The University of British Columbia

Examining $PM_{2.5}$ Concentration Levels Before and After COVID-19 Restrictions at Vancouver International Airport

Group 1: Paul Li (25131863), Edriane Maglinte (32068280), Jessica Matthews (71167324)

Dr. Nina Hewitt

GEOG 374 Final Project

16 April 2021

Introduction

The COVID-19 restrictions caused a shutdown of industrial and travel activities in 2020 to control the spread of the virus. Studies around the world have examined the impacts of COVID-19 on ambient air pollution (Berman & Ebisu, 2020; Ghahremanloo, Lops, Choi, Mousavinezhad, 2021; Ju, Oh, & Choi, 2021; Venter, Aunan, Chowdhury, & Lelieveld, 2020), which all concluded a statistically significant reduction of air contaminants during the COVID-19. However, no studies have focused on the impacts of international air travel restrictions on the pollution levels during COVID-19. For our study, we examined whether the decline in air travel during COVID-19 restrictions in Canada had a significant impact on local air pollution. We analyzed $PM_{2.5}$ concentrations from an air monitoring station at Vancouver International Airport (YVR #2).

Data analysis

$PM_{2.5}$ was chosen to study because it is one of the major air pollutants from vehicles (Masiol & Harrison, 2014; McKendry, 2000). We converted mean daily $PM_{2.5}$ concentrations into weeks (109 in total), which were then assigned a positive or negative value based on the first week of lockdown (March 18th, 2020) in BC.

Our exploratory analysis revealed weekly $PM_{2.5}$ data violated all three assumptions of Pearson's correlation coefficient including normality, homoscedasticity, and the absence of major outliers (Figure 1). Weekly data was slightly positively skewed from the normal quantile plot and heteroscedastic from the residual plot (Figure 1). Additionally, outliers were also present (Figures 1-2) and the dataset exhibited a non-monotonic and non-linear relationship between weeks and $PM_{2.5}$ concentrations.

Spearman, as a non-parametric test, is not based on the assumption of normality and is less sensitive to outliers. It can also be used to assess monotonic relationships and to determine if there is a monotonic component in non-monotonic data. Therefore, regression using Spearman's rank correlation coefficient was the only viable method to use, despite the limitation of addressing heteroscedastic data. Therefore, for our analysis, we used Spearman's to examine if there was a significant negative relationship between weeks after COVID-19 restrictions and pollutant concentrations.

We determined the null (H_0) and alternative hypotheses (H_1), and the significance level ($\alpha = 0.05$). The H_0 stated that the population correlation coefficient was not significantly different from 0 where there was no significant monotonic relationship between $PM_{2.5}$ concentrations and weeks during COVID-19. The H_1, on the other hand, stated the population correlation coefficient was significantly different from 0 where there was a monotonic relationship between $PM_{2.5}$ concentrations and weeks during COVID-19.

Results

Our results for the Vancouver International Airport (YVR) showed that there was a slight decline of $PM_{2.5}$ concentrations since the start of the COVID-19 restrictions ($\rho = -0.24$, $p < 0.01$; Figure 3). As the p-value was less than 0.01, we rejected the H_0 because the population correlation coefficient was different from 0 and there was enough evidence to support a monotonic relationship between $PM_{2.5}$ concentrations and weeks during COVID-19 despite the relationship being weak ($\rho = -0.24$). The direction of the least-squares best-fit line was influenced by the outliers in weeks 25 and 26, which would be further elaborated in the discussion (Figure 3). The trend of $PM_{2.5}$ also exhibited seasonality where the $PM_{2.5}$ concentrations were lowest in spring-summer and peaked in winter.

Discussion

The dataset chosen had limitations and was insufficient in some areas to truly report a decline in air pollution during COVID-19 restrictions. For example, more ambient air pollutants would need to be analyzed to track overall air pollution. The least-squares best-fit line reported that $PM_{2.5}$ increased at YVR (Figure 3). This was likely due to the spike in weeks 25-26 (Figure 2), which corresponded with the outliers (Figure 3). Air quality was highly influenced by seasonality. In August and September 2020, there were major forest fires in the Lower Mainland, causing spikes and extreme outliers (Figures 2-3). Vancouver was ranked number one for the worst air quality in the world (Crawford, 2020).

Other confounding climate variables might also be associated with the seasonality of $PM_{2.5}$ concentrations, which impacted the correlation between $PM_{2.5}$ concentrations and weeks after COVID-19 restrictions, thus resulting in a weak negative relationship at YVR. Specifically, temperature, relative humidity, wind speed, barometric pressure, and precipitation were all associated with $PM_{2.5}$ concentrations in warm and cold seasons from various studies across the world (Tai, Mickley, & Jacob, 2010; Yang, Yuan, Li, Shen, & Zhang, 2017). One study in the United States found that the daily variation in meteorology could explain up to 50% of $PM_{2.5}$ variability with temperature, relative humidity, and precipitation (Tai et al., 2010). Nevertheless, the $PM_{2.5}$ concentrations did exhibit a negative relationship with the weeks after COVID-19 restrictions at YVR. Additionally, we were unable to remove seasonality, which impacted our results. Pursuing Spearman's rank analysis also did not help address the issue of heteroscedasticity in which the law of homoscedasticity would still be violated given the distribution of weekly $PM_{2.5}$ concentrations. Future research should consider these obstacles.

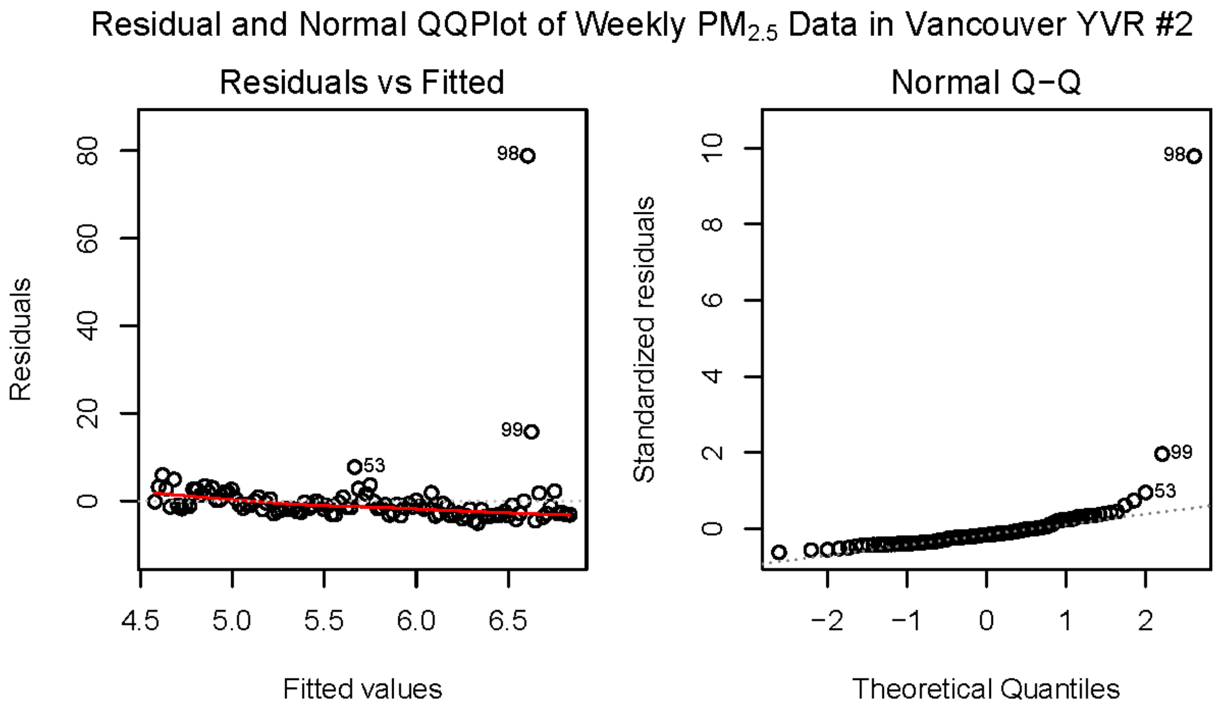

Figure 1: Residual and Normal QQPlot of Weekly $PM_{2.5}$ Data in Vancouver YVR #2

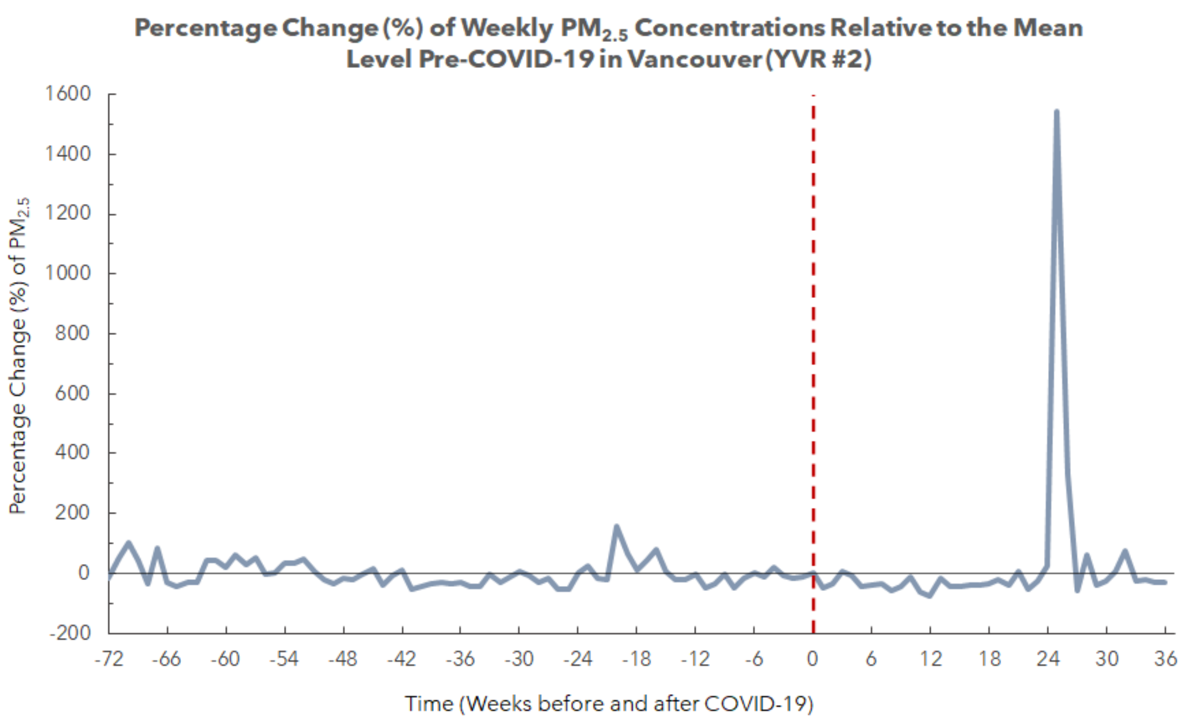

Figure 2: Percentage Change (%) of Weekly $PM_{2.5}$ Concentrations Relative to the Mean Level Pre-COVID-19 in Vancouver YVR #2

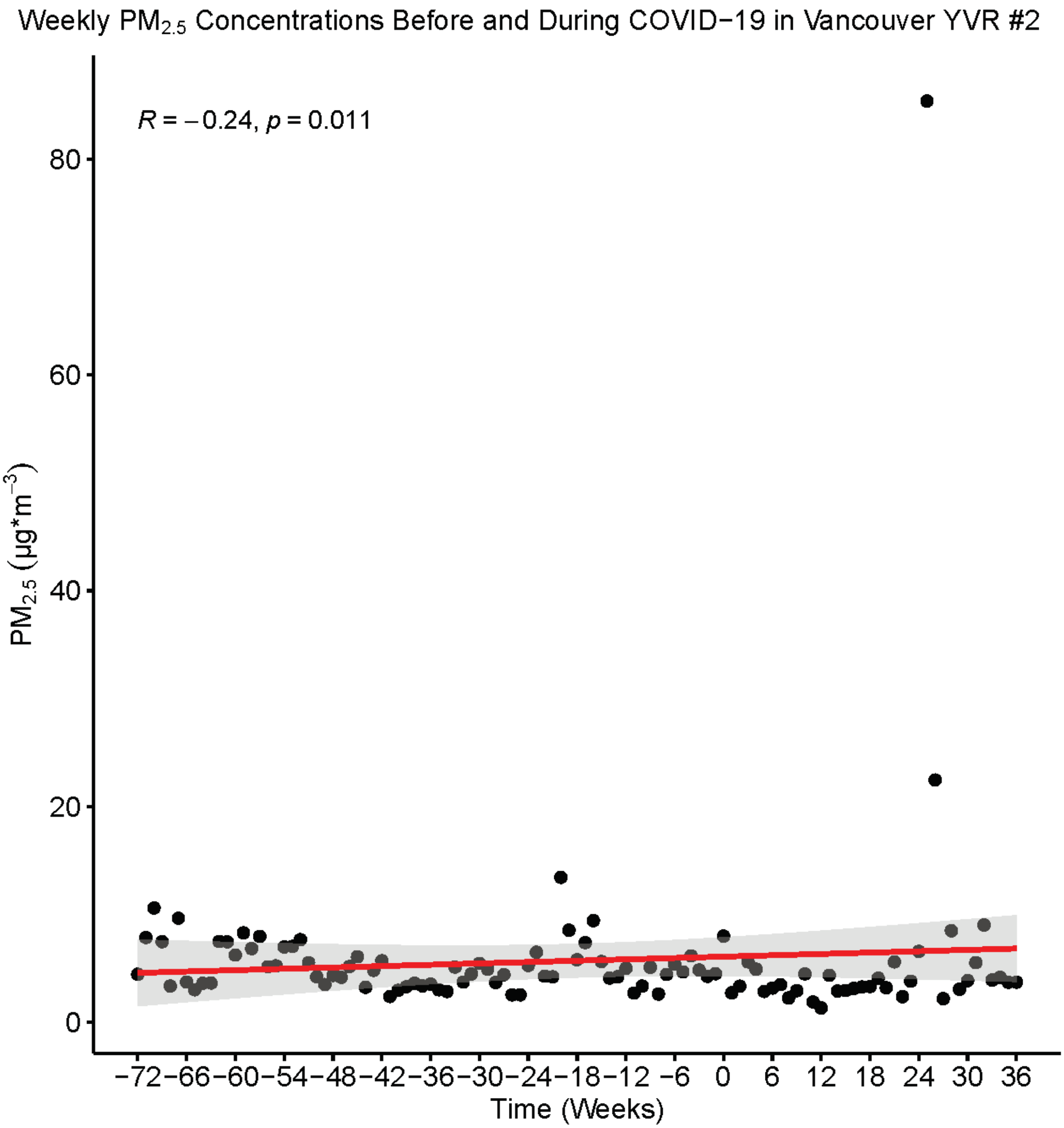

Figure 3: Weekly $PM_{2.5}$ Concentrations Before and During COVID-19 in Vancouver YVR #2 with 95% Confidence Interval

References

Berman, J. D., & Ebisu, K. (2020). Changes in U.S. air pollution during the COVID-19 pandemic. *Science of The Total Environment*, *739*, 139864. https://doi.org/10.1016/j.scitotenv.2020.139864

British Columbia Ministry of Environment. (n.d.). *BC Air Data Archive*. Retrieved from https://envistaweb.env.gov.bc.ca/

Bonardi, J.-P., Gallea, Q., Kalanoski, D., Lalive, R., Madhok, R., Noack, F., Rohner, D., & Sonno, T. (2021). Saving the world from your couch: The heterogeneous medium-run benefits of COVID-19 lockdowns on air pollution. *Environmental Research Letters*. https://doi.org/10.1088/1748-9326/abee4d

Crawford, T. (2020, September 13). Vancouver air quality among the worst in the world Saturday. *Vancouver Sun.* https://vancouversun.com/news/vancouver-air-quality-among-the-worst-in-the-world-saturday

Dawkins, G. (2019, July 7). Air quality warning issued for Winnipeg due to forest fire smoke. *Winnipeg Sun.* https://winnipegsun.com/news/local-news/air-quality-warning-issued-for-winnipeg-due-to-forest-fire-smoke.

Ghahremanloo, M., Lops, Y., Choi, Y., & Mousavinezhad, S. (2021). Impact of the COVID-19 outbreak on air pollution levels in East Asia. *Science of The Total Environment*, *754*, 142226. https://doi.org/10.1016/j.scitotenv.2020.142226

Ju, M. J., Oh, J., & Choi, Y.-H. (2021). Changes in air pollution levels after COVID-19 outbreak in Korea. *Science of The Total Environment*, *750*, 141521. https://doi.org/10.1016/j.scitotenv.2020.141521

Masiol, M., & Harrison, R. M. (2014). Aircraft engine exhaust emissions and other airport-related contributions to ambient air pollution: A review. *Atmospheric Environment*, *95*, 409–455. https://doi.org/10.1016/j.atmosenv.2014.05.070

McKendry, I. G. (2000). PM $_{10}$ Levels in the Lower Fraser Valley, British Columbia, Canada: An Overview of Spatiotemporal Variations and Meteorological Controls. *Journal of the Air & Waste Management Association*, *50*(3), 443–452. https://doi.org/10.1080/10473289.2000.10464025

Requia, W. J., Jhun, I., Coull, B. A., & Koutrakis, P. (2019). Climate impact on ambient PM2.5 elemental concentration in the United States: A trend analysis over the last 30 years. *Environment International*, *131*, 104888. https://doi.org/10.1016/j.envint.2019.05.082

Tai, A. P. K., Mickley, L. J., & Jacob, D. J. (2010). Correlations between fine particulate matter (PM2.5) and meteorological variables in the United States: Implications for the sensitivity of PM2.5 to climate change. *Atmospheric Environment*, *44*(32), 3976–3984. https://doi.org/10.1016/j.atmosenv.2010.06.060

Venter, Z. S., Aunan, K., Chowdhury, S., & Lelieveld, J. (2020). COVID-19 lockdowns cause global air pollution declines. *Proceedings of the National Academy of Sciences*, *117*(32), 18984–18990. https://doi.org/10.1073/pnas.2006853117

Yang, Q., Yuan, Q., Li, T., Shen, H., & Zhang, L. (2017). The Relationships between PM2.5 and Meteorological Factors in China: Seasonal and Regional Variations. *International Journal of Environmental Research and Public Health*, *14*(12), 1510. https://doi.org/10.3390/ijerph14121510