Irish Medical Journal
Established 1867

Issue: Ir Med J; Vol 114; No. 7; P413

Impact of COVID-19 Lockdown Restrictions: Ambient NO_2 and Asthma Hospital Admissions

K.I. Quintyne[1,2], C. Kelly[1], A. Sheridan[1], P. Kenny[3], M. O'Dwyer[3]

1. Department of Public Health, Health Service Executive (HSE) North-East, Navan, Co. Meath.
2. School of Public Health, University College Cork, College Road, Co. Cork.
3. National Ambient Air Quality Unit (NAAQU), Environmental Protection Agency (EPA), Clonskeagh Road, Co. Dublin.

Abstract

Aim

The World Health Organization (WHO) declared the COVID-19 pandemic a global health emergency. Many countries of the world, including Ireland, closed their borders and imposed nationwide lockdown. During this period, all major anthropogenic transport activities, which contribute to atmospheric pollution, were restricted. The current study examines the impact of the transport restrictions on ambient nitrogen dioxide (NO_2) concentrations and hospital admissions for asthma across Ireland.

Methods

This is a retrospective population-based cohort study. National ambient air quality monitoring network data were analysed to investigation variations in NO_2 concentrations. Asthma hospital admissions data were collected from the HSE Hospital In-patient Enquiry (HIPE) for Cork, Dublin, and Meath.

Results

During the period of transport restrictions, there were reductions in the annual mean NO_2 for Cork, Dublin and Meath (i.e. 12µg/m^3 to 11µg/m^3 ($p = 1$); 25µg/m^3 to 17µg/m^3 ($p < 0.001$); and 23µg/m^3 to 21µg/m^3 ($p = 1$)). Reductions in asthma hospital admissions were also observed. Among the 8,471 patient episodes included in this study, the mean [SD] age at admission was 47.2[22.9] years; 61% were female (n=5,134); mean [SD] length of stay was 4.9[10.9] days.

Conclusion

The findings of this study provide an opportunity to explore the impact of NO_2 emissions for Cork, Dublin and Meath on asthma hospital admissions, in order to improve air quality modelling and policy development of management of asthma.

Keywords: COVID-19; Air pollution; Ambient NO_2; Transport restrictions; Hospital morbidity.

Introduction

Coronavirus disease 2019 (COVID-19) is a declared pandemic of the 21st century.[1 2] It was initially identified in Wuhan, China in December 2019 as a pneumonia of unknown origin. The peculiarity of COVID-19 is that it is spread through droplets, and has spread rapidly globally.[2] The outbreak of COVID-19 has led many countries to shut their borders and impose nationwide lockdown. In Ireland, the COVID-19 transport restrictions were introduced from March 2020 to mitigate for contagion within the community.

Due to the COVID-19 lockdown, anthropogenic vehicular energy-consuming activities were restricted. These transport restrictions recommended that residents in Ireland reduce transport through closure of non-essential services; encouragement of where possible for employees to work remotely; and only allow individuals to movements within limited distance of their places of residence (initially two kilometres then five kilometres). [3] As the pandemic progressed and levels of COVID-19 in the community reduced, these travel restrictions were relaxed in May 2020, with the proviso that all non-essential travel was kept to a minimum to reduce congregation and propagation of infection.[3] In September 2020, Dublin saw the return of travel restrictions, which limited residents in Dublin from leaving the county. This was followed in October 2020 with re-introduction of full lockdown for Ireland due to rise in COVID-19 cases.[3] Gradual relaxation of travel restrictions started in early December 2020, but due to rapid rise in cases was short-lived and resulted in full travel restrictions returning in December 2020.[3] Reports on compliance with the government advice and guidelines COVID-19 varied from 60% to 80% from April to November 2020.[4] Recent studies using ground-based monitoring data have reported significant changes in ambient air pollutants during lockdowns.[5-10] The concentrations of ambient nitrogen dioxide (NO_2) declined significantly internationally, but varied geographically based on local confounding factors.

There are increasing reports in the literature about the impact of NO_2 on the natural history of persons with asthma (i.e. aggravating or triggering exacerbations). Additionally, research has noted that short-term exposure (i.e. less than 24 hours) even for annual mean NO_2 values of less than 50µg/m^3, have been associated with increased hospital admissions.[11-14] There is growing evidence to suggest that long-term exposure to NO_2 levels below the World Health Organization (WHO) recommended air quality annual mean guideline of 40µg/m^3 can be associated with less favourable health outcomes (i.e. hospital admissions, and mortality).[15-17]

Traffic is the major cause of air pollution, and a major source of outdoor NO_2 in Ireland.[18] There has been increasing attention of ambient air pollution from anthropogenic vehicular sources; a shift has occurred for tackling impact on human health and adherence to international commitment to air quality directives.

In this study, ambient NO_2 levels obtained from national ambient air quality network monitoring system were used to understand the impact of COVID-19 lockdown restrictions on the NO_2 concentrations in across Ireland. It will also explore the relationship between NO_2 and acute asthma hospital admissions for residents in Cork, Dublin, and Meath between 2018 and 2021.

This would allow the authors to add to the national and international bodies of evidence about the effect of ambient NO_2 on human health in Ireland and could validate scientific interpretation and support air pollution management, including inputs for air quality modelling.

Methods

This study used routinely gathered hospitalisation data collected from the Health Service Executive (HSE) Hospital In-Patient Enquiry (HIPE) system.[19] This repository is a well established, quality assured, national hospital care information system that uses ICD10-AM/ACHI/ACS coding to capture demographic, clinical and care data at discharge on all episodes of emergency and elective care across publicly funded hospitals in Ireland. Daily counts of hospital admissions were obtained for residents (all ages) with an address in Cork, Dublin, and Meath admitted on same day. These admissions were individuals with primary diagnoses of asthma (ICD 10AM codes J45, J46) for January 2018 to February 2021.

The NO_2 data collected from the national ambient air quality monitoring network in Cork, Dublin, and Meath were obtained from the Environmental Protection agency (EPA). The daily average results from each station were provided, and these were all combined to an overall daily average for Cork, Dublin, and Meath was generated. A further strategy was used: this involved employing equal cut-off points (i.e. quartiles) by ordering the distribution to review the impact of high versus low levels of NO_2.

In order to identify the impact on the acute hospital services, the following variables were examined: number of admissions; average age on admission (years); average length of stay (days); and gender. To take account for potential differences in age-profile of cases, data for asthma-related admissions were stratified according to the following age groups: 0 – 17 years; 18 – 64 years; and 65 + years.

Raw and calculated data was collated and entered into Excel (Microsoft 2016) and exported into IBM SPSS Statistics for Windows, Version 26.0 (Armonk, NY). We analysed the data by applying descriptive statistics. All results were considered significant at $p < 0.05$ (two-tailed). For correlation of metric variables, Spearman rank order (rho), and for correlations of nominal variables, the $\chi 2$-test, and for small sample sizes, the Fisher's Exact test was used. All results of various statistical tests are of an explorative nature.

Finally, as this research uses routinely collected data the population level rather than the individual level, it conforms to the Helsinki Declaration, and does not require approval from an ethics committee.

Results

The daily hospital admission data in Cork are shown in Figure 1, and revealed overall decreasing numbers of admissions for the three-year period ($p < 0.001$), that corresponded to a decrease in annual mean NO_2 levels ($p < 0.001$).

The daily hospital admission data in Dublin are displayed in Figure 2, and has shown overall reducing numbers of admissions for the three-year period ($p < 0.001$), which corresponded to a decrease in annual mean NO_2 levels ($p < 0.001$).

The daily hospital admission data in Meath are displayed in Figure 3, and highlighted overall decreasing numbers of admissions for the three-year period ($p = 0.005$), that corresponded to a decrease in annual NO_2 levels ($p = 0.003$).

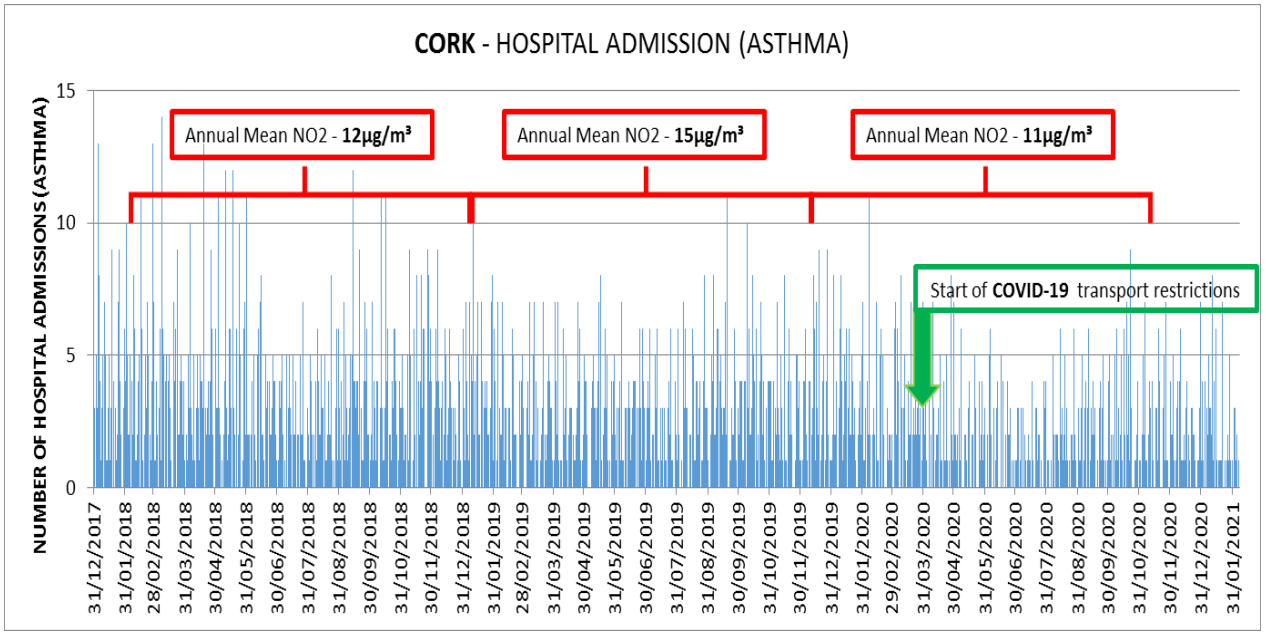

Figure 1: Daily number of asthma hospital admissions in Cork between 2018 and 2021.

Data provided from HIPE from 2020 to present is provisional, and subject to final validation.

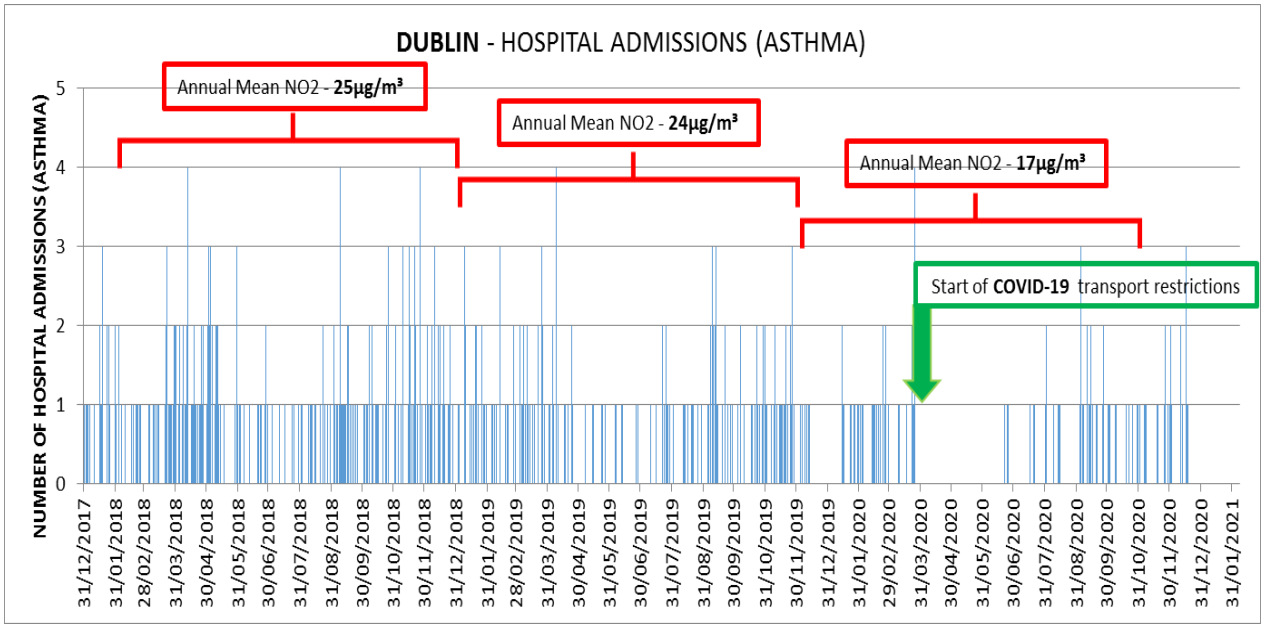

Figure 2: Daily number of asthma hospital admissions in Dublin between 2018 and 2021.

Data provided from HIPE from 2020 to present is provisional, and subject to final validation.

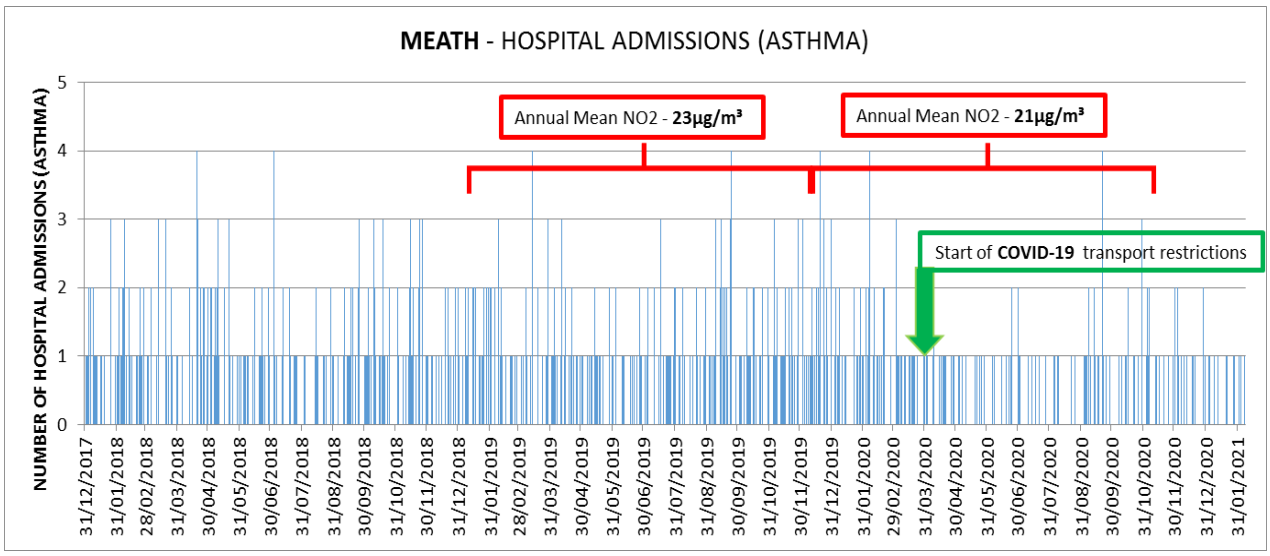

Figure 3: Daily number of asthma hospital admissions in Meath between 2018 and 2021.

Data provided from HIPE from 2020 to present is provisional, and subject to final validation. Among the 8,471 patient episodes included in this study, the mean [SD] age at admission was 47.2[22.9] years; 61% were female (n=5,134); mean [SD] length of stay was 4.9[10.9] days. The impacts of stratified levels of ambient mean NO_2 levels on hospital by county are described in **Table** 1. It highlighted statistically significant increases in number of asthma admissions in Cork and Meath with increasing levels of NO_2. It additionally revealed that the ambient levels of NO_2 in Meath did not exceed 31µg/m^3.

Table 1: Distribution of asthma hospital admissions for residents of Cork, Dublin, and Meath stratified by level of NO_2 from 2018 and 2021.

CHARACTERISTICS	MEAN NUMBER OF DAILY HOSPITAL ADMISSIONS				χ^2 TEST
	≤ 15µg/m^3	16 – 30µg/m^3	31 - 45µg/m^3	≥ 46µg/m^3	
ASTHMA - CORK					
All ages	3.15	3.70	3.87	3.60	**0.004**
0 – 17 years	1.21	1.23	1.14	1.00	0.848
18 – 64 years	2.29	2.65	2.53	2.75	**0.050**
65 + years	1.56	1.69	1.68	1.67	0.438
ASTHMA - DUBLIN					
All ages	1.24	1.31	1.43	1.44	0.140
0 – 17 years	2.63	2.75	2.75	3.28	0.072
18 – 64 years	1.66	1.69	1.68	1.87	0.338
65 + years	3.56	3.68	3.67	4.48	**0.046**
ASTHMA - MEATH					
All ages	1.21	1.55	No data	No data	**0.005**
0 – 17 years	1.08	1.00	No data	No data	0.526
18 – 64 years	1.13	1.21	No data	No data	0.450
65 + years	1.06	1.33	No data	No data	0.109

Data provided from HIPE from 2020 to present is provisional, and subject to final validation.

X^2 testing for Cork and Dublin compared ≤ 15µg/m^3 and ≥ 46µg/m^3 results.

X^2 testing for Meath compared ≤ 15µg/m^3 and 16 – 30µg/m^3 results.

Discussion

The main finding of this study using routinely gathered information was that there were reductions in levels of ambient NO_2 across Ireland from 2018 to 2020 were statistically associated with decreases in asthma hospital admissions. The reduction in this transport-related air pollutant (i.e. NO_2) was in large part due to the introduction of COVID-19 lockdown restrictions, which discouraged movement beyond distance from home and in turn reduced vehicular emissions. These findings are consistent with recently published reports.[5-7 9 10 17 20] There was some variation in the levels of ambient NO_2 noted in the areas selected for review, and the degree in reductions noted over the investigation period was not consistent. Additionally, it should be noted that Cork did not experience as high levels of ambient NO_2 as Dublin and Meath. These findings are probably related to heterogeneous combinations of population density, level of vehicular use, level of available mass transit infrastructure, and distribution of ambient air quality monitoring stations. Similiar factors have also be noted in literature. [8 16]

This study provides evidence of an association between population exposure to ambient air pollution (i.e. NO_2) and aggravation or exacerbation of asthma episodes that warrant acute hospital admissions. The decreases in ambient NO_2 and asthma hospital admissions following the introduction of COVID-19 lockdown restrictions coincided with overall reduction in acute hospital admissions due to pressure on healthcare system from COVID-19. This is not controlled for in this review, as it would require differential calculations on all diseases and requirements for acute and emergency hospital admissions. To support the results obtained, it was noted that there was a statistically significant correlation and impact from changes in NO_2 levels and asthma hospital admissions (i.e. showing that increases in daily ambient NO_2 and high overall ambient levels of NO_2 above the WHO threshold are associated with increases in hospital admissions in all areas). Furthermore, each area under review coincidentally did not have any major air pollution episodes (i.e. single limited event or ongoing events) reported to the HSE and EPA to support other factors influencing these findings. It should however be noted that this study cannot comment on whether NO_2 is the causal agent or rather serving as a marker of transport-related air pollution mixture for these findings.

Based on the results, it is reasonable to infer that the ambient NO_2 levels have short-term impact on asthma hospital admissions in Cork, Dublin and Meath. It has varying degrees of impact in the areas under review with different age groups being predominantly affected. The latter findings might be related to the socio-demographic factors in each area. Similar findings have been documented in the literature.[20] These findings may also be in addition to the implementation of the clinical asthma programme and further rollout of the asthma chronic disease management programme by General Practitioners (GPs); and the co-benefit outcome of COVID-19 restrictions, whereby circulation of respiratory pathogens that might trigger infective exacerbations of asthma were not allowed to propagate. These have also been reported in recent reports.[9 10 17]

It was also noted that the number of episodes of ambient NO_2 levels exceeding the WHO annual mean guideline of 40µg/m^3 have reduced with the introduction of COVID-19 lockdown restrictions. Given that vehicular transport is the major source of ambient NO_2 in Ireland, it is reasonable to assume that there is no other explanation for the change in this ambient air pollution.

A previously acknowledged caveat is that the ambient air quality monitoring network in Ireland may not have historically been sufficient to accurately characterise the spatial patterns for ambient NO_2 across Ireland. This can potentially lead to under-estimates in this daily ambient air pollutant. These may occur because the ambient air quality network has a limited number of stations, some of which might be more sued during transport restrictions. A number of statistical approaches have been employed to reduce this occurrence, including modelling and development of forecasting frameworks. However, these strategies are not a substitute for improved data collection, and the EPA is currently and continually enhancing and expanding the ambient air quality network.

There are a series of limitations linked to this study. The first limitation is that there is not homogenous distribution of ambient air quality monitoring units in all areas under investigation. The placement of units is based on predetermined criteria that conform to the European Environmental Agency (EEA) guidelines, and it would not be advisable to place these monitoring units in areas that are not compliant, as it will be challenging to validate the results obtained. The second limitations is related to the lack individual level information on medical co-morbidities and smoking status. This might have to further quantify the level of impact on persons at high-risk for impact of high levels of NO_2. Access to this level of information would be useful and relevant, but would require ethical approval, which was not necessary to undertake this current piece of work. In addition, the third limitation is that some of the individuals with asthma included might have impact from poor air quality episodes, which do not result in hospital admissions. Ambulatory care in general practice, outpatient settings, emergency room visits that do not conclude in hospital admission, and pharmacy attendances are not traditionally captured by the HIPE system. Given that there is no consistent and equitable way to gather any of the aforementioned healthcare interactions, the hospital admissions is the best surrogate for capturing morbidity related to poor ambient NO_2 levels for this piece of work.

Among residents in Cork, Dublin and Meath, decreases in ambient NO2, between 2018 and 2020, were significantly associated with lower asthma hospital admissions, following the introduction of COVID-19 lockdown restrictions. It also revealed that the ambient NO_2 levels were predominantly compliant with WHO annual mean guideline of 40µg/m^3. The findings of this work should serve as an impetus for development of air quality policy in Ireland to sustain lower levels of ambient NO_2.

Acknowledgements:
We are grateful to Healthcare Pricing Office (HPO) for allowing access to the HIPE data that was used in this study. We are also grateful to Dr Kevin Kelleher, Assistant National Director for Public Health & Child Health for his support and guidance in getting this study 'off the ground'.

Ethical Approval:
This research uses routinely collected data the population level rather than the individual level; it conforms to the Helsinki Declaration, and does not require approval from an ethics committee.

Declaration of Conflicts of Interest:
The authors declare no conflict of interest.

Corresponding Author:
Dr Keith Ian Quintyne
Department of Public Health
Railway Street
Navan
Co. Meath
E-Mail: keithi.quintyne@hse.ie

References:

1. Jee Y. WHO International Health Regulations emergency committee for the COVID-19 outbreak. Epidemiology and health 2020;42
2. Chen N, Zhou M, Dong X, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. The lancet 2020;395(10223):507-13.
3. Department Of Health (DOH). COVID-19 Updates 2020 [Available from: https://www.gov.ie/en/news/7e0924-latest-updates-on-covid-19-coronavirus/ Accessed 03/06/2021
4. Central Statistics Office (CSO). Social Impact of COVID-19 Survey November 2020 Well-being and Lifestyle under Level 5 Restrictions 2020 [Available from: https://www.cso.ie/en/releasesandpublications/ep/p-sic19wbl5/socialimpactofcovid-19surveynovember2020well-beingandlifestyleunderlevel5restrictions/ Accessed 03/06/2021
5. Wu X, Nethery RC, Sabath BM, et al. Exposure to air pollution and COVID-19 mortality in the United States. MedRxiv 2020
6. Berman JD, Ebisu K. Changes in US air pollution during the COVID-19 pandemic. Science of the Total Environment 2020;739:139864.
7. Dutheil F, Baker JS, Navel V. COVID-19 as a factor influencing air pollution? Environmental Pollution (Barking, Essex: 1987) 2020;263:114466.
8. Gautam S. COVID-19: air pollution remains low as people stay at home. Air Quality, Atmosphere & Health 2020;13:853-57.

9. Venter ZS, Aunan K, Chowdhury S, et al. COVID-19 lockdowns cause global air pollution declines. Proceedings of the National Academy of Sciences 2020;117(32):18984-90.
10. Venter ZS, Aunan K, Chowdhury S, et al. Air pollution declines during COVID-19 lockdowns mitigate the global health burden. Environmental research 2021;192:110403.
11. Weinmayr G, Romeo E, De Sario M, et al. Short-term effects of PM10 and NO2 on respiratory health among children with asthma or asthma-like symptoms: a systematic review and meta-analysis. Environmental health perspectives 2010;118(4):449-57.
12. Garcia E, Berhane KT, Islam T, et al. Association of changes in air quality with incident asthma in children in California, 1993-2014. Jama 2019;321(19):1906-15.
13. Quintyne K, Sheridan A, Kenny P, et al. Air Quality and Its Association with Cardiovascular and Respiratory Hospital Admissions in Ireland. Irish medical journal 2020;113(6):92-92.
14. Kelly FJ, Fussell JC. Air pollution and airway disease. Clin Exp Allergy 2011;41(8):1059-71. doi: 10.1111/j.1365-2222.2011.03776.x [published Online First: 2011/06/01]
15. Guarnieri M, Balmes JR. Outdoor air pollution and asthma. The Lancet 2014;383(9928):1581-92.
16. Casquero-Vera JA, Lyamani H, Titos G, et al. Impact of primary NO2 emissions at different urban sites exceeding the European NO2 standard limit. Science of The Total Environment 2019;646:1117-25.
17. Liu F, Wang M, Zheng M. Effects of COVID-19 lockdown on global air quality and health. Science of the Total Environment 2021;755:142533.
18. European Environmental Agency (EEA). Air quality in Europe—2019 report: European Environment Agency (EEA) Luxembourg, 2019.
19. eHealth Ireland. HPO HIPE 2021 [Available from: https://data.ehealthireland.ie/group/about/hpo-hipe Accessed 03/06/2021 2021.
20. Servadio JL, Lawal AS, Davis T, et al. Demographic Inequities in Health Outcomes and Air Pollution Exposure in the Atlanta Area and its Relationship to Urban Infrastructure. J Urban Health 2019;96(2):219-34. doi: 10.1007/s11524-018-0318-7 [published Online First: 2018/11/28]