JOURNAL OF HIGHER EDUCATION RESEARCH DISCIPLINES ISSN: (ONLINE) 2546-0579
Tangub City, Misamis Occidental, Philippines (PRINT) 2546-0560
December 2017

WHO SUFFERS MOST FROM GLOBAL AIR POLLUTION?

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ABSTRACT

This paper attempts to contribute to the fund of knowledge in addressing the problem of climate change. This paper utilized the weather prediction model by Edward Lorenz. This study made use of descriptive research design utilizing secondary data obtained from World Bank (2016). The data consisted of the annual exposure to air pollutants for every country and its contribution to greenhouse gas emission specifically CO_2 emission from 1995 – 2015. Ten (10) countries were randomly chosen to represent each of the continents of Asia, South America, North America, Europe and Africa. Carbon dioxide emission with 647,332 Kiloton is largely observed among the developed and highly developed countries which are highly-industrialized. Consistent with Lorenz weather and climate model, carbon emissions eventually settle in the Lorenz attractor consisting of two (2) wings. The Lorenz attractors are shown to be located in the Asian and African countries with low carbon emissions and have high mean annual exposure to air pollutants, i.e. from a region of high concentration to a region of low concentration. Consequently, the less developed nations suffer most from the effect of anthropogenic activities which emit carbon dioxide wastes into the earth's atmosphere. Establishment of carbon sinks, i.e. declaring a forest protected areas in the territorial domains of the identified highly industrialized countries is an urgent mitigating measure to halt or abate the impact of climate change globally.

Keywords: *air pollution, carbon dioxide, weather forecast model, global warming, climate change*

1.0 Introduction

Global warming is identified as a major factor to climate change (Gore, 2007).). Global warming or the rise in sea-surface temperature affects long-term weather patterns and, in turn, it is largely caused by the accumulation of greenhouse gases (particular CO_2) in the atmosphere. In recent years, more frequent and more intense typhoons and hurricanes are experienced worldwide with the Philippines getting its share surges (Typhoon Haiyan, 2012) leaving untold damages to lives and properties particularly in the coastal communities of the country. Countries, like the Philippines, with long coastal stretches are especially vulnerable to these severe weather disturbances. As recently as September of 2017, the coastal communities of Florida, USA, were not spared of the fury of two (2) category 4 storms, Harvey and Irma (CNN Storm updates, September 10, 2017).

Air pollutants, like carbon dioxide, are industrial wastes which are produced in millions of metric tons in highly-developed and developing economies. Even as these countries emit huge amounts of CO_2 every day, these air pollutants circulate around the world, thus, affecting other countries whose citizens are most exposed to air pollution realizing that global warming is a global issue that needs to be addressed by all citizens of this planet. Climate change conventions had been organized starting with the most prominent Kyoto Protocol (1997), the Rio de Janero Convention (2001) and the most recent Paris Climate Change Convention (2015). Ironically, the United States of America did not sign the most recent Paris argument and the Philippines likewise expressed reservations over this climate change agreement.

Climate change agreements essentially boil down to the issue of a trade-off between economic development and environmental conservation; between short-term benefits and long-term planetary consequences. World leaders remain doubtful about the real magnitude of their CO_2 emissions to the rest of the world. More evidence-based research needs to be undertaken to respond to this issue, establishing a firmer connection between air pollution and its effect to the rest of the world. This paper attempts to contribute to the fund of knowledge in this area.

2.0 Conceptual Framework

The study was anchored on the weather prediction model. The basis for most weather prediction models is the Lorenz equation (Journal of Atmospheric Science, 1963) in a paper entitled “Deterministic Non-periodic Flows”. The Lorenz equation is defined by three coupled differential equations:

$$\frac{dx}{dt} = \sigma(y - x$$

$$\frac{dy}{dt} = x\,(\rho - z) - y$$

$$\frac{dz}{dt} = xy - \beta z$$

Where σ, ρ, β, > 0. The variable $\times$ is proportional to the convective motion, γ is proportional to the temperature difference between the ascending and descending currents where similar signs of $\times$ and γ denote that warm air is rising and cold air is descending. The variable z is proportional to the distortion of the vertical temperature profile from linearity, a positive value indicating that the strongest gradients occur near the boundaries (Lorenz, 1963). From a technical standpoint, the Lorenz system is non-linear, non-periodic, three-dimensioned and deterministic.

If $\rho < 1$, then there is only one equilibrium point, the origin (0,0,0). This point corresponds to no convection. All orbits converge to the origin, which is a global attractor (Pchelintsev, 2014). A pitchfork bifurcation occurs at $\rho = 1$; when ρ>1 two additional critical; points appear. This corresponds to steady convection and is stable when $\rho < \frac{\sigma+\beta+3}{\sigma+\beta+1}$. At the critical value, both equilibrium points lose stability through a hoof bifurcation (Poland, 1993). Lorenz himself used the values $\sigma = 10$, $\beta = {}^{8}\!/_{3}$, and $\rho = 28$ where the system exhibits chaotic behavior for these and nearby values. Almost all initial points tend to an invariant set-the Lorenz attractor- a strange attractor and a fractal.

For small values of ρ, the system is stable and evolves to one of two fixed point attractors. When $\rho > 24.74$, the fixed points become repulsive and the trajectory is repelled by them in a very complex way.

Carbon dioxide air pollution contents obey the Lorenz model. In recent years, the system has come to a point where $\rho \geq 24.74$ so that we would expect that they would exhibit long-term weather changes or a manifestation of climate change. Starting from any point in the past 100 years, we expect that CO_2 emissions would spread in a manner consistent with a chaotic system of the of bifurcation type where all predictions would tend to the invariant Lorenz attractor – a strange attractor and a fractal.

Figure 1. Lorenz Attraction with $\rho = 28, \sigma = 10, \beta = {}^{8}/_{3}$

3.0 Methods and Design

This study made use of descriptive research design utilizing secondary data obtained from Brauer, M. et al. (2016) and Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States (2016). The data consist of the annual exposure to air pollutants for every country and its contribution to greenhouse gas emission specifically CO_2 emission from 1995 – 2015. Ten (10) countries were randomly chosen to represent each of the continents of Asia, South America, North America, Europe and Africa.

ASIA	AFRICA	NORTH AMERICA	SOUTH AMERICA	EUROPIAN UNION
Singapore	Algeria	USA	Brazil	Czech Republic
China	Egypt	Bahamas	Argentina	Norway
Philippines	Ethiopia	Puerto Rico	Venezuela	Belgium
Thailand	Kenya	Cuba	Mexico	Iceland
Malaysia	Libya	Panama	Peru	Ireland
Japan	Madagascar	Dominican Rep	Colombia	Denmark
Indonesia	Morocco	Jamaica	Chile	European union
India	Nigeria	Honduras	Ecuador	Luxembourg
Israel	South Africa	Aruba	Bolivia	Spain
Cambodia	Zimbabwe	Nicaragua	Paraguay	Greece

The minimum and maximum values were obtained to represent the worst carbon dioxide emitters (maximum) and the least emitters (minimum). Likewise, the maximum annual exposure to air pollutants was used as an indicator of the most exposed countries, while the minimum annual exposure to air pollutants was utilized to indicate the least exposed countries. To determine if the countries in various countries significantly differed in both measures, a one-way analysis of variance (ANOVA) was used. The ranking of the means was then used to assess where the most variations lie. Finally, to determine the relationship between carbon dioxide emission and exposure to air pollutants, a correlation analysis was performed.

4.0 Result and Discussion

Table1 shows the Analysis of Variance of Five continents of their annual exposure to air pollution.

Table 1. Analysis of Five Continents on their Annual Exposure to Air Pollution

One-way Analysis of Variance					
Source	DF	SS	MS	F	P
Factor	4	8488	2122	15.88	0.000
Error	45	6013	134		
Total	49	14501			

The results show that the annual exposure to air pollutants varied significantly across the fifty (50) countries belonging to different continents. An f-value of 15.88 exceeded the required value for significance beyond the .01 probability level. Noteworthy is the fact that countries belonging to the Asian and African continents received the most exposure annually to air pollutants while the more developed European and American countries received the least.

Table 2 shows the analysis of variance performed on the CO2 emissions of countries belonging to the five continents.

Table 2: One-way ANOVA: CO2 emission (Kt) of Asia, Europe, South America, North America, Africa

One-way Analysis of Variance					
Source	DF	SS	MS	F	P
Factor	4	2.777E+12	6.943E+11	1.10	0.369
Error	45	2.845E+13	6.321E+11		
Total	49	3.122E+13			

Tabular values demonstrate that the countries belonging to the five continents considered to essentially have the same levels of carbon dioxide emission. The computed f-valued failed to reach the required value for significance even at the .05 probability level. This simply means that all the countries share in the responsibility of maintaining a sustainable amount of carbon emission to the atmosphere. Nonetheless, it is worth noting that the Asian and African countries had slightly lower CO2 emission than did the European and American countries, reflecting a less rapid industrialization in the former two continents than in the latter two.

Table 3 shows the mean of annual pollution and its CO_2 emission in five continents of the world.

Table 3. Mean Annual Exposure to Air Pollution and CO2 Emission

Continents	Air pollution, Mean Annual exposure (micrograms per cubic meter)	Carbon Dioxide Emission (Kt) Mean
Asia	22.550105632	105632
Europe	12.952425627	425672
South America	18.48098439	98439
North America	18.860647332	647332
Africa	49.87035651	35651

Correlation Coefficient = -0.55, p = 0.22

Figure 2 shows a definite downward trend illustrating the fact that countries with higher CO2 emissions also had lower exposure to air pollution. This can be explained by the fact that in those countries which are highly industrialized, people are shielded from the impact of air pollution by their advanced technology whereas the least industrialized countries had no such technologies to speak of. Citizens of underdeveloped or developing nations have jobs that naturally expose them to natural elements, whereas those coming from developed and highly developed economies stay in air-conditioned and well-shielded offices.

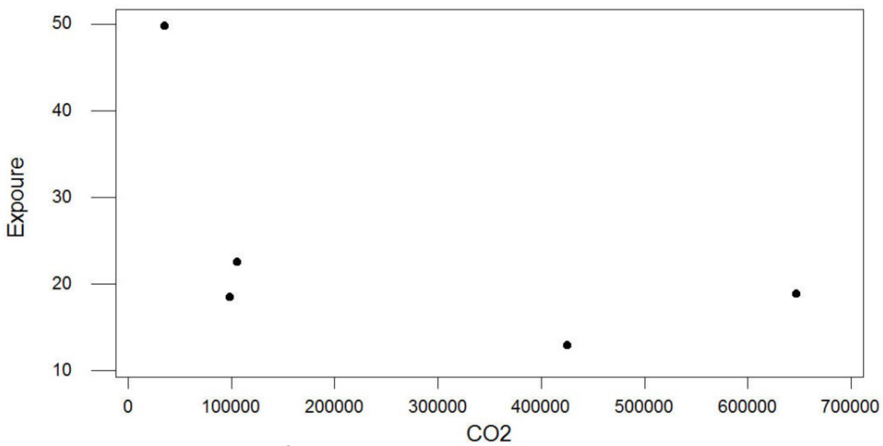

Figure 2: Scatterplot of the CO2 Emission and Annual Exposure to Pollutants

In sum, developed and highly developed economies produce more of carbon dioxide due to their industrial-based economies. However, because of the operation of Lorenz equations about the weather and air convection, such carbon dioxide emission tends to concentrate on the so-called Lorenz attractor. Unfortunately, the Lorenz attractor appears to be located precisely in those countries where carbon dioxide emissions are lower (Asian and African countries). Consequently, the less developed nations suffer most from the carbon emission of the more developed nations.

Asian and African countries have the larger annual mean exposure to air pollutants which could explain the higher number of reported morbidity and mortality rates due to respiratory illnesses in these parts of the globe. Of course, the Lorenz model itself may also explain the extreme weather conditions experienced more frequently and more intensely in these countries.

Of the various strategies adopted for mitigating the impact of climate change, the establishment of more "carbon sinks" to dissipate the accumulation of greenhouse gases in the Lorenz attractors appears to be the most effective and "do-able". This means that countries which produce most of the CO2 emissions should allocate portions of their territorial domains to absorb their carbon emissions. The current international agreement on carbon-trading has the effect of placing the burden to the less-developed and less-industrialized countries.

5.0 Conclusion

Carbon dioxide emission is largely observed among the developed and highly developed countries which are highly-industrialized. Consistent with Lorenz weather and climate model, carbon emissions eventually settle in the Lorenz attractor consisting of two (2) wings. The Lorenz attractors are shown to be located in the Asian and African countries with low carbon emissions and have high mean annual exposure to air pollutants, i.e. from a region of high concentration to a region of low concentration. Consequently, the less developed nations suffer most from the effect of anthropogenic activities which emit carbon dioxide wastes into the earth's atmosphere. Establishment of carbon sinks, i.e. declaring a forest protected areas, in the territorial domains of the identified highly industrialized countries is an urgent mitigating measure to halt or abate the impact of climate change globally.

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