Factors Contributing to Air Pollution Levels Using Factor Analysis

by

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ABSTRAK

Kajian ini bertujuan untuk mengenalpasti faktor dan sumber utama pencemaran udara di dalam empat stesen pemantauan udara yang dipilih di Malaysia. Data diperolehi dari Januari 2008 hingga Disember 2012. Pembolehubah yang berkaitan adalah dua faktor meteorologi (suhu dan kelembapan relatif) dan empat bahan pencemar udara (CO, PM_{10}, O_3 and NO_2). Kawasan yang menjadi fokus terdiri daripada empat kawasan yang berlainan iaitu; Perai (S1-perindustrian), Shah Alam (S2-bandar), Seberang Jaya (S3-pinggir bandar) dan Jerantut (S4-kawalan). Dua kaedah statistik dipilih untuk menganalisis set data iaitu analisis statistik deskriptif dan analisis faktor. Analisis statistik deskriptif menunjukkan bahawa Perai mencatatkan kepekatan tertinggi bagi CO, O_3 and NO_2 manakala Seberang Jaya mencatatkan kepekatan tertinggi untuk PM_{10}. Hasil analisis faktor, didapati bahawa terdapat tiga faktor di Perai, Shah Alam dan Jerantut manakala dua faktor di Seberang Jaya. Walau bagaimanapun, kombinasi komponen dalam setiap faktor adalah berbeza untuk setiap stesen. Namun begitu, terdapat kombinasi komponen yang signifikan di Perai di mana ia boleh dikategorikan sebagai Faktor Pencemaran Organik, Faktor Meteorologi dan Faktor Bahan Api. Keputusan ini membentangkan satu garis panduan untuk mewujudkan penilaian yang sesuai untuk ciri-ciri pencemaran dan sistem klasifikasi untuk stesen pemantauan kualiti udara di Malaysia.

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ABSTRACT

The aims of this study is to determine the major factors and causes of air pollution levels within the four selected Malaysian air monitoring stations. The data were obtained from January 2008 to December 2012. The variables concerned are two meteorological factors (temperature and relative humidity) and four air pollutants (CO, PM_{10}, O_3 and NO_2). The focus areas comprise of four different localities which are; Perai (S1-industrial), Shah Alam (S2-urban), Seberang Jaya (S3-suburban) and Jerantut (S4-control). Two statistical methods were selected to analyze the datasets which are descriptive statistical analysis and factor analysis. The descriptive statistical analysis showed that Perai recorded the highest concentrations of CO, O_3 and NO_2 while Seberang Jaya recorded the highest concentration of PM_{10}. The results of the factor analysis showed that there were three factors at Perai, Shah Alam and Jerantut while two factors at Seberang Jaya. However, the combination of the components in each factors are different for every station. Nevertheless, it has a significant combination of the components at Perai where it can be categorized as an Organic Pollution Factor, Meteorological Factor and Fuel Factor. These results present a guideline to establish evaluations appropriate to pollution characteristics and classification systems for air quality monitoring stations in Malaysia.

CHAPTER 1

INTRODUCTION

1.1 Backgrounds

Air pollution is a global problem in modern society, and becomes a major environmental issue throughout the world. In Malaysia, air pollution has been a major problem over the past few years due to swift urban development and it is influenced by pollution that is largely native to most areas (Latif et al., 2011). The rapid growth of the industrial sector and urbanization has been part of the cause to the high levels of air pollutants in the environment. In addition, the increase of motor vehicles for example, individual cars, business vehicles and motorcycles have caused an acute bottleneck in virtually every portions of the highway network, particularly in the central commercial areas and inevitably the nature in these areas has deteriorated due to the exhaust emission released from the engine of vehicles.

Describing air pollution is not easy. People can claim that every man-made (anthropogenic) emission released into the air is considered as air pollution, this is due to the fact that it will change the natural configuration of earth's atmosphere. On the other side, air pollution can be depicted as the presence of any gaseous, fluid or solid substance, including noise and radioactive radiation in the atmosphere that can attack materials, imperil human health and welfare of plants and animals, produce undesirable odours or reduce visibility.

The sources of air pollution can be categorized as two types, natural sources and man-made sources. Natural sources that contaminate the air included the evaporation of organic compounds, wind erosion, forest fires, pollen dispersal, volcanic eruptions and natural radioactivity. Man-made air pollution sources are called anthropogenic while from animals or plants is said to be biogenic. Its chronological growth has been described by progressively growing quantities of entire emissions, the creation of new sources of pollution emission and the emission of pollutants that had not previously been emitted by man-made sources. Currently, the main causes of man-made air pollution are motorized street traffic (particularly exhaust gases and wheel abrasion), the burning of fuels, and larger emissions from the manufacturing industries (Zell et al., 2010). Pollutants released from man-made sources like industrial sources, power and heat generation, waste disposal, and the operation of internal combustion engines have a maximum effect on the environment when compared to that caused by natural sources like volcanoes, coniferous forests, and hot springs.

Mobile sources, especially motor vehicles, stationary sources, including industrial waste incinerators, power plants and emission of urban construction works and quarries, along with open burning are the main sources of air pollution in Malaysia. Trans boundary emissions like uncontrolled wildfires, earthquake and volcanic eruptions from neighbouring countries also contributed to become the sources of air pollution to this country (Afroz et al., 2003). According to the Department of Environment (1977) in the article of CES 2014, motor vehicles contributed 68.5% of the emission of the pollutants to the atmosphere. While stationary sources (power plant and industrial) and other sources accounted for 26.7% and 4.8% respectively.

Pollutants can be categorized as primary or secondary. Primary pollutants are substances that are straightforwardly emitted into the air from sources. Carbon compounds (carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4) & volatile organic compounds (VOCs)), nitrogen compounds (nitrogen monoxide (NO), nitrous oxide (N_2O), & ammonia (NH_3)), sulphur compounds (hydrogen sulfide (H_2S) & sulphur dioxide (SO_2)), halogen compounds (chlorides, fluorides and bromides) and particulate matter (PM or "aerosols") are the main primary pollutants which are detrimental when the concentrations is higher. Secondary pollutant is a pollutant that is not specifically radiated from sources, but instead form in the air from primary pollutants. In other meaning it is called as "precursors". The main secondary pollutants which are identified to cause hazard when they accumulated at higher concentration are ozone (O_3) formed from photochemical reactions of nitrogen oxides, VOCs sulphuric acid droplets formed from SO_2, NO_2 and HNO_3 formed from NO and nitric acid droplets formed from NO_2, sulphates and nitrates aerosols (e.g., ammonium (bi)sulfate and ammonium nitrate) formed from reactions of sulphuric acid droplets and nitric acid droplets with NH_3, respectively and organic aerosols formed from VOCs in gas-to-particle reactions.

Malaysian Air Quality Index (MAQI) which is the first system of air quality index was developed by the Department of Environment (DOE) in 1993. When DOE revised its index system in 1996, it changed MAQI to Air Pollutant Index (API) as the tools to conveying the status of ambient air quality, ranging from good to hazardous. The Department of Environment (DOE) monitors the country's ambient air quality through 52 continuous monitoring stations located in urban, sub-urban and industrial areas to

observe any substantial alteration in the air quality which probably hazardous to the health of mankind and the environment. Nitrogen dioxide (NO_2), ozone (O_3), sulphur dioxide (SO_2), carbon monoxide (CO) and particulate matter of less than 10 microns in size (PM_{10}) are the air pollutants used in computing the API. Dominant of air pollutant with the highest concentration levels of the individual sub-index is used to determine the API value which provides a noteworthy method to assess the variations of air quality status (Awang et al., 2000). In Table 1.1, the API categories presented started from Good, Moderate, Unhealthy, Very Unhealthy and ultimately Hazardous.

Table 1.1: The Index Status of Air Pollutant

API Status	API
Good	0 – 50
Moderate	5 – 100
Unhealthy	101 – 200
Very Unhealthy	201 – 300
Hazardous	> 300

Source: Department of Environment, DOE (2013)

Environmental monitoring programs generate a large bulk of data which can provide a great deal of information about pollution, trend and effectiveness of policy with suitable statistical analysis. To achieve significant statistical results, the data used for analysis must be accurate, reliable and meet certain data quality objectives. Many statistical procedures have been used to analyze environmental data such as multivariate analysis. Over the last few years, the usage of multivariate analysis to complex datasets has seen growing momentum within the scientific community. And now, it has been

considered as a conventional standard of practice in most if not all disciplines. (Brereton, 2003). According to Massart and Kaufman (1983), multivariate analysis is a method for grouping, modelling and interpretation of huge data sets taken from programs which monitor the environment. As the result of the analysis conducted, it is probable that the dimensionality of the data as well as the process of extracting information may occur.

1.2 Problem Statement

Air pollution is a critical issue in Malaysia. This is due to the fact that it causes harmful effects to all living beings. According to the Malaysian Department of Environment annual report, the air quality at the present time is declining when compared to the past. Interpreting the huge amount of data in order to identify the real factor which contributes to pollution at any particular area is quite difficult because of the complexity of the data and therefore requires one to use the correct methods. To overcome this problem, factor analysis was chosen as a technique to identify contributing factors which lead to air pollution. Based on the identified factors, it is hoped that this study shall provide an input to the Department of Environment on the important factors which contributed to the air pollution at any given areas.

1.3 Objectives

The objectives of this study are:

i. To compare the average concentration of the air pollutants at four monitoring stations.

ii. To determine the major factors and air pollution levels at four monitoring stations.

iii. To determine the major causes of air pollutants.

1.4 Scope Of The Study

The focus areas of this study comprise of three different localities which are; urban, suburban and industrial and one control area (background area). According to the multivariate statistics approach, this study utilizes the daily data of four critical air pollutants and two meteorology parameters from the year of 2008 until 2012 to examine the major factors and sources and air pollution levels and discusses the correlation between pollutant and the concentration of air pollutants found in every area where the station that monitors air quality is located, to precisely show the variances of air status among monitoring areas. It then transforms into a guideline in providing assessments appropriate to the characteristics of pollution and systems of classification for monitoring areas that monitor the quality of air in Malaysia.

1.5 Conceptual Definition

According to Compendium of Environment Statistics (2014), the conceptual definition used in this study is defined as follows:

1.5.1 Ozone

Ozone is an inorganic molecule contain of three oxygen atoms. In chemical formula, it's written as O_3. It is a known toxic gas, pungent and colourless. Ground-level ozone is classified as a secondary pollutant because it is not emitted directly into the atmosphere. It results from photochemical reactions between oxides of nitrogen (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight (Ismail. M, 2011, Pudasainee et al., 2006). Photochemical ground-level ozone formation depends on a number of natural and anthropogenic factors. Typical summer fair weather conditions are responsible for an increase in ground-level ozone production (Jacob & Winner 2009).

1.5.2 Carbon Monoxide

Carbon Monoxide is an odourless, colourless, deadly and non-irritating but very poisonous gas. Carbon monoxide consists of one carbon atom and one oxygen atom (CO). Carbon monoxide comes from the incomplete combustion of natural gas, diesel or gasoline in traffic engines. High concentrations of CO commonly take place in areas

with substantial traffic intensity and congestion. Point sources of CO emissions also consist of industrial processes, non-transportation fuel combustion, and natural sources such as wild forest fires. Indoor sources consist of leaking gas stoves, heaters and generators (Han & Naeher, 2006).

1.5.3 Nitrogen Dioxide

Nitrogen Dioxide (NO_2) is formed in the ambient air through the oxidation of Nitrogen Monoxide (NO). It transforms in the air to form gaseous nitric acid and toxic organic nitrates. This reddish-brown toxic gas has a sharp and pungent odour. As a component of nitrogen oxides (NO_x), it goes through an intricate process of chemical and photochemical reactions with nitric oxide (NO), ozone, and other gases. The presence of NO_2 in the atmosphere can be attributed to two different sources. The first source is the primary pollutant which comes directly from emission. The second source is the secondary pollutant which originated from chemical reactions in the atmosphere. Exposure to NO_2 poses harmful effects to human health. Lung injury and airway responsiveness may occur due to short term exposures to the gas. Meanwhile infections to the respiratory system and weakened immunity may possibly follow in the case of long-term exposures (Han & Naeher, 2006).

1.5.4 Particulate Matter

A mixture of liquid droplets and solid particles found in the air are used to describe the Particulate matter or PM. It exists in different shapes and sizes and contains

numerous chemicals of varying nature. One of the particulate matters is the particle of less than 10 microns in diameter which is called as PM_{10}. PM_{10} can be a liquid or solid form and it includes aerosol, pollen, smoke and dust. The most important sources of these pollutant emissions include domestic combustion in household heating, road traffic, and industrial combustion. In addition to the emissions of primary particulate matter, particles are also formed in ambient air by chemical and physical processes from precursor gases (Kiesewetter et al., 2014).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Malaysia is one of the largest environmentally friendly and rich developing countries in the Earth, which is known as greening country. Yet nowadays Malaysia started to encounter the problem culminating from industrial pollution as well as the degradation of urban environments as the country races toward rapid economic and industrial growth by 2020. The effects of air pollution resume to become an anxiety for the authorities who want to lay measure with a specific objective to have it contained so that it will not represent a menace to all wellbeing. Records derived from previous programs that monitor the quality of the air indicate the fact which shown that some quantities of pollutants of the air in a number of urban areas is increasing over the long haul and occasionally the readings are intolerable as indicated by the national ambient quality standards (Afroz et al., 2003). Recommended Malaysia Ambient Air Quality Guidelines (RMAQG) which has been published by the Department of the Environment (DOE) since 1989 is used to measure the level of the air quality in Malaysia by characterizing the concentration bounds of selected air pollutants which could adversely influence the wellbeing and welfare of the overall community.

2.2 Air Pollutant Index Construction

The Air Pollutant Index is designed and sustained by methodical and systematic measurement with respect to the quality of the air in Malaysia so that it could be categorized and utilized especially in matters of health interest. In other words API is intended to report the condition of the air quality in a particular region or area. The Malaysian API system is based on the Pollutant Standard Index (PSI) system of the United States of America. The Malaysian DOE, in the context of this study, works by monitoring the ambient quality of air. In order to achieve this, the department has at its disposal a comprehensive network consisting of 52 stations which endlessly monitor the quality of air nationwide. These monitoring stations are deliberately situated in industrial, urban and suburban zones to identify noteworthy alteration to the quality of the air (Department of Environment, 1975: Malaysia Environmental Quality Report, 2013).

2.2.1 Key Air Pollutants

Disparity in the selection of crucial air pollutions, will continuously exist as different countries identify different pollutants whereby the most harmful to the population shall be singled out. (Elshout & Leger, 2006). According to Department of Environment the air pollutants identified as a part of calculating the API are sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), particulate matter with a diameter less than 10 microns (PM_{10}) and ground level ozone (O_3).