TEMPORAL DISTRIBUTION OF AIR POLLUTANTS ($PM_{2.5}$, PM_{10} AND O_3) IN YANGON CITY, MYANMAR DURING 2019-2021

Miss Tin Saw Pyae

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Hazardous Substance and
Environmental Management
Inter-Department of Environmental Management
GRADUATE SCHOOL
Chulalongkorn University
Academic Year 2021

การกระจายตัวของฝุ่นละอองขนาดเล็ก (PM_{10}, $PM_{2.5}$) และโอโซนในบรรยากาศของเมืองย่างกุ้ง ประเทศเมียนมาร์ ระหว่าง ปี ค.ศ. 2019 – 2021

น.ส.ทิน ซอว์ เปย์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาการจัดการสารอันตรายและสิ่งแวดล้อม
สหสาขาวิชาการจัดการสิ่งแวดล้อม
บัณฑิตวิทยาลัย จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2564

Thesis Title	TEMPORAL DISTRIBUTION OF AIR POLLUTANTS ($PM_{2.5}$, PM_{10} AND O_3) IN YANGON CITY, MYANMAR DURING 2019-2021
By	Miss Tin Saw Pyae
Field of Study	Hazardous Substance and Environmental Management
Thesis Advisor	Assistant Professor Dr. KRAIWUTH KALLAWICHA

Accepted by the GRADUATE SCHOOL, Chulalongkorn University in Partial Fulfillment of the Requirement for the Master of Science

-- Dean of the GRADUATE SCHOOL

(Associate Professor Dr. YOOTTHANA CHUPPUNNARAT)

THESIS COMMITTEE

-- Chairman

(Professor Dr. SRILERT CHOTPANTARAT)

-- Thesis Advisor

(Assistant Professor Dr. KRAIWUTH KALLAWICHA)

-- Examiner

(Dr. Ratchanon Piemjaiswang)

-- Examiner

(Dr. Vacharaporn Soonsin)

-- External Examiner

(Assistant Professor Dr. Arthit Phosri)

ทิน ซอว์ เปย์ : การกระจายตัวของฝุ่นละอองขนาดเล็ก (PM_{10}, $PM_{2.5}$) และ
โอโซนในบรรยากาศของเมืองย่างกุ้ง ประเทศเมียนมาร์ ระหว่าง ปี ค.ศ. 2019 – 2021. (TEMPORAL DISTRIBUTION OF AIR POLLUTANTS ($PM_{2.5}$, PM_{10} AND O_3) IN YANGON CITY, MYANMAR DURING 2019-2021) อ.ที่ปรึกษาหลัก : ไกรวุฒิ กัลวิชา

ปัจจุบันมลภาวะในอากาศสูงขึ้น สามารถเห็นได้จากทั่วโลกโดยเฉพาะเมืองใหญ่ การศึกษาการกระจายของมลพิษทางอากาศกลายเป็นหนึ่งในวิธีการสำคัญในการทราบลักษณะและธรรมชาติของมลพิษทางอากาศเพื่อการดำเนินการลดมลพิษทางอากาศทั่วโลก ในประเทศเมียนมาร์มีการศึกษาน้อยมากที่มุ่งเน้นในพื้นที่นี้ โดยเฉพาะการศึกษาในช่วงเวลาระยะสั้น ดังนั้นการศึกษานี้จึงมีวัตถุประสงค์เพื่อตรวจสอบการกระจายตัวของมลพิษทางอากาศชั่วคราว ($PM_{2.5}$, PM_{10} และ O_3) ตามด้วยแบบจำลอง MLR สำหรับการตรวจสอบอิทธิพลของปัจจัยทางอุตุนิยมวิทยาที่มีต่อความเข้มข้นของมลพิษทางอากาศ และแบบจำลองอนุกรมเวลาสำหรับการทำนายดัชนีคุณภาพอากาศ ความเข้มข้นของมลพิษทางอากาศรายชั่วโมงถูกรวบรวมโดยสถานีติดตามของสถานทูตสหรัฐอเมริกา ข้อมูลอุตุนิยมวิทยาประจำวันถูกเก็บรวบรวมโดยกรมอุตุนิยมวิทยาและอุทกวิทยา เมืองย่างกุ้ง ประเทศเมียนมาร์ การวิเคราะห์สหสัมพันธ์ของเพียร์สันถูกนำมาใช้เพื่อตรวจสอบทิศทางและขนาดของความสัมพันธ์ระหว่างข้อมูลอุตุนิยมวิทยาทั้งหมด เพื่อรวมไว้ในแบบจำลองการถดถอย ฤดูกาล (ฤดูร้อน ฤดูมรสุม และฤดูหนาว) และแบบจำลองการถดถอยพหุเชิงเส้นรายปีถูกวิเคราะห์เพื่อตรวจสอบปัจจัยที่เกี่ยวข้องสำหรับมลพิษทางอากาศในช่วงระยะเวลาการศึกษา นอกจากนี้ ดัชนีคุณภาพอากาศของ $PM_{2.5}$, PM_{10} และ O_3 ยังถูกคำนวณโดยสูตรมาตรฐานของสำนักงานปกป้องสิ่งแวดล้อมสหรัฐ หรือ United States *Environmental Protection Agency* (USEPA) สุดท้าย ARIMA of Time Series Modeling หรือ การวิเคราะห์ข้อมูลแบบอนุกรมเวลาได้ถูกนำมาใช้เพื่อการทำนายดัชนีคุณภาพอากาศของ $PM_{2.5}$, PM_{10} และ O_3 ของปี ค.ศ. 2022 สำหรับการวิเคราะห์ทางสถิติทั้งหมดที่มีอยู่ในการศึกษานี้ ได้นำ Excel และ R studio ซอฟต์แวร์มาใช้ในการวิเคราะห์ข้อมูล ผลจากการศึกษาโดยรวมพบว่าทั้งความเข้มข้นของมลพิษทางอากาศและดัชนีคุณภาพ ของ $PM_{2.5}$ มีค่า 0-93.6 μg/m3 และ 0-171 ซึ่งเกินระดับที่ WHO ยอมรับได้คือ 35.15 μg/m3 และต่ำกว่า 50 ในทำนองเดียวกัน ความเข้มข้นของมลพิษทางอากาศและดัชนีคุณภาพอากาศ ของ PM_{10} อยู่ที่ 0.1-149.27 μg/m3 และ 2-98 ซึ่งเกินระดับที่ WHO ยอมรับได้คือ 50 μg/m3 และต่ำกว่า 50 มลพิษทางฝุ่นละอองนั้นเลวร้ายที่สุดโดยเฉพาะในฤดูร้อนและฤดูหนาว ดัชนีคุณภาพอากาศของโอโซน (O_3) ระหว่างการศึกษาคือ 1-56 ซึ่งอยู่ในระดับที่ปลอดภัย อุณหภูมิจุดน้ำค้าง ความชื้นสัมพัทธ์และปริมาณน้ำฝนพบว่ามีความสัมพันธ์เชิงลบอย่างมีนัยสำคัญสำหรับสารมลพิษทั้งหมด ในขณะที่อุณหภูมิแวดล้อมมีความสัมพันธ์เชิงบวกอย่างมีนัยสำคัญกับสารมลพิษทั้งหมดในการศึกษานี้ แบบจำลองฤดูหนาวสำหรับฝุ่นละอองหรืออนุภาคขนาดเล็กมีประสิทธิภาพของแบบจำลองที่ดีที่สุดและอธิบายความผันแปรส่วนใหญ่ในเรื่องอนุภาค ความแปรปรวนของ $PM_{2.5}$, PM_{10} และโอโซน (O_3) เท่ากับ 60%, 45% และ 45% ตามลำดับ สามารถอธิบายได้ด้วยความชื้นสัมพัทธ์ในแบบจำลองรายปี แบบจำลองอนุกรมเวลาคาดการณ์ดัชนีคุณภาพอากาศของฝุ่นละอองหรืออนุภาคขนาดเล็กมีแนวโน้มเพิ่มขึ้นในปี ค.ศ. 2022 ในการศึกษานี้จะเห็นได้อย่างชัดเจนว่าดัชนีคุณภาพอากาศ ของ $PM_{2.5}$ และ PM_{10} นั้นสูงมากในเมืองย่างกุ้ง ประเทศเมียนมาร์ และมีการระบุปัจจัยที่มีอิทธิพลต่อการกระจายมลพิษทางอากาศ ดังนั้นจึงควรดำเนินการบรรเทาปัญหามลพิษทางอากาศอย่างเร่งด่วนในเมืองย่างกุ้ง ประเทศเมียนมาร์ สำหรับปัญหาด้านสุขภาพของผู้อยู่อาศัยในเมือง โดยผลจากการศึกษาในครั้งนี้มีวัตถุประสงค์เพื่อให้ข้อมูลที่จำเป็นเพื่อใช้เป็นข้อมูลอ้างอิงในการกำหนดมาตรฐานคุณภาพอากาศแวดล้อมและใช้ในกระบวนการกำหนดนโยบายระดับภูมิภาคและเพื่อให้ความรู้แก่ประชาชนโดยผ่านสื่อสิ่งพิมพ์ต่อไป

สาขาวิชา	การจัดการสารอันตรายและสิ่งแวดล้อม	ลายมือชื่อนิสิต ....
ปีการศึกษา	2564	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....

6388058220 : MAJOR HAZARDOUS SUBSTANCE AND ENVIRONMENTAL MANAGEMENT
KEYWORD: Myanmar, PM2.5, PM10, O3, Meteorological factors, Multiple Linear Regression, Time Series Modeling

Tin Saw Pyae : TEMPORAL DISTRIBUTION OF AIR POLLUTANTS ($PM_{2.5}$, PM_{10} AND O_3) IN YANGON CITY, MYANMAR DURING 2019-2021 . Advisor: Asst. Prof. Dr. KRAIWUTH KALLAWICHA

Nowadays, the rise in air pollution can be seen around the world especially in urban city. Studying the distribution of air pollution becomes one of the essential ways to know the characteristics and nature of air pollutants for air pollution mitigation actions around the world. In Myanmar, there are very few studies focusing on this area and these very few studies were carried out for short term periods. Therefore, this study was aimed to investigate the temporal distribution of air pollutants ($PM_{2.5}$, PM_{10} and O_3) following by MLR modeling for the influence of meteorological factors on air pollutant concentrations and Time series modeling for the prediction of AQI. Hourly air pollutant concentration was collected by US Embassy monitoring station and NGO monitoring station. Daily meteorological data was collected from department of Meteorological and Hydrology, Yangon, Myanmar. Pearson's correlation analysis was applied for checking the direction and magnitude of association between all meteorological data in order to include in regression models. Seasonal (summer, monsoon and winter) and annual multi linear regression models were analyzed to examine the associated factors for air pollution during study periods. Moreover, AQI for $PM_{2.5}$, PM_{10} and O_3 was calculated by the standard formula of USEPA. Finally, AQI prediction of PM_{10} and $PM_{2.5}$ for 2022 was done by ARIMA of Time Series Modeling. Excel and R studio software were used for all the statistical analysis contained in this study. Overall, both air pollutants concentration and AQI of $PM_{2.5}$ were 0-93.6 µg/m^3 and 0-171 which exceeded the acceptable level by WHO which are 35.15 µg/m^3 and under 50. Similarly, air pollutants concentration and AQI of PM_{10} were 0.1-149.27 µg/m^3 and 2-98 which exceeded the acceptable level by WHO which are 50 µg/m^3 and under 50. Particulate matter pollution is the worst especially in summer and winter. AQI of ozone during study period was 1-56 which was at a safe level. Dew point temperature, relative humidity and rainfall had significant negative association for all pollutants while, ambient temperature had significant positive association with all pollutants in this study. Winter models for particulate matters had the best model performance and explained majority of variation in particulate matters. 60%, 45% and 45% of variation in $PM_{2.5}$, PM_{10} and Ozone were successfully explained by relative humidity in annual model. Time series modeling forecasted AQI of particulate matters and saw an increasing trend in the year 2022. In this study, it can be clearly seen that AQI of $PM_{2.5}$ and PM_{10} are really high in Yangon city, Myanmar and the influence factors for distribution of air pollutants were identified. Therefore, urgent mitigation actions for air pollution should implement in the Yangon city, Myanmar for the health concerns of residents living in the city. The accurate and precise results from this study are aimed to give required information as a reference in setting national ambient air quality standard, in regional policy making process and also for giving awareness for the public through the publication.

Field of Study:	Hazardous Substance and Environmental Management	Student's Signature ....
Academic Year:	2021	Advisor's Signature ....

ACKNOWLEDGEMENTS

The completion of this thesis is contributed to kindly guidance, support, and motivation of many individuals. Foremost, I would like to express my sincere gratitude to my thesis advisor Dr. Kraiwuth Kallawicha. for giving me expert opinions, important suggestions, generous support and kind encouragement throughout the academic year. Without his excellence suggestions and guidance, it is impossible to accomplish this study.

I would like to express sincere thankfulness and deep gratitude to all my thesis exam committee; the chairman: Professor Dr. Sirilert Chotpantarat, examiners: Dr. Vacharaporn Soonsin, Dr. Ratchanon Piemjasiswang and external examiner: Dr. Arthit Phosri, for giving their precious time, valuable guidance and comments for my thesis.

My sincere thanks also goes to all my teachers at International Postgraduate Program in Hazardous Substances and Environmental Management (IP-HSM), Chulalongkorn University for providing great academic experiences throughout my study. I am especially thankful to the ASEAN and Non-ASEAN scholarship program, Chulalongkorn University for the finical support throughout the study period of my Master's degree.

I would like to offer my special thanks and appreciation to my family who support me unconditionally and also helping me for data collection from monitoring stations. My sincere thanks also goes to US Embassy Rangoon and Heinrich Boll Stiftung (HBS) for allowing me to use air quality monitoring data in this research. Last but not least, I also would like to thank my seniors, colleagues and friends for their kindness and sincere support throughout my Master's degree.

Tin Saw Pyae

TABLE OF CONTENTS

Page

List of Tables

Page

List of Figures

Page

CHAPTER I

INTRODUCTION

1.1 Background and Rationale

In many part of the world, air pollution has become a serious issue especially in densely populated areas. It is a global issue that needs to be addressed because it brings adverse health outcomes(Castells-Quintana, Dienesch et al. 2021). The United States Environmental Protection Agency (US EPA) has identified six major pollutants; lead (Pb), carbon monoxide (CO), nitrogen oxides (NO), particulate matter (PM), sulfur dioxides (SO_2) and ozone (O_3) as “criteria” pollutants. They identified them as criteria pollutants based on human health and environmental related criterions (https://www.cdc.gov/).

According to WHO, air pollution is a major contributor for environmental related health problems(Organization 2003). These health problems include minor effects such as upper respiratory irritation and chronic effects; for example, loss of lung capacity, lung cancer, asthma, heart disease, bronchitis and failure in lung function (Kampa and Castanas 2008). Even though there can be seen effectiveness of air pollution mitigation actions in some parts of our planet, a number of people in both industrialized countries and developing nations still encountered premature death yearly from the adverse effects of air pollution.

A record of 3.7 million premature deaths occurred in 2012 due to outdoor air pollution (UNEP 2014). Moreover, in developing nations of South-East Asia, indoor air pollution caused 3.3 million deaths and outdoor air pollution caused 2.6 million deaths, this meant that the problem of air pollution in these areas is larger than in other parts of the world (Bauer, Moebus et al. 2010). Myanmar also has been facing problems relating to air pollution. According to a report from Department of Population, the information relating to Yangon's air quality and also water quality is very limited (Aung, Noguchi et al. 2019). Yangon is the most important commercial and urbanized city of Myanmar (Forbes 2016). However, there were no air quality and emission monitoring stations in Myanmar in the past years(Sricharoenvech, Lai et al. 2020).

According to the articles published in 2020 about Yangon Air Quality, by Axel Harneit-Sievers and Rixta Sievers starting from the middle of 2019, there were three air quality monitoring stations which particularly monitored $PM_{2.5}$, PM_{10} and O_3. These monitoring stations were maintained by US Embassy, Heinrich Böll Stiftung Yangon Office – Myanmar, and Clean Air Yangon. Although there were a few research conducted for preliminary evaluation relating to indoor and outdoor air quality, distribution of different types of air pollutants in the atmosphere of Yangon that is based on secondary data obtained from current monitoring stations, is still lacking (Tun, Aung et al. 2018, Aung, Noguchi et al. 2019, Yi, Aung et al. 2020).

Many evidences showed that climate factors have a great influence on different kinds of pollutants (PM_{10}, NO_2, $PM_{2.5}$, and O_3), correlations between air quality and meteorological parameters are inconsistent among studies (Akpinar, Akpinar et al. 2009, Afzali, Rashid et al. 2014, Li, Qian et al. 2014). Certain climate factors cause transportation of aerial pollutants and leads to the formation of secondary pollutants. Periodical and topographical criteria of meteorological and air pollutants are obvious. The concentration of most air pollutants was affected by climate factors which have a great impacts on concentration of air pollutants depending on sources of pollution and locations(Liu, Zhou et al. 2020). The common climate factors affect the level of air pollution includes temperature, precipitation, relative humidity and wind speed (Han, Zhou et al. 2015).

The study of association between air pollutant parameter and meteorological conditions have also been carried out around the world (Giri, Adhikary et al. 2008, Luvsan, Shie et al. 2012, Wang and Ogawa 2015, Wang, Myint et al. 2018, Radzka 2020, Rojas, Borge et al. 2020, Munir, Coskuner et al. 2021) including Asian countries (Kliengchuay, Cooper Meeyai et al. 2018, Mohtar, Latif et al. 2018, Dung, Son et al. 2019). However, this type of research is still limited, especially in the context of Myanmar.

The US EPA developed a system called Air Quality Index (AQI) which categorizes the pollutants for the purpose of rating the safety level of air and for better understanding of air quality index in the society (Tan, Han et al. 2021). Generally, AQI varies from region to region in the degree of concentration (Guo, Zhao et al. 2020). Therefore, every country around the world needs to amend the level of pollutant concentration practically. The process of developing a new AQI for specific country include monitoring concentration of parameters hourly in target areas, converting the raw concentration into AQI value for each pollutant by the use of standard formulas by US EPA and announcing the highest values as the Air Quality Index for specific day (US-EPA 2012).

It is essential to understand the relationship of air pollutants and meteorological factors because this can help to formulate effective air quality control policies. There are so many challenges in Myanmar regarding to the implementation of Environmental Conservation Law; for example, absence of detail legislation relating to management of air pollution and not having some of the implementation plans for air pollution control. Therefore, studying the distribution of air pollutants and also finding the association between climate factors and major pollutants with the current available data set will be useful in preliminary steps for air pollution mitigation in Myanmar. The results obtaining from this kind of study are very useful and can be applied for regional policy making process such as setting national ambient air quality standard and also for giving awareness for the public (Purohit, Munir et al. 2013, Cannistraro, Cannistraro et al. 2016).

Especially, developing countries like Myanmar has very limited number for this kind of research and it is urgently needed to conduct a research for air quality development in the most urbanized city of Myanmar. Therefore, in this study, the association between air quality parameters and climate parameters (i.e., temperature, station pressure, rainfall, humidity, dew point temperature and wind speed) were analyzed by applying secondary data from meteorological department during the year of 2019 to 2021. AQI was considered for reaching the assessment of air in Yangon from AQI calculation of three different pollutants by using the raw concentration data from the year 2019 until 2021. Air quality forecasting for near future of $PM_{2.5}$ and PM_{10} was also included for investigating early warning against harmful air pollutants. This research is the first study in Myanmar to investigate the distribution of air pollutant from current monitoring stations and also to analyze the association between meteorological data and selected air pollutant in the context of Yangon city, Myanmar. As air pollution is one of the most wide spread and obvious kind of environmental damage, studying the distribution of air pollution in Yangon city Myanmar is aimed for better understanding of the nature of air pollutants and environmental factors that related to air pollution. The outcomes obtained from this study is targeted for both policy making process for air quality control and further research in the future.

1.2 Research Questions

1. How much variability in air pollutant concentration could be explained by selected meteorological factors i.e., temperature, pressure, humidity, dew point temperature, wind speed, and rainfall) in the atmosphere of Yangon city, Myanmar?
2. What is the seasonal distribution of AQI for selected pollutants (PM_{10}, $PM_{2.5}$ and O_3)?
3. What will be the AQI of particulate matters in 2022 and which air pollutants can represent more for health concerns?

1.3 Objectives

1.3.1 General objective

- To investigate the temporal distribution of three type of air pollutants (i.e., PM_{10}, $PM_{2.5}$ and O_3) in the atmosphere of Yangon city during a three-year period.

1.3.2 Specific objectives

(1) To investigate the distribution of PM_{10}, $PM_{2.5}$ and O_3 during 2019-2021

(2) To investigate the association between meteorological factors (i.e., temperature, pressure, dew point temperature, relative humidity, wind speed and rainfall) and the concentration of air pollutants (PM_{10}, $PM_{2.5}$ and O_3)

(3) To determine the AQI level and its distribution for each air quality parameters (i.e., PM_{10}, $PM_{2.5}$ and O_3) from daily data.

(4) To predict the air quality index of PM_{10} and $PM_{2.5}$ for the near future (1year)

1.4 Conceptual Framework

Independent Variables (Meteorological factors)	**Dependent Variables (Air pollutant concentration)**
• Temperature, • Pressure • Dew point temperature	• PM_{10} • $PM_{2.5}$

• Humidity • Wind Speed • Rainfall	• O_3

1.5 Scope of the study

Yangon is the important commercial city of Myanmar and the whole city is full of residential buildings and industrial areas (Sritarapipat and Takeuchi 2017). The location of the city is between Latitude 16.8861° N and Longitude 96.1951° E, and 34 km from the sea in the coastal area. Yangon covers an area of 598.8 km^2 having a population of approximately six million people (Tint and Kyaw). There are thirty-three townships in Yangon City. However, there are only three monitoring station for air quality until 2020 according to an article published in 2020. However, only two stations in two provinces in Yangon city can provide real time air quality data from 2019 to 2021. Therefore, raw data obtained from two monitoring stations was used for further analysis: Pearson's correlation and multiple linear regression (MLR) by R which is an open-source language was used for statistical computing and graphical presentation in this study. Moreover, the research also focused on observing AQI of measured air pollutants by using U.S. EPA derived formula. After calculating Air Quality Index (AQI), Time Series analysis was applied in order to analyze the distribution pattern of air quality index from 2019 to 2021 and time series modelling was conducted the AQI value of PM_{10} and $PM_{2.5}$ for the near future. The location of two air quality monitoring stations and meteorological stations are shown in Figure 1 by using Arc Map and Google earth pro software.

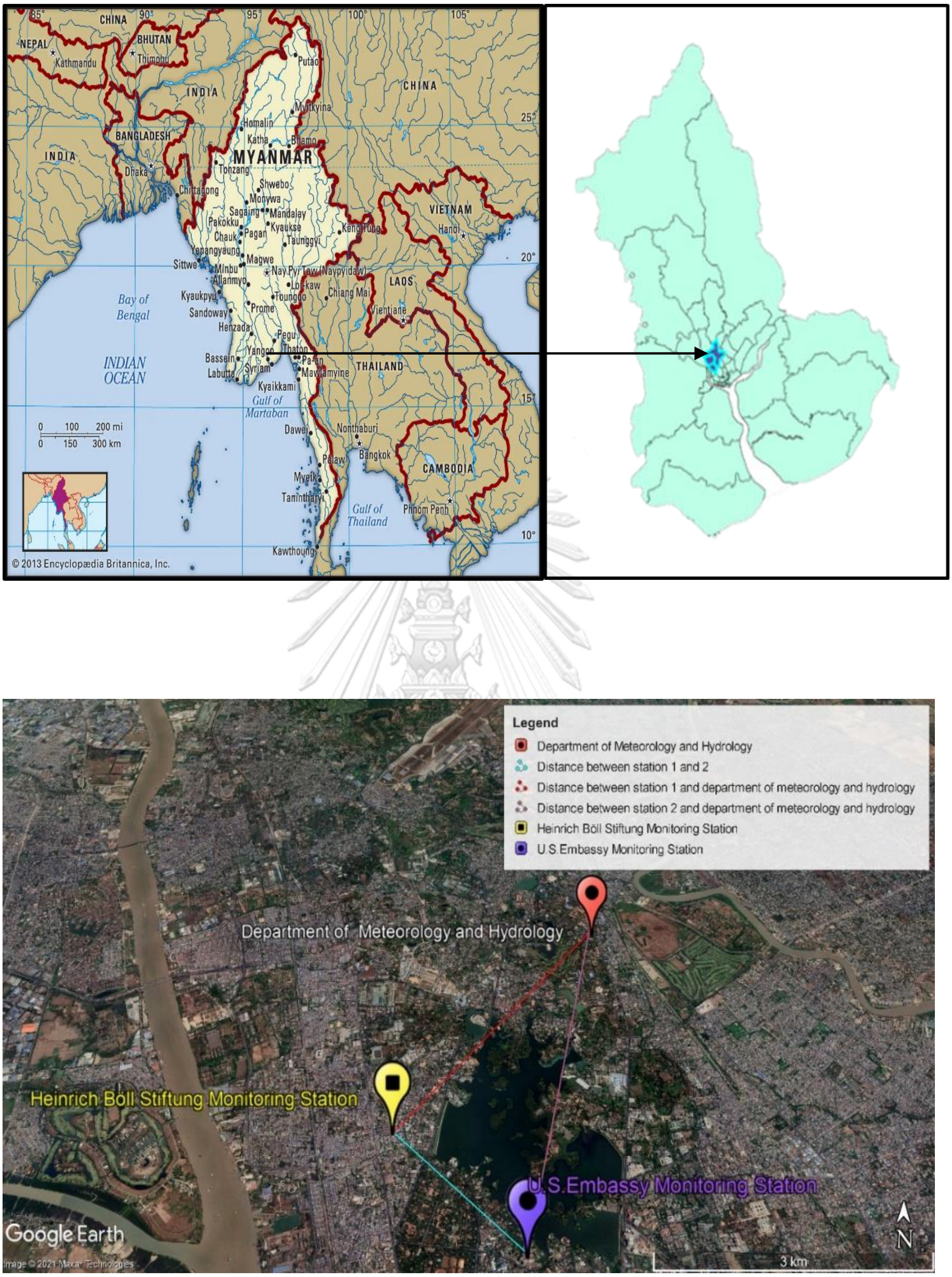

Figure 1 Location of monitoring stations

CHAPTER II

LITERATURE REVIEW

2.1 Theoretical Background

2.1.1 Air Pollution

There are two type of air pollutants; primary pollutant that released directly into the atmosphere and secondary pollutant which form from the reaction of other pollutants in the atmosphere. Ozone (O_3), Particulate matter (PM) and Peroxyacyl nitrates are examples of secondary pollutants. However, nitrogen oxide (NOx) and PM are released from a direct route or can be formed from the reaction of other pollutants, and they are included in two types of pollutant (Holman 1999). Majority of Man-made activities (anthropogenic) comes from transportation, manufacturing, construction, and residential (Agustine, Yulinawati et al. 2017).

2.1.2 The relationship between air pollutant concentration and climate factors

Various economical, geographical, and climatological variables have a great influence on the distribution of various kinds of air pollutants (Mohtar, Latif et al. 2018). These factors are unmanageable; however, they can extremely impact on the concentration of air pollutants. As for a crucial concern, peak of O_3 periods and temperature were related vigorously because of the association of temperature and stagnation periods increase photochemical reaction and bonfire emissions (Fiore, Naik et al. 2012).

It will be misleading if all meteorological variables are not included in finding the association between air pollutants and climatological factors because the air pollutants' concentration react to all climate factors as air mass (Mohtar, Latif et al. 2018). Various studies found that air humidity associated with the level of air pollutant. A study found that the higher water vapor lowers the ozone level (Jacob and Winner 2009), while another study found that the level of PM_{10} decreased when the humidity increased (Giri, Adhikary et al. 2008). On the other studies, the increase in the wind speed associate with the increase in the level of PM_{10} (Wang and Ogawa 2015), similar to another study conducted in Nagasagi, Japan showed that $PM_{2.5}$ have a negative correlation with temperature, a positive correlation with precipitation. In addition, it has found that a wind that originates from the west and blows in an eastward direction is the carrier for most pollutants over Nagasaki (Ng, Hashizume et al. 2019). One research done in Kathmandu valley stated that increasing in the level of rainfall was negatively correlated with PM_{10} concentration(Giri, Adhikary et al. 2008). In the previous study, it is indicated that moisture level is strongest predictors of PM concentration (Wise and Comrie 2005).

The use of time series analysis can clarify the distribution patterns of various kinds of air pollutants and found out that O_3 level are typically highest in January–March (Mohtar et al., 2018). Time series analysis requires at least three years of data for synthetic data generation for forecasting AQI of various pollutants (Devi, Sundar et al. 2013, Abhilash, Thakur et al. 2018, Zhang, Lin et al. 2018, Koo, Wong et al. 2020).

2.1.3 Air Pollution study in low-income countries

One of the global concerns in these days include poor air quality management such as assessment of reliable data including absent of air quality monitoring data and also not having a great concern about air pollution problem in developing countries. To address this problem effectively, both private and administrative sectors would require working cooperatively to realize the main goal of distinguishing, comprehensive understanding of air pollution problems that leads to many health problems around the world. Especially, lack of air pollution data is one of the main sources of problem because the government has no intention to invest for air quality monitoring sectors and also people became lack of awareness and cannot see how big the problem is.

Various studies that have been done as the first air quality study in low- and middle- income countries, applying low-cost air quality monitors to measure air quality parameters. The poor air quality area and major sources of pollution were identified (deSouza, Nthusi et al. 2017, Thu, Htun et al. 2018, Ngo, Asseko et al. 2019). Moreover, researchers also conduct research about the correlation between exposure to air pollution and specific types of diseases in these countries (Lelieveld, Evans et al. 2015, Jafta, Barregard et al. 2017, Mannucci and Franchini 2017).

Another kind of study that mostly done relating to air quality in developing countries are modeling study. These studies created models to predict concentration of pollutants based on the correlation between air pollutants and meteorological data and road traffic emission data (Ho and Clappier 2011, Li, Hsu et al. 2011, Chiwewe and Ditsela 2016, Aman, Manomaiphiboon et al. 2019).

2.1.4 Model or Analytical method for air pollutant distribution

Computer programming are widely used for analyzing and forecasting of large data because many tools available in computer can do more accurately and precisely. For examples, CC++, SPSS, SAS, Mat lab, Strata, FORTRAN, and 'R' has been used for the air quality modeling. As for R, this language is developed by Insightful Corporation under the Free Software Foundation's for General Public License (Chiang, Goes et al. 2012, Agustine, Yulinawati et al. 2017, Sivaprasad 2021). There are many different models that can be used for assessing the air pollutant distribution and examples include statistical interpolation, time series modelling, multiple linear regression, artificial neutral networks (Jerrett, Arain et al. 2005). Among them, Regression is the most widely used method for forecasting and finding the relationship between the independent and dependent variables. The following Table 1 shows the data requirements, weakness, strength of analytical analysis methods and models that are mostly applied for air pollution study.

Table 1 Comparison of mostly used analytical methods and models for air pollution study

Types of analysis	Data requirements	Weakness	Strength	References
MLR*	At least two dependent and independent variables	Two or more of the independent variables are highly associated to each other	Good for preliminary study	(Khademi & Behfarnia, 2016; Tranmer & Elliot, 2008)
Time Series	Longer time data is needed	Problems with accurately identifying the correct model to represent the data	Help to gain a useful glimpse of the future.	(Huang et al., 1998; Velicer & Plummer, 1998)

Types of analysis	Data requirements	Weakness	Strength	References
Kriging*	Monitoring site(10-100)	The original data points are seldom honored	Good for various land use and topography study sites	(Jerrett et al., 2005)
ANN*	large and complex multi-parameter datasets	Need lots of data, there is no specific rule for determining the structure of artificial neural networks.	Higher accuracy results	(Khademi & Behfarnia, 2016; Sarangi, Madramootoo, Enright, Prasher, & Patel, 2005)

*Note: MLR = Multiple Linear Regression, ANN = Artificial neutral networks, Kriging = Geo statistical interpolation technique

2.1.5 Linear regression and its component

A statistical technique called Regression has been widely used for numerous variables and could address many real-world problems. To estimate the inaccessible data, it is necessary that the model has maximum generalization ability of simulation and documented data is used. For interpretation and prediction purpose, regression is used because it can give strong explanation of how explanatory variables can affect response variables. Moreover, complex model can lead to the decrease in generalization ability and linear regression which has the least complexity is frequently applied by different fields. There are two types of linear regression. Including simple linear regression which contain one explanatory variable and one response variable and multiple linear regression which contains more than one explanatory variables. In the case of more than one explanatory variables, it is mostly referred to use multiple linear regression for two reasons. The first one is making the analysis separately cannot state the effect of combined set of independent variables on dependent variables and the second one is the estimation for response variable cannot done with the absent of simultaneous effect of explanatory variables. It is also important to check the variables whether to include or exclude in the model before starting regression.

There are 4 critical assumptions for classical MLR and they are independent observation of a variable, no serious outliers in a variable, normal distribution of a variable, and no multi-collinearity of a variable. These assumptions clarify variables that should be included in the model to give the reliable result (Fitzmaurice, 2016). The coefficient on the regression model is actually the assumed parameter value in the model for the actual condition. In multiple linear regression, R^2 indicate how much variation in the result can be described by the variation in the explanatory variables (Wang and Ogawa 2015, Etemadi and Khashei 2021). In MLR, the lowest *p*-value means the observed statistical test is meaningful because this value clarifies for rejecting null hypothesis and accepting alternative hypothesis. To analyze the distribution of air quality and also the influence of meteorological factors, many previous studies applied multiple linear regression (Li, Qian et al. 2014, Sahanavin, Prueksasit et al. 2018, Shi, Matsunaga et al. 2018).

2.1.6 Time Series Modelling

According to Tufte and Graves-Morris (1983), “The time-series plot is the most frequently used form of graphic design. With one dimension marching along to the regular rhythm of seconds, minutes, hours, days, weeks, months, years, or millennia, the natural ordering of the time scale gives this design a strength and efficiency of interpretation found in no other graphic arrangement" (Tufte 1983). The application of Time–series for environmental management problems contains identification of the different time-series components such as stationary, linear trend, random variables, regressive model, cyclic term (Devi, Sundar et al. 2013). For example, time-series analysis is applied in air pollution analysis for the purpose of categorizing air pollutant concentration into stationary, trend and periodicities. Seasonality in time-series means the presence of changes occurring weekly or monthly. For detecting seasonality, the autocorrelation function is used. Stationary of time-series means the mean and variance don't change over time; for instance, the values are not as a function time (Hamilton 2020). Basically, time-series modelling involves, moving average, exponential smoothing, and ARIMA. ACF and PACF functions are normally used to identify possible models for targeted values and parameters (Devi, Sundar et al. 2013).

2.1.7 Air Quality Index Standard

The best way to know how much polluted the air is and also the level of different kinds of risks associated to air pollution is the use of air quality index. An AQI is generally computed by the use of standard criterions that are developed on research for the safety levels of main pollutants. Air quality indexes is applied for two major purposes:

1. To inform the public about air quality in a comprehensible manner, so that they may take action to protect their health
2. To help countries develop and assess policies for better air

The basic approach of Air Quality Index contains converting the concentration of six air quality parameters (including CO, PM_{10}, $PM_{2.5}$ SO_2, NO_2, and O_3) into corresponding non-integer with a range from 0-500, individually. Some studies used AQI standards and national air quality standards have been used for the investigation of current air quality situation in some countries of the world.

In recent study, AQI standard developed by USEPA was applied for various pollutants as Sulfur dioxide (SO_2), Nitrogen dioxide (NO_2) and Suspended Particulate Matter (SPM) (Guo, Zhao et al. 2020). Daily air quality estimation in Delhi also have been done by ARIMA and multiple linear regression (MLR) models (Goyal, Chan et al. 2006)Moreover, high correlation between air quality index and meteorological variables also observed (Cogliani 2001). AQI values below 100 are generally assumed as acceptable level (Mohan and Kandya 2007). EPA's AQI guideline values related to $PM_{2.5}$, PM_{10} and O_3 is listed in Table 2.2 and the explanation for level of health concern is explained in Table 2.

Table 2 Reference table for Air Quality Index calculation by US EPA

Ozone (ppm) (BP_{Lo}-BP_{HI})	**$PM_{2.5}$ ($\mu g/m^3$) (BP_{Lo}-BP_{HI})**	**PM_{10} ($\mu g/m^3$) (BP_{Lo}-BP_{HI})**	**AQI Values (I_{HI}-I_{Lo})**	**Level of Health Concern**	**Meaning**
0.000-0.059	0-12	0-54	0-50	Good	There is no risk
0.060-0.075	12.1-35.4	55-154	51-100	Moderate	Acceptable ;however, pose a moderate health risk for people who are sensitive to air pollution
0.076-0.095	35.5-55.4	155-254	101-150	Unhealthy for sensitive Groups	All the people could be affected especially people who have underlying diseases would suffer more
0.096-0.115	55.5-150.4	255-354	151-200	Unhealthy	There is higher chances for everyone to suffer adverse health effects such as failure of lung
0.116-0.374	150.5-250.4	355-424	201-300	Very Unhealthy	Every people may suffer serious health impacts from pollution and people from sensitive groups should avoid outdoor activities
-	250.5-500	425-600	301-500	Hazardous	Everyone should avoid outdoor actives because people are the highest risk of suffering from serious adverse health effects

CHAPTER III

METHODOLOGY

3.1 Data Collection

(1) Meteorological data

All the meteorological data from January 2019 to December 2021 was collected from Department of Meteorology, Myanmar. For meteorological parameters, there are 2 monitoring stations maintained by Department of Meteorology in Yangon district. However, a station called “Hmawbi Station” is 100 km away from Yangon city. Thus, this monitoring station didn't include in this study. Finally, only one station was included. The meteorological station is located at No.50, Kaba-Aye Pagoda Road, Mayan gone Township, Yangon, Myanmar.

Meteorological parameters included in this study are rainfall (millimeter, mm), ambient temperature (degree Celsius, ˚C), relative humidity (percent, %), dew point temperature (degree Celsius˚ C), rainfall (millimeter, mm), atmospheric pressure (hectopascal ,hPa) and wind speed (mile per hour, m/h) and all data are presented as daily average.

(2) Air pollution data

For air pollutant data, there are two monitoring stations: U.S .Embassy monitoring station which is located at 110 University Avenue Road, Yangon and Heinrich Böll Stiftung Yangon Office which is located at Hlaing Myint Moh Lane 3,Hlaing Township, Yangon. The distance between two monitoring station is 5.1 km.; while the distance from meteorological station to HBS office and U.S. Embassy are 2.8 km and 5.9 km, respectively. $PM_{2.5}$ and PM_{10} concentration data from HBS office and $PM_{2.5}$ and ozone from U.S. Embassy are attained from two monitoring stations. The daily average concentration in the unit of µg/m^3 for PM_{10} and $PM_{2.5}$, and ppb for O_3 will be used for the data analysis.

3.2 Sampling method and Quality control

3.2.1 U.S. Embassy Monitoring Station –Measuring $PM_{2.5}$ and O_3

Principle of operation: The concentration of air pollution was measured hourly by BAM-1020. In the central unit, the sampling pump and the sampling inlet hardware are three major parts of detector. Every part is independent and can be easily decoupled for substitution and checking. The BAM-1020 apply beta ray attenuation for the purpose of calculating particle mass concentrations (μg/m^3). A 14C element (60μCi +/- 15μCi) emits a constant source of low-energy electrons also knows as beta particles. The beta rays are attenuated as they collide with particles collected on a filter tape. The decrease in signal detected by the BAM-1020 scintillation counter is inversely proportional to the mass loading on the filter tape. Routine service checks: Embassy monitoring station was routinely checked by the operator. The routine check included daily, weekly, monthly, bi-monthly, and annual check.

3.2.2 Heinrich Böll Stiftung Monitoring station-Measuring $PM_{2.5}$ and PM_{10}

The device used for monitoring $PM_{2.5}$ and PM_{10} is called Airveda, which is India's first accurate air quality monitored device. According to Heinrich Böll Stiftung, the device was placed at the back of their office. The device measures the $PM_{2.5}$, PM_{10}, and then send it to server. The data storage may affect by the poor Wi-Fi connection, server down or blackout. Routine service checks: HBS monitoring station was routinely checked by the operator. The routine check included daily, weekly, monthly, bi-monthly, and annual check.

3.3 Data Analysis

Step 1: Data preprocessing

After the data collection, both meteorological and air quality data was checked for data validation to clarify all the data was acceptable to use in data analysis. Firstly, descriptive statistics i.e., mean, median, and mode was analyzed. In addition, box plot was used to illustrate the distribution of data. Detailed criteria for determining the minimum amount of data from data set that is required to forecast the average value of air pollutant concentration by WHO,"

1) The 1-hour average (hourly) value must have a minimum of 75% of the monitoring data.

2) The 8-hour average value should have at least 75% of the monitoring data or about 18 hours of available monitoring data.
3) The 24-hour average (daily) value should have a minimum of 50% of hourly data in a day.
4) The seasonal and annual average values must have at least 50% of daily data in a year", was considered.

There were two data sets for air pollutant $PM_{2.5}$ concentration and the degree of correlation between these two data sets from different monitoring stations was observed. For this purpose, the correlation analysis which is normally applied to determine how much the measurement of air quality parameters from two station was used. Firstly, it was checked whether the data is normally distributed or not by skewness and kurtosis. Since both data sets were normally distributed, Pearson correlation coefficient analysis was used. Scatterplot was applied to provide a general illustration of the relationship between variables. Positive or negative sign *r* shows the direction of correction between variables.

Step 2: Multiple Linear Regression

Regression model was used to estimate the level of correlation between the predictors and criterion variables and explore the forms of relationships between them. Before making multiple linear regression, four assumptions criteria were checked. These assumptions included the independent observations of a variable, no serious outliers in a variable, normal distribution of a variable and no multi-collinearity among independent variables. For the last one, VIF (Variance Inflation Factor) to detect multi-collinearity was used. A variable with VIF of 1-10 was considered to be acceptable. Any variable with VIF greater than 10 indicated a problematic amount of collinearity and was removed from the model and run the analysis again. Finally, multiple linear regression analysis was used to find the association between meteorological factors and air pollutant concentration. The model for the distribution of air pollution in Yangon city; a random dependent variable (Y) relating to a set of explanatory variables x_1, x_2... x_k based on the multiple regression model, is as shown as follow:

$$Y = \gamma + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_n x_n + \varepsilon; \qquad \textit{Eq. 1}$$

Where, Y = the response variable such as pollutant concentration,

x_1, x_2,..., x_n = the independent variables (i.e., meteorological factors),

$\beta_1,..,\beta_n$ = the coefficients of the regression model and

ε = an error term factor.

The variable with the $p<0.001$ was considered as statically significant. After performing this model, the model validation was made by the following methods:

(1) Comparison of residual and fitted value to check the linearity of predictor variables (x) with response variable (y),

(2) Checking the normality of residual or error variance by Q-Q plot,

(3) Checking the homoscedasticity of residual or error variance by scale-location and

(4) Checking whether the data are free from outliers and influential observations by using Cook's distance.

When the normality assumption is violated, the variables were log transformed. For the last one, influential outliers, it was considered to remove when it comes to serious outliers and if the outliers are not serious enough, they were decided to include. Moreover, 10-fold cross validation which divided data sets into two segments; 90% of the random data for training set and 10% of random data for test set to give the RMSE and MAE value for determining the best the performance was also applied.

3.4 Air Quality Index (AQI) calculation and Time Series modelling

The key benefit of using an AQI is the ability to transform the information about air quality to the public with a way which is both easily and conveniently. AQI calculation of particulate matters ($PM_{2.5}$ and PM_{10}) from 2019- 2021 and O_3 from 2019 to 2020 was performed by using the AQI formula (EPA, 1999) for criteria pollutants which is given as:

$$I_P = \frac{I_{Hi} - I_{Lo}}{BP_{HI} - BP_{Lo}} (C_P - BP_{Lo}) + I_{Lo^\circ} \qquad \textit{Eq. 2}$$

Where,

I_P = the AQI for pollutant ‘p’

C_P = actual ambient concentration of the pollutant ‘p’

BP_{HI} = the concentration breakpoint that is greater than or equal to C p

BP_{Lo} = the concentration breakpoint that is less than or equal to C p

I_{Hi} = the AQI corresponding to BP_{Hi}

I_{Lo} = the AQI corresponding to BP_{Lo}

The obtained AQI values were used for time series analysis and time series modelling. All the Data sets were transformed into time series data first. Then, augmented Dickey Fuller (ADF) test for unit roots was carried out for checking the stationary of the time series data; $y_t = \mu + \emptyset y_{t-1} + \varepsilon_t$;where, H0: Ø=1, H1: Ø <1. Stationary of the time series means the variance, mean and standard deviation of the data are constant over the time. When our time series data were not stationary, differencing or transformation; $U_t = Z_t - Z_{t-1}$(first order), $W_t = U_t - U_{t-1}$(Second order) into stabilized series was done. After that, ACF (Auto correlation function) for *q* value and Partial correlation function (PACF) for *p* value were checked. However, to get the best fit of the model, Akaike's Information Criterion (AIC);

$$\text{AIC} = -2\log(L) + 2(p + q + k + 1) \qquad \textit{Eq. 3}$$

was applied for the selected data set. Then, the following ARIMA (p,d,q) model,

$$Z_t = \sum_{i=1}^{p} \varphi_i Z_{t-i} - \varepsilon_t = \sum_{i=1}^{p} \varphi_i Z_{t-i} - \sum_{j=1}^{q} \theta_i \varepsilon_{t-i} + ב_t \qquad \textit{Eq. 4}$$

was applied to predict for 2022. Model validation was done by using Ljung-Box test and 5-fold cross validation.

CHAPTER IV

RESULTS

In this study, the temporal distribution of three types of pollutants ($PM_{2.5}$, PM_{10} and Ozone) were investigated to determine the impact of observational meteorological factors on these pollutants. Secondly, Air Quality Index (AQI) for particulate matter ($PM_{2.5}$ and PM_{10}) were calculated, followed by the AQI prediction of these two pollutants for the near future. The duration considered in this study was three years period (2019-2021) and there were 1,096 observations for both air pollutants $PM_{2.5}$ and PM_{10} and 731 observations for O_3. There were 1096 observations for meteorological factors (maximum temperature, dew point temperature, relative humidity, station pressure, rainfall, and wind speed).

This chapter provides a detailed description of the results obtained from all analysis methods and modeling. There are three parts in the result session: descriptive findings, inferential findings, and findings from time series modelling. Firstly, validation of data was accounted for reliable descriptive statistics in all observations. Descriptive observations of each pollutant and each meteorological factor were included in the first part. This session clearly describes the characteristics of all variables found in the atmosphere of Yangon city.

Second part includes bivariate analysis and multivariable analysis to investigate the association between explanatory variables and response variables. The explanatory variables in this study are meteorological factors and response variables are air pollutant concentrations. In the third session, AQI calculations and prediction of AQI as a function of time by time series modelling via ARIMA model was presented.

4.1 Descriptive Findings

4.1.1 Air Pollutants Concentration

Collected air pollutant data included Ozone from US Embassy monitoring station, PM_{10} from NGO monitoring and $PM_{2.5}$ from both US Embassy and NGO monitoring station. For both Ozone and PM_{10}, the minimum amount of data from these two data sets to forecast the average value of air pollutant concentration was over 75%; therefore, data imputation was made by median imputation because only 3% was missing. Although the minimum amount of data that need to meet the average concentration standard by WHO for a three-year study period of $PM_{2.5}$ was over 75%, data imputation was done by correlation analysis for 8.2 % of missing value.

Table 3 shows the result of correlation analysis between $PM_{2.5}$ concentration of two stations; NGO monitoring station and US Embassy monitoring station, while Figure 2 illustrates a scatter plot of the correlation. The analysis shows a strong correlation between 2 stations with the correlation coefficient (r^2) of 0.84 (p <0.001). Therefore, 8.2% of $PM_{2.5}$ concentration missing value from US Embassy monitoring station was substituted by the $PM_{2.5}$ concentration of the same day. Table 4 also shows the summary statistics of air pollutants ($PM_{2.5}$, PM_{10} and O_3) during a three-year study period.

Table 3 Summary for correlation analysis of $PM_{2.5}$ between two stations

Air Pollutant	***r*-value**	***p*-value**
$PM_{2.5}$	0.84	< 0.001

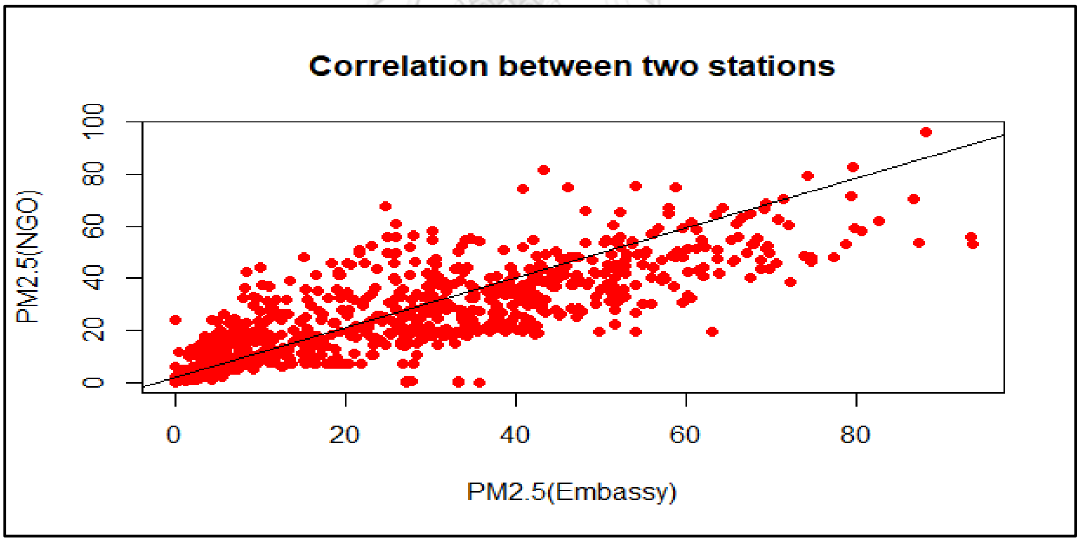

Figure 2 Scatterplot of significant $PM_{2.5}$ concentration correlation between two stations

According to summary statistic shown in Table 4, concentration of $PM_{2.5}$, PM_{10} and O_3 during the study periods range from 0-93.6 (µg/m^3), 0.1-149.27(µg/m^3) and 0.50- 62.25(ppb) respectively. Monthly average concentrations of all pollutants ($PM_{2.5}$, PM_{10}, O_3) during the study period were also investigated and the result are shown in

Table 5, Table 6 and the monthly average distributions graphs are shown in Figure 3 and Figure 4 respectively.

Table 4 Summary descriptive statistics of air pollutants ($PM_{2.5}$, PM_{10} and O_3)

Air Pollutants	**$PM_{2.5}$**	**PM_{10}**	**O_3**
No. of observation	1096	1096	731
Mean	24.02	40.16	7.50
Median	19.07	32.09	5.89
Min	0	0.10	0.50
Max	93.6	149.27	62.25
SD	21.01	30.21	6.94

Table 5 Monthly Average concentration of $PM_{2.5}$, PM_{10} during 2019-2021

Month	**$PM_{2.5}$ concentration ($\mu g/m^3$)**	**PM_{10} concentration ($\mu g/m^3$)**
January	51.49	75.20
February	52.33	78.69
March	44.33	69.17
April	33.30	47.95
May	16.81	30.15
June	5.70	15.96
July	4.19	14.26
August	4.82	17.62
September	5.06	14.62
October	5.63	29.01
November	21.00	36.65
December	39.89	50.35

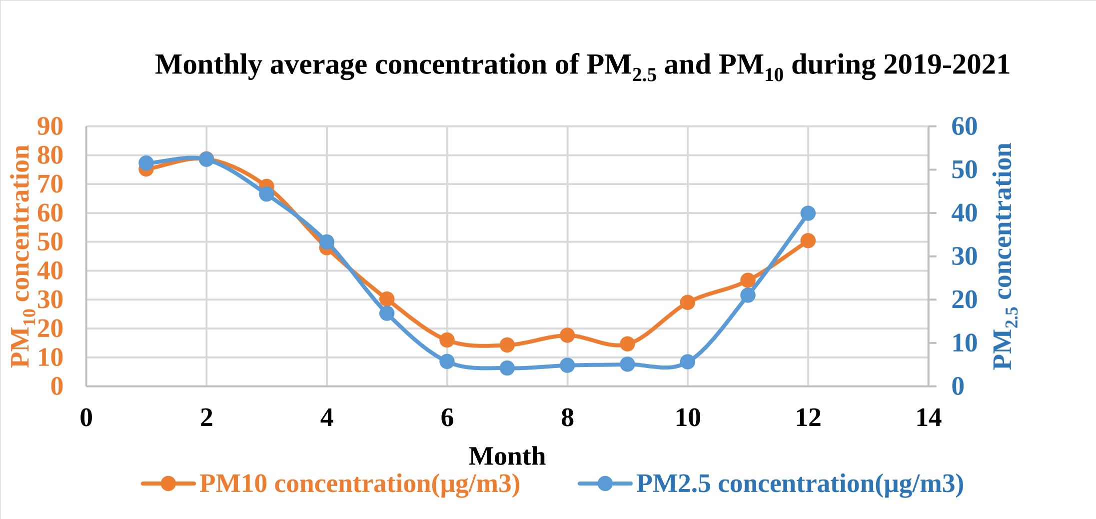

Figure 3 Monthly distribution of $PM_{2.5}$ and PM_{10} during 2019-2021

Table 6 Monthly Average concentration of Ozone during 2019-2020

Month	O_3 concentration (ppb) (2019)
January	10.32
February	10.59
March	9.30
April	10.09
May	6.39
June	4.92
July	13.63
August	6.47
September	3.86
October	5.24
November	7.82
December	9.00

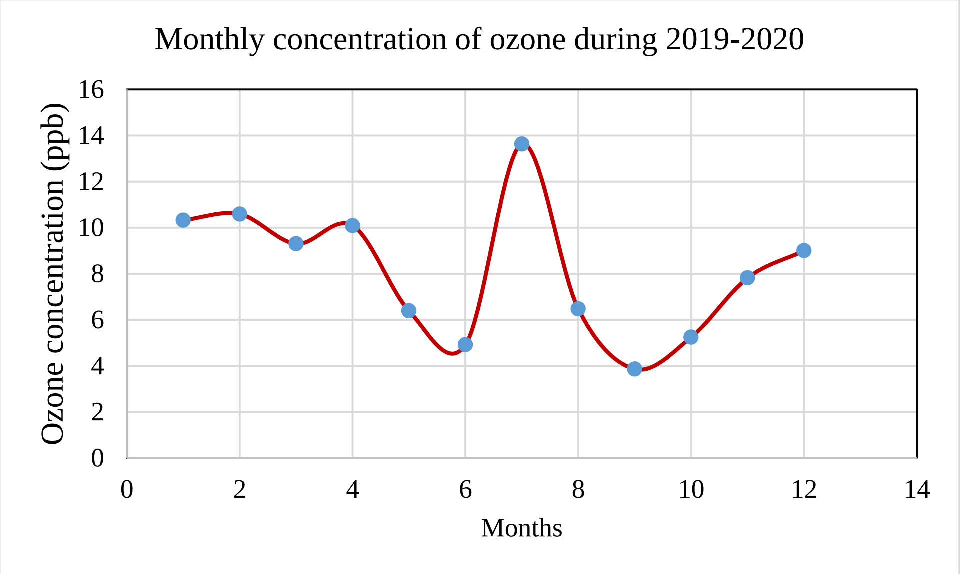

Figure 4 Monthly distribution of O_3 during 2019-2021

4.1.2 Meteorological factors

Meteorological factors included in this study are maximum temperature, dew point temperature, relative humidity, rainfall, wind speed and station pressure. There are 1096 observations for each meteorological factors. Summary statistics of meteorological factors is shown in the Table 7.

Table 7 Summary statistics of meteorological factors during study period

Meteorological factors	Maximum temperature (˚C)	Relative humidity (%)	Dew point temperature (˚C)	Rainfall (mm)	Station pressure (hPa)	Wind speed (mph)
No. of observation	1096	1096	1096	1096	1096	1096
Mean	33.94	62.27	23.09	7.60	1010.07	1.57
Median	32	62	24.60	0	1010.95	1.20
Min	33	21	9.60	0	107	0
Max	42.20	100	39	190	1018.9	4.60
SD	3.10	30.21	3.60	16.66	28.68	0.65

4.2 Inferential Findings

4.2.1 Bivariate association between air pollutant ($PM_{2.5}$) and meteorological factors

Pearson's correlation analysis stated the multiple correlation between $PM_{2.5}$ and meteorological factors. The result of correlation matrix from Pearson's correlation analysis between $PM_{2.5}$ concentration and meteorological factors is shown in Figure 5. Illustration of how much one variable was affected by another is shown in Figure 6. According to Pearson's correlation analysis, ambient temperature and dew point temperature had significant negative correlation with $PM_{2.5}$ concentration (*p*-value < 0.001). Similarly, rainfall had moderate negative correlation with $PM_{2.5}$ concentration (*p*-value < 0.001). Moreover, ambient temperature had moderate positive association with $PM_{2.5}$ (*p*-value < 0.001). However, station pressure and wind speed found no correlation with $PM_{2.5}$ concentration.

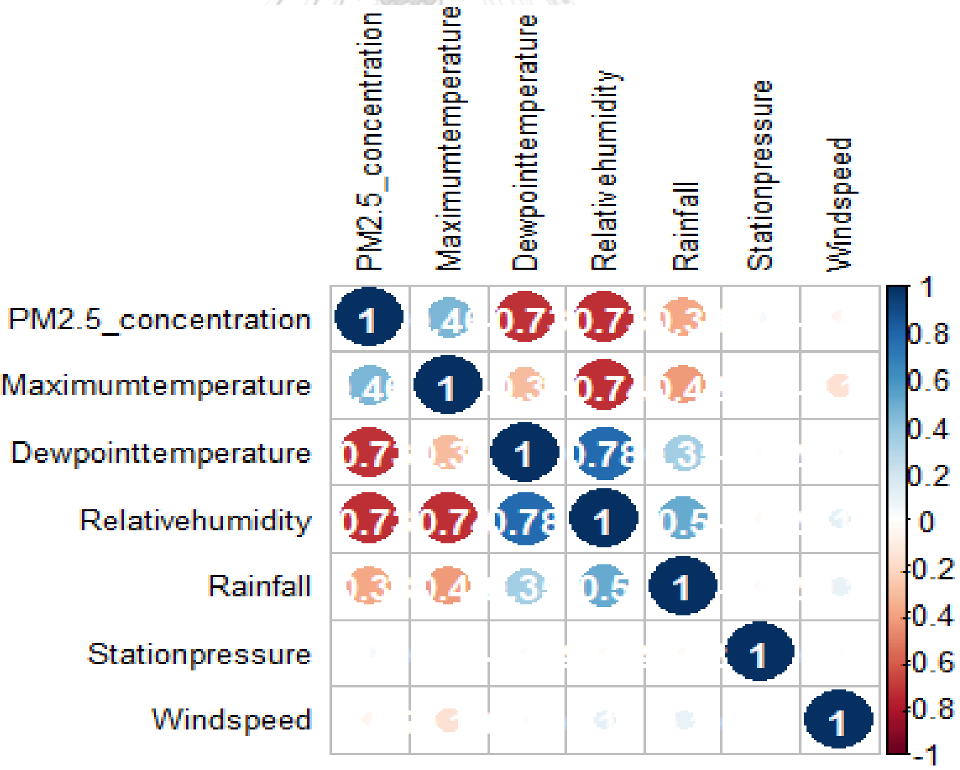

Figure 5 Summary correlation matrix of correlation analysis between $PM_{2.5}$ and meteorological factors

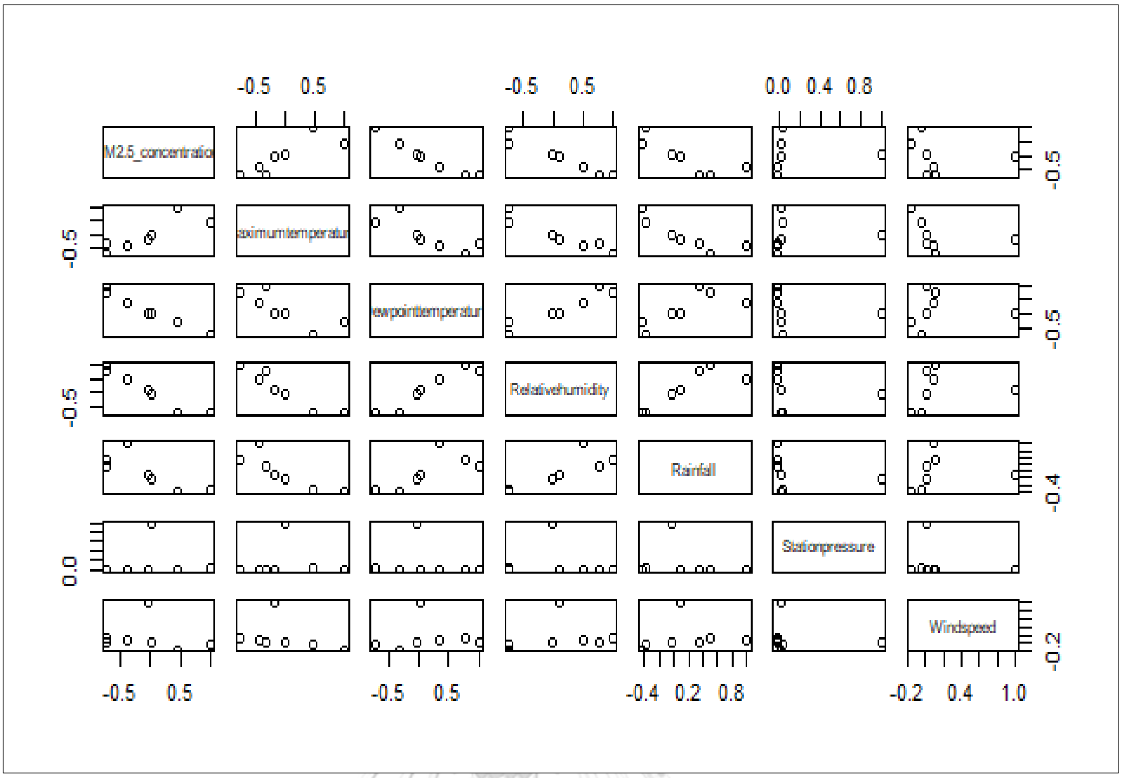

Figure 6 Scatterplot matrix of correlation analysis between $PM_{2.5}$ and meteorological factors

4.2.2 Bivariate association between air pollutant (PM_{10}) and meteorological factors

Pearson's correlation analysis stated the multiple correlation between PM_{10} and meteorological factors. The result of correlation matrix from Pearson's correlation analysis between PM_{10} concentration and meteorological factors is shown in Figure 7. Illustration of how much PM_{10} concentrations was affected by meteorological factors are shown in Figure 8. According to Pearson's correlation analysis, relative humidity and dew point temperature had significant negative correlation with PM_{10} concentration (p-value < 0.001). Similarly, rainfall had moderate negative correlation with PM_{10} concentration (p-value < 0.001). Moreover, ambient temperature had moderate positive association with PM_{10} with (p-value < 0.001). However, station pressure and wind speed found no correlation with PM_{10} concentration.

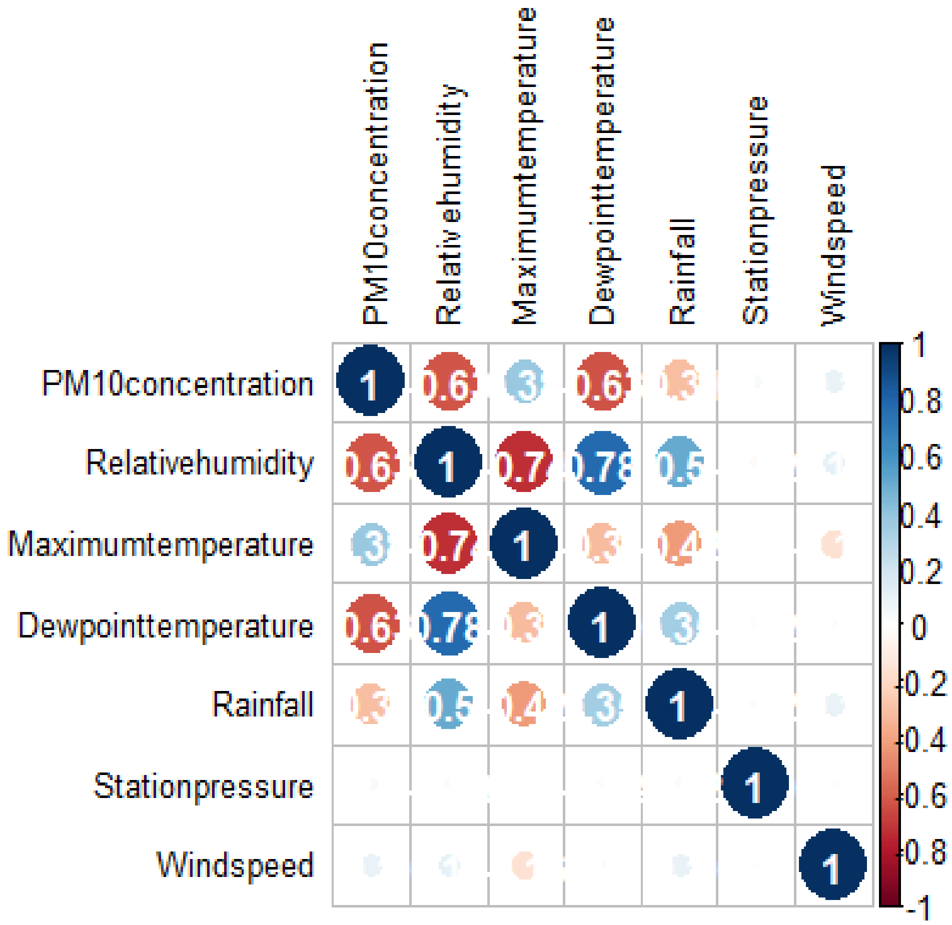

Figure 7 Summary correlation matrix of correlation analysis between PM_{10} and meteorological factors

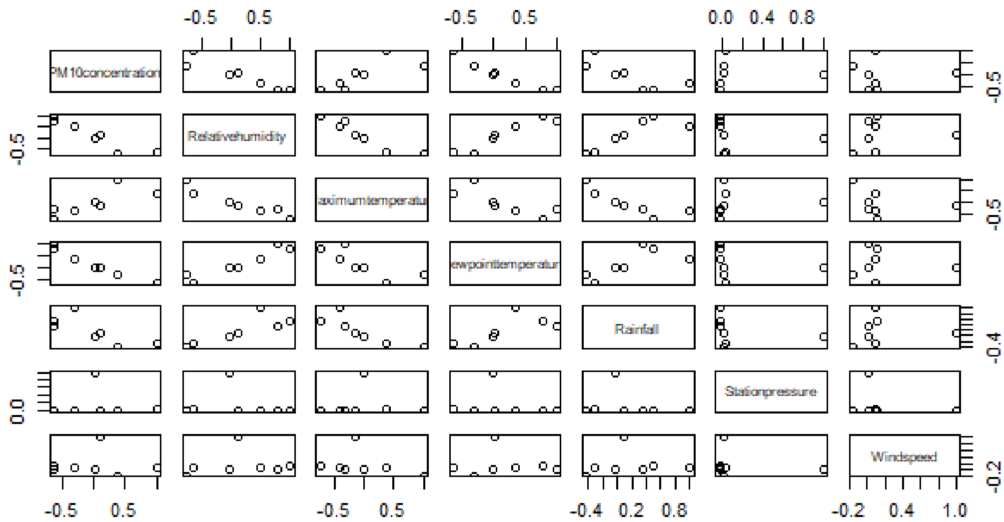

Figure 8 Scatterplot matrix of correlation analysis between PM_{10} and meteorological factors

4.2.3 Bivariate association between air pollutant (O_3) and meteorological factors

For Ozone concentration, the data was positively skewed and normality of the whole data set was done by log transformation. Pearson's correlation analysis stated the multiple correlation between O_3 and meteorological factors. The result of Pearson's correlation analysis between O_3 concentration and meteorological factors is shown in Table 8. Illustration of how much O_3 concentrations was affected by meteorological factors are shown in Figure 9. According to Pearson's correlation analysis, dew point temperature and relative humidity had negative correlation with O_3 concentration and ambient temperature had significant positive correlation with ozone (p-value < 0.001).

Table 8 Summary of correlation analysis between O_3 and meteorological factors

Meteorological factors	*r*-value	*p*-value
Ambient temperature	0.4	< 0.001
Dew point temperature	-0.35	< 0.001
Relative humidity	-0.40	< 0.001

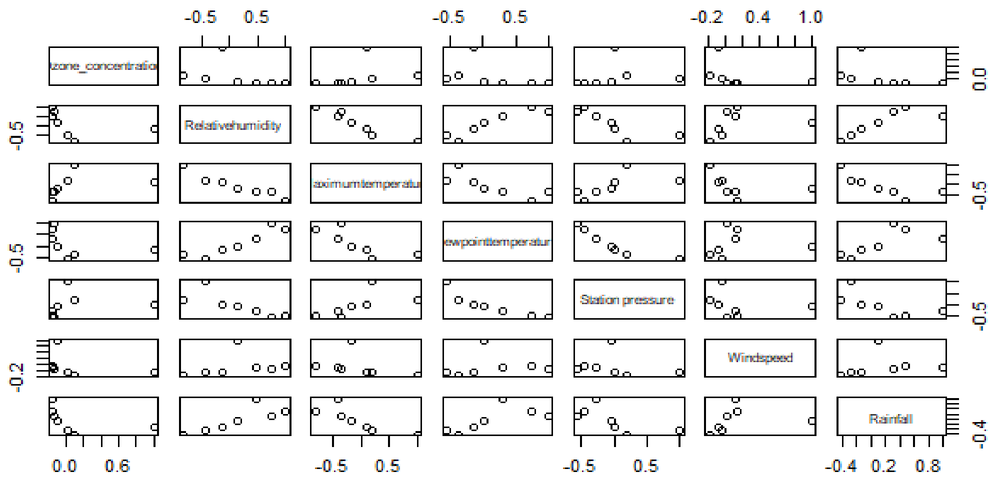

Figure 9 Scatterplots of significant correlation between O_3 and meteorological factors

4.2.4 Multiple Linear Regression Analysis

To investigate the remarkable effect of meteorological factors on selected air pollutant concentration, multiple linear regression analysis was done by making seasonal models; Summer (March-May), Monsoon (June-October) and Winter (November-February) and annual model by considering all the selected study periods together. The significant findings of multiple linear regression analysis are stated in the following sessions.

4.2.4.1 Seasonal Multiple Linear Regression model of $PM_{2.5}$

The influence of meteorological factors on $PM_{2.5}$ showed variations depending on seasons. The results obtained from seasonal multiple linear regression models are listed in Table 9, while Figure 10 shows the prediction and actual value in each season. According to four assumption criterions that were checked before developing the model, four explanatory variables were considered to include in the seasonal models. Explanatory variables included in summer, monsoon and winter models are maximum temperature, dewpoint temperature and relative humidity; however, rainfall was included in monsoon model because of the significant correlation between rainfall and $PM_{2.5}$ concentration during monsoon. From three seasonal models, coefficient of the regression model in relation to temperature is high (p<0. 001) although the value of R^2 is 0.19, 0.08 and 0.3 for summer, monsoon, and winter, respectively. The result of checking these three seasonal models by linearity assumption, linearitly assumption, homosdececity of error variance assumption and no influential outliers assumption proved these models were best fit models.

Table 9 Seasonal multiple linear regression Models of $PM_{2.5}$ in Yangon city

Seasons	**MLR model(y)**	**Adj-R^{2*}**
Summer	$PM_{2.5} = 25+1.5x_1-2.32x_2-0.06x_3$	0.19*
Monsoon	$PM_{2.5} = -18.24+0.84x_1-0.2x_2-0.02x_3-0.005x_4$	0.08*
Winter	$PM_{2.5} = 59+0.84x_1-1.16x_2-0.44x_3$	0.3*

***p-value < 0.001,x_1= "Temperature", x_2="Dew point temperature", x_3="Relative humidity",x_4="Rainfall"**

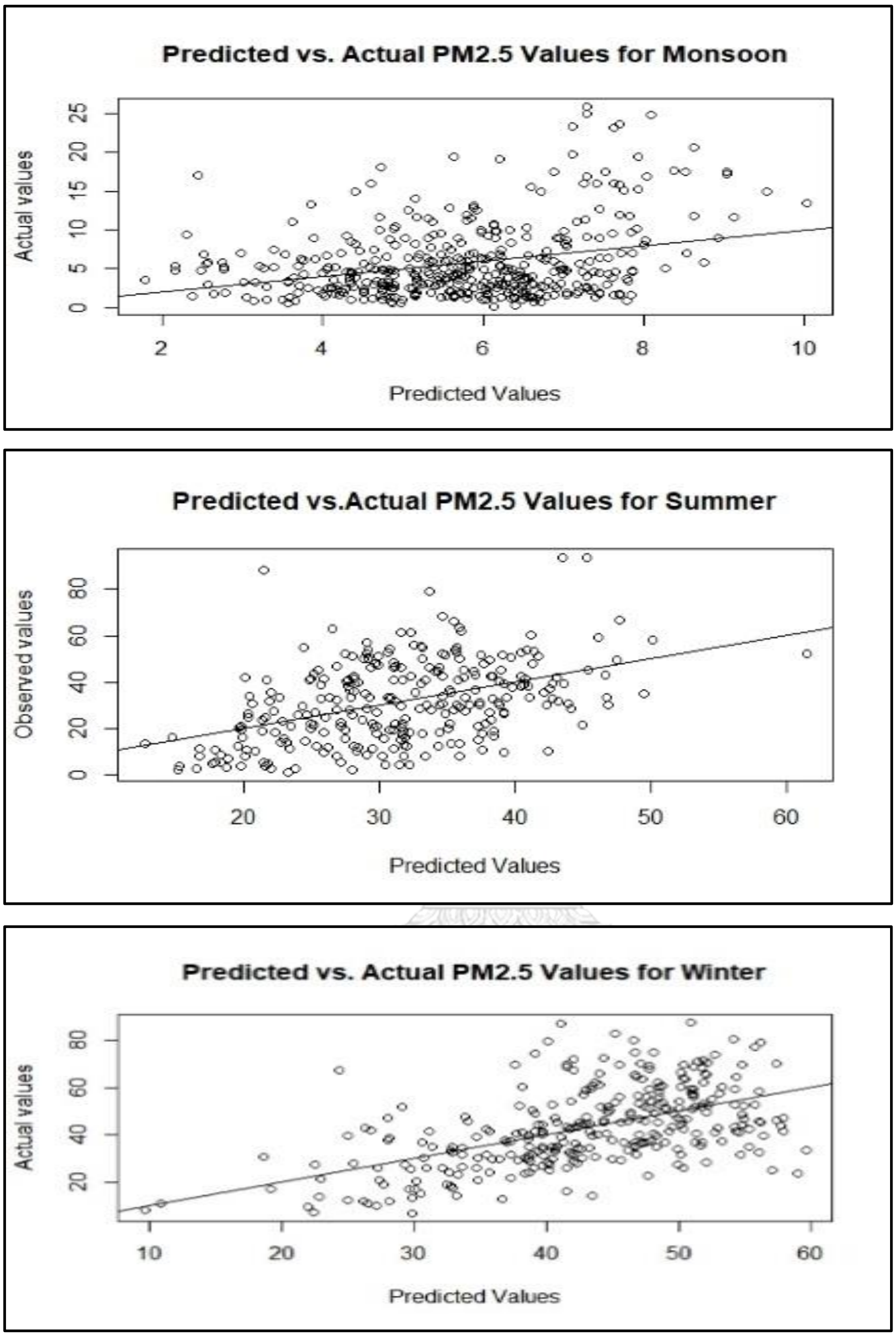

Figure 10 Scatter plot of Predicted vs. Observed $PM_{2.5}$ values for monsoon, winter and summer

4.2.4.2 Seasonal Multiple Linear Regression model of PM_{10}

The influence of meteorological factors on PM_{10} showed variations depending on seasons. The results obtained from seasonal multiple linear regression models are listed in Table 10, while Figure 11 shows the prediction and actual value in each season. According to four assumption criterions that were checked before developing the model, four explanatory variables were considered to include in the seasonal models of PM_{10}. Explanatory variables included in summer, monsoon and winter models are maximum temperature, dewpoint temperature and relative humidity; however, rainfall was included in monsoon model because of the significant correlation between rainfall and PM_{10} concentration during monsoon. From three seasonal models, it can be clearly seen that coefficient of the regression model in relation to temperature is high(p<0. 001) especially in winter although the value of R^2 is 0.08, 0.05 and 0.35 for summer, monsoon, and winter, respectively. The result of checking these three seasonal models by linearity assumption, linearitly assumption, homosdececity of error variance assumption and no influential outliers assumption proved these models were best fit models.

Table 10 Seasonal multiple linear regression Models of PM_{10} in Yangon city

Seasons	**MLR model(y)**	**Adj-R^{2*}**
Summer	PM_{10} = 98.91+0.2x_1-3.00x_2-0.05x_3	0.08*
Monsoon	PM_{10} =-68.14+2.78x_1-0.25x_2-0.03x_3-0.004x_4	0.05*
Winter	PM_{10} =117.09+0.56x_1-2.25x_2-0.59x_3	0.35*

***p-value < 0.001,x_1= "Temperature", x_2="Dew point temperature", x_3="Relative humidity",x_4="Rainfall"**

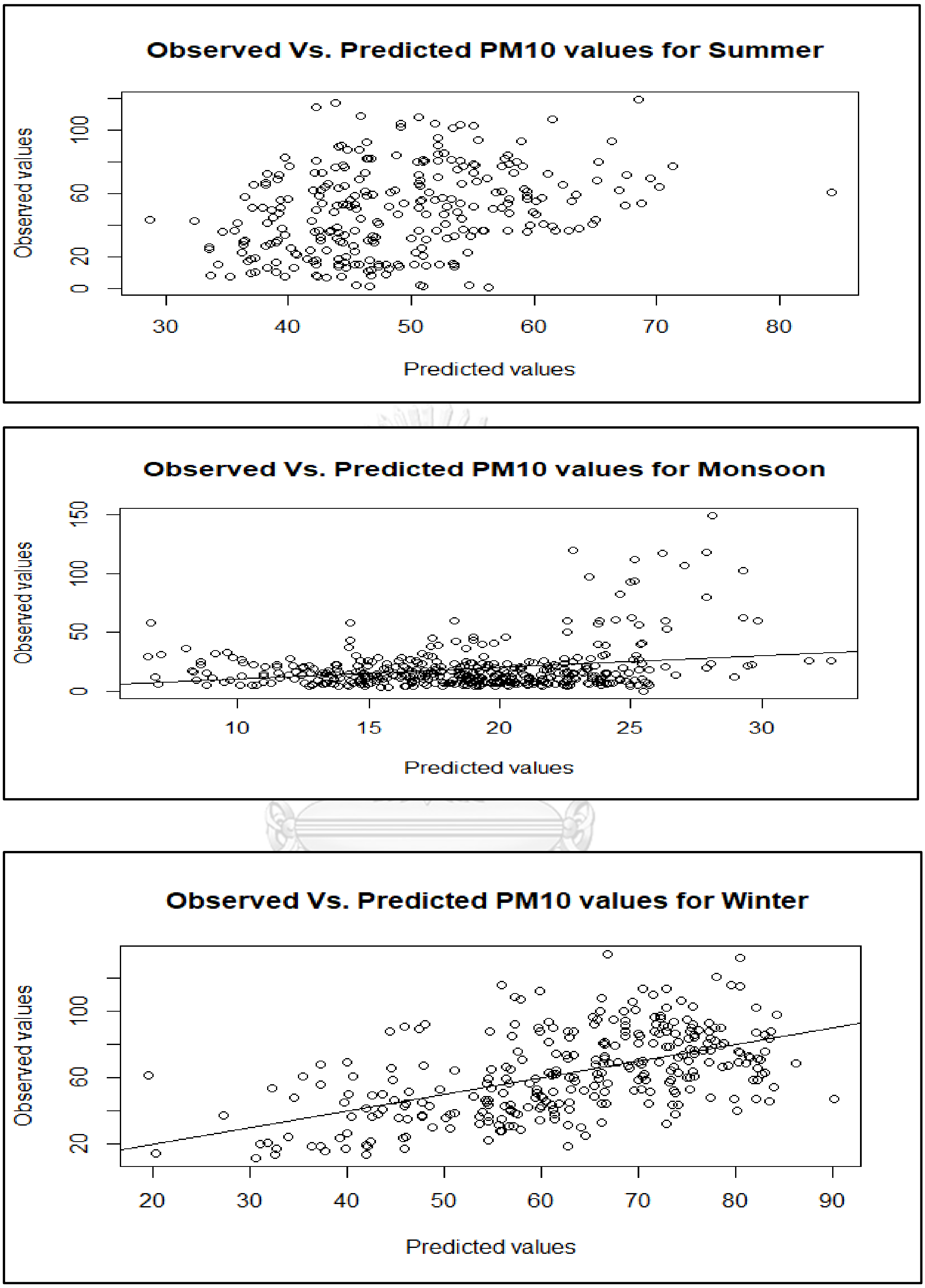

Figure 11 Scatter plot of Predicted vs. Observed PM_{10} values for summer, monsoon and winter

4.2.4.3 Annual Multiple Linear Regression model of $PM_{2.5}$

For the fianl fitted model during a three-year period, assumptions were checked before developing the model. According to the result of these assumptons, rainfall was excluded because it violated two assumptions. Furthermore, atmospheric pressure and winspeed were also excluded because they caused multi-collineartiy among explanatory variables. Finally, for the better performance of the model, only three meteorological factors (i.e., temperature, relative humidity, and dew point temperature) were included in the final model. The result of the fitted model is shown in Table 11. The results suggested that dew point temperature and relative humidity significantlly associated with $PM_{2.5}$ concentration (p<0. 05), while the max-temperature was borderline associated with $PM_{2.5}$ (p = 0.056). The adj-R^2 of the final regression model is 0.60. The result obtained from cross validation; 90 % of the randomly data selected from data set as training set and 10% of the data as testing set, suggested that the best fit model in this study is,

Y= 79.14+ 0.50 (Temperature) - 2.62(Dew point temperature) - 0.37(Relative humidity)

with R^2 value of 0.55 and (RMSE=14, MAE=10.8). After the validation, scatterplot of the best fit model was illustrated in Figure 12.

Table 11 Multiple linear regression model of $PM_{2.5}$ in Yangon City

Varibales	β coeff.	S.E.	*p*-value
Intercept	79.15	17.63	< 0.001
Maximum temperature	0.50	0.26	0.0561
Dewpoint temperature	-2.62	0.24	< 0.001
Relative humidity	-0.37	0.06	< 0.001

R^2: 0.60, RMSE:14

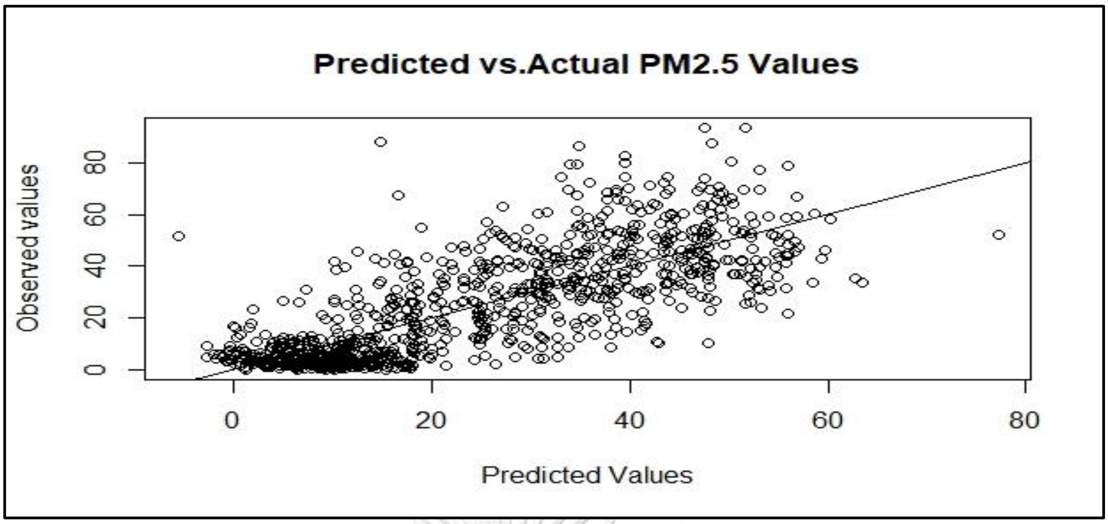

Figure 12 Scatter plot of Predicted vs. Observed $PM_{2.5}$ values

4.2.4.4 Annual Multiple Linear Regression model of PM_{10}

After checking the reliablity of the data set , four assumptions criterions which are types of sampling, checking outliers, normal distribution of individual variables and multi-collinearity among independent were checked. According to the result of these assumptions, rainfall was excluded because it violated two assumptions. Furthermore, atmospheric pressure and winspeed were also excluded because they caused not only multi-collineartiy among explanatory variables but alos violated one assumption. Finally, for the better performance of the model, only three meteorological factors (i.e., temperature, relative humidity, and dew point temperature) were included in the final model. The result of the final fitted model is shown in Table 12. The results suggested that relative humidity and dew point temperature significantlly associated with PM_{10} concentration (p<0. 001). The adj-R^2 of the final regression model is 0.45. The result obtained from cross validation; 90 % of the randomly data selected from data set as training set and 10% of the data as testing set, suggested that the best fit model in this study is,

Y= 136.03 - 3.09 (Dew point temperature) - 0.55 (Relative humidity)

with R^2 value of 0.45 and (RMSE=22.00, MAE=17.20). After the validation, scatterplot of the best fit model was illustrated in Figure 13.

Table 12 Multiple linear regression model of PM_{10} in Yangon City

Varibales	β coeff.	S.E.	*p*-value
Intercept	136.03	5.04	< 0.001
Dewpoint temperature	-3.09	0.40	<0.001
Relative humidity	-0.55	0.10	< 0.001

R^2: 0.45, RMSE:22.00

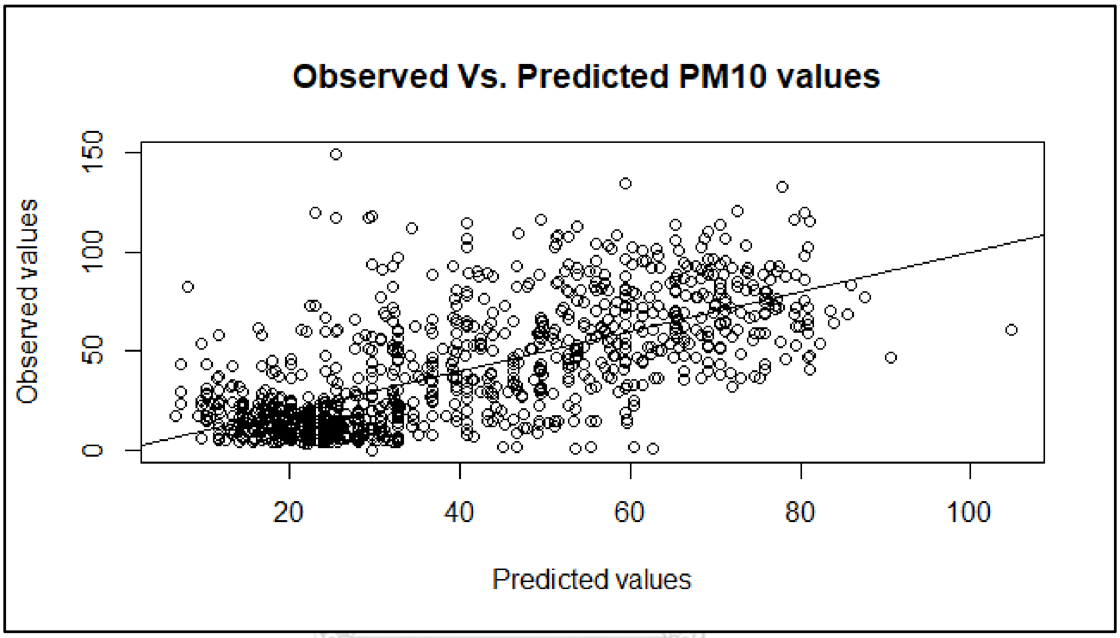

Figure 13 Scatter plot of Predicted vs. Observed PM_{10} values

4.2.4.5 Annual Multiple Linear Regression model of Ozone

For the fianl fitted model during a three-year period, assumptions were checked for all variables like before. Ozone concentration is positively skewed and log transformation was applied to obtain the normal distribution. When it comes to meteorologiacl factors, rainfall, atmospheric pressure and winspeed were excluded because they not only viloated assumptions but also caused multi-collineartiy among explanatory variables. Finally, for the better performance of the model, only three meteorological factors (i.e., temperature, relative humidity, and dew point temperature) were included in the final model. The result of the fitted model is shown in Table 13. According to the result, only relative humidity was boderlone associated with O_3 ,while other meteorological factors was no significant association with ozone. The adj-R^2 of the final regression model is 0.20 (p-value< 0.001). The result obtained from cross validation; 90 % of the randomly data selected from data set as training set and 10% of the data as testing set, suggested that the best fit model in this study is,

Y= 1.39 - 0.014(Relative humidity)

with R^2 value of 0.445 , MAE=0.3 and RMSE= 6.69. After the validation, scatterplot of the best fit model was illustrated in Figure 14.

Table 13 Multiple linear regression model of O_3 in Yangon City

Varibales	β coeff.	S.E.	*p*-value
Intercept	1.39	0.31	< 0.001
Relative humidity	-0.014	0.00	<0.001

R^2 =0.445, RMSE=6.69

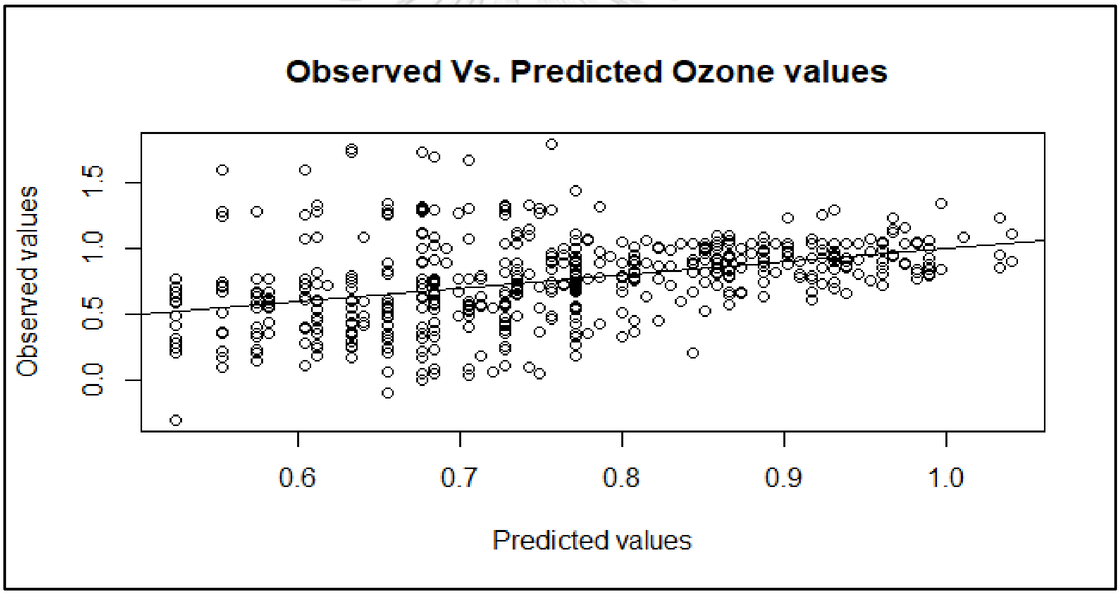

Figure 14 Scatter plot of Predicted vs. Observed O_3 values

4.3.1 AQI of air pollutants ($PM_{2.5}$ and PM_{10})

AQI of $PM_{2.5}$ and PM_{10} were calculated according to USEPA's formula for criteria pollutants. The summary statistics of the results of the daily AQI of $PM_{2.5}$ calculation are mean=69.13, median = 66.5, minimum =0, maximum =171 and SD=49.72. For PM_{10}, mean=33.46, median=30.5, minimum= 2, median=30.5 and SD= 22.41 respectively. Table 14 shows the summary of daily average AQI of PM_{10} and

$PM_{2.5}$, and related health hazards of ozone during study period, while Figure 15 and Figure 16 illustrate the daily distribution of $PM_{2.5}$ and PM_{10} during the study period.

Table 14 Summary of daily average AQI and health hazard of particulate matter for each month ($PM_{2.5}$ and PM_{10})

Month	$PM_{2.5}$ AQI	Health Hazard	PM_{10} AQI	Health Hazard
January	122.83	**Unhealthy for sensitive groups**	57.24	**Moderate**
February	133.58	**Unhealthy for sensitive groups**	63.70	**Moderate**
March	121.42	**Unhealthy for sensitive groups**	58.02	**Moderate**
April	94.04	**Moderate**	38.53	**Good**
May	56.47	**Moderate**	18.35	**Good**
June	23.14	**Good**	14.24	**Good**
July	16.92	**Good**	12.75	**Good**
August	20.62	**Good**	15.34	**Good**
September	18.88	**Good**	13.10	**Good**
October	36.99	**Good**	23.92	**Good**
November	78.07	**Moderate**	39.17	**Good**
December	110.53	**Unhealthy for sensitive groups**	44.55	**Good**

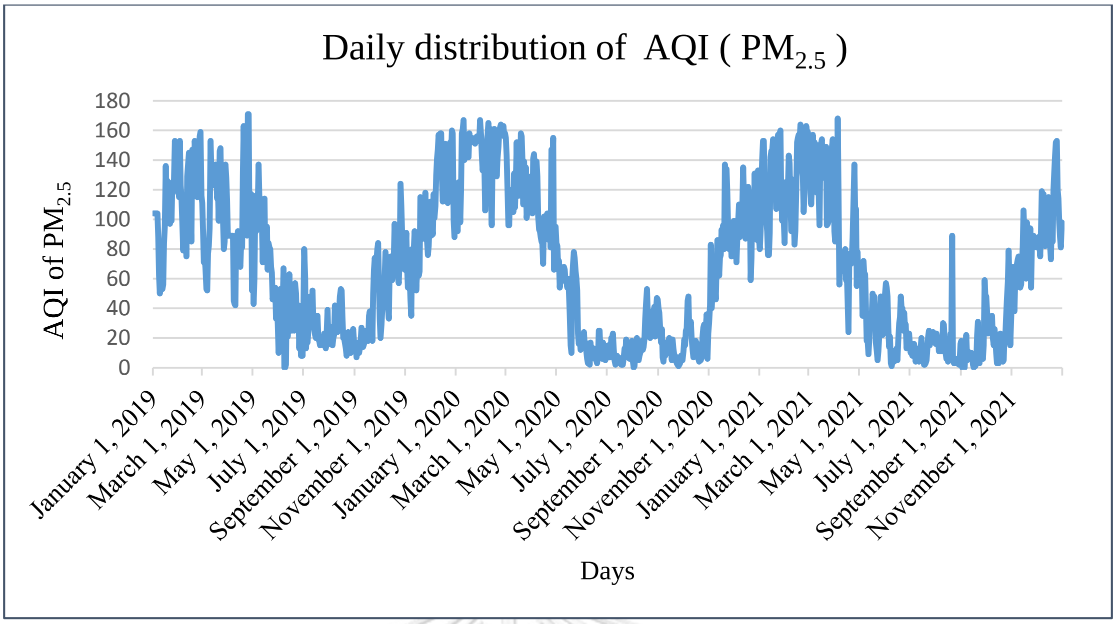

Figure 15 Daily distribution of AQI of $PM_{2.5}$

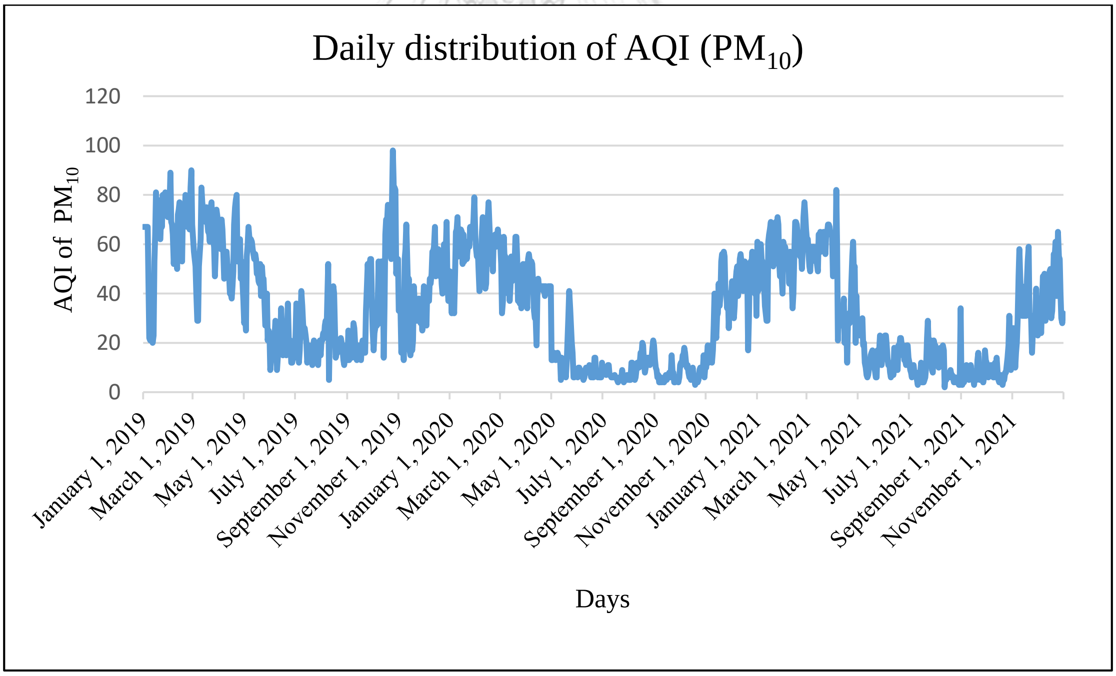

Figure 16 Daily distribution of AQI of $PM_{2.5}$

4.3.2 AQI of air pollutant (O_3)

AQI of ozone was calculated according to USEPA's formula for criteria pollutants. The summary statistics of the results of the daily AQI of ozone calculation are mean=6.81, median = 5, minimum =1, maximum =56 and SD=6.3. Table 15 shows summary of daily average AQI and related health hazards of ozone for each month during study period, while Figure 16 illustrates the daily AQI of ozone distribution during the study period.

Table 15 Summary of daily average AQI and health hazard of Ozone during for each month

Month	O_3 AQI	Health Hazard
January	10.00	**Good**
February	9.98	**Good**
March	9.63	**Good**
April	8.62	**Good**
May	5.00	**Good**
June	4.00	**Good**
July	12.50	**Good**
August	5.50	**Good**
September	3.50	**Good**
October	4.50	**Good**
November	7.00	**Good**
December	7.50	**Good**

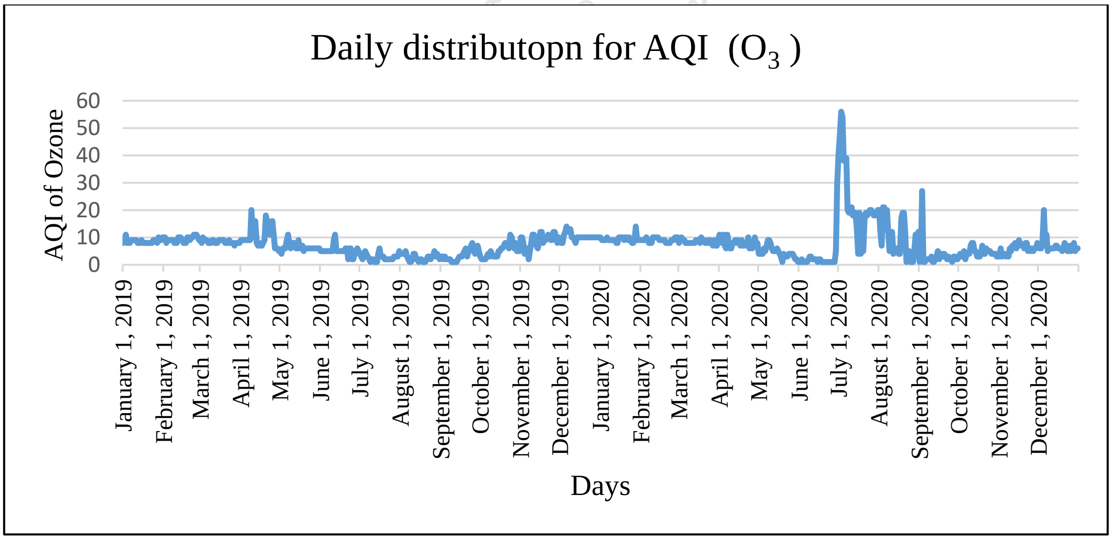

Figure 17 Daily distribution of AQI of Ozone

4.4 Time Series Modelling

Daily AQI values of PM_{10} and $PM_{2.5}$ from 2019 to 2021 were used to predict the AQI values for 2022. Firstly, the time series patterns of particulate matters were investigated by time series analysis. Figure 18 and Figure 19 depicts the time series of AQI values for $PM_{2.5}$.

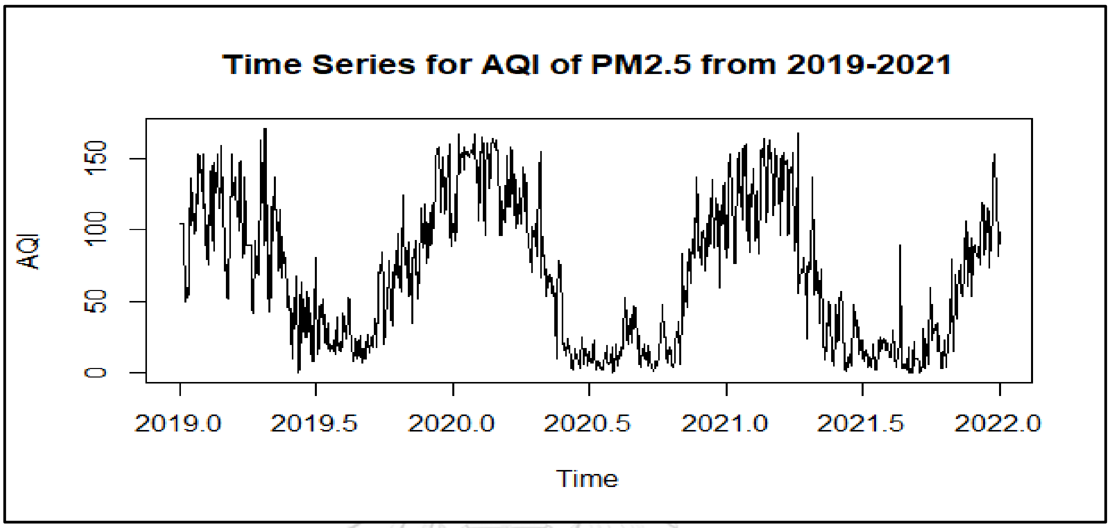

Figure 18 Time Series for AQI of $PM_{2.5}$ from 2019-2021

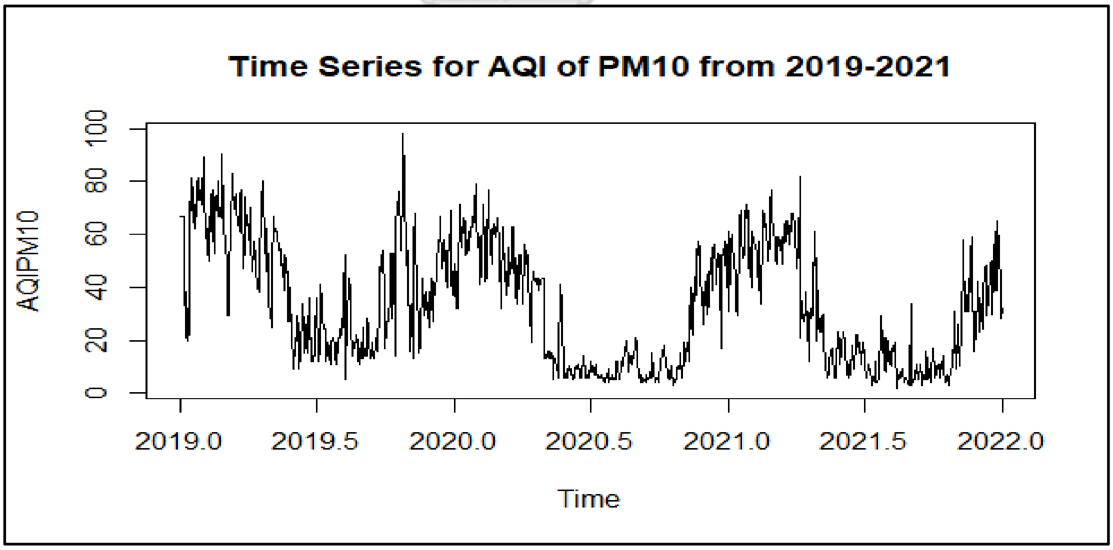

Figure 19 Time Series for AQI of PM_{10} from 2019-2021

Being a stationary time series is really important when forecast the future and stability of these series was investigated by Augmented Dickey-Fuller unit root test. For $PM_{2.5}$, the critical value of Dickey-Fuller test is -3.5 (p-value=0.4913), which showed that $PM_{2.5}$ time series is not stationary. Similar to PM_{10}, the critical value is-

3.7(*p*-value=0.2) and the series is considered as non-stationary. To fit this, Akaike Information criterion (AIC) was performed to get the stationary series and for investigating the correlation coefficient and partial correlation coefficient in building the model for prediction. According to the result of the AIC, the best fit model for both $PM_{2.5}$ and PM_{10} is (3, 1, 1) (0, 1, 0) with the lowest AIC value of 6646.009 for $PM_{2.5}$ and AIC value of 5582.341 for PM_{10}. Finally, prediction of AQI for both PM_{10} and $PM_{2.5}$ was made by applying the best fit model by AIC of p=3, q=1 and d=1. Illustration for the result of AQI prediction for $PM_{2.5}$ for near future (2022) is shown in Figure 20 and that of PM_{10} is shown in Figure 21. The validation of proposed model was checked by 5-Fold cross-validation and the resulted model performance for both $PM_{2.5}$ and PM_{10} models are shown in Table 16. Moreover, the performance of the ARIMA models for both $PM_{2.5}$ and PM_{10} according to cross validation are shown in Figure 22 and 23.

Table 16 Model performance for $PM_{2.5}$ and PM_{10} models From Cross-validation

Model	RMSE	MAE	MAPE	*p*-value	*Theil's U*
$PM_{2.5}$	17.43	13.18	49.21	<0.05	1.10
PM_{10}	7.54	5.28	20.04	<0.05	1.03

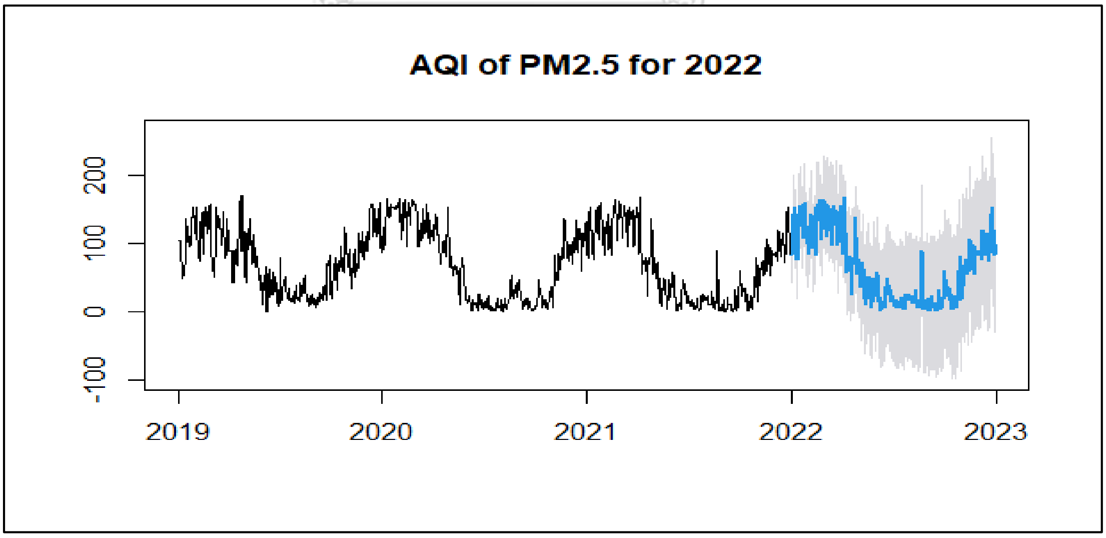

Figure 20 Forecast for $PM_{2.5}$ AQI model for 2022.The gray bands (95%) show the possible range of variation of AQI over the predicted period. Y-axis shows the AQI value of PM2.5 and X-axis represents the date.The blue line represents the forecasted value.

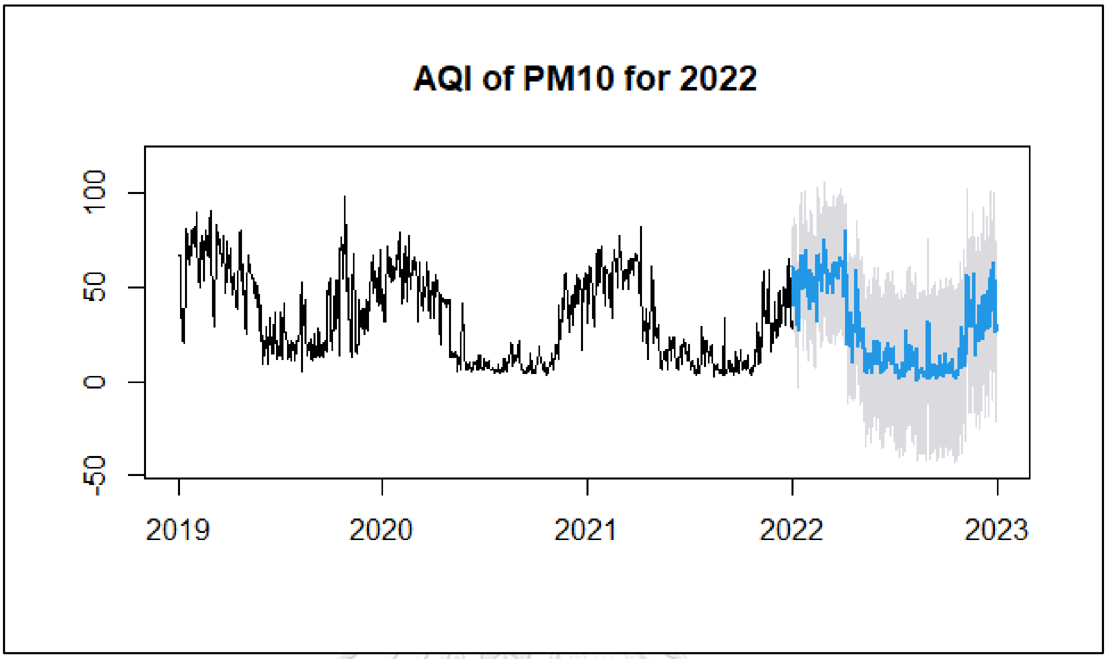

Figure 21 Forecast for PM_{10} AQI model for 2022.The gray bands (95%) show the possible range of variation of AQI over the predicted period. Y-axis shows the AQI value of PM_{10} and X-axis represents the date.The blue line represents the forecasted value.

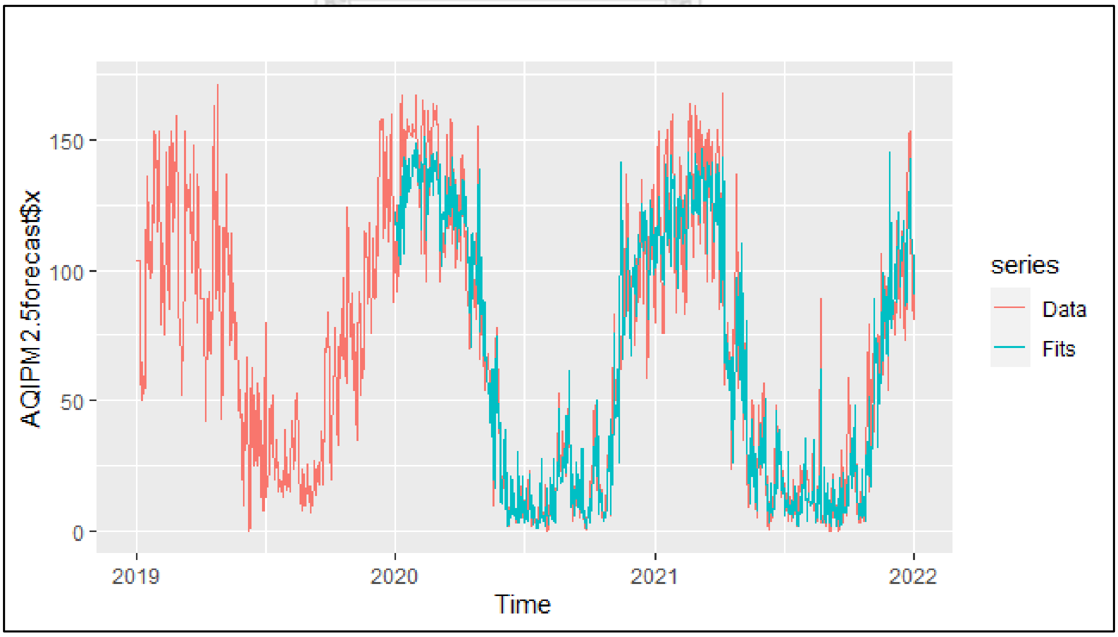

Figure 22 Model performance of ARIMA for AQI ($PM_{2.5}$)

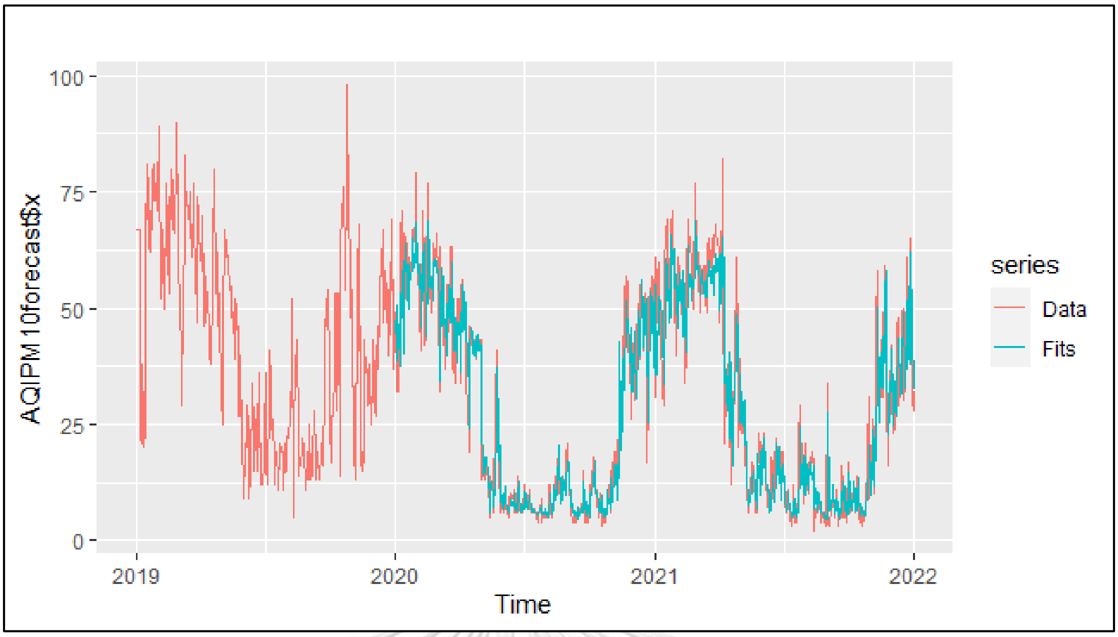

Figure 23 Model performance of ARIMA for AQI (PM_{10})

CHAPTER V

DISCUSSION

This study is the secondary data analysis of air pollutants data and meteorological factors data during 2019-2021 which aimed to investigate the association between meteorological factors and the concentration of air pollutants, to determine the AQI for each air quality parameters (PM_{10}, $PM_{2.5}$ and O_3) and to predict the air quality index of PM_{10} and $PM_{2.5}$ for the near future (1 year). In this session, the results of this study are discussed by comparing with findings of other research that have been done on the temporal distribution of air pollutants.

5.1 Descriptive statistics of variables in this study

5.1.1 Distribution of PM_{10} during 2019 -2021

During study period, PM_{10} concentration ranged from 0.10-149.27 µg/m^3 with the median value of 32.09 µg/m^3 (SD=30.21). This result is consistent with the distribution of PM_{10} study in seven townships within two weeks in 2018 because they also found that PM_{10} concentration in selected seven townships of Yangon city ranged from 126±56.66 µg/m^3 (Yi, Aung et al., 2020). Moreover, Tun et al., (2018) found that the baseline PM_{10} concentrations of Mingaladon area was 52.69±23.53 µg/m3 in their one month study in 2016. A study conducted by Ko, Jindal et al. (2022) stated that PM_{10} concentration at four different locations during their study from January to March 2021 was with a minimum value of 24.17 µg/m3 and maximum value of 63.8 µg/m3 . In current study the observed concentration of PM_{10} in Yangon city during three-year study period was higher than the 24-hour average PM_{10} concentration suggested by WHO which is 50 µg/m^3 (Weltgesundheitsorganisation, Organization, & Environment, 2021). Since excessive level of PM_{10} concentrations brought many adverse health effects , such as heart disease, stroke, rise in blood pressure, and cardiovascular diseases (Lee, Kim, & Lee, 2014), the current level of PM_{10} concentration in Yangon city is at the danger level for people especially for sensitive people with other kinds of health problems.

According to the result from Table 5 of investigating the monthly average concentration of PM_{10} during 2019-2021, monthly average concentration of PM_{10}

concentration was the lowest in monsoon (June-October), then the concentration slightly increased in summer (March-May) and finally PM_{10} concentration reached a peak in winter (November-February). Previous study stated that the highest PM_{10} mass concentration was observed in summer, followed by the winter and the rainy season in 2018 (Sricharoenvech et al., 2020). The clear illustration for the distribution of PM_{10} concentration can be seen in Figure 3. The rise of PM_{10} concentration in winter months and early months of summer could be attributed to agricultural waste management because of the harvesting of most vegetables usually take place in winter months (November-February) as there are many agricultural fields at the outskirts of Yangon. According to previous study about possible sources of PM_{10} in Yangon city, PM_{10} in Yangon city might be from dust (54.1%), secondary aerosols (13.8%), metal manufacturing (8.8%), biomass burning (8.5%) and roadway emissions (5.2%) (Sricharoenvech et al., 2020).

5.1.2 Distribution of $PM_{2.5}$ during 2019 -2021

As seen in Table 3, Pearson's correlation analysis between two $PM_{2.5}$ monitoring station pointed out 82% association of $PM_{2.5}$ data between US Embassy monitoring station and NGO monitoring station. Since the distance between these two monitoring station is only 4.2 km and the two monitoring and both are located near the busy roads, this lead to get the strong positive correlation between then (p-value < 0.001). In this study, only the dataset from US Embassy monitoring station was used after making 8.2% of data imputation by the dataset of NGO monitoring station. According to Table 4, during three-year study period, $PM_{2.5}$ concentration ranged from 0-93.6 µg/m^3 with a median value of 19.07 µg/m3 (SD =21.01). This means that the observed $PM_{2.5}$ concentration in Yangon city during the study period was higher than the acceptable $PM_{2.5}$ concentration by USEPA and WHO, which are 35.15 (µg/m^3) and 15 (µg/m^3) respectively (Organization & Environment, 2021).

According to the result from Table 5 of investigating the monthly average concentration of $PM_{2.5}$, monthly average concentration of $PM_{2.5}$ concentration was the lowest in monsoon (June-October), then the concentration slightly increased in summer (March-May) and finally $PM_{2.5}$ concentration reached a peak in winter (November-February). Recent study also found out that $PM_{2.5}$ concentration in Yangon city was

68 ± 11 µg/m^3 (summer) and 87 ± 17 µg/m^3 (winter) (N. Zhang, Maung, Win, Feng, & Yao, 2022). Previous study about preliminary analysis of $PM_{2.5}$ distribution in Yangon city during their study from 25 January 2018 to 29 January 2018 pointed out that $PM_{2.5}$ concentration in Yangon city was 83±28 µg/m^3 (Yi et al., 2020). Similarly, $PM_{2.5}$ concentration in the previous study relating to satellite-retrieved $PM_{2.5}$ concentrations in South and Southeast Asia from 1999 to 2014 Shi et al., (2018) mentioned that Myanmar had been experiencing in dramatic increasing trend of air pollutant concentration ($PM_{2.5}$) with a tendency of 0.5 µg/m^3 each year. In our study also, we can see a rise in $PM_{2.5}$ concentration each year expect for 2021. This may be because of COVID-19 pandemic that lead to a remarkable drop in the use of motor vehicles due to new normal ways of working style became one of the affecting factors for reduction in anthropogenic emissions of particulate matter (Aung et al., 2021).

5.1.3 Distribution of O_3 during 2019 – 2021

Ozone (O_3) which resulted from anthropogenic events including industrial and vehicular emissions of volatile organic compounds (VOC) and oxides of nitrogen (NO_x) became main reason for serious environmental problems that is difficult to control and predict. The concentration of O_3 in this study ranged from 0.50 - 62.25 ppb with the median value of 5.89 ppb (SD=6.94). The concentration of ozone in Yangon city is within the acceptable ozone level by WHO which is 100 ppb (Amann & Lutz, 2000) and the acceptable level by the USEPA which is 70 ppb (McCarthy & Lattanzio, 2014). Our finding is harmony with Aung et al., (2019), which was a seven day preliminary study of many different kinds of air pollutants including ozone in summer of 2017 and ozone concentration ranged from 10 – 26 ppb.

Monthly average concentration of ozone in 2019 and 2020 followed the same trend. It can be clearly seen that O_3 concentration slightly increased in winter and summer than in monsoon. Many previous studies also found out that ozone was dramatically higher during winter and spring than during previous years (Gramsch, Cereceda-Balic, Oyola, & Von Baer, 2006; Sinnhuber, Weber, Amankwah, & Burrows, 2003). According to Schnell et al.,(2009), the increase in concentration of ozone during winter was because of the high-pressure system that promotes cooler temperatures, low wind speeds and limited cloudiness. Increase in the concentration of ozone in some season was probably due to comparable industrial and meteorological conditions. Also for Yangon city, the influence of meteorological factors on ozone concentration will be considered in the next section.

5.2 Bivariate association between air pollutants and six meteorological factors

In this study, only relative humidity and dew point temperature had significant negative correlation with $PM_{2.5}$. While ambient temperature had moderate positive correlation with $PM_{2.5}$, rainfall had significant negative correlation with $PM_{2.5}$. Our finding is consistent with 10-year study in five European countries that stated that low temperature favored decrease in particulate matter pollution and high temperature led to the increase in particulate matter concentration (Barmpadimos, Keller et al. 2012). However, previous study in China with 732 observations of variables found out that temperature had significant negative correlation with $PM_{2.5}$ concentration with r = -0.457 (p-value<0.05) and there was no significant association between relative humidity and temperature (Li and Wang 2017). Similarly, another study in China stated that temperature and concentrations of particulate matter had negative correlation. Moreover, they pointed out that atmospheric pressure and concentrations of particulate matter were significantly positively correlated. Besides, the wind speed showed a slight impact on atmospheric pollution (Li, Guo et al. 2015).

Our study observed that only relative humidity and dew point temperature had significant negative correlation with PM_{10}. While ambient temperature had moderate positive correlation with PM_{10}, rainfall had significant correlation with PM_{10}. Our study is agreeable with another study that found the negative correlation between particulate matter and relative humidity (Jayamurugan, Kumaravel et al. 2013). However, one study demonstrated that the concentrations of PM_{10} and $PM_{2.5}$ were positively correlated with temperature and relative humidity and negatively correlated with wind speed (Zhao, Wang et al. 2014). From these results, it be clearly seen that the influence of meteorological factors can vary regions to regions. Relative humidity represent the amount of moisture content in the atmosphere at a given temperature and pressure. Moisture particle has a partial negative charge and partial positive charge that can easily bind to other gaseous particles and lead to wet deposition. That is why increase in relative humidity is negatively correlated with decrease in pollutant concentration. Similarly increasing in dew point temperature is associated with decreasing in pollutant concentration .Dew condensation that is the process of changing a solid or gaseous particles to liquid state also reduces concentration of gaseous particles. It is mostly occurred when the temperature is lower than the dew point temperature.

In this study, the correlation between ozone and meteorological factors is quite similar to that of $PM_{2.5}$ and PM_{10} expect for ambient temperature. The increase in ambient temperature, decrease in dew point temperature and relative humidity favored the increase in ozone concentration. Similarly, previous study by(Abdul-Wahab, Bakheit et al. 2005) found very weak positive correlation between ozone and temperature; and negative correlation with relative humidity. Moreover, (Kovač-Andrić, Brana et al. 2009) presented that "ozone concentrations are highly correlated with temperature, solar radiation time, visibility and pressure, while relative humidity and cloudiness were negatively correlated to O_3 ". For the association of ozone with climate factors, our findings are consistent with many previous findings.

5.3 Seasonal models for air pollutants ($PM_{2.5}$ and PM_{10})

Among all the seasonal models, winter models are the best for both $PM_{2.5}$ and PM_{10} because of its good model performance (highest R^2 and lowest RSME). Considering all seasonal models, the influence of meteorological factors under a combined set of all variables showed a significant difference from individual correlation. However, the direction of correlation such as positive or negative association between variables were still the same. When we look at the all seasonal models of $PM_{2.5}$ and $PM_{10,}$ influencing factors for the elevation of these two pollutants are dew point temperature, relative humidity and temperature. Although the influence of temperature on $PM_{2.5}$ concentration was more significant in summer than monsoon and winter, the impact of temperature on PM_{10} was more significant in monsoon showing that increasing temperature is the one of the major contributor for the rise in PM_{10} concentration during this season.

5.4 Annual model for air pollutants ($PM_{2.5}$, PM_{10} and O_3)

Firstly, six meteorological factors are included in all annual multiple linear regression model because they are acceptable according to four assumptions. Moreover, variance inflation factor (VIF) for all independent variables are within the acceptable limit of 10 and all independent variables are included. However, wind speed, atmospheric pressure couldn't explained the variation in air pollutant concentration and these two independent variables are excluded from the models. According to result of our study, annual PM_{10} model that contained three explanatory variables explained 45% of the variation in the PM_{10} concentrations by changes in relative humidity and dew point temperature. When we compared to this annual model with seasonal models, annual model had better model performance and variation in PM_{10} concentration can be better explained. Our study is agreeable with many previous MLR studies that found significant negative association between PM_{10} concentration and relative humidity, dew point temperature (Afzali, Rashid et al. 2014, Özdemir and Taner 2014). A recent study done in Turkey developed MLR model by including relative humidity and dew point atmospheric pressure and they observed that significant negative association with relative humidity and moderate positive association with station pressure and the model could explain 70% of PM_{10} variability(Özdemir and Taner 2014). Another study about modeling of PM_{10} with meteorological factors done in Kocaeli, Turkey observed that significant negative association with relative humidity, rain fall and positive association with temperature. When the water vapor in the air called relative humidity increase and reach to a point where the air can no longer hold the weight, rain occur. As a result of increasing relative humidity, particulate matter normally fall off because of the aggregation of particles and heaviness. Similar meaning is that increase humidity also cause rain and rain has scavenging effect and can remove pollutants in the atmosphere (Özbay, 2012).

$PM_{2.5}$ model that we developed in this study also pointed out that 60% of the variation in the $PM_{2.5}$ concentrations may be accounted for by changes in temperature, relative humidity and dew point temperature. The significant association between dependent variable and independent variables in our study is agreeable with previous studies. A recent study conducted in United States (1998-2008)(Tai, Mickley et al. 2010) included nine meteorological factors (temperature, relative humidity, precipitation, cloud cover, 850-hPa geo potential height, sea-level pressure tendency, wind speed, E–W and N–S wind direction) and their model could explain 50% of $PM_{2.5}$ variability Moreover, precipitation in their study had strong negative association with $PM_{2.5}$ concentration and temperature had positive association with $PM_{2.5}$ concentration (Tai, Mickley et al. 2010). The association between meteorological factors and air pollutant concentration can vary depending on geographical locations of the study and the correlation of $PM_{2.5}$ with relative humidity is positive in the Northeast and Midwest but negative in the Southeast and the West in the previous study (Tai et al., 2010). In addition, our study found positive association of temperature with $PM_{2.5}$ concentration; however, another study stated that negative temperature affected $PM_{2.5}$ concentration (Dawson, Adams et al. 2007).

The nature of relative humidity can influence the natural deposition of particulate matters and increase particulate matter concentration in the atmosphere. Moisture particles normally attach to particulate matter and the more moisture particles in the atmosphere means the more they attach to particulate matter. When the relative humidity reach 100%, dry deposition happens and it automatically reduced the particulate matter concentration in the atmosphere(Hernandez, Berry et al. 2017). Similarly for dew point temperature in this study, the increase in dew point temperature contributed to decrease in $PM_{2.5}$ concentration. Finally, increasing temperature in this study observed with increasing $PM_{2.5}$ concentration. This is because of the effect of increased daytime temperature on PM_{10} concentrations may be explained by the process of thermally-induced convection. When the temperature is increased, it can increases in gusts and winds, leading to the diffusion of particulate matter and resulting in rising pollution (Pepper, Gerba et al. 2011).

Our annual ozone model consists of three predictor variables (i.e., temperature, dew point temperature and relative humidity). However, only relative humidity had significant impact on ozone concentration and the final model include only one predictor variable and the model explained that 45% of the variation in the ozone concentrations may be accounted for by changes in relative humidity. Similarly, previous study in Croatia developed the multiple linear regression model for spring 2002 (R^2=0.67) with two independent variables which are sun radiation and relative humidity. In their study, they stated that decrease in relative humidity favored increased ozone concentration (Kovač-Andrić, Brana et al. 2009). Another study by (Dawson, Adams et al. 2007) also developed a model that included relative humidity and they found that 8-h average ozone concentration dropped gradually as relative humidity was increased and the model performance was linear (R^2=0.957)(Li, Yu et al. 2021) showed that ozone level in all cities of China decreased with an increase in relative humidity and relative humidity had an moderate association with ozone.

A study done in Nanjing showed that 43.4 ppb of O_3 was found at 40% relative humidity, and the lowest value of 10.9 ppb was found at 80% RH (Tu, Xia et al. 2007). Therefore, relative humidity was assumed as much more important one among many meteorological factors to assess the adverse effects of ozone on agriculture (Gong, Yue, Liao, & Ma, 2021).Majority of the study found negative association between ozone concentration and relative humidity. Moreover, many previous ozone distribution study found positive correlation with temperature and developed model by including temperature (Chen et al., 2020; Lin et al., 2021; Tarasova & Karpetchko, 2003). In our study, the monitoring period for ozone was only two years and it might be the fact that the association between temperature and ozone was not significant enough.

Increase in relative humidity reduce the ozone concentration because O_3 photolysis produces $O(^1D)$. $O(^1D)$ then reacts with a water molecule (H_2O) to generate two OH radicals, which favor ozone decomposition (M. Li et al., 2021). Moreover, relative humidity inhibits the chain length of hydroxyl radicals (OH and HO_2) and NO_2, thus limiting the O_3 generation (Reichert, Andres Hernandez et al. 2003).

5.5 Air Quality index in Yangon city

In this study, air quality index in relation to $PM_{2.5}$, PM_{10} and O_3 during 2019-2021 was investigated. According to the results obtained from AQI calculations, majority of AQI for both $PM_{2.5}$ and PM_{10} exceeded the acceptable level of health concern. When we look at the AQI of $PM_{2.5}$, level of AQI reached moderate level of health hazard and unhealthy level for sensitive group especially in winter months (November, December, January, February) and summer months (March, April, May).

The health concern for AQI calculated from PM_{10} is not as worst as that of $PM_{2.5}$ because AQI of PM_{10} is “good” in most of the months all around the year except for January, February, and March. Main sources of particulates matter in Yangon city are from coal burning power plants, exhaust from traffic congestions on busy roads and biomass burning. The main reason for increasing particulate matter in these months related to harvesting and burning from agriculture. Moreover, the condition of very low relative humidity in the atmosphere and hence there is no rain and extreme temperature might lead to the increase in AQI of particulate matter. The results observed in our study are agreeable with the AQI finding of other countries around the world that had very high AQI in winter and summer than in monsoon (Kumar and Goyal 2011, Rashki, Rautenbach et al. 2013, Ikram, Yan et al. 2015, Mehmood, Ahmad et al. 2020). Surprisingly, AQI of ozone in Yangon city, Myanmar is in the range of 0-50 and we didn't find out any AQI value exceed this limit.

5.6 Time Series modeling for air pollutants

During the study period, the seasonality distribution was observed for both PM_{10} and $PM_{2.5}$. The results revealed that AQI of particulate matters normally reached the bottom during monsoon and reached a peak in winter and summer. According to the result of ARIMA model, both the AQI of $PM_{2.5}$ and PM_{10} values showed a decreasing trend in 2022.

According to the result of the ADF test, our time series for both $PM_{2.5}$ and PM_{10} are not stationary. In this study, correlation of non-stationary series showed very slow reduction due to seasonality and subtraction process was carry out to get the stationary series. For both $PM_{2.5}$ and PM_{10} AQI time series, the best fit model (p,d,q) with the lowest AIC value was (3,1,1) with the seasonal variation of (0,1,0). For both $PM_{2.5}$ and PM_{10}, ACF is almost zero from lag 2 later on and it is concluded that MA (1) is the best for data. In addition, "p "optimum for both models was 3 because lag 3 is more significant than other lag. Finally, AQI of $PM_{2.5}$ and PM_{10} for the year 2022 was forecasted by using the order of ARIMA (3, 1, 1). According to 5-fold cross validation, the obtained models had reasonable RMSE, MAE and MAPE and *Theil's U* values. Our model is comparable with other previous studies that used ARIMA model for forecasting AQI of air pollutants. However, RMSE and MAE value found in previous models are more robust. For example, a study done in Oviedo, Spain used 7 years of monthly PM_{10} data to forecast 7 months ahead of monthly PM_{10}. Their results showed a model that can be used as an accurate prediction model with RMSE value of 1.99 (Nieto, Lasheras et al. 2018). Moreover, another study done in Erzurum, Turkey used ARIMA model to forecast the monthly PM_{10} concentration and their model could forecast 2 years ahead of PM_{10} concentration with RMSE value of 1.5 an MAE value of 1.26 (Abhilash, Thakur et al. 2018).

5.7 Conclusion

This is the first study in Myanmar that investigated the temporal distribution of air pollutants by using a large data set. The main objectives of this study is to understand the temporal distribution of three air pollutants ($PM_{2.5}$, PM_{10} and O_3) followed by how meteorological factors were associated with the concentration of $PM_{2.5}$, PM_{10} and O_3 in the atmosphere of Yangon city, Myanmar during 2019-2021. In addition to these, the study also included the calculation of AQI for $PM_{2.5}$, PM_{10} and ozone during study periods and AQI prediction of $PM_{2.5}$ and PM_{10} for 2022.

This study successfully explained the temporal distribution of air pollutants during 2019-2021. During three years study period, both $PM_{2.5}$ and PM_{10} concentration showed a decreasing trend although ozone concentration didn't show a significant change. Both $PM_{2.5}$ and PM_{10} concentrations in Yangon city normally reached a peak in winter and summer and the concentration in these months exceeded the acceptable $PM_{2.5}$ and PM_{10} concentration by WHO. PM_{10} and $PM_{2.5}$ concentrations in monsoon were more favorable.

Moreover, this study pointed out the variations in air pollutant concentrations in the atmosphere of Yangon city by meteorological factors. Increasing in relative humidity, rainfall and dew point temperature could explain the significant drop in PM_{10} and $PM_{2.5}$ concentration. Ambient temperature also accounted for the rise in particulate matter concentration. For ozone, temperature, relative humidity is major influence factors for the variability in ozone concentration. The models from this study may involve in significant role for improving air quality in Yangon because it can give precise predicting result about high-pollutants concentration days in the future. Moreover, this study would be the reliable reference for future air pollution models with other criteria pollutants in Yangon city.

In this study, Ozone concentration and AQI of ozone was still at the safety level even though there can be seen a rise in ozone concentration in winter months. However, AQI level of particulate matters reached over 100 in every year. Since high level of AQI is linked to a wide range of adverse health outcomes for residents, the current AQI of particulate matter in Yangon city had negative impacts for the health of residents. According to our study, it is necessary to take urgent mitigation action for reducing AQI level of particulate matters especially for winter months in Yangon city, Myanmar. Major sources for particulate matter in Yangon city are from biomass burning, motor vehicles, open landfill and power plants. Therefore, government should introduce alternative way for biomass burning such as chipping and mulching, making bio char and production of bioenergy. Moreover, implementation of better waste management system in the city , promoting sustainable transport and proposing emission guideline for power plants to balance environmental and economic benefits. Myanmar is lack of National Ambient Air Quality Standard and there is no much concern about air pollution mitigation action in the city. This research will be helpful for developing national ambient air quality standard in Myanmar by understanding the temporal distribution of air pollutants and the major influence factors for the elevation of air pollutants. The accurate and precise result from this study are aimed to give required information as a reference in setting air quality standard, regional policy making and also for giving awareness to the public.

5.8 Strengths, Limitations and recommendation

5.8.1 Strengths of the study

This is the first study in Myanmar that emphasized on temporal distribution of air pollutants within 3 years. Moreover, investigating AQI was also the first time for Yangon city and the resulted reliable AQI values can help in giving public awareness about poor air quality in Yangon. All the data sets in this study were over 90% of the requirements for acceptable data for air quality analysis. This study included multiple linear regression modeling and auto regressive moving average time series modeling and resulted model performance was good to predict future trends. The result from this study will definitely assist in future modeling studies for identifying air pollution sources in Yangon city. Moreover, the results may help for developing National Ambient Air Quality and also implementing air pollution control policy and strategies in Myanmar.

5.8.2 Limitations of the study

The first limitation is related to the availability of data and all the air pollution monitoring stations started from 2019 January and ended in 2021 December except for ozone data set, it is available from 2019-2020 and couldn't include in seasonal MLR and time series forecasting. Moreover, AQI prediction for $PM_{2.5}$ and PM_{10} used only three years AQI data. The second limitation is there were only two monitoring stations for air quality monitoring and spatial distribution of air pollutants and host spot determination could not carried out. Lastly, the variation in air pollutant concentration was determined by only meteorological factors and sources of pollution couldn't identified.

5.8.3 Suggested Recommendations

This study provides baseline information for future studies on the influence of meteorological factors on $PM_{2.5}$, PM_{10} and Ozone and real AQI of $PM_{2.5}$, PM_{10} and O_{3}. . If health and ecological risk assessment and identifying emission inventories could be done for Yangon city, it will be a good reference for implementing air pollution control strategies in the city. Therefore, further research should concern about the influence of meteorological factors on other criteria pollutants and they should include health risk assessment of criteria pollutants in Yangon city. Different models from this study can help to estimate the relationship between meteorological factors and their effects on air quality. In the future, research related to the spatial distribution of criteria pollutants should be conducted to identify sources contributions to air pollution. Government and non-government organization should put more effort on establishing reliable air quality monitoring stations around Yangon city and should concern about the rise of air pollution in winter by developing control strategies and mitigation actions. Finally, the health awareness regarding to higher level of AQI should be promoted to all citizens.

REFERENCES

Abdul-Wahab, S. A., C. S. Bakheit and S. M. Al-Alawi (2005). "Principal component and multiple regression analysis in modelling of ground-level ozone and factors affecting its concentrations." Environmental Modelling & Software **20**(10): 1263-1271.

Abhilash, M., A. Thakur, D. Gupta and B. Sreevidya (2018). Time series analysis of air pollution in Bengaluru using ARIMA model. Ambient Communications and Computer Systems, Springer**:** 413-426.

Afzali, A.,M. Rashid, B. Sabariah and M. Ramli (2014). PM10 pollution: its prediction and meteorological influence in PasirGudang, Johor. IOP conference series: earth and environmental science, IOP Publishing.

Agustine, I., H. Yulinawati, E. Suswantoro and D. Gunawan (2017). "Application of open air model (R package) to analyze air pollution data." Indonesian Journal of Urban and Environmental Technology **1**(1): 94-109.

Akpinar, E.K., S. Akpinar and H.F. Öztop (2009). "Statistical analysis of meteorological factors and air pollution at winter months in Elaziğ, Turkey." Journal of Urban and Environmental Engineering **3**(1): 7-16.

Aman, N., K. Manomaiphiboon, P. Pengchai, P. Suwanathada, J. Srichawana and N. Assareh (2019). "Long-term observed visibility in eastern Thailand: Temporal variation, association with air pollutants and meteorological factors, and trends." Atmosphere **10**(3): 122.

Aung, W.Y., M. Noguchi, E.E. P.N. Yi, Z. Thant, S. Uchiyama, T.-T. Win-Shwe, N. Kunugita and O. Mar (2019). "Preliminary assessment of outdoor and indoor air quality in Yangon city, Myanmar." Atmospheric Pollution Research **10**(3): 722-730.

Barmpadimos, I., J. Keller, D. Oderbolz, C. Hueglin and A. Prévôt (2012). "One decade of parallel fine (PM 2.5) and coarse (PM 10–PM 2.5) particulate matter measurements in Europe: trends and variability." Atmospheric Chemistry and Physics **12**(7): 3189-3203.

Bauer, M., S. Moebus, S. Möhlenkamp, N. Dragano, M. Nonnemacher, M. Fuchsluger, C. Kessler, H. Jakobs, M. Memmesheimer and R. Erbel (2010). "Urban particulate matter air pollution is associated with subclinical atherosclerosis:

results from the HNR (Heinz Nixdorf Recall) study." Journal of the American College of Cardiology **56**(22): 1803-1808.

Cannistraro, G., M. Cannistraro, A. Cannistraro, A. Galvagno and F. Engineer (2016). "Analysis of air pollution in the urban center of four cities Sicilian." Int. J. Heat Technol **34**(2): S219-S225.

Castells-Quintana, D., E. Dienesch and M. Krause (2021). "Air pollution in an urban world: A global view on density, cities and emissions." Ecological Economics **189**: 107153.

Chiang, R. H., P. Goes and E. A. Stohr (2012). "Business intelligence and analytics education, and program development: A unique opportunity for the information systems discipline." ACM Transactions on Management Information Systems (TMIS) **3**(3): 1-13.

Chiwewe, T. M. and J. Ditsela (2016). Machine learning based estimation of Ozone using spatio-temporal data from air quality monitoring stations. 2016 IEEE 14th International Conference on Industrial Informatics (INDIN), IEEE.

Cogliani, E. (2001). "Air pollution forecast in cities by an air pollution index highly correlated with meteorological variables." Atmospheric Environment **35**(16): 2871-2877.

Dawson, J. P., P. J. Adams and S. N. Pandis (2007). "Sensitivity of ozone to summertime climate in the eastern USA: A modeling case study." Atmospheric environment **41**(7): 1494-1511.

DeSouza, P., V. Nthusi, J. M. Klopp, B. E. Shaw, W. O. Ho, J. Saffell, R. Jones and C. Ratti (2017). "Research article A Nairobi experiment in using low cost air quality monitors." Clean Air Journal **27**(2): 12.

Devi, B. U., D. Sundar and P. Alli (2013). "An effective time series analysis for stock trend prediction using ARIMA model for nifty midcap-50." International Journal of Data Mining & Knowledge Management Process **3**(1): 65.

Dung, N. A., D. H. Son and D. Q. Tri (2019). "Effect of Meteorological Factors on PM 10 Concentration in Hanoi, Vietnam." Journal of Geoscience and Environment Protection **7**(11): 138.

Etemadi, S. and M. Khashei (2021). "Etemadi multiple linear regression." Measurement **186**: 110080.

Fiore, A. M., V. Naik, D. V. Spracklen, A. Steiner, N. Unger, M. Prather, D. Bergmann, P. J. Cameron-Smith, I. Cionni and W. J. Collins (2012). "Global air quality and climate." Chemical Society Reviews **41**(19): 6663-6683.

Forbes, E. I. (2016). "On the frontier of urbanization: informal settlements in Yangon, Myanmar." Independent Journal of Burmese Scholarship **1**(1): 197-238.

Giri, D., P. Adhikary and V. Murthy (2008). "The influence of meteorological conditions on PM10 concentrations in Kathmandu Valley."

Goyal, P., A. T. Chan and N. Jaiswal (2006). "Statistical models for the prediction of respirable suspended particulate matter in urban cities." Atmospheric environment **40**(11): 2068-2077.

Guo, J., M. Zhao, P. Xue, X. Liang, G. Fan, B. Ding, J. Liu and J. Liu (2020). "New indicators for air quality and distribution characteristics of pollutants in China." Building and Environment **172**: 106723.

Hamilton, J. D. (2020). Time series analysis, Princeton university press.

Han, L., W. Zhou, W. Li, D. T. Meshesha, L. Li and M. Zheng (2015). "Meteorological and urban landscape factors on severe air pollution in Beijing." Journal of the Air & Waste Management Association **65**(7): 782-787.

Hernandez, G., T.-A. Berry, S. Wallis and D. Poyner (2017). "Temperature and humidity effects on particulate matter concentrations in a sub-tropical climate during winter."

Ho, B. Q. and A. Clappier (2011). "Road traffic emission inventory for air quality modelling and to evaluate the abatement strategies: A case of Ho Chi Minh City, Vietnam." Atmospheric environment **45**(21): 3584-3593.

Holman, C. (1999). Sources of air pollution. Air pollution and health, Elsevier**:** 115-148.

Ikram, M., Z. Yan, Y. Liu and W. Qu (2015). "Seasonal effects of temperature fluctuations on air quality and respiratory disease: a study in Beijing." Natural Hazards **79**(2): 833-853.

Jacob, D. J. and D. A. Winner (2009). "Effect of climate change on air quality." Atmospheric environment **43**(1): 51-63.

Jafta, N., L. Barregard, P. M. Jeena and R. N. Naidoo (2017). "Indoor air quality of low and middle income urban households in Durban, South Africa." Environmental research **156**: 47-56.

Jayamurugan, R., B. Kumaravel, S. Palanivelraja and M. Chockalingam (2013). "Influence of temperature, relative humidity and seasonal variability on ambient air quality in a coastal urban area." International Journal of Atmospheric Sciences **2013**.

Jerrett, M., A. Arain, P. Kanaroglou, B. Beckerman, D. Potoglou, T. Sahsuvaroglu, J. Morrison and C. Giovis (2005). "A review and evaluation of intraurban air pollution exposure models." Journal of Exposure Science & Environmental Epidemiology **15**(2): 185-204.

Kampa, M. and E. Castanas (2008). "Human health effects of air pollution." Environmental pollution **151**(2): 362-367.

Kliengchuay, W., A. Cooper Meeyai, S. Worakhunpiset and K. Tantrakarnapa (2018). "Relationships between meteorological parameters and particulate matter in Mae Hong Son province, Thailand." International Journal of Environmental Research and Public Health **15**(12): 2801.

Ko, S. S. K., R. Jindal, K. Tantrakarnapa, N. Surinkul and W. Trivitayanurak (2022). "Investigations of Baseline Air Quality around the Proposed Yangon Outer Ring Road Construction (Eastern Section) Area in Myanmar." Engineering Access **8**(1): 123-128.

Koo, J. W., S. W. Wong, G. Selvachandran, H. V. Long and L. H. Son (2020). "Prediction of Air Pollution Index in Kuala Lumpur using fuzzy time series and statistical models." Air Quality, Atmosphere & Health **13**(1): 77-88.

Kovač-Andrić, E., J. Brana and V. Gvozdić (2009). "Impact of meteorological factors on ozone concentrations modelled by time series analysis and multivariate statistical methods." Ecological Informatics **4**(2): 117-122.

Kumar, A. and P. Goyal (2011). "Forecasting of daily air quality index in Delhi." Science of the Total Environment **409**(24): 5517-5523.

Lelieveld, J., J. S. Evans, M. Fnais, D. Giannadaki and A. Pozzer (2015). "The contribution of outdoor air pollution sources to premature mortality on a global scale." Nature **525**(7569): 367-371.

Li, C., N. C. Hsu and S.-C. Tsay (2011). "A study on the potential applications of satellite data in air quality monitoring and forecasting." Atmospheric Environment **45**(22): 3663-3675.

Li, H., B. Guo, M. Han, M. Tian and J. Zhang (2015). "Particulate matters pollution characteristic and the correlation between PM (PM 2.5, PM 10) and meteorological factors during the summer in Shijiazhuang." Journal of Environmental Protection **6**(05): 457.

Li, J. and L. Wang (2017). The research of PM2. 5 concentrations model based on regression calculation model. AIP conference Proceedings, AIP Publishing LLC.

Li, L., J. Qian, C.-Q. Ou, Y.-X. Zhou, C. Guo and Y. Guo (2014). "Spatial and temporal analysis of Air Pollution Index and its timescale-dependent relationship with meteorological factors in Guangzhou, China, 2001–2011." Environmental Pollution **190**: 75-81.

Li, M., S. Yu, X. Chen, Z. Li, Y. Zhang, L. Wang, W. Liu, P. Li, E. Lichtfouse and D. Rosenfeld (2021). "Large scale control of surface ozone by relative humidity observed during warm seasons in China." Environmental Chemistry Letters **19**(6): 3981-3989.

Liu, Y., Y. Zhou and J. Lu (2020). "Exploring the relationship between air pollution and meteorological conditions in China under environmental governance." Scientific reports **10**(1): 1-11.

Luvsan, M.-E., R.-H. Shie, T. Purevdorj, L. Badarch, B. Baldorj and C.-C. Chan (2012). "The influence of emission sources and meteorological conditions on SO2 pollution in Mongolia." Atmospheric Environment **61**: 542-549.

Mannucci, P. M. and M. Franchini (2017). "Health effects of ambient air pollution in developing countries." International journal of environmental research and public health **14**(9): 1048.

Mehmood, T., I. Ahmad, S. Bibi, B. Mustafa and I. Ali (2020). "Insight into monsoon for shaping the air quality of Islamabad, Pakistan: Comparing the magnitude of health risk associated with PM10 and PM2. 5 exposure." Journal of the Air & Waste Management Association **70**(12): 1340-1355.

Mohan, M. and A. Kandya (2007). "An analysis of the annual and seasonal trends of air quality index of Delhi." Environmental monitoring and assessment **131**(1): 267-277.

Mohtar, A. A. A., M. T. Latif, N. H. Baharudin, F. Ahamad, J. X. Chung, M. Othman and L. Juneng (2018). "Variation of major air pollutants in different seasonal conditions in an urban environment in Malaysia." Geoscience Letters **5**(1): 1-13.

Munir, S., G. Coskuner, M. S. Jassim, Y. A. Aina, A. Ali and M. Mayfield (2021). "Changes in air quality associated with mobility trends and meteorological conditions during COVID-19 lockdown in Northern England, UK." Atmosphere **12**(4): 504.

Ng, C. F. S., M. Hashizume, Y. Obase, M. Doi, K. Tamura, S. Tomari, T. Kawano, C. Fukushima, H. Matsuse and Y. Chung (2019). "Associations of chemical composition and sources of PM2. 5 with lung function of severe asthmatic adults in a low air pollution environment of urban Nagasaki, Japan." Environmental pollution **252**: 599-606.

Ngo, N. S., S. V. J. Asseko, M. O. Ebanega, S. M. A. o. Allo'o and P. Hystad (2019). "The relationship among PM2. 5, traffic emissions, and socioeconomic status: Evidence from Gabon using low-cost, portable air quality monitors." Transportation Research Part D: Transport and Environment **68**: 2-9.

Nieto, P. G., F. S. Lasheras, E. García-Gonzalo and F. de Cos Juez (2018). "PM10 concentration forecasting in the metropolitan area of Oviedo (Northern Spain) using models based on SVM, MLP, VARMA and ARIMA: A case study." Science of the Total Environment **621**: 753-761.

Organization, W. H. (2003). Health aspects of air pollution with particulate matter, ozone and nitrogen dioxide: report on a WHO working group, Bonn, Germany 13-15 January 2003, Copenhagen: WHO Regional Office for Europe.

Özdemir, U. and S. Taner (2014). "Impacts of meteorological factors on PM10: Artificial neural networks (ANN) and multiple linear regression (MLR) approaches." Environmental Forensics **15**(4): 329-336.

Pepper, I. L., C. P. Gerba and M. L. Brusseau (2011). Environmental and pollution science, Elsevier.

Purohit, P., T. Munir and P. Rafaj (2013). "Scenario analysis of strategies to control air pollution in Pakistan." Journal of Integrative Environmental Sciences **10**(2): 77-91.

Radzka, E. (2020). "The effect of meteorological conditions on air pollution in Siedlce." Journal of Ecological Engineering **21**(1): 97--104.

Rashki, A., C. Rautenbach, P. G. Eriksson, D. G. Kaskaoutis and P. Gupta (2013). "Temporal changes of particulate concentration in the ambient air over the city of Zahedan, Iran." Air Quality, Atmosphere & Health **6**(1): 123-135.

Reichert, L., M. Andres Hernandez, D. Stöbener, J. Burkert and J. Burrows (2003). "Investigation of the effect of water complexes in the determination of peroxy radical ambient concentrations: Implications for the atmosphere." Journal of Geophysical Research: Atmospheres **108**(D1): ACH 4-1-ACH 4-16.

Rojas, A. L. P., R. Borge, N. A. Mazzeo, R. I. Saurral, B. N. Matarazzo, J. M. Cordero and E. Kropff (2020). "High PM10 concentrations in the city of Buenos Aires and their relationship with meteorological conditions." Atmospheric Environment **241**: 117773.

Sahanavin, N., T. Prueksasit and K. Tantrakarnapa (2018). "Relationship between PM10 and PM2. 5 levels in high-traffic area determined using path analysis and linear regression." Journal of Environmental Sciences **69**: 105-114.

Shi, Y., T. Matsunaga, Y. Yamaguchi, Z. Li, X. Gu and X. Chen (2018). "Long-term trends and spatial patterns of satellite-retrieved PM2. 5 concentrations in South and Southeast Asia from 1999 to 2014." Science of the Total Environment **615**: 177-186.

Sivaprasad, R. (2021). "Forecasting Of Greenhouse Gases and Air Quality Prediction Using Matlab Analytics." Turkish Journal of Computer and Mathematics Education (TURCOMAT) **12**(11): 7226-7231.

Sricharoenvech, P., A. Lai, T. N. Oo, M. M. Oo, J. J. Schauer, K. L. Oo and K. K. Aye (2020). "Source apportionment of coarse particulate matter (PM10) in Yangon, Myanmar." International Journal of Environmental Research and Public Health **17**(11): 4145.

Sritarapipat, T. and W. Takeuchi (2017). "Building classification in Yangon City, Myanmar using Stereo GeoEye images, Landsat image and night-time light data." Remote Sensing Applications: Society and Environment **6**: 46-51.

Tai, A. P., L. J. Mickley and D. J. Jacob (2010). "Correlations between fine particulate matter (PM2. 5) and meteorological variables in the United States: Implications for the sensitivity of PM2. 5 to climate change." Atmospheric environment **44**(32): 3976-3984.

Tan, X., L. Han, X. Zhang, W. Zhou, W. Li and Y. Qian (2021). "A review of current air quality indexes and improvements under the multi-contaminant air pollution exposure." Journal of environmental management **279**: 111681.

Thu, M. Y., W. Htun, Y. L. Aung, P. E. E. Shwe and N. M. Tun (2018). Smart air quality monitoring system with LoRaWAN. 2018 IEEE International Conference on Internet of Things and Intelligence System (IOTAIS), IEEE.

Tint, Z. L. and N. M. Kyaw "Development of Liquefaction Potential Map for Yangon, Myanmar."

Tu, J., Z.-G. Xia, H. Wang and W. Li (2007). "Temporal variations in surface ozone and its precursors and meteorological effects at an urban site in China." Atmospheric Research **85**(3-4): 310-337.

Tufte, E. R. (1983). "The visual display of." Quantitative Information: 13.

Tun, S. N. L., T. H. Aung, A. S. Mon, P. H. Kyaw, W. Siriwong, M. Robson and T. Htut (2018). "Assessment of ambient dust pollution status at selected point sources (residential and commercial) of Mingaladon area, Yangon region, Myanmar." Journal of Health Research.

US-EPA (2012). Revised air quality standards for particle pollution and updates to the Air Quality Index (AQI), United States Environmental Protection Agency, Office of Air Quality ….

Wang, C., S. W. Myint, P. Fan, M. Stuhlmacher and J. Yang (2018). "The impact of urban expansion on the regional environment in Myanmar: A case study of two capital cities." Landscape ecology **33**(5): 765-782.

Wang, J. and S. Ogawa (2015). "Effects of meteorological conditions on PM2. 5 concentrations in Nagasaki, Japan." International journal of environmental research and public health **12**(8): 9089-9101.

Wise, E. K. and A. C. Comrie (2005). "Meteorologically adjusted urban air quality trends in the Southwestern United States." Atmospheric Environment **39**(16): 2969-2980.

Yi, E. E. P. N., W. Y. Aung, N. C. Nway, Z. Thant, M. Yagishita, Y. Ishigaki, D. Nakajima, T.-T. Win-Shwe and O. Mar (2020). Distribution of particulate matter (PM10) concentration in seven townships of Yangon, Myanmar. IOP Conference Series: Earth and Environmental Science, IOP Publishing.

Zhang, L., J. Lin, R. Qiu, X. Hu, H. Zhang, Q. Chen, H. Tan, D. Lin and J. Wang (2018). "Trend analysis and forecast of PM2. 5 in Fuzhou, China using the ARIMA model." Ecological indicators **95**: 702-710.

Zhao, C.-X., Y.-Q. Wang, Y.-J. Wang, H.-L. Zhang and B.-Q. Zhao (2014). "Temporal and spatial distribution of PM2. 5 and PM10 pollution status and the correlation of particulate matters and meteorological factors during winter and spring in Beijing." Huan jing ke xue= Huanjing kexue **35**(2): 418-427.

Clarity .(2021).Wind Speed & Direction .Access Date: 7 June 2022. Available at : https://www.clarity.io/blog/air-quality-measurements-series-wind-speed-and-direction

Queensland Government (2017) ."Influence of meteorology on air quality".Access Date: 7 June 2022 .Available at: https://www.qld.gov.au/environment/pollution/ monitoring/air/air-monitoring/meteorology-influence/meteorology-factors

VITA

NAME	Tin Saw Pyae
DATE OF BIRTH	9 June 1997
PLACE OF BIRTH	Zigon,Sagaing Division ,Myanmar
INSTITUTIONS ATTENDED	Mandalay University ,Mandalay, Myanmar
HOME ADDRESS	Ratchaprarop Tower Mansion, 99 Ratchaprarop, 14Makkasan ,Ratchathwei, Bangkok 10400