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REVISTA DE CIENCIAS SOCIALES Y HUMANÍSTICAS

RELATIONSHIP OF THE ENVIRONMENTAL INDEX AND THE OCCURRENCE OF DEATHS FROM CHRONIC RESPIRATORY DISEASE, CARDIOVASCULAR DISEASE AND DIABETES IN ADULTS OVER 65 YEARS OF AGE IN PANAMA CITY, 2003-2014

RELACIÓN DEL ÍNDICE AMBIENTAL Y LA OCURRENCIA DE MUERTES POR ENFERMEDAD RESPIRATORIA CRÓNICA, ENFERMEDAD CARDIOVASCULAR Y DIABETES EN ADULTOS MAYORES DE 65 AÑOS EN LA CIUDAD DE PANAMÁ, 2003-2014

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Abstract

There is scarce research regarding non-communicable diseases (NCDs) and the environment in Panama. Assessing the relationship between climate and pollution variables and deaths from selected NCDs (chronic respiratory disease, cardiovascular disease and diabetes) in adults age 65 years or more living in Panama City between 2003 and 2014. From different sources we collected monthly series of: 1) death by selected NCDs (Instituto Nacional de Estadística y Censo), 2) air pollutants PM_{10} and NO_2, (from the SIA -UP-) and sea temperatures change (from NOAA), and 3) climate variables (from Empresa de Transmisión Eléctrica S.A). An Environmental Index (EI) was constructed using the principal component factor analysis technique, derived from previous cointegration and stable seasonality analyses of all study variables using seasonal decomposition using the Additive Method of X-12 ARIMA. A

Societas
REVISTA DE CIENCIAS SOCIALES Y HUMANÍSTICAS
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relationship between mortality from the diseases studied and variations in environmental condition by cointegration tests and the stable seasonality for the EI was found ($p<0.01$), demonstrating joint pro-seasonality with the NCDs. The factorial loads comprising EI were maximum temperature: 0.23215; relative humidity: -0.52616; rainfall: -0.19430, wind speed: 0.21889; and PM_{10}: 0.10570. During June and July occurred the highest mortality for chronic respiratory disease and cardiovascular disease, respectively. Diabetes highest mortality happened in September and October. We report a procyclical evolution according to El Niño and La Niña severity with EI. EI and its monthly relationship to deaths caused by selected ENTs might be an early warning tool that allows mitigation or adaptation measures for the population aged 65 and over. Although the relationship between environmental variations due to climate and pollution has been demonstrated in a statistical way, with mortality in the study variables, it is important deepening the underlying interactions between climate and pollution.

Keywords: chronic respiratory disease, cardiovascular disease, diabetes, seasonality, climate change, adults, air pollutants.

Resumen

Existe escasa investigación sobre las enfermedades no transmisibles (ENT) y el medio ambiente en Panamá. Evaluar la relación entre las variables climáticas y de contaminación y las muertes por ENT seleccionadas (enfermedad respiratoria crónica, enfermedad cardiovascular y diabetes) en adultos de 65 años o más residentes en la Ciudad de Panamá entre 2003 y 2014. De diferentes fuentes recolectamos series mensuales de: 1) muerte por ENT seleccionadas (Instituto Nacional de Estadística y Censo), 2) contaminantes atmosféricos PM10 y NO2, (del SIA -UP-) y cambio de temperatura del mar (de NOAA), y 3) variables climáticas (de Empresa de Transmisión Eléctrica SA). Se construyó un Índice Ambiental (EI) utilizando la técnica de análisis factorial de componentes principales, derivado de análisis previos de cointegración y estacionalidad estable de todas las variables de estudio mediante descomposición estacional utilizando el Método Aditivo de X-12 ARIMA. Se encontró relación entre la mortalidad por las enfermedades estudiadas y las variaciones en la condición ambiental por pruebas de cointegración y la estacionalidad estable para las IE ($p<0,01$), demostrando proestacionalidad conjunta con las ENT. Las cargas factoriales que componen EI fueron temperatura máxima: 0,23215; humedad relativa: -0,52616; lluvia: -0.19430, velocidad del viento: 0.21889; y PM10: 0,10570. Durante junio y julio se presentó la mayor mortalidad por enfermedad respiratoria crónica y enfermedad cardiovascular, respectivamente. La mayor mortalidad por diabetes ocurrió en septiembre y octubre. Reportamos una evolución procíclica de acuerdo a la severidad de El Niño y La Niña con EI. La IE y su relación mensual con las muertes causadas por ENT seleccionadas podría ser una herramienta de alerta temprana que permita medidas de mitigación o adaptación para la población de 65 años y más. Si bien la relación entre las variaciones ambientales por el clima y la contaminación ha sido demostrada de manera estadística, con la mortalidad

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en las variables de estudio, es importante profundizar en las interacciones subyacentes entre el clima y la contaminación.

Palabras clave: Enfermedad Respiratoria Crónica, Enfermedad Cardiovascular, Diabetes, Estacionalidad, Cambio Climático, Adultos, Contaminantes del Aire.

Introduction

Climate change impacts economics and the health sector, as evidence disputed by scientific evidence, especially on Non-communicable Diseases (NCDs) (Watts et al. 2015). While traditional epidemiological analysis has focused on risk factors (lifestyles, diet and exercise), in recent years its relationship to climatic and environmental factors (temperature, humidity, pollution, etc.) has begun to be investigated. One of the most studied relationships between health and pollution was assessed with respiratory diseases, diabetes and cardiovascular diseases, among others(Avilez et al. 2016; Schraufnagel et al. 2019). High-fat and low-calorie diets are related to poverty and even cultural patterns in some cases or equally with increased demographic pressure on food production, which seeks to lower costs and increase yields with less safe farming and farming of consumer animals. Demographic pressure, urbanization and transport models incite sedentarism along with other risk factors. However, the relationship between NCDs and climate is a topic that is has recently been explored from a historical point of view. The investigation of this relationship requires the most precise or focused scientific evidence possible, as in the case of Panama. In this sense, a pioneering study was carried out in Panama aimed at measuring the association between air pollution in Panama City and increased mortality from chronic respiratory disease, cardiovascular disease and diabetes. This study is the first evaluation done in Panama on the association between air pollution and mortality. The objective was to assess the possible association between monthly levels of PM_{10}, O_3, and NO_2 and cardiovascular, seasonally, and diabetes mortality, as well as the variation of death in Panama City, Panama (Zúñiga et al. 2016).

High temperatures and pollution have been shown to have a pernicious effect on health, and above all as risk factors that complicate NCDs in both developed or developing countries, a product of accelerated global warming by Greenhouse Gases (GHG) (Avilez et al. 2016; Schraufnagel et al. 2019). These interactions deepen health inequities in NCDs care among developing countries particularly among the most vulnerable groups that in turn increase the burden of these conditions, measured using the loss of years of life by premature death (YLL's) and disability (DALYs). These interactions are a research area that requires much more attention (Schraufnagel et al. 2019)

There is scientific evidence linking the interaction of high temperatures and air pollution, complicating patients with cardiovascular or respiratory problems. Furthermore, there is evidence that global warming, in addition to arid climates, might lead to increased air pollution (Reisen and K. Brown 2006; Schraufnagel et al. 2019)). In this order, agricultural production in developing countries is linked

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to high deforestation processes, based on the logging and burning of primary forests, contributing to global warming and pollutant emissions (Friel et al. 2011)

Among the air pollutants, we can mention the particulate matter (PM), where its size is an essential determinant in terms of the site and efficiency of their lung deposition. Also, its size indicates their composition: $PM_{2.5\text{-}10}$ (coarse particles with aerodynamic diameters between 2.5 to 10 µm) consist mainly of mechanically generated particles from agriculture, mining, construction, road traffic and related sources, as well as biologically deed particles. $PM_{2.5}$ (fine particles with aerodynamic diameter 2.5 µm) come mainly from the combustion of fossil fuel from vehicle engines, fuel oil, wood, but also contains particles product of the spraying of the dust of roads and soil (Kozlowski 2017)

Numerous studies have linked $PM_{2.5}$ to harmful health effects. Most studies focused on the total mass of the particles, although their chemical composition varies substantially .(Cross et al. 2017). The chemical composition of the PM varies from city to city, and it depends on many factors such as geography, the season, weather conditions and the source of combustion (Dai and Hao 2016) According to the World Health Organization (WHO), PM was responsible for 3 million premature deaths globally in 2016 (Dai and Hao 2016). Several studies have estimated the effects of PM on human health, as well as its impact associated with its chemical composition (Dai and Hao 2016; Stillman et al. 2017). Bell et al. indicate an association between $PM_{2.5}$ and increased hospitalizations among both patients with both cardiovascular and respiratory diseases (Bold et al. 2016) Pope et al. also demonstrate associations between environmental contamination of fine particles and high risks of mortality from lung cancer and cardiopulmonary disease (Awan 2016) As indicated, the chemical composition comprising particulate matter varies, and it might include volatile organic compounds,; nitrate, sulfate, ammonia ions, and metals (such as sodium, calcium, lead, arsenic, cadmium, among others). Trace elements, emitted mainly by anthropogenic processes, are predominantly found in the fraction $PM_{2.5}$ (Higgins et al. 2017) Weather conditions play an essential role in the distribution of anion concentrations, as well as the pH of particles, depending on their aerodynamic diameter (Gallus et al. 2016).

Studies indicate a possible association between NO_2 on cardiac and respiratory mortality, particularly among subjects with specific pre-existing chronic cardiovascular conditions and diabetes (Smith et al. 2016) Similarly, urban pollution by NO_2, a motor vehicle emission, might increase the risk of heart attacks (Bizzarri et al. 2016).

Tropospheric ozone (O_3) is the main constituent of urban smog, being a secondary pollutant that forms in the atmosphere through the photochemical reaction of nitrogen oxides (NO_x) and volatile organic compounds. Tropospheric O_3 irritates mucous membranes and other tissues, such as the lungs, compromising a person's breathing ability (Hartmann-Boyce et al. 2016; Webb Hooper et al. 2017). However, in a study that took place in Inchon (South Korea), the individual contribution of tropospheric

Societas
REVISTA DE CIENCIAS SOCIALES Y HUMANÍSTICAS
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https://revistas.up.ac.pa/index.php/societas
Vol. 24, No. 1, pp. 126-146 - Enero - Junio, 2022
Fecha de recepción: 10/9/2021 / Fecha de aceptación: 05/10/2021

O_3 to mortality was not statistically significant compared to the unique contribution of $PM_{2.5,}$ NO_2, sulfur dioxide (SO_2) and carbon monoxide (CO), respectively. A combined index of pollution (including PM_{10}, NO_2, SO_2 and CO) might better explain the exposure-response dose relationship to total mortality than an individual atmospheric pollutant. Therefore, pollutants should be considered together in the risk assessment of air pollution, rather than measuring the risk of each pollutant (Rodriquez et al. 2016). On the other hand, concentrations of tropospheric O_3 are influenced by weather parameters. Their maximum concentrations occur during the afternoon, and their minimum ones during the early hours of the morning, there are high coefficients of correlation (up to 0.89). Standard weather parameters and the concentrations of both $NO_,$ and O_3 are determined with high precision using appropriate statistical tools particularly weather conditions (Vanderkam et al. 2016) In addition to this line of thoughts, other studies show a positive linear relationship between the maximum daily temperature and the maximum daily concentration of O_3 (Abdullahet al. 2017). The same study also show how other factors, such as wind speed, sun insulation, and the maximum temperature influences the concentration of tropospheric O_3 (Pacek et al. 2016)

Emissions of pollutants, especially from fossil fuels such as those used for electricity generation or in the automotive park, as well as cooking with biomass fuels in domestic cooking in developing countries, such as firewood, increase the risk of cardiovascular disease, Chronic Obstructive Pulmonary Disease (COPD) and cancer, in addition to causing climate change (Reisen and K. Brown 2006; Smith et al. 2004)). It is also worth mentioning that the pressure for the use of agricultural and livestock soil has enhanced the use of animal feed as well as the extensive use of maize as the main feed in livestock feed, poultry rearing or fish feeding, in addition to the agro-industrial sector producing ultra-processed or refined food, which affects the increase in NTM (Friel et al. 2011). This leads to the integration of environmental and productive factors that inevitably drive the impact of NCDs. In other words, the duality of climate factors concomitant with lifestyles, they fatally converge in the morbidity and mortality in NCDs and shows that there is a link between climate change and the food system and thus with NCDs.

The lower frequency of rainfall and increased temperatures negatively impacts food production, reducing greatly the quality supply and increasing their prices (Friel et al. 2011) This situation decreases the nutritional quality and increases the risk of disease, to which the food industry responds highly increasing the production of processed products that affect higher rates of NTM such as diabetes or cardiovascular disease, but that obesity resulting from an empty calorie-based diet is the main risk factor for these diseases and that health policies have focused most of their actions.

So far, the recommended measures to addressing this problem are aimed at adapting and mitigating the effects of climate change based on the Paris Agreement on Climate Change and the United Nations Framework Convention on Climate Change, for food production that uses water efficiently in the face of the cycles of El Niño and La Niña phenomena, as well as the use of human health-safe agrochemicals, in addition to the control of transgenic food production, among others recommendations,

Societas
REVISTA DE CIENCIAS SOCIALES Y HUMANÍSTICAS
ISSN:1560-0408 / ISSN L: 2710-7639
https://revistas.up.ac.pa/index.php/societas
Vol. 24, No. 1, pp. 126-146 - Enero - Junio, 2022
Fecha de recepción: 10/9/2021 / Fecha de aceptación: 05/10/2021

such as changing urbanization schemes and being consoled with the need for physical activity and a cleaner transport system, reducing greenhouse gas emissions and increasing the creation of green spaces(Nations 1993; Nations 2014).

Therefore, the fight against NIT is not only about changing lifestyles per se, but on the basis of a much more comprehensive view, under the understanding that the climate factor has a direct impact, not only because of pollution derived from the conditions of urbanity, sedentary is and inadequate food, but in the background is the main trigger of this multifactorial problem, which begins with the impact of climate change on food production and polluting emissions in water, soil and air(Kjellstrom et al. 2010; Wollenberg 2012) Most paradoxical is the fact that a lot of food is wasted globally by poor transport systems, storage or poor cold chains, compared to malnourished and obese populations. This helps to deepen not only the inequity in food access, but also in relation to the incidence of NCDs in poor populations.

The objective of this analysis is to determine the relationship between seasonal and cyclical changes in the environment and the occurrence of NCDs deaths in Panama City, by building an environmental index (EI), relative to the population aged 65 and over, one of the most vulnerable to these factors. These factors express the problems of the epidemiological and demographic transitions on the high health care costs of these diseases, especially as a population that is outside the range of activity ((Lye and Kamal 1977)

Methods

Source of primary data and study variables

Climate and pollution variables

The series of maximum temperature (ºC), wind speed (m/s), relative humidity (%), precipitation (mm) and thermal sensation (ºC), were supplied by the Hydrometeorology Directorate of the Electric Transmission Company, S.A. (ETESA). Weather stations allow to measure these variables through sensors (temperature and humidity, wind, rain gauge) that make up the weather station; in addition to other variables such as thermal sensation, maximum and minimum temperature.

The occurrence of El Niño and La Niña phenomena was reported by the National Centers for Environmental Information (NOAA). They were measured in the Tropical Pacific (divided into 4 regions) regularly monitored through fixed buoys and satellite measurements directed to diagnose and forecast the evolution of El Niño (warm state) or La Niña (cold state). The El Niño Index (ONI) was calculated as the average of 3 consecutive months of sea surface temperature (SST) anomalies measured by the ERSST.v3 sensor in El Niño Region 3.4 (5ºN to 5ºS and 120ºW to 170ºW) (Meier and Hatsukami

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Vol. 24, No. 1, pp. 126-146 - Enero - Junio, 2022
Fecha de recepción: 10/9/2021 / Fecha de aceptación: 05/10/2021

2016). Warm episodes were defined as el Niño when anomalies exceed the threshold of 0.5ºC above the mean SST during at least five consecutive months. If the abnormality was 0.5ºC below the mean SST during the same amount of time, a La Niña episode defined, instead.

Concerning pollutants data, the monthly time series for the study period were collected for each pollutant emissions, such as NO_2 and PM_{10} concentrations in Panama City. Data on $PM_{2.5}$ could not be collected because such measurements were not included during the whole study period. PM_{10} data corresponds to 24-hour averages, using the gravimetric method, and does not include continuous data. The information provided for NO_2 includes monthly averages using the passive diffusion method.

Mortality data

Data from the series of deaths of people who died at 65 years or older, were provided by the National Institute of Statistics and Census (INEC). They died in Panama City during the study period. The main causes of death of them were coded according to the tenth edition of the classification of selected diseases (CIE-10) were: diabetes (E10-E14), cardiovascular disease (I00-I99) and respiratory disease (J00-J99).

Statistical analysis

In the first phase, stable seasonality tests (Census X-12 ARIMA F test) were conducted for each of the variables under study. Utilizing the technique of decomposition of time series with the additive method, which for the case of climatic variables is more appropriate, resulting in a positive and negative scale depending on each month of the year, in which the negative values involve months of rain and the positive, months of the dry season(Ortiz Bultó PL 2004). These tests were done with a statistical significance level of $p < 0.01$.

The literature shows a long-term relationship between maximum temperature, PM_{10}, and pollution with the occurrence of deaths with diseases assess in this study in older adults during heat waves (Kjellstrom et al. 2010; Lye and Kamal 1977; Schraufnagel et al. 2019). The occurrence of cyclic or seasonal co-movements between these variables was also reported (Lee and Lee 2015). To do a similar assessment, cointegration Engle-Granger tests were performed for demonstrating whether these variables can have a long-term linear combination. The first test was performed between the maximum temperature and the $PM_{10.}$ Similarly, cross-testing was also made between deaths from chronic respiratory disease with maximum temperature and PM_{10}, respectively. The same test was assessed between cardiovascular disease with the maximum temperature and PM_{10}, as well as diabetes with the maximum temperature and PM_{10}. These tests were done with a significance level of $p<0.05$.

ISSN:1560-0408 / ISSN L: 2710-7639
https://revistas.up.ac.pa/index.php/societas
Vol. 24, No. 1, pp. 126-146 - Enero - Junio, 2022
REVISTA DE CIENCIAS SOCIALES Y HUMANÍSTICAS
Fecha de recepción: 10/9/2021 / Fecha de aceptación: 05/10/2021

In the third phase of analysis, the EI was constructed with climate and pollution variables, using the principal component factor analysis technique with a selection of a factor of three factors requested and with orthogonal varimax rotation. The Keyser-Meyer-Olkin (KMO) test was included to demonstrate the independence between these factors, the lower limit of which is 0.5. Similarly, only variables with factorial loads greater than 0.10 were selected. The first factor was selected for having the highest load saturation for the variables. Using a simple linear regression each variable in this factor was estimated for each datum in the series and finally the monthly average of that factor or variable was called the Environmental Index (EI). The EI also underwent the analysis of decomposition of time series as well as stable seasonality. Finally, EI was visualized crossed with seasonal indexes with the studied diseased, as well as the representation of its cyclical component with El Niño and La Niña events.
Statistical analyses were performed with Stata 14.0 and SPSS 20.0 software.

Results

The seasonality analysis was statistically significant for almost all variables except variable NO_2 (1.6945, 0.0812) at a $p<0.01$ level (Table 1). Therefore, this variable was excluded from the remaining analyses and the construction of the EI.

Table 1. Stable seasonality tests. Additive model.

Variables	F statitstic	p value
PM_{10}	3.0487	0.0012
$N0_2$	1.6945	0.0812
Maximum temperature	20.3707	0.0000
Relative Humidity	53.7202	0.0000
Rainfall	26.1583	0.0000
Wind speed	25.1969	0.0000
Chronic respiratory disease	3.5651	0.0002
Cardiovascular disease	2.4685	0.0077
Diabetes	2.4804	0.0074
Enviromental index	26.0579	0.0000

H_0: There is no evidence of stable seasonality.

Societas
REVISTA DE CIENCIAS SOCIALES Y HUMANÍSTICAS
ISSN:1560-0408 / ISSN L: 2710-7639
https://revistas.up.ac.pa/index.php/societas
Vol. 24, No. 1, pp. 126-146 - Enero - Junio, 2022
Fecha de recepción: 10/9/2021 / Fecha de aceptación: 05/10/2021

The results of the cointegration test of variables comprising EI by mortality were statistically significant (Table 2 shows the values and statistics). The cointegration tests show evidence pointing towards a long-term relationship regarding pro-seasonality and pro-cyclicity of PM_{10} and the maximum temperature.

Table 2. Engle-Granjer cointegration tests

Cross-tabulations	Variables	τ-statistic	p value	z-statistic	p value
PM_{10}/Maximum temperature	PM_{10}	-6.232781	0.0000	-60.32484	0.0000
	Maximum temperature	-5.628743	0.0000	-49.19157	0.0000
Chronic respiratory disease	Deaths among persons older than 65 years	-7.950074	0.0000	-88.98714	0.0000
	PM_{10}	-6.409044	0.0000	-64.13857	0.0000
	Deaths among persons older than 65 years	-8.722373	0.0000	-98.44052	0.0000
	Maximum temperature	-6.574012	0.0000	-62.55794	0.0000
Enfermedad cardiovascular	Deaths among persons older than 65 years	-8.674987	0.0000	-99.9859	0.0000
	PM_{10}	-6.827046	0.0000	-70.59596	0.0000
	Deaths among persons older than 65 years	-8.269844	0.0000	-92.89048	0.0000
	Maximum temperature	-5.853756	0.0000	-52.66759	0.0000
Diabetes	Deaths among persons older than 65 years	-8.204973	0.0000	-92.88711	0.0000
	PM_{10}	-6.16033	0.0000	-60.05152	0.0000
	Deaths among persons older than 65 years	-8.736284	0.0000	-100.5764	0.0000
	Maximum temperature	-6.081675	0.0000	-56.72825	0.0000

ISSN:1560-0408 / ISSN L: 2710-7639

https://revistas.up.ac.pa/index.php/societas

Vol. 24, No. 1, pp. 126-146 - Enero - Junio, 2022

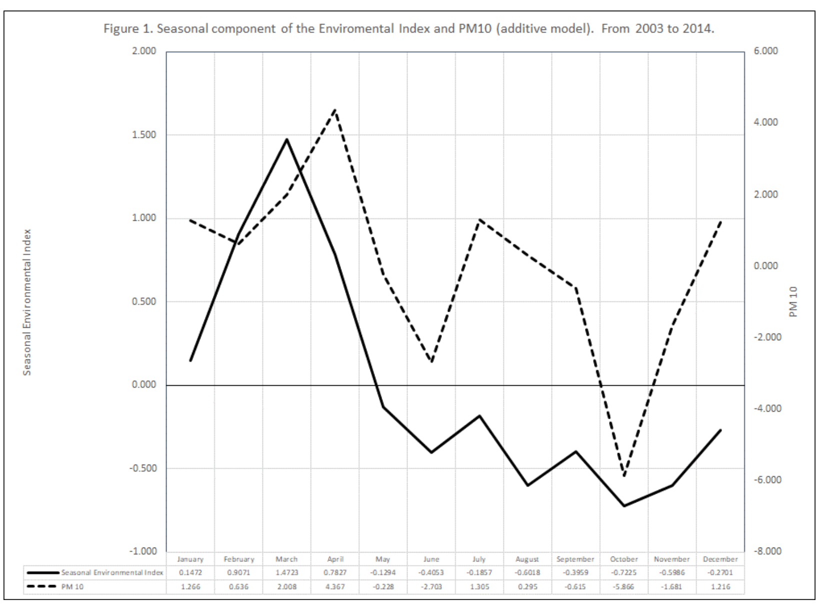
Fecha de recepción: 10/9/2021 / Fecha de aceptación: 05/10/2021

REVISTA DE CIENCIAS SOCIALES Y HUMANÍSTICAS

Regarding the construction of EI, it resulted in a statistically significant KMO coefficient with a value of 0.7459. The loads in the first factor were for the maximum temperature (0.23215), relative humidity (-0.52616), precipitation (-0.19430), wind speed (0.21889) and PM_{10} (0.10570). NO_2 was excluded because it had a load coefficient less than 0.10. The variables with the higher weights are climatic, especially for relative humidity and maximum temperature. But the coefficients of relative humidity and together with the added precipitation were the highest, representing a significant load in the index (-0.72046). The latter variables might indicate a possible higher weight of the rainy season regarding this study. Pollution less influential variable than those mentioned above might be more dependent on the combination of maximum temperature with precipitation, relative humidity or wind speed. The last row in Table 1 shows the statistically significant stable seasonality test of the ***F*** statistic (26.0579, p value < 0.01). Indicating the robustness of this indicator and its predictive power.

Graphical representations can help clarify some questions regarding hypothesis testing and index estimation. Figure 1 shows the cross tabulation of the seasonal components of EI and PM_{10} showing a relative pro-seasonality over the months of the year, marked by co-movements between January and June and July to December, but with a certain lag of PM_{10} in the face of monthly variations in the environmental index. What this representation does make clear is that in the months of dry season and temperature, between January and April, PM_{10} evolves upwards and as the rainy months advance in the second half of the year, PM_{10} pollution declines.

Figure 1. Seasonal component of the Environmental Index and PM10 (additive model). From 2003 to 2014.



ISSN:1560-0408 / ISSN L: 2710-7639
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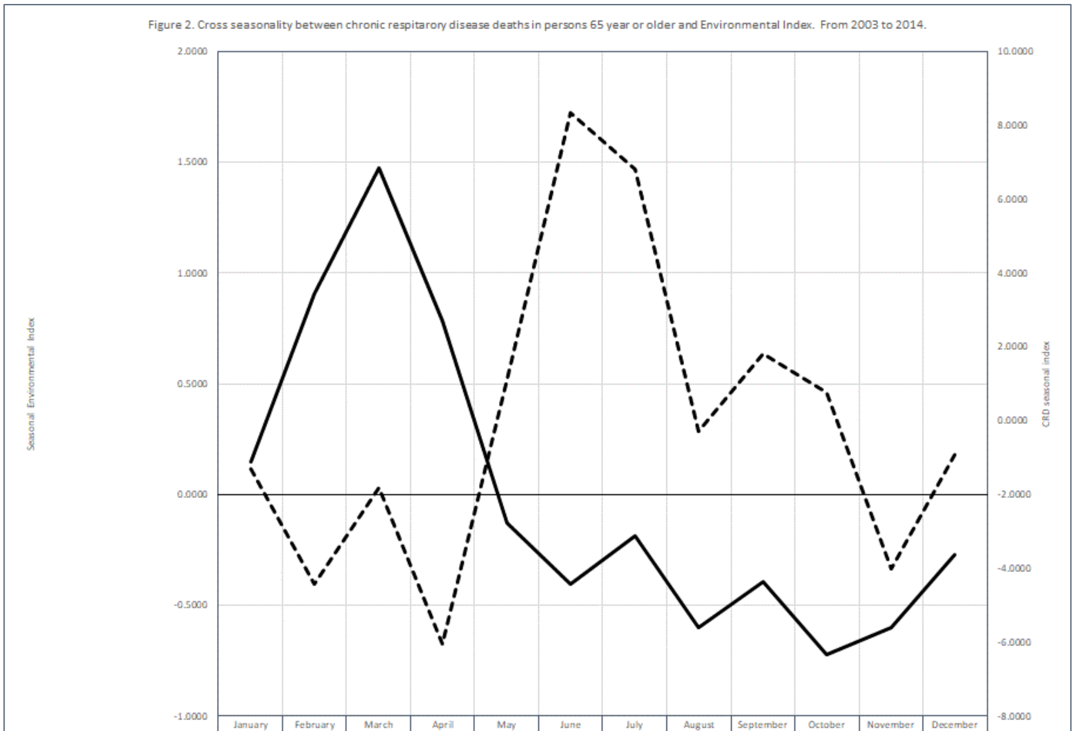
Vol. 24, No. 1, pp. 126-146 - Enero - Junio, 2022
Fecha de recepción: 10/9/2021 / Fecha de aceptación: 05/10/2021
Societas
REVISTA DE CIENCIAS SOCIALES Y HUMANÍSTICAS

Figure 2 shows the representation of the seasonal EI and deaths from respiratory diseases. Between January and May, the seasonal rate of deaths from respiratory diseases is below zero, while the value of the seasonal environmental index is above and then between May and November this ratio becomes contrary, having its highest peak in June. These interactions represent counter-seasonal movements: fewer deaths occurring during the dry season, compared to the months of more precipitation and humidity where more deaths happen.

Figure 2. Cross seasonality between chronic respiratory disease deaths in persons 65 year or older and Environmental Index. From 2003 to 2014.



	January	February	March	April	May	June	July	August	September	October	November	December
Seasonal Environmental Index	0.1472	0.9071	1.4723	0.7827	-0.1294	-0.4053	-0.1857	-0.6018	-0.3959	-0.7225	-0.5986	-0.2701
CRD seasonal index	-1.3019	-4.4231	-1.8019	-6.0595	1.0996	8.3269	6.7979	-0.2792	1.8193	0.7663	-4.0216	-0.9231

For deaths mainly caused by cardiovascular disease (Figure 3), seasonal developments were observed. During the month of February, the lowest number of deaths were reported. Afterwards, the deaths increased to an average level of 0.5 until April. From June the deaths increase reaching its peak

ISSN:1560-0408 / ISSN L: 2710-7639

https://revistas.up.ac.pa/index.php/societas

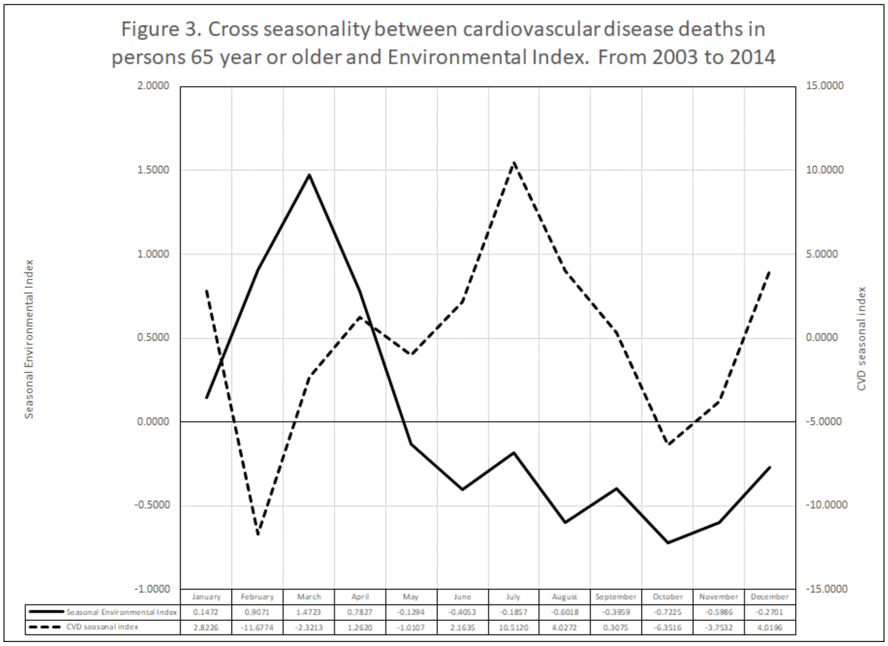
Vol. 24, No. 1, pp. 126-146 - Enero - Junio, 2022

Fecha de recepción: 10/9/2021 / Fecha de aceptación: 05/10/2021

Societas
REVISTA DE CIENCIAS SOCIALES Y HUMANÍSTICAS

level in July (above 1.5), and except for the month of October, they remain above the mean value higher than zero. These findings indicate that most deaths occur in the rainy season months.

Figure 3. Cross seasonality between cardiovascular disease deaths in persons 65 year or older and Environmental Index. From 2003 to 2014.



Regarding diabetes, as the cause of death (Figure 4), a counter-seasonal pattern was found. This finding was like those observed among deaths caused by respiratory disease, as well as cardiovascular disease, starting in June and maintaining until December at a level per above zero, reaching the highest levels between September and October. Similarly, the fewest deaths occur in the month of March.

Figure 4. Cross seasonality between diabetes deaths in persons 65 year or older and Environmental Index. From 2003 to 2014.

ISSN:1560-0408 / ISSN L: 2710-7639

https://revistas.up.ac.pa/index.php/societas

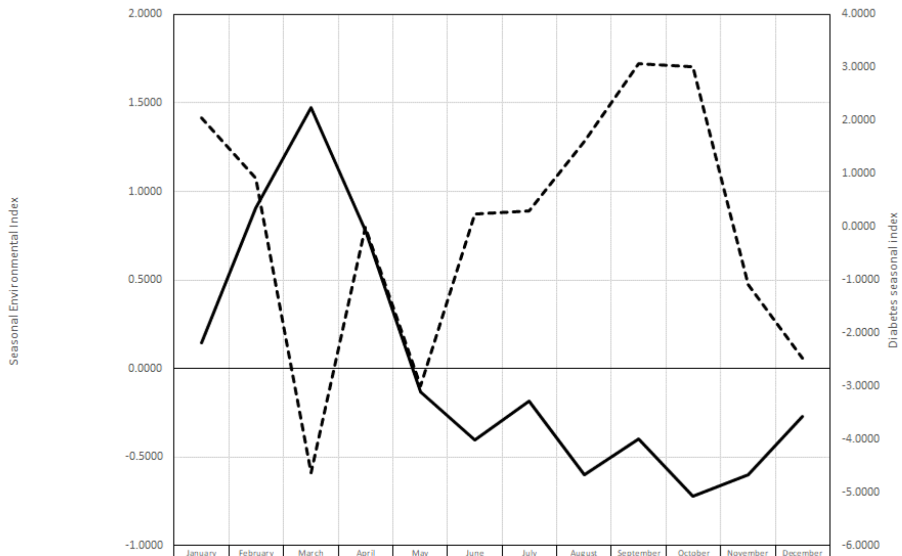
Vol. 24, No. 1, pp. 126-146 - Enero - Junio, 2022

Fecha de recepción: 10/9/2021 / Fecha de aceptación: 05/10/2021

Societas

REVISTA DE CIENCIAS SOCIALES Y HUMANÍSTICAS

Figure 4. Cross seasonality between diabetes deaths in persons 65 year or older and Environmental Index. From 2003 to 2014



	January	February	March	April	May	June	July	August	September	October	November	December
Seasonal Environmental Index	0.1472	0.9071	1.4723	0.7827	-0.1294	-0.4053	-0.1857	-0.6018	-0.3959	-0.7225	-0.5986	-0.2701
Diabetes seasonal index	2.0596	0.9081	-4.6222	-0.0162	-2.9859	0.2414	0.2945	1.6095	3.0672	3.0066	-1.0919	-2.4707

In general, it is observed that the months of May and June are months of transition between the smallest and highest number of deaths from the diseases studied during the year and in which precipitation and relative humidity play an important role, given their score in the index by s or relative weight in the first factor, as well as the maximum temperature.

Another element playing an important role in these relationships was the global temperature variation. These variations impact the different climatic zones of the world. Figure 5 shows a representation of the pattern of EI cycles and the cycle of global temperature variations identifying El Niño and La Niña phenomena. In some periods, there is an evolution against cyclical between the two variables, but in others, there are procyclical movements. For example, between January and April 2006, La Niña was relatively moderate in the global arena, and it was reflected by the Panamanian EI. In this case, the aggregate number of deaths for the three diseases under study was 574.

ISSN:1560-0408 / ISSN L: 2710-7639

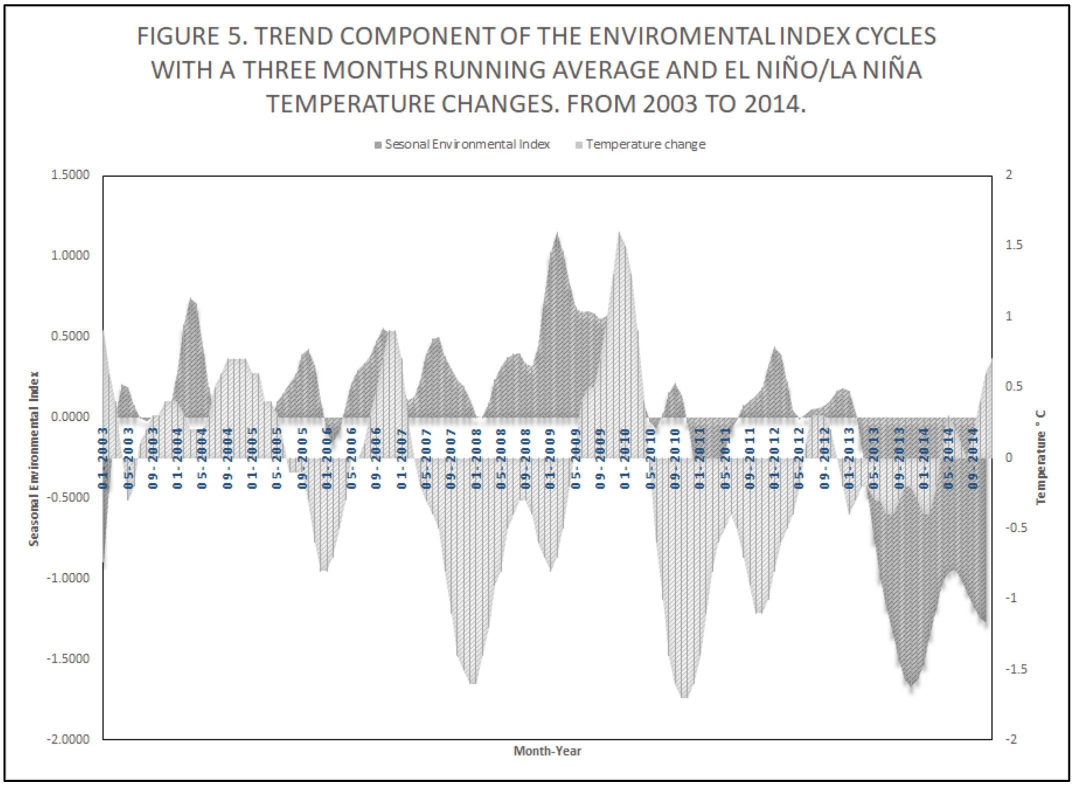
https://revistas.up.ac.pa/index.php/societas

Vol. 24, No. 1, pp. 126-146 - Enero - Junio, 2022

Fecha de recepción: 10/9/2021 / Fecha de aceptación: 05/10/2021

Societas *REVISTA DE CIENCIAS SOCIALES Y HUMANÍSTICAS*

Figure 5. Trend component of the Environmental Index cycles with three months running average and el niño/la niña temperature changes. From 2003 to 2014.



Between July 2009 and April 2010, El Niño was severe, being its effect moderate on the EI, but which, by the height of January 2009, had been severe or extreme, the number of deaths added was 1,687. Between July 2010 and 2011, La Niña was severe, while between January and April 2011 it was moderated in Panama, with a total of aggregate deaths of the three diseases studied of 2,335, while by the previous twelve months had been 2,272. Between April 2013 and 2014, La Niña was moderate, but severe or extreme in Panama, according to the EI, with a total of deaths of 2,290. These cyclical and countercyclical variations in temperatures contribute to some possible deviations from seasonal indices, which include deviations from the incidence of climate variables and pollution in the occurrence of deaths in the diseases studied.

In fact, the Dickey-Fuller unit root test for EI was statistically significant (-3,444, $p<0.05$). This test indicates a one-month lag, regarding the occurrence of a change in climate and its impact in the following month. Unsurprisingly, seasonal EI patterns and studied diseases were also certain lag.

ISSN:1560-0408 / ISSN L: 2710-7639
https://revistas.up.ac.pa/index.php/societas
Vol. 24, No. 1, pp. 126-146 - Enero - Junio, 2022
Fecha de recepción: 10/9/2021 / Fecha de aceptación: 05/10/2021

Discussion

Although the relationship between mortality from the diseases studied and variations in climate and environmental pollution are demonstrated as risk factors, it is vital to identify those foreseeable elements using time series breakdown technique and determine how stable they are. It is essential establishing in which months these events might have the most significant impact on mortality as well as understanding in the short and long term the impact that variations in temperature can have on global temperature local climatic variations (Zúñiga et al. 2016)

Our results show that seasonal correlations were observed between deaths from the diseases studied and variations in EI, in which, for example, the largest seasonal peak for cardiovascular disease happens in July, precisely a month in the middle of the rainy season. There is scientific evidence supporting the fact that low temperatures increase both morbidity and mortality from cardiovascular, cerebrovascular and respiratory disease. In the case of heat strokes, they can also increase the risk of dying among adult populations. Extreme temperature effects on death vary according to the study population (Arbuthnott et al. 2016; Song et al. 2017).

The most significant impact on EI on mortality from diseases under study mainly occurred in the months of the rainy season (the second half of the year). Physiological studies show that older adult populations are more likely to die after being exposed to extreme temperatures changes than younger peers (Blatteis 2012). Studies using time-series demonstrate that such changes impact the mortality on the diseases we studied among older adults facing both cold or heat strokes. The extreme temperature changes might be enhanced by the alternating occurrence of El Niño or La Niña phenomena (especially in Central America).

In addition to demographic changes and models of urbanization that might have a definite impact might also contribute to concentrated thermal islands and areas of dense air pollution such as happens in northern Europe, East Asia, and Australia (Arbuthnott et al. 2016; Gasparrini et al. 2017). Similarly, the build-up of greenhouse gases; the extensive agriculture and livestock enhancing food production of low nutritional quality, is another of how climate change impacts both health and impact on the burden of NCDs (particularly cardiovascular and respiratory conditions) (Amegah et al. 2016; Gasparrini et al. 2017).

On the other hand, there is an interaction between pollution and other climate variables. Rainfall and relative changes in humidity, as well as atmospheric pressure, are other elements to consider. There is scientific evidence of these interactions and their impact on diseases such as asthma and other respiratory diseases such as in Badalona (Barcelona) and the rest of Spain (Martínez-Rivera et al. 2019;

REVISTA DE CIENCIAS
SOCIALES Y HUMANÍSTICAS
ISSN:1560-0408 / ISSN L: 2710-7639
https://revistas.up.ac.pa/index.php/societas
Vol. 24, No. 1, pp. 126-146 - Enero - Junio, 2022
Fecha de recepción: 10/9/2021 / Fecha de aceptación: 05/10/2021

Vinuesa Sebastián et al. 2013). In contrast, our data suggest that such interaction (measured with EI) is mainly driven by climatic variation. Our data also suggest a relationship between EI and respiratory diseases mortality. It also follows that EI procyclicality with El Niño and La Niña phenomena have also been observed.

Environment control has become a cross-cutting axis of public health policy. It has two dimensions. One of these dimensions are associated to policies to temperature control: agricultural and livestock exploitation problems; and urbanization styles and transport systems which magnify greenhouse gas emissions. The other dimension refers to air emissions which are difficult to clear due to their interaction with the climatic conditions that changes during the year. For example, in Hefei City, China, there is an impact of these emission on respiratory disease and lung cancer mortality evidenced through time series analysis (Song et al. 2017; Zhu et al. 2019)). Our results show a consistent seasonal relationship between deaths from diseases under study, especially in chronic respiratory disease with EI.

EI, we developed, served to establish a dynamic, concerning its evolution for each specific month of the year. One might wonder what the result of the environmental control policies has been taken so far regarding air emissions generated by electricity production, and the use of fuel with no lead and decreased amount of Sulphur, among other air emission control policies in of Panama City. Although Panama City is small, its air pollution control policies might have similar implications for large cities such as by New York, given the higher density of real estate expanding (Kheirbek et al. 2016; Smith et al. 2004).

Limitations

A limitation of our results is the lack of data on other pollutants such as O_3, SO_2, among others. In addition, PM_{10} and NO_2 are short-lived pollutant, causing the EI to be biased towards climate variables. However, under the understanding that there is an interaction between pollutants and climatic variables, it is hard to separate one from each other. For this reason, we constructed an EI that attempted to approximate such relationship, especially for the population of adults over 65 years of age, one of the most vulnerable.

Similarly, EI, we constructed, has meant an approximation to the interaction of these hidden pollutants regarding climate change. The climate change might be the underlying element explaining this dynamic which turns out to be a useful tool for generating scenarios of higher and lower risk of mortality for measures that contribute to its epidemiological adaptation(Jenkins Molieri 2009)

Therefore, one key aspect of our work is that it might serve as evidence of the relationship between the occurrence of deaths and the current climate transition. However, while the limitation of not being able to assess more pollutants in addition to PM_{10} that might allow the estimation of a more robust EI remains, at least, we are one step closer assessing secular trends of these events (Jenkins Molieri 2009; Reisen and K. Brown 2006).

Despite the limitations of information in our EI estimates, it is a powerful and useful tool that allows establishing in which months of the year have the highest mortality in the population aged 65 years or older occurring with the interaction of climate variables and PM_{10}. EI can be an early health warning tool establishing mitigation measures at the most critical periods. However, it is relevant deepening further our understanding regarding the interaction between air pollutants in Panama, in the face of the monthly climate variations.

Conclusion

Adult populations 65 years of age and older were susceptible to the diseases under study. This susceptibility was modulated by environmental variables, and we assessed it using EI. There is a need to understand the interaction of these risk factors better to generate more scientific evidence in this regard. So, the EI might be a more powerful early health warning tool.

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ISSN:1560-0408 / ISSN L: 2710-7639

https://revistas.up.ac.pa/index.php/societas

Vol. 24, No. 1, pp. 126-146 - Enero - Junio, 2022

Fecha de recepción: 10/9/2021 / Fecha de aceptación: 05/10/2021

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ISSN:1560-0408 / ISSN L: 2710-7639
https://revistas.up.ac.pa/index.php/societas
Vol. 24, No. 1, pp. 126-146 - Enero - Junio, 2022
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Fecha de recepción: 10/9/2021 / Fecha de aceptación: 05/10/2021

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