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A Comparative Analysis of Air Quality between Taiwan and South Korea

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Abstract: Until now, there has been no research that uses a monitoring method approach that is easily accessible and costless using TAQMN. This study aimed to determine the air quality of Zhongli District (Taiwan), which we then compare with Incheon Metropolitan City (South Korea). These two regions have different characteristics in terms of population and territorial designation. From February 27 to March 8 of 2022, pictures of the Zhongli skyline were captured every morning at 9 a.m. at the Re Cheng-hall student dormitory of Chung Yuan Christian University. Additionally, the Zhongli skyline photo findings are contrasted with the information provided by TAQMN's air quality index monitoring system. Overall, the air quality index in Zhongli District is better than Taipei City in the same period. The air quality index (AQI) for the Zhongli area ranged between 45 and 121, where the period's median AQI was 57. Other significant variables include $PM_{2.5}$ and PM_{10} values of 14 g/m^3, 20 g/m^3 respectively. Overall, the air quality index in Zhongli district Taoyuan city in Taiwan is better than Incheon city in South Korea on the same period. The average AQI in Incheon varies from 58 to 124 over the course of a 24-hour period.

Keywords: TAQMN, AQI, online monitoring, costless monitoring

1. Introduction

An AQI is used by government agencies to communicate to the public how polluted the air currently is or how polluted it is forecast to become. Public health risks increase as the AQI rises (Cao et al., 2021). AQI is currently reported in many countries and regions around the world as a simple and easily understandable numeric scale ranging from 0 to 500 (Gorai et al., 2018). However, the AQI is determined by the pollutant that deviates the most from its reference standard (Suman, 2020). Ignoring other pollutants means that the AQI cannot capture the additive effects of multiple air pollutants. Another shortcoming of the AQI is that it cannot reflect the no- threshold exposure-response relationships of pollutants with mortality or morbidity (Stieb et al., 2008). The monitoring and evaluation of ambient air quality is the first important step in controlling air pollution. Huge amounts of monitoring data often do not convey air quality status to the scientific community, policy makers, regulatory and to the public in a simple and straightforward manner. Considering the health effects of air pollutants, environmental agencies have been using AQI for public information and data interpretation.

Air quality monitoring data is more copious as more air monitoring networks are installed and implemented in urban areas. Several pollutants are generally monitored by each station and hourly or daily average concentration data are calculated. Therefore, air monitoring networks provide a large mass of data. Therefore, their interpretation by public authorities and their presentation to the population becomes a hard task. Moreover, the diffusion of sources of information, such as the internet, enables the synthesis of the large mass of data coming from air monitoring networks into few and easy to understand indexes (Murena, 2004; Fitria et al., 2023). The main objective of air quality indexes is to measure air quality with respect to its effects on human health. This is a daily quality index. A daily AQI has been proposed by the Environmental Protection Agency (EPA). It is defined with respect to the five main common pollutants: carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM_{10}) and sulphur dioxide (SO_2). Pollutant concentrations are converted into a numerical index (AQI) which assumes values in the range 0–500. The overall range is subdivided into six ranges to which six categories of air quality correspond.

Taiwan Air Quality Monitoring System (TAQMN) and Air Korea are official platforms developed by the Ministry of Environment of Taiwan and Korea, respectively. Parameters that describe air quality comprehensively can be accessed through TAQMN and Air Korea, such as $PM_{2.5}$, PM_{10}, O_3, CO, SO_2, and NO_2. Therefore, the objective of this research is to analyze the air quality trends in Taiwan and Korea, represented by its largest and most populous cities, using nationally recognized online air quality monitoring platforms from each country, and comparing the performance of each platform. To the best of our knowledge, there has been no study on air quality that utilizes primary data for analysis from online monitoring systems. Our hypothesis predicts that there will be no significant difference between the two locations due to similar regional conditions, population density, and types of activities. However, other factors such as city management regulations may also have an influence, which could differ between the two locations. Although the accuracy of the data may not be as high as when collected independently, this effort at least facilitates the inventory of air quality in each city/country without requiring significant funding and time. This study can also serve as a basis for analyzing the accuracy of field measurement results.

2. Methodology

The picture of the Zhongli skyline was taken at the Re Cheng-hall student dormitory

CYCU every morning (at 7 a.m.) from February 27th to March 8th, 2022. It was taken with the Xiaomi Redmi 9 Pro brand cellphone camera in its default setting. In addition, the Zhongli skyline photo results are compared with the data air quality index monitoring system that is provided by Taiwan Air Quality Monitoring Network (Suhardono et al., 2023). TAQMN is a facility to measure wind speed, direction, other weather parameters, concentration of air pollutants (such as SO_2, NO_x, CO, O_3, THC etc), and particulate matter continuously all year round. The measured data can be remotely monitored and exported in various formats to the local central authorities. The data can be published via the Internet for easy public access to raise awareness on current air pollution levels. This way, the public can prevent outdoor activities and reduce health impacts during heavy polluted days (Imami et al., 2022). Furthermore. During the period of February 27 to March 8, 2022, the average 24-hour air quality index data in the Zhongli district of Taoyuan city will be compared with the average 24- hour air quality index data in the Sinheung AQI monitoring station Incheon City South Korea. This is to determine how much the amount of air pollution in the Zhongli district of Taoyuan city Taiwan has progressed when compared to other cities throughout the world, including other Asian cities (e.q., Incheon, South Korea).

The following are the reasons for selecting Incheon as the Zhongli district of Taoyuan comparative city: (1) Both Incheon and Zhongli/Taoyuan serve as buffer cities for the capital. Incheon, for instance, serves as a buffer city for Seoul, whereas Zhongli/Taoyuan serves as a buffer city for Taipei, (2) Both of them are home to several heavy industries in South Korea and Taiwan, which generate a significant amount of air pollution, (3) Both have population more than 2 million people. Incheon has around 2,818,000 people (in 2021) and Zhongli/Taoyuan has 2,272,000 people (in 2021) [13], (4) And both are in East Asian Country (Taiwan and South Korea).

Table 1. General information

* START POINT	* END POINT
▪ **Re Cheng Hall** CYCU Building ▪ **Coordinate point:** 24º57’37”N 121º14’45”E ▪ **Address:** No. 220, Puzhong Rd, Zhongli Taoyuan City, 320	▪ **Zhongli city centre area** ▪ **Coordinate point:** 24º57’30”N 121º13’12”E ▪ **Address**: No. 120, Section 1, Zhongyang W Rd,Zhongli District, Taoyuan City, 320
 A 12-story, 75 meters (246 ft) CYCU students dormitory building	 A 30-story, 123.7 meters (406 ft) skyscraper office building

* Both of buildings distance of 2,636.44 meters

Table 2. Comparation data between Zhongli/Taoyuan – Taiwan and Incheon - South Korea

City	**Zhongli/Taoyuan**	**Incheon**
Country	Taiwan	South Korea
Location	Approximately 40 km (25 miles) Southwest Taipei City	Approximately 35 km (21.75 miles) Southwest Seoul
Coordinates	24°59′28.6″N 121°18′51.58″E	37°29′N 126°38′E
Land Area	1,220 km^2 (470 sq. mil)	1,062.63 km^2 (410.28 sq. mil)
Population	2,272,000 people	2,818,000 people
Avg. Relative Humidity (%)	76.6	68.8
Avg. Daily Temperature (°C)	23.0	12.5
Total precipitation mm (inch.)	2,405.1 (94.68)	1,270.4 (47.54)
Maps		

3. Result and Discussion

3.1 Air Quality Index (AQI) in Zhongli district, Taoyuan City Taiwan

Air quality is a critical environmental concern that affects human health and ecosystems. Various countries have implemented measures to monitor and improve air quality. This article aims to provide a comprehensive comparison of air quality between Taiwan and South Korea, focusing on key pollutants and the effectiveness of air quality management strategies in each country. From February 27, 2022, to March 8, 2022, visual observations of the skyline in Taoyuan's Zhongli district were conducted. At 7 a.m., a photo of the skyline was taken using the default mode on a cellphone camera bearing the Xioami Redmi Note 9 Pro brand. As shown in Table 4, the visual condition of the Zhongli area's skyline changes daily due to weather factors such as fog, sunshine, and rain, as well as external factors such as pollution from motor vehicles, exhaust gas, and burning fireworks, incense, and incense paper during the State of Taiwan's peace commemoration celebrations. The results of visual data collected with a camera are then compared to data from the Taiwan EPA's online air quality index. The AQI data is collected at the same location and time as the air quality monitoring system station in Taoyuan, namely the Zhongli area of Taoyuan city at 7:00 a.m.

After observing using air quality monitoring system data originating from Taoyuan station, the AQI of the Zhongli area for 10 days from February 27 to March 8, 2022, that the AQI value fluctuated between 45-121. Where the lowest AQI was 45 for the period. This happened on March 6, 2022, at 7:00 am this morning indicating that the Zhongli district of Taoyuan City has good air quality. The values for each of the other main variables such as $PM_{2.5}$, PM_{10}, O_3, CO, SO_2 and NO_2 were 17 µg/m3, 42 µg/m3, 34.8 ppb, 0.48 ppm, 0.4 ppb and 20.5 ppb, respectively. On the other hand, the highest AQI value of 121 for the sampling period occurred on March 4, 2022, indicating that the Zhongli district of Taoyuan City has unhealthy air quality. The values for each of the other main variables such as $PM_{2.5}$, PM_{10}, O_3, CO, SO_2 and NO_2 were 44 µg/m^3, 63 µg/m^3, 2.7 ppb, 1.01 ppm, 1.4 ppb and 26.9 ppb. Analyzing the air quality data from both countries reveals important insights into pollutant levels and trends. PM2.5 and PM10, which are fine particulate matter, are major concerns due to their adverse health effects. Comparing the annual average concentrations of $PM_{2.5}$ and PM10 in Taiwan and South Korea can shed light on the severity of air pollution in each country. n terms of ozone (O_3), carbon monoxide (CO), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2), a comparative analysis can provide valuable information on the sources and levels of these pollutants. Understanding the variations in pollutant concentrations can help identify the effectiveness of emission control measures and the impact of industrial activities, transportation, and other factors.

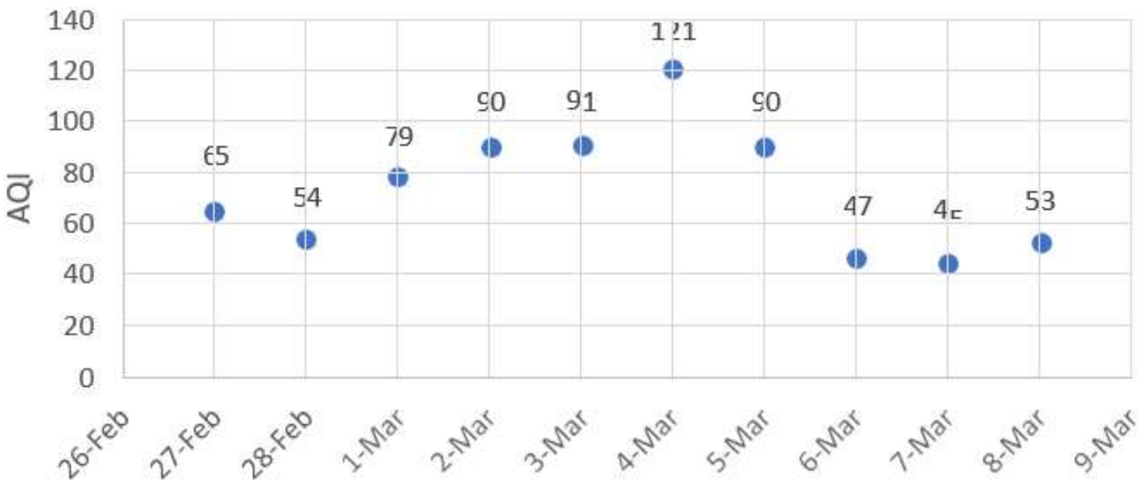
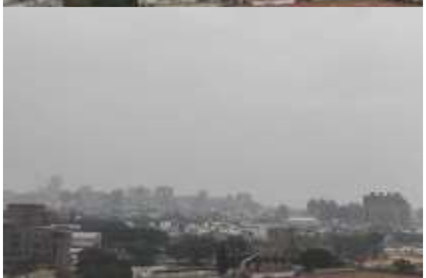
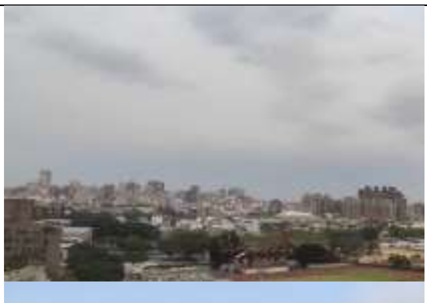
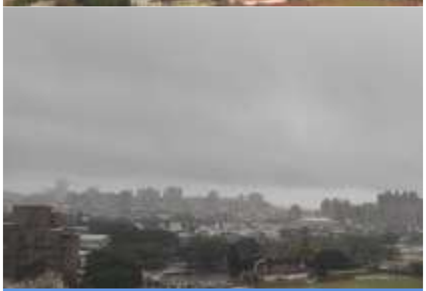


Figure 1. AQI in Zhongli District, Taoyuan City – Taiwan

The increased AQI value on March 4, 2022, maybe due to the accumulation of fireworks burning by the majority of Taiwan's population, particularly in the Zhongli district of Taoyuan city, because it coincides with the anniversary of Taiwan's peace, which falls on February 28, 2022, and the burning of fireworks, incense paper, incense, and vehicle exhaust during this festive period creates an atmosphere that lasts for three days. As a result, polluting gas emissions peaked on March 4, 2022. This is also consistent with the visual observation of the sky photo with the object focused on the financial star building in the Zhongli district's central business district (Fig. 2), which is not visible from the Re Cheng-hall Male CYCU dormitory, which is approximately 2,636.44 meters away using the Xiaomi Redmi Note 9 Pro cellphone camera. Regarding the look of the Financial Star Building Zhongli on March 7, 2022, it was cloudy due to the rain, but the air quality was good that day, with an AQI rating of 47. As illustrated in Figure 2 and Table 4, the higher the air quality index score, the greater the particulate matter (PM2.5 and PM10). This means that particulate matter has a significant role in defining the quality of the air.

Table 3. AQI Photos & Data

Date	Skyline Image	AQI	PM2.5 (μg/m^3)	PM10 (μg/m^3)	O3 (ppb)	CO (ppm)	SO2 (ppb)	NO2 (ppm)	Status
February 27th, 2022		65	19	31	14.1	0.74	1.6	24.1	Moderate
February 28th, 2022		54	25	26	6.3	0.77	1.8	27.8	Moderate
March 1st,2022		79	17	37	1.8	1.59	1.6	29.1	Moderate
March 2nd,2022		90	38	46	9.6	0.8	1.1	44.4	Moderate
March 3rd,2022		91	38	46	22.1	1.04	1.5	37.3	Moderate
March 4th,2022		121	44	63	2.7	1.01	1.4	26.9	Unhealthy

Date	Skyline Image	AQI	PM2.5 (μg/m^3)	PM10 (μg/m^3)	O3 (ppb)	CO (ppm)	SO2 (ppb)	NO2 (ppm)	Status
March 5th,2022		90	25	47	18.7	0.93	1.3	31	Moderate
March 6th,2022		47	17	42	34.8	0.48	0.4	20.5	Good
March 7th,2022		45	7	12	21	0.41	1.1	27.4	Good*
March 8th,2022		53	14	25	1.5	1.12	2	34.2	Moderate

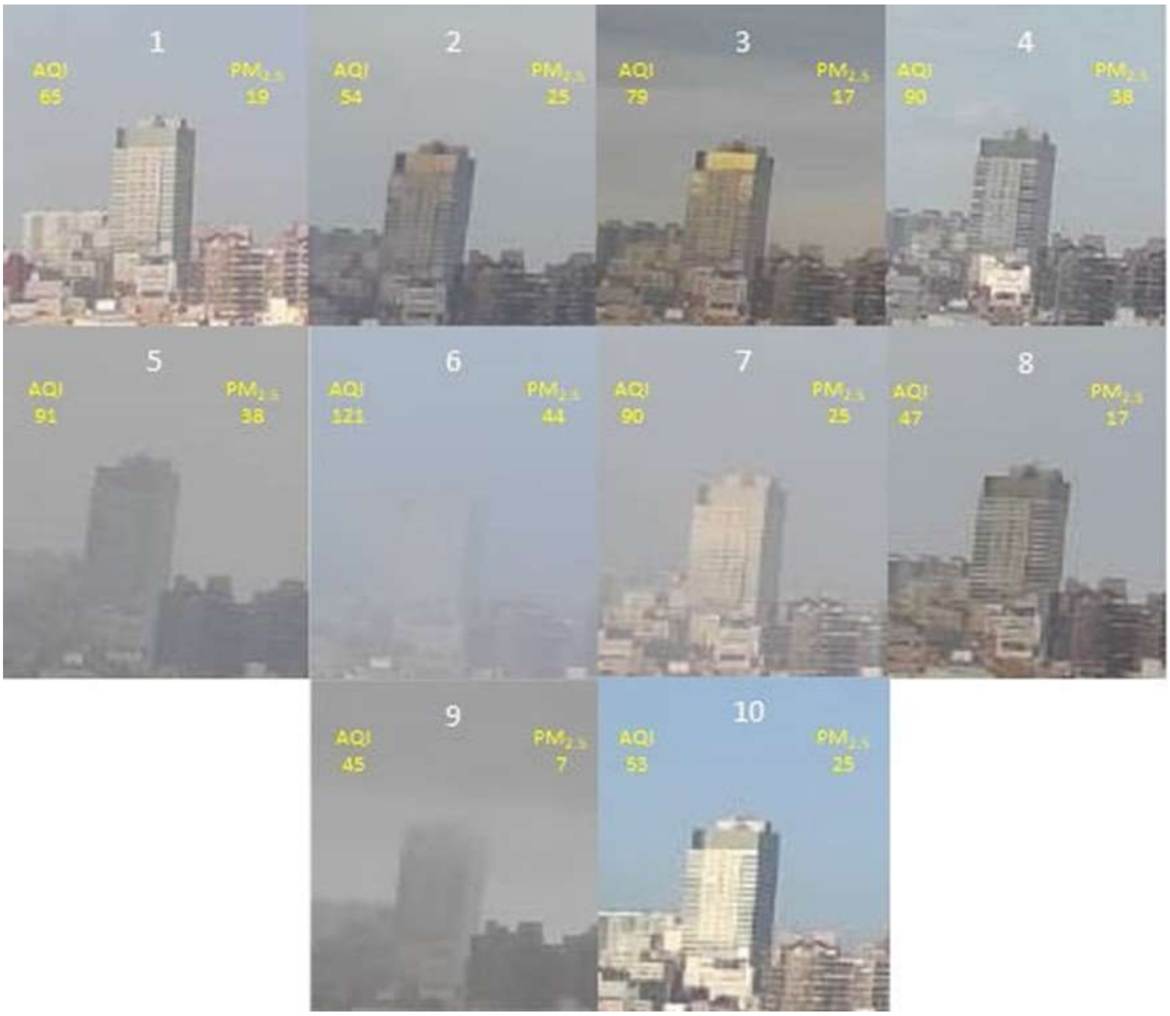


Figure 2. Skyline visual observation from Re Cheng-hall building to Financial Star Building on: (1) February 27th, 2022; (2) February 28th, 2022; (3) March 1st, 2022; (4) March 2nd, 2022; (5) March 3rd, 2022; (6) March 4th, 2022; (7) March 5th, 2022; (8) March 6th, 2022; (9) March 7th, 2022; (10) March 8th, 2022

Industrial activities often encompass the burning of fossil fuels, the release of particulate matter, and the discharge of diverse pollutants into the atmosphere. Pollutants such as SO_2, NO_x, VOCs, total PM, and other harmful substances may be emitted by facilities like factories, power plants, and manufacturing units. These pollutants can adversely impact air quality and human well-being. Elevated concentrations of pollutants, particularly in densely populated industrial zones, can contribute to the degradation of air quality. Implementing effective control measures, including the adoption of cleaner technologies, routine maintenance of industrial machinery, and the continuous monitoring of emissions, becomes imperative to minimize the repercussions of industrial activities on air quality (Gariazzo et al., 2007; Marinello et al., 2021).

The development and enforcement of environmental policies and regulations by governmental bodies are pivotal in the management and alleviation of air pollution. Stringent policies establish emission standards, oversee industrial procedures, and mandate the utilization of cleaner technologies. These policies may be directed at specific industries, stipulate emission thresholds, and incentivize the integration of pollution control practices. Rigorous enforcement ensures that industries adhere to these standards, resulting in reduced emissions and enhanced air quality. Environmental policies also advocate for the advancement and implementation of sustainable approaches, the utilization of renewable energy sources, and the deployment of strategies to prevent pollution. Governments and regulatory entities endeavor to strike a balance between industrial expansion and environmental preservation, aiming to sustain air quality at levels deemed safe for both human health and the overall ecosystem (Miranda et al., 2015; Kuklinska et al., 2015).

2.2 the Comparation of AQI between Zhongli/Taoyuan vs Incheon

Observations were also made using data from the air quality monitoring system at the AQI monitoring Sinheung station in Incheon, South Korea. This information is shown in table 5 below. Whereas the average AQI value in Incheon for the 24 hours from February 27 to March 8, 2022, fluctuates on the ranges of 45 to 118.

Table 4. AQI on February 27th to March 8th, 2022, in Sinheung Station, Incheon South Korea

Time		Air Quality Standards							Status
		AQI	$PM_{2.5}$	PM_{10}	O_3	CO	SO_2	NO_2	
Date	Day		(µg/m^3)		(ppm)		(ppb)	(ppb)	
27-Feb-22	Sunday	54	13.6	40.4	65.6	0.4164	9.8	45.2	Moderate
28-Feb-22	Monday	68	20	40.6	46.8	0.5128	12.7	77.4	Moderate
1-Mar-22	Tuesday	69	20.7	36	61.2	0.5327	10.5	44.6	Moderate
2-Mar-22	Wednesday	76	24	44.4	59	0.5517	11.5	54.7	Moderate
3-Mar-22	Thursday	114	40.9	74.9	40.3	0.7119	16.3	96.3	Unhealthy
4-Mar-22	Friday	108	38.4	141.2	83.8	0.5775	13.9	55.6	Unhealthy
5-Mar-22	Saturday	54	8.7	61.9	81.8	0.4055	10.7	18.7	Moderate
6-Mar-22	Sunday	45	10.9	37	67.3	0.4962	13	31.7	Good
7-Mar-22	Monday	67	19.8	44.6	31.5	0.563	15.3	77.7	Moderate
8-Mar-22	Tuesday	82	26.9	57.1	73.7	0.541	14.2	54.9	Moderate

Where the lowest AQI for average 24-hours was 45 for the period. This happened on March 6, 2022. This indicates that the Incheon South Korea has good air quality. The values for each of the other main variables such as $PM_{2.5}$, PM_{10}, O_3, CO, SO_2 and NO_2 were 10.9 µg/m3, 37 µg/m3, 67.3 ppb, 0.496 ppm, 13 ppb and 31.7 ppb, respectively. On the other hand, the highest AQI value of 114 for the sampling period occurred on March 3, 2022, indicating that the Incheon South Korea has unhealthy air quality. The values for each of the other main variables such as $PM_{2.5}$, PM_{10}, O_3, CO, SO_2 and NO_2 were 40.9 µg/m3, 74.9 µg/m3, 40.3 ppb, 0.71 ppm, 16.3 ppb and 96.3 ppb.

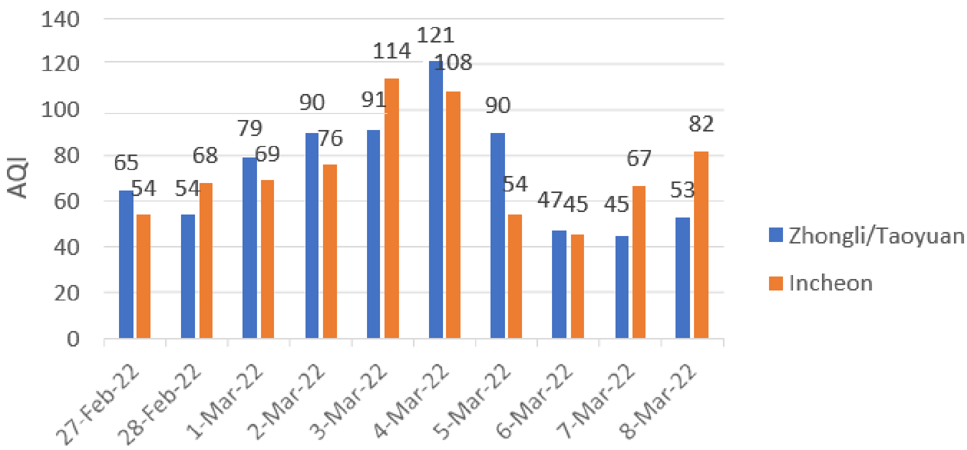


Figure 3. The Comparation of air quality index (AQI) between Zhongli/Taoyuan vs Incheon

Figure 3 show the comparation of air quality index (AQI) between Zhongli district of Taoyuan City Taiwan and Incheon City of South Korea for ten days from February 27 to March 8, 2022. As can be seen, the two cities have nearly identical levels of air quality, namely 45 - 121. where Zhongli/taoyuan was higher for 6 days in a row, namely February 27, March 1 - 2, and 4 - 6, 2022. On the other hand, Incheon city exceeded Zhongli/Taoyuan by

4 days in a row, such as February 28, March 3, and 7-8, 2022.

Similarly, the $PM_{2.5}$ value in figure 4 shows that both cities have a level of particulate matter pollution 2.5 that is nearly identical, with a range of values ranging from 8 to 43 µg/m3. Figure 5 shows Zhongli City is better than Incheon City in terms of PM_{10} pollution, with Zhongli City having the greatest PM_{10} pollution of 62 µg/m3 on March 4, 2022. On the other hand, Incheon City had the highest PM_{10} pollution level of 141.2 µg/m3 on the same day.

(A)

(B)

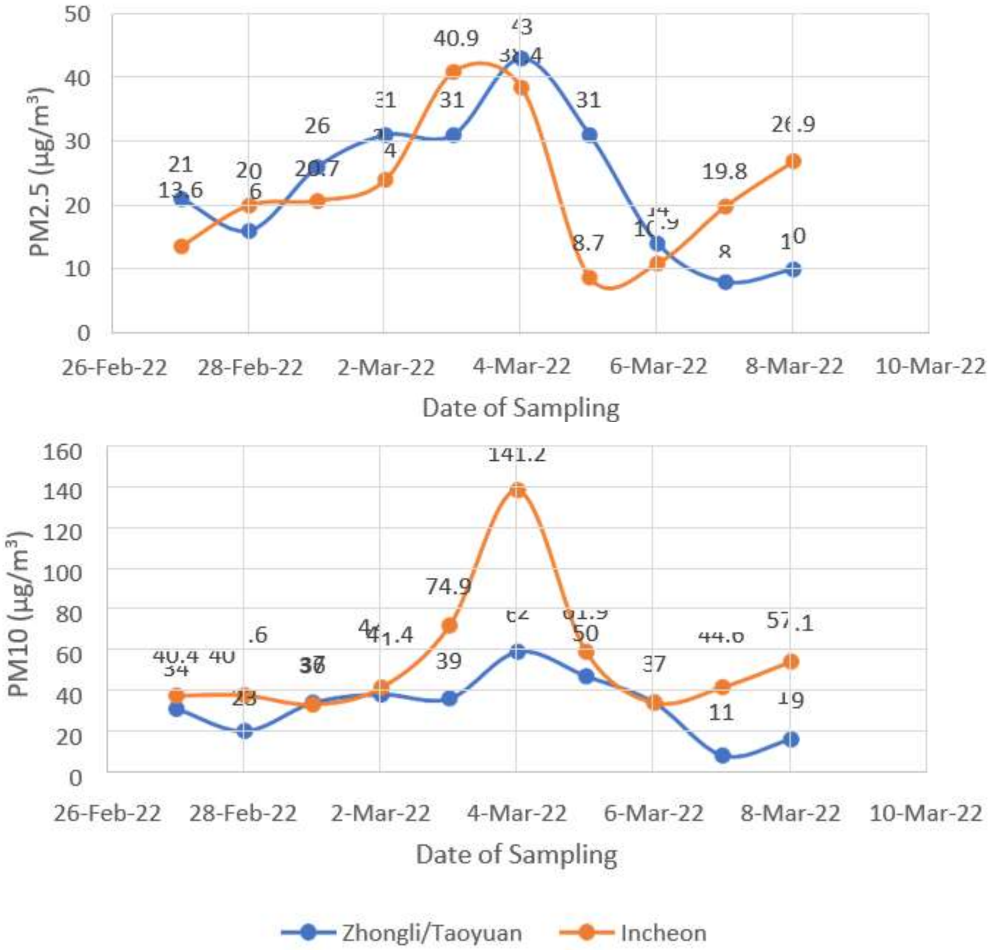


Figure 4. The Comparation of (A) $PM_{2.5}$ & (B) PM_{10} between Zhongli/Taoyuan vs Incheon

Population density and urbanization have significant implications for air quality. Taiwan and South Korea have densely populated cities, which can contribute to elevated pollution levels. Analyzing air quality data from major cities in both countries can help assess the impact of population density, urbanization, and related factors on air quality. While Taiwan and South Korea share similarities in terms of regional conditions, variations in air quality may arise due to factors such as geographical location, climate, industrial activities, and city management regulations. Exploring these regional differences and their influence on air quality can provide a deeper understanding of the unique challenges faced by each country. Both Taiwan and South Korea have implemented various strategies to improve air quality, including regulations on industrial emissions, vehicle emissions standards, and the promotion of renewable energy sources. Evaluating the effectiveness of these strategies in reducing pollutant levels can offer insights into the success of air quality management efforts in each country (Wu et al., 2019).

4. Conclusions

In conclusion, a comparative analysis of air quality between Taiwan and South Korea reveals valuable insights into pollutant levels, trends, and the effectiveness of air quality management strategies. By examining the data from official monitoring platforms and considering various influencing factors, this analysis contributes to our understanding of the air quality situation in both countries. Further research and collaboration between Taiwan and South Korea can lead to improved air quality management practices and the development of more effective policies to protect public health and the environment.

References

Cao, R., Wang, Y., Huang, J., Zeng, Q., Pan, X., Li, G., & He, T. (2021). The construction of the air quality health index (AQHI) and a validity comparison based on three different methods. Environmental Research, 197, 110987.

Fitria, N., Fillaeli, A., Jelsih, M., Koesmawati, T. A., Fitria, L., Awfa, D., ... & Nurhalimah, S. M. (2023). Health Risk Assessment of Heavy Metals on Total Suspended Particles in Semi Urban, Urban, and Industrial Areas of Bandung Metropolitan Area, Indonesia. Ecological Engineering & Environmental Technology, 24.

Gariazzo, C., Papaleo, V., Pelliccioni, A., Calori, G., Radice, P., & Tinarelli, G. (2007). Application of a Lagrangian particle model to assess the impact of harbour, industrial and urban activities on air quality in the Taranto area, Italy. *Atmospheric Environment*, *41*(30), 6432-6444.

Gorai, A. K., Tchounwou, P. B., Biswal, S. S., & Tuluri, F. (2018). Spatio-temporal variation of particulate matter (PM2. 5) concentrations and its health impacts in a mega city, Delhi in India. Environmental health insights, 12, 1178630218792861.

Imami, A. D., Zahra, A., Sari, N. K., & Prayogo, W. (2022). Spatial Analysis of Noise Levels and Evaluation of Noise Zones Around Radin Inten II International Airport, Lampung Province. Jurnal Presipitasi: Media Komunikasi dan Pengembangan Teknik Lingkungan, 19(3), 542-552.

Kuklinska, K., Wolska, L., & Namiesnik, J. (2015). Air quality policy in the US and the EU–a review. *Atmospheric Pollution Research*, *6*(1), 129-137.

Marinello, S., Butturi, M. A., & Gamberini, R. (2021). How changes in human activities during the lockdown impacted air quality parameters: A review. Environmental progress & sustainable energy, 40(4), e13672.

Miranda, A., Silveira, C., Ferreira, J., Monteiro, A., Lopes, D., Relvas, H., ... & Roebeling, P. (2015). Current air quality plans in Europe designed to support air quality management policies. Atmospheric pollution research, 6(3), 434-443.

Murena, F. (2004). Measuring air quality over large urban areas: development and application of an air pollution index at the urban area of Naples. Atmospheric Environment, 38(36), 6195-6202.

Stieb, D. M., Burnett, R. T., Smith-Doiron, M., Brion, O., Shin, H. H., & Economou, V. (2008). A new multipollutant, no-threshold air quality health index based on short-term associations observed in daily time-series analyses. Journal of the Air & Waste Management Association, 58(3), 435-450.

Suhardono, S., Septiariva, I. Y., Rachmawati, S., Matin, H. H. A., Qona'ah, N., Nirwana, B., ... & Prayogo, W. (2023). Changes in the Distribution of Air Pollutants (Carbon Monoxide) during the Control of the COVID-19 Pandemic in Jakarta, Surabaya, and Yogyakarta, Indonesia. Journal of Ecological Engineering, 24(4).

Suman, M. (2020). Air quality indices: A review of methods to interpret air quality status. Mater. Today Proc., 34, 863-868.

Wu, C. H., Tsai, I. C., Tsai, P. C., & Tung, Y. S. (2019). Large–scale seasonal control of air quality in Taiwan. Atmospheric Environment, 214, 116868.