Spatiotemporal Variation of $PM_{2.5}$ and its Source Contribution

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Introduction

- Exposure to $PM_{2.5}$ has adverse effects on our health because in our daily lives, we are often exposed to hazardous environments, including vehicle emissions, restaurant fumes, and religious activities. Due to its tiny particle size and ability to absorb more toxic substances, the World Health Organization classifies it as a Class 1 carcinogen.
- According to the research by Lung et al. (2020), they found that in July and December 2017, the most important factor affecting $PM_{2.5}$ concentration in Zhushan was season, followed by traffic and market activities. In this study, we will expand the time range to 2018-2022, and add Banqiao and Sanmin as locations to look at the spatiotemporal changes in $PM_{2.5}$ concentration before, during and after the pandemic.

Material

Instrument：AS-LUNG-O

There are sensors that detect particulate matter, carbon dioxide, temperature, and humidity in the environment. And Global Positioning System and real-time-clock module are also added.

Set up：

1. They were installed on light poles near potential pollution sources in three communities: Banqiao, Zhushan, and Sanmin.
2. Street background stations were set up in places in the community where there are no pollution sources nearby.
3. High-level stations were set up on approximately 4-story buildings.

Method

- **Data organization**

The $PM_{2.5}$ concentration, temperature, and humidity data per minutes from all measuring stations in the three communities were combined with the hourly rainfall and wind speed data from the CWB to create a 5-minute average data, and the time was divided into before the pandemic (May to December 2019), during the pandemic (May to December 2021), after the pandemic (May to December 2022).

- **Percent Coefficient of Variance (%CV)**

Formula ：$\frac{standard\ deviation}{mean} \times 100\%$

To know about the degree of variation of data between different stations, a larger %CV indicates higher spatial variability.

	Sation1	Sation2	Sation3	S.D	Mean
01:30					
⋮	⋮	⋮	⋮	⋮	⋮

→ 1 value of %CV

Schematic diagram 1.

- **Regression analysis**

Step1. Record potential pollution sources at measuring stations
Step2. Select possible contamination time and the day of the week
Step3. Put all the information into regression analysis to get the regression coefficients, if coefficient is higher, which means the factor has the larger contribution to $PM_{2.5}$ concentration.

	Station1	Station2	Station3	Station4
School	V(7、17) Mon. – Fri.			
Fried			V(12-14,17-19)	
Stop & Go traffic	V(6-22)	V(6-22)		V(6-22)
Restaurant				V(17-20) Sat. & Sun.
Temperature	V			V
Gas station		V		

Regression analysis → coefficient

Step1. Step2. Step3.

Schematic diagram 2.

Result

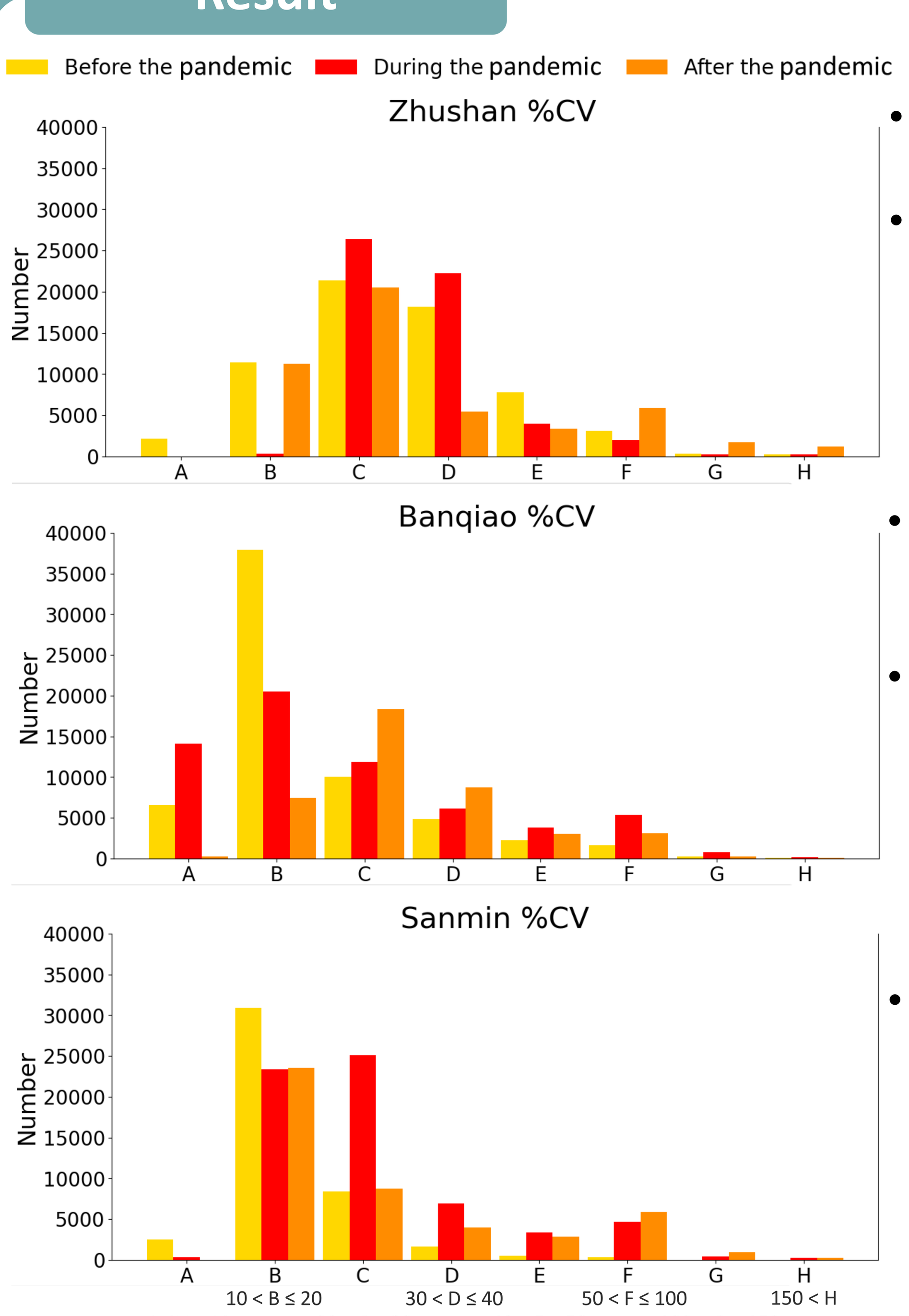

Figure 1. %CV of three communities.
The x-axis represents the range of %CV, and the y-axis represents the number of occurrences.

- At any time, the largest number of cases occurs in range C.
- In areas with higher %CV (G, H), we observe higher %CV values after the pandemic, indicating that the spatial variability of $PM_{2.5}$ concentration in Zhushan was higher after the epidemic.

- High cases before the pandemic and during the pandemic are in the B zone, whereas after pandemic is in the C zone.
- We observe higher %CV values during the pandemic, indicating that the spatial variability of $PM_{2.5}$ concentration in Banqiao was higher during the epidemic.

- Spatial variation is lower before the pandemic, with most cases falling within the A-D %CV ranges. However, spatial variability is higher during and after the pandemic in Sanmin.

Result

- **Zhushan – Source contribution**

Variables	Before epidemic	During epidemic	After epidemic	5月			6月			7月			8月			9月			10月			11月			12月		
Const	32.354	7.673	5.857																								
High-level(4F)	0.288	**2** 0.581	0.596			3					3							3		2	3		2			3	
Temple	**1** 11.260	**1** 14.486	**1** 4.922	1	1	1	1	2	1	2	2	3	3	1	3	1	1		2	1		2	1	3	2	1	
Passing-by vehicles	6.051	-1.028	-0.447				3			1		1	2	2			2			3							3
Stop-and-go traffic	1.737	-11.652	**3** 2.139			2												2	3		2						1
Windspeed	-1.424	**3** 0.035	-0.201					3									3										
Elementary	**2** 8.328	-5.531	-6.851				2	1		3			1			3						3			3		
Fried	3.649	-1.058	-1.142	3								/		3												2	
Market	**3** 7.011	-1.216	-0.931	2					3		1				2	2			1			1		2	1		
Gas	-2.568	-5.088	**2** 4.722			/			2						1			1			1			1			2
Relative humidity	-0.075	0.011	0.018																								
Temperature	-0.707	-0.059	-0.019									2											3				

Fig 2. Source contribution of $PM_{2.5}$ in Zhushan community.
Variables are potential sources of pollution, and the red numbers represent the top three contributors. The green background color represents before the pandemic, yellow background color represents during the epidemic, and red background color represents after the pandemic. The table at the back breaks each period into months to look at the top three contributors, and the colors have the same meaning.

In any time, the contribution of temples remains the most significant factor, while the contribution of school and the market is limited to before the pandemic, and after the pandemic, the contribution of stop-and-go traffic and gas station are larger. This phenomenon can also be seen among the top three contributions each month.

- **Banqiao – Source contribution**

Variables	Before epidemic	During epidemic	After epidemic	5月			6月			7月			8月			9月			10月			11月			12月		
Const	17.909	5.888	-1.076									/															
H	**3** 0.314	**2** 0.971	**2** 0.930		1	2	3	1	2		1	/	3	2	3	3	2	3		2	2	3	1	1	3	2	2
Temple	**1** 3.820	**1** 1.123	**1** 6.765	1		1	1		1	1	3	/	1	1	1	1	1	1	1	1	1	1			1	1	1
Laundry	-1.996	-0.712	-1.529									/															
Passing-by vehicles	-0.170	-1.232	**3** 0.221							3		/			2			2			3						
Stop-and-go traffic	-1.408	-1.609	-7.137									/												2			
Windspeed	-0.719	-0.374	-0.230		3							/															
Restaurant	**2** 2.177	-0.372	-0.196	2			2			2	2	/	2			2	3		2			2		3	2		
Relative humidity	0.014	-0.014	0.048					3				/								3			3				
Temperature	-0.214	**3** 0.013	0.086	3	2	3		2				/		3					3				2			3	3

Fig 3. Source contribution of $PM_{2.5}$ in Zhushan community.

In Banqiao, temples consistently have the highest contribution, both during and before the pandemic. High-level stations consistently rank in the top three. Interestingly, the impact of restaurants seems to be limited to the pre-pandemic period. When we look at each month, temple and high-level station are almost always in the top three. Before the pandemic, restaurant had the second-highest contribution each month. However, it's worth noting that in May, temperature becomes a significant factor.

- **Sanmin – Source contribution**

Variables	Before epidemic	During epidemic	After epidemic	5月			6月			7月			8月			9月			10月			11月			12月		
Const	1.868	9.968	2.115																								
H	1.058	**3** 1.082	**2** 1.111	1	2	1		2	3		1			3			2	2		2	2		2	2		1	3
Passing-by vehicles	0.320	-3.127	0.056	/							2			2	3			3				3			2		2
Stop-and-go traffic	0.653	**1** 3.457	**1** 2.653			2						3		1	1		1	1		1	1		1	1		2	1
Temple	**1** 2.909	-3.307	-1.476	/			3			2			2			1						2					
Windspeed	-0.008	-0.022	-0.013									2					3										
Fried	**3** 2.513	-8.071	1.276				2		1	1		1	1			3			1				/	3		/	
Construction	1.975	-4.714	-3.650	/				3								2			2			1			1		
Relative humidity	0.021	-0.068	0.009	3																							
Temperature	-0.084	-0.118	-0.057	2																3							
Market	**2** 2.615	-4.680	**3** 0.712	/	3		1		2	3	/		3	/	2		/		3	/	3		/	/	3	/	
Factory	1.428	**2** 2.817	-0.747	/	1	3		1			/			/			/			/			/	/		/	

Fig 4. Source contribution of $PM_{2.5}$ in Sanmin community.

Before the epidemic, there was less spatial variability due to the majority of cases being concentrated in areas A to D, which had relatively low %CV values. However, during and after the epidemic, spatial variability increased. Looking at each month, it's similar to what we saw before. However, we can't determine the actual contribution of market and factory because of missing data.

Conclusion

- Judging from the graphs of the three communities, the spatial variability is large during and after the pandemic.
- Regardless of where they are located, temples appear to be a significant source of pollution within communities.
- In Banqiao and Sanmin, the $PM_{2.5}$ concentration at high-rise sites seems to have a certain correlation with the ground concentration.
- At Banqiao Station and Zhushan Station, temples have made important. contributions; while at Kaohsiung Station, the contribution of temples was limited to before the pandemic, and stop-and-go traffic at other times has a greater impact.

Discussion

- In my research, I found that the regression coefficients of some potential pollution sources seemed to be different from previous studies.
- Sometimes, the $PM_{2.5}$ concentration near the pollution source is higher than that from higher-level stations.

Reference

- Lung et al., (2020) . A versatile low-cost sensing device for assessing $PM_{2.5}$ spatiotemporal variation and quantifying source contribution
- Hsu, C.H. and Cheng, F.Y. (2019). Synoptic Weather Patterns and Associated Air Pollution in Taiwan.

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