Air Pollution Attributable Deaths: A Global View Through Fractal Analysis

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Abstract

Air pollution is a global public health threat which requires in depth analysis for policy making. It contributes to the mortality in many urban areas. This study compares the variability of the clustered urban areas based on World Health Organization (WHO) region classified in terms of exposure to particulate matter with an aerodynamic diameter of 10 μm or less (PM10) from 2003-2010 and validated through its attributable death from 2004 & 2008. These diverse data were subjected for analysis employing fractal geometry and fractal statistics to compute its respective fractal dimensions. The purpose of such comparison is to validate a possible causative factor of the mortality. Findings revealed that the region with high variability in terms of fractal dimension in air pollution also displays more varied attributable death. This pattern is both demonstrated in all region. The paper concludes that the policies on environmental conservations in controlling air pollution and health care delivery system greatly contributes to the high fractal dimension of air pollution attributable death.

Keywords: air pollution, attributable death, global fractal analysis, particulate matter, fractal dimension

1.0 Introduction

Air pollution is one of the leading problems globally faced by people (Nagdeve, & International Institute for Population Sciences; 2004 & Wang, Xiao Yu, Hu, Wenbiao, & Tong, Shilu, 2009). Presently, there are increasing emission of fine particulate matter emitted from forest fires, power plants, industries, cooking or heating materials and automobiles that resulted into a negative effect causing damage to ozone layer and living creatures, human and animals (Schwelm, 2007, Environmental Protection Authority, n.d). This detrimental effect to human population causes such conditions that affect man's health. The attributable death (mortality) is the total death caused by air pollution such as respiratory problems, cardiovascular related conditions, cancer and many more. Cases to attributable to air pollution were estimated for mortality, respiratory and cardiovascular hospital admissions (all ages), incidence of chronic bronchitis, bronchitis episodes in children, restricted activity days and asthma attacks in adults and children (Kunzli, Kaiser, Medina & Studnicka, 2000). The mechanism of this pollutant transport and dispersion process depends largely on ones country's development (urbanization and industrialization) as well as their pollution management. In some western countries they estimated that car emission kills more than motor vehicular accidents (Hooper, 2006).

Conversely, pollutant emitting activity prompted many countries particularly United States which employ various methods to intervene and come up with health policies for pollution

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(Pope, 2004). Lawmakers are motivated for expansion of more rigorous international standards for levels of particulate matter in urbanization to maintain public safety. The ambient air pollution, specifically particulate matter with polycyclic aromatic hydrocarbons and other genotoxic chemicals, is suspected to increase the risk for lung cancer. Many epidemiological studies have shown higher risks for lung cancer in association with various measures of air pollution (Pope, Burnett, & company, 2013). Mortality studies suggest that the exposure–response relationships for particulate-matter pollution in the case of both short-term and long term exposures are nearly linear, with no discernible safe thresholds within relevant ranges of exposure

Wang (2008) evaluated extended period air effluence trends in Brisbane, Australia. Data used were from Queensland Environmental Protection Agency (QEPA), utilized daily average concentration on particular matter with less than 10μ min aerodynamic diameter; nitrogen dioxide ozone, and sulphur dioxide from 1980-2004 in two localities. Polonomial regression model was used as treatment. The study found out that there were significant rise and fall features for air population concentrations in both monitoring sites in Brisbane. Also, there were significant spatial variations in air pollution concentrations between the two areas. Moreover, chronic exposures to airborne particles that leads to increased health risk such as cardiovascular and respiratory diseases

Most of the studies examined association between air pollution and health outcomes using air pollution data from one or more monitoring station (Kan & Chen, 2003; Kunzli and company, 2000). Geographical area can be a significant contributory factor in mortality and morbidity at lower and lower air pollutants level (Chen, Mengersen & Tong, 2007; Belle et al, 2004). This has a strong spatial and temporal patterns which is the new trend of studies today, it offer new opportunity for assessing impact of air pollution. The levels of air pollution often change over time and space. Recently, Geographical Information System and related mapping provide important tools in the visualization, exploration and modeling of environment and health data (Wang, 2008).

In the context of various related literature mentioned, the gap of this study were magnified and paved much interest for the researchers to further validate previous claims. None of the study subjected global air pollution and their respective attributable death (mortality) in general. Most of the studies focused on individual and group of countries. Furthermore, the urban areas in every region which has an exposure to particulate pollutants were not clearly distinguished as to how it greatly affects human population.

In this paper, the researchers utilized two types of data such as World Health Organization Thematic Map and air pollution attributable death as basis for special pattern integrating fractal statistics as newest trend in analyzing data in global perspective, specifically fractal dimension was used to describe the air pollution noted in every region. The purpose of such utilization of fractal statistics is to assess and validate the variability of the contributing factors affecting man's health. The fractal dimensions of an entity are an index to roughness of the features of object (Mandelbrot, 1967). The higher the roughness, irregularities the objects means they have higher fractal dimension. This will be translated from geometrical concept to fractal statistics (Padua, 2012). Through this dimensional breakthrough in statistics, it would be useful for every human being to clearly picture out the contributing factor as the relative cause to such health diseases.

2.0 Research Design and Methods

The design of the study focuses on the availability of the data on environmental health specifically the exposure of particulate matter in urban areas around the world provided by the World Health Organization Map Production (World Health Organization, 2012) and its attributable death as result (World Health Organization, 2004 & 2008) . These two data were subjected for analysis employing fractal analysis. The thematic map presenting the 1100 urban areas around the world from 2003-2010 was subjected for fractogram to compute the fractal dimension of each classification according to its degree of level. The said map already had representation on the urban areas as shown with traceable point which is convenient to the researchers for computation and analysis. In order to develop specific information of the data on hand, the researcher followed the World Health Organization region to cluster the urban areas. The fractal dimension of the air pollution attributable death per region was also computed to determine its implication from the urban areas with exposure to particulate matter.

Figue 1 presents the variables of the study employing surrogate measures emphasizing the types of data to be subjected for fractal analysis. It also highlighted the database of each variable.

Table 1: Worldwide Database for Analysis

Variables	Surrogate Measures	Type of Data	Databases
Air pollution	Exposure to particulate matter with an aerodynamic diameter of 10 um or less (PM10) ☐ Green (<20) ☐ Yellow (20-49) ☐ Orange (50-99) ☐ Dark Red (100-149) ☐ Purple (>150)	Thematic map	World Health Organization Map Production (2003-2010)
Attributable death	Air pollution attributable death	Numerical data	World Health Organization

Figure 1 shows the worldwide map showing the 1100 urban areas around the world with exposure to particulate matter with an aerodynamic diameter of 10 um or less (PM10) from 2003-2010.

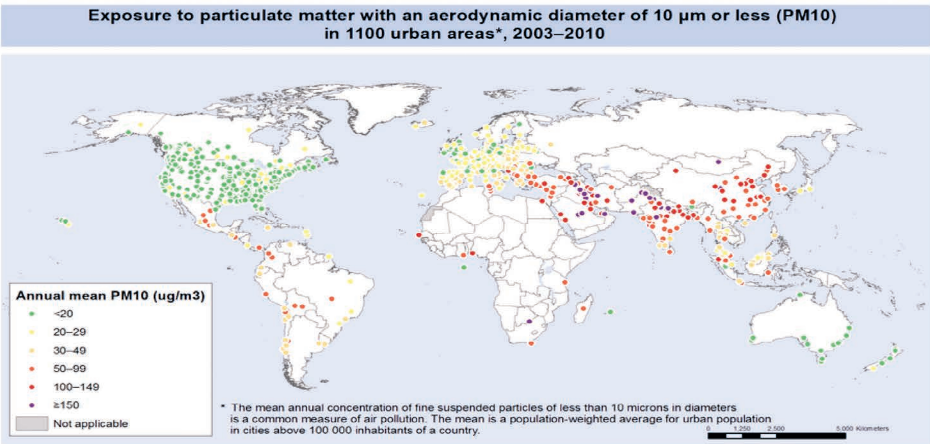


Figure 1: Worldwide map showing exposure to particulate matter

The clustering of the urban areas worldwide based on the region of World Health Organization as shown in Figure 2. These region were Africa, America, Europe, Eastern Mediterranean, Western Pacific and South East Asia. These regions were highlighted with different colors so as to cluster its perimeter as the basis for fractogram computation.

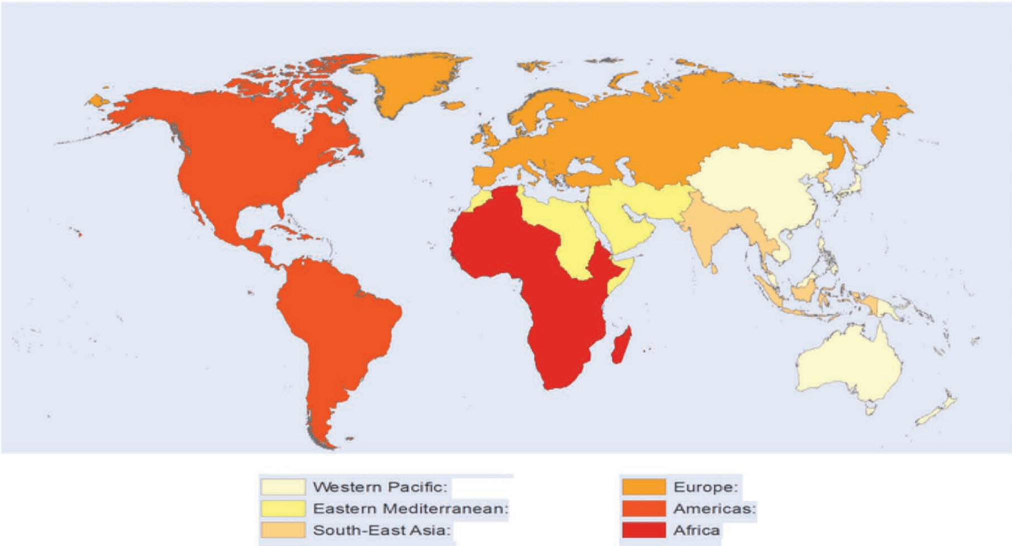


Figure 2: Clustering of urban areas according to World Health Organization region

3.0 Basic Concepts on Fractal Analysis and Fractal Dimension

This part discusses brief background on fractal spectrum adapted from Padua (2012). We used fractal spectrum as the main tool in investigating the incident of air pollution and its attributable death basing on the World Heallh Organization Map Production by (World Health Organization, 2003-2010). The usefulness of multifractal analysis in scrutinizing seismic data in Italy was established by Lapeenna et al. (2003); also by Panduyos and Padua (2013), and some other authors. With our study, the main tool utilized was Legendre's multifractal spectrum which involves looking for series of multiple fractality folds.

Fractal statistical analysis applies to situations where the mean or first moment does not exist. It also applies to situations where smaller fluctuations dominate the larger ones . Padua (2012) suggested using a power law distribution similar to Pareto's distribution given by:

$$1....f(x) = \frac{\lambda-1}{\theta}\left(\frac{x}{\theta}\right)^{-\lambda} \quad, \lambda > 0, \theta > 0, x \geq \theta$$

where λ is defined as the fractal dimension of X and θ is the smallest (positive) value of the random variable.

The maximum likelihood estimator of λ is:

$$2.... \hat{\lambda} = 1 + \frac{1}{\log\left(\frac{x}{\theta}\right)}$$

so that each observation contributes to the fragmentation of the support X. Padua (2013) demonstrated that the distribution of the maximum likelihood estimators obey an exponential type of distribution so that both the mean and variance of the fractal dimensions exist.

A device called fractal spectrum or λ(s) spectrum was suggested by Padua et al.(2013) to identify locations on the support X where high data roughness or fragmentation occur and where smoothness appear to dominate. The spectrum is defined as:

Deviations from smoothness indicate the severity of poverty incidence in a given context. A test for deviation from smoothness i.e. H0 :$\lambda = 1$, is suggested in the second paper of Padua (2012) and the reader is referred to the paper as provided in the list of references.

3..... $\lambda(s) = 1 - \dfrac{\log(1-\alpha)}{\log(\frac{x}{\theta})} = 1 - \dfrac{\log(1-\alpha)}{s}$

where X_α is the αth percentile of X and s = $\log\left(\frac{x}{\theta}\right)$

4.0 Spatial Analysis on Air Pollution

The available worldwide map showing points of location of the urban areas were subjected for fractogram. This downloadable thematic map taken from the official website of the World Health Organization specifically in the map gallery section. It was plotted in the paint software in order to convert the images to .JPEG for the inputs to be made in the FRAKOUT.COM software available for free from the internet. The sizes and number of cells were copied from the software upon tracing the sets of cluster per region in terms of reference points and variations of its level. Figure 3, 4, 5, 6, 7 and 8 show sample tracing of clusters per region according to its classification.

Figure 3 shows the clustered urban areas in Africa region in terms of dark red classification with annual mean PM10 of 100-149 ug/m3. The highlighted cluster in the region is diagonal in shape across the center.

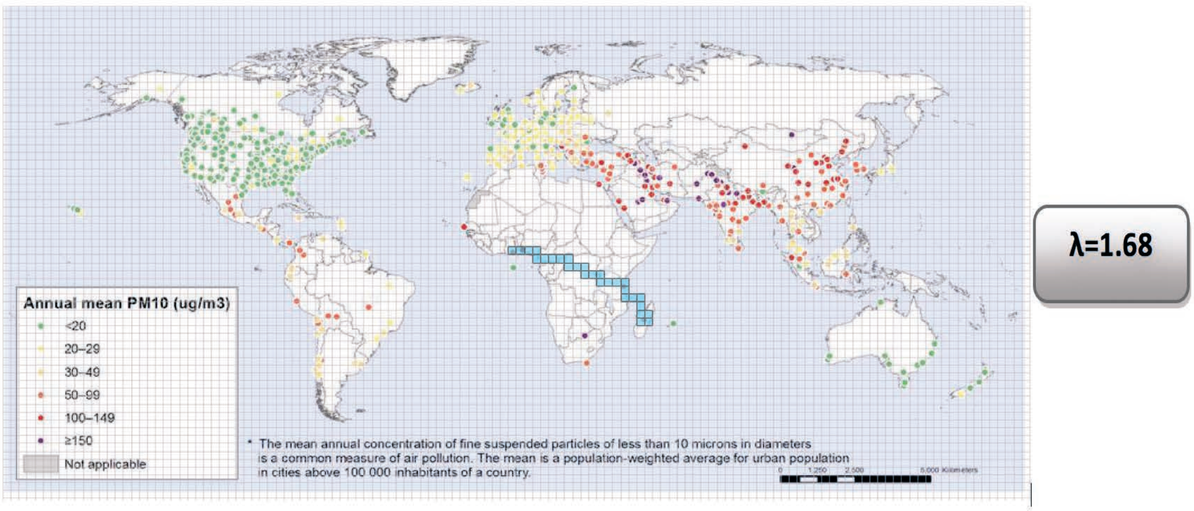


Figure 3. Sample clustered urban areas in terms of classifying annual mean of particulate matter in Africa region

Figure 4 shows a clustered urban areas in America region in terms of green classification with annual PM10 (ug/m3). The clustered urban areas indicate were not evenly distributed in the region. It is crowded mostly at the center of the region.

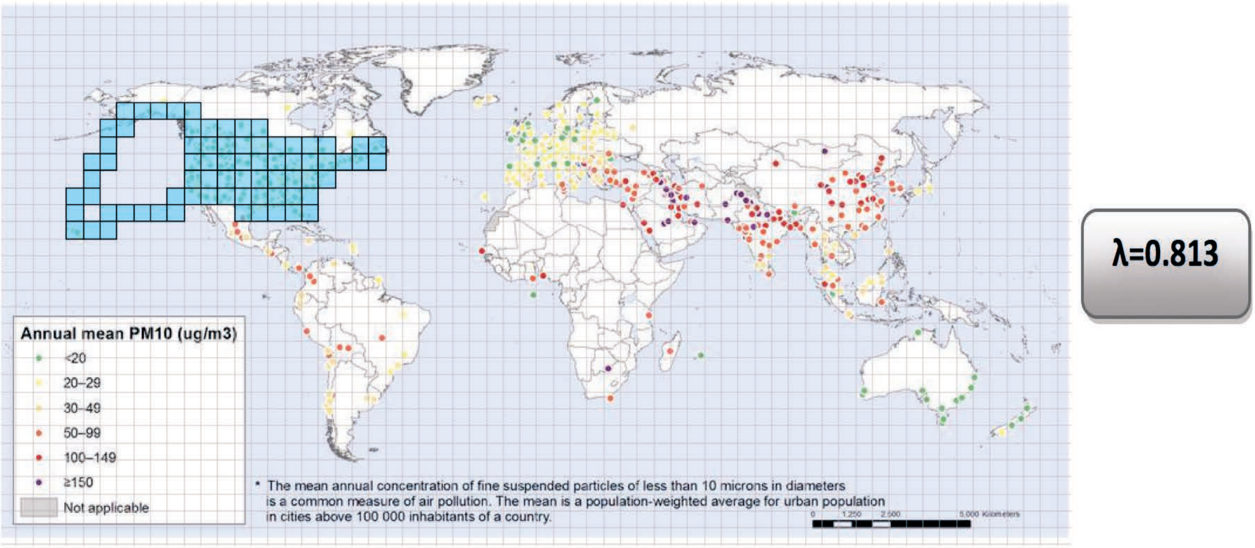


Figure 3. Sample clustered urban areas in terms of classifying annual mean of particulate matter in Africa region

The figure 5 presents the clustered urban areas in Europe region in terms of annual mean of particulate matter with yellow classification. The highlighted trace in the region is wide and accumulated in many neighboring countries.

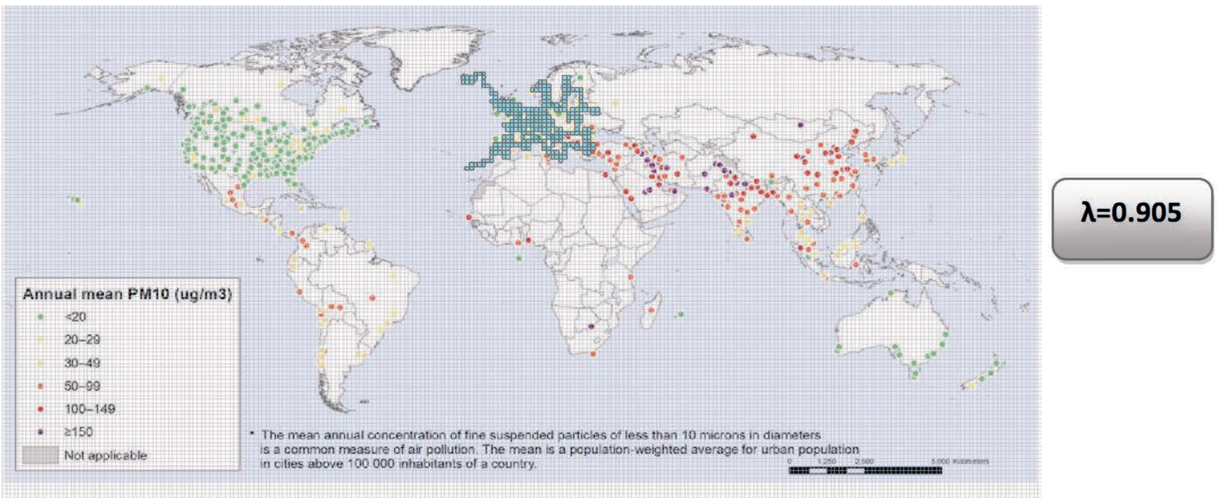


Figure 5. Sample clustered urban areas in terms of classifying annual mean of particulate matter in Europe region

Figure 6 shows the clustered urban areas in Eastern Mediterranean region with an annual mean of particulate matter in purple classification. The said clustered classification is dominantly located in many third world countries.

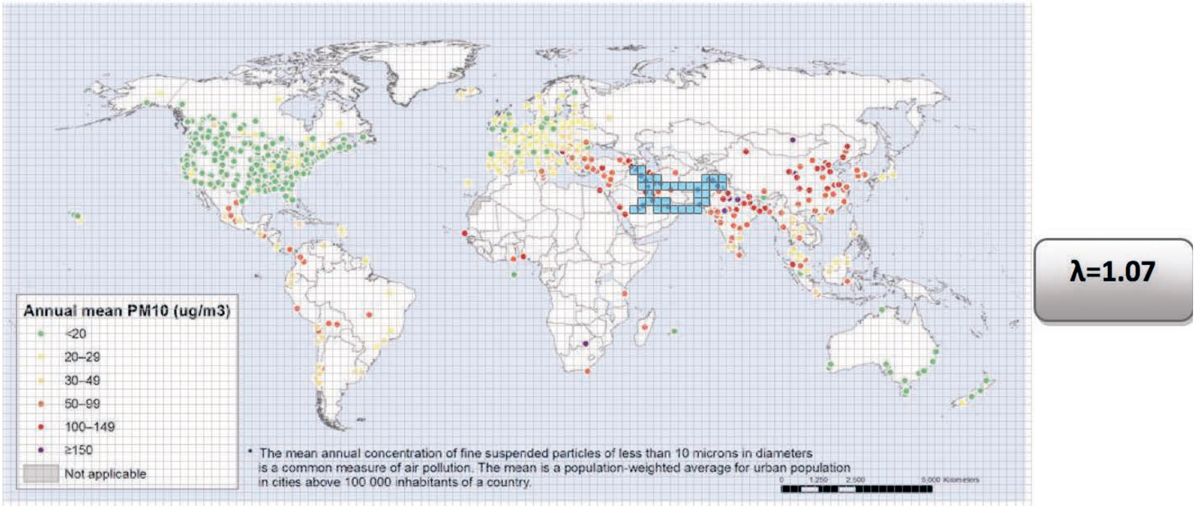


Figure 6. Sample clustered urban areas in terms of classifying annual mean of particulate matter in Eastern Mediterranean region

Figure 7 shows the highlighted clustered region in Western Pacific in terms of orange classification with an annual mean of particulate matter with an aerodynamic diameter of 50-99 µm/m3 (PM10). The geographical tracing of the clustered classification is mostly seen in China.

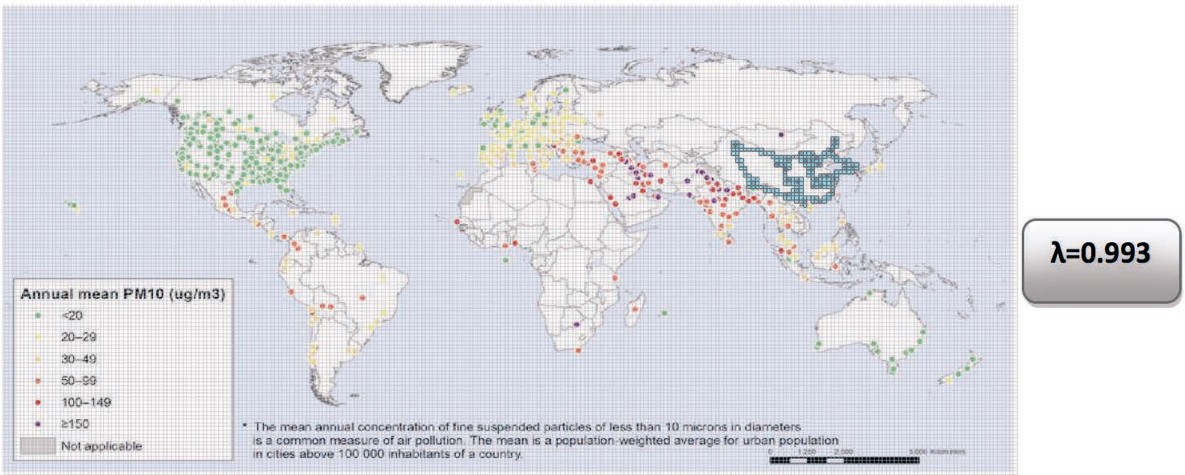


Figure 7. Sample clustered urban areas in terms of classifying annual mean of particulate matter in Western Pacific region

The figure 8 shows the clustered urban areas in South East Asia region in terms of dark red classification with an annual mean of particulate matter with an aerodynamic diameter of 100-149 µm/m3. The highlighted trace is also situated mostly in third world countries.

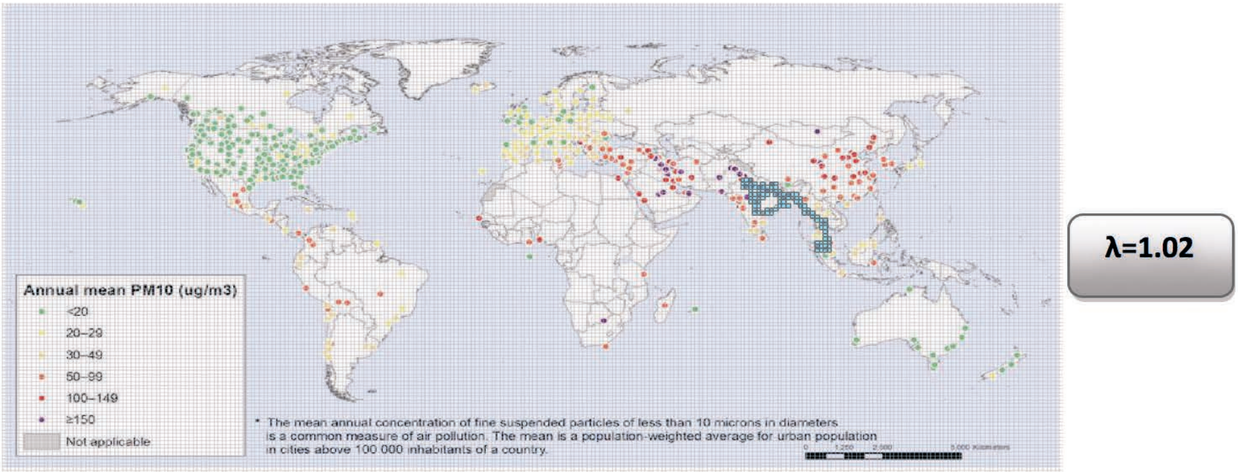


Figure 8. Sample clustered urban areas in terms of classifying annual mean of particulatematter in South East Asia region

5.0 Fractal Analysis on Air Pollution Attributable Death

The fractal dimension of the air pollution attributable death by WHO region is also computed in this presentation. The histogram air pollution attributable death per region shows definite pattern of non-normal distribution as shown in Figure 9.

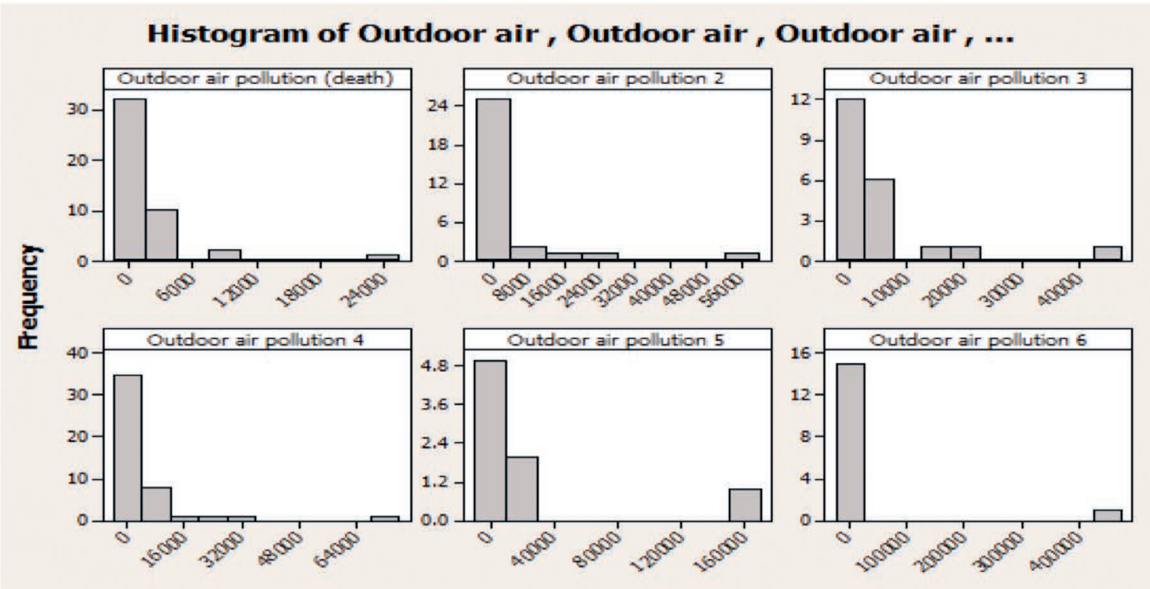


Figure 9. Histogram of the air pollution attributable death by WHO region

The non-normal distribution is also evidenced in the probability plot of the air pollution attributable death per region with P-value of <0.005 as shown in Figure 10.

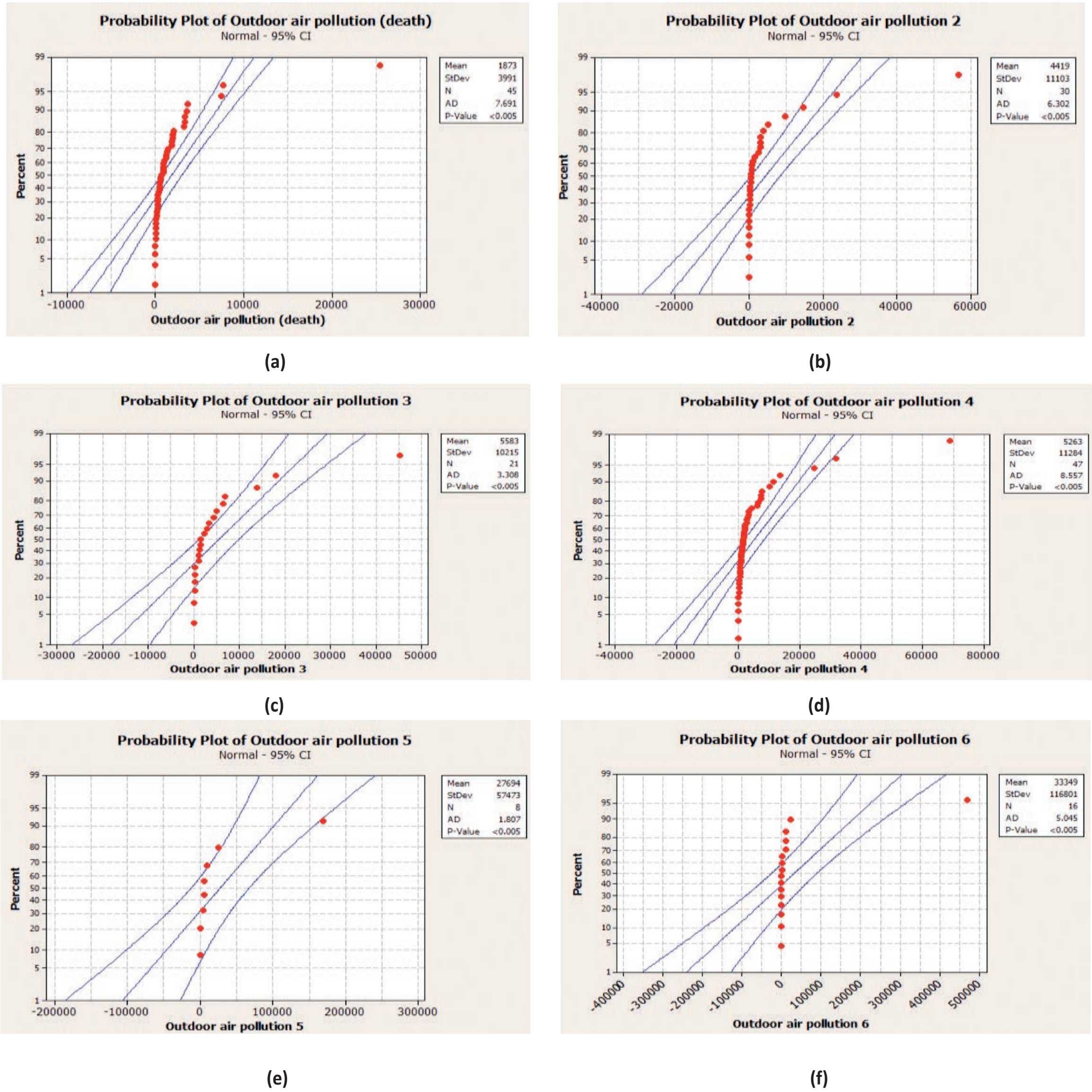
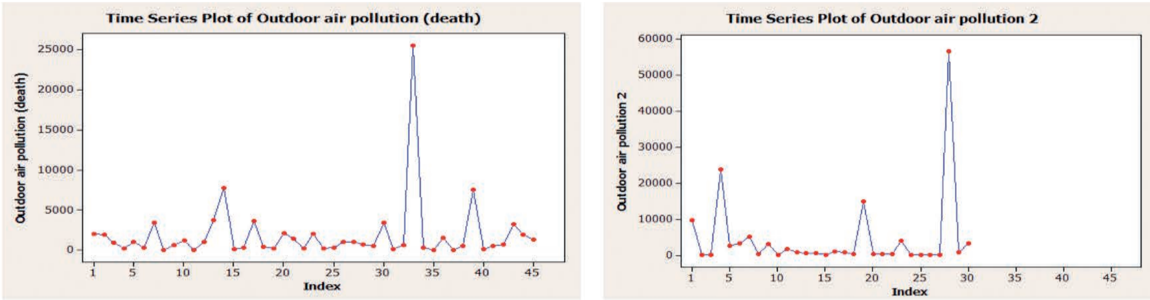


Figure 10. Probability plot of the air pollution attributable death by WHO region (a) Africa (b) America (c) Europe (d) Eastern Mediterranean (e) Western Pacific and (f) South East Asia region

Figure 11 shows the time series of values from a non-normal distribution of the air pollution attributable death per region. This is to present the variability of mortality per region. Spikes are observed in the graph of the time series.



(a) (b)

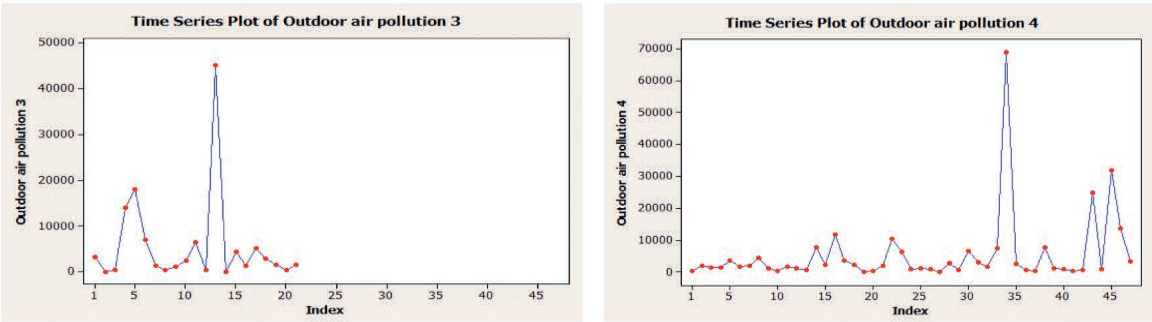


Figure 11. Time series plot of the air pollution attributable death by WHO region (a) Africa (b) America (c) Europe (d) Eastern Mediterranean (e) Western Pacific and (f) South East Asia region

The histogram of the estimated values of lambda of the air pollution attributable death from the standard normal distribution shows a definite pattern of fractal distribution as shown in Figure 12.

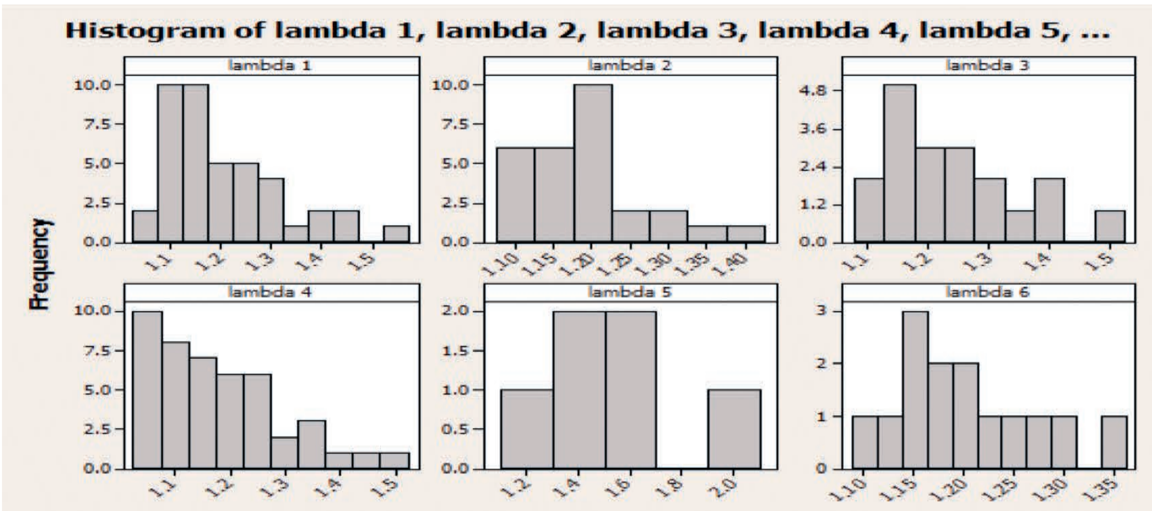


Figure 12. Histogram of lambda values of the air pollution attributable death by WHO region

WHO Region	Particulate matter with an aerodynamic diameter of 10 µm or less (PM10)					Air pollution attributable death
	Green (<20 ug/m³)	Yellow (20-49 ug/m³)	Orange (50-99 ug/m³)	Dark Red (100-149 ug/m³)	Purple (>150 ug/m³)	
Africa	1.36	-	1.11	1.68	-	1.21
America	0.813	0.837	-	1.08	-	1.19
Europe	-	0.905	1.02	1.02	-	1.18
Eastern Mediterranean	-	-	1.04	0.952	1.07	1.24
Western Pacific	0.951	1.11	0.993	0.976	-	1.20
South East Asia	-	1.07	1.04	1.02	1.47	1.53

Table 2. Fractal Dimension of each Variables per WHO Region

6.0 Results and Discussion

This study analyzed two types of data with different methods used in computing fractal dimensions. The fractal geometry and fractal statistics were utilized to compute two different data such as thematic map and numerical data. The two methods employed were geared to trace the impact of air pollution in urban areas to the public health. Chen & Kan (2008) emphasized that air pollution and population health are considered to be the most critical issues in environmental welfare and public health. As also cited by Bruce, Perez-Padilla & Albalak (2000) that air pollution is a global public health threat requiring in depth analysis through continuous research and effective policy making.

The table 2 shows the empirical findings of the data being computed with respective fractal dimensions. To note some of the region shows non-classification in some data sets. The fractal dimension measures the ruggedness of the data being analyzed. It gauges the impact of the air pollution per region to its attributable death.

In the findings of the data, the variability of the variables was clearly observed. The higher the fractal dimension of an exposure to particulate matter in many clustered urban areas in each region, the higher the variability of its mortality rate. This pattern was clearly shown in the table 2 which remarkably relates that the air pollution has significant impact to incidence of death per region. Navrud (2001) believed that health impacts make up a significant portion in the damage costs resulted from air pollution.

In the context of air pollution, the South East Asia region is the most air polluted clustered urban areas with fractal dimension of 1.47 in purple classification, the highest annual mean of PM10 of >150 µm/m3. Likewise, in the attributes to the death in the region, it also marked the highest fractal dimension of 1.53. The second highest region is the Eastern Mediterranean region with the fractal dimensions of 1.07 (PM10) in purple classification and 1.24 (attributable death). This is followed by Africa, Western Pacific, America and Europe region in terms of its attributable death with lambda values 0f 1.24, 1.20. 1.19 and 1.18 respectively. These observable patterns validated many research findings across the region.

The high fractal dimension on air pollution attributable death implies two main issues that are significant on its impact to man's health. These are the assorted policies on environmental conservation in controlling air pollution and health care delivery system being developed and implemented in many countries per region. Such policies are crucial in the fundamental framework of socio-political dimension that are key functions of both public and private sectors in the society. The environmental predicament brought about by urbanization and drastic change in technological advancement seriously affects the quality of life. The policy on environmental issues concerning air pollution varies in most clustered urban areas in each region causing more rugged pattern on exposure to particulate matter. On the other hand, the adaptation on diverse health care programs among countries also intensifies the roughness on the mortality rate caused by irregular patterns on the exposure to particulate matter.

The findings greatly supported many research studies globally. This study strengthened more the empirical evidence of the contributing factor affecting man's health. It causes various health diseases to human population. Brunekreef & Holgate (2002) claimed in their study that exposure to pollutants such as airborne particulate matter and ozone has been associated with increases in attributable death (mortality) and hospital confinement due to respiratory and cardiovascular diseases. This is further supported in the study of Kelly (2003) in which their findings have shown that there is clear associations between cardiovascular morbidity, decreased lung function, increased hospital admissions, mortality and airborne concentrations of particulate pollutants. The consequence of long term exposure of pollutants to human may lead to an acute inflammatory effect on normal human lung fields (airways). Further studies indicate in both children and adults have shown that exposure to particulate matter such as nitrogen dioxide and sulphur dioxide are associated with clinical manifestations of bronchitis. These risk factors have been related to reduce lung function growth and are reversed if the communities displace to the area with lower particulate concentrations in the atmosphere.

Moreover, the findings also confirmed the study of Krzyzanowski, Cohen & Anderson (2002) which implied that air pollution is a significant factor shaping public health in many developing countries. As observed in South East Asia region, the most polluted urban areas showed the highest fractal dimension in particulate pollutants also resulted the highest relative attributable death (mortality). The harmful effect may be due to poor policy implemented relative to the environmental development. Unlike in the case of Europe region as the least particulate pollutants among other region, the European environmental policy was strengthened in the evolution of Europeanized framework (Ward, 2003). This policy formulated among State Members of the organization adheres to common and hazardous problem to the citizens. Although complex political characterization comprises the member states, their main role is to initiate and formulate unified European policy applicable to all members. On its broadest sense, the Europe region has the most unified and standardized environmental policy among others.

The variability of attributable death in many developed regions is more rugged compared than those highly developed region. For example, the America and Europe region have more accessible health care delivery system than those of South East Asia, Eastern Mediterranean and Africa regions. They are more aggressive in terms of health care services and health care facilities. The health expenditure allocated by the government is remarkably high which caters the need of their citizens in terms of health benefits. The least variance mortality attributed to death in these two regions would also link to advancement of technology in medical field. Most of these countries have the capacity to provide more precise and accurate diagnostic procedures and treatments compared to developing countries. The accessibility of the medical resources and facilities, advanced expertise of medical health workforce and high health expenditure are the main factors causing such variability in many regions.

Myers & Green (2002) emphasized that medical advancement is escalated the way health care system is organized, delivered and financed. This medical advancement can only be attained if the economic growth rate in many countries is high and equitable to sustain the need of the population. Naidu & Chand (2013) relates health expenditure to economic growth rate. Therefore, most of the developing countries have limited capacity to upgrade health care services and accelerate advancement of medical technology in the use of diagnosing and managing terminal conditions caused by air pollution. This premise is observable in developing countries which has more varied attributable death caused by increased air pollution. Improvement in the health care services reduces mortality. Thus, the improvement in health care delivery system and policy improve the national public health welfare.

7.0 Conclusion

The findings of the study revealed that if the variability of the particulate matter is high, the variance of the attributable death is also relatively rugged. This pattern is remarkably observed in all regions. As evidenced in South East Asia region as the highest polluted urban areas with lambda values of 1.47 (air pollution) and 1.53 (attributable death). This is superseded by Eastern Mediterranean (λ- 1.07 & 1.24), Africa (λ- 1.68 & 1.21), Western Pacific (λ- 0.976 & 1.20), America (λ- 1.08 & 1.19) and Europe region (λ- 1.02 & 1.18).

The high fractal dimension on air pollution attributable death is deeply rooted on the diversed policies on environmental conservation in controlling air pollution and health care delivery system being formulated and utilized in most countries in each region. The air pollution is indeed a health threat to the population. It is greatly associated in many health conditions as one of the leading factors affecting man's health. Such conditions include respiratory problems, cardiovascular related conditions and cancer. This paper concludes that the urban areas with high exposure to particulate matter in air pollution substantially attributes to the high mortality (attributable death) in the population globally.

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