CIRCULAR STATISTICAL ANALYSIS OF WIND DIRECTION AND WIND SPEED ON OZONE CONCENTRATION

NOORAIN ZINOL

UNIVERSITI SAINS MALAYSIA

2017

CIRCULAR STATISTICAL ANALYSIS OF WIND DIRECTION AND WIND SPEED ON OZONE CONCENTRATION

by

NOORAIN ZINOL

Thesis submitted in fulfillment of the requirements for the degree of Master of Science

August 2017

ACKNOWLEDGEMENTS

First of all, Alhamdulillah. I am very grateful to Allah s.w.t that had giving me His guidance, barakah, strength and determination for me to complete this project. Managing and writing of this dissertation has been one of the most significant academic challenges I have ever had to face. This dissertation would never be completed without the assistance of several peoples and organizations. I would like to take this opportunity to present my appreciation for their contributions.

I must express my deepest appreciation to my supervisor, Professor Ahmad Shukri Yahaya for his guidance, patience, and cooperation throughout this study. His valuable suggestions and encouragement enabled me to handle this project with confidence. This thesis would not have been possible without his vision and direction. I am very fortunate for having the opportunity to work with him and I will cherish these memories for my entire life. This dissertation would not have been possible without the constant support and encouragement of my family and friends especially during the difficult times faced during this research.

Deepest thanks to Jabatan Alam Sekitar Malaysia for the data used to carry out this research. Thank you all and I pray that The Almighty will grant each of you the happiness here and hereafter. My grateful thanks go to my mother, Puan Fatimah who paid my tuition fees so that I could pursue on my studies. Although she hardly knows how writing thesis is and understand what I research on, but she willing to support any decision I make. Her love in supporting me and keeping me in their prayers is truly appreciated. Last but not least thanks to my beloved fiancé Hasrul, always urging me to finish this writing as soon as possible so that we can get marry end of this year.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

λ	Sunlight
θ	Angle
R^2	Coefficient of determination
$\overline{x}$	Mean
S	Standard Deviation
m	Median
μ	Mean Angle
ρ	Mean Resultant Length
V	Circular Variance
v	Circular Standard Deviation
δ	Circular Dispersion
κ	Concentration
Z	Rayleigh Test
V_n^*	Kuiper's Test
U	Rao's Spacing Test
w	Range Statistics Test
r	Linear - LinearCorrelation
$r_{x\theta}$	Circular – Linear
bw	bandwidth

LIST OF ABBREVIATIONS

ANN	Artificial neural network
API	Air pollutant Index
CD	Cloud Direction
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DoE	Department of Environment (Malaysia)
DT	Daytime
DU	Dobson Unit
E	East
HO_2	Hydroperoxy
hv	sunlight
IA	Index of Agreement
LL	Local Linear estimator
MAAQG	Malaysia Ambient Air Quality Guideline
MLR	Multiple Linear Regression
N	North
NAE	Normalized absolute error
NE	North East
NEM	Northeast Monsoon
NO	Nitrogen Oxide
NO_2	Nitrogen Dioxide
NT	Nighttime
NW	Nadaraya-Watson estimator

NW	North West
O3	Ground Level Ozone
OH	Oxygen Hydroxide
P	Pressure
PA	Prediction Accuracy
PM	Particulate Matter
PM_{10}	10 Micron
$PM_{2.5}$	2.5 Micron
ppb	parts per billion
ppm	parts per million
R	Software Environment for Statistical Computing and Graphics
R^2	Coefficient of Determination
RF	Rainfall
RH	Relative Humidity
RMSE	Root mean square error
RO_2	Peroxy radicals
RSPM	Respiratory Suspended Particulate Matter
S	South
SE	South East
SO_2	Sulphur Dioxide
SPSS	Statistical Package for the Social Science
SR	Solar Radiation
SW	South West
SWM	Southwest Monsoon
Temp	Temperature

UV	Ultraviolet
VOCs	Volatile Organic Compounds
W	West
WD	Wind Speed
WS	Wind Speed

ANALISIS BERSTATISTIK MEMBULAT BAGI ARAH DAN KELAJUAN ANGIN TERHADAP KEPEKATAN OZON

ABSTRAK

Perkembangan pembangunan bersama dengan peningkatan penduduk dan peningkatan penggunaan pengangkutan telah menyumbang dalam menurunkan kualiti udara di Malaysia. Tujuan kajian ini adalah untuk meramal dan memodelkan hubungan diantara pembolehubah linear dan pembolehubah membulat dengan menggunakan fungsi ketumpatan kebarangkalian dan analisis regresi. Pemerhatian dilakukan di stesen Shah Alam, Prai, Pasir Gudang dan Jerantut dalam tempoh sepuluh tahun dari tahun 2004 hingga 2013. Nilai min bagi kepekatan O_3 untuk semua lokasi tidak melebihi had MAAQG. Ketumpatan membulat dan rajah angin telah digunakan untuk menunjukkan ciri arah angin termasuk arah min, min panjang paduan dan penumpuan. Kajian ini mencadangkan kehadiran angin yang menonjol telah bertiup dari utara dan arah selatan Semenanjung Malaysia disebabkan oleh monsun timur laut dan monsun barat daya. Empat fungsi taburan disuaikan dengan data arah angin dan telah mendapati bahawa taburan Cauchy membungkus menunjukkan prestasi yang baik berdasarkan analisis purata panjang perentas. Analisis diteruskan dengan korelasi linear-membulat, regresi linear-membulat dan regresi linear berganda. Kebanyakkan korelasi positif ditemui antara arah angin dan kepekatan O_3 di semua stesen pada waktu siang dan malam. Dari regresi linear-membulat, kepekatan O_3 telah diramalkan dari arah angin dan keputusan menunjukkan bahawa beberapa bacaan di stesen Shah Alam melebihi had yang telah dibenarkan MAAQG (0.06 ppm). Model ramalan diteruskan dengan regresi linear berganda dengan memasukkan sinus dan kosinus arah angin sebagai pembolehubah

tak bersandar berserta dengan kelajuan angin. Didapati bahawa model ramalan sebelah malam memberikan ketepatan yang tinggi berbanding dengan waktu siang.

CIRCULAR STATISTICAL ANALYSIS OF WIND DIRECTION AND WIND SPEED ON OZONE CONCENTRATION

ABSTRACT

The rapid development along with increased population and transportation usage has deteriorated air quality status in Malaysia. The purpose of this research is to predict and modelling the casual relationship between circular and linear variables using probability density functions and regression analysis. The observations were made at Shah Alam, Prai, Pasir Gudang and Jerantut station over ten years period from 2004 until 2013 respectively. Mean values for O_3 concentrations at all locations did not exceed MAAQG level limit. Circular density and wind rose plot were used to describe the characteristics of wind direction including mean direction, mean resultant length and concentration. This study suggested the presence of prominent wind that were blowing from north and south direction of Peninsular Malaysia due to southwest monsoon and northeast monsoon. Four distributions function were fitted to the wind direction data and it was found that wrapped Cauchy fit the data very well based on mean chord length. The analysis was further conducted with circular-linear correlation, circular-linear regression and multi linear regression model. Most of positive correlations were found between wind direction and O_3 concentration in all stations during daytime and nightime. From the circular – linear regression, O_3 concentration were predicted from wind direction and the results showed that few values in Shah Alam station exceeded the permissible limit by MAAQG (0.06 ppm). Prediction model were continued with multi linear regression by including the sine and cosine of wind direction as independent variables as well as wind speed variable. It was found that nighttime models provide better accuracy than daytime.

CHAPTER ONE

INTRODUCTION

1.1 General

Air pollution is a term to explain the contamination of the air with harmful or poisonous substances that may harm animals, vegetation, humans, and materials (DEP, 2017). Emissions of unwanted chemicals gases or substances which exceeds the capacity of natural processes to convert or disperse them, can result in the degradation of air quality (Schwela and Haq, 2008). Pollutants emissions resulted from direct air emissions or through the production of secondary pollutants as a result of chemical reactions will take place in the air (Mohammed et al., 2013).

The goal of achieving industrial country status by the year 2020 and the associated rapid economic growth have started to impose costs in terms of industrial pollution and the degradation of urban environment (Begum et al., 2013). Depletion of fisheries, air and water pollution, and contamination by industrial wastes have become more serious in Malaysia in recent years. Among them, air pollution is the major issue that has been affecting human health, agricultural crops, forest species, and ecosystems.

Concentrations of air pollutants in Asia are higher than those are in Europe and North America, and levels are expected to worsen over time (Akimoto, 2003). As more air pollutants are emitted, ozone concentrations in East Asia have correspondingly increased. Created substantially by secondary production, $PM_{2.5}$ levels have reached a critical level, with levels frequently exceeding environmental standards (Shim, 2017).

According to data released by the UN Agency World Health Organization, Malaysia has become one of the least air polluted urban environments in Asia compared to Beijing, New Delhi and Jakarta (Rohde and Muller, 2015). Nevertheless, air pollutant might travelled miles from the origin driven by wind affected the neighborhood country. Ramanathan and Feng (2009) claimed that each part of the world is connected through fast atmospheric transport which open possibility for pollutant to travel at longer distance.

Fuel combustion is a key to air pollution source in Asian cities which tends to increase with population size along with economic activities. Major source of air pollution contributing to at least 70%–75% of the total air pollution is emission from mobile source such as motor vehicles. Another 20%-25% of the air pollution were contributed from stationary source such as power plant, factories and etc. However forest fire (open burning) contributed 3%-5% of total air pollution in Malaysia for the past five years (Afroz et al., 2003; Yahaya et al., 2006 and Azid et al., 2015).

Under those circumstances, Malaysia and Singapore has been affected by 'haze' caused by open burning of forests from neighborhood country, Indonesia. Repeated haze episodes in Southeast Asia recently has become an annual phenomenon during the drier months. On 24 September 2015, API reading had crossed into the 'Very Unhealthy' range on its way to a 'Hazardous' rating with value between 264-321; the highest levels in 2015 (Ewing, 2015). Most recent haze in 2016, more than half of the country's 52 monitoring stations registered as "unhealthy" resulting in schools being closed. According to The Malaymail Online, (2016), API reading exceeding 223 at 'very unhealthy' stage has caused the closing of 83 schools in Sabah. People are advised to avoid outdoor activities in order to prevent widespread illnesses particularly among the elderly and those with breathing difficulties.

Swathes of rainforest in Sumatra are periodically burnt off by farmers and settlers to open up land for oil palm plantations and agricultural for commercial purposes. The smoke were drifted over with the wind southwest monsoon to the Peninsular of Malaysia. East Malaysia (Sarawak and Sabah) also suffer from similar burning in Indonesia's Kalimantan province (Subekti et al., 2017). Apparently, Malaysia has its own hotspots resulting from local industrial and vehicular pollution which contribute to affects the situation to become becoming worst.

Unlike factory and vehicle emissions, wildfire smoke is not filtered by catalytic converters. The toxic components of the smoke vary according to the type of material that is burning. Sumatra's peat fires for example has produced smoke which is more harmful than ordinary forest fires (Qadri, 2001). Peat fires also last longer as they smoulder underground and are harder to put out. As the results result, poor air quality in Malaysia usually will continue continues until a change of in weather conditions and heavy rainstorms clear clearing the air.

1.2 Environmental Air Pollution In Malaysia

Malaysia is a coastal nation located in the centre of Southeast Asia, surrounded by Thailand in the northwestern, Indonesia in the southern and Brunei in the eastern part (Malaysia, 2006). Malaysia consists of a Peninsula Malaysia and approximately one third of the island of Borneo East Malaysia. These two regions are separated by some

640 miles of the South China Sea. The country covers a total area of 330,252 square kilometers (km^2), where the total land area is 328,550 km^2 and the water area, 1,200 km^2 (Malaysia, 2006). The country experiences relatively uniform temperature throughout the year, with the mean temperature in the lowlands ranging between 26 °C and 28°C (Malaysian Meteorological Department, 2006). It has a tropical climate with annual southwest monsoon from April to October and northeast monsoons from October to February (Hussin et al., 2006).

According to report on Urban Air Quality Management (2006), Malaysia is a middle-income country that has transformed itself in the late 1990's from a producer of raw materials into an emerging multi sector economy. The industries in Peninsular Malaysia including rubber and palm oil processing and manufacturing, light manufacturing industry, electronics, tin mining and smelting, and logging and processing timber. Sabah and Sarawak has logging and agriculture processing as well as petroleum production and refining. Urbanization process in population growth, industries and lifestyle leads to higher traffic density, increases energy demand and contributes to air pollution problems.

Significant changes in air pollution concentration for Malaysia are closely monitored by the DoE using 52 Continuous Ambient Air Monitoring Stations (CAQM) which have been installed across Malaysia. The station were strategically placed at urban, sub urban, industrial and background areas and the air quality were reported to citizens using Air Pollution Index (API) system. According to DoE (2015), New Ambient Air Quality Standard was established in order to replace the older Malaysia Ambient Air Quality Guideline (MAAQG) that has been used since 1989.

Deputy Natural Resources and Environment Minister Datuk Hamim Samuri said that additional parameter $PM_{2.5}$ was outlined in 11th Malaysia Plan 2016-2020 to include the measurement in all 52 monitoring stations in Malaysia. It would take longer for Malaysia to fully implement it however, as for now 12 air quality monitoring stations have been set up in Kuala Lumpur, Putrajaya, Melaka, Kuala Terengganu, Tanah Merah, Langkawi, Ipoh, Kuching and Penang to measure $PM_{2.5}$. (The Malaysian Times, 2015).

The New Ambient Air Quality Standard adopts 6 air pollutants criteria that include 5 existing air pollutants which are carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter with the size of less than 10 micron (PM_{10}), sulphur dioxide (SO_2), and ground level ozone (O_3) and one additional parameter which is particulate matter with the size of less than 2.5 micron ($PM_{2.5}$). The air pollutants concentration limit will be strengthen in stages until year 2020.

Table 1.1 shows the New Malaysia Ambient Air Quality Standard which form the basis for calculating the Air Pollution Index (API). There are 3 interim targets set which include interim target 1 (IT-1) in 2015, interim target 2 (IT-2) in 2018 and the full implementation of the standard in 2020. As depicted in Table 1.1, ground level O_3 were known as secondary pollutant contributed in API reading. Vehicle emissions accounted for largest share in formation of O_3 concentration in Malaysia beside industrial activities (DoE, 2015).