Monitoring Spatiotemporal Distribution Characteristics of Air Pollutants in Tianjin by Satellite Remote Sensing

Chen Ziyi[a]
Southwest Forestry University, Tianjin, China

Keywords: Satellite Remote Sensing, Air Pollutants, Point of Information.

Abstract: In recent years, science and technology sustainably develop, Satellite Remote Sensing technologies are widely used in many aspects. Moreover, Satellite Remote Sensing can be more efficient, convenient and objective to monitoring various environments by electromagnetic radiation. While the air environment condition become more worse than before, so people pay more attention to air condition and atmospheric environment monitoring by remote sensing become the main way. This study analyses the possible relationship between air pollutants and POI data. The experiment was to assess effects of human activities on atmospheric environment and provide some advice for human activities in the future. What is more, in this research, utilizing obtained data of air pollutants and point of information data analyse their Spatiotemporal distribution characteristics and mathematical relation in order to get some objective evidence. In conclusion, the results show that POI data is correlated but different from the distribution data of different air pollutants.

1 INTRODUCTION

According to the atmosphere pollutants correct interpretation from China government departments: In line with the definition provided by the International Organization for Standardization, air pollutants usually refers to that some material enter the atmosphere with enough concentration and time because of human activities and nature phenomena, hence it endangers people's comfort level, health, welfare and Living environment. It is important that presents serious environmental problems and endangers people's physical condition (Bergmann et al, 2020), it includes multiple diseases such as heart disease, greenhouse effect, traffic delays, upper respiratory tract infections， etc. In order to effective control air pollutants and how to solve the above problem, it is necessary to long-term monitor at first. At present, there are two ways to detect air gas, one is the direct sampling method, and the other is concentration sampling method (China Patent No. CN201110050054.5, 2012). Aerosols monitoring technologies include weight method, β radiation absorption method and Tapere Element Oscillating Microbalance (Fu et al, 2011). However, as said above, all the methods are surface sampling, so they are always influenced by air gas data quality, monitoring equipment quantity and quality, sampling position and sampling range. By contrast, Satellite Remote Sensing technologies have many advantages, including real-time, high efficiency, not limited by time and space, and also can distinguish various kinds of gas. Meanwhile, Satellite Remote Sensing can continuously monitor change of pollutants status of atmospheric gas and water body, forecast environmental quality, effectively enlarge the environment of monitoring area and improve the ability of data acquisition, processing, transmission and application (Wang et al, 2011), so this study analyze atmospheric environment condition with Satellite Remote Sensing data.The sphere and intensity of human activities has expanded rapidly because modern society follows the rapid development of science and technology, which has brought great harm to the ecological environment. This study will combine different types of human conditions by point of information with air pollutants distribution diagram to analyze the relationship between the two. After that, this study also explores

[a] https://orcid.org/0009-0007-3662-3364

Ziyi, C.
Monitoring Spatiotemporal Distribution Characteristics of Air Pollutants in Tianjin by Satellite Remote Sensing.
DOI: 10.5220/0013036000004601

In *Proceedings of the 1st International Conference on Innovations in Applied Mathematics, Physics and Astronomy (IAMPA 2024)*, pages 216-222
ISBN: 978-989-758-722-1

air pollutants spatiotemporal distribution relationship by visual interpretation method and look for a connection between air pollutants and human activities. Ultimately, the study result can improve some reference information for future environmental protection implementation measures, prospect of human development and range of human activity.

2 METHODOLOGIES

Air pollutants consist of two parts: particulate and gaseous, which is including but not limited to sulfur compounds, oxides of carbon, nitrogenous compounds, aerosol, especially fine particles contain a lot of toxic and harmful substance. This study utilizes software of ArcGIS and Envi to process POI data and different stages satellite images of air pollutants distribution, which will be used to research air pollutants spatiotemporal distribution characteristics and the relationship among seasons, years and human activities in centre of Tianjin.

2.1 Study Area

According to the public information provided by the Tianjin Municipal People's Government, where it is located in north China, north China Plain, the total area is 11966.45 square kilometres and a coastline of 153.669 kilometres, multi ports. Among them, the six districts led by Heping District are the central urban areas, which is place of origin and also the centre of economy, politics, culture and education. This city is bounded to the east by the Bohai Sea as well as the north by Yanshan Mountain and it is a transition zone of coastal plains and mountains. What is more, Tianjin weathers are more influenced by oceanic climate, which is for distinct seasons and belong to warm temperate sub-humid monsoon climate. Tianjin is rich in foreign trade and has a mature and advanced maritime transport because it borders the well-developed capital of Beijing. Be affected by economy, tertiary industries are always in the leading position across the whole of China. At present, the total resident population reached 13.64 million. As can be seen from the above, this region is characterized by complex economic conditions and human activities. Meanwhile, there are various natural factors, such as wetlands, forest, rivers, over eighty kinds of fish speciesm and other creatures.

2.2 Data Sources and Experimental Methods

Table 1: Data Information (Picture credit: Original)

Datasets	Format	Source
Air pollutants	NetCDF	The website of China National Qinghai-Tibet Plateau Tibetan Plateau Data Center
POI	Point features	AMap Services, China

2.2.1 Data Information of Pollutants

All the remote sensing data used in this paper stem from China authoritative and open data center website that produced by Wei, J and Li, Z. In this investigation, the images from distant observation of the above four pollutants are regionally cropped using ArcMap tools, and then the data information of the studied region is obtained.

2.2.2 POI Data

The data of POI is derived from Amap service system. The Kernel Density Estimation of ArcGIS was applied to process the relevant POI data (land use type) in Tianjin and obtain the density map of data points. The density map will be an indicator of human activity conditions. All kinds of POI data should be analyzed in spatial distribution at first and convert Excel tables to a document of csv format for vectorization, then generate an accurate shp document with coordinates. Next step is importing the document into the program and completing the analysis to get a map.

2.3 Data Analysis

This stage operation methods of Creating Fishnet and Extracting Multi Values to Points, which can acquire digital data from 4 kinds of air pollutants and 3 kinds of POI raster data. With the extracted values, data should be imported Excel table, because it is convenient to preliminarily analysed and use data. Data eventually is imported Statistical Product and Service Solutions with a way of Spearman to explore the potential relationship and influences between POI and atmospheric contaminants.

3 ANALYSIS AND OUTCOME

3.1 Temporal Analysis

The variation atmospheric contaminants characteristics of spatial and temporal were analysed by using different time series data, and the trend of pollutant concentration variation in different seasons and different regions was discussed.

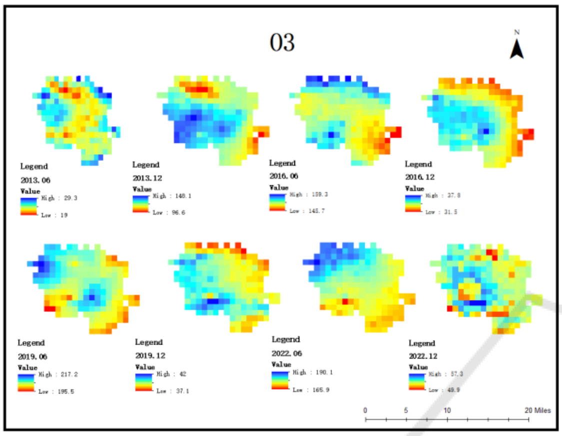

Figure 1: O3 (Picture credit: Original; Data from: Wei, J., Li, Z. (2023). ChinaHighO3: High-resolution and High-quality Ground-level MDA8 O3 Dataset for China (2000-2022). National Tibetan Plateau / Third Pole Environment Data Center. https://doi.org/10.5281/zenodo.10477125.)

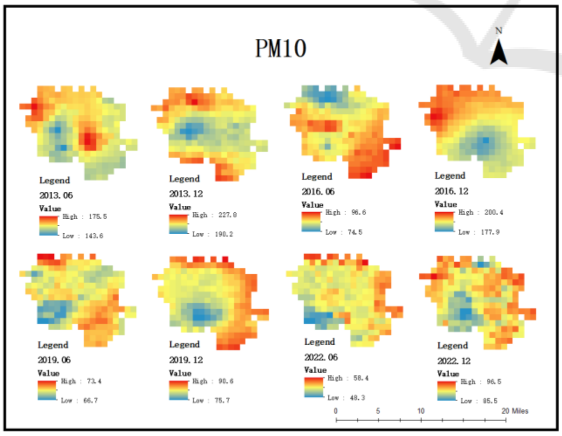

Figure 2: PM10 (Picture credit: Original; Data from: Wei, J., Li, Z. (2023). ChinaHighPM10: High-resolution and High-quality Ground-level PM10 Dataset for China (2000-2022). National Tibetan Plateau / Third Pole Environment Data Center. https://doi.org/10.5281/zenodo.3752465).

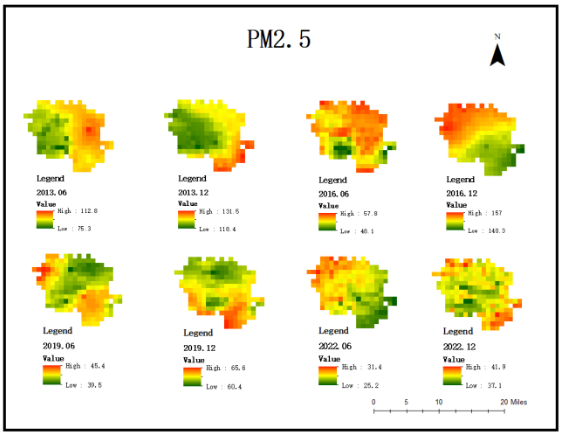

Figure 3: PM2.5 (Picture credit: Original;Data from: Wei, J., Li, Z. (2023). ChinaHighPM2.5: High-resolution and High-quality Ground-level PM2.5 Dataset for China (2000-2022). National Tibetan Plateau / Third Pole Environment Data Center. https://doi.org/10.5281/zenodo.3539349.)

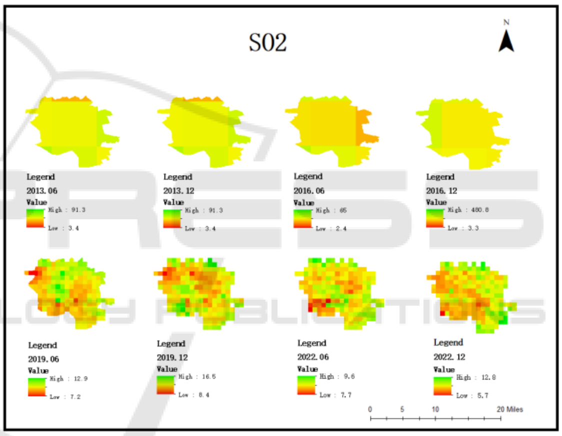

Figure 4: SO2 (Picture credit: Original; Data from: Wei, J., Li, Z. (2023). ChinaHighSO2: High-resolution and High-quality Ground-level SO2 Dataset for China (2013-2022). National Tibetan Plateau / Third Pole Environment Data Center. https://doi.org/10.5281/zenodo.4641538).

From the above figure of O_3 (Figure 1), most June values were much higher than December values from 2013 to 2022, and values has continually risen from 2013 to 2019, which is from 29.3 to 217.2 in summer. Only the value from 2022 has decreased to 190.1. The principal reason for this condition is sufficient chemical reaction. O_3 is produced and high concentration where the temperature is high enough and it has more hours of light. The value of O_3 was 148.1 in December 2013, and then the high value of O_3 dropped significantly to 37.8 in December 2016. One year later value has increased slightly to 42 in

December 2019, after that, the value changed again to 57.3 in December 2022.

From the above figure of PM_{10} and $PM_{2.5}$ (Figure 2 & Figure 3), most December values were much higher than June values from 2013 to 2022. There are several factors that should be responsible for this. The major reason is that two air pollutants are produced by the direct emission of tiny particles from various industrial processes, like daily power generation and coal burning. Winters in northern China are particularly cold, the government provides heating by coal burning, which causes more exhaust gases with tiny particles to be emitted and two kinds of contaminant concentration values are higher in December. PM_{10} has been declining in June since 2013, from 175.5 to 58.4. In contrast, the December values is really complex. First, the high value in December dropped from 227.8 to 90.6, from 2013 to 2019. In December 2022, the values have increased to 96.5. The map of 2.5-micrometer Particulate Matte shows a trend with descending in each June since 2013, from 112.8 to 31.4. Four data of different years have gone through a process of first increasing and then decreasing. SO_2 data (Figure 4: SO") cannot be interpreted a small and precise region because the resolution is 10 KM before 2019; therefore, this study only analyzes data from 2019 onwards. The values for June and December are not much different from year to year.

3.2 Spatial Analysis

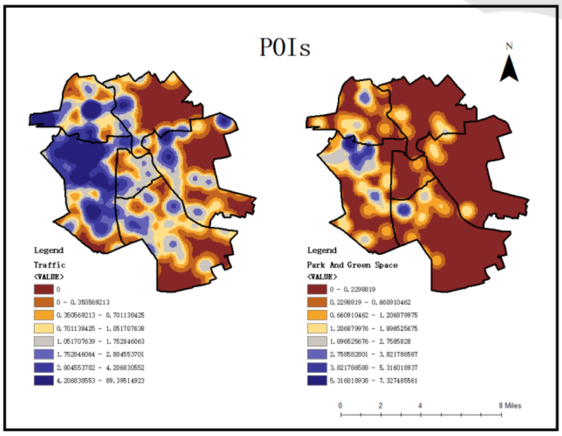

Figure 5: Traffic and Park of POI (Picture credit: Original)

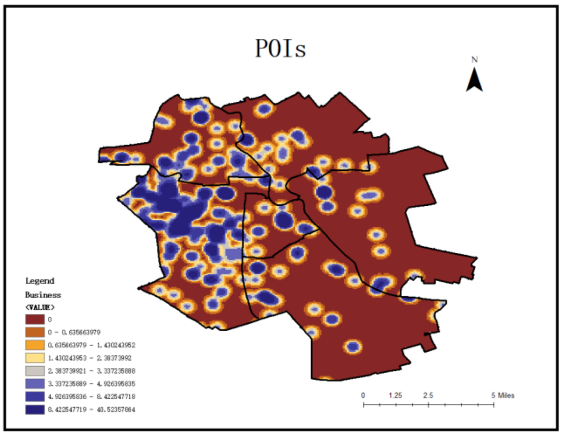

Figure 6: Business of POI (Picture credit: Original).

As can be seen from the figure the POI data (Figure 5Figure 5: Traffic and Park of POI & Figure 6) is divided into three categories: commercial, parkland and transport. The high values of these three types of data are concentrated in the western part of the main urban area of Tianjin and spread in all other directions, but the distribution of various air pollutants at different times of the year is really different, so SPSS software was applied for deciphering to ensure the accuracy of data correlation. Since the POI data are only available beyond 2023, the 2022 annual mean data for each air pollutant were obtained for analysis. Between the Greenbelt and Parks category of points of interest and O_3 had a strongest correlation about 0.349 and they are both increase and decrease, whereas SO_2 had a negative and smaller correlation with PM_{10}; Traffic points of interest had a strong and negative correlation with the SO_2 distribution map, but the association with the distribution of $PM_{2.5}$ is positive; The correlation between points of interest in the business category and the distribution of each air pollutant is low. The result based on the data presented in the table show correlation coefficients between 0.2 and 0.4 indicating that the individual air pollutants are weakly correlated with the intensity of human activities represented by the POI. The following tables are shown outcomes:

Table 2: Correlation between Park of POI and air pollutants (Picture credit: Original).

		Park	O_3	$PM_{2.5}$	SO_2	PM_{10}
Spearman Rho	R	.	.349**	.315**	-.284**	-.222**
	Sig.	.	.000	.000	.000	.000
	N	.	5694	5694	5694	5694
**. <0.01 , The correlation is significant.						

Table 3: Correlation between Traffic of POI and air pollutants (Picture credit: Original).

		Traff-ic	O_3	$PM_{2.5}$	SO_2	PM_{10}
Spearm--an Rho	R	.	.287**	.302**	-.303**	-.222**
	Sig.	.	.000	.000	.000	.000
	N	.	5694	5694	5694	5694
**. <0.01 , The correlation is significant.						

Table 4: Correlation between Traffic of POI and air pollutants (Picture credit: Original).

		Busi-ness	O_3	$PM_{2.5}$	SO_2	PM_{10}
Spearm--an Rho	R	.	.258**	.245**	-.186**	-.167**
	Sig.	.	.000	.000	.000	.000
	N	.	5694	5694	5694	5694
**. <0.01 , The correlation is significant.						

Points of interest in the Green Space and Park have the strongest and positive correlation with the distribution of ozone and the coefficient of association is 0.349, while SO_2 has a negative and smaller correlation with PM_{10}.

3.3 Results

The Parks and Green Spaces of points of interest had the strongest and favorable relevance of O_3, having a correlation value about 0.349. This shows that parks and green spaces concentration distribution is positively pertinence with O_3, since the formation of O_3 is related to its precursor substance (Volatile Organic Compounds, VOCs) and Nitrogen oxide (NO_x). However, the green vegetation discharges the Biogenic Volatile Organic Compounds (BVOCs) to accelerate production of O_3 (Bao et al, 2023). Meanwhile, the stomata on the leaves and stems of vegetation can absorb and sediment and it indeed has certain effect of adsorption and conversion on O_3. As a consequence, there is a great correlation between the O_3 concentration and parks, but the study areas are also influenced by various human activities because it is the centre of Tianjin.

Among the SO_2, PM_{10} and POI of Parks and Green Spaces show a trend that is negative and little correlation, so woodland and grassland play an important role in reducing, producing and controlling particulate matter concentrations (Zhai et al, 2022), which is due to have a function. The special function can help purify the atmosphere of polluting gases; therefore, it can also absorb SO_2. When blades fell to the dirt, the sulfur-absorbing leaves with in air rot back into the soil. At the same time, parks or open spaces, in which only pedestrians and tourists move about, are essentially free from internal conditions that generate all types of air pollutants. This has the effect of making SO_2 and PM_{10} concentrations relatively small.

Traffic points of interest had a strong and adverse relationship with SO_2, while 2.5-micrometer Particulate Matter had a relatively feeble but positive connection. It is possible that SO_2 and $PM_{2.5}$ are mainly emitted through industry; especially, the coal burning for heating during the cold in northern China. However, Tianjin began to run new energy pure electric buses since 2020. Afterwards, the full use of such buses, and the government decided that private cars are restricted in the main urban area of the city and actively promote using public transport and new energy vehicles. Hence, SO_2 is negatively correlated with traffic interest points. According to a document of *China Mobile Source Environmental Management Annual Report (2023)* released by China's Ministry of Ecology and Environment, the operation of gasoline-driven vehicles still produces a lot $PM_{2.5}$, So the analysis results is positively correlated.

Commercial POI has little relevance to other 4 kinds of air pollutants, correlation coefficient is between 0.2 to 0.3. This means that there is a weak impact of commercial activities on air pollutants, due to the dispersed source of pollution. Apart from that, different types of business have a wide variation in impact for air pollutants.

4 CONCLUSIONS

The relationship between various POI, such as parks and green Spaces, traffic and commerce, and air pollutants in Tianjin were analyzed by SPSS, O_3 concentration increased with the rising of the number of parks and green Spaces. It is possible that biovolatile organic compounds (BVOCs) released by plants and produce ozone in sunlight. However, O_3 concentration was influenced by the adsorption and transition abilities of stomata. So it is necessary to balance the relationship between green space expansion and air quality in future urban plannings.

Secondly, the study found that parks and green Spaces had a negative correlation and little effect on SO_2 and PM_{10} concentrations. This is mainly due to the fact that plants have a self-purification function of vegetation, it can effectually reduce SO_2 and particulate matter concentrations. In addition, forests and grass lands not only adsorb SO_2, but also can take sulfur back to lands when plants rot. To conclude, the construction of urban green space helps beautify the environment as well as improves air quality to a certain extent.

In terms of transportation POI, the correlation between SO_2 and traffic POI is strong and negative, because Tianjin government promoted new energy buses and restricted the use of private cars in recent years. Although the use of new energy buses has reduced SO_2 emissions, gasoline-powered vehicle still produce lots of $PM_{2.5}$. To sump up, the government should durably execute this policy and improved the relevant laws.

Then, the correlation between commercial points of interest and various types of air pollutants is weak.

The reason why the different types of business activities have different contribution values for air pollutants distribution. To summarize, the results need further detailed analysis because of indeterminacy.

Finally, the study revealed the complex relationship between different POI and air pollutants in Tianjin and also supplied some scientific advice for civic plannings and environmental protection. Ultimately, these recommendations can lead to sustainable urban development and environmental improvement.

REFERENCES

Hu, H. (2012). Real-time monitoring of the environment and gas sampling methods (CHN. Patent No. CN201110050054.5). China National Intellectual Property Administration.

Fu, M., Zheng, Y., Xu, X., NIU, L. (2011). Advances of study on monitoring and evaluation of PM2.5. Meteorology and Disaster Reduction Research, 34(4):1-6. https://cstj.cqvip.com/Qikan/Article/Detail?id=40851670

Wang, X., Chen, R., Kan, H. (2011). Application of Remote Sensing Technology in Atmospheric Pollutant Monitoring: a Review of Recent Studies. Journal of Environment and Health, 28(10), 4.https://www.cnki.com.cn/Article/CJFDTotal-HJYJ201110028.htm

Wei, J., Li, Z. (2023). ChinaHighO3: High-resolution and High-quality Ground-level MDA8 O3 Dataset for China (2000-2022). National Tibetan Plateau / Third Pole Environment Data Centre. https://doi.org/10.5281/zenodo.10477125.

Wei, J., Li, Z., Li, K., Dickerson, R., Pinker, R., Wang, J., Liu, X., Sun, L., Xue, W., & Cribb, M. (2022). Full-coverage mapping and spatiotemporal variations of ground-level ozone (O3) pollution from 2013 to 2020 across China. Remote Sensing of Environment, 270, 112775. https://doi.org/10.1016/j.rse.2021.112775

Wei, J., Li, Z. (2023). ChinaHighSO2: High-resolution and High-quality Ground-level SO2 Dataset for China (2013-2022). National Tibetan Plateau / Third Pole Environment Data Centre. https://doi.org/10.5281/zenodo.4641538.

Wei, J., Li, Z., Wang, J., Li, C., Gupta, P., & Cribb, M. (2023). Ground-level gaseous pollutants (NO2, SO2, and CO) in China: daily seamless mapping and spatiotemporal variations. Atmospheric Chemistry and Physics, 23, 1511–1532. https://doi.org/10.5194/acp-23-1511-2023

Wei, J., Li, Z. (2023). ChinaHighPM2.5: High-resolution and High-quality Ground-level PM2.5 Dataset for China (2000-2022). National Tibetan Plateau / Third Pole Environment Data Centre. https://doi.org/10.5281/zenodo.3539349.

Wei, J., Li, Z., Lyapustin, A., Sun, L., Peng, Y., Xue, W., Su, T., & Cribb, M. (2021). Reconstructing 1-km-resolution high-quality PM2.5 data records from 2000 to 2018 in China: spatiotemporal variations and policy implications. Remote Sensing of Environment, 252, 112136. https://doi.org/10.1016/j.rse.2020.112136

Wei, J., Li, Z., Cribb, M., Huang, W., Xue, W., Sun, L., Guo, J., Peng, Y., Li, J., Lyapustin, A., Liu, L., Wu, H., & Song, Y. (2020). Improved 1 km resolution PM2.5 estimates across China using enhanced space-time extremely randomized trees. Atmospheric Chemistry and Physics, 20(6), 3273-3289. https://doi.org/10.5194/acp-20-3273-2020

Wei, J., Li, Z. (2023). ChinaHighPM10: High-resolution and High-quality Ground-level PM10 Dataset for China (2000-2022). National Tibetan Plateau / Third Pole Environment Data Centre. https://doi.org/10.5281/zenodo.3752465.

Wei, J., Li, Z., Xue, W., Sun, L., Fan, T., Liu, L., Su, T., & Cribb, M. (2021). The ChinaHighPM10 dataset: generation, validation, and spatiotemporal variations from 2015 to 2019 across China. Environment International, 146, 106290. https://doi.org/10.1016/j.envint.2020.106290

Bao, X., Zhou, W., Zheng, Z., Xu, L. (2023). The interactions and mechanisms between biogenic volatile organic compounds emissions and ozone concentrations in urban areas: A review. Acta Ecologica Sinica, 43(5). https://doi.org/10.5846/stxb202202240431

Zhai, H., Yao, J., Wang, G., & Tang, X. (2022). Study of the effect of vegetation on reducing atmospheric pollution particles. Remote Sensing, 14(5), 1255. https://doi.org/10.3390/rs14051255

China Mobile Source Environmental Management Annual Report (2023)

Akimoto, H. (2003). Global air quality and pollution. Science, 302(5651), 1716 – 1719. https://doi.org/10.1126/science.1092666

Bergmann, S., Li, B., Pilot, E., Chen, R., Wang, B., & Yang, J. (2020). Effect modification of the short-term effects of air pollution on morbidity by season: A systematic review and meta-analysis. Science of the Total

Environment, 716, 136985. https://doi.org/10.1016/j.scitotenv.2020.136985

Chen, Yaping., Deng, Akot. (2023). Evolution and Influencing Factors of Urban Built-Up Areas in the Yangtze River Delta Urban Agglomeration. IEEE Access. PP. 1-1. 10.1109/ACCESS.2023.3336735.