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Research paper

Fitting Statistical Distribution on Air Pollution: an Overview

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Abstract

High event of air pollution would give adverse effect to human health and cause of instability towards environment. In order to overcome these issues, the statistical air pollution modelling is an important tool to predict the return period of high event on air pollution in future. This tool also will be useful to help the related government agencies for providing a better air quality management and it can provide significantly when air quality data been analyze appropriately. In fitting air pollutant data, statistical distribution of gamma, lognormal and Weibull distribution is widely used compared to others distributions model. In addition, the aims of this overview study are to identify which distributions is the most used for predicting the air pollution concentration thus, the accuracy for prediction future air quality is the important aspect to give the best prediction. The comprehensive study need to be conducted in statistical distribution of air pollution for fitting pollutant data. By using others statistical distributions model as main suggested in this paper.

Keywords: *Air pollution, statistical distribution, pollutant concentration prediction.*

1. Introduction

The quality of ambient air has been one of the problems in the world nowadays. The increasing population would increase the numbers of industrial production to accommodate the human need, power generation and motor vehicle which led to air pollution problems. The issue of air pollution has been occurred worldwide [1]. The long-term and short-term are categorized as significant effect on human health when exposing to air pollution [2] and approximately 800,000 deaths per year caused by air pollution worldwide reported [3]. The number does not stop there, studies conducted by Kim et al., [4] exposure of PM_{10} not only can cause health effect but it takes around 2.1 and 0.47 million people die by exposing this pollutant. This figure shows that air pollution it a seriously can damage and reduce the human activities. These numbers show that air pollution not only can give adverse effect to human but it can so hazardous to human that could be a silent killer.

Expose to a high level of pollutants in short period would lead to premature mortality due to respiratory and cardiovascular diseases [5]. While long-term human exposure would lead to cause hypertensive disorder, numerous types of cancer and increase the risk of death from the mortality of tuberculosis patient [3].

Air pollution can be divided into two types of pollutants which are a primary and secondary pollutant. A pollutant that has the same form when emitting from source classified as primary pollutant [6]. The changes form due to oxidation or reaction after emitting from sources with primary pollutant defined as secondary pollutant [7]. In urban areas, the industrial and motor vehicle activity is the main source contributor to air pollution [8].

In Malaysia, Department of Environment (DOE) is the responsible agency to monitor the air quality level. There have 52 monitoring stations throughout the country and DOE monitored the air quality quality level based five types of pollutants which is particulate matter sizing less than 10 micrometers (PM_{10}), surface layer ozone (O_3), carbon monoxide (CO), Sulphur dioxide (SO2) and nitrogen dioxide (NO_2). In 2014, 4452 cases which are about 79% of total complain regard to environmental pollution in Malaysia and it be the highest complaint among the environmental pollution [9].

In a decade, the transboundary smoke haze pollution become annual phenomena that deterioration on local air quality in Asian country including Malaysia. The haze has been attributed from forest and peat fires in Indonesia that contained a loading of particulate matter, toxic, graphitic carbon that is hazardous to human health [10].

The air pollution index (API) is used as a standard for a guideline to the level of air pollution in Malaysia and this guideline shows in Table 1. This guideline is to identify how the air quality condition either is good or hazardous. The worst haze incident in Malaysia reported in 1997 and 2014 when monitoring stations recorded the API over 300 [9]. Hence, it becomes necessary to make a prediction of air pollution using statistical distributions in Malaysia in order to ensure the air quality level not exceeds the limit that been state by Malaysia Ambient Air Quality Guideline (MAAQG).

Therefore, statistical modeling is an important tool to predict the return period of a high event of air pollution in future. The information and data may useable to the government agencies to develop policies related to air pollution and implement alternative energy sources to reducing the emission of air pollution [12]. It's also useful to help the related government agencies to provide early information and precaution to the community for early prepared if there has provided the return period of high event air pollution.

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Table 1: The Malaysia air pollution index

Air Pollution Index	Diagnosis
0 – 50	Good
51 – 100	Moderate
101 – 200	Unhealthy
201 – 300	Very Unhealthy
301 - 500	Hazardous

2. Probability Density Function

The probability density functions (PDF) have been used for many years to analyze the air pollution and describe the frequency of high concentration of the pollutant [13]. Moreover, the PDF can determine the shape of concentration distribution thus, it can be used for many purposes. The emission level also plays a role in the air quality, thus, is becoming an important aspect to select the appropriate probability model to examine the concentration data that needed to environmental management

3. Distribution Fitting

3.1. Estimation Fitting

There are several methods to estimate the parameter which is a method of moment, maximum likelihood method, probability weighted moment, least square moment and another method. Estimation of parameter among important part of modeling and predicting, thus it show how accurate of the estimator.

3.2. Type of Distribution

There are many types of distribution that can be used to fit the air pollution data. Since Georgopoulus and Seinfeld [14] explored and describing statistical distribution of air quality of pollutant concentration. The most popular distribution widely used is Weibull, Lognormal and Gamma distribution in order fitting air pollution using statistical distribution. However, there is several more others distribution can be applied for purposes of fitting air pollutant distribution in air quality. The most widely used statistical distribution in literature and others distribution that may apply.

4. Application of Statistical Distributions in Air Pollution

There are many statistical distributions has been used in order to fitting the distribution data of air pollution. As mention early, the statistical distribution of Weibull distribution, lognormal distribution, and gamma distribution is widely used to predict the air pollution concentration. It is very useful for having a statistical distribution model due to the impact on human health by air pollution and protecting the surrounding environment in the future. This section will explored the statistical distribution that used by others previous researcher to fitting the air pollution data to predict the return period of high event.

The study found the lognormal distribution as the fit model for the distribution daily average of PM_{10} concentration using the pollutant concentration from 1995 until 1999 for three location namely as Hsin-Chu, Sha-Lu, and Gian-Jim, Taiwan. Three types of statistical distribution which is Weibull, lognormal and V Pearson distribution has been assess before determine the best statistical distribution [15]. Another study by Lu [16] in central, Taiwan and it's found the Weibull, gamma and lognormal distribution is not accurately predicted when there have high concentrations of PM_{10} which give parent distribution to diverge. This study also found the exponential and extreme value as methods that fitted well in actual PM_{10} data. While, Sedek et al., [17] found the lognormal distribution as the best-fitted model to prediction of PM_{10} concentrations in Kuala Lumpur using data from 1998 to 2002. Hamid et al., [18] also use log normal to fit the distribution. The study was conducted in Nilai area which categorized as an industrial area. Modeling air pollution can be used thus, the final result can be used as the decision to reducing the air pollutant impact.

The statistical distribution study to fit several air pollutants has been conducted in Xi'an, China. The purpose of the study is to identify the appropriate distribution model to represent the daily average of the concentration of that pollutant state. This study revealed the pearson 6, extreme value and log-logistic as the best-fitted model to Sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and particulate matter (PM_{10}) and daily average concentrations, respectively [19].

The study on a comparison between Weibull, gamma and lognormal distribution with Frechet and gumbel distribution has been assessing for predict the exceedances of future PM_{10} concentrations. The result found that the Frechet and gumbel distribution has shown the better fitting compare to Weibull, gamma and lognormal. This study proves that gumbel and Frechet distribution can give a better fit than the most widely used distribution [20]. While, Noor et al., [21] revealed that the lognormal distribution is the best distribution that fitted to the PM_{10} concentrations in industrial area in Shah Alam, Selangor.

Another study related to statistical distribution has been conducted by Ghazali et al.,[22]. The objective of the study is predicting the ozone concentrations levels and the result shows that the beta distribution can be applied to predict the ozone concentrations compared to others distributions. Meanwhile, in Nigeria, Oguntunde et al., [23], used gamma distribution as the best-fitted model that can be applied for predict the future concentrations of air pollution in the study. The Weibull, lognormal and gamma distribution has been assessing in this study to determine the fitted model. Maciejewska et al., [24] using several statistical distribution to determine the return period of the extreme concentration in Warsaw, Poland. The result found that lognormal distribution was the most appropriate model to represent the middle-range values, while the high concentration was satisfactory predicted by the exponential distribution which was used to estimate the return periods of extreme concentration for winter month.

Another study on statistical distribution to predict ozone concentration at the coastal area at Port Klang, Selangor and Port Dickson were used Weibull distribution [25]. The study used a single distribution to fit the concentration. Moreover, Al-Dhurafi et al., [26] study on the probability distribution model of air pollution and the main purpose of the study is to identify the statistical model for the distribution of air pollution index (API) using statistical distribution of gamma, Weibull, lognormal and exponential distribution and there result show that the gamma distribution as fitted to most the air pollution data. A study by Sansudin et al., [27] studies the movement of air quality in Johor Bahru, Nilai, Kota Kinabalu and Kuantan Malaysia. The distributions such as gamma and lognormal were used in these studies. The area was chosen because it based on the frequently high PM_{10} concentration reading. Johor Bahru and Nilai are industrial areas and it using two parameter gamma distributions while for a residential area in Kota Kinabalu and Kuantan using two parameter log-normal distributions. In the result stated that gamma distribution is best to distribute on to represent the industrial area, while for log-normal are best to represent the residential area in these studies.

Noor et al., [28] study a modeling of the PM_{10} concentration industrial area at Nilai, Malaysia. The statistical distribution of this study used which are Weibull distribution, log-normal distribution, and gamma distribution. As the results show that in 2006 lognormal distribution is the best-fitted distributions in 2006 while Weibull distribution fitted well data of 2007. In China a study by Xi et al., [29] the application of statistical distribution for predict-

ing PM_{10} concentration in air quality management has been applied in 5 representative cities of China. The study is to estimate the frequency of daily average PM_{10} concentration and also to know the reduction of the particulate matter emission to meet AQS from the statistical properties. A statistical distribution such as Log-normal, Weibull, and Gamma was been used for this study. In the result found that log-normal are suitable for fitting the distribution data.

Vivekanandan., [30] studies the comparison of parameter estimation procedure of between Gumbel and Frechet distributions for modeling purposes. Even though this study is about comparing the method that suit for the distributions, however other distribution was used to fit the concentration data. In addition, this step is to see how well the other distribution fits to the concentration data. Ahmat et al., [31] study on the Malaysia PM_{10} using Gumbel, Weibull, and Pareto distribution to assess the PM_{10} concentration data in three different location. The study was conducted at Pasir Gudang, Bukit Rambi, and Nilai. Meanwhile, Yahaya et al., [32] found which Blom method is best for large sample size, and for the small sample size are best using Landwehr and Hazen. However the medium sample Landwehr plotting formula well. The error and the accuracy measure are considered taken simultaneously. Predicting the return period of the air pollutant in this study based on the error measures which are NAE, RMSE, PA, and R_2. Studies by Pekasiewics [33] also use a single distribution to predict the air pollution which is Cauchy distributions were used in this stud. Meanwhile in Izmir Turkey, studies has been conducted by Ozay et al., [34] on statistical analysis using two parameter Weibull distributions and Rayleigh distribution and were conducted in Alacati region. The result Weibull distribution is the best fit to represent the characteristic of the distribution. These studies show the other statistical distribution are not fully utilized to fitting the distribution data.

A study by Ouardo et al.,[35] on criteria for the selection of probability distribution. The studies were used Gamma distribution, log-Pearson type iii, and kappas were used to fit distribution data. Thus, plotting the distribution can give instantaneous and provide more information on the criteria and provide the characteristics of the distribution. Besides, the best fit distribution in these studies is gamma based on the performance indicator. Meanwhile, Papanastasiou and Melas [36] study about application of PM_{10} statistical distribution to air quality management. The study was conducted in central Greece which is facing the bad situation on the level of air quality thus, a solution should be taken to predict how many number of day exceeds the limit that compliant to the European Union (EU) Air Quality Standard (AQS). The Lognormal were used in this study to predict the air quality level especially PM_{10} concentration which the result can be utilized for air pollution control strategies. Moreover, the study found that the lognormal fits well to the distribution which proves by the goodness of fit test. In addition this study found concentration higher during winter and lower in summer, this is due to the central heating operation in winter. The application of fitting statistical distribution was used to compare which the distribution well fitted in the data.

A study by Zaharim et al., [37] use Weibull and lognormal to evaluate the wind speed data that observed from June 2007 until September 2007. Both distributions were verifying using Goodness of fit test to determine the performance of the parameter. In this study found that the Weibull is the well fitted to the distribution. Berthe et al., [38] used gumbel Weibull distribution for modeling and predicting the precipitation in Mali. The climate change encourage greatly affect the economy and it increased the social instability through the year tend to make this study happen. In the end of the study, found that gumbel Weibull distribution showing a good technique of predicting the precipitation with some method and test the result show the efficient to estimate the recorded precipitation. Predicting air pollutant concentration is very useful to be used in future planning. The air pollution not only can affect to human health but it can affect the stability of the environment. A study by Yunus and Hasan [39] is to predict the hourly concentration of PM_{10} by using Weibull, lognormal, and gamma distribution. The study was conducted in two different locations which are Seberang Perai and Petaling Jaya respectively. All three distributions fit the data well except when extreme value occurs, the result shows the pattern of prediction can be analyze. In addition, there are some room of improvement can be added which is climatology and meteorological variables for the modeling and predicting purpose.

The summaries of previous statistical distribution that applied in air pollution modeling show in Table 2.

Table 2: Applications of statistical modeling for prediction purposes

Prediction Area	Author(s)	The best distribution
Hsin-Chu, Sha-Lu, and Gian-Jim, Taiwan	Lu, 2002 [15]	Lognormal
Central Taiwan	Lu, 2004[16]	Exponential and extreme value
Kuala Lumpur,Malaysia	Sedek *et al*., 2006[17]	Lognormal
Nilai, Negeri Sembilan, Malaysia	Hamid *et al*.,2013 [18]	Lognormal
China	Jiang *et al*., 2015 [19]	SO_2 =Pearson 6 NO_2 = extreme value PM_{10}= Log-Logistic
Seberang Perai, Pulau Pinang,Malaysia	Yusuf *et al*., 2011 [20]	Gumbel and Frechet
Shah Alam, Selangor, Malaysia	Noor *et al*., 2011 [21]	Lognormal
Cheras, Selangor,Malaysia	Ghazali *et al*.,2014 [22]	Beta
Lagos State, Nigeria	Oguntunde *et al*., 2014 [23]	Gamma
Warsow,Poland	Maciejewska *et al*.,2015 [24]	Lognormal
Port Klang, Selangor and Port Dickson,Negeri Sembilan,Malaysia	Nasir *et al*., 2016 [25]	Weibull
Kuala Lumpur,Malaysia	Al-Dhurafi *et al*., 2016 [26]	Gamma
Johor Bahru, Nilai, Kota Kinabalu and Kuantan,Malaysia	Sansudin *et al*., 2011 [27]	Gamma
Nilai,Malaysia	Noor *et al*., 2011 [28]	Lognormal
5 representative cities of China	Xi *et al*.,2013 [29]	Lognormal
Fatehabad and Tohana regions, India	Vivekanandan., (2013)[30]	Gumbel and Frechet
Pasir Gudang, Bukit Rambi, and Nilai,Malaysia	Ahmat *et al*., (2015)[31]	Gumbel
Using three different sample size	Yahaya *et al*., 2012 [32]	Gumbel
Using sample size	Pekasiewics.,2014 [33]	Cauchy
Alacati region	Ozay *et al*.,2016 [34]	Weibull
UAE	Ouardo *et al* .,2016 [35]	Gamma
Central Greece	Papanastasiou and Melas, 2010 [36]	Lognormal
Universiti Kebangsaan Malaysia (UKM)	Zaharim *et al*.,2010 [37]	Weibull
Mali	Berthe *et al*.,2015 [38]	Gumbel weibull
Seberang Perai and Petaling Jaya,Malaysia	Yunus and Hasan, 2017 [39]	Lognormal

5. Conclusion

The modelling of the statistical distribution of air pollution is an important tool to predict the return period of a high event of air pollution in future. It also can be used to help the related government agency to provide an early precaution measure especially to

the elderly, children and person with the asthmatic problem. These tools also useful in develop policies for future development by government agency whether the selected development areas need to have an environmental assessment in order to reduce risk to human health.

The several studies that discuss in this paper, the gamma distribution, lognormal distribution and Weibull distribution is the most used in fitting distribution air pollutants data. However, others distribution such as Gumbel distribution, Nakagami distribution, Frechet distribution and others also may suitable to fit the air pollutants distribution. Moreover, in order to fit the best distribution of air pollutant data usually depending on the areas of study and it is not unique to that particular area. There are only a few studies on air pollution in fitting distributions on air pollutants data in Malaysia by using others distribution compared to Weibull, gamma, and the lognormal distribution. Therefore, there is more study can be conducted using others distribution to fitting air pollutants distribution in Malaysia and help the local authorities in air quality management.

In addition, the aims of this overview study are to identify which distributions are the most used for predicting the air pollution concentration thus, give the accuracy for prediction future air quality.

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