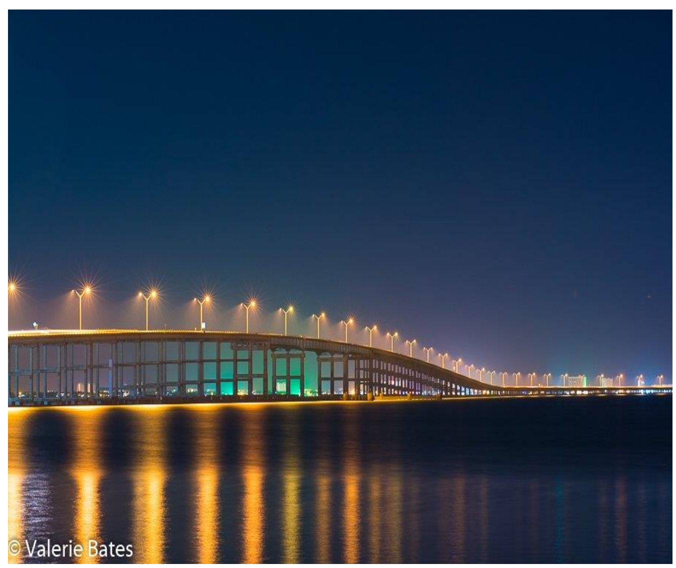
Particulate Matter before and during Lockdown

Reyna I. Tovar

University of Texas Rio Grande Valley

Picture 1https://www.travelandleisure.com/credit: philipus / alamy



Picture 2 https://twitter.com/portisabeltexas/status:credit:Valerie Bates

“Particulate Matter before and During Lockdown”

Author: Reyna Tovar

04/28/2021

Abstract

Upon the outbreak of (SARS-CoV-2) or COVID-19, on January 30th, 2020, the World Health Organization declared a global health emergency (*WHO Coronavirus (COVID-19) Dashboard*, n.d.). In Texas, to decelerate the spread of this virus, most non-essential activities were inhibited. The industries most affected were airlines, food, and beverage, automotive, travel, education, oil gas and drilling, retail, and sports and entertainment. All these sectors have one variable in common, and that is the need of transport. The lockdown measures have involved us in an involuntary experiment, and we can respond to the actual situation with the following question: If we eliminate nearly all combustion vehicles from the cities by allowing only public transport and the transport of basic supplies, what would be the air quality? (Baldasano, 2020). In some of the recent research, the improvement in air quality during lockdown period was related to the closure of industries and reduction in vehicle transit (Selvam et al., 2020).

Introduction

Did the Texas lockdown hinder PM 2.5 concentrations for the years 2020 and 2021? Although all pollutants are hazardous to human health, $PM_{2.5}$ is of the most concern. These particles are so small, as they are inhaled, they can travel into the lungs and can also reach the blood stream (Godish, Davis and Fu). Particulate matter is not a single pollutant, but is made up of particles of many different sizes and chemical composition, from a wide range of natural and anthropogenic sources (Holman, 1999). These particles are toxic, and inhalation of these substances can lead to decreased lung function. Particulate matter is the sum of all solid and liquid particles suspended in the air. It is a complex mixture which includes both organic and inorganic particles such as pollen, dust, soot, bacteria, smoke, allergens, and liquid droplets (Godish et al., 2015). These particles vary greatly in size, composition, and origin. Some particulate matter comes directly from the atmosphere, for instance when fuel is burnt or when dust is carried by wind. These particles are known as primary particulate matter. Some particulate matter develops through chemical processes or chemical reactions amongst primary particulate matter. These particles are known as secondary particulate matter. The classification based on size of particles is widely accepted and used worldwide (epa.gov criteria air pollutants). The 24-hour standard level is 35 μg/m^3 and an annual average level of 12 μg/m^3 is the current acceptable value. When particles exceed the safe limits, they can start causing human problems such as headache, dizziness, irritation in eye and nose. Longtime exposure can cause cardiovascular, respiratory, and cardiopulmonary diseases such as bronchitis, lung cancer, developmental and reproductive effects. These can become chronic and can further exacerbate exposure to bacteria and viruses such as COVID-19. Additionally, PM can cause abrasions to plants, reduction in photosynthesis due to blocking radiation, and changes to soil chemistry (Grantz et al., 2003).

Methods

Study Location

The objective of this research is to assess the Particulate Matter 2.5 (μg/m^3) average, daily observations of two cities along the Texas coast. The data used are the hourly concentrations of particulate matter 2.5 along with meteorological parameters that include hourly wind speed and wind direction. Quantitative data will be analyzed through numerical comparisons and statistical inferences. The observations will be for the month of March for the years 2019, 2020, and 2021.

And that is, with the purpose of evaluating the effects on air quality generated by the Texas lockdown. The first data collected comes from an air quality monitoring station in the city of Corpus Christi, Texas (fig. 2). The site coordinates are Latitude: 27º 48' 16" North (27.8044887º) and Longitude: -97º 25' 54" West (-97.4315532º), elevation 6.0 m.

Figure 2 EPA site 483550032 CAMS 0098. Nueces County, address: 3810 Huisache Street 78407

The second air quality monitoring location is in the city of South Padre Island, Texas (fig. 3), lying between Latitude: 26º 4' 16" North (26.0711000º) and Longitude: -97º 9' 28" West (-97.1577000º), elevation 3.0 m. $PM_{2.5}$ measurements, resultant wind speed and direction were downloaded from the Texas Commission on Environmental Quality (TCEQ) at the Environmental Agency of Texas (*Air*, n.d.). Collecting data from these resources is the best methods to answer research questions because data from the instruments used meets EPA quality assurance criteria for regulatory purposes. Because not all sectors of industrial manufacturing, transportation of goods, and automotive were shut down, I hypothesize that air quality for the two cities in question will show no shift, change or improvement from the year prior or a year after the pandemic.

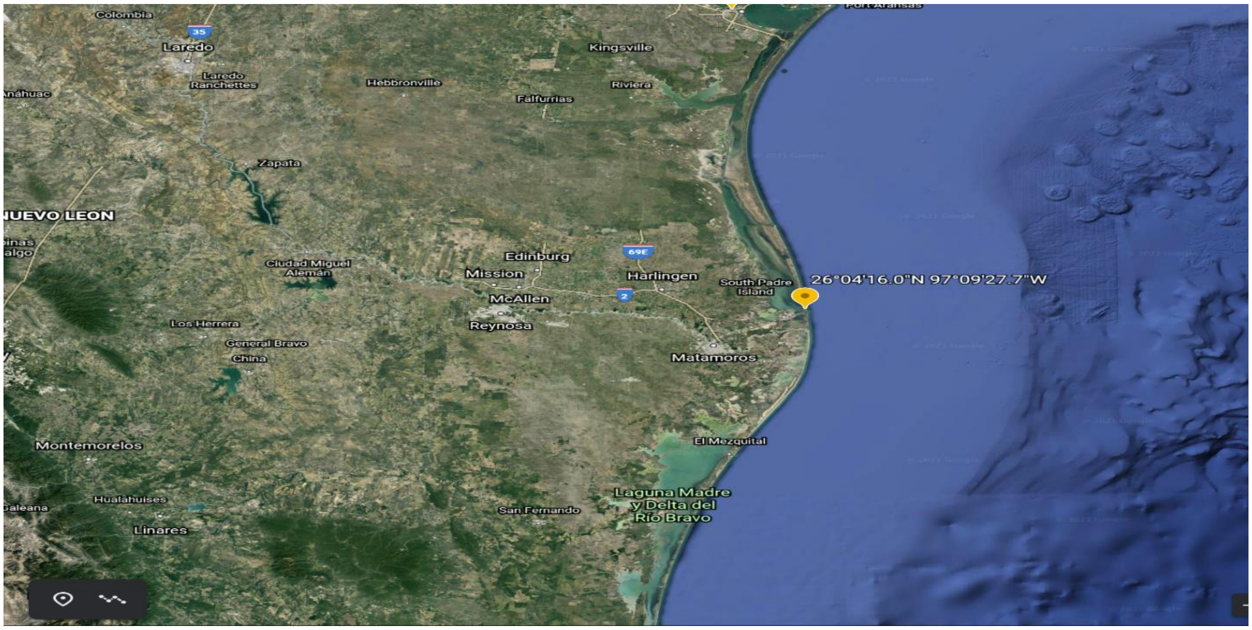


Figure 3 EPA site 480612004 CAMS 0323, 0667. Cameron County, Address: Lot B 69 ½ 78597

Data Analysis and Results

Statistical analysis was done using Python version 3.9 and Excel Version 2008. A descriptive analysis was executed for all the data including the mean, minimum and maximum. A paired t-test and p-value score was used to analyze for statistical differences between the means concentrations of pollutants for each month. A box and whisker plot were used to show the shape of the distribution. And a Pearson's correlation test was used to assess the relationship between pollutants and meteorological factors.

As shown in (fig. 4), during March 2019, in Corpus Christi and South Padre Island, Tx the $PM_{2.5}$ concentration ranged between 1.8 and 17, 4.1 $\mu g/m^3$, and 17.1 $\mu g/m^3$ and averaged 8.47, and 8.60 $\mu g/m^3$ respectively. During March 2020, in Corpus Christi and South Padre Island, Tx the $PM_{2.5}$

concentration ranged between 3.3 and 16.4, and 6.3 μg/m³, and 22.6 μg/m³ and averaged 10.38 μg/m³, and 14.05 μg/m³ respectively. In March 2021, concentrations were in the range of 1.7-22.1, and 5.4-25.0 μg/m³, with averages of 8.18 μg/m³, and 13.09 μg/m³, respectively.

For the city of Corpus Christi, PM $_{25}$ concentrations for 2020 were 22.35%, higher than that of 2019. For 2021 PM $_{25}$ concentrations were 21.255% lower than that of 2020. Based on the data from the three years, the average PM 2.5 concentrations decreased by 3.76%.

For the city of South Padre Island, PM $_{25}$ concentrations for 2020 were 63.48%, higher than that of 2019. For 2021 PM $_{25}$ concentrations were 6.89% lower than that of 2020. Based on the data from the three years, the average PM 2.5 concentrations increased by 52%.

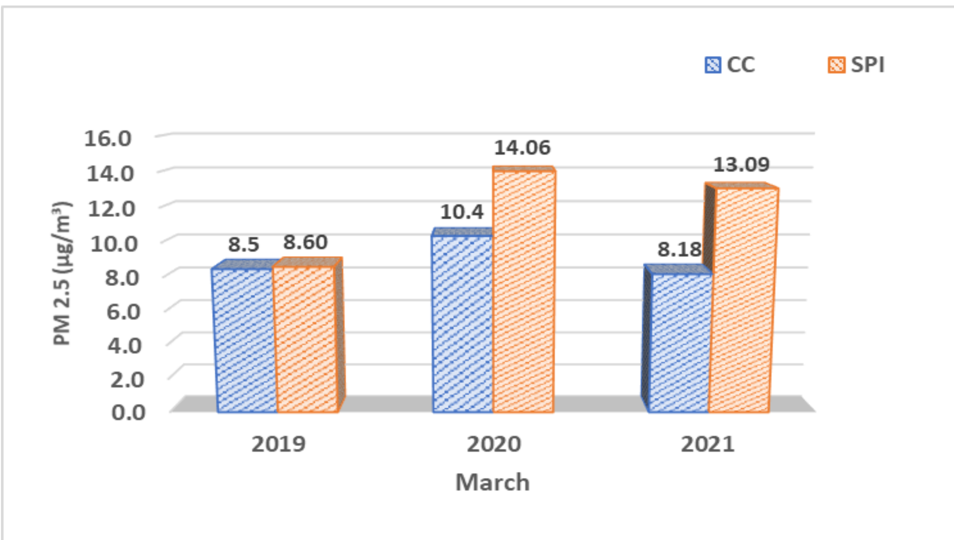


Figure 4 March PM 2.5 Average

Relationship between PM 2.5 and Resultant Wind Direction

The average wind speed for *South Padre Island*, Tx and *Corpus Christi*, Tx (fig 5 &6) for March 2019 was 5.80 mph with a minimum of 2.20 to a maximum of 13.40 mph and 8.49 mph with a minimum of 0.50 to a maximum of 14.90 mph respectively. Average wind direction was S 48° E and ranged from N3°E to N11°W and, S68°E, and ranged from N 3° E to 0° N respectively.

Average wind speed for SPI and CC on 2020 (fig. 7 & 8) was 6.91 mph with a minimum of 3.20 to a maximum of 11.40 mph and 9.46 mph with a minimum of 3.50 to a maximum of 14.90 mph winds respectively. Average wind direction for SPI in 2020 was S 39° E and ranged from N25°E to N3°W and for CC was S68°E and ranged from N3°E to 0°N. And for 2021(fig 9 & 10), average wind speed for SPI and CC was 5.91 mph with a minimum of 2.30 to a maximum of 10.00 mph and 8.65 mph with a minimum of 1.80 to a maximum of 14.90 mph winds respectively. Average wind direction was S 73° E and ranged from 0° N to N 3° W and, S 56° E, and ranged from N6°E to N30°W respectively. Wind orientation for years 2020 and 2021 was like that of 2019.

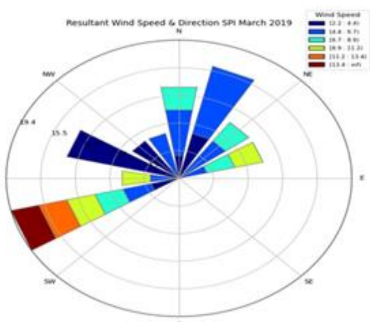


Figure 5 Wind Rose plot for SPI, Tx March 2019

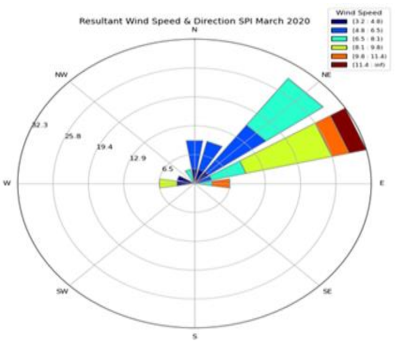


Figure 7 Wind Rose plot for SPI, Tx March 2020

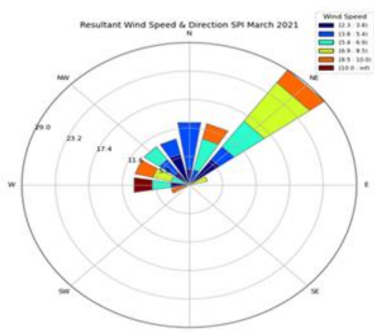


Figure 9 Wind Rose plot for SPI, Tx March 2020

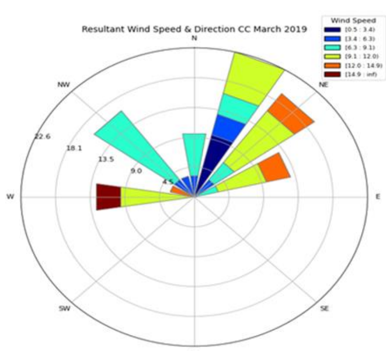


Figure 6 Wind Rose plot for Corpus Christi, Tx March 2019

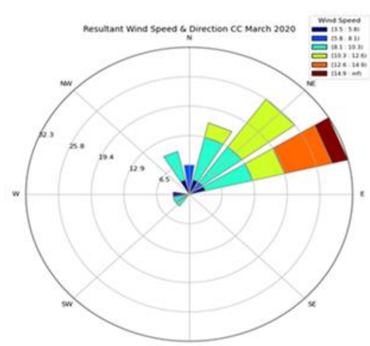


Figure 8 Wind Rose plot for Corpus Christi, Tx March 2020

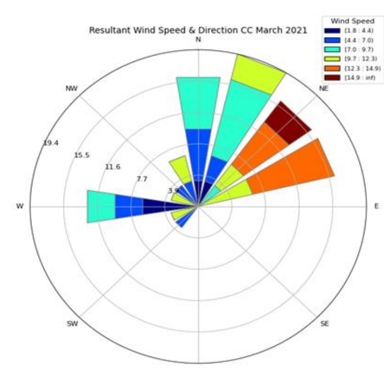


Figure 10 Wind Rose plot for Corpus Christi, Tx March 2021

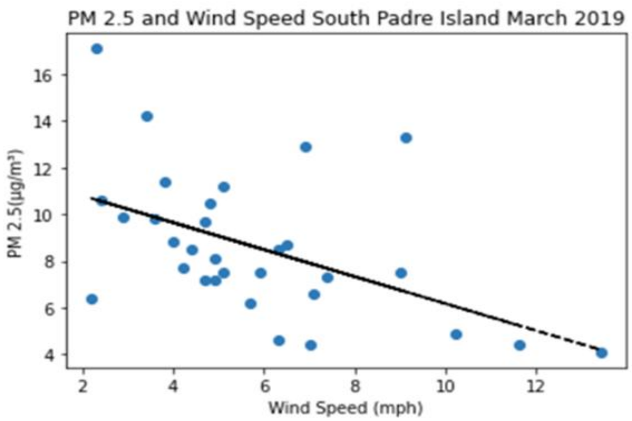


Figure 11 Correlation Analysis between PM2.5 and Wind Speed.

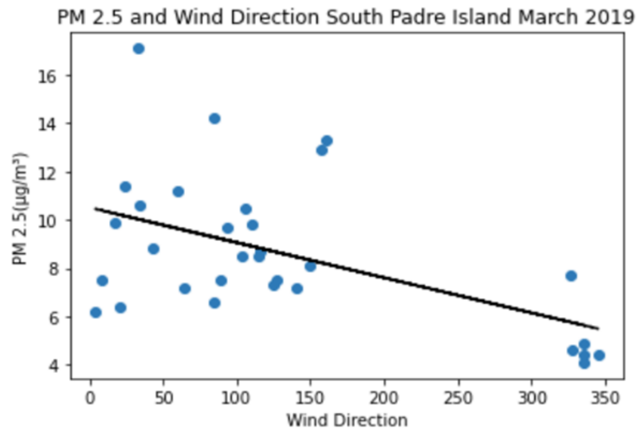


Figure 12 Correlation Analysis between PM2.5 and Wind Direction.

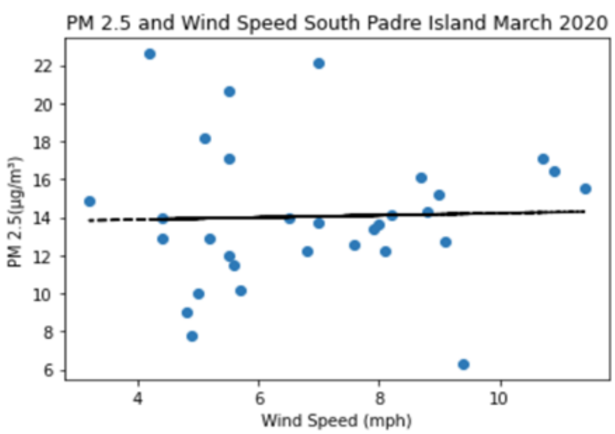


Figure 13 Correlation Analysis between PM2.5 and Wind Speed.

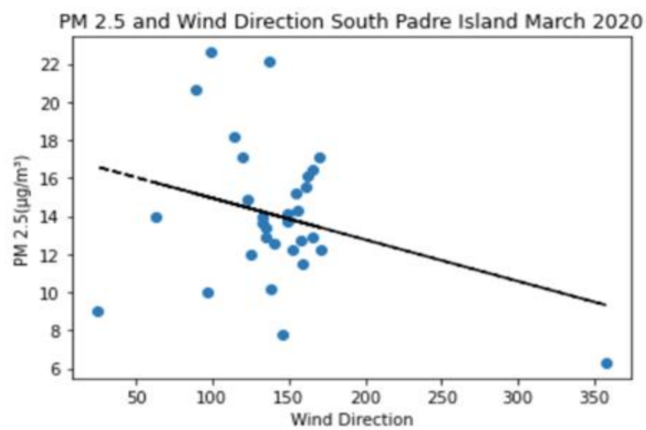


Figure 14 Correlation Analysis between PM2.5 and Wind Speed.

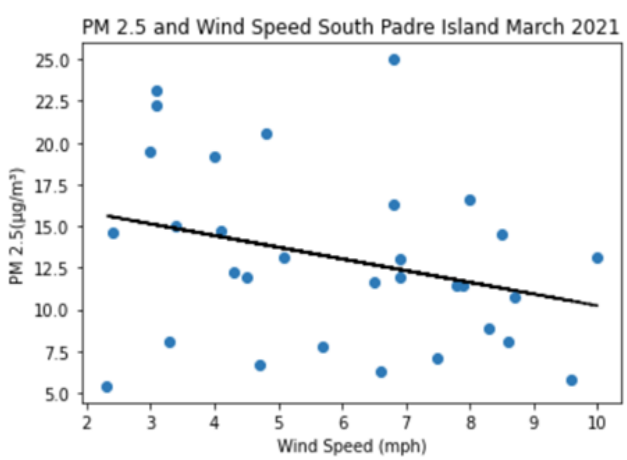


Figure 15 Correlation Analysis between PM2.5 and Wind Direction.

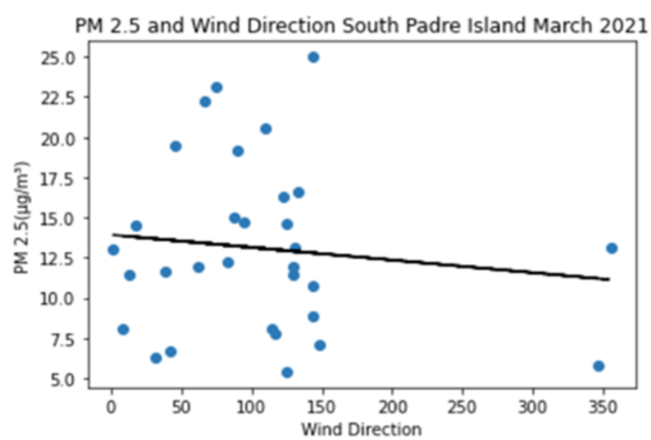


Figure 16 Correlation Analysis between PM2.5 and Wind Direction.

A Pearson's Correlation coefficient (r) was calculated for South Padre Island, Tx for the years 2019, 2020, and 2021 to assess the relationship between $PM_{2.5}$, and the meteorological data: resultant wind direction and resultant wind speed. For 2019; $PM_{2.5}$ and R.W. direction, the r value was -0.522782, indicative of a moderate negative linear relationship (fig.12). The correlation coefficient for $PM_{2.5}$ and R.W. speed are -0.504279, also indicative of a moderate negative linear relationship (fig. 11). For 2020; $PM_{2.5}$ and R.W. direction, the r value was -0.245394 indicative of a weak negative linear relationship (fig. 14). And the correlation coefficient for $PM_{2.5}$ and R.W. speed are 0.336390, indicative of a weak positive relationship (fig. 13). For the year 2021, $PM_{2.5}$ and R.W. direction, the r value was -0.118461 indicative of a weak, negative linear relationship (fig 16). And the correlation coefficient for $PM_{2.5}$ and R.W. speed are 0.300220, indicative of a weak positive linear, relationship (fig. 15). Overall, none of the variables show a strong positive or negative linear relationship, therefore there is no significant correlation between $PM_{2.5}$, and their meteorological variables for the three years in question.

Table 1 Pearson's Correlation Table SPI, TX 2019

SPI, Tx	March 2019	PM2.5 (µg/m^3)	R.W. Direction	R.W. Speed
March 2019	1	-0.11861	-0.073162	-0.000825
PM2.5 (µg/m^3)	-0.011861	1	-0.522782	-0.504279
R.W. Direction	-0.073162	-0.522782	1	0.622344
R.W. Speed	-0.000825	-0.504279	0.622344	1

Table 2Pearson's Correlation Table SPI, TX 2020

SPI, Tx	March 2020	PM2.5 (μg/m³)	R.W. Direction	R.W. Speed
March 2020	1	0.530486	-0.027561	0.336390
PM2.5 (μg/m³)	0.530486	1	-0.245394	0.034751
R.W. Direction	-0.027561	-0.245394	1	0.557678
R.W. Speed	0.336390	0.034751	0.557678	1

Table 3Pearson's Correlation Table SPI, TX 2021

SPI, Tx	March 2021	PM2.5 (μg/m³)	R.W. Direction	R.W. Speed
March 2021	1	0.355071	-0.286470	-0.055950
PM2.5 (μg/m³)	0.355071	1	-0.118461	0.300220
R.W. Direction	-0.286470	-0.118461	1	0.462796
R.W. Speed	-0.055950	0.300220	0.462796	1

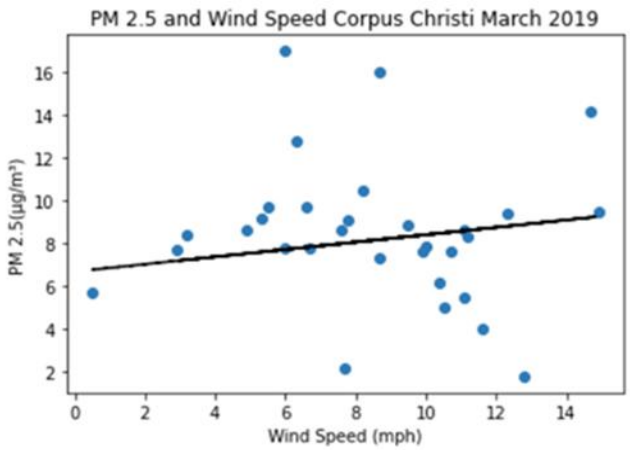


Figure 17 Correlation Analysis between PM2.5 and Wind Speed

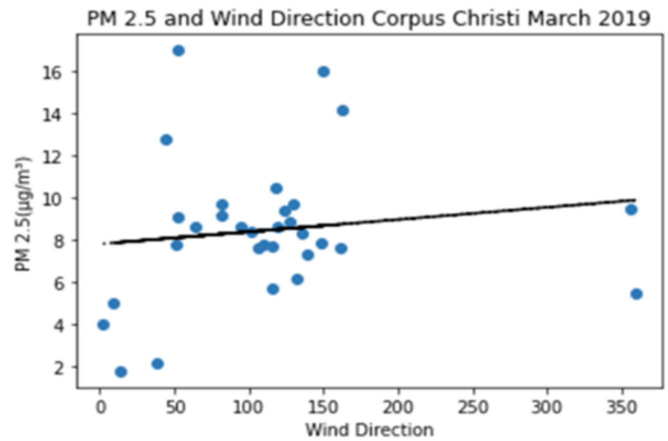


Figure 18 Correlation Analysis between PM2.5 and Wind Direction.

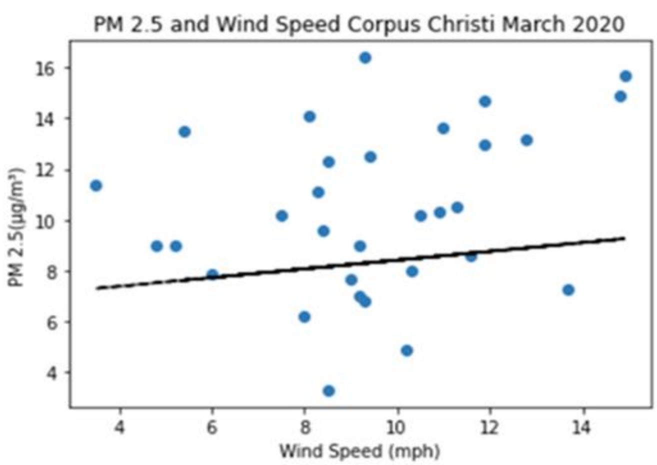


Figure 19 Correlation Analysis between PM2.5 and Wind Speed

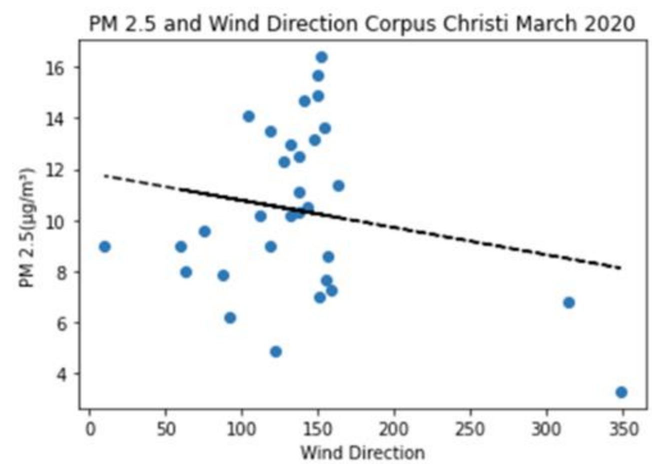


Figure 20 Correlation Analysis between PM2.5 and Wind Direction.

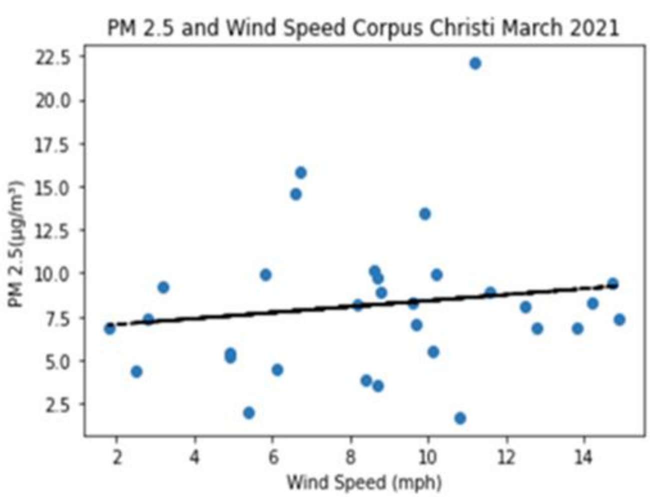


Figure 21 Correlation Analysis between PM2.5 and Wind Speed

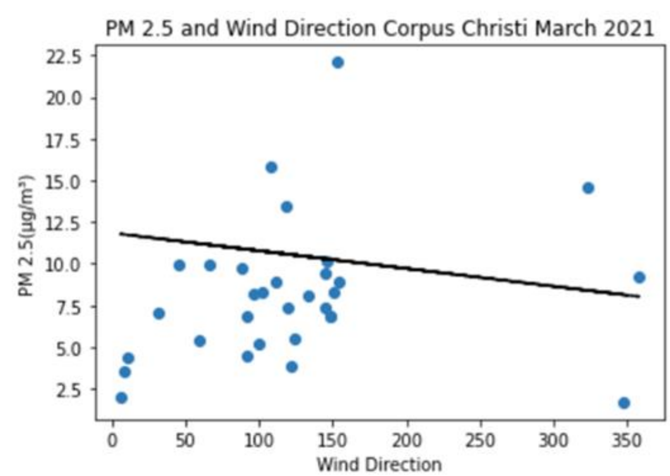


Figure 22 Correlation Analysis between PM2.5 and Wind Direction.

Pearson's Correlation coefficient (r) was also calculated for Corpus Christi, Tx for the years 2019, 2020, and 2021 to assess the relationship between $PM_{2.5}$, and the meteorological data: resultant wind direction and resultant wind speed. For 2019; $PM_{2.5}$ and R.W. direction, the r value is 0.137441, indicative of a weak positive linear relationship (fig.18). The correlation coefficient for $PM_{2.5}$ and R.W. speed are -0.072141, indicative of a weak negative linear relationship (fig. 17). For 2020; $PM_{2.5}$ and R.W. direction, the r value was -0.203627 indicative of a weak negative linear relationship (fig. 20). And the correlation coefficient for $PM_{2.5}$ and R.W. speed is 0.263736, indicative of a weak positive relationship (fig. 19). For the year 2021, $PM_{2.5}$ and R.W. direction, the r value was 0.211921 indicative of a weak, positive linear relationship (fig 22). And the correlation coefficient for $PM_{2.5}$ and R.W. speed are 0.152140, indicative of a weak positive linear, relationship (fig. 21). Overall, none of the variables show a strong positive or negative linear relationship, therefore there is no significant correlation between $PM_{2.5}$, and their meteorological variables for the three years in question.

Table 4Pearson's Correlation Table CC, TX 2019

Corpus Christi, Tx	March 2019	PM2.5 (μg/m³)	R.W. Direction	R.W. Speed
March 2019	1	-0.254009	-0.199347	-0.023767
PM2.5 (μg/m³)	-0.254009	1	0.137441	-0.072141
R.W. Direction	-0.199347	0.137441	1	0.336978
R.W. Speed	-0.023767	-0.072141	0.336978	1

Table 5Pearson's Correlation Table CC, TX 2020

Corpus Christi, Tx	March 2020	PM2.5 (µg/m³)	R.W. Direction	R.W. Speed
March 2020	1	0.525340	-0.389969	-0.046712
PM2.5 (µg/m³)	0.525340	1	-0.203627	0.263736
R.W. Direction	-0.389969	-0.203627	1	0.229016
R.W. Speed	-0.046712	0.263736	0.229016	1

Table 6Pearson's Correlation Table CC, TX 2021

Corpus Christi, Tx	March 2021	PM2.5 (µg/m³)	R.W. Direction	R.W. Speed
March 2021	1	0.413722	0.276648	0.124601
PM2.5 (µg/m³)	0.413722	1	0.211921	0.152140
R.W. Direction	0.276648	0.211921	1	0.151638
R.W. Speed	0.124601	0.152140	0.151638	1

A Box and Whisker plot was used to show the standardized way of the distribution of data. The boxplot is based on a five number summary which are; the minimum, first quartile (Q1) the middle number between the smallest number (not the "minimum") and the median of the dataset, (Q2) middle value of the dataset , third quartile (Q3) the middle value between the median and the highest value (not the "maximum") of the dataset and the maximum. (Galarnyk, 2020). For the purpose of this study, the interquartile range (IQR): 25th to the 75th percentile was also included. Figure 16 shows the distribution of $PM_{2.5}$ measured in μg/m³, for South Padre Island Tx. For 2019, the box and whisker plot show that the Q1 is 6.6, Q2 is 8.1, Q3 is 10.5 and the IQR is 3.9. The range is 13 and there is an outlier of 17.1. For the year 2020, Q1 is 12.2, Q2 is 13.7, Q3 is 16.1 and the IQR is 3.9. The range is 16.3 and there were some outliers in the range of (6.3, 22.1, and 22.6). These measurements are 1.5 times the length of the box and therefore the values are not normally distributed. For the year 2021, the Q1 is 8.1, Q2 is 12.2, Q3 is 16.3, and the IQR is 8.2. The range is 19.6 and there are no outliers.

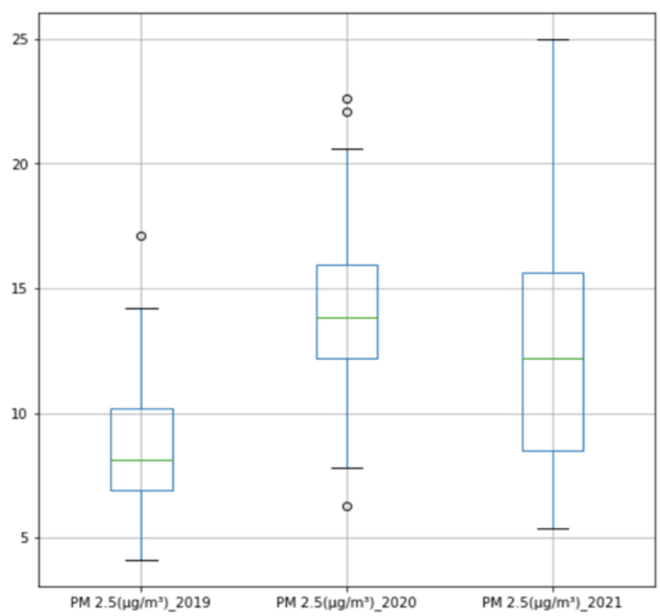


Figure 23 South Padre Island Box and Whisker Plot for PM 2.5 March 2019, 2020, and 2021.

The box and whisker plot in (fig.17) show the distribution of particulate matter for Corpus Christi, Tx. in 2019. The Q1 is 7.3, Q2 is 8.4, Q3 is 9.5 and the IQR is 2.2. The range is 15.2 and there are outliers of (1.8, 2.2, 14.2, 16, 17) indicating that the values are not normally distributed. For the year 2020, the Q1 is 7.9, Q2 is 10.2, Q3 is 13.2 and the IQR is 5.3. The range is 13.1 and there are no outliers. For the year 2021, the Q1 is 5.4, Q2 is 8.1, Q3 is 9.7, and the IQR is 4.3. The range is 20.4 and there was an outlier with the value of 22.1.

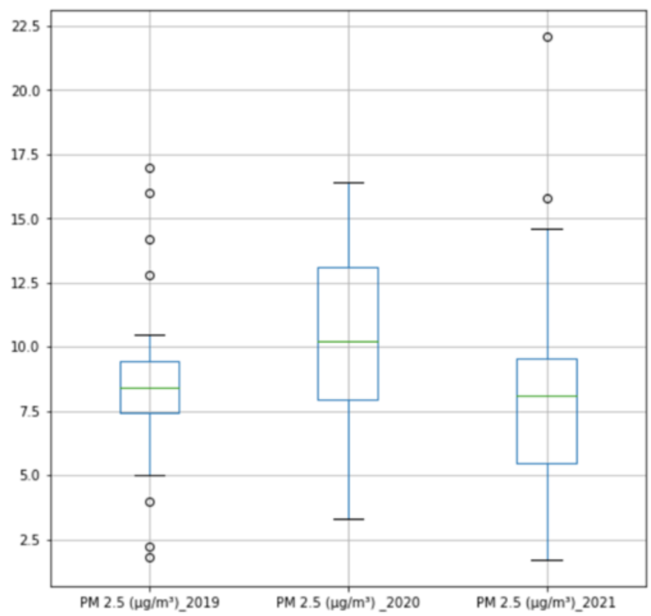


Figure 24 Corpus Christi, Tx Box and Whisker Plot for PM 2.5 March 2019, 2020, and 2021.

Conclusion

Based on the data there seems to have been a staggering increase of Particulate Matter $_{2.5}$ for the city of South Padre Island, Tx. Results show that for the year 2019, 2020, and 2021 the average wind direction was S48°E, S39°E, and S73°E respectively. Average speed was 5.80 mph, 6.91 mph and 5.91 mph, respectively. Wind direction was similar for the three years with orientation from the South to South East. None of the R-values in the Pearson's correlation test showed a strong negative or positive relationship between $PM_{2.5}$ and its meteorological parameters, therefore the wind speed and direction held not dictation on how the pollution was distributed.

The average $PM_{2.5}$ was 8.60 μg/m³, had an increase in 2020 of 14.05 and a slight decrease in 2021 of 13.09. For the year 2020, there was a 63.48% PM2.5 increase and for 2021 there was a 6.89% decrease. Overall, there was a 52% increase from 2019 to 2021, reflecting that there was change therefore, for the city of South Padre Island, Tx we reject the null that there was no shift or change in pollution levels.

Based on the data for Corpus Christi, Tx, Results show that for the year 2019, 2020, and 2021 the average wind direction was S68°E, S68°E, and S56°E respectively. Average speed was 8.49 mph, 9.46 mph and 8.65 mph, respectively. Wind direction was similar for the three years with orientation from the South to South East. None of the R-values in the Pearson's correlation test showed a strong negative or positive relationship between $PM_{2.5}$ and its meteorological parameters, therefore, the wind speed and direction held not dictation on how the pollution was distributed. The average $PM_{2.5}$ for 2019 was 8.47 μg/m³, had an increase in 2020 of 10.38 μg/m³, and a slight decrease in 2021 of 8.18 μg/m³. For the year 2020, there was a 22.35% $PM_{2.5}$ increase and for 2021 there was a 21.55% decrease. Overall, there was a 3.76% decrease from 2019 to2021, reflecting that there was change therefore, for the city of Corpus Christi, Tx we reject the null that there was no shift or change in pollution levels.

References

Air. (n.d.). Texas Commission on Environmental Quality. Retrieved April 26, 2021, from https://www.tceq.texas.gov/agency/air_main.html

Baldasano, J. M. (2020). COVID-19 lockdown effects on air quality by NO2 in the cities of Barcelona and Madrid (Spain). *Science of The Total Environment*, *741*, 140353. https://doi.org/10.1016/j.scitotenv.2020.140353

Galarnyk, M. (2020, July 6). *Understanding Boxplots*. Medium. https://towardsdatascience.com/understanding-boxplots-5e2df7bcbd51

Grantz, D. A., Garner, J. H. B., & Johnson, D. W. (2003). Ecological effects of particulate matter. *Environment International*, *29*(2), 213–239. https://doi.org/10.1016/S0160-4120(02)00181-2

Holman, C. (1999). 8—Sources of Air Pollution. In S. T. Holgate, J. M. Samet, H. S. Koren, & R. L. Maynard (Eds.), *Air Pollution and Health* (pp. 115–148). Academic Press. https://doi.org/10.1016/B978-012352335-8/50083-1

Selvam, S., Muthukumar, P., Venkatramanan, S., Roy, P. D., Manikanda Bharath, K., & Jesuraja, K. (2020). SARS-CoV-2 pandemic lockdown: Effects on air quality in the industrialized Gujarat state of India. *Science of The Total Environment*, *737*, 140391. https://doi.org/10.1016/j.scitotenv.2020.140391

WHO Coronavirus (COVID-19) Dashboard. (n.d.). Retrieved April 26, 2021, from https://covid19.who.int