by manmade chemicals, causing what is sometimes called a "hole in the ozone. Ozone at ground level is a harmful air pollutant, because of its effects on people and the environment, and it is the main ingredient in “smog."

Ground O_3 is mainly produced from photochemical reactions involving volatile organic compounds (VOCs) and nitrogen oxides (NOx) (Zhong, Chen, & Saikawa, 2019). Ground level ozone continues to be a health problem in many urban areas. It is well known that temperature influences ozone information. As a photochemical air pollutant, high temperature with sunlight in the presence of ozone precursors encourage ozone formation. Both temperature and ground level ozone are expected to increase in response to expected global climate change (Lu, Gelfand, & Holland, 2018).

Ozone in the air we breathe can harm our health. People with asthma, children, older adults and people who are active outdoors especially outdoor workers are the people most at risk from breathing air containing ozone. In addition, people with certain genetic characteristics and people with reduced intake of certain nutrients such as vitamins C and E are at greater risk from ozone exposure.

Ozone can cause the muscles in the airways to constrict, trapping air in the alveoli. This leads to wheezing and shortness of breath. Ozone can make it more difficult to breathe deeply and vigorously. Ozone can cause coughing and inflame the airways. Furthermore, ozone can aggravate lung diseases such as emphysema and chronic bronchitis. This makes the lungs more susceptible to infection. The frequency of asthma attacks will also increase gradually.

2.5 Nitrogen Dioxide

Nitrogen dioxide is a nasty-smelling gas. Some nitrogen dioxide is formed naturally in the atmosphere by lightning and some is produced by plants, soil and water. Nitrogen dioxide is an important air pollutant because it contributes to the formation of photochemical smog, which can have significant impacts on human health. The major source of nitrogen dioxide is the burning of fossil fuels: coal, oil and gas. Most of the nitrogen dioxide in cities comes from motor vehicle exhaust. Other sources of nitrogen dioxide are petrol and metal refining, electricity generation from coal-fired power stations, other manufacturing industries and food processing.

The main effect of breathing in raised levels of nitrogen dioxide is the increased likelihood of respiratory problems. Nitrogen dioxide inflames the lining of the lungs, and it can reduce immunity to lung infections. This can cause problems such as wheezing, coughing, colds, flu and bronchitis. Increased levels of nitrogen dioxide can have significant impacts on people with asthma because it can cause more frequent and more intense attacks. Children with asthma and older people with heart disease are most at risk.

The long-term effects on mortality of exposure to nitrogen dioxide (NO_2) were assessed in the World Health Organization (WHO) Air Quality Guidelines in 2005 and the overall evidence was considered limited, given the small number of studies available. Neither the development of chronic diseases nor lung cancer was clearly associated with NO_2 in any of the studies taken into consideration in the 2005 WHO report. However, short-term mortality studies, studies of the impairment of lung function growth in children and investigations of recurrent respiratory problems all suggested a NO_2 effect. Recent documents on traffic exposure from the American Thoracic Society and the Health Effects Institute considered NO_2, among other traffic-related pollutants, and concluded that there is evidence suggesting that these pollutants have a causal role in mortality and the development of chronic respiratory diseases (Faustini, Rapp, & Forastiere, 2014).

Several studies have indicated that NO_2 concentrations exhibit substantial spatial variability within urban areas, with higher concentrations found in high traffic areas. NO_2 pollution is higher along busy roads, in city centres and districts near highways, and is related to traffic volume and the distance to the highway (Dedele, Grazuleviciene, & Miskinyte, 2017).

2.6 Sulphur Dioxide

Sulphur dioxide (SO_2) is one of the major air pollutants. Sulphur dioxide is a gas. It is invisible and has a nasty, sharp smell. It reacts easily with other substances to form harmful compounds, such as sulphuric acid, sulphurous acid and sulphate particles (Li, Wang, & Zhang, 2018). About 99% of the sulphur dioxide in air comes from human sources. The main source of sulphur dioxide in the air is industrial activity that processes materials that contain sulphur such as the generation of electricity from coal, oil or gas. Some mineral ores also contain sulphur, and sulphur dioxide is released when they are processed. In addition, industrial activities that burn fossil fuels containing sulphur can be important sources of sulphur dioxide. Sulphur dioxide is also present in motor vehicle emissions, as the result of fuel combustion.

Sulphur dioxide affects human health when it is breathed in. It irritates the nose, throat, and airways to cause coughing, wheezing, shortness of breath, or a tight feeling around the chest. The strong effects of sulphur dioxide are felt very quickly and most people would feel the worst symptoms in 10 or 15 minutes after breathing it in. Those most at risk of developing problems if they are exposed to sulphur dioxide are people with asthma or similar conditions. Sulphur dioxide can be life-threatening if you are exposed to very high levels. These life-threatening levels rarely occur in community settings and are mainly seen in work settings where sulphur dioxide is used or directly generated.

Short-term exposure to high concentrations of sulphur dioxide can cause health concerns especially for people with asthma, chronic obstructive pulmonary disease (COPD), young children, and the elderly. Symptoms may include constriction or tightening of the airways in the lungs, coughing, wheezing, and shortness of breath, as well as irritation of the respiratory system and eyes. For these sensitive individuals, sulphur dioxide exposure can result in increased visits to emergency departments and hospital admissions for respiratory illnesses. A study in Hefei China even showed that the exposure to SO2 is linked to hand, foot and mouth disease (HFMD) which is quite common among the children (Wei et al., 2019).

Long-term exposure to sulphur dioxide can also affect your health. It can reduce your ability to breathe deeply or take in as much air for each breath. The particles produced by the reaction of sulphur dioxide with other compounds in the air can penetrate deeply into the lungs. These particles can then damage the lining of the lungs as well as cause other effects in the body. Particles can worsen existing heart and respiratory disease, including emphysema and bronchitis. Children who have been chronically exposed to sulphur dioxide may also develop more breathing problems as they get older.

2.7 Carbon Monoxide

The continuous growth of the world population in the 21st century aggravates contamination problems and air pollutants seem to play a significant role in the process. Some of the contributing factors include a higher number of vehicles and dynamic industrial development, coupled with inadequate protective measures, such as lack of chimney filters and failure to implement new, environmentally compatible technologies. One of the most common toxic gases contaminating the atmosphere is carbon monoxide (CO) (Maga et al., 2017).

Carbon monoxide is a gas and is found in air. High levels of carbon monoxide are poisonous to humans and, unfortunately, it cannot be detected by humans as it has no taste or smell and cannot be seen. CO is a colourless, odourless gas that can be harmful when inhaled in large amounts. The natural concentration of carbon monoxide in air is around 0.2 parts per million (ppm), and that amount is not harmful to humans. CO is released when something is burned. The greatest sources of CO to outdoor air are cars, trucks and other vehicles or machinery that burn fossil fuels. A variety of items in your home such as unvented kerosene and gas space heaters, leaking chimneys and furnaces, and gas stoves also release CO and can affect air quality indoors. Natural sources of carbon monoxide include volcanoes and bushfires.

Carbon monoxide affects healthy and unhealthy people. Increased levels of carbon monoxide reduce the amount of oxygen carried by haemoglobin around the body in red blood cells. The result is that vital organs, such as the brain, nervous tissues and the heart, do not receive enough oxygen to work properly. No more than 2.5% of haemoglobin can be bound to carbon monoxide before some health effects become noticeable. At very high concentrations of carbon monoxide, up to 40% of the haemoglobin can be bound to carbon monoxide in this way (Hess, 2017). This level will almost certainly kill humans.

For healthy people, the most likely impact of a small increase in the level of carbon monoxide is that they will have trouble concentrating. Some people might become a bit clumsy as their coordination is affected, and they could get tired more easily. People with heart problems are likely to suffer from more frequent and longer angina attacks, and they would be at greater risk of heart attack. Children and unborn babies are particularly at risk because they are smaller and their bodies are still growing and developing. Breathing air with a high concentration of CO reduces the amount of oxygen that can be transported in the blood stream to critical organs like the heart and brain (Levy, 2015).

At very high levels, which are possible indoors or in other enclosed environments, CO can cause dizziness, confusion, unconsciousness and death. Very high levels of CO are not likely to occur outdoors. However, when CO levels are elevated outdoors, they can be of particular concern for people with some types of heart disease. These people already have a reduced ability for getting oxygenated blood to their hearts in situations where the heart needs more oxygen than usual. They are especially vulnerable to the effects of CO when exercising or under increased stress. In these situations, short-term exposure to elevated CO may result in reduced oxygen to the heart accompanied by chest pain also known as angina.

2.8 Toxic Air Pollutants

Hazardous air pollutants, also known as toxic air pollutants or air toxics, are those pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects. Examples of toxic air pollutants include:

i. benzene, which is found in gasoline;
ii. perchloroethylene, which is emitted from some dry-cleaning facilities; and
iii. methylene chloride, which is used as a solvent and paint stripper by a number of industries.

Other examples of air toxics include dioxin, asbestos, toluene, and metals such as cadmium, mercury, chromium, and lead compounds.

Most air toxics originate from human-made sources, including mobile sources (e.g., cars, trucks, buses) and stationary sources (e.g., factories, refineries, power plants), as well as indoor sources (e.g., some building materials and cleaning solvents). Some air toxics are also released from natural sources such as volcanic eruptions and forest fires. People are exposed to toxic air pollutants in many ways that can pose health risks, such as by:

i. Breathing contaminated air.
ii. Eating contaminated food products, such as fish from contaminated waters; meat, milk, or eggs from animals that fed on contaminated plants; and fruits and vegetables grown in contaminated soil on which air toxics have been deposited.
iii. Drinking water contaminated by toxic air pollutants.
iv. Ingesting contaminated soil. Young children are especially vulnerable because they often ingest soil from their hands or from objects they place in their mouths.
v. Touching (making skin contact with) contaminated soil, dust, or water (for example, during recreational use of contaminated water bodies).

Once toxic air pollutants enter the body, some persistent toxic air pollutants accumulate in body tissues. Predators typically accumulate even greater pollutant concentrations than their contaminated prey. As a result, people and other animals at the top of the food chain who eat contaminated fish or meat are exposed to concentrations that are much higher than the concentrations in the water, air, or soil.

People exposed to toxic air pollutants at sufficient concentrations and durations may have an increased chance of getting cancer or experiencing other serious health effects. These health effects can include damage to the immune system, as well as neurological, reproductive (e.g., reduced fertility), developmental, respiratory and other health problems (Chowdhury et al., 2018). In addition to exposure from breathing air toxics, some toxic air pollutants such as mercury can deposit onto soils or surface waters, where they are taken up by plants and ingested by animals and are eventually magnified up through the food chain. Like humans, animals may experience health problems if exposed to sufficient quantities of air toxics over time.

United States Environmental Protection Agency will update the information about toxic air pollutants from time to time. There are two options that we can try access them. National Air Toxics Assessment is a site that provides emissions and health risk information on 33 air toxics that present the greatest threat to public health in the largest number of urban areas. Maps and lists are available and can be requested by state or county level (USEPA, 2014). Toxics Release Inventory is a database includes information for the public about releases of toxic chemicals from manufacturing facilities into the environment through the air, water, and land. The data can be accessed by typing in your zip code (USEPA, 2018).

2.9 Health Effects

Air pollution refers to the release of pollutants into the air that are detrimental to human health and the planet as a whole. Air pollution is an important problem to address because of its adverse health, economic, and environmental impacts. The health impacts of outdoor air pollution on humans are often related to the respiratory and cardiac systems and include heart disease, lung cancer, ischemic heart disease, chronic obstructive pulmonary disease (COPD), and asthma.

The Health Effects Institute found out that ozone pollution contributed to 234,000 deaths from chronic lung disease while $PM_{2.5}$ exposure accounted for 4.1 million deaths from respiratory and cardiac illnesses in 2016 (Of, 2018). The major economic impacts of air pollution include increased healthcare expenditures to treat the aforementioned conditions, reduced labour productivity, and reduced economic output from a depleted labour force. The environmental impacts of outdoor air pollution include urban smog and soot, reduced visibility due to haze, climate change acceleration via greenhouse gas emissions, and stratospheric ozone depletion.

Air pollution and the emission of the previously mentioned gasses or particles have a number of economic and health related issues attached to them. Air pollution is a contributor to climate change, acid rain, causes thinning of the ozone layer, heart problems, lung cancer, carbon monoxide poisoning, strokes, pulmonary disease, liver disease, breathing issues, and issues with the nervous system. There are an estimated 5.5 premature deaths caused by air pollution per year.

2.10 Air Pollution

Air pollution is a mixture of natural and man-made substances in the air we breathe. It is typically separated into two categories which are outdoor air pollution and indoor air pollution.

Outdoor air pollution involves exposures that take place outside of the built environment. Examples include:

i. Fine particles produced by the burning of fossil fuels (i.e. the coal and petroleum used in energy production)
ii. Noxious gases (sulphur dioxide, nitrogen oxides, carbon monoxide, chemical vapours, etc.)
iii. Ground-level ozone (a reactive form of oxygen and a primary component of urban smog)
iv. Tobacco Smoke

Indoor air pollution involves exposures to particulates, carbon oxides, and other pollutants carried by indoor air or dust. Examples include:

i. Gases (carbon monoxide, radon, etc.)
ii. Household products and chemicals
iii. Building materials (asbestos, formaldehyde, lead, etc.)
iv. Outdoor indoor allergens (cockroach and mouse dropping, etc.)
v. Tobacco smoke
vi. Mold and pollen

In some instances, outdoor air pollution can make its way indoors by way of open windows, doors, ventilation, etc.

Air pollution contribute too many environmental problems, including urban smog, acid rain, and climate change, it also has a massive impact on public health. Air pollution from fine particulate matter which are the atmospheric particles with a diameter less than 2.5 micrometers, or $PM_{2.5}$ for short causes 4.2 million global deaths per year, the 5th highest risk factor for death worldwide (Of, 2018). Air pollution poses a significant economic threat because the high risk of death and disease due to air pollution decreases economic productivity. Because air pollution does not follow national borders, it is a transboundary form of pollution, which requires cooperation between governments and key polluters, especially private companies, to manage emissions.

2.11 Ambient Air Monitoring

Ambient air monitoring is an integral part of an effective air quality management system. Reasons to collect such data include to:

i. assess the extent of pollution;
ii. provide air pollution data to the general public in a timely manner;
iii. support implementation of air quality goals or standards;
iv. evaluate the effectiveness of emissions control strategies;
v. provide information on air quality trends;
vi. provide data for the evaluation of air quality models; and
vii. support research (e.g., long-term studies of the health effects of air pollution).

There are different methods to measure any given pollutant. A developer of a monitoring strategy should examine the options to determine which methods are most appropriate, taking into account the main uses of the data, initial investment costs for equipment, operating costs, reliability of systems, and ease of operation. The locations for monitoring stations depend on the purpose of the monitoring. Most air quality monitoring networks are designed to support human health objectives, and monitoring stations are established in population centers. They may be near busy roads, in city centers, or at locations of particular concern (e.g., a school, hospital, particular emissions sources). Monitoring stations also may be established to determine background pollution levels, away from urban areas and emissions sources.

Prior to the ASMA network, the government of Malaysia operated approximately six ambient air monitoring stations with equipment donated by the Japanese government, with all stations located in the Klang Valley. The ASMA network provided data to assess the air quality throughout the country. ASMA data have since been widely used as leverage by NGOs and citizen groups seeking improvements in air-quality policies and enforcement. ASMA data provided evidence for an August 2005 Malaysia University of Science and Technology study, which recommends that the air-quality monitoring network be expanded, that the state create and enforce air quality standards, and require periodic inspection of all vehicles (Hight & Ferrier, 2006).

Over more than a decade of operation, ASMA has evolved to offer broader sets of environmental services within Malaysia, including environmental impact assessment, site assessment and remediation, waste management and control, and training in these and other fields. However, the air monitoring system still need to be improved continuously. Good decisions about air quality rely on good relevant data. That has often been inaccessible because accurate measurement equipment has been bulky, hard to operate and formidably expensive. Reliable air quality technology is crucial for a worldwide growing market which are the industrial companies, environmental consultants, research organisations, government and local government agencies.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter presents the research methodology employed in this research in order to get the data and ensure all objectives for this study are achieved. The methodology discusses the widely-adopted research concepts and paradigms in information systems research like laboratory tests procedure, and analysis of data works. The first section started with the apparatus used in this research which is the Aeroqual AQM 65 and its location. The procedure for obtaining data is also listed out in this section. Lastly, the calculation of API and categorisation of API are also discussed in the following section.

3.2 Apparatus

The apparatus used in this research is Aeroqual AQM 65. This apparatus enables continuous measurement of common air pollutants. Its information is available in real time. The data can be retrieved remotely via direct internet connection or cloud-based interface. The data for this research will be taken for 13 months which is from March 2018 till March 2019. Then the API value is obtained through calculation and is categorized respectively.

Figure 3.1: Monitoring station at Pekan.

Figure 3.2: Aeroqual AQM 65 at Pekan

3.3 Location

There are various factors that should be considered while choosing the site for air monitoring to ensure that the data collected is valid and reliable (Ministry for the Environment, 2009). The factors are as follow:

i. Sites should not be adjacent to structures that distort the air flow.

ii. Sites should prone to effects of adsorption and absorption.

iii. Sites where chemical or physical interference may occur should not be considered.

iv. Sites need to have good access and not vulnerable to vandalism.

v. Sites should not be affected by extraneous local emissions.

The sampling location is located at a peat swamp area nearby Kuala Pahang, Pekan with the coordinate 3.5437° N, 103.4289° E. We are able to check the status of the apparatus through the online software. It will alert the owner and the responsible authority through an email if the apparatus needs technical support or a change of the gas filters.

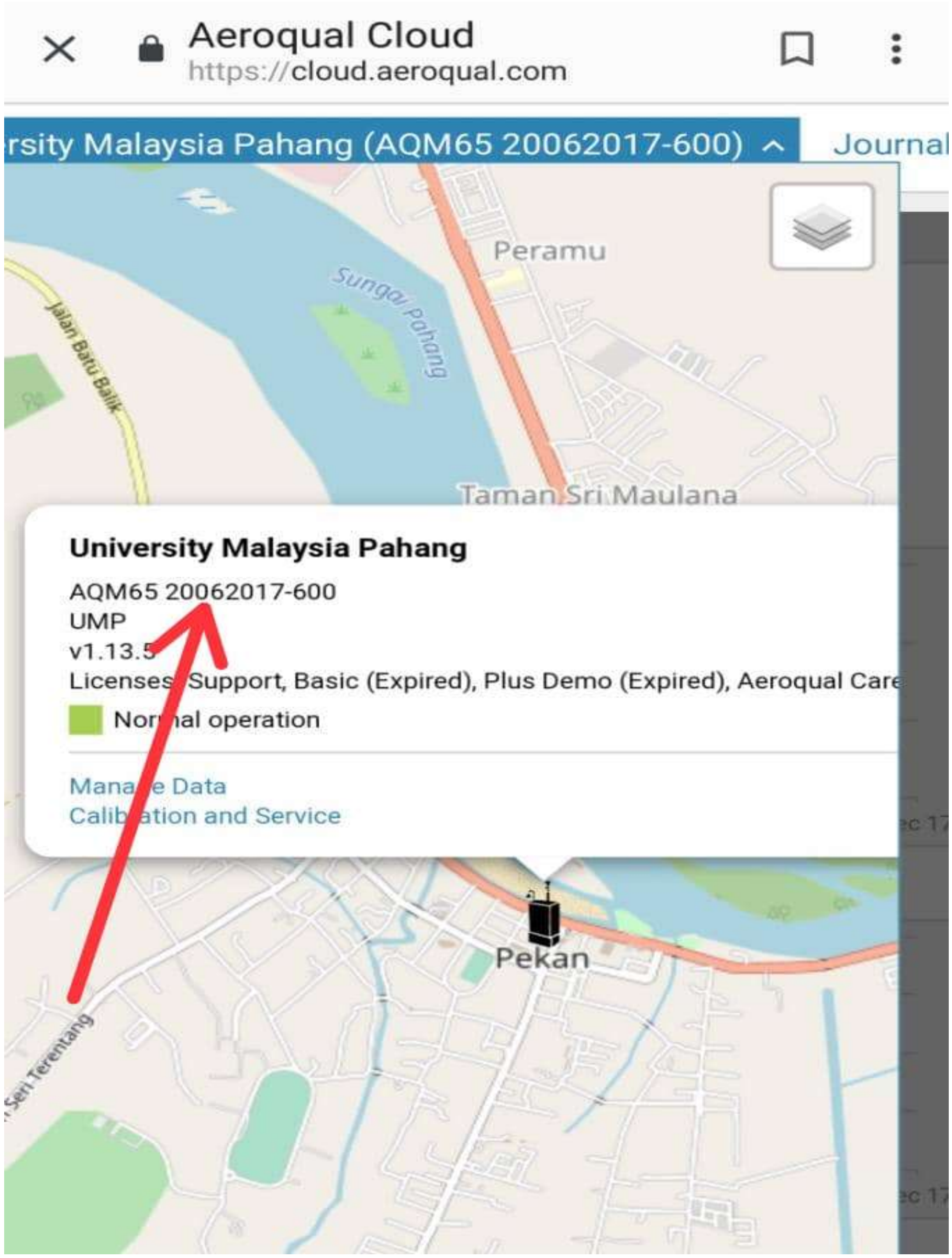

Figure 3.3: The signal shown when the Aeroqual AQM 65 is on and running.

Source: Aeroqual Cloud

3.4 Procedure

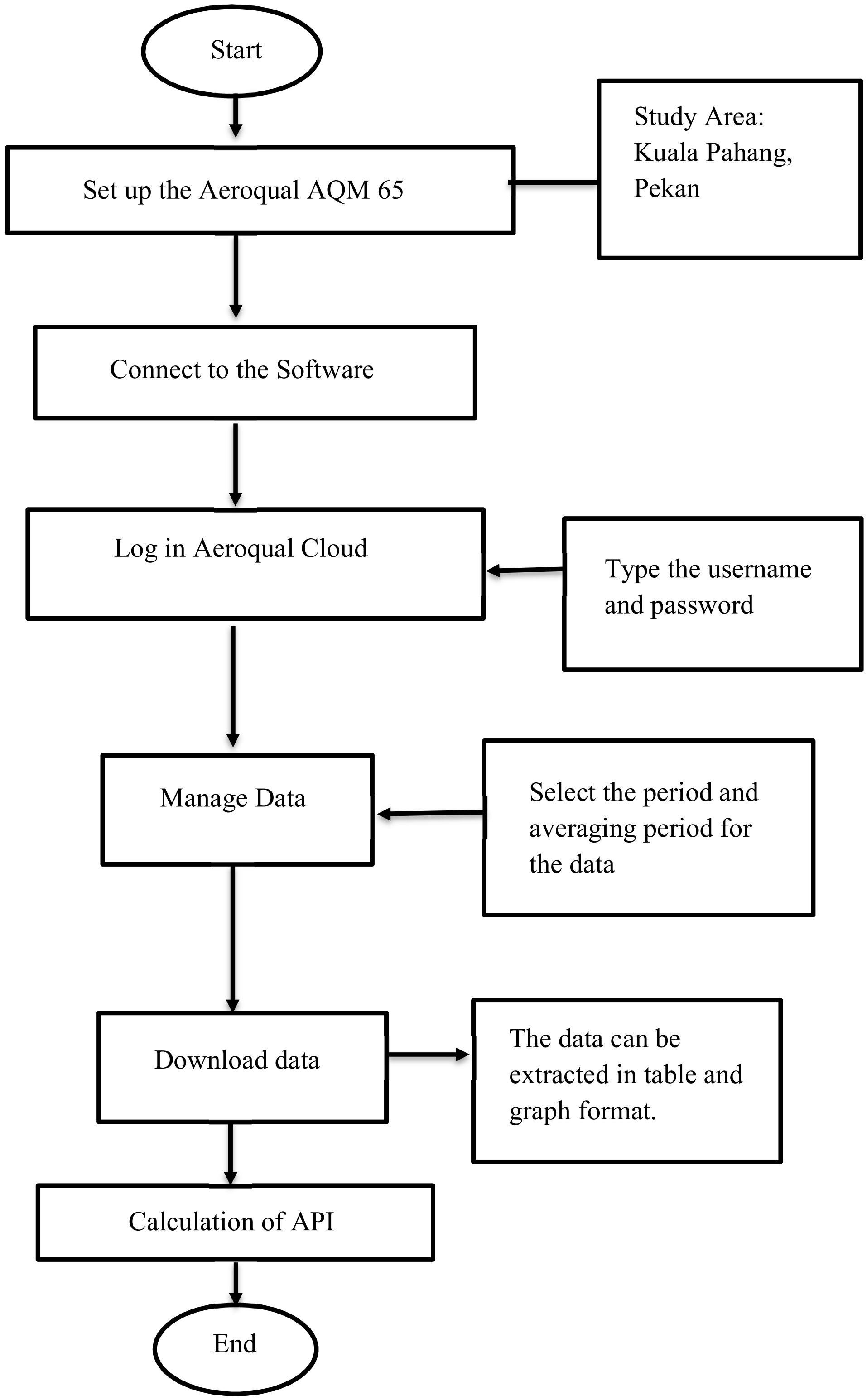

Figure 3.4: Steps conducting the research

3.5 Calculation of API

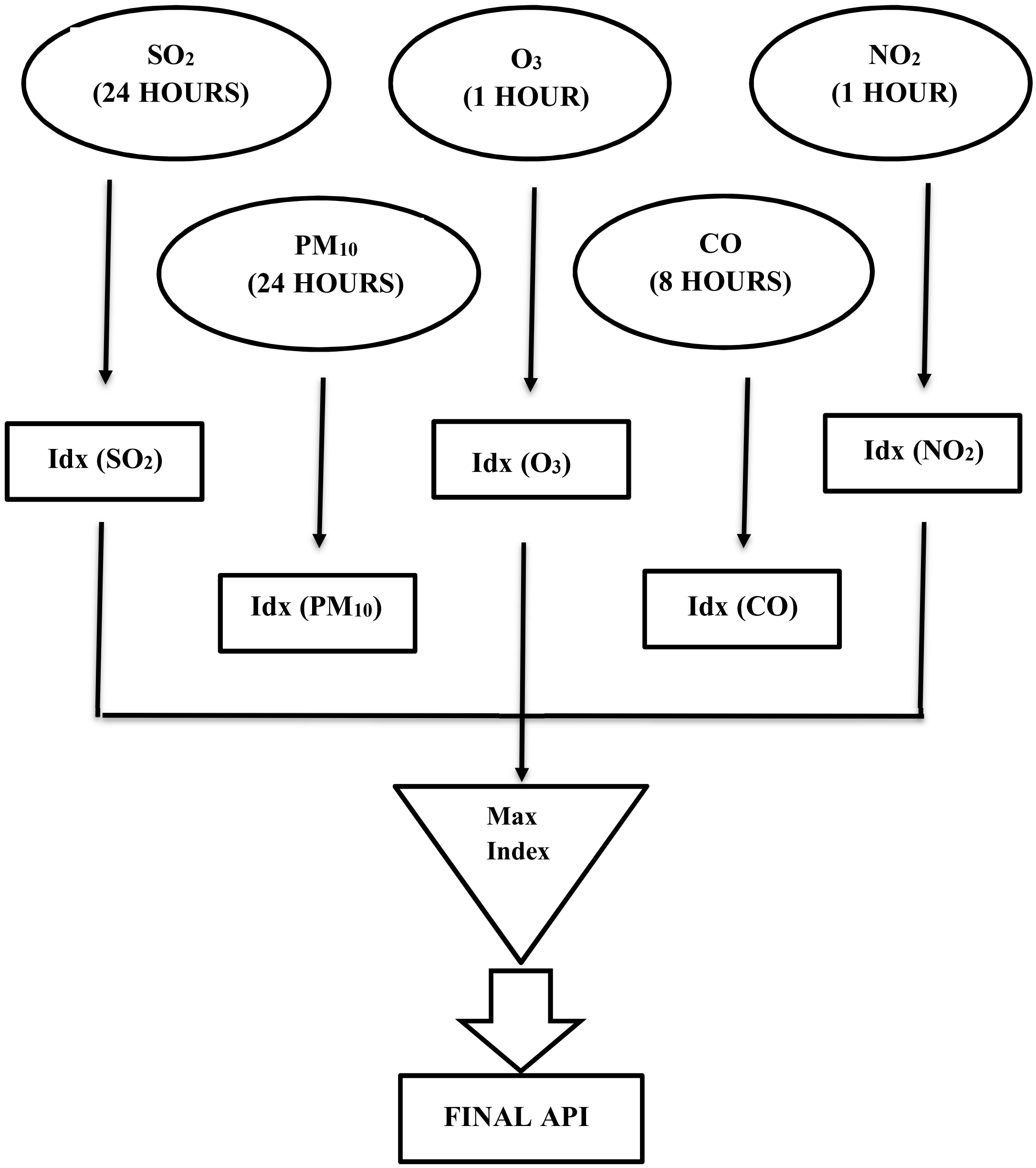

Figure 3.5：Air pollutant index calculation process flow chart

Source：A Guide to Air Pollutant Index in Malaysia (2000)

For the calculation of API, there are few steps that are needed to be followed. Firstly, the five main pollutants that are responsible for the API value which are CO, PM_{10}, NO_2, SO_2 and O_3 are recorded. The recorded values are then substituted into the equations for each particular pollutant with the value falling in the specific range.

For CO:

Table 3.1: Equations for API of CO

x < 9	API = conc. x 11.11111
9 < x < 15	API = 100 + [(conc.- 9) x 16.66667]
15 < x < 30	API = 200 + [(conc.- 15) x 16.66667]
x > 30	API = 300 + [(conc.- 30) x 10]

Source: A Guide to Air Pollutant Index in Malaysia (2000)

For O_3:

Table 3.2: Equations for API of O_3

x < 0.2	API = conc. x 1000
0.2 < x < 0.4	API = 200 + [(conc.- 0.2) x 500]
x > 0.4	API = 300 + [(conc.- 0.4) x 1000]

Source: A Guide to Air Pollutant Index in Malaysia (2000)

For NO_2:

Table 3.3: Equations for API of NO_2

x < 0.17	API = conc. x 588.23529
0.17 < x < 0.6	API = 100 + [(conc.- 0.17) x 232.56]
0.6 < x < 1.2	API = 200 + [(conc.- 0.6) x 166.667]
x > 1.2	API = 300 + [(conc.- 1.2) x 250]

Source: A Guide to Air Pollutant Index in Malaysia (2000)

For SO_2:

Table 3.4：Equations for API of SO_2

x < 0.04	API = conc. x 2500
0.04 < x < 0.3	API = 100 + [(conc.- 0.04) x 384.61]
0.3 < x < 0.6	API = 200 + [(conc.- 0.3) x 333.333]
x > 0.6	API = 300 + [(conc.- 0.6) x 500]

Source：A Guide to Air Pollutant Index in Malaysia (2000)

For PM_{10}:

Table 3.5：Equations for API of PM_{10}

x < 50	API = conc.
50 < x < 150	API = 50 + [(conc.- 50) x 0.5]
150 < x < 350	API = 100 + [(conc.- 150) x 0.5]
350 < x < 420	API = 200 + [(conc.- 350) x 1.4286]
420 < x < 500	API = 300 + [(conc.- 420) x 1.25]
x > 500	API = 400 + [conc.- 500]

Source：A Guide to Air Pollutant Index in Malaysia (2000)

After getting the index value of each particular pollutant, we will select the maximum index among the five individual sub-indexes to be the final API Index.

3.6 Air Pollutant Index (API)

Air pollutant index is the index for reporting air quality. It ranges from 0 to 500 and is dimensionless. It provides indicator for the air quality. The final API value obtained at the results will then be categorised respectively. Hence, we get to learn the condition of the air surrounding us. It is very crucial in air monitoring as we need to ensure the air is safe for human health and the environment at all times.

Table 3.6: Air Pollutant Index Classification

API Value	API Category	API Colour
0-50	Good	Green
51-100	Moderate	Yellow
101-150	Unhealthy for sensitive groups	Orange
151-200	Unhealthy	Red
201-300	Very Unhealthy	Purple
301-500	Hazardous	Maroon

Source: Depart of Environment (DOE 2015)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the analysis of data followed by a discussion of the research findings. The results are presented in graph and table form. The results displayed the air monitoring data conducted on the peat swamp area at Kuala Pahang, Pekan in order to identify their air quality status from March 2018 till March 2019. The air pollution assessment trends are also clearly shown by the graphs tabulated. The daily concentration of the five main pollutants which are carbon monoxide, nitrogen dioxide, ozone, sulphur dioxide and particulate matter with 10 microns responsible for the air pollutant index is also listed out clearly in the section below. In this section. After determining the final API, the values are also tabulated in a graph and being discussed. Lastly, the monthly frequencies are shown in a bar chart to see how frequently the air quality is in good, moderate, unhealthy for sensitive groups, unhealthy and very unhealthy level respectively.

4.2 Carbon Monoxide (CO)

Table 4.1: Daily Concentration of Carbon Monoxide from March 2018 till September 2018

Day	Concentration of pollutant (ppm)						
	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18
1	0.178	0.332	0.102	0.125	0.124	0.181	0.124
2	0.175	0.291	0.055	0.205	0.175	0.166	0.148
3	0.147	0.242	0.103	0.206	0.169	0.124	0.154
4	0.178	0.213	0.188	0.131	0.162	0.191	0.208
5	0.12	0.272	0.204	0.165	0.147	0.163	0.191
6	0.195	0.243	0.205	0.197	0.184	0.256	1.182
7	0.223	0.204	0.126	0.192	0.127	0.204	0.395
8	0.188	0.186	0.203	0.28	0.179	0.194	0.371
9	0.16	0.19	0.176	0.239	0.225	0.213	0.199
10	0.156	0.216	0.128	0.262	0.239	0.201	0.177
11	0.204	0.238	0.137	0.284	0.157	0.429	0.184
12	0.206	0.221	0.173	0.357	0.165	1.444	0.409
13	0.217	0.107	0.415	0.234	0.259	2.009	0.408
14	0.244	0.081	0.471	0.153	0.458	1.38	0.385
15	0.287	0.138	0.445	0.198	1.536	2.541	0.399
16	0.265	0.192	0.278	0.255	0.935	0.57	0.403
17	0.182	0.181	0.356	0.375	0.954	0.306	0.334
18	0.17	0.114	0.364	0.285	1.009	0.277	0.322
19	0.157	0.192	0.268	0.182	1.263	0.159	0.035
20	0.136	0.141	0.27	0.171	0.409	0.158	0.002
21	0.24	0.108	0.471	0.15	0.224	0.175	0.052
22	0.113	0.07	0.386	0.095	0.567	0.198	0.005
23	0.124	0.115	0.281	0.129	0.367	0.235	0.006
24	0.284	0.194	0.166	0.112	0.288	0.191	0.002
25	0.226	0.196	0.251	0.124	0.314	0.275	0.201
26	0.195	0.202	0.331	0.175	0.226	0.484	0.283
27	0.244	0.206	0.222	0.191	0.375	0.261	0.252
28	0.265	0.143	0.254	0.15	0.217	0.343	0.271
29	0.26	0.121	0.189	0.149	0.266	0.185	0.255
30	0.286	0.129	0.153	0.156	0.174	0.125	0.309
31	0.3		0.158		0.111	0.244	

Table 4.2: Daily Concentration of Carbon Monoxide from October 2018 till March 2019

Day	Concentration of pollutant (ppm)					
	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19
1	0.473	0.105	0.103	0.334	0.075	0.132
2	0.48	0.348	0.144	0.437	0.066	0.13
3	0.403	0.205	0.15	0.312	0.067	0.119
4	0.515	0.124	0.121	0.267	0.109	0.179
5	0.427	0.101	0.168	0.202	0.099	0.132
6	0.437	0.158	0.117	0.135	0.115	0.138
7	0.357	0.105	0.108	0.107	0.112	0.247
8	0.325	0.038	0.084	0.114	0.117	0.247
9	0.35	0.097	0.102	0.106	0.115	0.312
10	0.304	0.107	0.091	0.092	0.066	0.236
11	0.221	0.119	0.114	0.113	0.098	0.378
12	0.1	0.102	0.122	0.175	0.125	0.392
13	0.105	0.144	0.115	0.147	0.067	0.336
14	0.093	0.145	0.125	0.165	0.058	0.187
15	0.152	0.26	0.132	0.176	0.077	0.141
16	0.125	0.154	0.146	0.201	0.08	0.213
17	0.157	0.188	0.152	0.171	0.115	0.343
18	0.14	0.168	0.117	0.155	0.143	0.441
19	0.121	0.181	0.138	0.15	0.099	0.554
20	0.133	0.195	0.145	0.165	0.121	0.116
21	0.161	0.259	0.189	0.167	0.125	0.154
22	0.045	0.123	0.263	0.18	0.125	0.1
23	0.05	0.005	0.298	0.243	0.102	0.25
24	0.062	0.096	0.285	0.289	0.109	0.136
25	0.074	0.152	0.26	0.332	0.118	0.114
26	0.035	0.139	0.214	0.277	0.075	0.083
27	0.02	0.167	0.26	0.237	0.089	0.145
28	0.014	0.187	0.294	0.21	0.148	0.502
29	0.035	0.123	0.234	0.156		0.235
30	0.015	0.134	0.168	0.107		0.257
31	0.103		0.202	0.102		

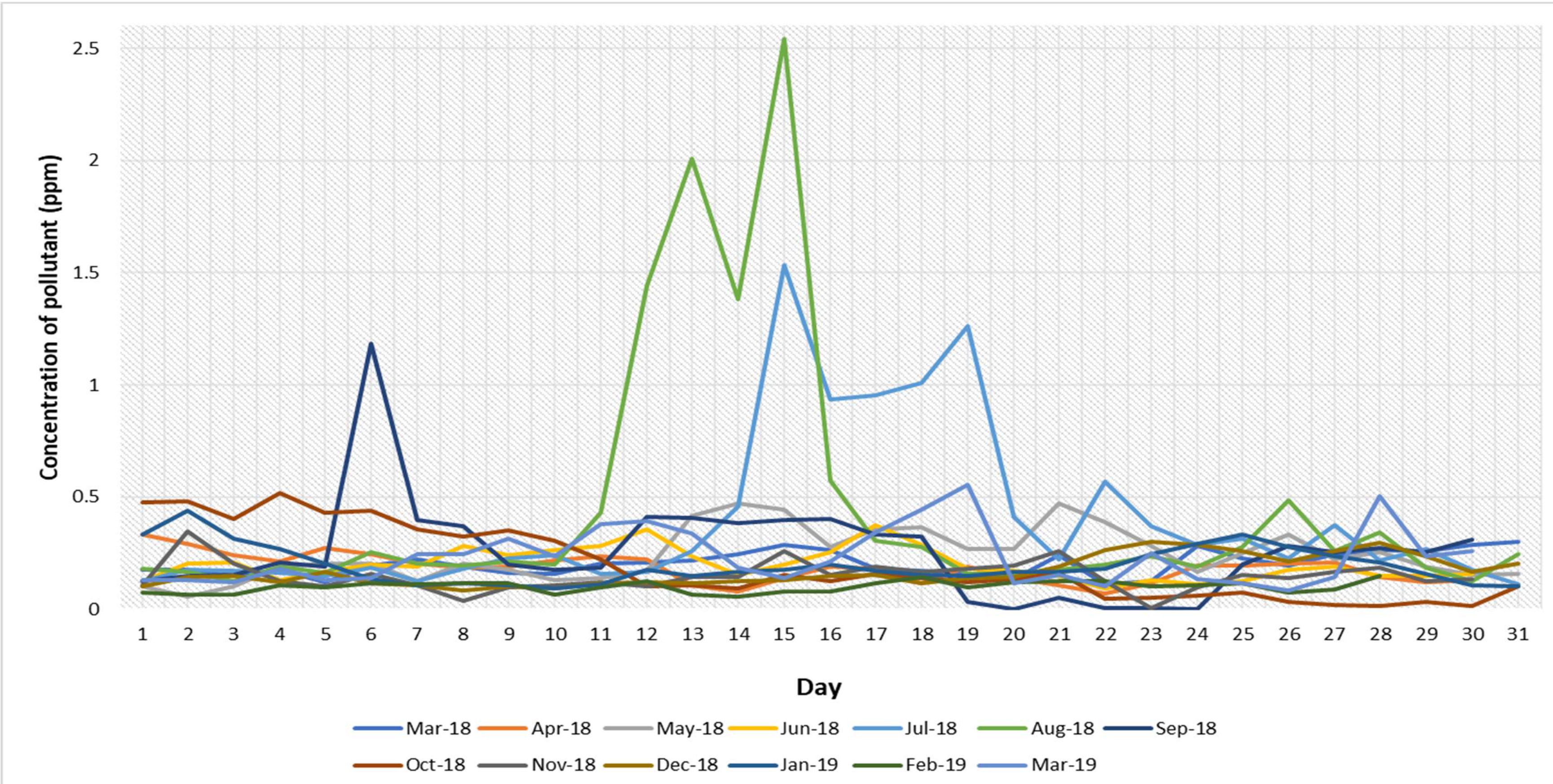

Figure 4.1: Daily concentration of CO at Kuala Pahang, Pekan from March 2018 till March 2019

Table 4.1 and table 4.2 are the concentrations of carbon monoxide recorded by Aeroqual AQM 65 from March 2018 till March 2019. From the table, the lowest concentration for CO is 0.014 ppm which happens on the 28th October 2018 whereas the highest concentration, 2.541 ppm occurs on the 15th August 2018. The range of the concentrations are from 0.014 ppm – 2.541 ppm. From Figure 4.1, it can be seen that the concentrations are quite high in the middle of July and August 2018. The limit value for human health protection under CO category is 8.73 ppm which is 10 mg/m^3 and is recommended by World Health Organisation (Spray et al., 2017). This shows that the CO concentrations do not exceed the limit value and is still safe for the environment and the people.

The amount of carbon stored in one hectare (2.4 acres) of tropical peat forest depends on the thickness of the peat, ranging from about 1,000 metric tons, for depths of a meter (3 feet) to 7,500 metric tons in peat 13 meters (40 feet) deep. Roughly, tropical peatlands store an average of 2,009 metric tons carbon per hectare. According to the U.S. Environmental Protection Agency (EPA) greenhouse equivalence calculations, the average amount of carbon stored in one hectare of peat is equivalent to the greenhouse gases released in one year by 1,551 passenger vehicles in the United States. When peat swamp forests are left untouched, that carbon remains locked in the soil. However, if a swamp is drained, the exposure of peat to oxygen allows microbes to break down the organic matter, releasing that carbon into the atmosphere.

4.3 Nitrogen Dioxide (NO_2)

Table 4.3: Daily Concentration of Nitrogen Dioxide from March 2018 till September 2018

Day	Concentration of pollutant (ppm)						
	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18
1	0.009	0.079	0.009	0.002	0.006	0.006	0.007
2	0.008	0.069	0.015	0.005	0.01	0.004	0.01
3	0.007	0.106	0.01	0.003	0.011	0.006	0.009
4	0.007	0.096	0.01	0.003	0.008	0.004	0.008
5	0.004	0.028	0.008	0.004	0.007	0.006	0.007
6	0.006	0.035	0.007	0.004	0.009	0.006	0.002
7	0.007	0.059	0.002	0.005	0.007	0.008	0.005
8	0.006	0.047	0.004	0.004	0.008	0.008	0.005
9	0.006	0.045	0.001	0.004	0.009	0.005	0.006
10	0.008	0.028	0.001	0.004	0.006	0.005	0.005
11	0.018	0.013	0.001	0.007	0.009	0.005	0.005
12	0.015	0.005	0.002	0.007	0.008	0.003	0.002
13	0.013	0.005	0	0.007	0.006	0.003	0.002
14	0.01	0.006	0	0.005	0.005	0.002	0.002
15	0.008	0.008	0.001	0.004	0.002	0.003	0.001
16	0.007	0.008	0.001	0.006	0.003	0.003	0.001
17	0.006	0.005	0.002	0.006	0.003	0.005	0.001
18	0.009	0.007	0.001	0.006	0.003	0.004	0.001
19	0.009	0.008	0.001	0.005	0.002	0.005	0.005
20	0.011	0.012	0.002	0.007	0.003	0.004	0.002
21	0.006	0.009	0.002	0.007	0.005	0.006	0.002
22	0.007	0.007	0.002	0.006	0.003	0.004	0.001
23	0.01	0.011	0.002	0.006	0.004	0.004	0.001
24	0.01	0.016	0.002	0.005	0.005	0.005	0.002
25	0.015	0.068	0.003	0.007	0.005	0.004	0.001
26	0.018	0.024	0.002	0.009	0.005	0.003	0.004
27	0.024	0.018	0.003	0.007	0.004	0.005	0.001
28	0.021	0.018	0.003	0.005	0.007	0.005	0.002
29	0.017	0.012	0.003	0.011	0.007	0.008	0.001
30	0.017	0.014	0.003	0.007	0.005	0.008	0.001
31	0.03		0.003		0.006	0.007	

Table 4.4: Daily Concentration of Nitrogen Dioxide from October 2018 till March 2019

Day	Concentration of pollutant (ppm)					
	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19
1	0.002	0.002	0.004	0.017	0.047	0.229
2	0.002	0.006	0.005	0.011	0.032	0.461
3	0.002	0.002	0.005	0.005	0.02	0.811
4	0.001	0.003	0.004	0.005	0.018	0.584
5	0.001	0.002	0.005	0.007	0.034	0.472
6	0.006	0.003	0.004	0.006	0.047	0.056
7	0.003	0.002	0.005	0.007	0.028	0.018
8	0.004	0.001	0.003	0.008	0.025	0.018
9	0.004	0.004	0.003	0.007	0.008	0.017
10	0.004	0.003	0.004	0.009	0.014	0.004
11	0.003	0.005	0.004	0.011	0.021	0.003
12	0.003	0.003	0.006	0.01	0.015	0.003
13	0.001	0.004	0.006	0.008	0.018	0.004
14	0.001	0.003	0.006	0.008	0.03	0.005
15	0.003	0.005	0.005	0.01	0.047	0.017
16	0.003	0.003	0.005	0.014	0.078	0.028
17	0.003	0.005	0.006	0.007	0.026	0.031
18	0.003	0.003	0.006	0.015	0.015	0.015
19	0.002	0.004	0.005	0.019	0.032	0.006
20	0.003	0.007	0.007	0.018	0.029	0.008
21	0.004	0.005	0.006	0.018	0.03	0.019
22	0.005	0.005	0.007	0.02	0.043	0.009
23	0.005	0.005	0.01	0.052	0.106	0.008
24	0.006	0.005	0.008	0.359	0.174	0.005
25	0.003	0.005	0.008	0.457	0.08	0.005
26	0.002	0.004	0.009	0.207	0.052	0.006
27	0.002	0.003	0.007	0.042	0.341	0.009
28	0.002	0.004	0.007	0.076	0.101	0.006
29	0.002	0.004	0.008	0.04		0.009
30	0.002	0.006	0.01	0.087		0.011
31	0.003		0.014	0.047		

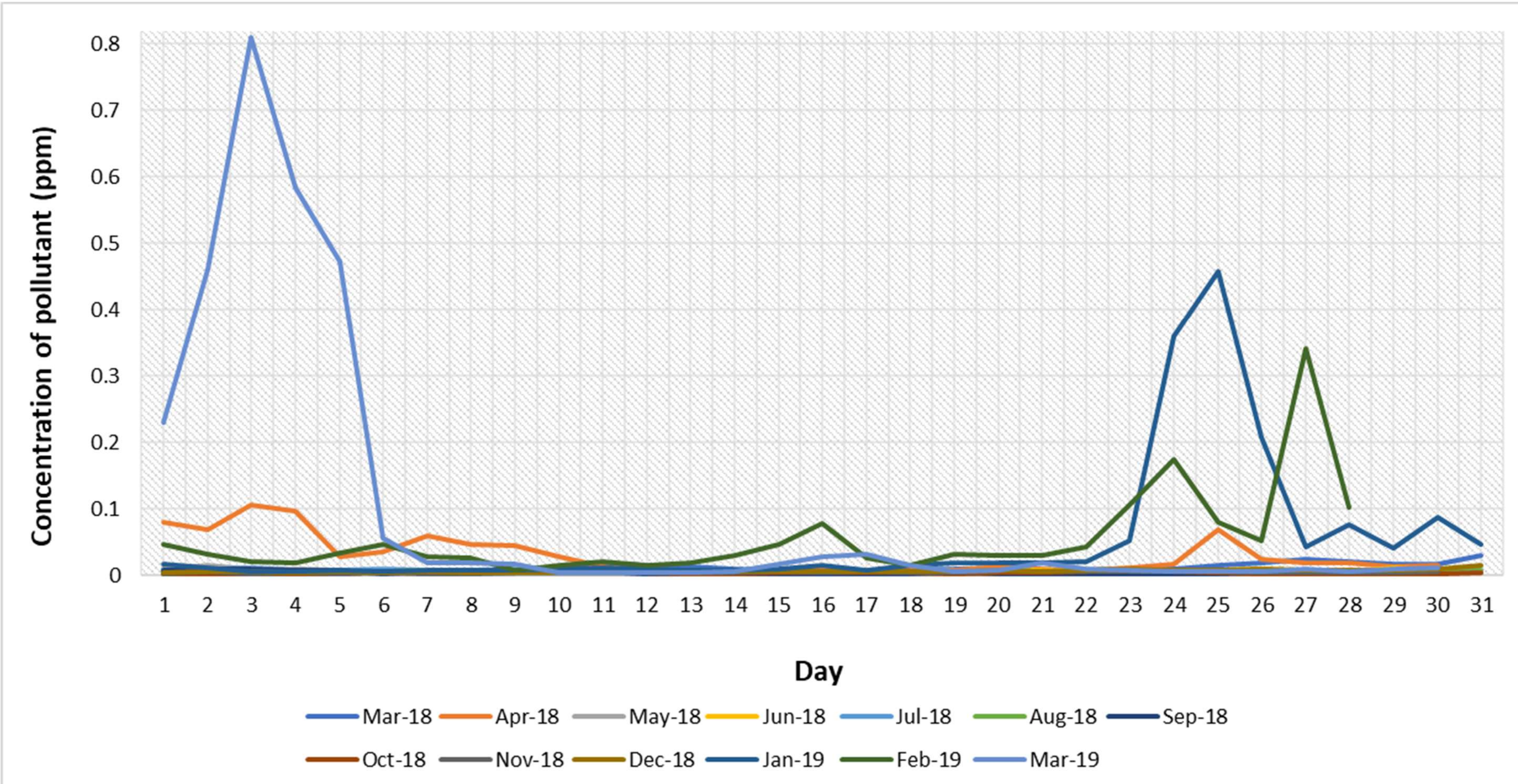

Figure 4.2: Daily concentration of NO_2 at Kuala Pahang, Pekan from March 2018 till March 2019

Table 4.3 and table 4.4 are the concentrations of nitrogen dioxide recorded by Aeroqual AQM 65 from March 2018 till March 2019. From the table, the lowest concentration for NO_2 is null which happens on the 13th and 14th May 2018 whereas the highest concentration, 0.811 ppm occurs on the 3rd March 2019. The range of the concentrations are within 0 ppm – 0.811 ppm. From Figure 4.2, it can be seen that the concentrations are quite high in the early of March 2019. This may due to prolonged dry weather happened at Kuala Pahang, Pekan. Nitrogen dioxide is known as a precursor to particulate matter. The limit value for human health protection under NO_2 category is 21 ppm and is recommended by World Health Organisation (Spray et al., 2017). This shows that the NO_2 concentrations do not exceed the limit value and is still safe for the environment and the people.

According the EU Common Agricultural Policy, the peatland areas are considered vulnerable areas that are most likely to contribute to a strong increase of greenhouse gas emissions. Nitrogen pollution may also come from irrigation water run-off from agricultural fields with nitrogen fertilizers. Bogs and heathlands in semi-natural regions generally do not release large amounts of the nitrous oxide since they usually do not receive high levels of nitrogen-rich runoff directly. However, peatbog has shown that the ability of a peatland to adsorb nitrogen deposition onto surface Sphagnum moss known as the nitrogen filter declines with long-term exposure to elevated deposition. Concentrations of reactive nitrogen then build up in the peat porewater and can leach into subsurface water and groundwater, potentially causing eutrophication of downstream ecosystems.

4.4 Ozone (O_3)

Table 4.5: Daily Concentration of Ozone from March 2018 till September 2018

Day	Concentration of pollutant (ppm)						
	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18
1	0.036	0.054	0.018	0.023	0.036	0	0.019
2	0.032	0.048	0.022	0.015	0.028	0	0.022
3	0.033	0.052	0.017	0.017	0.026	0	0.021
4	0.028	0.048	0.018	0.013	0.02	0	0.027
5	0.029	0.039	0.016	0.012	0.023	0	0.02
6	0.03	0.042	0.021	0.01	0.024	0	0.023
7	0.032	0.045	0.016	0.016	0.017	0	0.025
8	0.03	0.04	0.015	0.018	0.016	0	0.021
9	0.033	0.044	0.006	0.024	0.025	0	0.016
10	0.038	0.037	0.012	0.026	0.024	0	0.017
11	0.052	0.03	0.015	0.028	0.02	0	0.011
12	0.047	0.03	0.02	0.033	0.018	0	0.014
13	0.039	0.032	0.024	0.036	0.014	0	0.02
14	0.032	0.029	0.033	0.037	0.015	0	0.024
15	0.029	0.032	0.025	0.034	0.016	0.014	0.017
16	0.032	0.024	0.026	0.03	0.019	0.027	0.018
17	0.032	0.018	0.028	0.028	0.033	0.025	0.023
18	0.035	0.026	0.016	0.029	0.038	0.026	0.015
19	0.033	0.017	0.015	0.024	0.039	0.024	0.012
20	0.033	0.021	0.018	0.025	0.045	0.023	0.016
21	0.029	0.018	0.013	0.023	0.046	0.018	0.019
22	0.035	0.023	0.016	0.02	0.038	0.028	0.03
23	0.037	0.012	0.015	0.016	0.036	0.024	0.024
24	0.039	0.025	0.012	0.016	0.033	0.022	0.026
25	0.041	0.037	0.014	0.015	0.028	0.016	0.029
26	0.038	0.026	0.013	0.023	0.02	0.019	0.027
27	0.04	0.019	0.01	0.025	0.019	0.021	0.024
28	0.038	0.022	0.016	0.026	0.016	0.021	0.017
29	0.035	0.02	0.017	0.027	0.019	0.023	0.02
30	0.039	0.019	0.018	0.026	0.02	0.026	0.022
31	0.043		0.02		0.025	0.023	

Table 4.6: Daily Concentration of Ozone from October 2018 till March 2019

Day	Concentration of pollutant (ppm)					
	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19
1	0.019	0.033	0.009	0.024	0.022	0.039
2	0.02	0.031	0.009	0.019	0.02	0.044
3	0.022	0.026	0.009	0.014	0.019	0.048
4	0.019	0.019	0.012	0.022	0.019	0.047
5	0.026	0.013	0.013	0.022	0.021	0.045
6	0.037	0.013	0.011	0.019	0.022	0.036
7	0.025	0.012	0.01	0.019	0.021	0.033
8	0.012	0.015	0.01	0.019	0.02	0.038
9	0.023	0.019	0.01	0.019	0.016	0.033
10	0.018	0.015	0.011	0.021	0.02	0.032
11	0.021	0.011	0.01	0.021	0.022	0.029
12	0.017	0.011	0.009	0.018	0.022	0.036
13	0.026	0.007	0.014	0.018	0.024	0.035
14	0.018	0.014	0.012	0.019	0.025	0.042
15	0.024	0.013	0.01	0.019	0.026	0.047
16	0.032	0.015	0.012	0.02	0.028	0.046
17	0.029	0.013	0.012	0.017	0.025	0.047
18	0.032	0.014	0.015	0.025	0.024	0.042
19	0.027	0.012	0.013	0.025	0.027	0.038
20	0.029	0.019	0.014	0.024	0.026	0.047
21	0.034	0.011	0.016	0.023	0.027	0.039
22	0.022	0.022	0.024	0.024	0.029	0.036
23	0.02	0.019	0.026	0.032	0.032	0.029
24	0.014	0.019	0.019	0.04	0.035	0.031
25	0.023	0.021	0.019	0.039	0.033	0.039
26	0.017	0.02	0.019	0.033	0.032	0.045
27	0.018	0.018	0.01	0.028	0.041	0.037
28	0.016	0.016	0.017	0.031	0.035	0.031
29	0.021	0.012	0.02	0.026		0.044
30	0.033	0.012	0.021	0.027		0.048
31	0.04		0.02	0.021		

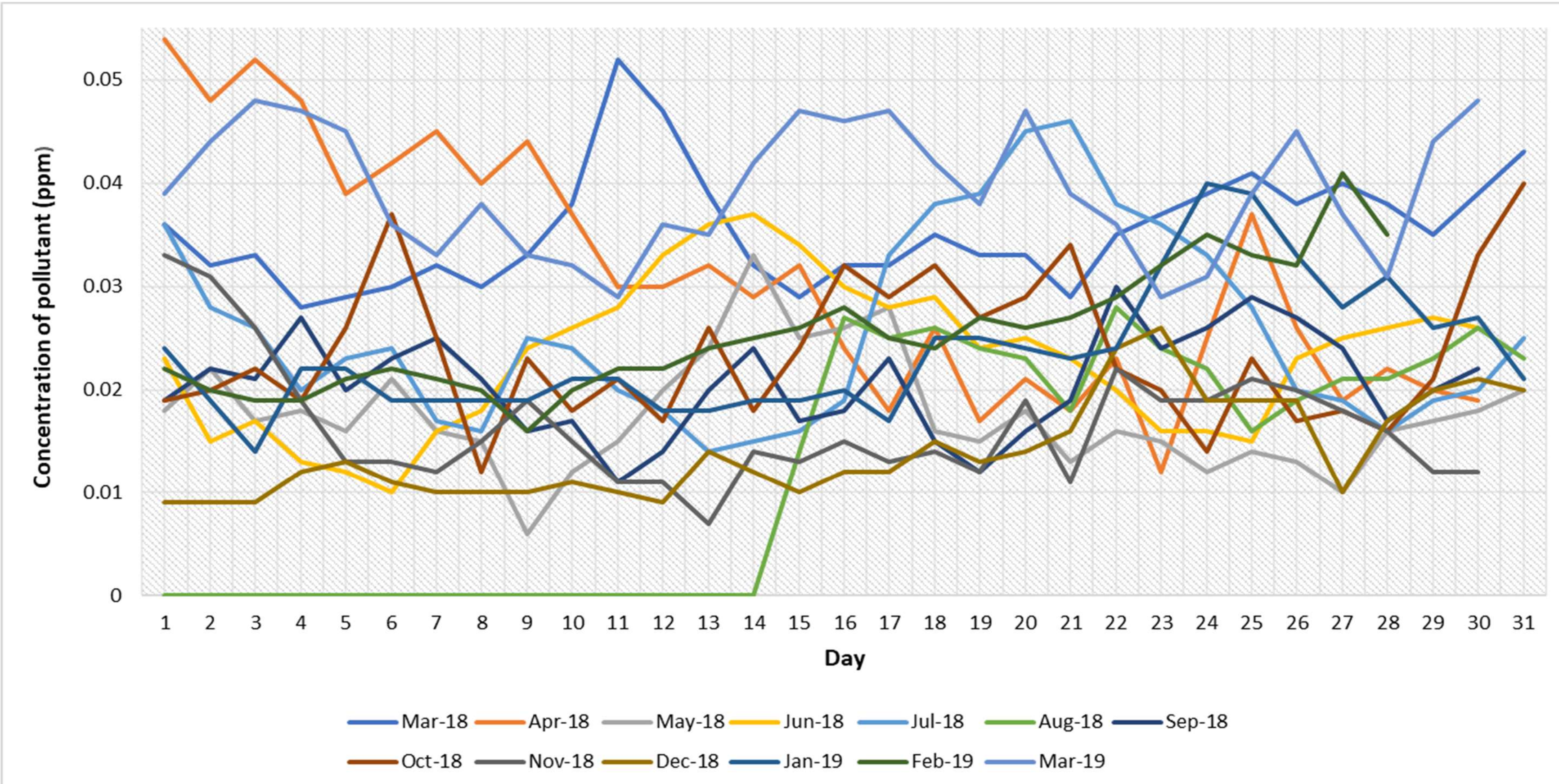

Figure 4.3: Daily concentration of O_3 at Kuala Pahang, Pekan from March 2018 till March 2019

Table 4.5 and table 4.6 are the concentrations of ozone recorded by Aeroqual AQM 65 from March 2018 till March 2019. From the table, the lowest concentration for O_3 is null on the 1st till 14th August 2018 whereas the highest concentration, 0.054 ppm occurs on the 1st April 2018. The range of the concentrations are from 0 ppm – 0.054 ppm. From Figure 4.3, it can be seen that the concentrations are quite consistent throughout the 13 months without any drastic change. This may due to chemical reaction between emitted pollutants and the presence of the sunlight. The limit value for human health protection under O_3 category is 5 ppm and is recommended by World Health Organisation(Spray et al., 2017). This shows that the O_3 concentrations do not exceed the limit value and is still safe for the environment and the people.

Another major impact of peat fires with far reaching effects on other ecosystems is air pollution. Adverse effects on human health in the region have been well discussed. According to Ostermann and Brauer Forest fires release toxic gases such as CO, ozone (O_3) and nitrogen dioxide (NO_2). Many people will be exposed to dangerously high levels of air pollution during the fires, with an increase in asthma, bronchitis and other respiratory illnesses (Yule, 2010). In addition, many communities are relying on forest goods and services such as timber and non-timber forest products and use of clean water whose quantity and quality is dependent on the presence of the forest. Forest fires thus destroy the income sources of these communities.

4.5 Sulphur Dioxide (SO_2)

Table 4.7: Daily Concentration of Sulphur Dioxide from March 2018 till September 2018

Day	Concentration of pollutant (ppm)						
	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18
1	0.002	0.002	0.001	0	0	0	0
2	0.002	0.002	0.001	0.001	0	0	0
3	0.002	0.002	0.001	0	0	0	0
4	0.001	0.002	0.001	0	0	0	0
5	0.002	0.001	0.001	0	0	0	0
6	0.002	0.002	0.001	0	0	0	0
7	0.002	0.002	0.001	0	0	0	0
8	0.002	0.001	0	0	0	0	0
9	0.001	0.002	0	0	0	0	0
10	0.002	0.002	0	0	0	0	0
11	0.001	0.002	0	0	0	0.001	0
12	0.002	0.001	0	0	0	0.001	0.001
13	0.001	0.001	0.001	0	0	0	0.001
14	0.002	0.001	0.001	0	0	0	0.001
15	0.002	0.001	0	0	0.001	0	0.001
16	0.001	0.001	0	0	0	0	0.001
17	0.002	0.001	0.001	0	0.001	0	0.001
18	0.001	0.001	0	0	0	0	0.001
19	0.002	0.001	0	0	0	0	0.002
20	0.002	0.001	0	0	0	0	0.001
21	0.002	0.001	0	0	0	0	0
22	0.002	0.001	0	0	0	0	0.001
23	0.002	0.001	0	0	0	0	0
24	0.002	0.001	0	0	0	0.001	0.001
25	0.002	0.001	0	0	0	0	0.002
26	0.001	0.001	0	0	0	0	0.002
27	0.002	0.001	0	0	0	0	0.002
28	0.002	0.001	0	0	0	0	0.002
29	0.002	0.001	0	0	0	0	0.002
30	0.002	0.001	0	0	0	0	0.002
31	0.002		0		0	0	

Table 4.8: Daily Concentration of Sulphur Dioxide from October 2018 till March 2019

Day	Concentration of pollutant (ppm)					
	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19
1	0.002	0	0	0	0.001	0.001
2	0.002	0	0	0	0.001	0.001
3	0.002	0	0	0	0.001	0.001
4	0.002	0	0	0	0.001	0.001
5	0.002	0	0	0	0.001	0.001
6	0.002	0	0	0	0.001	0.001
7	0.002	0	0	0	0.001	0.001
8	0.002	0	0	0.001	0.001	0.001
9	0.002	0	0	0	0.001	0.001
10	0.001	0	0	0	0.001	0.001
11	0	0	0	0	0.001	0.001
12	0	0	0	0	0.001	0.001
13	0	0	0.001	0	0.001	0.001
14	0	0	0	0.001	0.001	0.001
15	0	0	0	0	0.001	0.001
16	0	0	0	0	0.001	0.001
17	0	0	0	0	0.001	0.001
18	0	0	0	0	0.001	0.001
19	0	0	0	0.001	0.001	0.001
20	0	0	0	0	0.001	0.001
21	0.001	0	0.001	0	0.001	0.001
22	0.002	0	0	0	0.001	0.002
23	0.002	0.002	0	0	0.001	0.001
24	0.003	0	0	0	0.001	0.001
25	0	0	0	0	0.001	0.001
26	0	0	0	0	0.001	0.002
27	0	0	0	0	0.001	0.001
28	0	0	0	0	0.002	0.001
29	0	0	0	0.001		0.001
30	0	0	0	0.001		0.001
31	0		0	0.001		

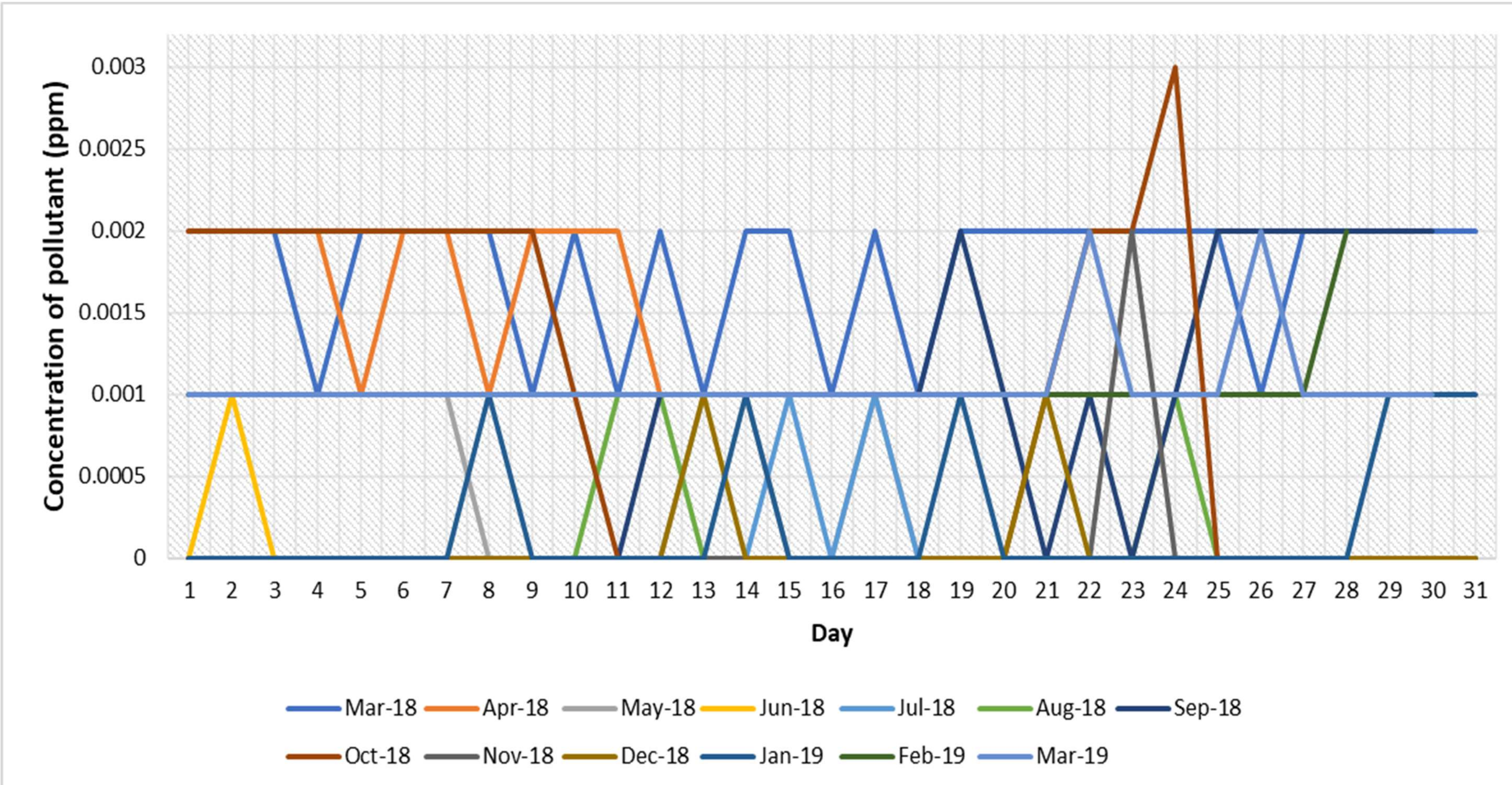

Figure 4.4: Daily concentration of SO_2 at Kuala Pahang, Pekan from March 2018 till March 2019

Table 4.7 and table 4.8 are the concentrations of sulphur dioxide recorded by Aeroqual AQM 65 from March 2018 till March 2019. From the table, we can assume that the release of sulphur dioxide at the peat swamp area in Kuala Pahang, Pekan is the most consistent among the other four main pollutants. The concentrations of sulphur dioxide mostly fall in the range from 0 ppm – 0.003 ppm. From Figure 4.4, it can be seen that the concentrations are very consistent throughout the study period with little difference. The limit value for human health protection under SO_2 category is 7.63 ppm which is 20 mg/m^3 and is recommended by World Health Organisation(Spray et al., 2017). This shows that the SO_2 concentrations do not exceed the limit value and is still safe for the environment and the people.

Dry peat ignites very easily and can burn for days or weeks, even smouldering underground and re-emerging away from the initial source. This makes these fires incredibly difficult to extinguish, and highly unpredictable and uncontrollable. According to the U.S. Environmental Protection Agency (EPA), dry peat ignites very easily and can burn for days or weeks, even smouldering underground and re-emerging away from the initial source. This makes these fires incredibly difficult to extinguish, and highly unpredictable and uncontrollable. Sulphur can be in different forms and have various reactions in the peat. The hydrogen sulphide could react with peat components, thus incorporating sulphur in the organic material. Atschuler indicates that sulphur associated with ester-sulphate may be the source of pyritic sulphur in low sulphur freshwater peat swamps.

4.6 Particulate Matter (PM_{10})

Table 4.9: Daily Concentration of Particulate Matter with 10 microns from March 2018 till September 2018

Day	Concentration of pollutant (µg/m³)						
	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18
1	3.17	7.92	2.99	2.4	2.54	3.43	3.11
2	1.94	6.51	1.86	1.61	2.9	5.06	3.4
3	1.5	5.4	1.98	3.43	3.64	4.77	4.48
4	2.13	3.87	1.95	3.96	3.1	8.32	4.48
5	1.57	5.07	2.92	4.15	3.78	7.19	3.65
6	2.42	4.93	3.59	5.43	6.56	9.44	19.65
7	1.92	3.59	3.33	6.52	4.63	6.47	7.17
8	2.66	5.16	3.81	8.84	6.03	5.31	6.19
9	3.62	5.17	3.27	5.25	6.23	6.8	3.82
10	5.98	3.66	1.93	10.21	6.22	6.71	3.97
11	7.86	4.01	1.83	9.36	4.09	12	4.72
12	7.26	3.42	2.07	9.65	4.36	29.93	13.95
13	5.79	2.32	8.73	6.02	9	32.34	24.28
14	4.45	1.51	9.63	3.07	13.2	26.86	15.92
15	4.46	2.2	7.72	4.22	25.13	37.15	15.13
16	3.3	1.92	4.69	5.39	21.37	13.05	13.18
17	2.32	2.57	5.96	6.33	22.13	8.85	11.59
18	2.18	2.19	6.81	5.71	19.68	9.18	6.23
19	2.87	2.6	4.68	4.54	23.03	7.59	3.16
20	3.34	2.26	4.26	3.92	10.54	5.13	2.27
21	4.63	2.39	8.03	3.33	7.04	5.8	1.36
22	2.14	2.14	7.56	1.89	13.64	5.62	2.4
23	2.6	3.36	4.71	2.62	9.64	6.39	3.17
24	7.19	4.1	2.57	1.67	7.41	6.07	3.25
25	5.91	5.76	4.71	1.63	7.74	7.18	3.47
26	3.31	3.24	6.56	2.91	5.43	10.3	3.84
27	3.62	2.31	2.84	3.44	8.91	7.27	3.77
28	5.08	2.4	2.74	2.31	5.45	7.92	4.72
29	4.78	3.11	3.35	2.17	7.75	4.72	3.98
30	5.24	3.6	1.94	2.87	3.71	3.57	5.19
31	6.18		2.77		2.1	6.02	

Table 4.10: Daily Concentration of Particulate Matter with 10 microns from October 2018 till March 2019

Day	Concentration of pollutant (µg/m³)					
	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19
1	7.49	3.74	1.57	2.12	1.64	2.19
2	7.06	2.19	1.44	2.1	1.47	1.78
3	5.46	0.99	1.74	1.55	1.53	1.42
4	8.39	1.33	1.33	1.55	1.75	2.1
5	7.53	1.13	1.04	2.18	1.43	1.04
6	3.85	1.08	1.32	2.1	1.52	1.29
7	1.53	1.59	1.1	2.7	1.43	2.68
8	1.56	1.07	1.05	2.56	1.22	2.81
9	1.85	1.03	1.52	2.09	1.18	5.3
10	1.9	1.22	1.34	1.83	0.82	2.3
11	1.5	1.45	1.71	1.83	1.15	4.27
12	1.19	1.36	1.53	1.73	1.79	4.83
13	1.67	1.94	1.05	1.98	2.08	4.61
14	0.92	1.74	2.07	2.38	2.07	2.47
15	1.37	1.65	1.59	2.28	1.89	1.68
16	1.84	1.37	1.21	1.83	1.41	3.2
17	2.69	2.17	1.33	2.04	1.67	5.82
18	1.24	2.41	0.9	2.64	1.18	6.11
19	1.19	2.13	1.5	2.79	0.97	8.37
20	1.36	2.1	1.58	2.68	0.97	0.94
21	2.95	1.82	2.01	2.29	1.38	1.7
22	1.76	1.54	2.81	2.01	1.44	1.3
23	1.53	1.37	3.26	3.19	1.11	3.61
24	1.24	2.17	2.61	3.51	1.33	1.66
25	1.47	2.11	2.04	3.47	1.27	1.76
26	1.85	1.65	1.23	2.77	1.09	1.57
27	1.57	1.84	1.39	3.25	1.98	2.49
28	1.57	1.41	1.99	3.53	2.8	9.11
29	2.08	1.61	1.79	2.49		2.34
30	2.79	1.63	1.63	2.21		3.1
31	3.79		1.79	2.13		

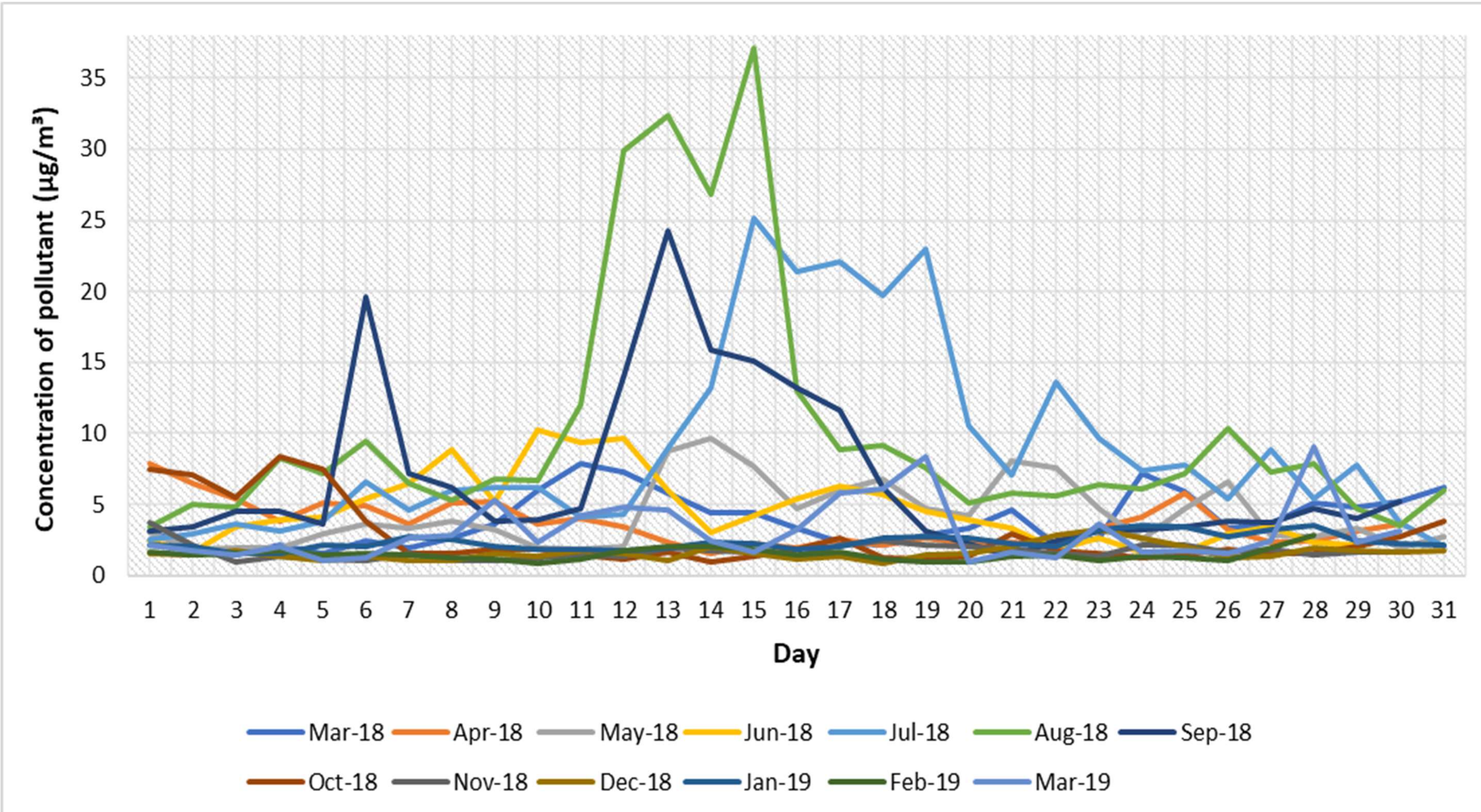

Figure 4.5: Daily concentration of PM_{10} at Kuala Pahang, Pekan from March 2018 till March 2019

Table 4.9 and table 4.10 are the concentrations of particulate matter with 10 microns recorded by Aeroqual AQM 65 from March 2018 till March 2019. From the table, the lowest concentration for PM_{10} is 0.9 µg/m³ which happens on the 18th December 2018 whereas the highest concentration, 37.2 µg/m³ occurs on the 15th August 2018. The range of the concentrations are from 0.9 µg/m³ - 37.2 µg/m³. From Figure 4.5, it can be seen that the concentrations are quite high in the middle of July, August and September 2018. The limit value for human health protection under PM_{10} category is 50 µg/m³(Spray et al., 2017). This shows that the PM_{10} concentrations do not exceed the limit value and is still safe for the environment and the people.

In peatland ecosystems, fires comprise both flaming and smouldering combustion. While flaming, surface fires consume vegetation and litter, smouldering fires burn into and below the ground consuming the peat itself as a fuel source. Flaming fires may pass rapidly through the vegetation but smouldering fires burn slowly and persist for long periods of time, burning repeatedly in response to changing soil moisture and penetrating to different peat depths. Peat fires in Southeast Asia may burn for days, weeks or even months and are very difficult to control. Many occur in remote, off-road locations where they are difficult to extinguish using conventional fire-fighting techniques. They can also re-ignite, even after rain, and are often only fully extinguished by a rising ground water table following heavy rain This is a pertinent issue for this densely populated region where there is the potential for exposure of large numbers of people to smoke inhalation. Once there is fire, there is smoke and it may cause haze. Particulate matter with 10 microns is the main contributor to the haze phenomenon. According to the Department of Environment, smoke from Indonesian peat fires resulted in severe haze pollution incidents affecting Malaysia in 1997, 2002, 2006, 2009, 2013, 2014 and again in 2015. These pollution events are so acute that they result in serious economic and social impacts, including the closure of schools, the cancellation of flights, a downturn in business revenues and tourism, and human health problems, even for those experiencing short-term exposure to the smoke.

4.7 Daily API Value

Table 4.11: Daily API Value from March 2018 till September 2018

Day	API Value						
	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18
1	36	54	18	23	36	3.5	19
2	32	48	22	15	28	5.1	22
3	33	62.4	17	17	26	4.8	21
4	28	56.5	18	13	20	8.3	27
5	29	39	16	12	23	7.2	20
6	30	42	21	10	24	9.4	23
7	32	45	16	16	17	6.5	25
8	30	40	15	18	16	5.3	21
9	33	44	6	24	25	6.8	16
10	38	37	12	26	24	6.7	17
11	52	30	15	28	20	12	11
12	47	30	20	33	18	30	14
13	39	32	24	36	14	32.3	20
14	32	29	33	37	15	26.9	24
15	29	32	25	34	16	37.2	17
16	32	24	26	30	19	27	18
17	32	18	28	28	33	25	23
18	35	26	16	29	38	26	15
19	33	17	15	24	39	24	12
20	33	21	18	25	45	23	16
21	29	18	13	23	46	18	19
22	35	23	16	20	38	28	30
23	37	12	15	16	36	24	24
24	39	25	12	16	33	22	26
25	41	40	14	15	28	16	29
26	38	26	13	23	20	19	27
27	40	19	10	25	19	21	24
28	38	22	16	26	16	21	17
29	35	20	17	27	19	23	20
30	39	19	18	26	20	26	22
31	43		20		25	23	

Table 4.12: Daily API Value from October 2018 till March 2019

Day	API Value					
	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19
1	19	33	9	24	27.6	113.7
2	20	31	9	19	20	167.7
3	22	26	9	14	19	235.2
4	19	19	12	22	19	196.3
5	26	13	13	19	21	170.2
6	37	13	11	19	27.6	36
7	25	12	10	19	21	33
8	12	15	10	19	20	38
9	23	19	10	19	16	33
10	18	15	11	21	20	32
11	21	11	10	21	22	29
12	17	11	9	18	22	36
13	26	7	14	18	24	35
14	18	14	12	19	25	42
15	24	13	10	19	27.6	47
16	32	15	12	20	45.9	46
17	29	13	12	17	25	47
18	32	14	15	25	24	42
19	27	12	13	25	27	38
20	29	19	14	24	26	47
21	34	11	16	23	27	39
22	26	22	24	24	29	43
23	19	20	26	32	62.4	36
24	14	19	19	144	100.9	29
25	23	21	19	166.7	47.1	31
26	17	20	19	108.6	32	39
27	18	18	10	28	139.8	45
28	16	16	17	44.7	59.4	37
29	21	12	20	26	-	31
30	33	12	21	51.2	-	44
31	40	-	20	27.6	-	48

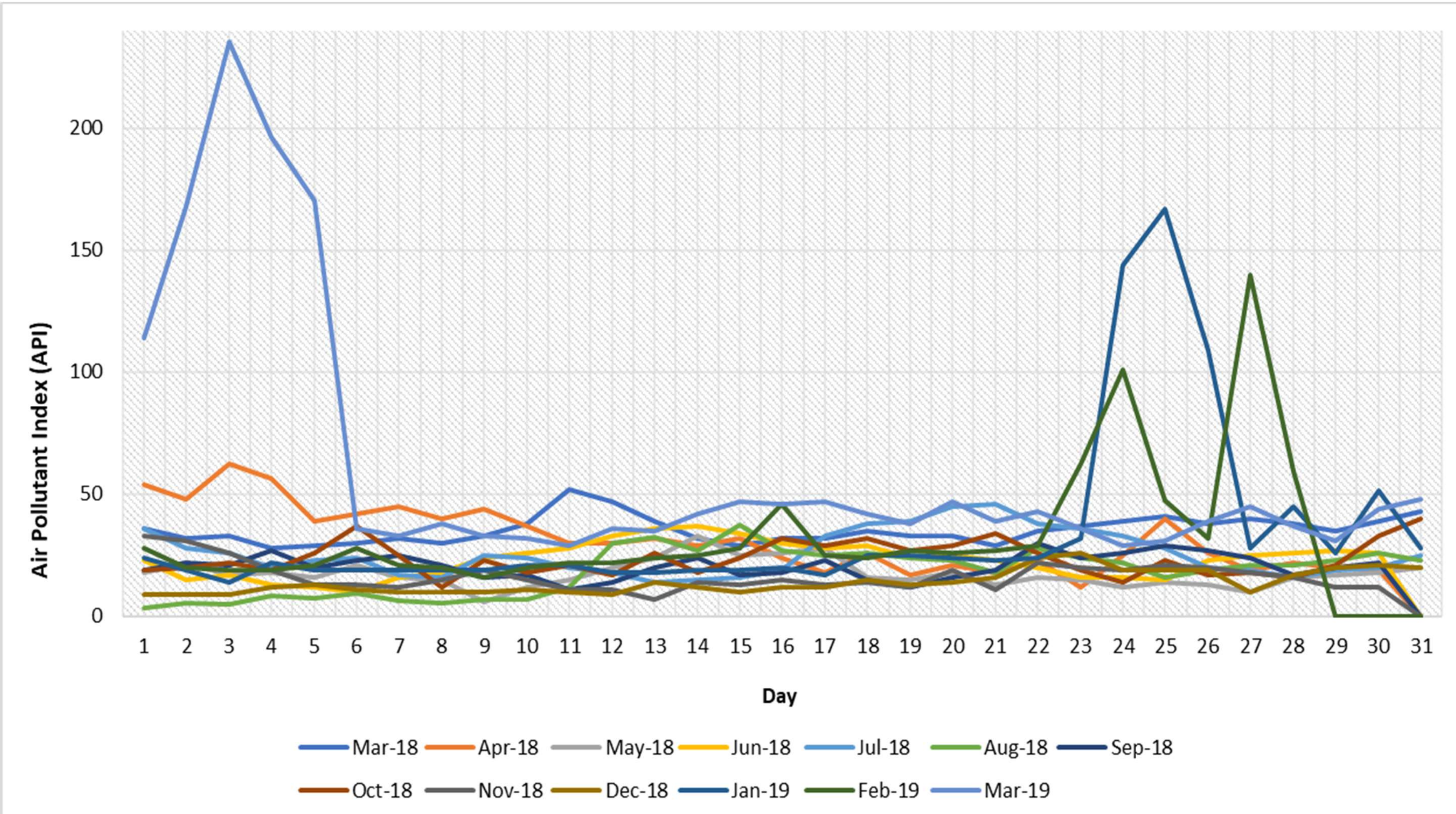

Figure 4.6: Daily API Value at Kuala Pahang, Pekan from March 2018 till March 2019

After substituting the pollutants' concentrations into the equations mentioned in the methodology, the final daily API value is listed in table 4.6 and is tabulated in a graph. Figure 4.6 shows the trend of API from March 2018 to March 2019 at peat swamp area at Kuala Pahang, Pekan. Values of API greater than 100 were analysed in this study as unhealthy for sensitive groups, unhealthy and very unhealthy which will likely contribute significant damage to health, environment, and property. From the graph tabulated, the trend of API shows that there are few days in January, February and March 2019 which are over 100. It can be seen that the API value is quite high from the end of February 2019 till early March 2019. The highest API recorded is 235.2 on the 3rd March 2019 at Kuala Pahang, Pekan which is at the very unhealthy level. For unhealthy category, the highest API, 196.3 was recorded on the 4th March 2019. As for the unhealthy for sensitive groups category, 113.7 was the highest API which occurred on the 1st March 2019. This might due to the haze episodes experienced in Malaysia due to the transboundary pollution from Indonesian forest fires. Haze is one of the factors made up of CO, SO_2, NO_2, O_3, dust, and metals, where these include five major air pollutants in API. Its formation includes several factors, for instance prolonged dry weather, a stable atmosphere, and an abundant pollutant supply from urban or rural sources (Rahman H.A, 2013). At the time, the air monitoring station at Kuala Pahang, Pekan was facing the dry season which brings less rainfall. Besides, the parameters such as O_3 and PM_{10} are responsible for air quality variations (Azid A. et al, 2015). Thus, the presence of these pollutants has its own impact to air quality. Particulate matter is the main contributor to this situation where during the haze period, the concentration of PM_{10} is much higher compared to the non-haze period (How C.Y., Ling Y.E., 2016). Besides, the high API value might be due to the increasing ozone concentrations resulting from the sunrise coinciding with increasing solar radiation (Tyagi S. et al, 2016). There are also other factors that impact air pollution distribution are wind speed, wind direction, and solar radiation. Different levels of API present might be due to the different sources of pollutants present at that place. From the analysis, especially for March 2019, the peat swamp area faced each API category of good, unhealthy for sensitive groups, unhealthy and very unhealthy. This can be shown from the graphs in Figure 4.7. A study shows several countries in the Southeast Asian region, including Malaysia, facing Southeast Asian haze occurring from 1 June 2013, with January-February and June-August every year being most likely to experience haze (Rahman H.A, 2013).

4.8 Monthly Frequencies

Table 4.13: Monthly Frequencies at Kuala Pahang, Pekan

Month	Frequency (%)				
	Good	Moderate	Unhealthy for sensitive groups	Unhealthy	Very Unhealthy
Mar-18	96.8	3.2	0	0	0
Apr-18	90	10	0	0	0
May-18	100	0	0	0	0
Jun-18	100	0	0	0	0
Jul-18	100	0	0	0	0
Aug-18	100	0	0	0	0
Sep-18	100	0	0	0	0
Oct-18	100	0	0	0	0
Nov-18	100	0	0	0	0
Dec-18	100	0	0	0	0
Jan-19	90.3	3.2	6.5	0	0
Feb-19	85.8	7.1	7.1	0	0
Mar-19	83.9	0	3.2	9.7	3.2

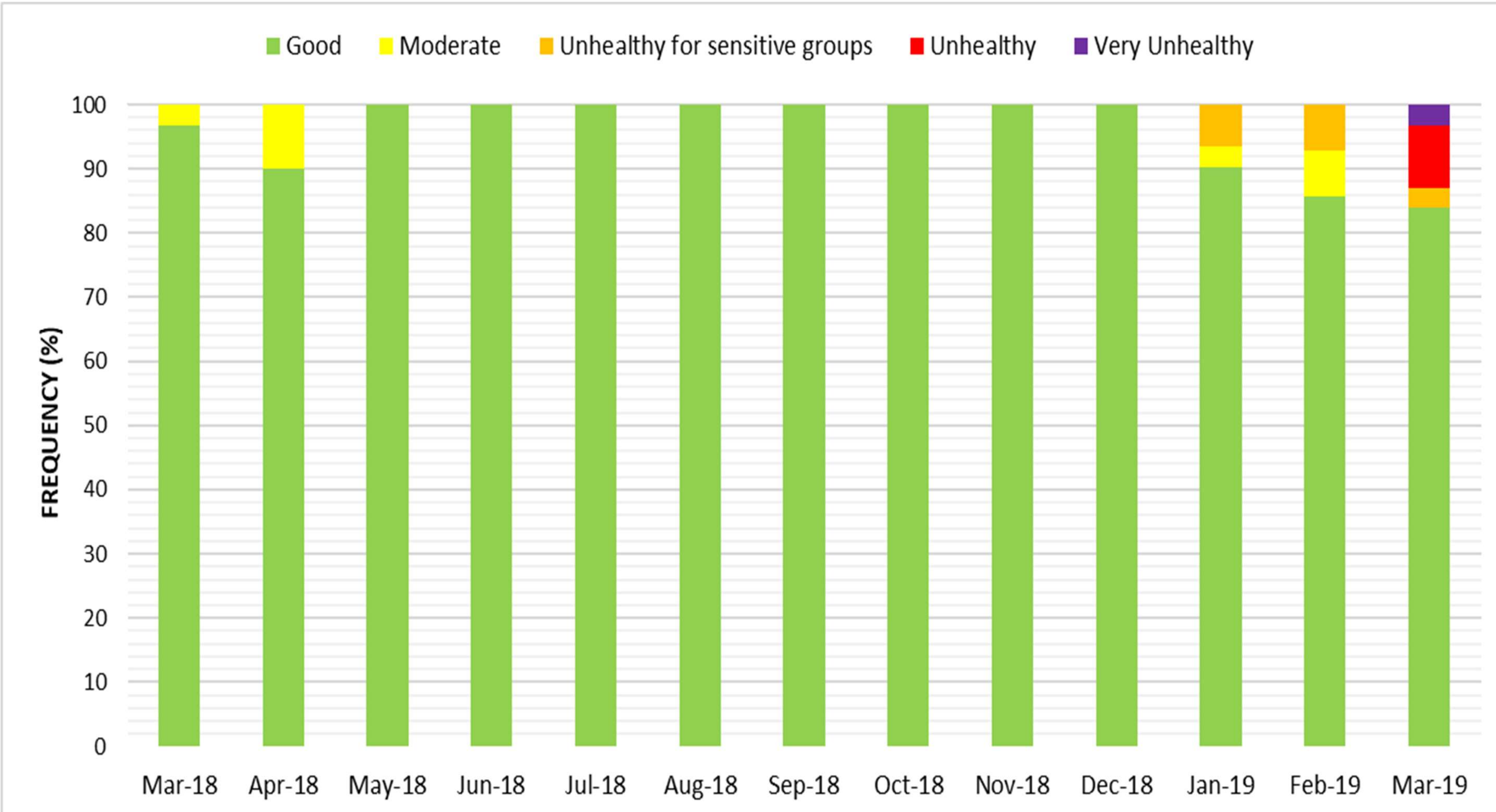

Figure 4.7: Monthly Frequencies at Kuala Pahang, Pekan

Figure 4.7 shows monthly frequencies of API categories, including good, moderate, unhealthy for sensitive groups, unhealthy and very unhealthy – which change over the 13 months. Each month from March 2018 to March 2019 shows a high frequency of API at good and moderate levels where the API value is in the range 0-100, which falls within the good (0-50) and moderate (51-100) categories. However, API at the levels of unhealthy for sensitive groups, unhealthy and very unhealthy as well as information absent also is present in those months. The API from May 2018 till December 2018 achieve 100% at good levels whereas the other months are at least 83% and above. This indicates that the overall air quality at Kuala Pahang, Pekan is quite healthy. Moderate levels have 3.2% in March 2018, 3.2% in January 2019 and 7.1% in February 2019. From January 2019 to March 2019, the unhealthy for sensitive groups also occupy 6.5%, 3.2% and 7.1% respectively. Lastly, the most critical part which is the very unhealthy level happens to cover 3.2% which occurs during March 2019. This is due to the haze episode and prolonged dry weather mentioned earlier, where the air monitoring station at Kuala Pahang, Pekan experienced a high level of API. The air quality should always be monitored precisely to protect human health and the surrounding environment. The haze episodes often cause numerous health problems and also affect daily activities. There was once when the air quality is too worse that the government of Malaysia had to declare a state of emergency in June 2013 due to the worst haze levels in 16 years (Mabahwi, 2015). The thick smoke from the haze blanketed Peninsular Malaysia and reduced visibility nationwide. In October 2010 some areas in Johor reached very unhealthy levels due to land and forest fires in Riau Province in Central Sumatera, Indonesia (DOE, 2010). However, some information was absent in the 13 months. The absent data was forecasted. Absent information is very important as each concentration of pollutants present might affect people as well as the environment. The absence of information might be due to equipment failure and human error.

CHAPTER 5

CONCLUSION

5.1 Introduction

The purpose of this study was to monitor air pollutant index (API) at a peat swamp area towards using real time air monitoring via Aeroqual. The air pollution assessments have also been discussed in the previous topics. The five main pollutants concentrations responsible for the API value have also been investigated in the previous section. It has been successfully performed in satisfying the three objectives that had been outlined in Chapter 1 of this study. This chapter reports the conclusions and recommendations that resulted from this study for further research.

5.2 Conclusion

API value reading is vital for determining the status of air quality on that particular day. The worst quality of air can harm human health, the environment, and also economic development. From the API reading obtained, the government can take action to reduce the worst air quality by taking suitable pollution control strategies. This Aeroqual AQM 65 is the first in Malaysia to be located in a peat swamp area nearby Kuala Pahang, Pekan. This is important because in the conventional method, the operation and maintenance fees are higher. By using this AQM 65, it makes life simpler and more convenient.

The main finding of results is to monitor the air pollutant index at the peat swamp area using real time air monitoring. Other than that, the air pollution assessments are determined and the five major pollutant concentrations are also investigated. Below are a few points that are concluded in this thesis. The five major pollutants contributing to API value does not exceed their particular limit value at Kuala Pahang, Pekan. This can be seen through their highest value and also from each of the graphs. The overall quality in Kuala Pahang, Pekan is quite healthy as the frequencies are mostly in the range 83% to 100%. There was only once throughout the 13 months where the API achieve the very unhealthy level with 235.2 which occurred on the 3rd March 2019.

As the climate and global warming worsens day by day, it might be crucial to be able to understand the air quality status more precisely and quickly especially in a peat swamp area. The peat swamp area often releases air pollutants that contributes to air pollution particularly during hot season. Aeroqual AQM 65 not only cost saving, but also needs less manpower and at the same time produces high accuracy data. The ease to export data and analyse the data through online software makes everything easier.

5.3 Recommendations

Air pollution control strategies need to be achieved to reduce air pollution. Some considerations in designing an effective air quality control strategy include the environmental and economic factors. Implementation of measures that control the sources of pollution. Compliance and enforcement programs are also very important to include. These programs help owners or operators of sources understand the importance, as well as the actions that environmental authorities can take if the sources do not comply.

Peatlands are recognized throughout the world as a vital economic and ecological resource, though until recently they have received little attention from the international conservation community. Peatlands are ecosystems contributing to biological diversity, the global water cycle, global carbon storage relevant to climate change, and other wetland functions valuable to human communities. However, peatlands globally have been identified as a major storehouse of the world's carbon, exceeding that of forests. This is why it is crucial to manage the peatlands properly. The UN Food and Agriculture Organization (FAO) has presented 10 strategic actions that can ensure peatlands contribute their full potential to global agreements such as the Paris Agreement on climate change and Sustainable Development Goals. These include:

i. assessing the distribution and state of peatlands

ii. measuring and reporting emissions from peatlands
iii. protecting and restoring peatlands with targeted financial support
iv. stimulating market-based mechanisms to support peatlands
v. engaging and supporting local communities
vi. sharing experience and expertise on peatland conservation, restoration and improved management.

Everyone has the responsibility to preserve the environment as the pollutants are mostly created by human beings. Involving the public may be the best and most effective way. Encouraging the participation of the regulated community and others, including the general public should be done when developing the control strategy. This early consultation reduces later challenges and can help streamline implementation.

Governments getting starting in managing air quality should focus first on obvious sources of air pollution and the quickest means of controlling air emissions. More sophisticated and comprehensive strategies can be developed over time. The goal for all control strategies is to achieve real and measurable air emission reductions.

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APPENDIX A
DATA EXPORT FROM AQM 65 (MARCH 2018)

Date	CO (ppm)	NO2 (ppm)	O3 (ppm)	SO2 (ppm)	PM1 (µg/m³)	PM2.5 (µg/m³)	PM10 (µg/m³)	TSP (µg/m³)	MFC S (mL/min)	MFM Z (mL/min)	ITEMP (°C)	TEMP (°C)	RH (%)
1/3/2018	0.178	0.009	0.036	0.002	2.69	3.06	3.17	3.24	0	0	30.1	30.28	73.7
2/3/2018	0.175	0.008	0.032	0.002	1.62	1.86	1.94	1.98	0	0	30	29.53	77.1
3/3/2018	0.147	0.007	0.033	0.002	1.27	1.44	1.5	1.51	0	0	30.1	30.41	73.6
4/3/2018	0.178	0.007	0.028	0.001	1.8	2.04	2.13	2.17	0	0	30	30.18	74.3
5/3/2018	0.12	0.004	0.029	0.002	1.37	1.52	1.57	1.6	0	0	30.1	30.68	71.8
6/3/2018	0.195	0.006	0.03	0.002	2.11	2.33	2.42	2.5	0	0	30	30.03	74.2
7/3/2018	0.223	0.007	0.032	0.002	1.57	1.82	1.92	1.96	0	0	30	28.98	78.9
8/3/2018	0.188	0.006	0.03	0.002	2.01	2.47	2.66	2.72	0	0	30	29.32	76.8
9/3/2018	0.16	0.006	0.033	0.001	3.03	3.5	3.62	3.66	0	0	30	30.36	72.5
10/3/2018	0.156	0.008	0.038	0.002	4.97	5.77	5.98	6.06	0	0	30	30.35	71
11/3/2018	0.204	0.018	0.052	0.001	6.74	7.64	7.86	7.93	0	0	30	30.17	72
12/3/2018	0.206	0.015	0.047	0.002	6.23	7.08	7.26	7.31	0	0	30	30.08	73
13/3/2018	0.217	0.013	0.039	0.001	4.9	5.61	5.79	5.87	0	0	30	28.51	79.3
14/3/2018	0.244	0.01	0.032	0.002	3.75	4.29	4.45	4.49	0	0	30	29.82	74
15/3/2018	0.287	0.008	0.029	0.002	3.89	4.33	4.46	4.48	0	0	30	29.47	75.9

16/3/2018	0.265	0.007	0.032	0.001	2.89	3.21	3.3	3.36	0	0	30	30.01	75.2
17/3/2018	0.182	0.006	0.032	0.002	2.07	2.27	2.32	2.34	0	0	30.1	30.84	70.8
18/3/2018	0.17	0.009	0.035	0.001	1.89	2.11	2.18	2.21	0	0	30	30.46	72.8
19/3/2018	0.157	0.009	0.033	0.002	2.49	2.78	2.87	2.92	0	0	30	30.48	72.2
20/3/2018	0.136	0.011	0.033	0.002	3.01	3.25	3.34	3.39	0	0	30.1	30.75	70.6
21/3/2018	0.24	0.006	0.029	0.002	4.25	4.52	4.63	4.69	0	0	30	30.4	72.2
22/3/2018	0.113	0.007	0.035	0.002	1.79	2.05	2.14	2.18	0	0	30.1	30.9	69.9
23/3/2018	0.124	0.01	0.037	0.002	2.17	2.49	2.6	2.64	0	0	30	30.58	69.2
24/3/2018	0.284	0.01	0.039	0.002	6.13	6.94	7.19	7.25	0	0	30	29.94	72.6
25/3/2018	0.226	0.015	0.041	0.002	4.87	5.71	5.91	5.96	0	0	30.1	30.22	73.9
26/3/2018	0.195	0.018	0.038	0.001	2.86	3.21	3.31	3.4	0	0	30	29.8	75.1
27/3/2018	0.244	0.024	0.04	0.002	2.99	3.48	3.62	3.65	0	0	30	30.41	72.9
28/3/2018	0.265	0.021	0.038	0.002	4.23	4.9	5.08	5.13	0	0	30	29.71	74.8
29/3/2018	0.26	0.017	0.035	0.002	4.04	4.62	4.78	4.83	0	0	30.1	30.39	72.5
30/3/2018	0.286	0.017	0.039	0.002	4.7	5.14	5.24	5.3	0	0	30.1	30.63	73.9
31/3/2018	0.3	0.03	0.043	0.002	5.55	6.01	6.18	6.28	0	0	30.1	30.31	73.8

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APPENDIX B
DATA EXPORT FROM AQM 65 (APRIL 2018)

Date	CO (ppm)	NO2 (ppm)	O3 (ppm)	SO2 (ppm)	PM1 (µg/m³)	PM2.5 (µg/m³)	PM10 (µg/m³)	TSP (µg/m³)	MFC S (mL/min)	MFM Z (mL/min)	ITEMP (°C)	TEMP (°C)	RH (%)
1/4/2018	0.332	0.079	0.054	0.002	7.23	7.76	7.92	7.99	0	0	30.1	30.26	74.3
2/4/2018	0.291	0.069	0.048	0.002	5.65	6.31	6.51	6.59	0	0	30	30.3	72.6
3/4/2018	0.242	0.106	0.052	0.002	4.65	5.22	5.4	5.51	0	0	30	30.68	68.8
4/4/2018	0.213	0.096	0.048	0.002	3.33	3.74	3.87	3.94	0	0	30	30.5	68.7
5/4/2018	0.272	0.028	0.039	0.001	4.57	4.95	5.07	5.15	0	0	30	30.19	71.8
6/4/2018	0.243	0.035	0.042	0.002	4.49	4.82	4.93	4.99	0	0	30	30.1	72.7
7/4/2018	0.204	0.059	0.045	0.002	3.23	3.5	3.59	3.66	0	0	30	30.34	69.5
8/4/2018	0.186	0.047	0.04	0.001	4.5	5.01	5.16	5.26	0	0	30	30.14	72.6
9/4/2018	0.19	0.045	0.044	0.002	4.41	5.02	5.17	5.25	0	0	30.1	30.68	72.3
10/4/2018	0.216	0.028	0.037	0.002	3.09	3.52	3.66	3.74	0	0	30.1	30.62	72.5
11/4/2018	0.238	0.013	0.03	0.002	3.49	3.88	4.01	4.08	0	0	30.1	30.77	72.2
12/4/2018	0.221	0.005	0.03	0.001	2.99	3.32	3.42	3.47	0	0	30.1	30.47	75.1
13/4/2018	0.107	0.005	0.032	0.001	1.98	2.24	2.32	2.36	0	0	30.1	31.19	73.5
14/4/2018	0.081	0.006	0.029	0.001	1.23	1.42	1.51	1.58	0	0	30	29.77	77.7
15/4/2018	0.138	0.008	0.032	0.001	1.81	2.09	2.2	2.24	0	0	30.1	30.98	73

16/4/2018	0.192	0.008	0.024	0.001	1.59	1.84	1.92	1.96	0	0	30	28.92	78.8
17/4/2018	0.181	0.005	0.018	0.001	2.05	2.43	2.57	2.61	0	0	30.1	29.64	77.7
18/4/2018	0.114	0.007	0.026	0.001	1.84	2.11	2.19	2.22	0	0	30.1	30.9	73.4
19/4/2018	0.192	0.008	0.017	0.001	2.01	2.43	2.6	2.66	0	0	30	29.55	77.5
20/4/2018	0.141	0.012	0.021	0.001	1.85	2.15	2.26	2.31	0	0	30	29.65	78.2
21/4/2018	0.108	0.009	0.018	0.001	1.89	2.25	2.39	2.43	0	0	30.1	29.97	76
22/4/2018	0.07	0.007	0.023	0.001	1.86	2.07	2.14	2.18	0	0	30.1	32.67	68.2
23/4/2018	0.115	0.011	0.012	0.001	2.89	3.23	3.36	3.37	0	0	30	27.9	81.1
24/4/2018	0.194	0.016	0.025	0.001	3.26	3.79	4.1	4.26	0	0	30	29.73	77.6
25/4/2018	0.196	0.068	0.037	0.001	5.03	5.5	5.76	5.91	0	0	30.1	30.7	76.6
26/4/2018	0.202	0.024	0.026	0.001	2.59	2.97	3.24	3.34	0	0	30	30.02	75.5
27/4/2018	0.206	0.018	0.019	0.001	1.86	2.18	2.31	2.35	0	0	30	29.39	78.8
28/4/2018	0.143	0.018	0.022	0.001	2.04	2.29	2.4	2.45	0	0	30.1	30.89	73.2
29/4/2018	0.121	0.012	0.02	0.001	2.79	3.02	3.11	3.17	0	0	30.1	31.13	74.6
30/4/2018	0.129	0.014	0.019	0.001	2.89	3.34	3.6	3.68	0	0	30	29.3	80.1

APPENDIX C
DATA EXPORT FROM AQM 65 (MAY 2018)

Date	CO (ppm)	NO2 (ppm)	O3 (ppm)	SO2 (ppm)	PM1 (µg/m³)	PM2.5 (µg/m³)	PM10 (µg/m³)	TSP (µg/m³)	MFC S (mL/min)	MFM Z (mL/min)	ITEM P (°C)	TEMP (°C)	RH (%)
1/5/2018	0.102	0.009	0.018	0.001	2.34	2.72	2.99	3.09	0	0	30	29.41	77
2/5/2018	0.055	0.015	0.022	0.001	1.35	1.67	1.86	1.92	0	0	30	30.26	72.8
3/5/2018	0.103	0.01	0.017	0.001	1.57	1.78	1.98	2.13	0	0	30.3	30.2	75.4
4/5/2018	0.188	0.01	0.018	0.001	1.61	1.85	1.95	2.01	0	0	30	31.1	73.3
5/5/2018	0.204	0.008	0.016	0.001	2.53	2.8	2.92	3.03	0	0	30	29.64	78.1
6/5/2018	0.205	0.007	0.021	0.001	3.19	3.46	3.59	3.7	0	0	30.1	30.82	74.2
7/5/2018	0.126	0.002	0.016	0.001	2.86	3.19	3.33	3.42	0	0	30.1	31.02	72.2
8/5/2018	0.203	0.004	0.015	0	3.33	3.63	3.81	3.92	0	0	30.1	30.46	76.1
9/5/2018	0.176	0.001	0.006	0	2.89	3.16	3.27	3.34	0	0	30.1	31.28	73.8
10/5/2018	0.128	0.001	0.012	0	1.68	1.85	1.93	1.97	0	0	30.1	31.33	72.9
11/5/2018	0.137	0.001	0.015	0	1.63	1.76	1.83	1.87	0	0	30	31.27	71.3
12/5/2018	0.173	0.002	0.02	0	1.86	2	2.07	2.12	0	0	30.1	31.29	72.2
13/5/2018	0.415	0	0.024	0.001	8.33	8.59	8.73	8.88	0	0	30	30.69	72.7
14/5/2018	0.471	0	0.033	0.001	9.14	9.49	9.63	9.73	0	0	30	30.66	73.7
15/5/2018	0.445	0.001	0.025	0	7.14	7.51	7.72	7.88	0	0	30	29.84	78.2

16/5/2018	0.278	0.001	0.026	0	4.11	4.5	4.69	4.85	0	0	30.1	30.5	75.2
17/5/2018	0.356	0.002	0.028	0.001	5.37	5.74	5.96	6.13	0	0	30	29.82	76.7
18/5/2018	0.364	0.001	0.016	0	6.35	6.67	6.81	6.89	0	0	30.1	30.75	74.5
19/5/2018	0.268	0.001	0.015	0	4.25	4.55	4.68	4.79	0	0	30.1	30.83	73.6
20/5/2018	0.27	0.002	0.018	0	3.83	4.11	4.26	4.35	0	0	30	29.1	79.1
21/5/2018	0.471	0.002	0.013	0	7.58	7.9	8.03	8.12	0	0	30.1	30.64	75.1
22/5/2018	0.386	0.002	0.016	0	7.11	7.42	7.56	7.67	0	0	30	30.03	77.8
23/5/2018	0.281	0.002	0.015	0	4.2	4.51	4.71	4.83	0	0	30	29.77	77.8
24/5/2018	0.166	0.002	0.012	0	2.11	2.4	2.57	2.63	0	0	30	30.34	75.2
25/5/2018	0.251	0.003	0.014	0	4.31	4.58	4.71	4.81	0	0	30	30.51	75.8
26/5/2018	0.331	0.002	0.013	0	6.13	6.43	6.56	6.66	0	0	30	29.46	79
27/5/2018	0.222	0.003	0.01	0	2.3	2.65	2.84	2.92	0	0	30	28.86	80.7
28/5/2018	0.254	0.003	0.016	0	2.27	2.6	2.74	2.8	0	0	30	29.61	78.3
29/5/2018	0.189	0.003	0.017	0	2.87	3.21	3.35	3.4	0	0	30	30.45	77
30/5/2018	0.153	0.003	0.018	0	1.53	1.78	1.94	2.05	0	0	30	28.04	82.6
31/5/2018	0.158	0.003	0.02	0	1.98	2.49	2.77	2.88	0	0	30	28.96	79.5

APPENDIX D
DATA EXPORT FROM AQM 65 (JUNE 2018)

Date	CO (ppm)	NO2 (ppm)	O3 (ppm)	SO2 (ppm)	PM1 (µg/m³)	PM2.5 (µg/m³)	PM10 (µg/m³)	TSP (µg/m³)	MFC S (mL/min)	MFM Z (mL/min)	ITEMP (°C)	TEMP (°C)	RH (%)
1/6/2018	0.125	0.002	0.023	0	1.64	2.12	2.4	2.49	0	0	30	29.55	76.8
2/6/2018	0.205	0.005	0.015	0.001	0.94	1.37	1.61	1.69	0	0	30	28.78	79.9
3/6/2018	0.206	0.003	0.017	0	2.76	3.23	3.43	3.51	0	0	30.1	30.76	76.2
4/6/2018	0.131	0.003	0.013	0	3.44	3.8	3.96	4.08	0	0	30.1	30.97	76
5/6/2018	0.165	0.004	0.012	0	3.41	3.91	4.15	4.32	0	0	30.1	30.98	75.2
6/6/2018	0.197	0.004	0.01	0	4.84	5.23	5.43	5.56	0	0	30.1	30.59	76.9
7/6/2018	0.192	0.005	0.016	0	5.98	6.34	6.52	6.64	0	0	30.1	30.55	78.9
8/6/2018	0.28	0.004	0.018	0	8.08	8.54	8.84	9	0	0	30	29.38	80.1
9/6/2018	0.239	0.004	0.024	0	4.49	4.97	5.25	5.48	0	0	30	29.74	76.1
10/6/2018	0.262	0.004	0.026	0	9.52	9.96	10.21	10.43	0	0	30.1	30.77	76.6
11/6/2018	0.284	0.007	0.028	0	8.55	9	9.36	9.54	0	0	30	29.2	79.9
12/6/2018	0.357	0.007	0.033	0	8.78	9.33	9.65	9.83	0	0	30	29.77	76.7
13/6/2018	0.234	0.007	0.036	0	5.29	5.75	6.02	6.18	0	0	30.1	30.28	74.1
14/6/2018	0.153	0.005	0.037	0	2.61	2.9	3.07	3.22	0	0	30.1	30.39	73.8
15/6/2018	0.198	0.004	0.034	0	3.76	4.03	4.22	4.47	0	0	30	30.39	73.3

16/6/2018	0.255	0.006	0.03	0	4.86	5.19	5.39	5.52	0	0	30	29.41	77.7
17/6/2018	0.375	0.006	0.028	0	5.79	6.16	6.33	6.44	0	0	30	28.69	80.2
18/6/2018	0.285	0.006	0.029	0	5.13	5.51	5.71	5.88	0	0	30	29.38	78.5
19/6/2018	0.182	0.005	0.024	0	4.02	4.36	4.54	4.69	0	0	30	30.01	75.8
20/6/2018	0.171	0.007	0.025	0	3.38	3.72	3.92	4.11	0	0	30	30.23	74.4
21/6/2018	0.15	0.007	0.023	0	2.89	3.15	3.33	3.44	0	0	30	29.43	76.9
22/6/2018	0.095	0.006	0.02	0	1.56	1.75	1.89	1.99	0	0	30	30.96	71.2
23/6/2018	0.129	0.006	0.016	0	2.13	2.4	2.62	2.72	0	0	30	28.34	79.1
24/6/2018	0.112	0.005	0.016	0	1.13	1.45	1.67	1.8	0	0	30	28.54	77.4
25/6/2018	0.124	0.007	0.015	0	1.15	1.46	1.63	1.73	0	0	30	28.41	78.4
26/6/2018	0.175	0.009	0.023	0	2.23	2.7	2.91	2.98	0	0	30	27.17	82.9
27/6/2018	0.191	0.007	0.025	0	2.77	3.2	3.44	3.58	0	0	30	28.91	77.3
28/6/2018	0.15	0.005	0.026	0	1.81	2.13	2.31	2.46	0	0	30	30.03	73.5
29/6/2018	0.149	0.011	0.027	0	1.56	1.93	2.17	2.25	0	0	30	27.01	83.4
30/6/2018	0.156	0.007	0.026	0	2.14	2.63	2.87	3.01	0	0	30	28.3	79.3

APPENDIX E
DATA EXPORT FROM AQM 65 (JULY 2018)

Date	CO (ppm)	NO2 (ppm)	O3 (ppm)	SO2 (ppm)	PM1 (µg/m³)	PM2.5 (µg/m³)	PM10 (µg/m³)	TSP (µg/m³)	MFC S (mL/min)	MFM Z (mL/min)	ITEMP (°C)	TEMP (°C)	RH (%)
1/7/2018	0.124	0.006	0.036	0	2.01	2.36	2.54	2.69	0	0	30	29.56	76.4
2/7/2018	0.175	0.01	0.028	0	2.13	2.6	2.9	3	0	0	30	27.91	81.9
3/7/2018	0.169	0.011	0.026	0	2.66	3.27	3.64	3.78	0	0	30	27.73	82.4
4/7/2018	0.162	0.008	0.02	0	2.08	2.76	3.1	3.23	0	0	30	28.85	77.7
5/7/2018	0.147	0.007	0.023	0	2.87	3.46	3.78	3.96	0	0	30	29.46	76.9
6/7/2018	0.184	0.009	0.024	0	5.82	6.29	6.56	6.76	0	0	30	29.59	77.4
7/7/2018	0.127	0.007	0.017	0	3.99	4.43	4.63	4.77	0	0	30	30.03	76
8/7/2018	0.179	0.008	0.016	0	5.43	5.83	6.03	6.19	0	0	30	29.95	76.2
9/7/2018	0.225	0.009	0.025	0	5.59	6	6.23	6.42	0	0	30	28.8	79.8
10/7/2018	0.239	0.006	0.024	0	5.65	6.01	6.22	6.4	0	0	30	29.94	75.4
11/7/2018	0.157	0.009	0.02	0	3.47	3.84	4.09	4.29	0	0	30	28.99	78.6
12/7/2018	0.165	0.008	0.018	0	3.77	4.14	4.36	4.57	0	0	30	29.65	79.2
13/7/2018	0.259	0.006	0.014	0	8.38	8.8	9	9.25	0	0	30.1	30.07	79.1
14/7/2018	0.458	0.005	0.015	0	12.47	12.92	13.2	13.62	0	0	30	30.27	75.3
15/7/2018	1.536	0.002	0.016	0.001	23.92	24.74	25.13	26.01	0	0	30	30.35	70.7

16/7/2018	0.935	0.003	0.019	0	20.52	21.11	21.37	21.77	0	0	30	30.13	75.8
17/7/2018	0.954	0.003	0.033	0.001	21.25	21.84	22.13	22.51	0	0	30	29.9	77.8
18/7/2018	1.009	0.003	0.038	0	18.74	19.36	19.68	20.08	0	0	30	29.83	78.6
19/7/2018	1.263	0.002	0.039	0	22.13	22.76	23.03	23.47	0	0	30	30.56	75.9
20/7/2018	0.409	0.003	0.045	0	9.98	10.34	10.54	10.78	0	0	30	30.65	75.4
21/7/2018	0.224	0.005	0.046	0	6.45	6.85	7.04	7.21	0	0	30	30.24	76.6
22/7/2018	0.567	0.003	0.038	0	12.98	13.41	13.64	14	0	0	30	30.69	73.6
23/7/2018	0.367	0.004	0.036	0	8.97	9.33	9.64	9.97	0	0	30	28.86	77.7
24/7/2018	0.288	0.005	0.033	0	6.82	7.19	7.41	7.55	0	0	30	28.99	79
25/7/2018	0.314	0.005	0.028	0	7.2	7.55	7.74	7.89	0	0	30	29.69	78.3
26/7/2018	0.226	0.005	0.02	0	5	5.28	5.43	5.58	0	0	30	30.01	73.5
27/7/2018	0.375	0.004	0.019	0	8.41	8.77	8.91	9.04	0	0	30	30.79	73.9
28/7/2018	0.217	0.007	0.016	0	4.92	5.24	5.45	5.56	0	0	30	28.93	78.2
29/7/2018	0.266	0.007	0.019	0	7.15	7.53	7.75	7.91	0	0	30	29.09	79.3
30/7/2018	0.174	0.005	0.02	0	3.24	3.53	3.71	3.88	0	0	30	30.22	75.4
31/7/2018	0.111	0.006	0.025	0	1.67	1.92	2.1	2.2	0	0	30	29.38	77.3

APPENDIX F
DATA EXPORT FROM AQM 65 (AUGUST 2018)

Date	CO (ppm)	NO2 (ppm)	O3 (ppm)	SO2 (ppm)	PM1 (µg/m³)	PM2.5 (µg/m³)	PM10 (µg/m³)	TSP (µg/m³)	MFC S (mL/min)	MFM Z (mL/min)	ITEMP (°C)	TEMP (°C)	RH (%)
1/8/2018	0.181	0.006	0	0	2.89	3.23	3.43	3.57	0	0	30	26.67	82.1
2/8/2018	0.166	0.004	0	0	4.33	4.81	5.06	5.23	0	0	30	29.06	77
3/8/2018	0.124	0.006	0	0	4.3	4.62	4.77	4.9	0	0	30	30.23	75.5
4/8/2018	0.191	0.004	0	0	7.77	8.15	8.32	8.47	0	0	30	30.47	76.3
5/8/2018	0.163	0.006	0	0	6.61	7	7.19	7.37	0	0	30	30.23	76.9
6/8/2018	0.256	0.006	0	0	8.8	9.23	9.44	9.62	0	0	30	29.47	79.5
7/8/2018	0.204	0.008	0	0	5.64	6.13	6.47	6.62	0	0	30	28.55	79.8
8/8/2018	0.194	0.008	0	0	4.67	5.08	5.31	5.47	0	0	30	28.44	79.2
9/8/2018	0.213	0.005	0	0	6.14	6.56	6.8	6.99	0	0	30	29.15	78.5
10/8/2018	0.201	0.005	0	0	6.13	6.5	6.71	6.9	0	0	30	29.4	77.8
11/8/2018	0.429	0.005	0	0.001	11.37	11.8	12	12.21	0	0	30	30.12	77.7
12/8/2018	1.444	0.003	0	0.001	28.91	29.63	29.93	30.43	0	0	30	30.09	73.3
13/8/2018	2.009	0.003	0	0	31.34	32.1	32.34	32.69	0	0	30	29.84	76.4
14/8/2018	1.38	0.002	0	0	25.96	26.64	26.86	27.1	0	0	30	30.02	77.8
15/8/2018	2.541	0.003	0.014	0	36	36.91	37.15	37.43	0	0	30	29.84	77.5

16/8/2018	0.57	0.003	0.027	0	12.43	12.85	13.05	13.22	0	0	30	30.11	77
17/8/2018	0.306	0.005	0.025	0	8.23	8.63	8.85	8.98	0	0	30	29.36	79.1
18/8/2018	0.277	0.004	0.026	0	8.61	9.01	9.18	9.35	0	0	30	29.76	78.1
19/8/2018	0.159	0.005	0.024	0	7.04	7.42	7.59	7.7	0	0	30	29.64	78.5
20/8/2018	0.158	0.004	0.023	0	4.67	4.99	5.13	5.23	0	0	30	29.99	75.9
21/8/2018	0.175	0.006	0.018	0	5.31	5.64	5.8	5.92	0	0	30	29.98	76
22/8/2018	0.198	0.004	0.028	0	5.16	5.46	5.62	5.76	0	0	30	29.73	75.5
23/8/2018	0.235	0.004	0.024	0	5.99	6.26	6.39	6.57	0	0	30	30.88	71.8
24/8/2018	0.191	0.005	0.022	0.001	5.61	5.9	6.07	6.35	0	0	30	30.42	72.5
25/8/2018	0.275	0.004	0.016	0	6.79	7.04	7.18	7.34	0	0	30	30.41	72.6
26/8/2018	0.484	0.003	0.019	0	9.88	10.17	10.3	10.44	0	0	30	30.09	75.2
27/8/2018	0.261	0.005	0.021	0	6.89	7.14	7.27	7.43	0	0	30	30	76.5
28/8/2018	0.343	0.005	0.021	0	7.47	7.77	7.92	8.04	0	0	30	29.63	75
29/8/2018	0.185	0.008	0.023	0	4.33	4.55	4.72	4.84	0	0	30	29.05	76.4
30/8/2018	0.125	0.008	0.026	0	3.19	3.43	3.57	3.65	0	0	30	29.53	73.8
31/8/2018	0.244	0.007	0.023	0	5.65	5.91	6.02	6.1	0	0	30	29.8	75.9

APPENDIX G
DATA EXPORT FROM AQM 65 (SEPTEMBER 2018)

Date	CO (ppm)	NO2 (ppm)	O3 (ppm)	SO2 (ppm)	PM1 (µg/m³)	PM2.5 (µg/m³)	PM10 (µg/m³)	TSP (µg/m³)	MFC S (mL/min)	MFM Z (mL/min)	ITEMP (°C)	TEMP (°C)	RH (%)
1/9/2018	0.124	0.007	0.019	0	2.77	2.99	3.11	3.24	0	0	30	29.78	74.2
2/9/2018	0.148	0.01	0.022	0	3.04	3.27	3.4	3.54	0	0	30	29.43	74
3/9/2018	0.154	0.009	0.021	0	4.08	4.33	4.48	4.59	0	0	30	29.36	74
4/9/2018	0.208	0.008	0.027	0	4.09	4.32	4.48	4.7	0	0	30	29.39	73.7
5/9/2018	0.191	0.007	0.02	0	3.3	3.52	3.65	3.77	0	0	30	29.57	75.5
6/9/2018	1.182	0.002	0.023	0	19	19.49	19.65	19.8	0	0	30	27.99	78.2
7/9/2018	0.395	0.005	0.025	0	6.67	7	7.17	7.32	0	0	30	28.4	78.5
8/9/2018	0.371	0.005	0.021	0	5.67	6	6.19	6.32	0	0	30	28.79	77.5
9/9/2018	0.199	0.006	0.016	0	3.4	3.67	3.82	3.94	0	0	30	27.73	80.3
10/9/2018	0.177	0.005	0.017	0	3.5	3.8	3.97	4.11	0	0	30	28.9	76.2
11/9/2018	0.184	0.005	0.011	0	4.25	4.55	4.72	4.84	0	0	30	29.01	75.3
12/9/2018	0.409	0.002	0.014	0.001	9.67	12.22	13.95	14.38	0	0	30	28.52	76.2
13/9/2018	0.408	0.002	0.02	0.001	19.28	22.68	24.28	24.71	0	0	30.1	29.7	76.9
14/9/2018	0.385	0.002	0.024	0.001	11.48	13.91	15.92	16.42	0	0	30	28.32	78.7
15/9/2018	0.399	0.001	0.017	0.001	10.88	13.25	15.13	15.81	0	0	30	28.08	79.5

16/9/2018	0.403	0.001	0.018	0.001	9.78	11.73	13.18	13.63	0	0	30	29.91	74.5
17/9/2018	0.334	0.001	0.023	0.001	8.21	10.44	11.59	11.95	0	0	30.1	29.98	73.3
18/9/2018	0.322	0.001	0.015	0.001	3.53	5.06	6.23	6.48	0	0	30	28.04	79.9
19/9/2018	0.035	0.005	0.012	0.002	2.56	2.88	3.16	3.32	0	0.04	30.3	30.43	74
20/9/2018	0.002	0.002	0.016	0.001	1.59	2.02	2.27	2.38	0	0.02	30	28.77	76.7
21/9/2018	0.052	0.002	0.019	0	0.86	1.19	1.36	1.4	0	0	30	28.42	78.3
22/9/2018	0.005	0.001	0.03	0.001	1.93	2.25	2.4	2.49	0	0	30	28.51	79.7
23/9/2018	0.006	0.001	0.024	0	2.64	2.99	3.17	3.31	0	0	30	30.11	72.9
24/9/2018	0.002	0.002	0.026	0.001	2.7	3.05	3.25	3.44	0	0	30	30.65	73.6
25/9/2018	0.201	0.001	0.029	0.002	3.03	3.33	3.47	3.57	0	0	30	30.33	75
26/9/2018	0.283	0.004	0.027	0.002	3.44	3.71	3.84	3.94	0	0	30	29.97	75.8
27/9/2018	0.252	0.001	0.024	0.002	3.33	3.6	3.77	3.98	0	0	30	30.57	73.4
28/9/2018	0.271	0.002	0.017	0.002	4.01	4.33	4.72	5.56	0	0	30	30.78	73.9
29/9/2018	0.255	0.001	0.02	0.002	3.61	3.84	3.98	4.14	0	0	30	30.78	72.4
30/9/2018	0.309	0.001	0.022	0.002	4.73	5.03	5.19	5.33	0	0	30	30.86	73.6

APPENDIX H
DATA EXPORT FROM AQM 65 (OCTOBER 2018)

Date	CO (ppm)	NO2 (ppm)	O3 (ppm)	SO2 (ppm)	PM1 (µg/m³)	PM2.5 (µg/m³)	PM10 (µg/m³)	TSP (µg/m³)	MFC S (mL/min)	MFM Z (mL/min)	ITEMP (°C)	TEMP (°C)	RH (%)
1/10/2018	0.473	0.002	0.019	0.002	7.07	7.36	7.49	7.61	0	0	30	30.83	73.8
2/10/2018	0.48	0.002	0.02	0.002	6.68	6.93	7.06	7.21	0	0	30	30.99	72.2
3/10/2018	0.403	0.002	0.022	0.002	5.13	5.33	5.46	5.58	0	0	30	29.68	74.4
4/10/2018	0.515	0.001	0.019	0.002	8.02	8.28	8.39	8.53	0	0	30	30.2	75.4
5/10/2018	0.427	0.001	0.026	0.002	7.17	7.42	7.53	7.66	0	0	30	30.37	74.2
6/10/2018	0.437	0.006	0.037	0.002	3.55	3.74	3.85	3.9	0	0	30	29.95	77.3
7/10/2018	0.357	0.003	0.025	0.002	1.3	1.45	1.53	1.56	0	0	30	28.5	80.4
8/10/2018	0.325	0.004	0.012	0.002	1.22	1.45	1.56	1.61	0	0	30	28.86	78.6
9/10/2018	0.35	0.004	0.023	0.002	1.49	1.73	1.85	1.9	0	0	30	27.63	83.5
10/10/2018	0.304	0.004	0.018	0.001	1.46	1.75	1.9	1.94	0	0	30	28.65	80.1
11/10/2018	0.221	0.003	0.021	0	1.19	1.39	1.5	1.54	0	0	30	29.4	77.3
12/10/2018	0.1	0.003	0.017	0	0.82	1.06	1.19	1.25	0	0	30	28.98	79.2
13/10/2018	0.105	0.001	0.026	0	1.09	1.48	1.67	1.75	0	0	30	28.68	79.7
14/10/2018	0.093	0.001	0.018	0	0.57	0.79	0.92	0.97	0	0	30	27.85	79.2
15/10/2018	0.152	0.003	0.024	0	0.87	1.21	1.37	1.43	0	0	30	29.07	76.7

16/10/2018	0.125	0.003	0.032	0	1.44	1.71	1.84	1.95	0	0	30	29.67	73.6
17/10/2018	0.157	0.003	0.029	0	2.22	2.51	2.69	2.85	0	0	30	29.21	76.3
18/10/2018	0.14	0.003	0.032	0	0.96	1.13	1.24	1.3	0	0	30	27.45	80.3
19/10/2018	0.121	0.002	0.027	0	0.71	1.02	1.19	1.27	0	0	30	28.78	76.1
20/10/2018	0.133	0.003	0.029	0	0.92	1.21	1.36	1.41	0	0	30	29.42	76.7
21/10/2018	0.161	0.004	0.034	0.001	2.54	2.81	2.95	3.01	0	0	30	28.12	82.8
24/10/2018	0.045	0.006	0.014	0.003	0.86	1.05	1.24	1.34	0	0.01	30.1	29.78	73.7
25/10/2018	0.074	0.003	0.023	0	1.02	1.33	1.47	1.52	0	0	30	29.47	76.8
26/10/2018	0.035	0.002	0.017	0	1.46	1.72	1.85	1.89	0	0	30	30.3	75.7
27/10/2018	0.02	0.002	0.018	0	1.23	1.45	1.57	1.62	0	0	30	29.76	77.8
28/10/2018	0.014	0.002	0.016	0	1.15	1.4	1.57	1.61	0	0	30	30.14	75.7
29/10/2018	0.035	0.002	0.021	0	1.74	1.98	2.08	2.11	0	0	30	30.81	74.3
30/10/2018	0.045	0.002	0.033	0	2.31	2.64	2.79	2.82	0	0	30	29.03	79.9
31/10/2018	0.103	0.003	0.04	0	3.08	3.58	3.79	3.84	0	0	30	28.51	79.4

APPENDIX I
DATA EXPORT FROM AQM 65 (NOVEMBER 2018)

Date	CO (ppm)	NO2 (ppm)	O3 (ppm)	SO2 (ppm)	PM1 (µg/m³)	PM2.5 (µg/m³)	PM10 (µg/m³)	TSP (µg/m³)	MFC S (mL/min)	MFM Z (mL/min)	ITEMP (°C)	TEMP (°C)	RH (%)
1/11/2018	0.105	0.002	0.033	0	3.06	3.56	3.74	3.81	0	0	30	30.22	73.3
2/11/2018	0.348	0.006	0.031	0	1.78	2.06	2.19	2.24	0	0	30	28.46	79.6
3/11/2018	0.205	0.002	0.026	0	0.66	0.87	0.99	1.03	0	0	30	28.36	80
4/11/2018	0.124	0.003	0.019	0	1.02	1.23	1.33	1.34	0	0	30	29.34	79.5
5/11/2018	0.101	0.002	0.013	0	0.83	1.02	1.13	1.19	0	0	30	28.67	81.2
6/11/2018	0.158	0.003	0.013	0	0.8	0.99	1.08	1.11	0	0	30	27.53	82.8
7/11/2018	0.105	0.002	0.012	0	0.99	1.39	1.59	1.68	0	0	30	28.24	79.9
8/11/2018	0.038	0.001	0.015	0	0.63	0.92	1.07	1.13	0	0	30	29.72	75.8
9/11/2018	0.097	0.004	0.019	0	0.67	0.87	1.03	1.09	0	0	30	29.28	78.3
10/11/2018	0.107	0.003	0.015	0	0.84	1.09	1.22	1.25	0	0	30	29.77	77.1
11/11/2018	0.119	0.005	0.011	0	1.08	1.33	1.45	1.48	0	0	30	29.59	77
12/11/2018	0.102	0.003	0.011	0	1.02	1.24	1.36	1.41	0	0	30	29.87	76.1
13/11/2018	0.144	0.004	0.007	0	1.41	1.77	1.94	2	0	0	30	28.16	81.9
14/11/2018	0.145	0.003	0.014	0	1.32	1.61	1.74	1.78	0	0	30	29.23	78.9
15/11/2018	0.26	0.005	0.013	0	1.24	1.49	1.65	1.71	0	0	30	29.12	79.8

16/11/2018	0.154	0.003	0.015	0	1	1.25	1.37	1.43	0	0	30	29.8	76.5
17/11/2018	0.188	0.005	0.013	0	1.76	2.02	2.17	2.22	0	0	30	28.98	80.1
18/11/2018	0.168	0.003	0.014	0	1.89	2.2	2.41	2.49	0	0	30	28.08	80.2
19/11/2018	0.181	0.004	0.012	0	1.68	1.97	2.13	2.21	0	0	30	29.18	78.1
20/11/2018	0.195	0.007	0.019	0	1.69	1.95	2.1	2.16	0	0	30	28.39	81.1
21/11/2018	0.259	0.005	0.011	0	1.29	1.63	1.82	1.88	0	0	30	25.47	87.9
23/11/2018	0.005	0.005	0.02	0.002	1.13	1.3	1.37	1.44	0	0.01	30.1	32.09	67.7
24/11/2018	0.096	0.005	0.019	0	1.75	2.02	2.17	2.25	0	0	30	30.4	72.1
25/11/2018	0.152	0.005	0.021	0	1.59	1.91	2.11	2.18	0	0	30	29.22	78.3
26/11/2018	0.139	0.004	0.02	0	1.16	1.47	1.65	1.71	0	0	30	29.4	77.1
27/11/2018	0.167	0.003	0.018	0	1.49	1.73	1.84	1.88	0	0	30	28.33	82.4
28/11/2018	0.187	0.004	0.016	0	1.06	1.28	1.41	1.45	0	0	30	27.72	84.1
29/11/2018	0.123	0.004	0.012	0	1.17	1.47	1.61	1.66	0	0	30	29.24	79.4
30/11/2018	0.134	0.006	0.012	0	1.19	1.48	1.63	1.67	0	0	30	27.73	83.3

APPENDIX J
DATA EXPORT FROM AQM 65 (DECEMBER 2018)

Date	CO (ppm)	NO2 (ppm)	O3 (ppm)	SO2 (ppm)	PM1 (µg/m³)	PM2.5 (µg/m³)	PM10 (µg/m³)	TSP (µg/m³)	MFC S (mL/min)	MFM Z (mL/min)	ITEMP (°C)	TEMP (°C)	RH (%)
1/12/2018	0.103	0.004	0.009	0	1.12	1.42	1.57	1.59	0	0	30	26.49	87.2
2/12/2018	0.144	0.005	0.009	0	1.02	1.29	1.44	1.48	0	0	30	26.11	86.5
3/12/2018	0.15	0.005	0.009	0	1.2	1.56	1.74	1.79	0	0	30	27.5	84.6
4/12/2018	0.121	0.004	0.012	0	0.97	1.2	1.33	1.34	0	0	30	29.57	79.3
5/12/2018	0.168	0.005	0.013	0	0.76	0.94	1.04	1.07	0	0	30	28.71	81.1
6/12/2018	0.117	0.004	0.011	0	0.98	1.21	1.32	1.35	0	0	30	29.17	79.7
7/12/2018	0.108	0.005	0.01	0	0.77	1	1.1	1.12	0	0	30	27.94	82.5
8/12/2018	0.084	0.003	0.01	0	0.63	0.92	1.05	1.07	0	0	30	29.15	78.6
9/12/2018	0.102	0.003	0.01	0	1.18	1.42	1.52	1.55	0	0	30	28.49	82.5
10/12/2018	0.091	0.004	0.011	0	1.07	1.25	1.34	1.38	0	0	30	29.47	79.5
11/12/2018	0.114	0.004	0.01	0	1.26	1.56	1.71	1.76	0	0	30	28.89	80.5
12/12/2018	0.122	0.006	0.009	0	1.12	1.37	1.53	1.59	0	0	30	27.05	85.8
13/12/2018	0.115	0.006	0.014	0.001	0.85	0.98	1.05	1.06	0	0	30	25.21	88.1
14/12/2018	0.125	0.006	0.012	0	1.59	1.92	2.07	2.11	0	0	30	27.72	82
15/12/2018	0.132	0.005	0.01	0	1.12	1.44	1.59	1.64	0	0	30	28.27	81.3

16/12/2018	0.146	0.005	0.012	0	0.89	1.11	1.21	1.23	0	0	30	27.81	82.9
17/12/2018	0.152	0.006	0.012	0	0.98	1.22	1.33	1.37	0	0	30	28.63	79.8
18/12/2018	0.117	0.006	0.015	0	0.66	0.82	0.9	0.93	0	0	30	29.77	76
19/12/2018	0.138	0.005	0.013	0	1.26	1.43	1.5	1.53	0	0	30	29.59	78
20/12/2018	0.145	0.007	0.014	0	1.27	1.47	1.58	1.62	0	0	30	29.42	76.3
21/12/2018	0.189	0.006	0.016	0.001	1.67	1.91	2.01	2.02	0	0	30	29.8	77
22/12/2018	0.263	0.007	0.024	0	2.53	2.73	2.81	2.85	0	0	30	30.16	75
23/12/2018	0.298	0.01	0.026	0	2.97	3.16	3.26	3.33	0	0	30	30.12	73.3
24/12/2018	0.285	0.008	0.019	0	2.35	2.53	2.61	2.67	0	0	30	30.35	74.4
25/12/2018	0.26	0.008	0.019	0	1.79	1.96	2.04	2.09	0	0	30	30.18	74.1
26/12/2018	0.214	0.009	0.019	0	0.94	1.11	1.23	1.25	0	0	30	28.9	78.1
27/12/2018	0.26	0.007	0.01	0	0.94	1.24	1.39	1.43	0	0	30	27.68	82.4
28/12/2018	0.294	0.007	0.017	0	1.57	1.85	1.99	2.04	0	0	30	29.7	76.7
29/12/2018	0.234	0.008	0.02	0	1.51	1.69	1.79	1.89	0	0	30	30.42	73.6
30/12/2018	0.168	0.01	0.021	0	1.4	1.56	1.63	1.68	0	0	30	30.95	72.6
31/12/2018	0.202	0.014	0.02	0	1.53	1.7	1.79	1.85	0	0	30	29.51	75.6

APPENDIX K
DATA EXPORT FROM AQM 65 (JANUARY 2019)

Date	CO (ppm)	NO2 (ppm)	O3 (ppm)	SO2 (ppm)	PM1 (µg/m³)	PM2.5 (µg/m³)	PM10 (µg/m³)	TSP (µg/m³)	MFC S (mL/min)	MFM Z (mL/min)	ITEMP (°C)	TEMP (°C)	RH (%)
1/1/2019	0.334	0.017	0.024	0	1.67	1.94	2.12	2.29	0	0	30	29.79	72.3
2/1/2019	0.437	0.011	0.019	0	1.76	1.97	2.1	2.19	0	0	30	28.6	74.6
3/1/2019	0.312	0.005	0.014	0	1.26	1.42	1.55	1.7	0	0	30	30.21	69.3
4/1/2019	0.267	0.005	0.022	0	1.24	1.41	1.55	1.7	0	0	30	30.41	69.9
5/1/2019	0.202	0.007	0.022	0	1.9	2.11	2.18	2.22	0	0	30	29.63	78.9
6/1/2019	0.135	0.006	0.019	0	1.83	2.04	2.1	2.13	0	0	30	29.74	77.6
7/1/2019	0.107	0.007	0.019	0	2.41	2.65	2.7	2.74	0	0	30	30.52	74.8
8/1/2019	0.114	0.008	0.019	0.001	2.26	2.5	2.56	2.61	0	0	30	30.51	74.3
9/1/2019	0.106	0.007	0.019	0	1.85	2.05	2.09	2.11	0	0	30	30.51	73.9
10/1/2019	0.092	0.009	0.021	0	1.6	1.78	1.83	1.87	0	0	30	30.43	73.5
11/1/2019	0.113	0.011	0.021	0	1.59	1.78	1.83	1.86	0	0	30	30.25	71.4
12/1/2019	0.175	0.01	0.018	0	1.46	1.66	1.73	1.77	0	0	30	29.89	73.1
13/1/2019	0.147	0.008	0.018	0	1.73	1.92	1.98	2.01	0	0	30	30.02	74.8
14/1/2019	0.165	0.008	0.019	0.001	2.08	2.31	2.38	2.41	0	0	30	29.69	75.4
15/1/2019	0.176	0.01	0.019	0	2	2.21	2.28	2.35	0	0	30	30.04	71.7

16/1/2019	0.201	0.014	0.02	0	1.6	1.76	1.83	1.89	0	0	30	29.2	75.6
17/1/2019	0.171	0.007	0.017	0	1.76	1.97	2.04	2.06	0	0	30	26.83	85.1
18/1/2019	0.155	0.015	0.025	0	2.31	2.57	2.64	2.68	0	0	30	29.84	72
19/1/2019	0.15	0.019	0.025	0.001	2.45	2.71	2.79	2.83	0	0	30	29.84	72.5
20/1/2019	0.165	0.018	0.024	0	2.37	2.62	2.68	2.71	0	0	30	30.3	72.4
21/1/2019	0.167	0.018	0.023	0	2.01	2.23	2.29	2.32	0	0	30	29.89	72.4
22/1/2019	0.18	0.02	0.024	0	1.75	1.94	2.01	2.04	0	0	30	29.56	72.2
23/1/2019	0.243	0.052	0.032	0	2.89	3.13	3.19	3.24	0	0	30	29.84	72.9
24/1/2019	0.289	0.359	0.04	0	3.18	3.43	3.51	3.54	0	0	30	29.57	71.2
25/1/2019	0.332	0.457	0.039	0	3.15	3.38	3.47	3.51	0	0	30	29.06	69.3
26/1/2019	0.277	0.207	0.033	0	2.5	2.69	2.77	2.81	0	0	30	29.13	69.7
27/1/2019	0.237	0.042	0.028	0	2.98	3.2	3.25	3.29	0	0	30	28.93	75.6
28/1/2019	0.21	0.076	0.031	0	3.22	3.47	3.53	3.57	0	0	30	28.51	77.5
29/1/2019	0.156	0.04	0.026	0.001	2.25	2.44	2.49	2.52	0	0	30	29.71	73.8
30/1/2019	0.107	0.087	0.027	0.001	1.97	2.16	2.21	2.25	0	0	30	29.94	71.8
31/1/2019	0.102	0.047	0.021	0.001	1.88	2.07	2.13	2.17	0	0	30	29.44	74.4

APPENDIX L
DATA EXPORT FROM AQM 65 (FEBRUARY 2019)

Date	CO (ppm)	NO2 (ppm)	O3 (ppm)	SO2 (ppm)	PM1 (µg/m³)	PM2.5 (µg/m³)	PM10 (µg/m³)	TSP (µg/m³)	MFC S (mL/min)	MFM Z (mL/min)	ITEMP (°C)	TEMP (°C)	RH (%)
1/2/2019	0.075	0.047	0.022	0.001	1.46	1.61	1.64	1.67	0	0	30	30.24	72.1
2/2/2019	0.066	0.032	0.02	0.001	1.32	1.44	1.47	1.49	0	0	30	30.19	73.8
3/2/2019	0.067	0.02	0.019	0.001	1.37	1.5	1.53	1.56	0	0	30	30.53	73
4/2/2019	0.109	0.018	0.019	0.001	1.58	1.71	1.75	1.8	0	0	30	30.14	74.2
5/2/2019	0.099	0.034	0.021	0.001	1.28	1.4	1.43	1.45	0	0	30	30.2	71.1
6/2/2019	0.115	0.047	0.022	0.001	1.38	1.48	1.52	1.54	0	0	30	29.78	69.7
7/2/2019	0.112	0.028	0.021	0.001	1.29	1.39	1.43	1.44	0	0	30	29.94	70.7
8/2/2019	0.117	0.025	0.02	0.001	1.12	1.2	1.22	1.26	0	0	30	30.27	72
9/2/2019	0.115	0.008	0.016	0.001	1.07	1.15	1.18	1.21	0	0	30	30.44	73.3
10/2/2019	0.066	0.014	0.02	0.001	0.73	0.8	0.82	0.84	0	0	30	30.71	69.3
11/2/2019	0.098	0.021	0.022	0.001	1.01	1.1	1.15	1.19	0	0	30	29.76	67.2
12/2/2019	0.125	0.015	0.022	0.001	1.63	1.74	1.79	1.85	0	0	30	30.35	70
13/2/2019	0.067	0.018	0.024	0.001	1.87	2.04	2.08	2.15	0	0	30	30.18	74.5
14/2/2019	0.058	0.03	0.025	0.001	1.83	2.02	2.07	2.09	0	0	30	30.76	68.6
15/2/2019	0.077	0.047	0.026	0.001	1.67	1.83	1.89	1.93	0	0	30	30.28	68.4

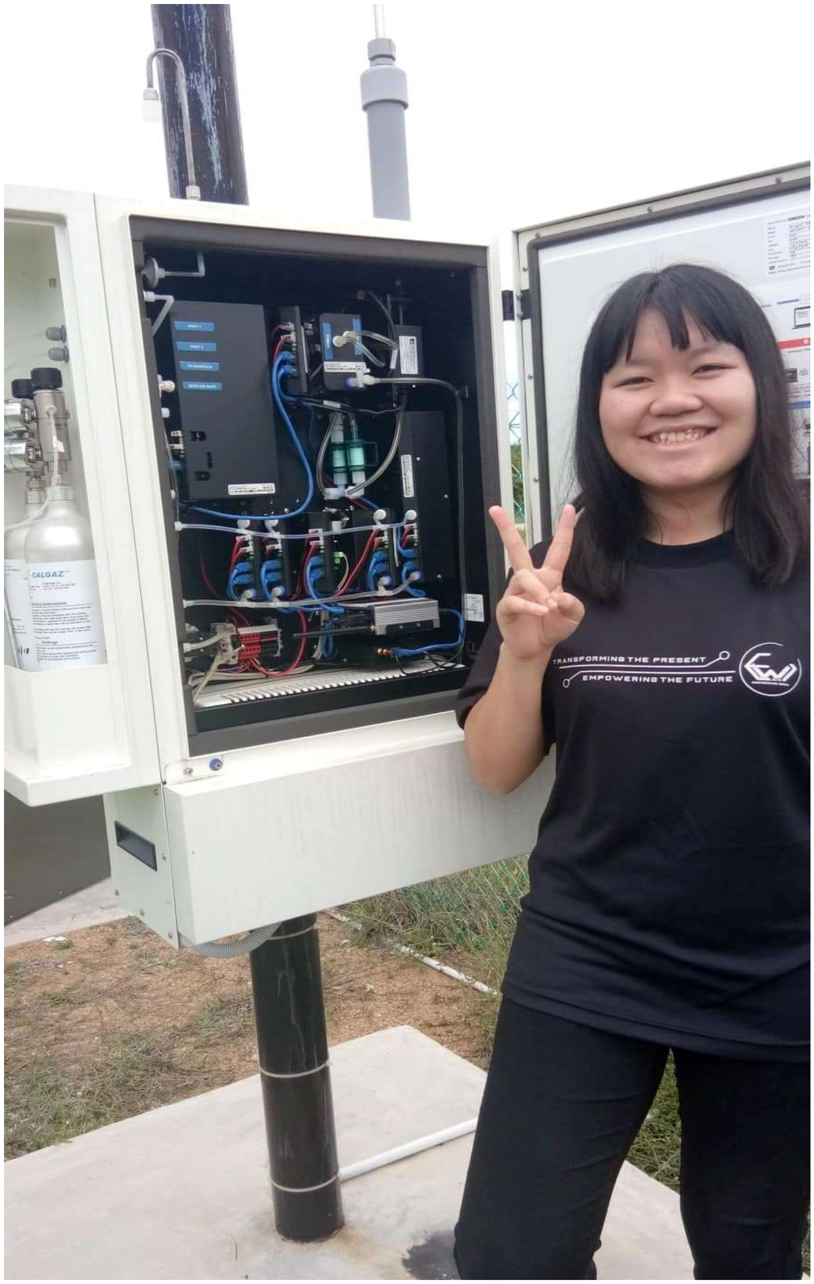
16/2/2019	0.08	0.078	0.028	0.001	1.23	1.37	1.41	1.44	0	0	30	30.6	66.2
17/2/2019	0.115	0.026	0.025	0.001	1.51	1.63	1.67	1.7	0	0	30	30.29	70
18/2/2019	0.143	0.015	0.024	0.001	1.07	1.14	1.18	1.25	0	0	30	29.43	75.7
19/2/2019	0.099	0.032	0.027	0.001	0.88	0.95	0.97	1	0	0	30	30.91	70.3
20/2/2019	0.121	0.029	0.026	0.001	0.87	0.95	0.97	0.99	0	0	30	30.21	72.4
21/2/2019	0.125	0.03	0.027	0.001	1.24	1.35	1.38	1.4	0	0	30	30.26	72.7
22/2/2019	0.125	0.043	0.029	0.001	1.29	1.41	1.44	1.47	0	0	30	30.46	71
23/2/2019	0.102	0.106	0.032	0.001	0.98	1.08	1.11	1.14	0	0	30	30.2	67.3
24/2/2019	0.109	0.174	0.035	0.001	1.2	1.3	1.33	1.35	0	0	30	30.15	67.7
25/2/2019	0.118	0.08	0.033	0.001	1.14	1.23	1.27	1.32	0	0	30	30.43	69.9
26/2/2019	0.075	0.052	0.032	0.001	0.95	1.06	1.09	1.15	0	0	30	30.44	71.6
27/2/2019	0.089	0.341	0.041	0.001	1.75	1.93	1.98	2.01	0	0	30	30.86	66.9
28/2/2019	0.148	0.101	0.035	0.002	2.55	2.74	2.8	2.88	0	0	30	29.9	73

APPENDIX M
DATA EXPORT FROM AQM 65 (MARCH 2019)

Date	CO (ppm)	NO2 (ppm)	O3 (ppm)	SO2 (ppm)	PM1 (µg/m³)	PM2.5 (µg/m³)	PM10 (µg/m³)	TSP (µg/m³)	MFC S (mL/min)	MFM Z (mL/min)	ITEMP (°C)	TEMP (°C)	RH (%)
1/3/2019	0.132	0.229	0.039	0.001	1.95	2.11	2.19	2.27	0	0	30	30.39	69.1
2/3/2019	0.13	0.461	0.044	0.001	1.59	1.73	1.78	1.81	0	0	30	30.32	66.9
3/3/2019	0.119	0.811	0.048	0.001	1.26	1.37	1.42	1.44	0	0	30	29.74	66.3
4/3/2019	0.179	0.584	0.047	0.001	1.96	2.05	2.1	2.17	0	0	30	29.85	67.2
5/3/2019	0.132	0.472	0.045	0.001	0.93	1	1.04	1.08	0	0	30	30.67	68.2
6/3/2019	0.138	0.056	0.036	0.001	1.18	1.26	1.29	1.32	0	0	30	30.06	74.7
7/3/2019	0.247	0.018	0.033	0.001	2.53	2.63	2.68	2.72	0	0	30	30.73	72.5
8/3/2019	0.247	0.018	0.038	0.001	2.67	2.76	2.81	2.85	0	0	30	30.5	72
9/3/2019	0.312	0.017	0.033	0.001	5.16	5.26	5.3	5.35	0	0	30	30.8	69.5
10/3/2019	0.236	0.004	0.032	0.001	2.19	2.27	2.3	2.32	0	0	30	30.66	69.9
11/3/2019	0.378	0.003	0.029	0.001	4.12	4.21	4.27	4.41	0	0	30	30.68	72.2
12/3/2019	0.392	0.003	0.036	0.001	4.66	4.77	4.83	4.9	0	0	30	31.01	72.8
13/3/2019	0.336	0.004	0.035	0.001	4.47	4.57	4.61	4.65	0	0	30	30.96	70
14/3/2019	0.187	0.005	0.042	0.001	2.35	2.42	2.47	2.5	0	0	30	31.46	66.3
15/3/2019	0.141	0.017	0.047	0.001	1.55	1.64	1.68	1.72	0	0	30	31.56	62.6

16/3/2019	0.213	0.028	0.046	0.001	3.04	3.15	3.2	3.24	0	0	30	31.19	66.1
17/3/2019	0.343	0.031	0.047	0.001	5.63	5.76	5.82	5.87	0	0	30	31	65.1
18/3/2019	0.441	0.015	0.042	0.001	5.93	6.06	6.11	6.16	0	0	30	31.28	65.4
19/3/2019	0.554	0.006	0.038	0.001	8.17	8.32	8.37	8.41	0	0	30	31.43	67.8
20/3/2019	0.116	0.008	0.047	0.001	0.83	0.91	0.94	0.96	0	0	30	31.92	64.7
21/3/2019	0.154	0.019	0.039	0.001	1.59	1.67	1.7	1.85	0	0	30	26.46	84.6
23/3/2019	0.1	0.009	0.036	0.002	1.2	1.27	1.3	1.32	0	0	30.1	33.14	66.1
24/3/2019	0.25	0.008	0.029	0.001	3.46	3.56	3.61	3.65	0	0	30	31.56	71.4
25/3/2019	0.136	0.005	0.031	0.001	1.55	1.63	1.66	1.7	0	0	30	31.65	71.2
26/3/2019	0.114	0.005	0.039	0.001	1.58	1.71	1.76	1.78	0	0	30	31.33	71.6
27/3/2019	0.083	0.006	0.045	0.002	1.4	1.53	1.57	1.58	0	0	30	31.87	67.3
28/3/2019	0.145	0.009	0.037	0.001	2.3	2.45	2.49	2.52	0	0	30	31.64	71.4
29/3/2019	0.502	0.006	0.031	0.001	8.88	9.07	9.11	9.14	0	0	30	30.17	76.8
30/3/2019	0.235	0.009	0.044	0.001	2.16	2.29	2.34	2.36	0	0	30	30.3	76.9
31/3/2019	0.257	0.011	0.048	0.001	2.92	3.04	3.1	3.14	0	0	30	29.43	76.9

APPENDIX N
AEROQUAL AQM 65 AT PEKAN

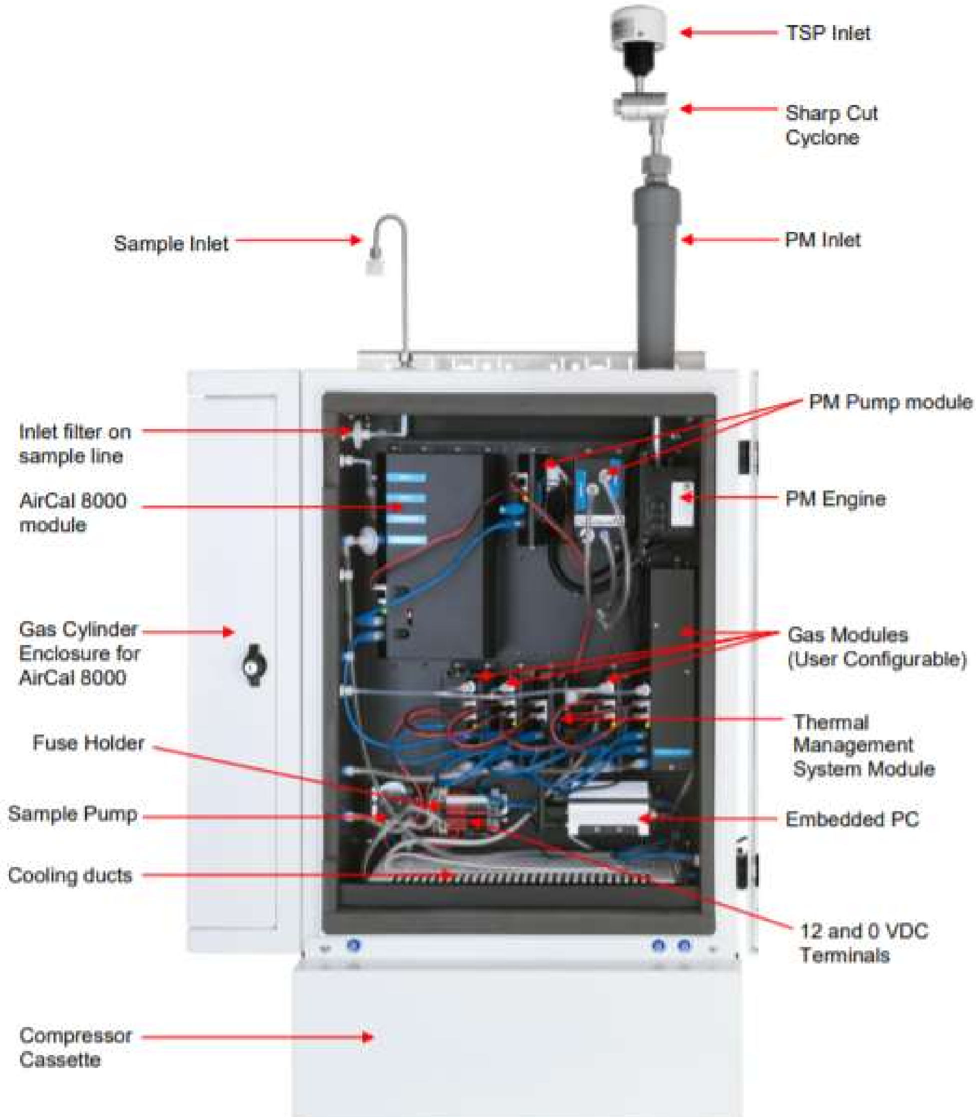


APPENDIX O
AEROQUAL AQM 65 MANUAL

1. Description

The Aeroqual AQM 65 is a compact air quality station designed for precise measurement of ambient pollution and environmental conditions. Its platform is configurable to measure a wide range of air pollutants such as ozone (O_3), nitrogen dioxide (NO_2), carbon monoxide (CO), sulphur dioxide (SO_2) PM_{10}, and $PM_{2.5}$ as well as meteorological parameters such as temperature, humidity, wind speed and direction.

The AQM 65 is complete air quality station consisting of a custom made IP65 rated aluminium enclosure which houses a power module, thermal management system, embedded PC running Aeroqual Connect software and user configured analyser modules.



Note 1: The placement of individual modules will vary depending on the user configuration

1.1. External Connections

There are 4 external water tight glands located on the right hand side of the AQM 65 enclosure. The black gland is an Ethernet output for use when a wired connection to the instrument is required (See Section 3.1.1. for more information). The 3 other glands are designed to allow third party sensors to be wired into the instrument.

1.2. Gas Modules

The AQM 65 can be configured with a range of gas modules. All modules are mounted onto the base plate using 4 or 2 screws depending on the module size. Inlet and outlet tubes are connected to the gas distribution manifold and exhaust respectively. The inlet tubing used is PFA 3.2ID x 0.75WT and the exhaust tubing used is Tygon R3603.2ID x 1.6WT.

1.2.1. Gas Sensor Specifications

Gas Modules	Range	Noise /ppm	Lower detectable limit /ppm	Precision
Ozone O_3 (GSS)	0-0.5 ppm	<0.001	0.001	<0.002 ppm 0 to 0.1 ppm <2% of reading above 0.1 ppm
Nitrogen Dioxide NO_2 (GSS)	0-0.2 ppm	<0.001	0.001	<0.003 ppm 0 to 0.1 ppm <3% of reading above 0.1 ppm
Carbon Monoxide CO (GSE)	0-25 ppm	0.020	0.040	<0.050 ppm 0 to 2 ppm <3% of reading above 2 ppm
Sulfur Dioxide SO_2 (GSE)	0-10 ppm	0.004	0.009	<0.009 ppm 0 to 0.3 ppm <3% of reading above 0.3 ppm
Nitrogen Oxides NO_x (GSS)	0-0.5 ppm	<0.001	0.001	<0.003 ppm to 0.1 ppm <3% of reading above 0.1 ppm
Hydrogen Sulfide H_2S (GSE)	0-10 ppm	0.006	0.012	<0.012 ppm 0 to 0.4 ppm <3% of reading above 0.4ppm
Carbon Dioxide CO_2 (NDIR)	0-2000 ppm	<5	10	<10 ppm 0 to 400 ppm <3% of reading above 400 ppm
Volatile Organic Compounds VOC (PID)	0-20 ppm	0.005	0.010	<0.010 ppm 0 to 0.5 ppm <2% of reading above 0.5 ppm
Non-methane hydrocarbons NMHC (GSS)	0-25 ppm	0.020	0.040	<0.05 ppm 0 to 1 ppm <5% of reading above 1 ppm
Ammonia NH_3 (GSE)	0-10 ppm	0.050	0.100	<0.1 ppm 0 to 2 ppm <5% of reading above 2 ppm

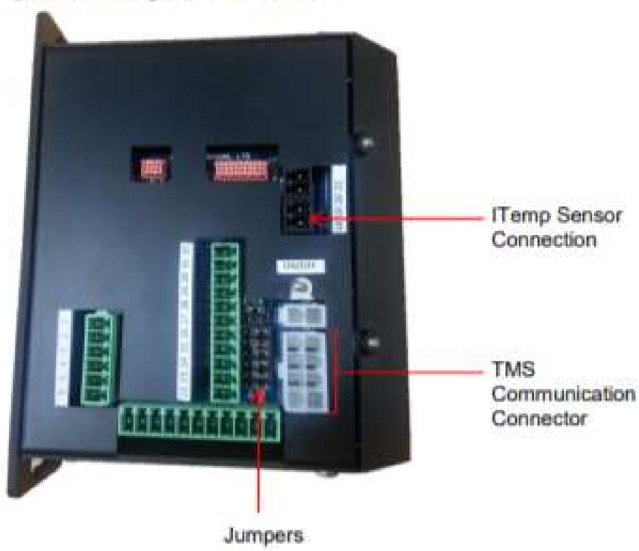
Note: The sensor specifications are subject to change; please contact Aeroqual for latest performance data

1.3. Thermal Management System

The AQM 65 has a thermal management control system to maintain a stable internal temperature irrespective of ambient temperature changes. The TMS cassette is located at the base of the instrument and comprises of a Danfoss compressor, IP55 cooling fan and ducting. The TMS cassette is separate from the main enclosure and can be removed if required.

The control software is stored on the System Management module which is installed inside the main housing. The module initiates the compressor, fans and heater when necessary to maintain the internal temperature at a constant of within ±0.2°C.

System Management Module



Note: The jumpers in the system management module should be positioned as shown in the image above.

1.4. Sensirion SHT75 Temperature and Humidity Sensor

The Humidity and Temperature Sensor is a Sensirion single chip device which contains a capacitive polymer sensing element for relative humidity and a band-gap temperature sensor. More detailed specifications are in the table below. The temperature and humidity sensor is housed in a connector located on the bottom of the enclosure. It is connected directly to the system manager module. For full details visit the company website www.sensirion.com.

Air Temperature	
Range	-40°C to + 124°C
Accuracy	±0.3°C
Resolution	0.01°C
Relative Humidity	
Range	0-100 %RH
Accuracy	±2 %RH
Resolution	0.1 %RH

1.5. Auxiliary Module (Optional)

The auxiliary module acts as an interface between third party sensors and the AQM 65 communication bus. It is configured with different operating modes which can be user selected by adjusting the dipswitches located on the side of the module. Aeroqual has integrated a number of third party sensors and is able to supply the auxiliary module preconfigured for your sensor.

The tables below list the various functions:

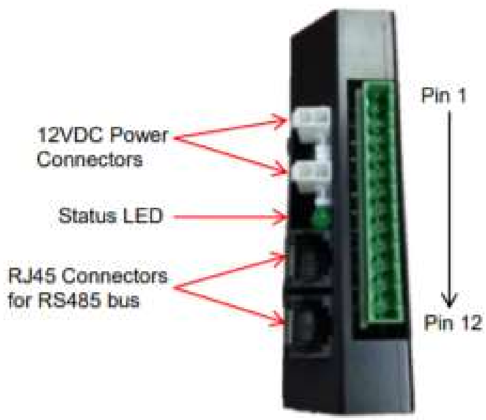
Firmware: AUX_MODULE_01.
Use for: Analogue inputs, Vaisala WXT520 weather, Gill Windsonic wind, Cirrus MK: 427 noise

1	2	3	4	Function
OFF	OFF	OFF	OFF	Default - standard Auxiliary module with AN1, AN2, Freq
ON	OFF	OFF	OFF	Vaisala WXT520 with RS232 communication + AN1, AN2, Freq
OFF	ON	OFF	OFF	Vaisala WXT520 with RS232 communication + Cirrus MK427 Noise
ON	ON	OFF	OFF	Wind Sonic with RS232 communication + AN1, AN2, Freq
OFF	OFF	ON	OFF	Wind Sonic with RS232 communication + Cirrus MK427 Noise
ON	OFF	ON	OFF	Cirrus MK427 Noise module only

Firmware: AUX_MODULE_02.
Use for: Analogue inputs, Met One MSO weather, Met One 034b wind, Cirrus MK:427 noise.

1	2	3	4	Function
OFF	OFF	OFF	OFF	Default - standard Auxiliary module with AN1, AN2, Freq
ON	OFF	ON	OFF	Cirrus MK427 Noise module only
OFF	ON	ON	OFF	Met One MSO with RS232 communication + Cirrus MK427 Noise
ON	ON	ON	OFF	Met One MSO with RS232 communication + AN1, AN2, Freq
OFF	OFF	OFF	ON	Met One 034B analogue module + Cirrus MK427 Noise

The third party sensor needs to be correctly wired into the auxiliary module for it to function correctly. The image and table below provide further information on wiring the auxiliary module.



Wiring of Aux Module:

PIN 1: GND
PIN 2: 12V FUSED
PIN 3: RESERVED
PIN 4: RESERVED
PIN 5: RX
PIN 6: TX
PIN 7: 0-5V IN
PIN 8: 4-20mA IN
PIN 9: FREQ IN
PIN 10: AGND
PIN 11: METONE 034B PWR
PIN 12: CIRRUS ACTUATOR

Example of wiring:

Wind Sonic	(Pin 1) GND, SIGNAL GND	(Pin 2) 12V	(Pin 5) RX	(Pin 6) TX
Vaisala	(Pin 1) GND for operating, data & heating	(Pin 2) 12V for operating & heating	(Pin 5) RX	(Pin 6) TX
Met One MSO	(Pin 1) GND, SIGNAL, COMMON, SHIELD	(Pin 2) 12V	(Pin 5) RX	(Pin 6) TX
Met One 034B	(Pin 1) GND	(Pin 11) METONE 034B PWR	(Pin7) WD	(Pin 9) WS
Cirrus MK:427	(Pin 1) GND, ACTUATOR GND	(Pin 2) 12V, LOOP IN	(Pin 8) LOOP OUT	(Pin 12) ACTUATOR IN

A programming port is also exposed through the side of the module to allow custom programs to be loaded into the module.

Note 1: Aeroqual can supply a standard programming tool for distributors to reprogram the auxiliary module to the specified requirements.

Note 2: The above wiring connections are subject to change, please refer to the third party sensor manuals for the latest wiring instructions.

Note 3: The Wind Sonic comes with an Aeroqual supplied cable and therefore the latest wire outputs will be sent with the cable.

1.6. Particle Monitor

The particle monitor is an optional device that can be installed in the AQM 65 to provide reliable real time indicative particulate measurement of TSP, PM10, PM2.5 or PM1 using a well proven near forward light scattering nephelometer and high precision sharp cut cyclone.

1.6.1. Nephelometer

Aeroqual uses a customised nephelometer optical sensor from Met One Instruments. The optical sensor uses light scattering from particulate matter to provide a continuous real-time measurement of airborne particle mass. The light source is a visible laser diode and scattered light is measured in the near forward angle using a focusing optics and a photo diode.

The sensor has an on-board temperature sensor which is corrected for thermal drift, sheath air filter to keep the optics clean, automatic baseline drift correction and a fibre optic span system to provide a check of the optical components.

Safety: This sensor is considered a Class I laser product. Class I laser products are not considered to be hazardous. There are no user serviceable parts inside the cover of the sensor. The device contains a laser operating at 670 nm which is visible to the eye and can cause damage to the eye if directly exposed. Only trained service personnel should attempt servicing or repair of the sensor.

The electrical connections to the nephelometer are summarised below:

Wire colour	**Function**
Orange (x2)	Fibre optic solenoid
Red	5V (power in)
Black	Ground
White	Signal out (0-5 V)
Black/white	Signal Ground
Yellow	Laser current monitor (10mV = 1 mA laser current)
Grey	Temperature output

1.6.2. Inlet heater

The nephelometer uses a 12 V heater on the sample inlet tube to reduce the humidity of sampled air to prevent particle growth and fogging of the nephelometer optics in high RH conditions.

1.6.3. Inbuilt filters

The nephelometer contains two filters which should be replaced at specified intervals. The "Sample" filter is a coarse filter designed to protect the sample pump from excessive particle build-up. The "Purge" filter is a fine filter which filters the sheath air flow and also produces particle-free air during the auto-zero cycle. See Section 8.4.8 for information on changing the filters.

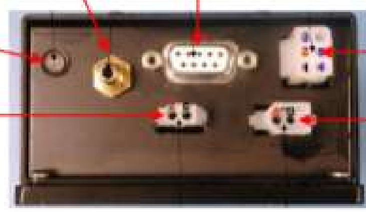
1.7. Profiler

1.7.1. Optical Particle Counter

Aeroqual uses a customised optical particle counter from Met One Instruments. The particle counter uses scattered light to measure and count particles. Light from a laser diode is collimated to illuminate the aerosol sample flow. When a particle is present it scatters the incident laser light which is detected using a 60° solid angle elliptical mirror at right angles to the laser beam. The amount of scattered light is converted to a voltage pulse and the amplitude of the pulse is calibrated to a particle diameter. The particles are thus assigned on the basis of size to one of eight channels.

1.7.2. Connections

The connections to the optical particle counter are at the bottom of the unit. There is also a LED which turns red if there is a fault condition. The optical unit requires an earth wire to be connected between the housing and the 0VDC line on the power bus. Please check that this is fitted if the unit has been replaced.



1.7.3. Data Outputs

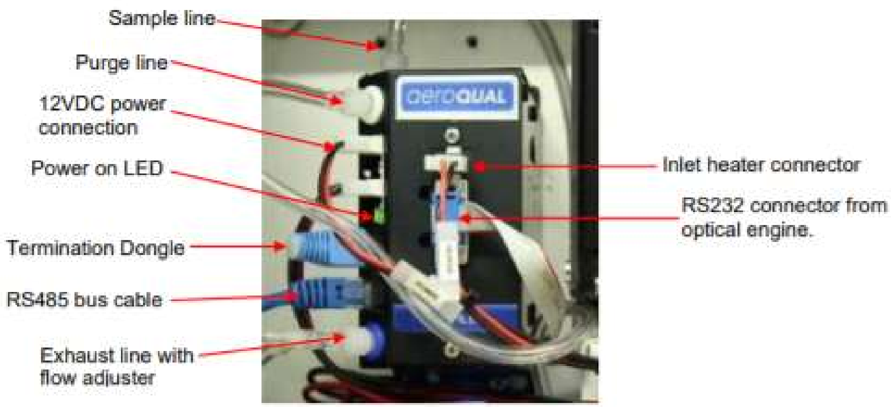
The Profiler can be configured to display and log the measurements detailed in the table below. The sensor name is that used in the active sensors list and module settings.

Sensor Name	Definition	Range	Units
8PC0.3	number of particles with diameter larger than 0.3 μm	0-100000	particles/L
8PC0.5	number of particles with diameter larger than 0.5 μm	0-100000	particles/L
8PC0.7	number of particles with diameter larger than 0.7 μm	0-100000	particles/L
8PC1.0	number of particles with diameter larger than 1.0 μm	0-100000	particles/L
8PC2.0	number of particles with diameter larger than 2.0 μm	0-100000	particles/L
8PC2.5	number of particles with diameter larger than 2.5 μm	0-100000	particles/L
8PC5.0	number of particles with diameter larger than 5.0 μm	0-100000	particles/L
8PC10	number of particles with diameter larger than 10 μm	0-100000	particles/L
PM1	Particle mass below 1 μm	200	ug/m3
PM2.5	Particle mass below 2.5 μm	2000	ug/m3
PM10	Particle mass below 10 μm	5000	ug/m3
TSP	Total suspended particle mass	5000	ug/m3

1.8. Particle Mass Pump Modules

The pump modules for the Nephelometer and Profiler contain a microprocessor for mass calculation and a pump for sampling. The pump module varies depending on whether a Nephelometer or Profiler has been installed in the AQM 65.

1.8.1. Profiler Pump Module

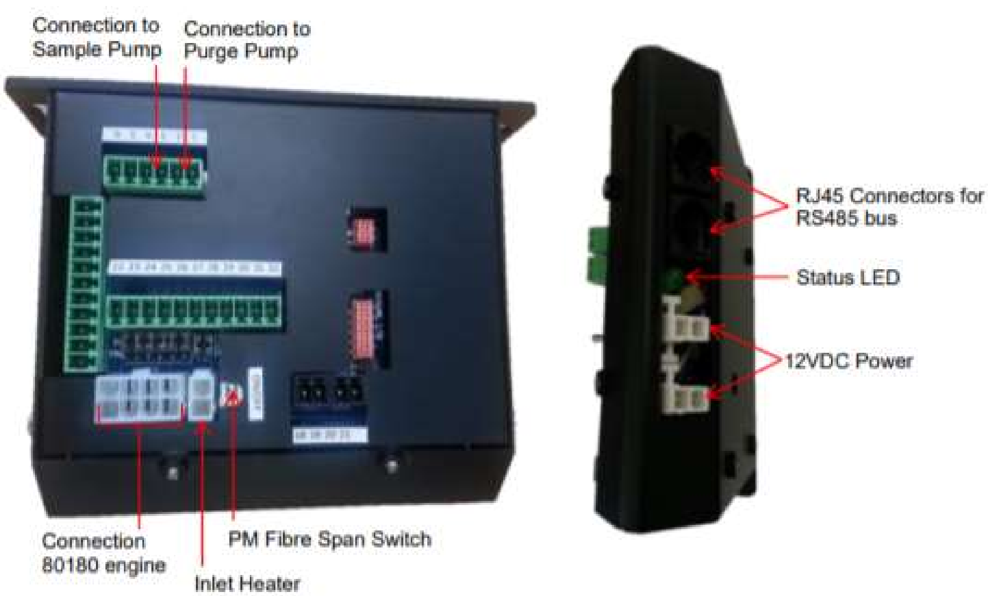


1.8.2. Nephelometer Pump Module

The Pump Module is split into two sections:

1. The electronics
2. The pump and pneumatics

The functionality of the electronics module can be seen below:

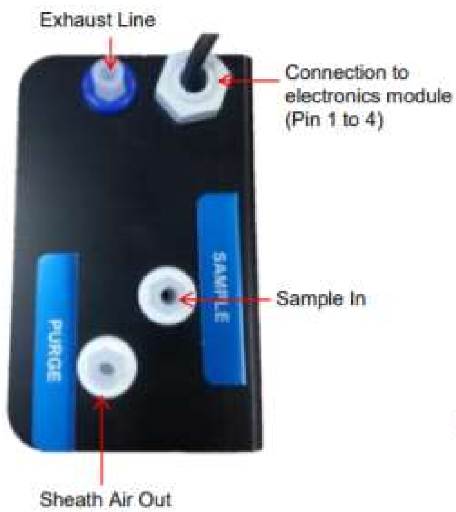


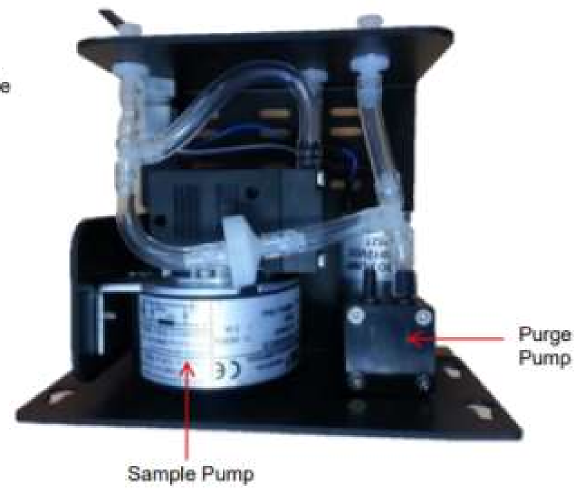
Note: The jumpers in the current module should be positioned as shown in the previous image.

Pin 1 = 12V (blue)
Pin 2 = GND (white) } Purge Pump

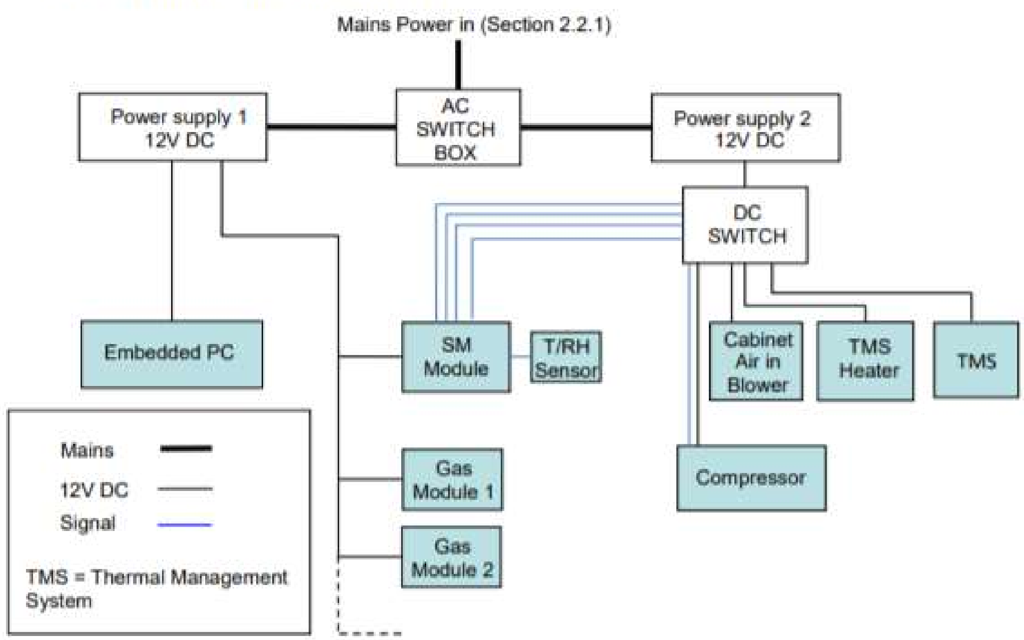
Pin 3 = 12V (red)
Pin 4 = GND (black) } Sample Pump

The pump and pneumatics are easy to access for servicing and replacement:





1.9. Electrical Connections



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RS485 Bus

The two wire RS485 bus connections are made using 20 cm CAT5 cables between the sensor modules

12 VDC Power Bus

All modules inside the AQM 65 operate from the 12VDC power. The power is supplied by a daisy chain of black and red cables. To turn off the 12VDC power to the upper cabinet release the fuse holder.

Status LED

Each module includes a status LED which indicates that the electrical status of the module is functioning correctly. It does not indicate the calibration status of the module.

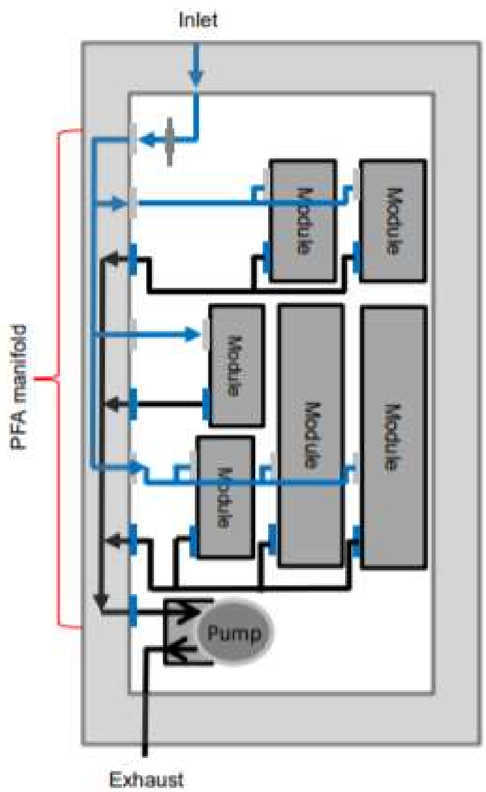
a) Continuous on indicates correct electrical functionality
b) Slow flash (1 second) indicates warm up period
c) Fast flash (0.2 seconds) sensor failure
d) LED not on indicates no power to module.
e) The System Manager LED is a special case. This flashes to indicate RS485 bus traffic.

1.10. Pneumatic Connections

The sample gas passes into a PFA manifold behind the left hand side wall and is distributed to the sensors. The gas modules sample via a single pump located in the bottom left of the enclosure. The pump is easily accessible for maintenance. The sample inlet tubing is PFA tubing which is inert and smooth walled. The module exhaust tubing is Tygon 3603 PVC tubing.

Note: The ports on the manifold which are not used must be capped off to prevent leaks.

Note 2: The blue lines represent the sample flow and the black lines represent the exhaust flow.



An adjustable bypass valve is included between the vacuum and pressure side of the pump. This is to allow an adjustment to be made to the module flow rates and to relieve the excess pressure placed on the pump when only one or two modules are installed.

The total sample flow rate will be dependent on the number of gas sensor modules in the AQM. All module flows are controlled by critical orifices located within the sensor modules. See Section 8.3.3.for expected flow rates.

2. Set Up

The purpose of this section is to enable the user to correctly assemble, configure and commission their AQM 65 prior to field installation.

2.1. Unpacking

a) Examine the Shockwatch label on the side of the shipping box. If the indicator is red do not refuse shipment. Make a notification on delivery receipt and inspect for damage. If damage is discovered, leave item in original packaging and request immediate inspection from carrier within 15 days of delivery date (3 days international).

b) Verify the serial number label on the documentation matches the serial label on the AQM (located on inside of enclosure).

c) Verify that all components have been shipped as per the packing slip. Contact your Distributor or Aeroqual if you suspect any parts are missing.

d) Unpack the AQM.

e) Remove all internal shipping/packaging material from the AQM enclosure.

f) Retain the packaging.

Note: Always transport the AQM in the three piece aluminum skins with foam packing provided to avoid breakages. Wrap all peripheral assemblies in their original packaging also. The AQM is a sensitive instrument and should be transported with care.

2.2. Assembly

2.2.1. Connect Mains Power

Caution: The high voltage mains supply must be wired by a certified electrician in compliance with local electrical regulations.

To connect the mains power follow the steps below:

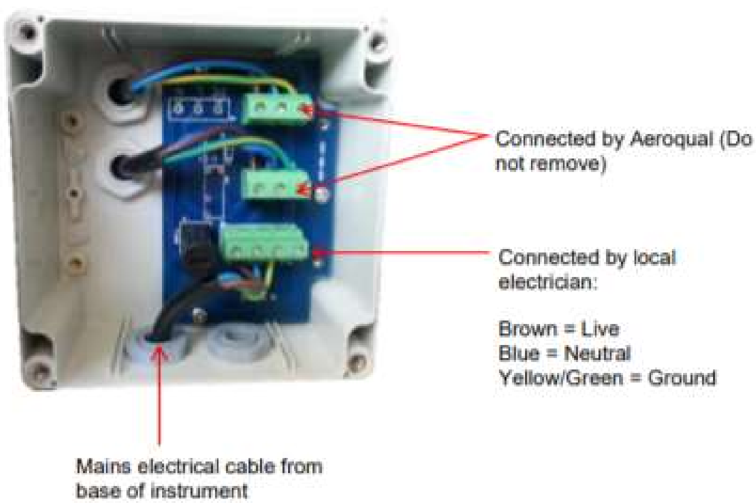
1. Unscrew the front panel of the AQM 65 TMS cassette. There are 4 screws at each corner that need to be removed to allow the front panel to slide off. The door must be open to access these screws.
2. Unscrew the lid of the terminal box to access the wiring.

3. The mains electrical cable needs to be fed through the gland at the base of the instrument into the terminal box.

Note 1: The AQM65 can be placed flat on its back to access the gland

Note 2: Ensure the nut gland and rubber plug have been fed through the electrical cable before feeding the cable through the gland at the base of the instrument

4. Wire the cable to the terminal block



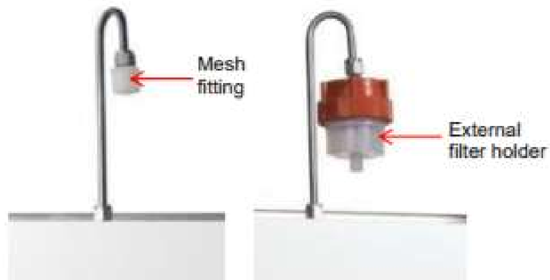
5. Tightly screw the gland at the base of the instrument to secure the cable in place and create a waterproof seal.

6. Replace the lid of the terminal box and the front panel of the TMS cassette.

2.2.2. Connect Inlet System

Once the AQM 65 has been wired the inlet system needs to be connected before the instrument is turned on. The inlet system consists of an inert fluoropolymer and glass inlet with mesh fitting which is designed to prevent unwanted materials, such as water and dust, being drawn into the instrument. The inlet pipe is connected to the top of the AQM 65.

A 5/8 spanner is required to securely tighten the ¼" stainless steel compression fitting.



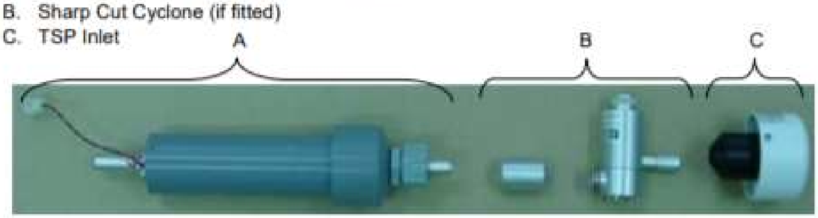
If an external filter holder has been purchased with the AQM 65, remove the mesh fitting from the inlet pipe and screw the filter holder into place. The arrow on the filter holder should be pointing upwards.

2.2.3. Assembly of heated inlet for PM/Profiler (Optional)

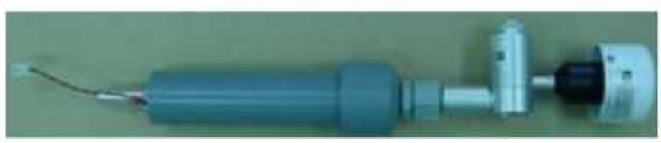
If the AQM 65 is configured with a Nephelometer or Profiler the heated inlet needs to be connected prior to the instrument being turned on.

Parts List:

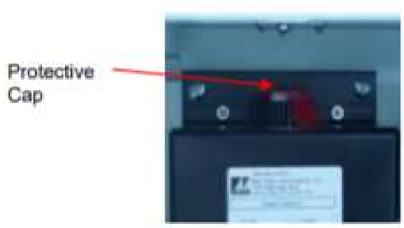
A. Inlet Tube/Heater including power cable
B. Sharp Cut Cyclone (if fitted)
C. TSP Inlet



i. Connect parts A, B and C

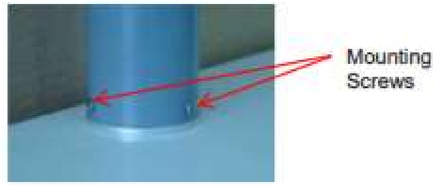


ii. Open door of enclosure and remove protective cap from the optical engine



iii. Insert Inlet Tube Assembly through base mount and fix the three mounting screws

Note 1: Ensure the power cable is fed through the inlet hole when connecting the inlet



iv. Connect power to Inlet Tube/Heater inside the enclosure

2.2.4. Connect third party sensors (Optional)

Third party sensors such as the Vaisala Weather Transmitter WXT520 or Met One MSO are connected to the unit via the external glands located on the right hand side of the enclosure. Feed the cable through the glands and connect to the auxiliary module using the instructions in Section 1.5.

Note: Turn off the AQM 65 before plugging in any external third part sensor.

2.3. Connect to the AQM 65

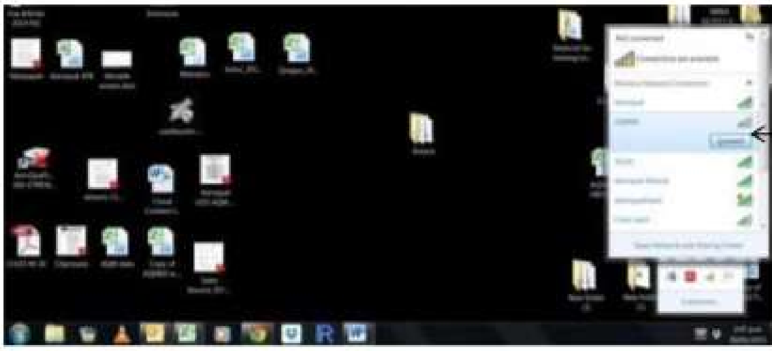
Aeroqual Connect is the standard user interface which comes with the AQM instrument and allows the user to be connected directly to the AQM instrument. It can be accessed via WiFi, Ethernet or a cellular modem. The on-board computer has an Ethernet output for direct wired connection. . Alternatively, connection can be made over WIFI by connecting to the AQM network (Access point mode), a local network (Client mode) or via a modem.

2.3.1. Initial Connection via Access Point Mode

The default setting of the instrument when first purchased will be to connect to Aeroqual Connect via access point mode. Access point mode allows connection to the AQM via the AQM network signal which will show up on a laptop, tablet or smart phone within range. This type of connection will most commonly be used when working on the AQM in the field. However, it will also be used to initially connect when the instrument first arrives.

Connecting by this mode will mean the user's device is connected via WIFI directly to the AQM. There will be no internet connection on the user device when using this option. To connect you will need to select the AQM WIFI network and enter the password.

Note: The default password will be "Aeroqual".



AQM Network Signal

Once a WiFi connection has been made Aeroqual Connect can be accessed via the PC browser by entering the IP address 10.10.0.1 in the address bar. The login screen below will then be displayed.

1. An Aeroqual Connect login name and password will be provided when Aeroqual Connect is first purchased. If you do not know your login details please contact technical@aeroqual.com.
2. Once you have logged in the homepage will be displayed.

Note 1: Different applications will appear depending on the user accessibility configured for your account.

Note 2: See Section 3 for more connection options

2.4. Initial Commissioning

The objective of the initial commissioning process is to enable the user to gain knowledge in the operation of the instrument and to demonstrate that it is functioning correctly prior to remote installation. The process consists of a set of tasks that check that the AQM is operating correctly.

> **Undertaking the commissioning procedure correctly is an important part of the product transfer process and customer acceptance. It confirms that you have received the product in good working order and it has been shipped to you without damage.**

Equipment required:

- AQM Logbook
- PC
- Flow meter covering the range 0-2.5 LPM
- Zero air source
- Span gases corresponding to the sensors in the AQM
- Calibrator or gas flow meters for generating suitable span gas concentrations
- Humidifier (supplied in service kit)

Note: Before starting the commissioning process it is important that the AQM is fully warmed up. Run the instrument overnight sampling either outside ambient air or indoor air with an activated carbon filter connected to the inlet.

2.4.1. System Checks

Sensor Configuration

- Select the "Configure Instrument" application in Aeroqual Connect and check the parameters listed under the Active Sensors heading are correct.
- The sensors should match the sensors listed on the invoice and in the instrument logbook.
- If they do not match add the missing sensors and remove any sensors that are not configured in the AQM 65 (See Section 4.5.3. for more information).

Sensor Logging

- Check all the configured sensors are logging correctly in Aeroqual Connect.
- Select the "Manage Data" application and view the data in table format.
- All sensors should be reporting data with no errors.

Note: If a sensor is not reading correctly see Section 9 for troubleshooting or contact Technical@aeroqual.com

TMS settings

- Close the door to the AQM and run overnight.
- To check the stability of the internal temperature plot ITemp vs. Time for a period of several hours and ensure the internal temperature is stable to within ±1°C and matches the ITemp value stated in the logbook e.g. Set point = 30°C.
- Select the "Manage Data" application in Aeroqual Connect and view the ITemp chart to view the plotted data.

Modem Communication OK (Optional)

- The modem will be preconfigured at the Aeroqual factory.
- To complete configuration of the modem plug directly from the modem Ethernet port to a laptop Ethernet port, browse to 192.168.127.254. and follow the instructions in Section 3.1.2
- Establish a connection to the AQM 65 via the modem to confirm the connection is successful.

2.4.2. System Values

AQM inlet flow

Using a volumetric flow meter record the flow on the AQM sample inlet. Check it is the same as the inlet flow stated in the AQM logbook.

Module flows

Use a volumetric flow meter to record the flow on the inlet port of the gas modules. These should match those of the Logbook. If the flow rate does not match the rate written on the module adjust the flow using the AQM manifold bypass valve and/or check for leaks (see Section 9.3.4 for leak checking).

Particle Monitor/Profiler flow

If a particle monitor or profiler is present, use a volumetric flow meter to record the flow on the external inlet. Remove the TSP head and connect the flow meter to the top of the sharp cut cyclone. The inlet flow can be adjusted via the bleed screw on the purge line. Afterwards replace the inlet components with care making sure there is no leak.

Note 1: Particle Monitor inlet flow rate should be 2LPM

Note 2: Profiler inlet flow rate should be 1LPM

2.4.3. Zero and Span Checks for Gas Modules

Refer to Section 6 on how to carry out zero and span checks and calibration.

A full commissioning process will require gas calibration and flow equipment (not supplied with the AQM 65). In the absence of gas calibration and flow measurement capabilities, measurement of outside air over a 24 hour period and comparison of this data with measurements from a local "reference" air monitoring station will provide evidence of correct span operation.

3. Connecting to Aeroqual Connect and Cloud

As previously mentioned in Section 2.3, Aeroqual Connect is the standard user interface which comes with the AQM 65. Access point mode is the default setting and has already been discussed in Section 2.3.1. There are several other connection options available which are all useful at different times.

Once the first connection has been made (via access point mode) the WiFi communications can be configured according to how you would like the system to respond. This can be done via the settings tab under the Configure Instrument application.

3.1. Connection Options

3.1.1. Client Mode

Client mode allows connection to the AQM via a local network (e.g. your office network). If there is a local WIFI or LAN network available at the AQM installation site then the AQM can be set up to connect to this network. This might be the case if the AQM is installed on the perimeter of an industrial site and the WiFi network extends out to where the AQM is installed.

Alternatively the AQM 65 can be connected to the local network via an Ethernet cable from the AQM to the local router using the Ethernet output on the side of the AQM.

When the AQM is connected to your local network (such as your office WiFi network), the local network will automatically assign a local IP address to the AQM. The IP address assigned to the instrument can be found in the Configure Instrument application when logged in via Aeroqual Cloud.

Entering this IP address into the web browser will open Aeroqual Connect for that specific instrument, assuming you are within the local network.

If the local network allows outside access (e.g. via VPN), connection to the AQM can be made from anywhere in the world. In the more common scenario where the local network does not permit outside access you may still connect to the AQM using Aeroqual Cloud through the internet because most local networks permit internet access.

To configure the AQM to use client mode the instrument needs to be configured via the settings tab under the Configure Instrument application.

1. The WiFi mode needs to be set to Client
2. The WiFi SSID (local network name) needs to be entered (e.g. your office WiFi name)
3. The WiFi password needs to be entered (e.g. the password for your office WiFi)

Note 1: Before changing the WIFI settings it recommended that you have another connection to the instrument established – typically by connecting the instrument to your LAN using the Ethernet connection and using Connect with the LAN IP address.

Note 2: Once WiFi client mode is set up Aeroqual Connect will automatically disconnect from WiFi access point mode. Connection will then need to be made via Aeroqual Cloud (See section 3.2) to see the local IP address assigned to the instrument.

Note 3: If the local WiFi network password changes or you enter it incorrectly, you could be locked out of the AQM. If this happens you will need to re-set the AQM back to factory default settings, which puts the AQM back in to Access Point mode with a default password. You can then reconfigure the settings correctly. Contact technical@aeroqual.com for information on how to perform this process.

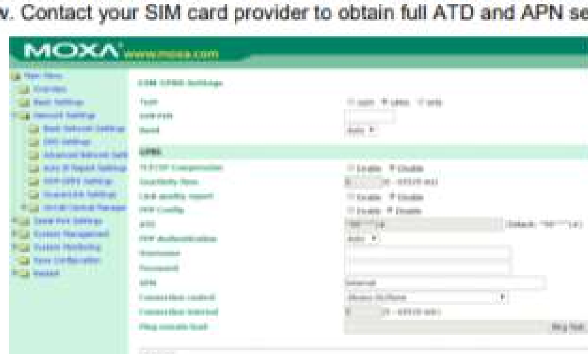
3.1.2. Cellular Network Connection

If the AQM has an IP modem installed in the instrument a connection can be made via a cellular network. This option is useful when remote access to the AQM is required but there is no local network signal at the AQM installation site so client mode cannot be used.

Note1: A local data telecommunications contract and SIM card is required.

Note 2: The AQM 65 uses approximately 30 megabytes per sensor per month. Choose a data plan appropriate to the expected data use on the AQM 65.

1. The IP modem will need to be set up by plugging directly from the modem Ethernet port to a laptop Ethernet port and browsing to 192.168.127.254.
2. In the menu select Network Settings → GSM GPRS Settings and configure settings as per picture below. Contact your SIM card provider to obtain full ATD and APN settings. Click Submit button.



3. Unplug MOXA unit from the network and plug it into AQM65 embedded PC. Restart AQM65 embedded PC and modem.
4. In the Configure Instrument application the Ethernet Mode setting needs to be set to Auto (DHCP). WiFi mode should still be set to Access Point so a direct connection can still be made.
5. If you do not wish to use Aeroqual Cloud, a DynDNS service will need to be set up to create a permanent web address for the AQM.
6. A Dyn account can be created at https://account.dyn.com/cart/?via=upgrade-now

7. Log in to your account and add a new host name:

8. Go back to MOXA modem configuration interface, and choose System Management - > Misc. Network Settings - > DDNS. Select enable and DynDns.org. Input the host name created in Dyn account, user name and password as well for the Dyn account. Then click Submit button, Save and Restart. Now the modem should be ready to be connected via host name.
9. Enter the set up web address into the web browser to access Aeroqual Connect.

Note 1: No data is stored on the DynDNS server. It only acts as an access point to communicate with the AQM.

Note 2: In some countries the telecommunications provider will block incoming requests to the modem. If this is the case DynDns will not work with regular SIM cards. Contact your telecommunications company about using an APN or use a private APN.

3.2. Aeroqual Cloud

When using Aeroqual Cloud, the user is connected to the Aeroqual Cloud server. The AQM instrument is also connected to the Cloud server. The user connects to Cloud over the internet; the AQM is connected to the Cloud server using WiFi, Ethernet or Cellular (modem required). Aeroqual Cloud is a website.

Aeroqual Cloud allows management of either a single AQM unit or a network of AQM units by using any internet-enabled browser.

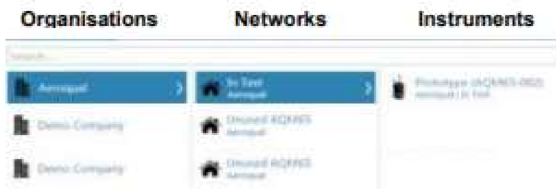
Aeroqual Cloud has all of the control features of Aeroqual Connect. The additional benefits of having Aeroqual Cloud include:

- Data from the AQM is backed up to a secure server. In Aeroqual Connect, data is only stored on the on-board PC.
- Data is available even if the instrument is turned off.
- Email and SMS alerts can be set up
- It is easy to manage multiple instruments at the same time.
- There is a faster connection when compared to Aeroqual Connect
- Reduced data costs

As a user, you simply access Aeroqual cloud through the internet; Aeroqual Cloud is a website which provides total control over your AQM. You will need to go to http://cloud.aeroqual.com and enter your login name and password.

Note 1: If you do not know your login name and password please contact technical@aeroqual.com

As well as having access to all the features available in Aeroqual Connect, Aeroqual Cloud can be used to manage a network of AQMs. Depending on the user accessibility configured to your account, AQM units can be managed by Organisations and Networks. This feature is available in the Administration application.



The AQM must have internet access for you to see it and control it using the Cloud website.
For the AQM to have internet access it must be either in Client mode, as described above, and be on a network which permits internet access (most networks do permit internet access). A modem is not required in this situation.

Or if a local network is not available, the AQM must have an IP modem installed and a SIM card and data contract with a local telecommunications provider.

3.2.1. Manual Sync

If the AQM is outside of cellular and WiFi range, the AQM data can always be downloaded to your device using a WiFi access point (see Section 2.3.1.) when at the AQM site. The data will be downloaded to an unreadable file and will include all information stored on the AQM on-board PC. The file can then be uploaded onto Aeroqual Cloud, once a WiFi or cellular network is available, to view the data from the unit, including diagnostics and settings.

To download the data: In Aeroqual Connect select Manual Sync in the Manage Data application. Here it will prompt you to select a location on your PC to download the data to.

To upload the data: In Aeroqual Cloud select Manual Sync in the Manage Data application. Here it will prompt you to upload the file which was previously downloaded from Aeroqual Connect.

Note 1: If there is a lot of data to download from Aeroqual Connect multiple manual syncs may need to be performed. The date in the manual sync function updates showing how much data has been downloaded.

Aeroqual Connect is the lead system. If both the Aeroqual Connect and Cloud systems are being run simultaneously, any changes made in Aeroqual Connect will override the changes made in Aeroqual Cloud.

3.3. Connection Scenarios

There are a number of ways to connect to the AQM instrument using Aeroqual Connect or Aeroqual Cloud. To help clarify which connection should be used please refer to the tables below which shows the 4 most common scenarios.

AQM Location	User Location	Recommended Connection
Office/Lab	Office/Lab	The AQM should be connected to the office WIFI network using client mode. You can then connect using Aeroqual Cloud. Aeroqual technicians will also be able to connect using Aeroqual Cloud if support is required. A wired Ethernet connection can also be made from the AQM direct to the local router.
AQM in the field and modem is installed	Office	If the AQM is on a 3G network permanently you can connect using Aeroqual Cloud from your office at any time.
AQM in the field and modem is installed	At AQM site	If you are in the field with the AQM, you can connect directly to the AQM via Aeroqual Connect using the AQM as an access point
AQM in the field and no modem installed	At AQM site	If you are in the field with the AQM and there is no 3G available you can connect as an access point while in the field. Use manual sync to upload data to Aeroqual Cloud when back in the office and WIFI is available.

If you are not using Aeroqual Cloud there are 3 options:

AQM Location	User Location	Recommended Connection
AQM in the field and modem is installed	Office	If the AQM is on a 3G network permanently use a DYDNS service to connect directly to the AQM via Aeroqual Connect.
AQM in the field and modem is installed	At AQM site	If you are in the field with the AQM, you can connect directly to the AQM via Aeroqual Connect using the AQM as an access point
AQM in the field	At AQM site	If there is no 3G available you can only connect to the AQM using WIFI access point whilst on site.

4. Using Aeroqual Connect and Cloud

Aeroqual Connect and Cloud have a range of applications available which allow the user to access data, assess performance, schedule calibrations and diagnose faults remotely.

4.1. Journal

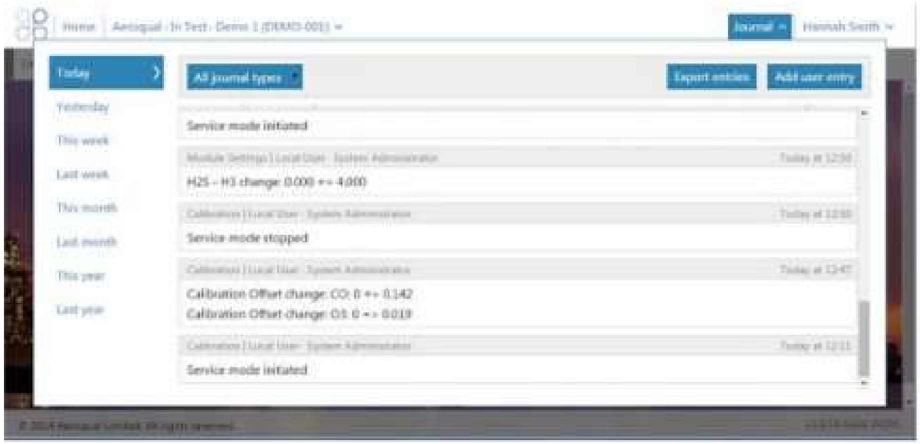
The journal can be accessed by selecting Journal on the menu bar located at the top of the screen. It is used to log when any changes are made to the AQM. The journal is searchable by date using the side bar and filtered via the drop down menu.

The filter allows entries to be searched by:

- User Entry – Manually entered journal entries
- Calibration – Changes associated to calibration e.g. gain and offset modifications and notification when service actions start and stop
- Configuration – Changes made to the AQM configuration e.g. sensor added or communications altered
- Module Settings – Changes made to the sensor module settings
- System changes – Notifies when the AQM starts up, shuts down or is rebooted

Note 1: To manually create a journal entry select "Add user entry", type in the relevant information and press save.

Note 2: Service mode is initiated by starting "Manual Service Mode" in the Calibration and Service application. A journal entry will be automatically generated when the service is started and stopped.



4.2. Manage Data

The manage data application allows the user to view the data either as a chart or in a table. There is the option to view the raw or averaged data as well as the ability to filter the data to show specific time periods. The data can also be exported for further analysis within this application.

Note: Manual sync can be found under the manage data application (See Section 3.2.1.)

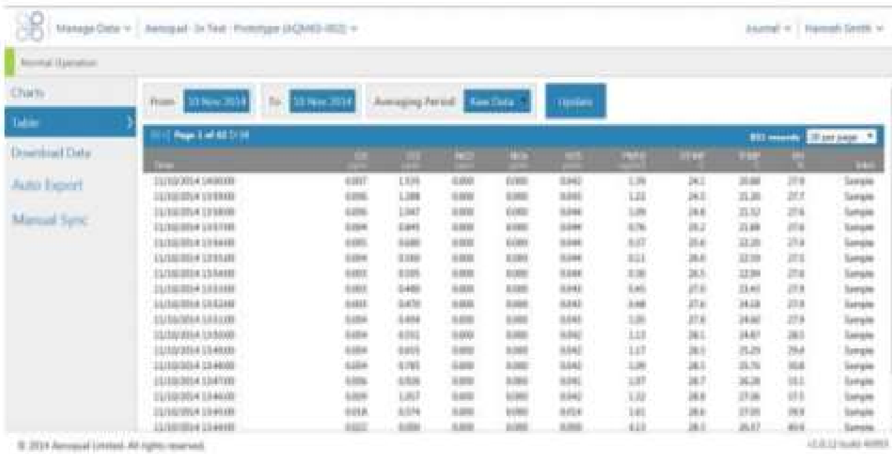
4.2.1. Charts

- To view the data in graphical format select the "Charts" option.
- The charts can be configured to view a specific time period using the "From" and "To" dates shown at the top of the screen.
- An averaging period can also be selected from the drop down menu

4.2.2. Table

- To view the data in a table select the "Table" option.
- The data can be configured to view a specific time period using the "From" and "To" dates shown at the top of the screen.

- The data can also be filtered using the "Averaging Period" drop down menu to display:
    - Raw data
    - 1 minute averages
    - 15 minute averages
    - 1 hour averages
    - 8 hour averages
    - Daily averages



Note: The Inlet column is used to show the status of the instrument. During normal running the Inlet column will display "sample". This will change to show when the unit is undergoing a calibration or service.

4.2.3. Download Data

- Data can be downloaded by selecting "Download Data".
- A specific data set can be chosen for download by using the "From" and "To" date selection.
- The Journal can also be downloaded if required.

Note: The data will be downloaded in csv. format

4.2.4. Auto Export (Only Available in Aeroqual Cloud)

The auto export option allows the data to be automatically exported to either a selected email address or to an FTP server. To set either of these features up they need to be enabled by selecting the enable check box under the auto export option.

Email: To enable auto export to a specific email the frequency, format and averaging period needs to be selected. There is also the option to include the journal in the export. Make sure a correct email address is entered and save the changes for it to take effect.

FTP: To enable auto export to a FTP server the frequency, format and averaging period needs to be selected. There is also the option to include the journal in the export. The FTP server, user name and password also need to be entered correctly. Save the changes for it to take effect.

Note: The journal captures any error messages; these are particularly useful for troubleshooting.

4.3. Calibration and Service

The calibration and service application allows the user to perform manual adjustments to the gain and offset settings for all the modules installed in the AQM. If an AirCal 8000 is installed automatic span and zero checks can also be configured in this application.

4.3.1. Gain and Offset

- Selecting the "Gain and Offset" menu will display the gain and offsets for all the configured modules in the AQM. Between 5 and 50 real time measurements will also be displayed, as well as the average and standard deviation for the shown readings. These numbers will automatically update.

- Prior to any manual calibration or servicing activities the "Manual Service Mode" button should be started. This will ensure the raw data is highlighted and labelled appropriately to show that a service is being performed. This is particularly helpful to alert when a calibration has taken place to ensure the readings are disregarded from any future data analysis.

Note 1: Any flagged data is disregarded when calculating averaged readings.

Note 2: Remember to stop the "Manual Service Mode" after the service has been completed to ensure future reported data is tagged as "Sample" data.

Note 3: The Manual Service Mode will automatically stop after 24 hours if left running.

- The calibration parameters can be adjusted manually by clicking the setting that requires changing, entering the new value and pressing save.

4.3.2. AirCal 8000

- If an AirCal 8000 is configured, the option to set up and run the calibration will be shown in the Calibration and Service application.

Note: If the AirCal 8000 tab does not appear please check the system has been set up to show the calibration system is connected. Please read Section 4.5 which explains how to do this in the Configuration application.

- Zero air and span gas can be set to release at a specific time for a chosen running period.
    1. When the calibration table (Run 1) is first accessed there will be no information in the cells describing the point configuration.
    2. To configure the points click in the relevant cell and select either Zero, Span Port 1 or Span Port 2.
    3. The dilution ratio and run time will also need to be configured for Zero, Port 1 and Port 2. This is dependent on the concentration in the gas cylinder and the concentration required for calibration.

Note 1: The dilution ratio can be calculated by using the equation and information in Section 6.3.1.

Note 2: A maximum of 5 points can be configured. This is useful if a mixed gas cylinder is being used and a different dilution ratio is required for each gas.

4. Once the table has been configured correctly the AirCal can be set to run at a user defined time on a daily, weekly or monthly basis using the configuration options above the table.

Note 4: Remember to check the "Enabled" box to initiate the schedule. Alternatively, the calibration can be run immediately by starting the "Manual Run".

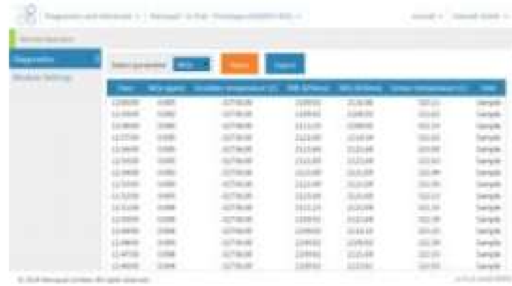
5. A maximum of 3 runs can be configured.
6. To configure the run schedule, enter the port, dilution ratio and run time information in the remaining tables under "Run 2" and "Run 3". Finally set the frequency and start time for each run to take place.

4.4. Diagnostics and Advanced

The diagnostics and advanced application allows the user to view the sensor module settings as well as the sensor diagnostics. This information is useful when fault diagnosing an issue with a module. The diagnostic data can be exported for further analysis and the sensor module settings can be updated or modified in this application.

4.4.1. Diagnostics

- The diagnostics view will display the sensor diagnostics for the selected parameter. The data can be paused or exported using the buttons above the table.
- 40 minutes of data will be displayed at a time and the data will automatically update unless the pause button is pressed.

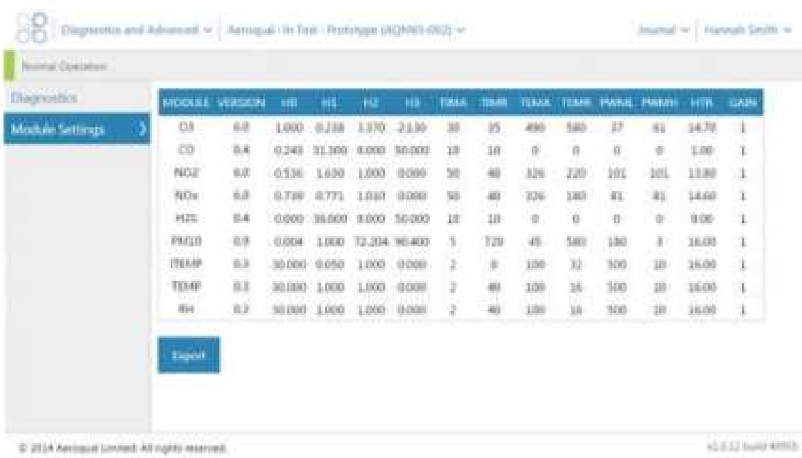


4.4.2. Module Settings

The module settings view will show the individual sensor module settings and version number for all the parameters configured inside the AQM.

- The module settings can be changed by selecting the value that needs changing, entering the new value and clicking save.

Note: Incorrect modification of sensor module settings may cause irreversible damage. Do not change settings without contacting Aeroqual or a qualified service agent.



4.5. Configure Instrument

The configure instrument application stores all the configuration settings relevant for the specific AQM connected. Depending on the user type different features will be accessible. The application can also be used to view a complete sensor list for all sensors that can be configured on the AQM, filter data and set up SMS and email alerts.

4.5.1. Settings

The settings tab is split into 4 columns which display different information relevant to the AQM.

4.5.2. Configuring the System

- The serial number is listed here. It cannot be changed and is also shown on the log book and inside the AQM enclosure.
- The name of the instrument can be set by the user, for example, to reflect the location or customer that is running the AQM
- The device, software version and time last contact was made with the cloud server is listed here for reference.
- If an AirCal 8000 is installed in the AQM the "Auto Calibration Module Installed" will be set to AirCal 8000. This will ensure the AirCal 8000 tab is displayed under the Calibration and Service application.
- The time zone of the AQM can be set here to display the correct date for the region the AQM is installed in.
- Service time out can be set here. This is important if the manual service mode is left on by accident. The time out value will stop manual service mode after the time period set.
- The restart instrument checkbox will force a restart of the embedded PC. The checkbox will be cleared automatically after restart.

4.5.3. Configuring the Sensors

- The default unit of measurement is ppm gas sensors and ug/m3 for PM sensors.
- The poll interval and poll time out functions will control how often data is polled from the AQM station to the user interface. These should not be changed.
- The active sensors will be displayed here. If a sensor module has been added the sensor will need to be selected from the drop down menu and added to the active sensors list. Sensors can also be removed by clicking on the sensor name.

Note 1: For information on the legacy section please contact Aeroqual.

Note 2: For information on the communications section please see Section 3.

4.5.4. Alerts (Only Available in Aeroqual Cloud)

SMS and email alerts can be set up in this section. Alerts can be set to notify when:

1. a concentration exceeds the user defined set point
2. a sensor fails
3. the AQM is in operation mode
4. the AQM goes offline

An email address and/or SMS number needs to be entered into the relevant fields to allow the alerts to be sent. Multiple alerts can be set up by pressing the Add a new alert button.

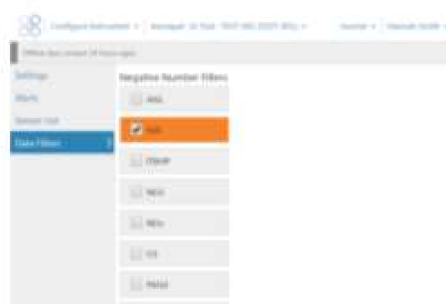
Note: Phone numbers need to be in the format +64234566 with no spaces. A space is treated as a separate phone number.

4.5.5. Sensor List

The sensor list tab displays all the sensors that can be configured into the AQM. The table is mainly for reference and shows all the settings configured for each sensor e.g. the units and conversion factors. If a new sensor list is released it can be imported in this section.

4.5.6. Data filters

The negative number filter can be turned on for specific parameters in this section. If you do not want the data to show negative numbers for certain parameters, check the checkbox of that specific parameter. Any negative numbers reported will now show as zero.



Note: The negative number filter is NOT applied to RAW readings. It is applied to all averaged readings.

5. Gas Module Calibration

Calibration is an activity that requires attention to detail and accuracy. You should read this entire calibration section and understand it before starting, even if you are an experienced practitioner.

5.1. Introduction

Key calibration concepts to understand before starting are given below.

- Zero and span adjustments on the AQM 65 are performed by adjusting the OFFSET and GAIN values which are located in the Calibration and Service application on Aeroqual Cloud/Connect. The equation that relates the OFFSET and GAIN to the instrument reading is given below:

  AQM65 Reading = GAIN x (Sensor Module Output - OFFSET)

- The gas modules in the AQM 65 are calibrated by applying certified gas to the AQM 65 inlet and monitoring their response on the Calibration and Service App in Aeroqual Cloud/Connect

- All zero and span calibrations or checks should be performed with gas mixtures in a balance of air. The calibration standard may be in a balance of nitrogen (N_2) but it should be diluted by at least 50 times with air before exposing to the AQM.

- Fluorocarbon (PTFE, PVDF, FEP or PFA) tubing should be used for all gas delivery lines to the AQM65. Fittings should be stainless steel or fluorocarbon.

- The AQM 65 is supplied with a thermal management system to maintain a stable internal temperature. You must calibrate the AQM with the door closed to enable the unit to stabilize at its correct temperature.

- Run the AQM for at least 6 hours before attempting a gas sensor calibration.

- Zero and span gas needs to have a minimum level of humidity in order for the sensors to perform correctly. This is a key difference compared with reference analyzer calibrations which are typically performed with very dry calibration gases. It is recommended that you purchase an Aircal 1000 or 8000 for calibrating the AQM65.

5.2. Calibration Gas Humidity

Aeroqual's gas sensor calibration can be adversely affected by the very dry (dew point < -20°C) air generated by third party calibration sources. It is strongly recommended that you purchase an Aircal 8000 or Aircal 1000 portable calibrator for calibrating the AQM65. These calibrators are specially designed to optimally prepare the calibration gases for the AQM65. If you are using an Aircal 8000 or an Aircal 1000 you do not need to use the additional nafion humidifier.

If you are using a third party calibrator with a dry zero air source or a cylinder of zero air then you will need to humidify the calibration gases before they are delivered to the AQM65. Aeroqual supplies with the AQM65 service kit a **nafion humidifier** for this purpose. It contains a nafion membrane from Permapure (www.permapure.com) which allows the transport of water molecules across the membrane with high selectivity and no loss of calibration gases.

Calibration system	Nafion Humidifier Required (Yes/No)
Aircal 1000	No
Aircal 8000	No
2B 306 O3 calibrator	No
Zero air generator with dryer (e.g. Teledyne 701, Sabio 1001, Environics 7000)	Yes
Zero air cylinder	Yes
Direct span injection	Yes

Nafion Humidifier Instructions for use:

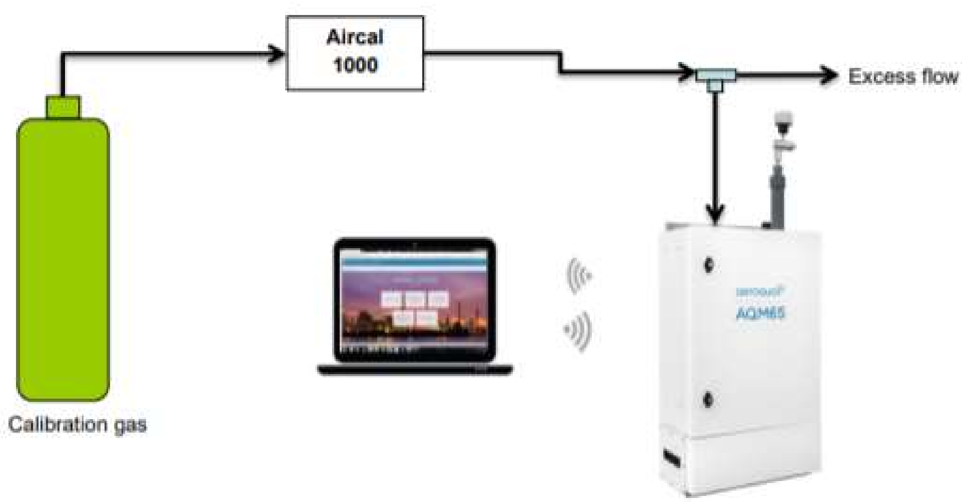
- Remove the lid and fill the humidifier with clean water up to the top of the label, covering the black internal tubing. Refit the lid.
- Connect the humidifier inline between the outlet from your dilution calibrator and the inlet of the AQM65.
- Set the calibration gas flow to a flow rate of between 3-5 LPM to generate a humidity level of 25 to 40% RH at an indoor temperature of 22°C
- The nafion tube will become contaminated over time and should be changed every 2 years.

6. Calibration setup

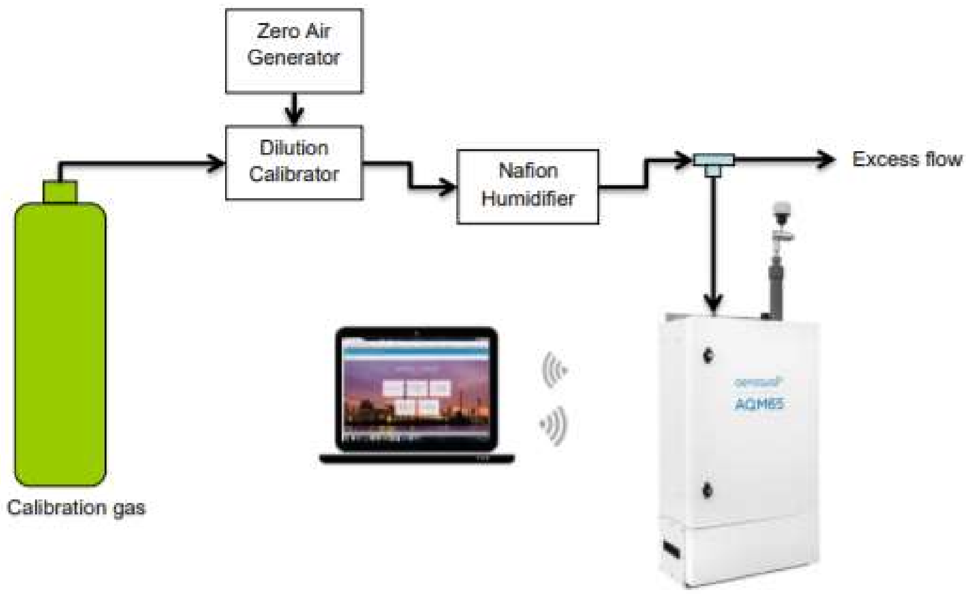
The recommended calibration setup is shown for both Aircal 1000 and third party systems in the diagrams below. The sampling cane inlet on the AQM65 should be removed and the calibration gas to be delivered to the instrument via a T fitting to allow excess flow to be vented. **Do not pressurize the AQM65.**

It is convenient to use ¼ inch OD or 6 mm OD PTFE tubing for the sample delivery lines from the calibrator to the instrument and a stainless steel or PTFE compression fitting for the T.

Aircal 1000 Calibration System



Third Party Calibration System



6.1. Zero Calibration Procedure

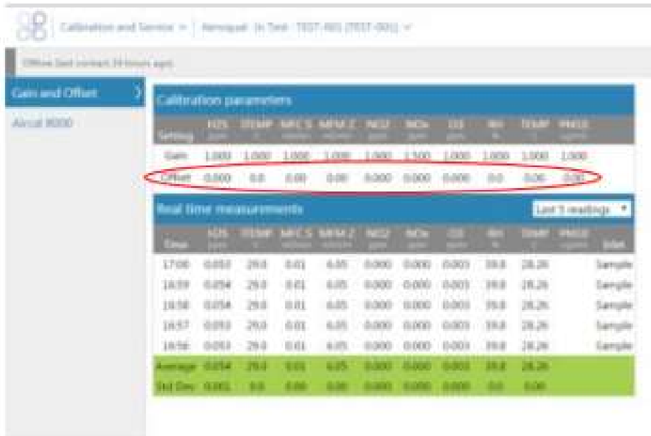
1. Ensure the AQM65 has been powered on for at least 6 hours before starting, the door is closed and the internal temperature is stable.
2. Check the sample inlet flow to make sure it matches the factory performance report value. If not check for leaks. Do not proceed further until you are satisfied the sample flow is correct.
3. Setup the required calibration equipment, login to Aeroqual Cloud/Connect and launch the Calibration and Service App.
4. Turn on the zero air to the AQM and establish a flow rate 2-4 LPM to the T-fitting.
5. Check there is excess flow at the exhaust of the T-fitting
6. Allow the AQM to sample the zero air until stable readings are obtained (about 30 minutes) on the Real time measurements window. If the Real time Average readings are outside the acceptable limits in the table below then the gas sensor modules will require an OFFSET adjustment. If the average readings are within the acceptable limits then the OFFSET does not need to be changed.

Sensor	Acceptable average zero reading/ ppm
O3, NO2, NOx, SO2, H2S	0.000 +/- 0.002
CO	0.000 +/- 0.050
NMHC	0.000 +/- 0.050
PID	0.000 +/- 0.010
CO2	0 +/- 10

7. To calculate the new OFFSET for each sensor use the equation below.

New OFFSET = Old OFFSET + (AQM 65 gas reading/Gain factor)

8. Adjust the OFFSET values for each gas sensor in the Calibration and Service application by entering the new value in the table circled in red in the picture below.



6.2. Span Calibration Procedure

1. Please perform a zero calibration before starting a span. Confirm the sample flow is correct, the door is closed and the internal temperature is stable.
2. Setup the required calibration equipment, login to Aeroqual Cloud/Connect and launch the Calibration and Service App.
3. Turn on the span gas to the AQM and establish a flow rate 1-4 LPM to the T-fitting.
4. Check there is excess flow at the exhaust of the T-fitting and this vented safely.
5. Allow the AQM to sample the span gas until stable readings are obtained (about 30 minutes) on the Real time measurements window. If the Real time Average readings are outside of the acceptable limits for the span point (see section 6.2.1) then the gas sensor modules will require a GAIN adjustment. If the average readings are within the acceptable limits then the GAIN does not need to be changed.
6. Calculate the new gain.

New Gain factor = Old Gain factor x Span Gas Concentration / AQM 65 Gas Reading

7. Adjust the GAIN values for each gas sensor in the Calibration and Service application by entering the new GAIN directly into the table circled in red in the picture below.

Note: All calibration adjustments are recorded in the Journal

6.2.1. Recommended Span Points and Acceptance limits

A table of recommended single span concentrations for AQM sensor modules is given in the table below as well as the acceptance limits for the points. A more detailed table of calibration points including gas standards is given in section

Gas	Span Point / ppm	Acceptance limits
O3, NO2	0.1	+/- 0.005
NOx	0.2	+/- 0.010
CO	5	+/-0.1
VOC (isobutylene)	10	+/-0.5
SO2, H2S	0.2	+/-0.01
NMHC (isobutylene)	10	+/-0.5
CO_2	1000	+/-40
PID (isobutylene)	10	+/-0.2

6.2.2. Gas Phase Titrations

A dilution calibrator with a built in O3 source will allow a Gas Phase Titration (GPT) of NO to NO2. The advantage of this method of generating NO2 is that it enables the use of the more stable NO gas for NO2 sensor calibrations. The Aircal 1000 does not have this facility. If you plan to use a calibrator with GPT capability you should only use a small excess of O3 (<0.025 ppm) because excessive O3 may adversely affect the NO2 calibration.

Alternatively use an excess of NO to enable a NOx calibration simultaneously. For example, a setting of 0.2 NO and 0.1 O3 would produce 0.1 ppm NO2 and 0.2 ppm NOx.

6.3. AirCal 8000 (Optional)

The AirCal 8000 is an integrated calibration system for the AQM 65. It consists of three main components:

1. **Housing:** Gas cylinder housing with regulators
2. **Gas Dilution Module:** 2 span gas inputs with a zero air mass flow meter (MFM) 0-3 SLPM and a mass flow controller (MFC) 0-0.05 SLPM.
3. **Zero Air Source:** Scrubbing media activated carbon, Purafil chemisorbant and heated carulite

6.3.1. Overview

The AirCal system delivers a controlled concentration of calibration gas for calibration of ambient gas instruments. To do this the calibration gas inside the cylinder is mixed with zero air, which is generated by the scrubbing material inside the AirCal 8000 module. The calibration gas is therefore diluted by the zero air to provide a given concentration which is directed into the AQM 65. The concentration of calibration gas is calculated using a dilution ratio which is determined by the zero air and cylinder gas flow rates.

The zero air generator will deliver a flow rate of approximately 2 – 2.5 LPM. The flow rate of the zero air is monitored using a mass flow meter (MFM).

The flow rate of the cylinder gas is controlled dynamically using a mass flow controller (MFC). The cylinder gas flow rate can range from between 0.005 – 0.045 LPM. The MFC will adjust the flow of the calibration gas so as to maintain a user defined dilution ratio according the equation:

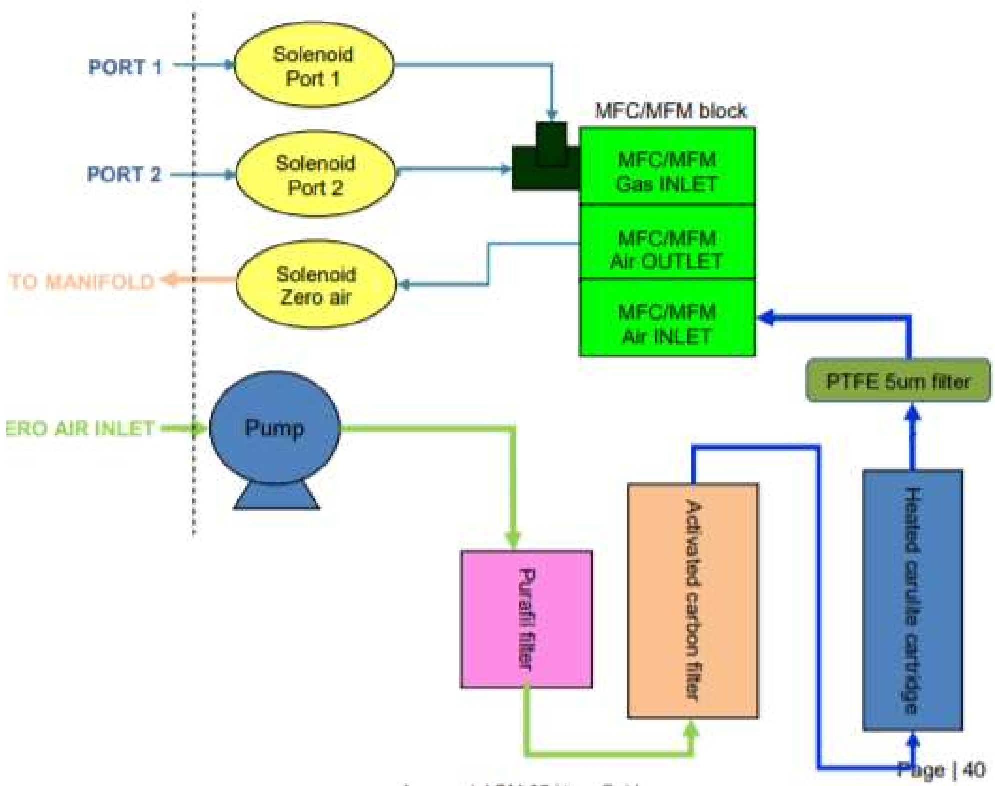
$$MFC = \frac{MFM}{(Dilution\ Ratio - 1)}$$

The user dilution ratio needs to be calculated in order to deliver the required concentration of calibration gas.

Example: If 10ppm of CO was required and the cylinder concentration is 1000ppm, then the required dilution ratio would be 100. The dilution ratio of 100 will be entered into the table located in the AirCal 8000 tab under the Calibration and Service Application. The MFC flow rate will automatically adjust to meet the desired calibration gas concentration.

Note: The MFM and MFC flow rates can be logged and displayed in Aeroqual Connect/Cloud by adding them to the sensor list (see Section 4.5.3.).
Note: All AirCal 8000 procedures will be logged in the Journal.

The pneumatics of the AirCal 8000 system can be seen below:



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6.3.1. Gas cylinder Housing

Gas bottles

The AirCal 8000 system allows for two gas bottles to be contained in a secure compartment on the side wall of the AQM enclosure.

To achieve the best performance from the AirCal 8000 it is important to connect gas cylinders with gas concentrations which are appropriate for the calibration being performed. Example cylinder concentrations are as follows:

Gas	Recommended Cylinder concentration ppm	Maximum Concentration Achievable ppm	Minimum concentration achievable ppm
CO	1000	20	2
NO / NO2	20	0.4	0.04
Isobutylene for PID / NMHC	1000	20	2
SO2 / H2S	50	1	0.2

Note 1: The recommended dilution ratio range is between 50 and 500
Note 2: If the cylinder contains calibration gas in a balance of Nitrogen, a minimum dilution ratio of 50 should be used

Gas lines in to AQM

The regulator provides gas into the AQM via 1/8 OD stainless steel tube with a 1/8 compression fitting at the end of the tube to allow connection to the regulator.

Regulators

The AirCal 8000 comes supplied with 2x two stage regulators designed for Calgaz style bottles. The maximum input pressure allowed into the first stage is 3000 psi. The inlet fitting is a ¼ FNPT. The regulator is also supplied with a ¼ FNPT to 5/8 x 18 thread fitting which will allow it to be attached to many commercially available gas cylinders including the Calgaz range.

The outlet fitting from the regulator is a 1/8 FNPT thread fitting. The regulator is supplied with a 1/8 FNPT to ¼ Swagelok compression fitting.

Gas Connection

Screw the gas cylinder into the stainless steel regulator and adjust the pressure valve (screw in) until the outlet pressure is 9 PSI.

6.3.2. Configuring the AirCal 8000 scheduler

Calibration can be configured to run at a set time for a chosen running period. See Section 4.3.2. for information on setting up the run scheduler in Aeroqual Connect/Cloud. The gain and offset parameters can then be adjusted as described in Section 6.1. and 6.2.

6.4. Calibration Standards and Equipment

6.4.1. Calibration Gas

There are several considerations to be made when selecting gases for span calibration of the AQM. The first is which gas composition to purchase and at what concentration. The size of gas cylinder must also be considered.

The gases required for performing a calibration using the direct method are different from those needed to perform a calibration using the dilution method. Aeroqual does not recommend direct delivery of calibration gas standards.

Dilution Method

Calibration gas is purchased at high concentrations and is then diluted to the appropriate span concentrations. The gas can be purchased in a balance of air or nitrogen. If you purchase the AirCal1000 or AirCal8000, you will perform a zero calibration with the built in zero air generator without the need to purchase a cylinder of zero air.

Direct Method

In this method the calibration gas is not diluted but directly delivered from the cylinder to the instrument. This is not recommended because most gases are not stable for long at the low concentrations used by the AQM65. If this method is used you must purchase span gas with balance of air only. If you are calibrating using the direct method, you will also need to purchase a cylinder of **certified zero air** in order to perform a zero (baseline) calibration. You will also need to humidify the gas if using the nafion humidifier.

6.4.2. Recommended Span points and Cylinder concentrations

MODULE	O3	NO2	NOx	CO	SO2	PID	CO2	H2S	NMHC
Module Span Range	0.5 ppm	0.2 ppm	0.5 ppm	25 ppm	10 ppm	20 ppm	2000 ppm	10 ppm	25 ppm
Recommended Span Gas	O3	NO2	NO (or NO2)	CO	SO2	C4H8	CO2	H2S	C4H8
Recommended single span point	0.1	0.1	0.2	10	0.25	10	1000	0.25	10
Recommended 5 point linearity checks	0.2, 0.150, 0.1, 0.05, 0	0.2, 0.15, 0.1, 0.05,0	0.5, 0.25, 0.1, 0.05, 0	20, 10, 5, 2.5, 0	0.5, 0.25, 0.1, 0.05, 0	20, 10, 5, 2.5, 0	1000, 750, 500, 250, 0	0.5, 0.25, 0.1, 0.05, 0	20, 10, 5, 2.5, 0
Recommended cylinder concentrations for dilution method	N/A	25	50	1000	25	1000	50000	25	1000
Recommended cylinder/source concentrations for direct method (Balance air)	0.1	0.1	0.2	10	0.25	10	1000	0.25	10

6.4.3. Gas cylinders

There are many cylinder sizes available from small portable cylinders through to larger cylinders. Both the small and large gas cylinders can be used to calibrate the AQM. The smaller cylinders are more

convenient especially for field calibrations, the larger cylinders will last longer but will be more difficult to transport to the site where the AQM is installed and these issues should be considered when selecting a cylinder size.
It is important to understand how long your gas cylinder will last so that you can plan your gas cylinder purchases. To plan your purchases you must understand:

1. What volume of gas your cylinder holds
2. How much gas you will use per calibration
3. The frequency of calibrations
4. The number of AQM stations requiring calibration
5. The expiry date of the calibration gas (different gases have different expiry dates)

A few considerations to remember:

- Smaller gas cylinders, such as the 58L size from CalGaz, hold approximately 58 litres of calibration gas.
- As a general rule (a conservative estimate) you will use approximately 1 to 2 litres of gas per AQM gas module when performing a calibration if using the dilution method.
- You will use 15 to 30 litres per calibration if using the direct method. Depending on what calibration frequency you decide upon, you can then calculate how long the cylinder will last.

The three images below demonstrate a small portable gas cylinder (size 58L) from CalGaz, and a large and medium size cylinder from AirLiquide. All sizes are suitable for use with the Aeroqual Aircal1000 and AQM, the decision as to which size is best to use is based upon the considerations discussed above.



6.4.4. Gas regulators

You must make sure that the regulator you purchase fits onto your gas cylinder. Note that different cylinders have different fittings. Your gas cylinder supplier should be able to recommend or supply either a suitable fixed flow regulator or a two stage regulator depending on your needs. The same regulator may not be able to be used for all gases because of incompatibilities between the material of the regulator and the gas, make sure you check the regulator/gas compatibility with your regulator supplier.

A two stage pressure regulator is recommended for all gas cylinders for best control and safety. An example of a suitable two stage regular for use with Calgaz type bottles is the **Model 1001 CGA** available from Aeroqual (see regulator on the left image below).

If you need to calibrate using the direct method you will need to purchase a flow regulator. The flow rate should exceed the inlet flow rate of your AQM. The recommended fixed flow rate is 1.0 LPM. An example of a fixed flow regulator is shown on the right hand image.

Regulator gas fittings: Barb vs Compression fitting

It is also important to make sure you have the correct gas outlet fitting on the regulator. A barb fitting is **not** suitable for use with the pressure regulator (dilution calibration method). For this you will need to purchase a gas compression fitting like that shown in the images below. A barb fitting is acceptable if the fixed flow regulator (direct calibration method) is being used. Your regulator supplier may or may not be able to supply a suitable fitting.

6.4.5. Recommended fittings and tubing for Aircal 1000

The Aeroqual AirCal1000 gas inlet ports are stainless steel 1/8" compression fittings. Aeroqual recommends using 1/8" OD PTFE tubing for calibration gas which requires 1/8" compression fittings to connect the AirCal1000 to the pressure regulator. The fitting on the AirCal1000 comes with the appropriate compression fitting, but you must complete the connection to the gas regulator.

If your pressure regulator has a 1/8" Female NPT thread you should purchase part number **SS-200-1-2** from Swagelok This is fitting 1 in the above image.

If your pressure regulator has a ¼" Female NPT thread you should purchase part number **SS-200-1-4** from Swagelok This is fitting 2 in the above image.

See the following video for WHEN and HOW to apply PTFE tape.
http://norcal.swagelok.com/blog/bid/88017/Skill-Applying-PTFE-tape-to-tapered-pipe-threads

6.5. Calibration Frequency

Calibration is an activity that requires attention to detail and accuracy and therefore its frequency is a balance between the costs of service and data uncertainty. For some applications such as compliance monitoring the calibration frequency may be regulated, for others it is a choice. The optimum frequency will depend on the importance of the dataset, the support budget and the stability of the instrument under the prevailing conditions. At the high cost end of the spectrum are national ambient monitoring networks and the USEPA Quality Assurance Handbook (see http://www.epa.gov/ttnamti1/qalist.html) is a good example of how prescriptive calibration requirements for such applications can be.

Aeroqual makes the following recommendations about calibration frequency for the AQM65

1. Follow all regulatory calibration requirements if these are defined for the AQM65 monitoring purpose.
2. Always calibrate or check the instrument response after the following events:
   - Relocation of the instrument
   - Repairs or service that might affect its calibration
   - A power interruption in operation of more than a few days
   - Upon any indication of instrument malfunction or change in calibration

3. Plan routine calibrations at an interval that is consistent with the importance of the data quality. Calibration interval guidance is given in the table below.

Maximum AQM65 calibration intervals for different environmental conditions and required data quality.

	Environmental Conditions		
Data Quality	**Benign**	**Moderate**	**Demanding**
Highest	Monthly	2 weeks	1 week
Medium	2 month	1 month	2 weeks
Lower	3 month	6 weeks	3 month

7. Third Party Sensors

7.1. Met One MSO

Description: Measures wind speed and direction; air temperature; relative humidity; and barometric pressure

Specifications: For full details visit the company website www.metone.com

Wind Speed	
Range	0-50 m/s
Accuracy	±2%
Resolution	0.1 m/s
Wind Direction	
Range	0-360°
Accuracy	±5°
Resolution	1°
Air Temperature	
Range	-40°C - +60°C
Accuracy	±0.5°C
Resolution	0.1°C
Relative Humidity	
Range	0-100%
Accuracy	±4%
Resolution	1%
Barometric Pressure	
Range	500-1100 mbars
Accuracy	± 2 mbars
Resolution	0.1 mbar

7.2. Vaisala Weather Transmitter WXT520

Description: Measures wind speed and direction; liquid precipitation; barometric pressure; air temperature; and relative humidity

Specifications: For full details visit the company website www.vaisala.com

Wind Speed	
Range	0-60 m/s
Accuracy	±3% (0-35 m/s)
Wind Direction	
Range	0-360°
Accuracy	±3°
Liquid Precipitation	
Rainfall	
Output Resolution	0.1mm/min
Barometric Pressure	
Range	600-1100 hPa
Accuracy	±1 hPa @ -52 to +60 °C
Air Temperature	
Range	-52 to +60 °C
Accuracy @ +20 °C	±0.3 °C
Relative Humidity	

Measurement range Accuracy	0-100 %RH ±3 %RH (0-90 %RH); ±5 %RH (90-100 %RH)

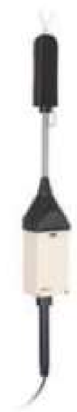
7.3. Gill WindSonic

Description:	2-axis ultrasonic wind sensor, measures wind speed and direction
Specifications:	For full details visit the company website www.gill.co.uk

Wind Speed	
Range	0-60 m/s
Accuracy	±2° @ 12 m/s
Resolution	0.01 m/s
Wind Direction	
Range	0-359° (no dead band)
Accuracy	±3° @ 12 m/s
Resolution	1 °

7.4. Cirrus MK427 Noise Sensor

Description:	Outdoor environmental noise meter:
Specifications:	For full details visit the website www.cirrus-environmental.com/



Frequency Weighting	dB(A) to IEC 61672-1:2002
Automatic Calibration	Electrostatic Actuator System with DC voltage control
Measurement Range	30 – 100dB(A)
Resolution	0.1 dBA

7.5. Novalynx 240-200SZ Silicon Pyranometer

Description: Outdoor environmental solar radiation meter:

Specifications: For full details visit the website www.novalynx.com/

Sensor	High stability silicon voltaic detector
Accuracy	± 5% typical under natural daylight conditions
Sensitivity	100 µA per 1000 W/m² typical
Linearity	Max deviation of 1% up to 3000 W/m²
Resolution	0.1 W/m²
Temperature dependence	0.15% per °C max
Operating temperature	-40°C to +65°C (-40°F to +149°F)

8. Field Installation

8.1. Site Selection

Careful consideration needs to be taken when selecting the air quality monitoring site.

The key AQM site selection considerations are:

1. **Placement** - local walls, buildings, trees etc. will affect the gas concentrations at a micro-spatial level. Please refer to the discussion of placement guidelines written by the EPA in document *40 CFR 58, Appendix E.*

2. **Access** – the AQM 65 will require servicing and calibration. Therefore the site should be easily accessible for personnel to undertake calibration without placing themselves at risk. The site may also need to be secure so care is needed to ensure both accessibility and security is taken into account.

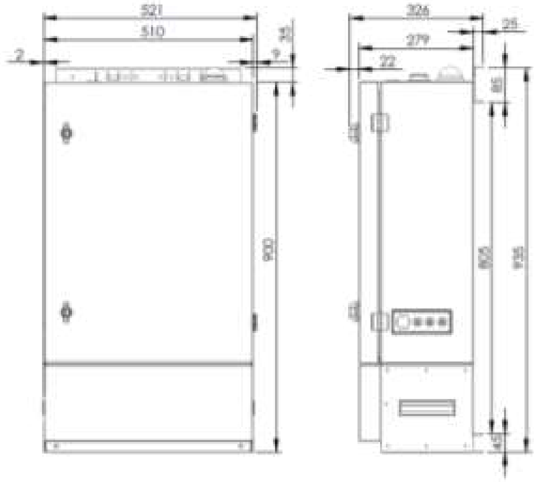
3. **Environmental** - the installation site should be selected to minimize exposure to
   - Dust (avoid sites where windblown soil and debris is present)
   - Vibration (avoid support structures close to trains, trams, heavy trucks)
   - Weather extremes (avoid solar exposure, wind chill)
   - Power outages (fit a UPS if power outages are expected)

4. **Interferences** - the site should be selected to minimize exposure to interferences from point sources such as industrial plant, restaurants, swimming pools, etc. unless the purpose is specifically to monitor such sites. If in doubt please contact Aeroqual.

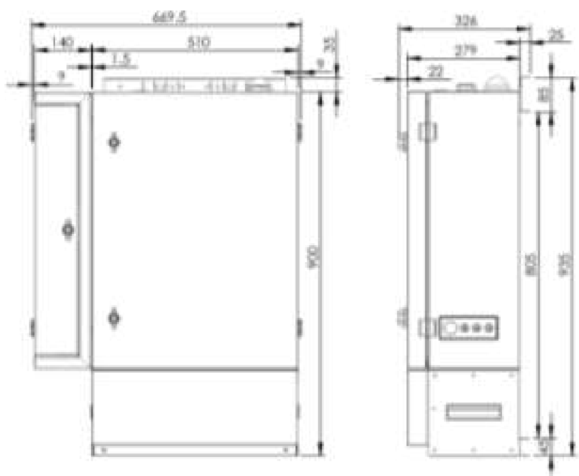
8.2. Dimensions

The AQM 65 dimensions can be seen in the diagrams below.

Standard AQM 65



AQM 65 with AirCal 8000



Note 1: The dimensions are reported in mm

Note 2: The PM inlet will add an additional 480mm to the height of the AQM 65

8.3. Mounting

The AQM 65 unit is approximately 30kg and therefore needs a foundation to support this weight.

The AQM 65 comes with a pole mounting kit. This consists of two sets of U bolts with 4 nuts and 4 spring washers. This provides flexibility as to where the unit can be mounted. The U bolts specifications are 3-1/2 PIPE X 3/8 304 U BOLT.

If a sample inlet extension is required, use inert tubing such as PTFE or PFA smooth wall tubing to minimize contamination and reaction of the sample line. Maximum recommended length is 5 m.

9. Maintenance

9.1. Safety Requirements

- Replacement of any part should only be carried out by qualified personnel using only parts from the manufacturer
- Always disconnect power source before removing or replacing any components
- Surfaces marked with a "Caution, Hot Surface" and an internationally recognised symbol may get hot and deliver burns
- If installed, the 80180 Particle Monitor is a Class 1 laser product and is not considered dangerous if used correctly. It should not be powered up with the cover removed.

9.2. Maintenance Schedule

The following tables outline a typical periodic maintenance schedule for the AQM 65, Particle Monitor and Profiler. This schedule is based on experience under normal conditions and may need to be modified to suit specific operating conditions. Calibration checks are normally performed at an interval consistent with regulatory policy or if none exists, consistent with the data use.

Maintenance instructions for all other third party equipment can be found in the relevant User Guide for that instrument. These can be found on the USB stick supplied with your instrument.

9.2.1. Standard AQM

Procedure	Section	Frequency
Change AQM Inlet Filter	7.3.1.	Weekly
Gas Sensor Zero/Span Calibration	4.0.	Monthly
Check Sample Inlet Flow Rate	7.3.2.	Quarterly
Check Gas Sensor Module Flow Rate	7.3.3.	Yearly
Leak Check Gas Sensor Plumbing	7.3.3.	Yearly

9.2.2. Particle Monitor

Procedure	Section	Frequency
Sample Flow Check	7.4.1.	Monthly
Purge Flow Check	7.4.2.	Monthly
Sheath Flow Check	7.4.3.	Monthly
Manual Zero Air Check	7.4.5.	Monthly
Fibre Span Check	7.4.6.	Monthly
Laser current check	7.4.7.	Monthly
Filter Changes	7.4.8.	6 to 12 months
Cyclone and Inlet Cleaning	7.4.9.	3 Months
Cyclone Disassembly	7.4.9.	12 Months
Optical sensor factory calibration	Contact Aeroqual	24 Months

9.2.3. Profiler

Procedure	Section	Frequency
Sample Flow Check	7.5.1.	Monthly
Sheath Flow Check	7.5.2.	Monthly
Manual Zero Air Check	7.4.5.	Monthly
Filter Changes	7.5.4.	6 to 12 months
Inlet Cleaning	7.5.5.	6 months
Factory Calibration	Contact Aeroqual	Annual

9.3. AQM Maintenance Procedures

9.3.1. Replacing the Inlet Filter

The 5µm inlet filter should be replaced every 1-2 weeks depending on the specific conditions of the monitoring environment. Unscrew and unplug the filter and replace. Ensure there are no leaks at the seal when new filter is installed.

9.3.2. Measuring Sample Inlet Flow Rate

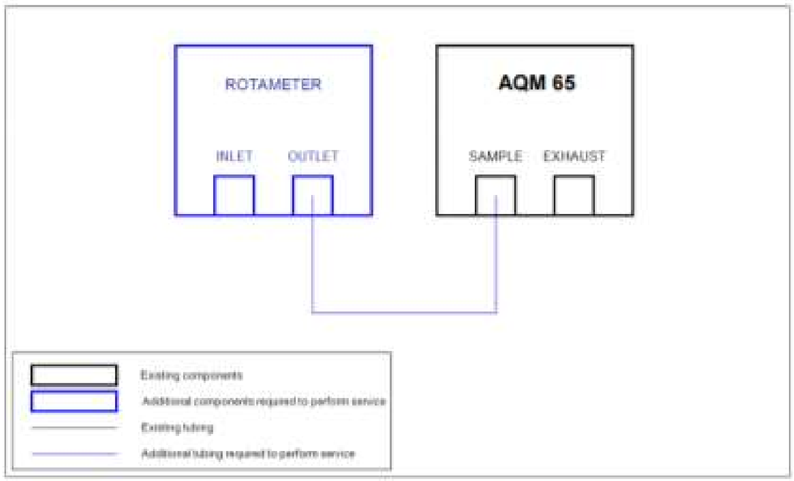
Using a volumetric flow meter record the flow on the AQM sample inlet. Check it is the same as the inlet flow stated in the AQM 65 logbook. Connect the air outlet side of the flow meter to the sample inlet and leave the air inlet side of the flow meter open to atmosphere.

Note: The inlet flow can also be measured via connection of the flow meter to the inlet filter.

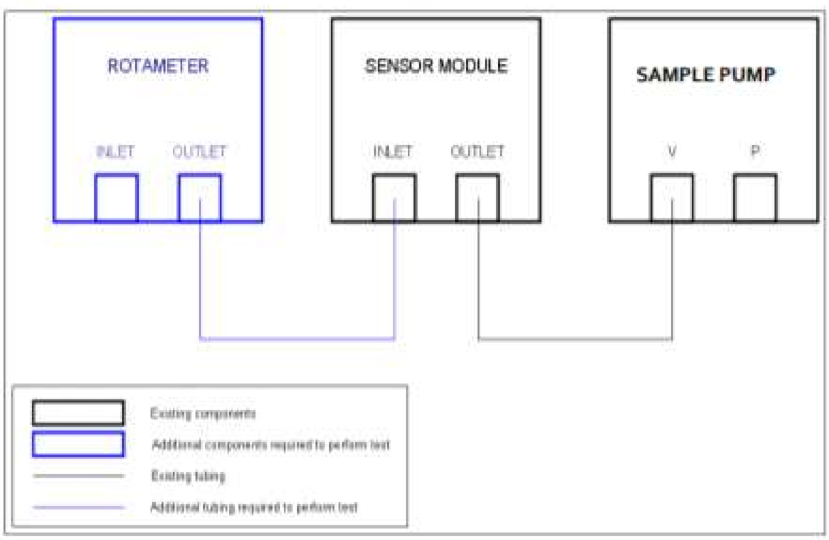
9.3.3. Gas Sensor Module Flow Rate

Using a volumetric flow meter record the flow on the gas sensor module inlet.

- Disconnect the sample inlet connection from the gas sensor module and connect the volumetric flow meter.
- Connect the air outlet side of the flow meter to the gas sensor module inlet and leave the air inlet side of the flow meter open to atmosphere.



- Verify that the module flow rates are within the expected levels as shown in the table below.



Note 3: The sum of the module flow rates should be equal to the sample inlet flow rate.

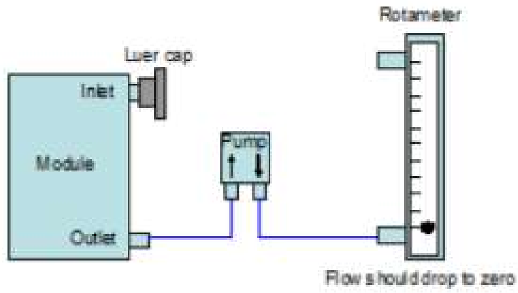
Module	**Inlet Flow (LPM)**
AQM sample inlet flow depends on configuration	0.060 to 1.5 LPM
PM10 & PM2.5 sample	2.000 LPM
PM10 & PM2.5 sheath	0.100 LPM
PM10 & PM2.5 flow during zero cycle	0.3 to 0.5 LPM
Particle Profiler inlet and exhaust	1.0 LPM
Ozone	0.100 to 0.150
NO2	0.055 to 0.065
CO	0.100 to 0.150
SO2	0.055 to 0.065
H2S	0.055 to 0.065
VOC	0.100 to 0.150
NMHC	0.100 to 0.150
CO2	0.100 to 0.150
PID	0.100 to 0.150

9.3.4. Leak Check Gas Sensor Plumbing

You will need a 0-2 LPM flow meter and a 0-0.5 LPM flow meter, tubing, and a 2 LPM diaphragm pump

Sensor Modules

- O_3 and NO_2 modules can be leak tested by attaching a 0-0.5 LPM flow meter to the outlet and checking that the flow drops to 0 LPM when the inlet is blocked off. If not there is a leak. Disassemble the module and check the connections and tubing. If no obvious leaks are found the module should be reassembled and returned to the manufacturer.
- Other gas modules should be leak tested by disconnecting the inlet and outlet tubing. Connect a diaphragm pump to the outlet of the module and check the flow drops to 0 LPM when the inlet is blocked off. If not there is a leak. Disassemble the module and check the connections and tubing. If no obvious leaks are found the module should be reassembled and returned to the manufacturer.



9.3.5. Removing and Replacing AQM Modules

All modules are mounted onto the base plate with 4 screws.

To remove a module, follow these steps:

1. Turn off AQM
2. Remove all air tubes, plugs and cabling fitted to the particular module.
3. Loosen the 4 screws holding the module to the base plate.
4. Slide the module into the screw holder slots and remove module.
5. Cap the un-used tubing connections to avoid contamination with luer caps supplied with the unit.
6. Ensure that the power and communication connections are reconnected for all modules.
7. Reconfigure the active sensor list under the Configure Instrument application to represent the new module configuration.

To replace the sensor module reverse this process ensuring that the module fixes back onto the base plate securely and that the air tubes are replaced and firmly fitted to prevent any air leakage.

9.4. Particle Monitor

9.4.1. Sample Flow Check

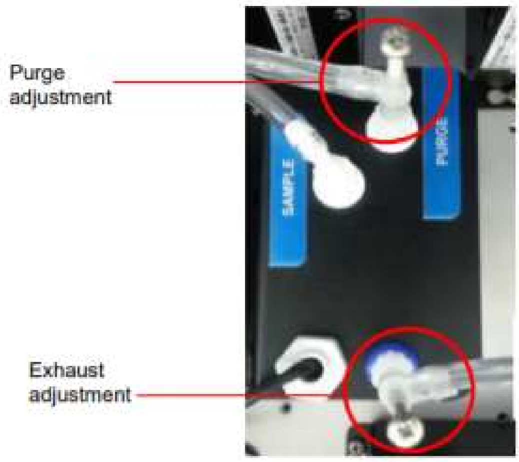
A constant flow is essential to ensure the sharp cut cyclone is separating out the correct particle size to be measured e.g. PM10 or PM2.5. To measure the flow, remove the TSP head from the inlet and connect the volumetric flow meter to the top of the sharp cut cyclone using the adaptor supplied with the instrument. Ensure the flow meter is on a steady surface before reading the flow rate.

Note 1: The adaptor tubing should be connected to the TOP of the volumetric flow meter (negative flow)

The PM inlet flow can be adjusted via the flow adjuster on the exhaust and purge line.

- If the flow is **less than** 2.0 LPM then **close the purge flow screw** (turn clockwise) until 2.0 LPM is achieved.
- If the flow is **greater than** 2.0 LPM then **open the purge flow screw** (turn anticlockwise) until the flow is 2.0 LPM.
- If you can't adjust the flow to 2 LPM using the purge flow screw then close (clockwise) the exhaust flow screw until 2.0 LPM is achieved.

Afterwards replace the inlet components with care making sure there is no leak.



9.4.2. Purge Flow Check

Initiate the purge cycle in Aeroqual Connect or Cloud. The purge cycle is designed to pump air backwards through the optical engine as a cleaning mechanism. It also acts as a zero air check and adjusts the zero automatically. This will occur every 12 hours (720 minutes) automatically. To check the purge flow is operating correctly:

- Enter the Diagnostics and Advanced application and select the Module Settings tab.
- In the settings table change the TIMA for the PM parameter to 1.000 (1minute) and click save.

Use a volumetric flow meter to record the flow using the same steps as measuring the sample flow.

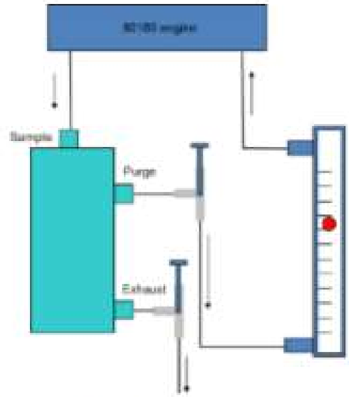
Note 1: The adaptor tubing needs to be connected to the BOTTOM of the volumetric flow meter (positive flow)

Note 2: The flow rate should be > 0.3 LPM

If the flow is less than 0.3 LPM then open the Purge Adjuster by turning the adjustment anti-clockwise until 0.3 LPM is reached.

Note 3: Remember to reset the TIMA to 720. It may take a few moments for the purge cycle to complete. The unit can also be restarted to stop the purge cycle.

Note 4: It is important to re-measure the inlet sample flow rate following a purge flow adjustment. The sample flow rate must be stable at 2.0 LPM.



9.4.3. Sheath Flow Check

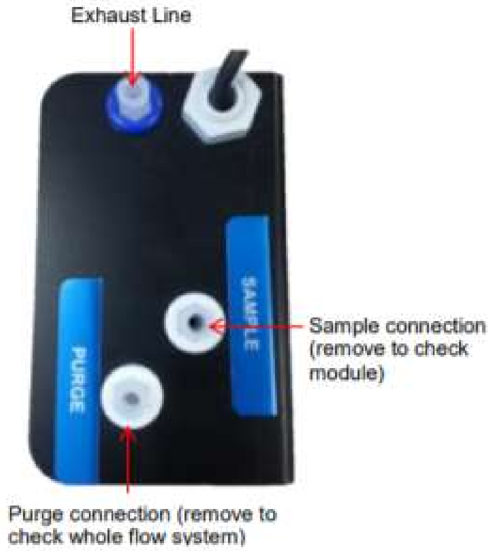
The sheath flow is a constant stream of air which ensures the optics remains clean. It is important this is working correctly to maintain the accuracy of the measurement. In order to check the flow, a volumetric flow meter needs to be connected between the purge flow adjuster and particle engine as seen in the diagram.

Note 1: The flow should be approximately 0.2 LPM

9.4.4. Leak Check

If the correct sample, purge or sheath flow cannot be achieved, there may be a leak in the pump module or 80180 engine. First check the entire flow system:

- Remove the purge connection from the module and plug the end of the purge line
- Remove the TSP head and block the PM inlet.
- Connected the pressure end of a flow meter to the exhaust port of the module.
- If there is no leak the flow should drop to zero.



If the flow does not drop to zero it suggests there is a leak somewhere in the system. To check the pump module:

- Keep the purge line disconnected.
- Remove the sample connection and cap off the module sample port.
- Connect the exhaust port of the module to the pressure end of a flow meter.
- The flow should drop to zero.

If there is no leak in the pump system check the tubing and connectors along the flow path carefully. If you cannot isolate the leak it is likely the leak is located in the engine. In this case, the engine will need to be sent back to the Aeroqual factory. Please contact technical support.

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If there is a leak in the pump system the tubing should be checked. If the source of the leak cannot be found, the module will need to be sent back to the Aeroqual factory. Please contact technical support.

9.4.5. Manual Zero Air Check

A zero air check can also be carried out manually as a way to ensure the purge is working correctly. To do this the TSP inlet needs to be removed and the particle filter (supplied in the service kit) needs to be attached to the monitor. Ensure there is a good seal around the cyclone inlet.

The filter will remove 99.99% of particulates from ambient air. Wait 5 minutes and then check the readings on the control module. The reported value should be 0 +/- 3 µg/m3. If it is not then the auto zero cycle is not performing correctly. You will need to check the purge filter (Section 8.4.8.) and replace if dirty and also check the purge flow to make sure it is correct.

9.4.6. Fibre Span Check

Perform a manual zero air check first then initiate the fibre span by turning the switch on the Particle Monitor to on. The fibre span check is used to detect any major component failures such as the laser, photo detector or lens. Wait approximately 4 minutes until the measurement value increases and record the PM10 measurement from the controller. The fibre span measurement should be within ± 20% of the fibre span concentration noted in the logbook. If it is significantly lower, then either the module optics are dirty or the laser is ageing. Contact Aeroqual for advice.

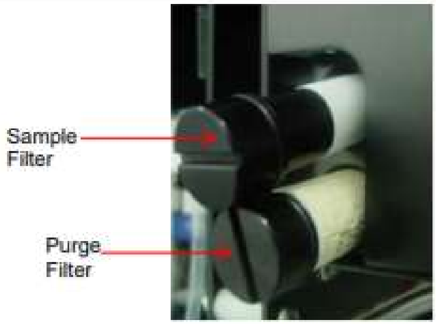
9.4.7. Laser Current Check.

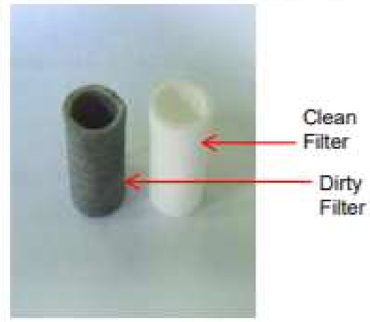
To determine the laser current go to the Diagnostics and Advanced application and select the Diagnostics tab. The column titled "Laser current (mA)" will provide the laser current reading. If the laser current has drifted up or down by more than 3mA, the engine may need servicing; please contact Aeroqual for advice.

Note: The laser current should be stable at 12 ±3 mA

9.4.8. Filter Changes

There are two internal filters which are located on the side of the optical engine. They are designed to provide protection and clean purge air. These will become dirty and must be replaced periodically.
To do this, unscrew the filters from the side of the optical engine and replace with new filters. These can be purchased from Aeroqual. Please contact technical support for a quotation.

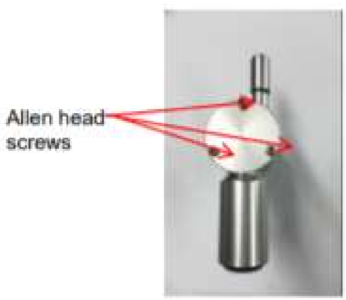




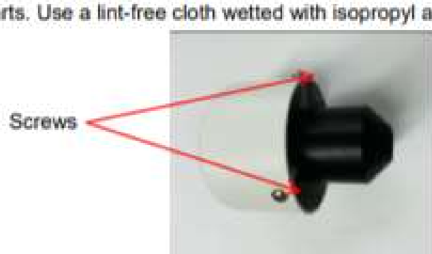
9.4.9. Cyclone and Inlet Cleaning

The dust cap of the sharp cut cyclone will accumulate particulate matter and will need to be periodically cleaned. Blow out the cyclone with compressed air and unscrew the dust cap and clean. Replace the cap tightly and ensure there are no potential leaks.

The cyclone can be disassembled completely by removing the three Allen head screws and pulling it apart. The internal parts should be cleaned with isopropyl alcohol once a year.



The TSP inlet can also be dismantled by unscrewing the 3 screws and separating the head into two parts. Use a lint-free cloth wetted with isopropyl alcohol to clean both the inside and outside of the inlet.



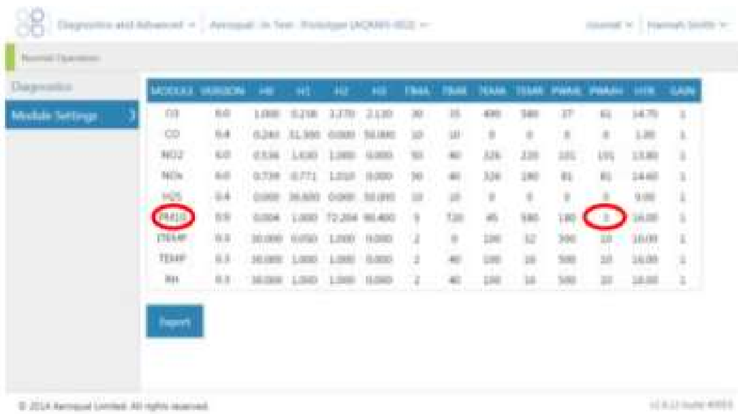
9.4.10. Changing the Size Fraction Measured

The PM engine installed can be configured to measure different size fractions by changing the sharp cut cyclone connected to the inlet. To ensure the correct size fraction is reported the AQM 65 needs to be reconfigured.

1. **Change the PWMH value for the PM module**

   a. Enter the Diagnostics and Advanced application and select Module Settings. The PWMH value needs to be changed to match the new sharp cut cyclone size fraction installed.

   b. Click on the relevant PM module PWMH parameter and change the value in accordance to the table below and press save.



2. **Change the sensor configuration**

   a. Go to the Configure Instrument application and select Settings. Under the active sensors list remove the PM sensor previously installed by pressing the x. Then add the new PM sensor from the drop down list.

Sharp cut installed	PWML Value
TSP	4
PM10	3
PM2.5	2
PM1	1

9.5. Profiler

9.5.1. Sample Flow Check and Adjustment

A set flow rate is essential to ensure consistency in the measurement. To measure the flow, remove the TSP head and connect the volumetric flow meter to the top of the inlet using the adaptor supplied with the instrument. Ensure the flow meter is on a steady surface before reading the flow rate.

Note 1: The adaptor tubing should be connected to the TOP of the volumetric flow meter (negative flow)

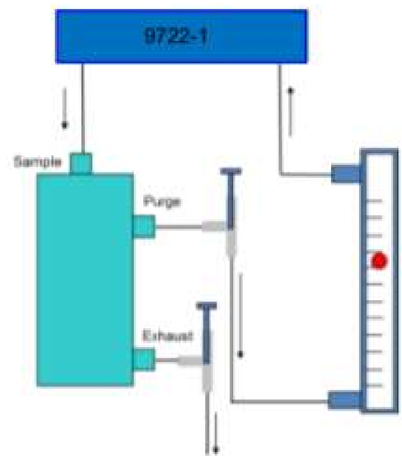
Note 2: The flow should be 1.0 LPM

The inlet flow can be adjusted via the flow adjuster on the exhaust line.

- If the flow is **greater than** 1.0 LPM then **close the exhaust flow screw** (turn clockwise) until 1.0 LPM is achieved.
- If the flow is **less than** 1.0 LPM then **open the exhaust flow screw** (turn anticlockwise) until the flow is 1.0 LPM.

Afterwards replace the inlet components with care making sure there is no leak.

9.5.2. Sheath Flow Check



The sheath flow is a constant stream of air which ensures the optics remains clean. It is important this is working correctly to maintain the accuracy of the measurement. In order to check the flow, a volumetric flow meter needs to be connected between the purge flow adjuster and particle engine as seen in the diagram.

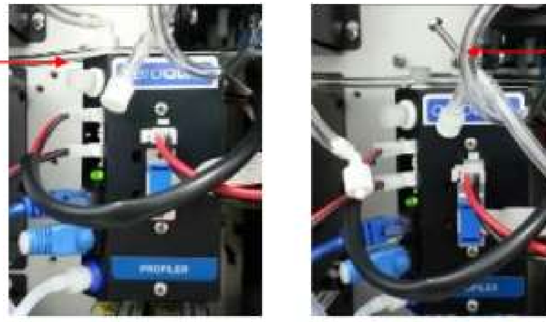
Note 1: The flow should be approximately 1-1.5LPM

9.5.3. Leak Check

If the correct sample or sheath flow cannot be achieved, there may be a leak in the pump module or engine. First check the entire flow system:

- Remove the purge connection from the module and plug the end of the purge line
- Remove the TSP head and block the PM inlet.
- Connected the pressure end of a flow meter to the exhaust port of the module.
- If there is no leak the flow should drop to zero.

Purge connection (remove to check whole flow system)



Sample connection (remove to check module)

If the flow does not drop to zero it suggests there is a leak somewhere in the system. To check the pump module:

- Keep the purge line disconnected.
- Remove the sample connection and cap off the module sample port.
- Connect the exhaust port of the module to the pressure end of a flow meter.
- The flow should drop to zero.

If there is a leak in the pump module the module will need to be sent back to the Aeroqual factory. Please contact technical support.

If there is no leak in the pump module it is likely the leak is located in the engine. In this case, the engine will need to be sent back to the Aeroqual factory. Please contact technical support.

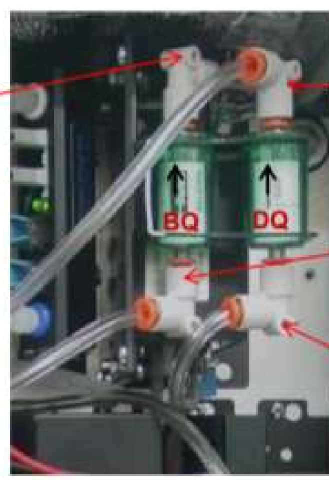
9.5.4. Filter Changes

There are two green filters which are located to the left of the sample filter holder. They are designed to provide protection to the pump and optical window. The filters will become dirty and must be replaced periodically.

To do this, unclip the filters from the connectors and replace. Ensure the filters are connected the right way in accordance to the flow arrow. These filters can be purchased from Aeroqual. Please contact technical support for a quotation.

BQ filter – Zero air filter
DQ filter – Sample air filter

Connects to **top** of Profiler Engine



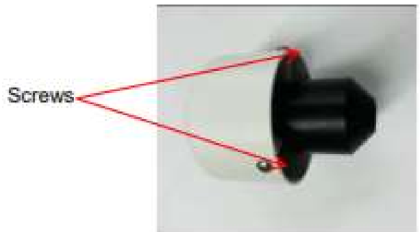
Connects to **sample** on profiler module

Connects to **purge** on profiler module

Connects to **bottom** of Profiler Engine

9.5.5. Inlet Cleaning

The TSP inlet can be dismantled by unscrewing the 3 screws and separating the head into two parts. Use a lint-free cloth wetted with isopropyl alcohol to clean both the inside and outside of the inlet.



10. Troubleshooting

10.1. AQM 65 Basics

Symptom	Possible Cause	Fault isolation/Solution
Gas sensor readings incorrect	Insufficient warm up	Allow the sensors to fully warm up after power down. This may take 2-3 hours.
	Incorrect zero calibration	Repeat zero calibration with clean air.
	Incorrect span calibration	Perform span check.
	Sensor module leaking	Check for leaks
	Sensor pump failed	Measure flow. If pump has failed replace.
	Sensor module parameters have been corrupted or lost.	Go into Diagnostics menu and review Module parameter table. Compare with logbook.
NO_2 sensor reading very high	Incorrect zero calibration	Repeat zero calibration with clean air.
	O_3 Scrubber failed	Expose the NO_2 sensor with 0.1 ppm of O_3. If the response is large (>0.5 ppm) then the scrubber has failed. Replace.
Gas Sensor readings noisy or unstable	Leaks	Leaks dilute the sample stream and can cause low span readings and incorrect zero readings. Perform a leak test.
	Calibration incorrect	Repeat calibration

	Module is faulty	Replace module
	Particle filter	Replace if dirty
Blank in Data table (No response)	No Response from Sensor module. Not connected correctly	Check that the electrical connectors on the sensor modules are firmly connected.
	Bus cable	Check RS485 bus cable continuity.
Occasional Blankin Data Table	RS485 bus cable is faulty	Replace bus cable.
	Module RS485 chip faulty	Remove one module at a time to identify faulty module and then replace.

10.2. Particle Monitor/Profiler

Symptom	Possible Cause	Fault isolation/Solution
PM values seem incorrect	Sample flow incorrect	Check sample flow and adjust to correct value using flow adjusters
	Sample and/or purge filters dirty	Replace filters
	Gain factors incorrect	Perform span calibration
	Offset factor incorrect	Perform zero calibration
Low Sensitivity	Laser is old	Laser needs replacing.
	The laser current can be measured under the Diagnostics and Advanced application. If above 20 mA then fault	Send to your authorised distributor or contact Aeroqual technical support.
Low Sensitivity	Dirty optics	Optics need cleaning
	Check H0 value for PM in Module Parameter Table. Ig above 0.1 then optics are dirty	Send to your authorised distributor or contact Aeroqual technical support.
Noisy Readings	Dirty optics	Optics need cleaning

	Laser is old	Send to your authorised distributor or contact Aeroqual technical support. Laser needs replacing. Send to your authorised distributor or contact Aeroqual technical support.
Negative readings	Purge filter new and shedding particles Purge flow zero Purge filter dirty	Run zero cycles until purge filter no longer shedding particles. Adjust purge flow Replace purge filter
Fibre Span has changed significantly since installation	Dirty Optics Laser is old	Optics need cleaning Send to your authorised distributor or contact Aeroqual technical support. Laser needs replacing. Send to your authorised distributor or contact Aeroqual technical support.
Readings flat	Laser failed (check laser current) Photo-detector failed	Laser needs replacing. Send to your authorised distributor or contact Aeroqual technical support. Send optical engine to Met One for replacement detector and calibration.

10.3. Diagnostics

The AQM has a number of sources for diagnostic information if a problem arises. These are described below:

Journal: All instrument events are logged in the Journal which can be accessed in Aeroqual Connect or Cloud.

Messages: This is located on the Aeroqual Connect and Cloud tool bar. If the AQM 65 is connected to the computer then event messages will be written to the Messages window in real-time.

Diagnostics: This is located under the Diagnostics and Advanced application. Individual sensor modules can be interrogated to determine if there is a problem which may not have been picked up by normal fault detection. Please consult Aeroqual Technical Support to understand how to read the diagnostics for different modules.