Research Implementation

Hypothesis: The reduction of traffic volumes due to lockdown has contributed to improvement in air quality in Ireland.

Abstract

The outbreak of the Covid-19 coronavirus has led countries around the world to impose nationwide lockdown strictly restricting the mobility of people. This has a great impact on air quality (Quintyne *et al*, 2021). Ireland also went through three phases of total lockdown in two years between 2020 and 2021. Following the restriction, many articles and newspapers have reported that air pollution had dropped dramatically. In Ireland, nitrogen dioxide NO_2 fell by 40%-50% in 2020 in comparison to 2019 (Irish Times, 2020) (EPA Ireland, 2020). The purpose of this study was to see whether the lockdown in Ireland led to the improvement of air quality or not. The third phase of lockdown January-February 2021 was selected for this study with the baseline period in the previous year. Three major cities Dublin, Limerick, and Cork were the study areas. A real-time data of air components concentrations and weather elements rainfall and temperature during the and before lockdown were tracked and calculated using an arithmetic mean equation to see the changes in values over time. Particulate matter $PM10$ and $PM2.5$ were increased during the lockdown despite the significant amount of rainfall. The temperature was slightly colder during the lockdown that it may have some influence over the increase in particulate matter. However, the study found that the nitrogen oxide NO_2 was greatly decreased throughout the lockdown compared to the baseline previous period. This could be claimed that this reduction in NO_2 was due to the traffic and mobility restriction during the lockdown as road traffic is considered the main source of NO_2 in Ireland.

Methodology

This empirical analysis is based on a quantitative and comparative approach of study. The hypothesis that the reduction of traffic volumes due to lockdown has contributed to improvement in air quality in Ireland is observed using real-time air quality and weather data. To study whether air quality was improved or not in the given period, I observed the changes in concentrations of three air components are Particulate Matter $PM10$, $PM 2.5$, and Nitrogen dioxide NO_2. The data for air quality is taken from four air quality monitoring stations from three different cities. Two

stations are based in Dublin city, at Dun Laoghaire and Rathmines Dublin 6. One station is based in cork city at Cork University and the other in Limerick at People's Park Limerick. These three different cities are chosen to study whether the mobility restrictions imposed to stop the spread of the coronavirus by the Irish government have an impact on air quality in Ireland as many other countries mentioned in the research design. Moreover, meteorological factors also can influence air quality in the atmosphere. Therefore, two elements of weather conditions, rainfall, and temperature were also observed in the same timeframe as the air components.

The map below shows the locations of the air quality monitoring stations from where the data for this study is taken.

Air Quality Monitoring Stations (AQMS) in the study areas:

Source: Google Earth Pro

In Ireland, there were three phases of lockdown imposed since the covid-19 virus entered the country. The first complete shutdown lasted for two months from the 27th March until mid-May in 2020. The second was from the 21st of October until the 1st of December 2020. The last phase of restriction was from the 1st of January 2021 lasted for more than two months (Department of Health, 2020). In this empirical analysis, the third phase of the lockdown timeframe is used to compare the air quality with the same timeframe in the previous year 2020.

Note: The timeframe and baseline period of study have been slightly changed than the initial purpose in my research design due to missing data. The intended study period was the first lockdown, which was from 27th March to the mod-May with baseline period 2019. Instead, this research study the third strict lockdown, which was from the 1st of January until the 5th of March 2021. For this study tow full months, January and February of 2021, and the same months in the 2020 timeframe are used. January-February 2020 was still pre-pandemic in Ireland.

Air Components Particulate Patter(PM_{10}, $PM_{2.5}$) and Nitrogen dioxide NO_2

Ireland, 2020). I observed the changes in concentration of these three components during the third strict lockdown in comparison to the same timeframe the previous year before lockdown. I first abstracted the daily data of the given three individual air components during the lockdown in January and February 2021 of 60 days. The daily data is the mean of hourly data. I then calculated the mean values of each component to see the average concentrations of each air pollutant in the air in those 60 days. To compare the results with the before lockdown, the average values of the same components in the same period were calculated in a similar way above. The concentration of PM10, PM2.5, and NO2 is measured in µg/m3 micrograms per cubic meter.

The arithmetical equation used to calculate the mean (µ) value:

$$\mu = \frac{\sum_{i=1}^{N} X_i}{N}$$

Weather components Rain-Fall and Temperature

We know that rainfall could effectively remove particulate matters from the air and this could contribute to the improvement of air quality in the atmosphere for a short period depending on the duration and amount of rainfall(Wu et al, 2021). Ambient temperature also affects particulate matter emission rates (Nam et al. 2010) So as meteorological elements such as rain and temperature could influence the air quality I also observed rainfall and temperature of the same periods before and during the lockdown in the same three cities. The weather data is taken from Met Eireann. For Dublin, the data was taken from the Phoenix Park weather station for Cork city from the Cork airport and likewise for Limerick city from the Limerick airport weather station. The results are discussed below in the results and discussions sections.

Results

Table 1: Mean (μ) values of PM_{10}, $PM_{2.5}$, and NO_2 before and during lockdown in four stations.

Cities	Before Lockdown Mean (Jan-Feb 2020)			During Lockdown Mean (Jan-Feb 2021)			Difference		
	PM_{10}	$PM_{2.5}$	NO_2	PM_{10}	$PM_{2.5}$	NO_2	PM_{10}	$PM_{2.5}$	NO_2
Dun Laoghaire Dublin	12.59	8.48	42.27	13.05	9.09	29.1	-0.46	-0.61	13.17
Rathmines Dublin 6	11.12	7.42	46.83	12.41	8.99	29.19	-1.29	-1.57	17.64
Cork	NA	10.19	34.87	NA	11.55	25.16	NA	-1.36	9.71
Limerick	17.04	12.81	48.57	19.91	16.49	27.3	-2.87	-3.68	21.27

Table 1 displays the mean(μ) values of 60 days' of all three pollutants Particulate Matter PM10, PM2.5, and Nitrogen dioxide NO2 before and during the lockdown in four stations in three cities. The PM10 data of Cork was not available therefore it is null. The differences of all values of all components between the two timeframes are also given in the table.

The arithmetic mean (μ) values show that there was a significant increase in PM10 and PM2.5 in all cities during the lockdown. In Dun Laoghaire, the PM10 was slightly increased form 12.59µg/m3 to 13.03µg/m3 and PM 2.5 from 8.48µg/m3 to 9.09µg/m3. In Rathmines Dublin PM10 and PM2.5, increased from 11.12µg/m3 7.42µg/m3 to 12.41µg/m3 and 8.99 respectively. PM2.5 in Cork also increased from 10.19µg/m3 to 11.55µg/m3. In comparison to other cities, Limerick had the biggest increase in both pollutants. PM10 increased from 10.04µg/m3 to 19.91µg/m3 and PM2.5 from 12.81µg/m3 to 16.49µg/m3 in Limerick.

However, there was a huge decrease in Nitrogen dioxide NO2 in all cities during the lockdown. In Dun Laoghaire and Rathmines Dublin the average NO2 concentration before lockdown during January and February in 2020 were 42.27µg/m3 and 46.83µg/m3 these decreased to only 29.1µg/m3 and 29.19µg/m3 respectively during the period of lockdown in 2021. The average difference before and during the lockdown in Dun Laoghaire was 13.17µg/m3 and in Rathmines Dublin 17.64µg/m3. In Cork, it was reduced from 34.87µg/m3 to 25.16µg/m3 with an average difference of 9.71µg/m3. The biggest NO2 reduction was in Limerick with an average difference of 21.27µg/m3. In Limerick, the NO2 reduced from 48.57µg/m3 to 27.3µg/m3 during the lockdown. These changes in results over time are shown in the graphs below.

**Table 2:** Average Rainfall in (mm) in Dublin, Cork, and Limerick

|	Rainfall Phoenix Park Dubin		Rainfall Cork Rirport		Rainfall Limerick Airport		
	January	February	January	February	January	February	Sum
Before lockdown 2020	39.6	141.5	112.2	199.3	74.8	244.5	811.9
During lockdown 2021	115.6	61.7	121.8	235.9	105.5	82.6	723.1

Table 2 contains the monthly mean(μ) values of rainfall in Dublin, Cork, and Limerick before and during the lockdown. It shows that even though that there was slightly more rainfall before lockdown but it greatly varies by month and city. During the lockdown, Dublin was wetter by 75% compared to the previous January but February was drier by about the same percentages than previous February. Likewise, Limerick followed the same pattern. Whereas, Cork was wetter throughout during the lockdown.

Table 3: Average Temperature in degree Celsius (ºC) in Dublin, Cork, and Limerick.

|	Tem. Phoenix Park Dubin		Tem. Cork Rirport		Tem. Limerick Airport	
	January	February	January	February	January	February
Before lockdown 2020	6.6	6.2	6.2	6	6.7	6.7
During lockdown 2021	4.3	6.6	4.7	5.8	4.5	6.7

Table 3 contains the monthly mean(μ) values of temperature in Dublin, Cork, and Limerick before and during the lockdown. It shows that overall during lockdown was colder. Dublin was colder in January compared to the previous January but February was slightly warmer than the previous February. Limerick was a lot colder in January during the lockdown than previous January and February remained unchanged. Cork was colder during the lockdown.

Figure 1: Changes in Particulate Matter (PM_{10} and $PM_{2.5}$) concentrations before and during lockdown in Dublin, Limerick and Cork.
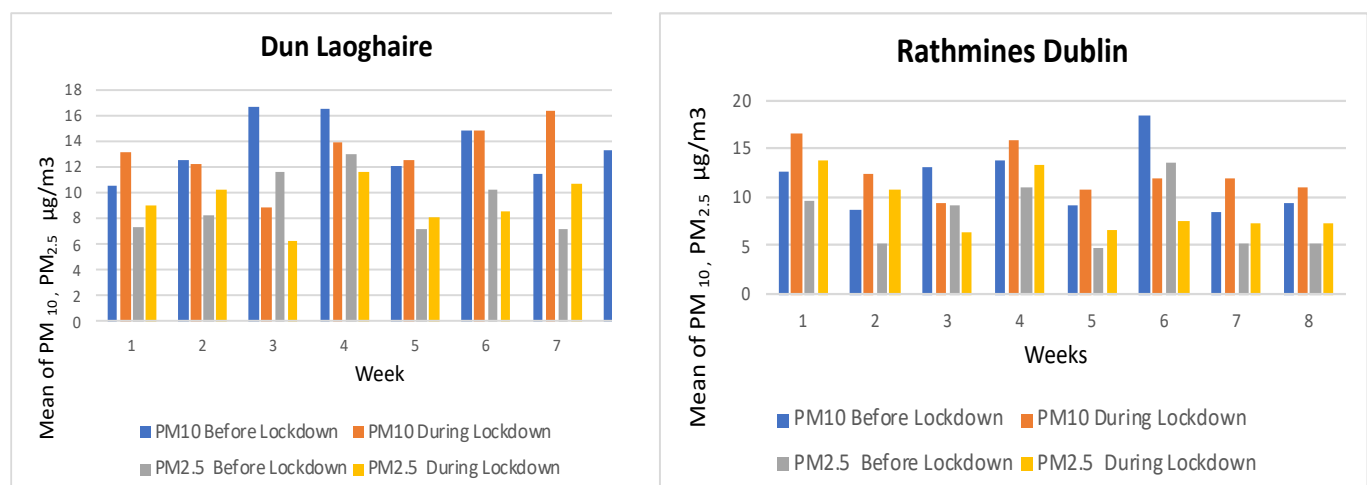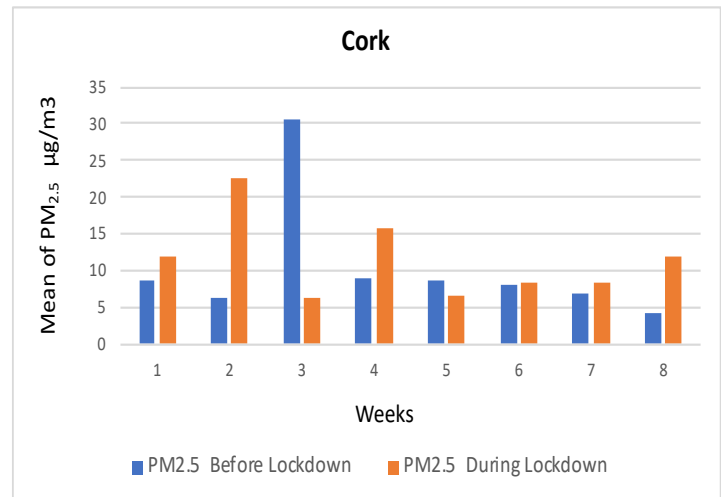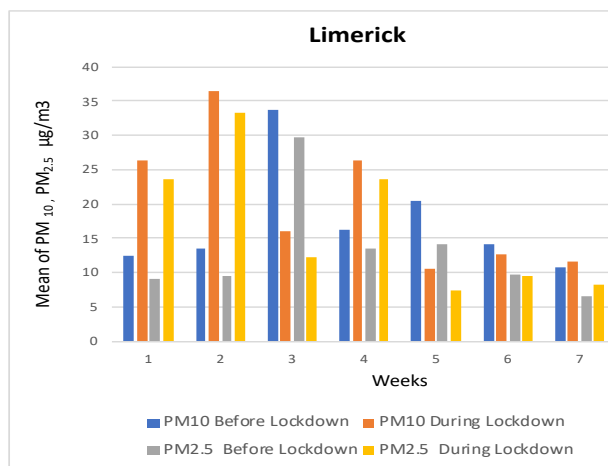
The bar graphs above demonstrate the patterns of changes in concentration of PM10 and PM2.5 in the air on weekly basis over the period of two months before and during the lockdown in all four places. The mean (μ) PM10 and PM2.5 are shown on the Y-axis and the given period in the week on the X-axis. The blue bar represents the PM10 concentration before lockdown and the orange bar during the lockdown. The grey bar represents the concentration of PM2.5 before lockdown and the yellow bar represents during the lockdown. As in the table above these graphs also show the overall increase in PM10 and PM2.5 during the lockdown. There are not many changes in Dublin. Whereas in Limerick there is a significant increase in both PM10 and PM2.5. In Cork, the PM10 data was unavailable therefore the graph shows only PM2.5, which is slightly increased during the lockdown.

Figure 2: Changes in Nitrogen Oxide (NO_2) concentrations before and during lockdown in Dublin, Limerick and Cork.
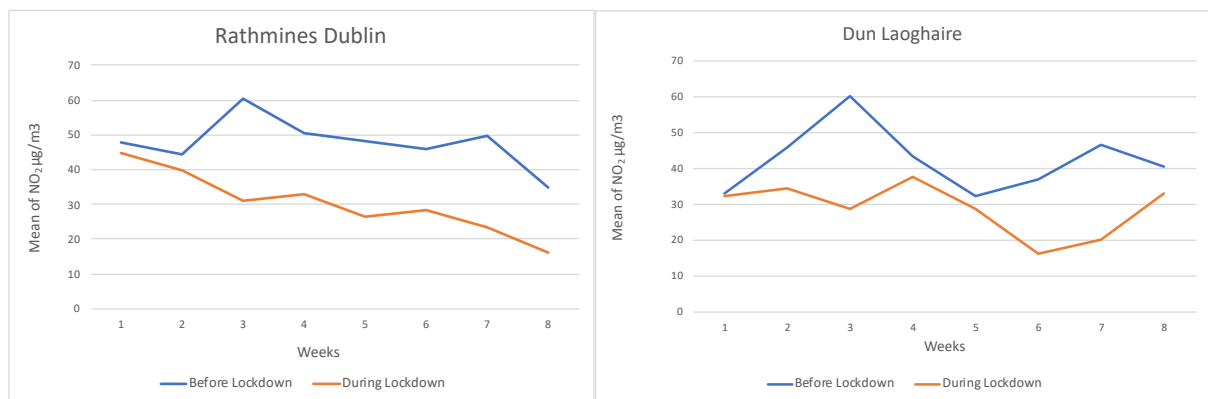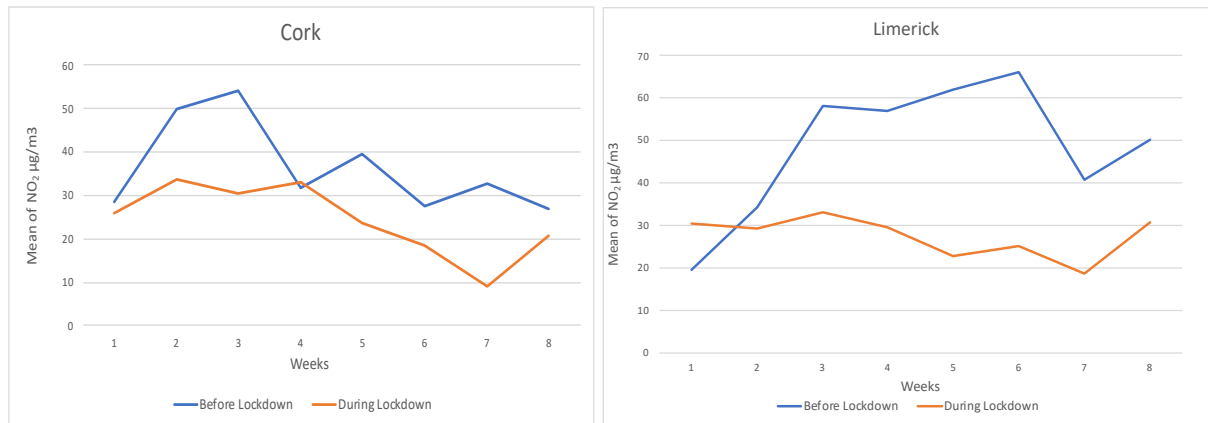
The line charts above displays the patterns of changes in concentration of Nitrogen dioxide NO2 pollutant in the atmosphere of three cities over the period of 60 days before and during the lockdown. The Y-axis shows the mean (μ) of NO2 on the in $\mu g/m3$ and the X-axis shows the given time frame. The blue line represents the concentration of NO2 before lockdown and the orange line represents during the lockdown. All charts show a significant decrease in NO2 concentration during the lockdown.

Discussion

This study has attempted to investigate the impact of strict lockdown on environmental components such as PM10, PM 2.5, and NO2 before and during the period of lockdown. From the obtained results that it could be noted that the government's response to the covid-19 virus by mobility restrictions have significant impacts on the air quality with substantial differences among air pollutants in all three cities in Ireland. Results above show that particulate matter PM10, PM2.5 was even increased during the lockdown. Whereas, nitrogen oxide was significantly reduced in comparison to the same period of time in the previous year.

Rainfall is an effective way to remove major air pollutants such as PM2.5. (Wu et al, 2021) Table 2 shows that during lockdown Dublin and Limerick were wetter compared to the previous January and drier in February than previous February. Whereas, Cork was wetter throughout during the lockdown. These rainfall conditions did not reduce the concentration of particulate matter. It is said that when temperature decreases emission particulate matter rates increase (Nam et al. 2010). Table 3 shows that both Dublin and Limerick were colder in January compared to the previous January. Cork was colder throughout the lockdown. It may have contributed to an increase in the particulate matter to some extent.

The results above show during the lockdown Particulate matter levels were increased significantly during the lockdown. Particulate matter is considered to be the main pollutant in Ireland and it is said to be responsible for a broad range of health impacts in the country as well as across the world. Particulate matter consists of very small particles which can be solid and liquid. It is estimated that there are approximately 1,300 premature deaths annually in Ireland caused by air quality from only fine Particulate Matter PM2.5. The sources of these pollutants in Ireland are mainly such as home heating, road traffic, construction. All solid fuels coal, peat, wood produce fine particulate matter PM2.5 emissions. This can impact respiratory and cardiovascular health greatly (EPA Ireland, 2020).

According to the EPA report 2020, nitrogen dioxide levels were reduced up to 50% in 2020 compared to the previous year 2019. The results in table 1 show that NO2 was hugely dropped during the third phase of lockdown January-February in 2021 compared to the same months in 2020. The figure 2, the line charts clearly visualize the pattern of the NO2 deduction over the given time. In Ireland, the primary source of nitrogen dioxide is claimed to be road transport (EPA Ireland, 2020). Therefore it can be argued that the traffic mobility restrictions imposed by the government during the lockdown seem to be the key factor for the results of the NO2 reductions in Ireland as in many other countries such as India, Brazil, China, Korea, and Morocco.

Conclusion

The positive impacts of restrictions on traffic and mobility on air quality during the third phase of lockdown are studied with the baseline period in the previous year in three cities Dublin, Limerick, and Cork. Real-time data of air quality and weather were used. A quantitative and comparative method was used to conduct the empirical analysis. The air component particulate matter PM10, PM 2.5, and nitrogen dioxide NO2 were tracked in the data as they are considered to be the most pollutants in the atmosphere. Meteorological elements rainfall and temperature also were tracked along with the air components. The results were calculated using the arithmetic mean equation as it includes all the given values. Particulate Matter PM and PM 2.5 were increased during the lockdown despite the volume of rainfall. The temperature remains slightly colder during the lockdown it may have some effects on air components. Nitrogen oxide NO2 was greatly reduced in Ireland too during the lockdown as in many countries, which were mentioned previously in the research design.

References

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Data sources

Air Quality data
https://airquality.ie/

Meteorology data
https://www.met.ie/climate/available-data
https://data.gov.ie/organization/meteireann?q=&tags=+Daily&sort=views+desc