The relationship between $PM_{2.5}$ concentrations, climate change and COVID-19 in Taiwan

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ABSTRACT

The quality of air can significantly impact people's daily lives. Our analysis of the PM2.5 concentration variations by month in Taiwan from 2020 to 2023 revealed that the year 2021 had relatively high PM2.5 levels, while 2022 experienced lower levels. This trend could likely be associated with the reduction in traffic due to the COVID-19 pandemic. In examining the relationship between PM2.5 concentrations and temperature in the Fengyuan area, we observed a slight correlation, with the year 2020 showing a higher correlation.

Keywords: ***PM2.5, air quality, temperature, traffic volume***

1. Research Question and Hypothesis

1. What is the relationship between $PM_{2.5}$ concentration and climate change in various regions of Taiwan?
2. What has been the impact of the COVID-19 on $PM_{2.5}$ concentration in central Taiwan?

2. Introduction and review of literature

Atmospheric particulate matter, commonly known as aerosols, consists of complex components. Its primary sources include earth surface dust, composed of oxides, minerals, and other substances. Another significant source is sea salt, which mirrors the composition of ocean water. Particulate matter also arises from natural processes like volcanic eruptions, dust storms, forest fires, and sea spray, contributing to what is known as primary PM2.5 particles. Secondary PM2.5 particles form when chemicals emitted from natural and human activities undergo photolytic or other chemical reactions. Such activities include coal, oil, and gas burning in power plants, steel manufacturing, petrochemical industries, vehicular emissions, shipping, building paints, agricultural fertilization, animal waste, and domestic sewage.

Pateraki et al. (2012) utilized 53 months of empirical data in Greece and found that $PM_{2.5}$ was significantly correlated with human emission behaviors only under meteorological conditions with wind speeds less than 4.43 m/s and temperatures ranging from 1.9°C to 21.7°C. Furthermore, research from Nagasaki, Japan, suggests there may be a threshold effect of wind speed on particulate matter concentration. The study noted a positive correlation between wind speed and $PM_{2.5}$ concentration when wind speed exceeded 3 m/sec.

3. Research Methods and research equipment

We utilize temperature and precipitation data from the Globe database, supplemented with historical air quality data from the Air Quality Monitoring Network provided by Taiwan's Environmental Protection Department. Taiwan is divided into four geographical regions: North, Central, South, and East. Using Excel, we organize the data to compare $PM_{2.5}$ trend lines across various

locations in Taiwan, as well as temperature and precipitation in the Fengyuan area. Additionally, we analyze the daily traffic volume reference values for highways near the Fengyuan area from the Taiwan Ministry of Transportation's Highway Bureau between 2020 and 2023.

4. Results

(1) Annual Variation of $PM_{2.5}$ Concentration:

Analysis of $PM_{2.5}$ concentrations across various regions in Taiwan indicates that, within each subregion, the months of January to March typically exhibit higher $PM_{2.5}$ levels, while May to August tend to have lower concentrations. This pattern is especially pronounced in the northern, central, and southern parts of Taiwan. In the eastern region of Taiwan, the $PM_{2.5}$ concentrations are noticeably lower throughout the year compared to other areas. (Fig 1.)

(2) Annual Differences in $PM_{2.5}$ Concentration:

Between the years 2020 and 2023, it is observable that the PM2.5 levels were higher in 2021, with a significant spike in concentrations during the months of February and March compared to other years. (Fig 1.)

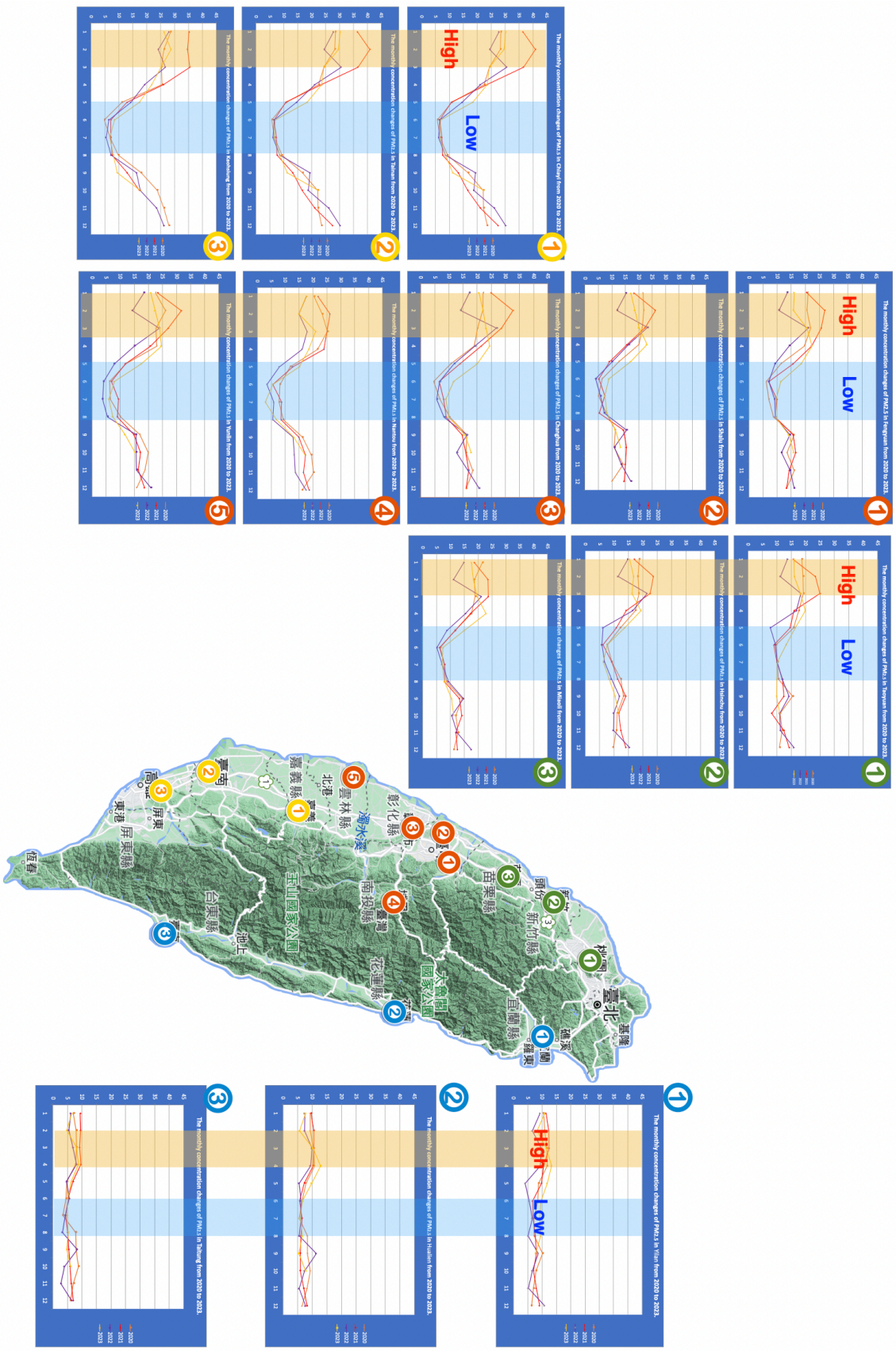

Fig 1. Monthly Variation of $PM_{2.5}$ Concentrations in Different regions of Taiwan from 2020 to 2023.

(3) Relationship Between $PM_{2.5}$ Concentration and Temperature in Fengyuan Area:

Given that our school is located in Fengyuan in central Taiwan, where GLOBE atmospheric observations are conducted, we are particularly interested in the relationship between air quality and weather changes in the area. Research findings suggest a negative correlation between $PM_{2.5}$ concentration and temperature, which was more evident in the year 2020.(Fig 2)

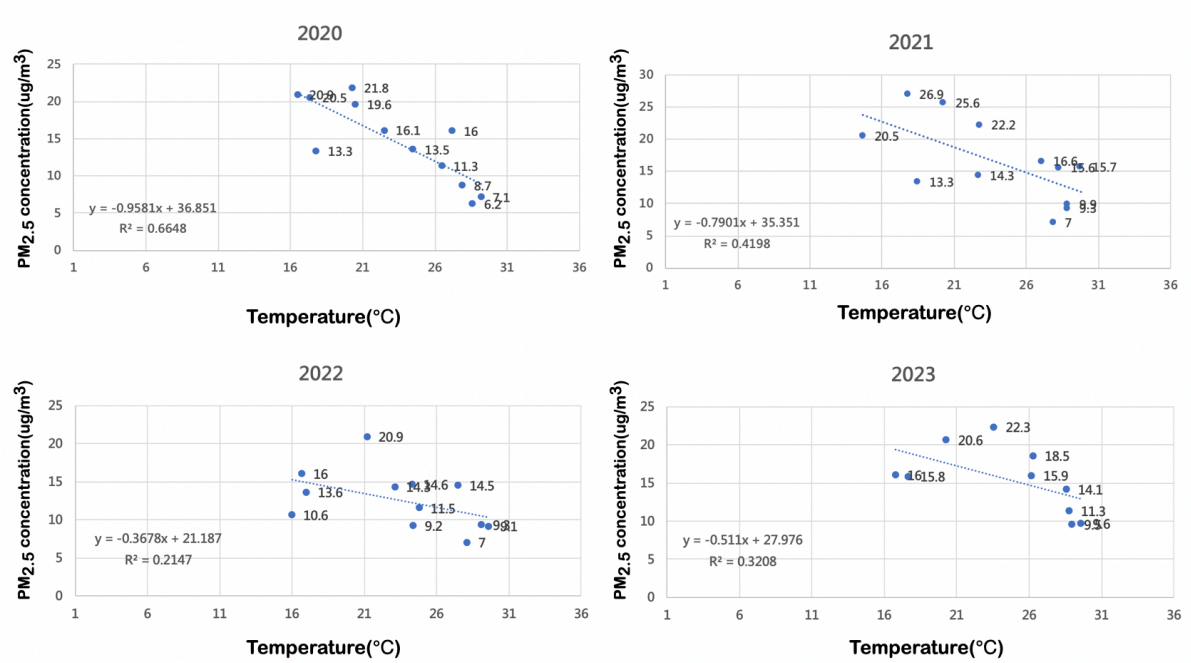

Fig 2. The relationship between $PM_{2.5}$ concentration and temperature in Fengyuan area

(4) Analysis of Traffic Volume on the Freeway Near Fengyuan from 2020 to 2023：

As Taiwan implemented school closures at the end of May 2021 due to the COVID-19 pandemic, the impact of the epidemic on daily life can indeed be observed from the freeway traffic volumes. We also aim to explore the relationship between changes in traffic volume and air pollution.(Fig 3)

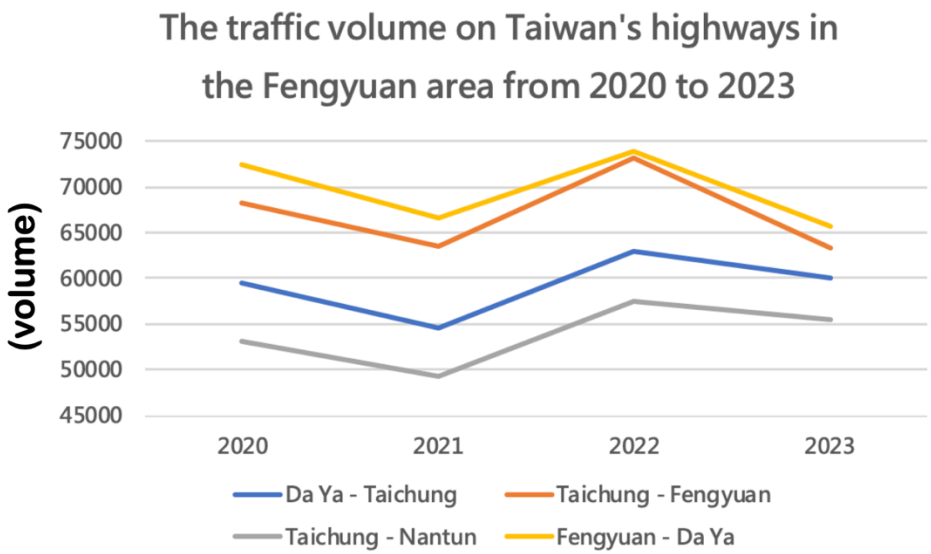

Fig 3. 台灣豐原地區鄰近高速公路路段，於 2020~2023 年間的平日車流量統計

5. Discussion

(1) $PM_{2.5}$ concentrations in northern, central, and southern Taiwan are noticeably higher than in eastern Taiwan: It can be seen from Fig 1 that, between 2020 and 2023, regions west of the Central Mountain Range in Taiwan, including the northern (green numbers 1-3), central (red numbers 1-5), and southern areas (yellow numbers 1-3), exhibit significantly higher $PM_{2.5}$ concentrations compared to the eastern region (blue numbers 1-3). This is likely due to the western part of Taiwan having more developed industrial and commercial sectors, higher population density, and a larger number of vehicles, whereas the east has fewer factories, fewer vehicles, and lower population density. According to data released by the Taiwan Environmental Protection Administration, $PM_{2.5}$ emissions from industries (including the power sector) account for 23% of the national $PM_{2.5}$ emissions, with vehicle emissions and exposed ground dust also contributing significantly, indicating that industry and transportation are the main sources of $PM_{2.5}$ in Taiwan. Thus, the $PM_{2.5}$ concentration in the eastern region of Taiwan is significantly lower than in the northern, central, and southern regions.

(2) During 2020-2023, January to March each year sees the highest $PM_{2.5}$ concentrations: This phenomenon is significantly more pronounced in northern, central, and southern Taiwan than in eastern Taiwan, likely

related to the climatic conditions of the region. After autumn, the northeast monsoon begins in Taiwan, making the eastern and northeastern parts of the island face the wind, while central and southern Taiwan are on the leeward side, experiencing clear, dry, and calm weather. This allows air pollutants to accumulate more easily, and the northeast monsoon often carries foreign pollutants from mainland China to Taiwan. Previous research indicates a significant negative correlation between $PM_{2.5}$ concentrations and cumulative rainfall, and a relationship with wind speed (Hwang, Su-Lun, Yu-Ching Lin, Su-Er Guo, Miao-Ching Chi, Chieh-Mo Lin, Chiang-Ting Chou, and Yu-Shan Huang, 2016), hence autumn and winter (approximately September to the following February) are the main rainy seasons in eastern Taiwan, resulting in significantly lower $PM_{2.5}$ concentrations compared to other regions.

(3) During 2020-2023, May to August each year records the lowest $PM_{2.5}$ concentrations: This may be related to Taiwan's unique climate. May to June marks the rainy season due to stationary fronts, while July to September is the typhoon season, leading to higher rainfall during these months and thus lower $PM_{2.5}$ concentrations.

(4) As seen in Fig 2, there is a negative correlation between $PM_{2.5}$ concentration and temperature in the Fengyuan area of Taiwan, which could be related to atmospheric convection. Higher temperatures enhance atmospheric convection, preventing the accumulation of air pollutants, and higher temperatures are also associated with lower $PM_{2.5}$ concentrations during periods of stationary fronts or typhoons.

(5) Fig 3 shows that 2021 had the lowest traffic flow on highways near the Fengyuan area, coinciding with the spread of COVID-19 in Taiwan starting in May 2021. Schools were closed at the end of May until the second half of 2022 when the situation stabilized and schools resumed. This may explain why $PM_{2.5}$ concentrations were lower in the northern, central, and southern regions of Taiwan between January and March 2022.

6. Bibliography/Citations

Hwang, S.-L., Lin, Y.-C., Guo, S.-E., Chi, M.-C., Lin, C.-M., Chou, C.-T., & Huang, Y.-S. (2016). *Correlations between atmospheric fine particulate matter and meteorological variables in the Chia-Nan Area of Taiwan, 2006-2014*. Taiwan Journal of Public Health, 35(6), 575-586. https://doi.org/10.6288/TJPH201635105066

Division of Labor:

W.C.W: Responsible for determining the research direction, converting data into charts for analysis, and concurrently searching for data and literature.
C.T.E: Responsible for data and literature research, as well as conceptualizing the layout and expression of content for the report.

Collaborative Efforts in Research: A Reflection

This report embodies the wisdom and effort of both team members, Wei Ci Wei and CHEN TZ-EN. Throughout our collaboration, we deeply appreciated the value of division of labor, realizing that efficient division of tasks can significantly enhance the efficiency of completing the paper within a limited timeframe. Moreover, we encountered numerous challenges during the data search process. Fortunately, through our collective efforts, we successfully identified solutions. Through this collaboration, we learned more research techniques and honed our abilities to write academic papers. Additionally, we recognized that trust forms the crucial foundation for team cohesion. We look forward to continuing our collaboration in the future, achieving more goals together, and continuously growing and learning through our teamwork.