Austin Journal of Allergy

Open Access

Austin Publishing Group

Research Article

Asthma Trends in Mississippi Coastal Region with Air Pollutants and Meteorological Factors

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Received: November 28, 2016; **Accepted:** January 12, 2017; **Published:** January 19, 2017

Abstract

An understanding of interplay between asthma, criteria air pollutants, and meteorological factors is essential to predicting human health and reducing the capital costs on controlling asthma prevalence. A systematic relationship between asthma and variables related to air quality and weather in a location will help mitigate or reduce impact of asthma over the people in it. The impact of industries, transportation, and weather on health is complex and needs continuous monitoring for controlling health disorders. The present study examines Poisson Regression Model of the daily data of asthma admissions, Particulate Matter ($PM_{2.5}$), Ozone (O_3), Nitrogen dioxide (NO_2), temperature, and humidity in selective locations of Mississippi coastal region of Gulf of Mexico for the period 2003 to 2011. The study region consists of three locations, namely Gulfport, Pascagoula, and Waveland because of the extent of data availability. Overall, the results indicate a negative correlation of asthma with temperature and the effect was statistically significant ($p < 0.05$) in all the regions. The correlation of other variables was not consistent uniformly, and their influence on asthma was not statistically significant except in few cases.

Keywords: Poisson Regression Model; Pearson correlation; Asthma; Criteria Pollutants; time series

Introduction

The inland regions of Gulf of Mexico are affected by industries, and transportation, in addition to extreme weather conditions caused by tropical storms. The increasing industrial activities such as oil and gas production and thermal power plants are drastically affecting the air quality and hence health over the heavily populated neighborhoods of US Gulf coast ranging from Houston to the Louisiana zone [1]. The air quality in these regions is also indirectly affected by the increasing transportation and construction associated with the rapid industrial growth over the US Gulf of Mexico. The weather patterns also play a prominent role in the dispersion of primary and secondary pollutants over the atmosphere to distant places from the sources [2,3].

A survey of literature does show a possibility of linkage of predominant cases of ill-health caused by air pollution in developing as well as developed countries [4-7]. Among other health disorders, asthma prevalence is also considered to be affected by air pollutants, and several research investigations have shown positive association between asthma and air pollution [8-13].

The present work investigates Poisson regression modeling to envisage the relationship between asthma with criteria air pollutants and meteorological parameters over three locations in the Mississippi Gulf coast, namely Gulfport, Pascagoula, and Waveland during the period 2003 to 2011. The locations are selected based on their industrial growth, proximity to the coast, and availability of data. The air pollutants considered are Particulate Matter of diameter less than 2.5 microns ($PM_{2.5}$), Ozone (O_3), and Nitrogen Oxide (NO_2); while the meteorological parameters considered are temperature, and humidity.

Materials and Methods

Consider a random variable Y_t, representing the time series count data $Y_1, Y_2, \ldots, Y_T$ and X_i representing the regression covariate variables, then Y_t Poisson distributed over X with a mean value of μ is given by,

$$Y_t \sim Poisson\ (\mu_t)$$

The log linear regression model of Poisson distribution in terms of regression coefficient (β) is given by,

$$\log(\mu_t) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots$$

In the present situation, Y_t is the daily counts of asthma admissions at time t and X_i the independent variable (for the air pollution and meteorological parameters); the parameter β_i represents regression coefficient and is a measure of association between an independent variable, X_i (for the air pollution and meteorological parameters), and the risk of the outcome Y for the asthma admission. The log linear relationship is given by,

$$\log(\mu_t) = \beta_0 + \beta_1 O_3 + \beta_2 NO_2 + \beta_3 PM_{2.5} + \beta_4 temperature + \beta_5 Humidity$$

The regression coefficient β_i also signifies forecasting proportional change in the value of Y_t for a given a unit change in X_t,

Using SPSS statistical package, the Poisson Regression model is applied to the asthma data without time lag, and analyzed the associations by considering the causes variables individually. This was done to utilize the maximum number of valid datasets.

$$\log(\mu_t) = \beta_0 + \beta_1 O_3$$

$$\log(\mu_t) = \beta_0 + \beta_1 NO_2$$

Citation: Tuluri F and Gorai AK. Asthma Trends in Mississippi Coastal Region with Air Pollutants and Meteorological Factors. Austin J Allergy. 2017; 4(1): 1026.

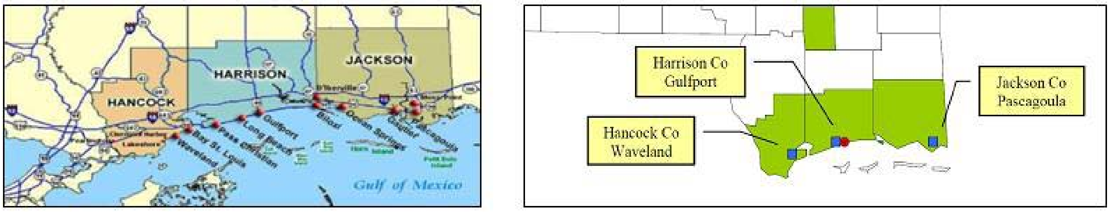

Figure 1: Mississippi Gulf Coast region, and Air Quality Monitors along Mississippi Gulf Coast.

Figure 2: Time series of asthma, $PM_{2.5}$, Ozone, NO_2, Temperature, and Humidity of data of Mississippi Gulf Coast regions during the period of 2003 to 2011.

$$\log(\mu_t)= \beta_0+ \beta_1 PM_{2.5}$$

$$\log(\mu_t)= \beta_0+ \beta_4 temperature+\beta_5\ Humidity$$

Study area

The locations considered for the study are Gulfport in Harrison county, Pascagoula in Jackson county, and Waveland in Hancock county. The three counties are adjacent to the Mississippi Gulf Coast and are strategically located in the Coast (See Figure 1 and Figure 2) [14,15]. The objective in choosing each of these locations in their respective county is because of the possibility of correlating the asthma prevalence of the local area to the corresponding air quality data, and meteorological data. The population of the Mississippi Gulf Coast appears to be growing and is projected to increase because of the demand for job employment in the casinos, aerospace and defense industries in addition to job opportunities in the oil & gas industries, power plants, and construction. Based on the US Census Bureau estimate, the population of the three cities to the corresponding county of Gulfport/Harrison, Pascagoula/Jackson, and Waveland/Hancock are respectively 69,220/194,029, 22,429/140,298, and 6541/45,255 [16]. MS Department of Health Report reports adult asthma prevalence of 7.2% for the health district of these counties [17].

Asthma data

Asthma admission data in Gulfort, Pascagoula, and Waveland for the period 2003 to 2011 is obtained upon request from Mississippi Department of Health [18]. The raw data was reconstructed into county wise and extracted for the three locations of interest for the present study.

Air pollutant data

Air quality data for Gulfport, Pascagoula, and Waveland is obtained from two sources–Air Quality Division of Mississippi

Table 1: Descriptive Statistics of the cause variables of Mississippi Gulf Coast Region.

Region: Gulfport	N	Minimum	Maximum	Mean	Std. Dev	Variance
Asthma	2953	0	9	0.95	1.112	1.235
$PM_{2.5}$ (µg/m^3)	2730	0.6	52.2	12.242	5.906	34.878
Ozone (ppb)	2102	15	98	40.097	14.07	197.99
NO_2 (µg/m^3)	2530	0.7	73	14.746	9.059	82.06
Temperature (°C)	2944	-2	33	20.798	7.187	51.67
Humidity (%)	2944	33	99	74.511	11.356	128.96
Valid N (list-wise)	1835					
Region: Ascagoula	N	Minimum	Maximum	Mean	Std. Dev	Variance
Asthma	3287	0	7	0.47	0.732	0.536
$PM_{2.5}$ (µg/m^3)	1003	2	42	10.84	5.454	29.746
Ozone (ppb)	2115	11	96	45.51	13.965	195.021
NO_2 (µg/m^3)	2477	0	34	6.15	3.514	12.348
Temperature (°C)	3128	-17.8	36.7	19.652	7.8834	62.148
Humidity (%)	3287	0	100	74.673	20.3276	413.211
Valid N (listwise)	518					
Region:Waveland	N	Minimum	Maximum	Mean	Std. Dev	Variance
Asthma	3287	0	4	0.075	0.3034	0.092
$PM_{2.5}$ (µg/m^3)	1497	0	41	5.226	6.3599	40.448
Ozone (ppb)	1406	0	74.5	29.821	10.1235	102.485
NO2 (µg/m^3)	808	0	19.8	3.644	2.4249	5.88
Temperature (°C)	1420	-17.8	32.2	19.621	7.8524	61.66
Humidity (%)	1606	0	100	77.523	15.668	245.486
Valid N (listwise)	42					

Table 2: Correlations among the data variables of Mississippi Gulf Coast Region.

Gulfport:							
		Asthma	$PM_{2.5}$	Ozone	NO_2	Temperature	Humidity
Asthma	Pearson Correlation	1	-.038*	0.041	0.024	-.072**	-.038*
	N	3287	3051	2102	2791	3278	3278
Pascagoula:							
		Asthma	$PM_{2.5}$	Ozone	NO_2	Temperature	Humidity
Asthma	Pearson Correlation	1	0.007	-0.014	-0.007	-.094**	-0.006
	N	3287	1003	2115	2477	3128	3287
Waveland:							
		Asthma	$PM_{2.5}$	Ozone	NO_2	Temperature	Humidity
Asthma	Pearson Correlation	1	-.056*	-0.004	-0.016	-0.02	-.052*
	N	3287	1497	1406	808	1420	1606

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Department of Environmental Quality [19] and from U.S. EPA's Environmental Protection Agency (U.S. EPA) air quality system data mart [20]. For the purpose of present study three criteria air pollutant parameters were selected, namely Particulate Matter of diameter less than 2.5 microns ($PM_{2.5}$), Ozone (O_3), and Nitrogen dioxide (NO_2) and the daily concentrations were obtained during the period 2003 to 2011.

Meteorological data

The daily temperature and humidity data of Gulfport, Pascagoula, and Waveland are obtained for the period 2003 to 2011 from Weather Underground web source [21].

Results and Discussion

The descriptive statistics of asthma admissions, the air pollutants,

Table 3: Poisson Regression Model for increase in asthma for a unit increase in the predictor variable.
Excluded represents missing data out of the total sample size of 3287; *denotes Statistically Significant.

	Excluded	β	p value	exp (β)	95% Wald Confidence Interval for exp(β)	
Gulfport					Lower	Upper
PM	246	-0.0083	0.049*	0.992	0.985	1
O_3	1186	0.003	0.044*	1.003	1	1.007
NO_2	497	0.003	0.279	1.003	0.998	1.008
Temperature	0	-0.01	0.00*	0.99	0.994	1.001
Humidity	0	-0.002	0.229	0.998	0.994	1.001
Pascagoula						
PM	2284	0.002	0.815	1.002	0.986	1.018
O_3	1172	-0.002	0.51	0.998	0.994	1.003
NO_2	810	-0.003	0.721	0.997	0.981	1.013
Temperature	159	-0.021	0.00*	0.979	0.972	0.986
Humidity	159	0.004	0.07	1.004	1	1.009
Waveland						
PM	1790	-0.039	0.012*	0.962	0.933	0.991
O_3	1887	-0.002	0.85	0.998	0.981	1.015
NO_2	2479	-0.03	0.654	0.97	0.852	1.105
Temperature	1867	-0.007	0.493	0.993	0.973	1.013
Humidity	1867	-0.007	0.177	0.993	0.983	1.003

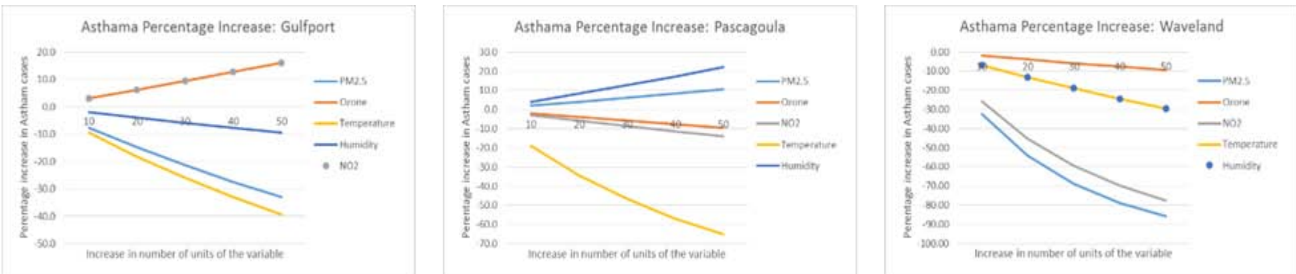

Figure 3: Asthma Projection with increase in the cause variables (by 10 units) for the regions of Gulfport, Pascagoula, and Waveland in the Mississippi Gulf Coast based on the data during the period 2003 to 2011.

and the meteorological variables is shown in Table 1.

During the period between 2003 and 2011 and for the case of Gulfport region, the minimum monthly average concentrations of asthma total admissions, $PM_{2.5}$, Ozone, NO_2, Temperature, and Humidity are 0, 0.6 µg/m^3,15 ppb, 0.7 µg/m^3, -2^{0}C, and 33% respectively. Similarly, the corresponding maximum average concentrations are 9, 52.2 µg/m^3, 98 ppb, 73 µg/m^3, 33^{0}C, and 99% respectively. For the case of Pascagoula region, the minimum monthly average concentrations of asthma total admissions, $PM_{2.5}$, Ozone, NO_2, Temperature, and Humidity are 0, 2 µg/m^3,11 ppb, 0 µg/m^3, -17.8^{0}C, and 0% respectively; and the corresponding maximum average concentrations are 7, 42µg/m^3, 96 ppb, 34µg/m3, 36.7^{0}C, and 100% respectively. For the case of Waveland region, the minimum average concentrations of asthma total admissions, $PM_{2.5}$, Ozone, NO_2, Temperature, and Humidity are 0, 0µg/m^3, 0 ppb, 0µg/m^3, -17.8^{0}C, and 0% respectively; and the corresponding maximum average concentrations are 4, 41 µg/m^3, 74.5 ppb, 19.8 µg/m^3, 32.2^{0}C, and 100% respectively.

The correlation among the data variables is shown in Table 2. There is a negative correlation between asthma and $PM_{2.5}$ and is statistically significant ($p<0.05$) for the Gulfport and Waveland regions. Ozone shows positive correlation for Gulfport region, while the other two regions show negative correlation, but in either case the correlation is not statistically significant. As expected, the temperature and humidity show negative correlations in all the three regions, and is statistically significant in many instances.

The Poisson Regression Model analysis was conducted in zero lag condition for each of the regions of the study and the results are given in Table 3. The association between asthma and $PM_{2.5}$ appears to be negative and statistically significant for the Gulfport and Waveland regions while it is positive and not statistically significant for the Pascagoula region. The association between asthma and O_3 is positive and statistically significant, but for the other two regions it is negative and not statistically significant. The association between asthma and NO_2 is not statistically significant in all the three regions and shows positive for the Gulfport region only. The association of asthma with temperature is negative and statistically significant in most of the cases but the association with humidity though negative in many cases and is not statistically significant in all the cases. In all the cases the association for NO_2 is not statistically significant mostly because of the limited data availability compared to the rest of the variables of study.

Using the values of the log linear regression coefficients (β), percent increase of asthma of the residents is projected for a step-wise increment of 10 units in each of the causing variables for each of the region, and the projected plots are shown in Figure 3. Considering the statistically significant situations, for the region of Gulfport an increase of PM from zero by 10 μg/m^3 projects a decrease in asthma cases by about 8, while an increase of O_3 by 10 ppb results in an increase of asthma by 3. In the region of Waveland, the model predicts a decrease in asthma by about 32 by an increase of PM from by 10 μg/m^3.

The results of the present study though providing a basic understanding of the association of the air pollutants and asthma in the Mississippi Gulf Coast region, is limited by many factors such as the pollutant and meteorological data availability, socio-economic factors, indoor or background pollution, and population migration. The number of variables used in the Poisson distribution model is rather small and widely varying among the regions of study – Gulfport (1835), Pascagoula (518), and Waveland (42). In general, the Poisson distribution model does require a large data set [22] for obtaining significant results and their consistency among other regions. Additionally, the mechanisms of specific air pollutants on various respiratory disorders is not clear [23,24], while some investigations considered air pollutants as the cause for asthma that can lead to severe respiratory disorders. Chan et al. [25] have shown positive impact of PM10 on asthma outpatient and emergency settings. In our earlier study [26], we also observed that $PM_{2.5}$ might have positive correlation in the increase of asthma rate in New York State. However, Nawahda [27] study shows that increased levels of $PM_{2.5}$ and surface ozone in Japan is not significantly contributing to increased asthma prevalence among the school children to assume for a strong association. But, a controlled laboratory study [28] do show that ozone positively aggravates asthma. The literature survey warrants more critical investigations for understanding the association between asthma and specific pollutants. Hence, the results of the present study may be considered as a rapid and easy evaluation of the data to obtaining first order effects and may not be considered as reflecting exact association.

Conclusion

The present work shows a comparative study of Poisson Regression Model to finding association between asthma with criteria pollutants and weather parameters over three locations in the Mississippi Gulf coast, namely Gulfport, Pascagoula, and Waveland during the period 2003 to 2011. The regions are considered because of the availability of the data to study the influence of industrial growth and unpredictable weather patterns on the asthma of the residents. The air pollutants considered are Particulate Matter of diameter less than 2.5 microns ($PM_{2.5}$), Ozone (O_3), and Nitrogen Oxide (NO_2); while the meteorological parameters considered are temperature, and humidity. Considering the statistically significant situations, the association between asthma and $PM_{2.5}$ appears to be negative for the Gulfport and Waveland regions, while it is positive association between asthma and O_3 for the Gulfport region. As expected, a negative association is observed between asthma and temperature in most of the cases. The association with humidity though negative in many cases and is not statistically significant in all the cases. In all the cases the association for NO_2 is not statistically significant mostly because of the limited data availability compared to the rest of the variables of study. The results are limited by the full availability of data for the corresponding variables, and also by the influence of other factors such as indoor environment and demographics which are not considered in the present study. In view of the limitations, the results of the present study may be considered as a rapid and easy evaluation of the data to obtaining first order effects of air pollutants and asthma in the Mississippi Gulf Coast region, and may not be considered as reflecting exact association. However, the Poisson Regression Model facilitates studying the association of asthma for mitigating and making policy decisions for controlling its prevalence.

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Austin J Allergy - Volume 4 Issue 1 - 2017
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Citation: Tuluri F and Gorai AK. Asthma Trends in Mississippi Coastal Region with Air Pollutants and Meteorological Factors. Austin J Allergy. 2017; 4(1): 1026.