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Study on Improving the Accuracy of Mobile Air Quality Monitoring Systems

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Abstract

Purpose: The purpose of this study is to develop a highly accurate mobile air quality monitoring system suitable for use in various event-specific locations, such as fireworks festivals or construction sites. **Research design, data and methodology:** The study focuses on optimizing the selection and design of equipment for a mobile air quality monitoring system, aiming to reduce production costs and improve measurement accuracy. It includes a comparative analysis with existing Air Quality Monitoring Stations (AQMS) and enhances calibration methods to stabilize performance under various environmental conditions. This approach ensures a cost-effective, accurate, and efficient mobile air quality monitoring system. **Results:** By utilizing measurement data collected from various regions, further improvements can be made in the future to develop a more efficient and accurate mobile air quality monitoring system. The accuracy of the existing mobile air quality monitoring system has been enhanced through this study, making it applicable for measurements in various fields. **Conclusions:** With the growing concern about air pollution, a mobile air quality monitoring system could be effectively utilized in areas where event-based air pollution occurs, such as firework festivals or construction sites. In the future, by utilizing data from various regions, further improvements and enhancements can be made to the system, leading to a more efficient and accurate mobile air quality monitoring system.

Keywords : Air Quality Measurement System, Mobile Air Quality Monitoring System, Calibration System, Mobile Calibration Water Removal System, SPSS Statistics

JEL Classification Code : I30, I31, I32, I38, I39

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1. Introduction

The Ministry of Environment and local governments have established and are operating air quality monitoring networks to conduct basic research on air quality standards and monitor pollution levels. In Seoul, the first four air quality monitoring stations were installed in 1973. As of June 2023, a total of 645 monitoring stations are in operation

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nationwide, including urban air monitoring networks, national background concentration monitoring networks, suburban air monitoring networks, roadside air monitoring networks, and port air monitoring networks. The Korea Environment Corporation utilizes data from these nationwide monitoring networks as fundamental data for various areas, including domestic policy foundations, emission source standards, and environmental reference data. The utilization of this data is expected to increase further in the future.

However, fixed national air quality monitoring networks face limitations when used in complaint-prone areas or in response to pollutant leakage incidents due to their regional constraints. To address these issues, the National Institute of Environmental Research, municipal and provincial public health and environmental research institutes, and local governments are increasingly using mobile air quality monitoring systems installed in vehicles (Lee et al., 2012). These systems offer solutions to the existing limitations.

This study enhances the precision and calibration capabilities of the mobile air quality monitoring system. Therefore, we aim to conduct research on how the completed mobile air quality monitoring system can be utilized for various event-related measurements, such as at firework festivals or construction sites.

2. Literature Review

Through optimized design, we aim to select the measurement equipment to be installed in the mobile air quality monitoring system, reducing production costs, improving measurement accuracy, and evaluating efficiency through comparative analysis with the existing Air Quality Monitoring System (AQMS). The research method is as follows:

2.1. Selection of Measurement Equipment by Air Quality Standards

The air pollutants (Ma & Kang, 2023) to be measured by the mobile air quality monitoring system were selected according to air quality standards. These include particulate matter (Lee et al., 2022) pollutants such as PM-10 and PM-2.5 (Ma et al., 2004), and gaseous pollutants such as SO_2, NO_2, CO, and O_3. Within the scope of the urban air quality monitoring networks currently operating in Anyang and Incheon, equipment suitable for the six measurement parameters was selected by considering accuracy, precision, and response time. After comprehensive review of the specifications and manufacturers, the optimal equipment was chosen from three models that exhibited excellent accuracy, precision, and response time.

The number of decimal places used to display the results for each air pollutant varies. According to standards prior to 2023, SO_2, NO_2, and O_3 should be rounded to the fourth decimal place and displayed to the third decimal place. CO should be rounded to the second decimal place and displayed to the first decimal place, while PM-10 and PM-2.5 should be rounded to the first decimal place and displayed as whole numbers. The detailed specifications regarding these decimal place displays are outlined in Table 1.

Table 1: Unit of Pollutant and Method of Displaying Measured Values (before 2023)

Substance	Unit	Effective Number of Digits	Remarks
SO_2	ppm	0.001ppm	Round off to the fourth decimal place
NO_2	ppm	0.001ppm	Round off to the fourth decimal place
O_3	ppm	0.001ppm	Round off to the fourth decimal place
CO	ppm	0.1ppm	Round off to the second decimal place
PM-10	ug/m^3	$1ug/m^3$	Round off to the first decimal place
PM-2.5	ug/m^3	$1ug/m^3$	Round off to the first decimal place

Note: SO_2 and NO_2 of the National background and Suburb air quality networks are rounded off to the fifth decimal place to the fourth decimal place.

2.2. Design for Improving the Environment of the Mobile Air Quality Monitoring System

2.2.1. Considerations for Designing the Mobile Air Quality Monitoring System

When designing and manufacturing the vehicle for the mobile air quality monitoring system, the selection of models was limited to domestic vehicles. However, the Hyundai Starex, a 4-wheel-drive van known for its durability and ease of access to rough and sloped roads, was chosen. To maximize the efficiency of the internal space, all seats, except for the driver's and passenger's seats, were removed. This optimization allows measurement personnel to perform their monitoring and calibration tasks safely and efficiently. Special attention was given to the layout of the measurement equipment, safety precautions, and placement of accessories to ensure smooth operations.

To minimize vibrations that occur during movement and installation, the vehicle's floor was equipped with vibration-dampening treatments. Additionally, the floor was reinforced to support the weight of a 19-inch rack used for equipment installation. A space for equipment storage was created on the roof of the vehicle, and stainless-steel roof reinforcement work was conducted to facilitate easy and efficient operations.

2.2.2. Considerations for Equipment Selection and Installation in the Mobile Air Quality Monitoring System

The mobile air quality monitoring system is equipped with instruments to measure six air pollutants: PM-10, PM-2.5, SO_2, NO_2, CO, and O_3. In addition, the system includes a portable data logger for data storage and management, a small heating and cooling unit to stably control the heat generated by the measurement instruments and power supply, an exhaust vent for the removal of harmful gases during calibration, a sample line to remove interfering substances (Andersen et al., 1998) for accurate measurements, and an AVR (Automatic Voltage Regulator) to supply consistent power to the measurement devices.

The manufactured mobile air quality monitoring system will undergo field testing and regular air quality proficiency tests to identify any issues and analyze the collected data. The vehicle design blueprint is presented in **Fig. 1**.

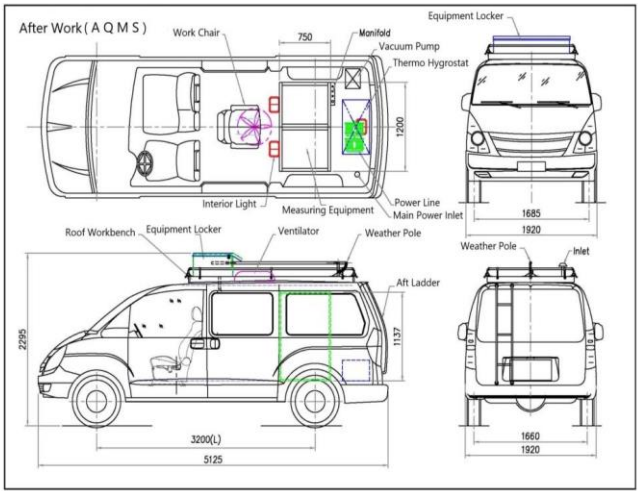


Figure 1: Mobile Air Quality Measurement System Blueprint

2.2.3. Efficiency Improvement Measures for the Mobile Air Quality Monitoring System

To enhance the efficiency of the mobile air quality monitoring system, research was conducted on the calibration system. The existing fixed zero gas and span gas calibration devices were replaced with mobile zero gas and span gas calibration devices. This allowed for the calibration and stabilization of each measurement instrument. The ultimate goal was to develop a system that improves calibration data and enhances overall efficiency.

The zero gas calibrator (Fig. 2) is a device designed to calibrate the minimum scale readings of the measurement instruments by generating zero gas, which is free of the target pollutants. The device introduces gas at a set flow rate and performs continuous measurements over a 24-hour period. If the zero reading shows the maximum deviation from the initial value, this phenomenon is referred to as zero drift.

Figure 2: Portable Zero Point Calibrator

The span gas calibrator (Fig. 3) is a device used to calibrate the maximum scale readings within the range of the measurement instruments by generating a mixture of standard gases. During the zero drift test, span gas is injected at least twice, at the start, midpoint, and end of the test, instead of zero gas, to record the instrument's readings. If the span reading shows the maximum deviation from the initial value, this phenomenon is referred to as span drift.

Figure 3: Portable Span Point Calibrator

The mobile calibration device developed is capable of performing both zero and span calibration simultaneously and can be used even in harsh environmental conditions (MOE, 2012). However, the equipment is expensive and requires skilled technicians for proper operation. In the mobile air quality monitoring system, maintaining high precision and accuracy in the data relies heavily on performing zero and span calibrations for each measurement device. It has been confirmed that, especially during long-term measurements, temperature and humidity at the measurement site significantly affect the calibration results. Therefore, stable calibration is crucial under varying environmental conditions to ensure data reliability.

Table 2: Comparison of Calibration Equipment Features

Category	Fixed Calibration Equipment	Mobile Calibration Equipment
Advantage	1. Reducing calibration time 2. Low equipment price 3. Relatively simple to drive	1. Equipment can be moved 2. Span calibration and zero calibration at the same time 3. Environmental conditions can also be used here
Disadvantage	1. Installation costs are relatively high 2. Take up a lot of space 3. Need stable environmental conditions	1. Expensive equipment purchase costs 2. Requires skilled technicians

. In this study, to reduce the error rate of calibration gases caused by humidity changes due to seasonal variations, we designed and developed a Mobile Calibration Water Removal System (MCWS), as shown in Fig. 4. This system was implemented to ensure the stability of calibration gases, thereby improving the accuracy of the mobile air quality monitoring system's calibration process. The MCWS helps mitigate the impact of humidity on calibration gases, contributing to more reliable measurement results

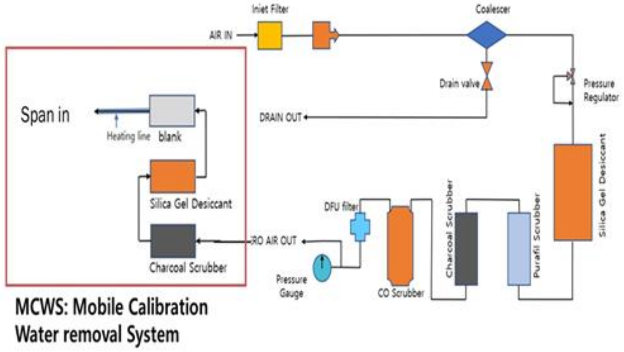


Figure 4: Mobile Calibration Water Removal System Scheme (MCWS)

The environmental standards include three categories of particulate pollutants: fine dust (PM-10) and ultrafine dust (PM-2.5), which affect the alveoli through respiration, and heavy metal pollutants such as lead (Pb). In addition to these, the gaseous pollutants consist of four key substances (Han & Kim, 2015): SO_2, NO_2, CO, and O_3, which are primarily emitted from industrial activities and energy production sectors. Furthermore, with industrialization, benzene—a carcinogenic and highly harmful substance—has been added as a monitored and regulated item.

In this study, among the eight pollutants specified in the air quality standards, we selected two particulate pollutants (PM-10 and PM-2.5) (Oh et al., 2023) and four gaseous pollutants (SO_2, NO_2, CO, and O_3), totaling six substances for detailed investigation.

3. Research Methods and Materials

The equipment for each parameter of the mobile air quality monitoring system (MOE·NIER, 2022). was selected based on precision, accuracy, and data response speed, using instruments currently employed in Korea's urban air quality monitoring networks. For gaseous pollutant measurement (KEITI, 2018), the following instruments from Teledyne were chosen: T100 for SO_2, T200 for NO_2, T300 for CO, and T400 for O_3. For particulate pollutant measurement, Met-One's E-BAM was selected to measure PM-10 and PM-2.5.

Using the improved mobile air quality monitoring system, a comparative analysis was conducted between the hourly data from the Daebu-dong urban air quality monitoring network and the mobile system's measurements during the periods from November 30, 2021, to February 16, 2022, and February 6-7, 2023. The collected data were analyzed for correlation and similarity using the statistical software SPSS.

The mobile air quality monitoring system (NIER, 2023) developed in this study has been certified for equipment stability through five rounds of proficiency tests organized by the National Institute of Environmental Research (NIER) from 2018 to 2023.

3.1. Mobile Air Quality Monitoring System Production

3.1.1. Selection of Measurement Equipment

3.1.1.1. Selection of PM-10 and PM-2.5 Equipment

For the measurement of particulate pollutants, PM-10 and PM-2.5, the E-BAM model from MetOne was selected. The specifications of this equipment are detailed in Table 3. MetOne's PM-10 and PM-2.5 measurement devices hold over 90% market share in the national background concentration monitoring networks, and more than 80% of domestic measurement companies utilize this equipment. This widespread adoption reflects the reliability and precision of the E-BAM model in monitoring particulate matter.

Table 3: Specification of PM-10, PM-2.5 Measuring Equipment (MetOne)

Manufacturer	MetOne
Model	E-BAM
Flow Rate	16.7 L/min inlet flow rate; actual volumetric flow
Filter Tape	Continuous glass fiber filter; 30 mm x 21 m roll; > 60 days/roll
Measurement range	0 - 10 mg/m^3 (0 - 10,000 $\mu g/m^3$)
Beta Source	14C (carbon-14); 60 μCi ±15 μCi (2.22 MBq)
Temperature Range Operating	-25° to +50°C.
Humidity Range Inlet	0 – 90% RH, noncondensing
Demensions	Height: 18 in (46 cm) Width: 16 in (41 cm) Depth: 9 in (23 cm)

3.1.1.2. Selection of SO_2, NO_2, CO, and O_3 Measurement Equipment

The measurement equipment for gaseous pollutants was selected based on a comparison of model specifications and matchin0g performance with the existing monitoring (Ju & Hwang, 2011) station equipment. The selected models were Teledyne's T100 (SO_2), T200 (NO_2), T300 (CO), and T400 (O_3). These models were chosen primarily for their superior precision, accuracy, and response speed compared to other models. Additionally, these instruments hold the highest market share within Korea's monitoring networks, and their reliability and accuracy have been proven, allowing for stable data collection even under adverse weather conditions. The detailed specifications of the selected models are presented in **Table 4**.

Table 4: Specification of SO2, NO2, CO, O3 Measuring Equipment (Teledyne)

Manufacturers and Models	Teledyne T100	Teledyne T200	Teledyne T300	Teledyne T400
Pollutants	SO_2	NO_2	CO	O_3
Ranges	0-50,500,200 ppb, ~ 20 ppm	0-50,500,200 ppb, ~ 20ppm	0-1,50,100~1000 ppm	0-50,500,200 ppb, ~ 20ppm
Units	ppb, ppm, ug/m3, mg/m3	ppb, ppm, ug /m3, mg/m3	ppb, ppm, ug /m3, mg/m3	ppb, ppm, ug/m3, mg/m3
Noise	0.2ppb	0.2ppb	0.02ppm	0.3ppb
Lower etectable Limit	0.4ppb	0.4ppb	0.04ppm	0.6ppb
Zero Drift	0.5ppb/24hours	0.5ppb/24hours	0.1ppm/24hours	1.0ppb/24hours
Span Drift	0.5% of full scale/24hours	0.5% of full scale/24hours	0.5% of full scale/24hours	1% of full scale/24hours
Rise and Fall Time	100sec(95% FS)	60sec(95% FS)	60sec(95% FS)	20sec(95% FS)
Precision	0.5% of reading	0.5% of reading	0.5% of reading	0.5% of reading
LInearity	1% of full scale	1% of full scale	1% of full scale	1% of full scale
Temperature Range	5~40℃	5~40℃	5~40℃	5~40℃

3.2. Mobile Air Quality Monitoring System Production

The field test photos of the completed mobile air quality monitoring system (Samad & Vogot, 2020) are presented in Fig. 5. These images demonstrate the system's deployment and operation in real-world conditions, highlighting its functionality and the setup used for data collection during the tests.

Figure 5: Mobile Air Quality Measurement System Outdoor Area

In the vehicle's interior front section (Fig. 6), 19-inch racks are installed on both the left and right sides of the driver's seat. The left rack houses the portable data logger, which is responsible for data collection, as well as the gaseous pollutant measurement equipment: Teledyne T100 (SO_2), T200 (NO_2), T300 (CO), and T400 (O_3), arranged in a single row. The right rack contains the particulate measurement equipment E-BAM PM-2.5, the main power panel, and an Automatic Voltage Regulator (AVR) to ensure stable power supply to all devices.

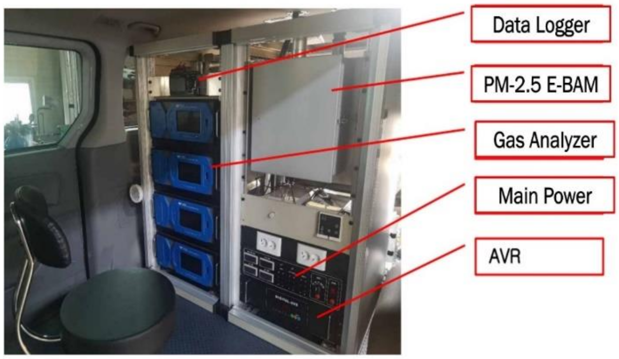
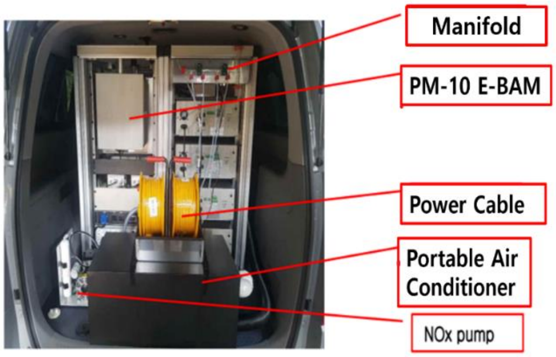


Figure 6: Mobile Air Quality Measurement System In-Front

In the rear section of the vehicle (Fig. 23), a sampling manifold and gas distributor made from PYREX and Teflon are installed to remove interfering substances and ensure smooth distribution (Choi et al., 2023) of sample gases. The PM-10 E-BAM particulate matter (Lee et al., 2018) measurement device is positioned directly opposite the PM-2.5 E-BAM device, maximizing space efficiency. A 60-meter power cable is fixed for external power supply, and a small heating/cooling unit and NOx pump are installed at the bottom for optimal system performance.

On the roof of the vehicle (Fig. 24), there is an equipment storage box, a ventilation fan for circulating exhaust gases from inside the vehicle, and a foldable weather mast. Inside the storage box, you will find the gas sampling manifold, and automatic weather observation devices such as the thermo-hygrometer and wind direction/wind speed sensors, along with the inlets for PM-10 and PM-2.5.

The estimated power consumption of the developed vehicle was calculated based on the Ministry of Environment's guidelines for installing and operating air quality monitoring networks. The expected consumption is approximately 6.79 kW to 7.29 kW.



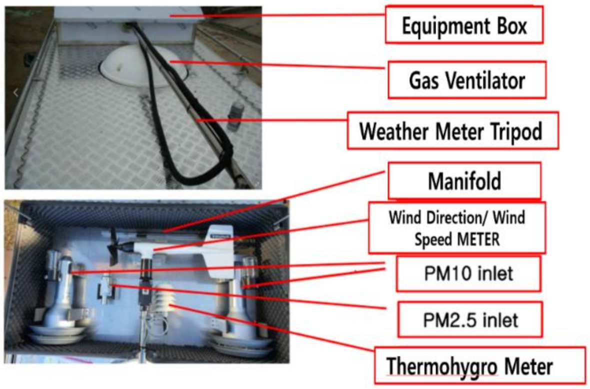


Figure 7: Mobile Air Quality Measurement System Roof and Storage Box

3.3. Efficiency Improvement Measures for the Mobile Air Quality Monitoring System

3.3.1. Improvements in Calibration Devices for Measurement Equipment

To remove harmful gases generated during calibration and to create sufficient workspace for calibration tasks, a water removal system was developed. In order to ensure the accuracy of measurement data, calibration must be performed in the field. Using fixed calibration equipment can lead to high costs and spatial limitations; therefore, mobile calibration equipment was used for these tasks. Mobile calibration devices (Do et al., 2013) are particularly sensitive to moisture, making them essential when the ambient humidity exceeds 80%, such as during rain or precipitation events.

Fig. 8 illustrates the manufacturing process of the water removal system, while Fig. 9 shows the improved Mobile Calibration Water Removal System (MCWS). This system was developed to enhance calibration accuracy and maintain system efficiency in high-humidity conditions

Figure 8: Prototype of MCWS

Figure 9: Primary Improvement of MCWS

The Mobile Calibration Water Removal System (MCWS) is composed of the following stages: inlet → activated carbon → silica gel → empty chamber → outlet. The distance between each component was minimized, and a heating wire was installed on the final gas outlet line to reduce moisture condensation. To ensure adequate removal of interfering gases and moisture, the activated carbon and silica gel components were upgraded to a large-capacity system.

First, humidity in the air was measured using a hygrometer, followed by the activation of the MCWS, after which moisture levels were measured again at the outlet. Before the improvements, the average humidity was 53.7%, while after the enhancements, the humidity decreased to 47.7%, representing a reduction of approximately 10%. The efficiency of the MCWS before and after the improvements is detailed in **Table 5**.

Table 5: Improved MCWS Effect of Mobile Air Quality Measurement System

Category	Before Improvement	After Improvement	Reduction efficiency(%)
Aug 17th	54.6	40.1	27
Aug 18th	49	45.2	8
Aug 19th	49.9	47.1	6
Aug 20th	54.2	40.7	25
Aug 21th	57	55.2	3
Aug 22th	55.8	50.2	10
Aug 23th	59.9	51.1	15
Aug 24th	47.1	45.4	4
Aug 25th	49.7	48.3	3
Aug 26th	68	59.4	13
Aug 27th	47.2	42.3	10
Aug 28th	52.1	47.9	8
Min.	47.1	40.1	3
Max.	68	59.4	27
Avg.	53.7	47.7	10

By applying the Mobile Calibration Water Removal System (MCWS), air quality measurement equipment can be operated more stably and effectively even in high-moisture environments, such as during the monsoon season. The cost-saving effects of the MCWS implementation are analyzed in Table 19, focusing on economic viability.

The cost analysis was based on data from the bid for the "2024 Daegu-Gyeongbuk Air Quality Monitoring Network Operation and Management Services" posted on the public procurement website Narajangteo. As of March 2023, the operating costs for the 642 air quality monitoring networks across the country were taken as the reference. According to the tender announcement, the operating cost per monitoring station is 18,670,000 KRW, and the total nationwide operating cost is 11,986,140,000 KRW.

Based on the 10% humidity reduction effect derived from this study, a 10% reduction in operating costs was applied. This results in a cost savings of 1,867,000 KRW per station, and a nationwide savings of 1,198,614,000 KRW.

Table 6: Cost Reduction Effect from the Application of Developed MCWS

Category	National Air Quality Measurement Networks Operating Cost				
	Stations	Costs/yr	Total/yr	Efficiency	Cost Reduction Effect
Based on Station	1	18,670	18,670	10%	1,867
Based on Country	642	18,670	11,986,140	10%	1,198,614

3.4. Comparison of Measurement Data from the Mobile Air Quality Monitoring System and the Urban Air Quality Monitoring Network: Location B

The measurement results from the mobile air quality monitoring system (Elen et al., 2012) were compared with the daily average values from the nearby Daebu-dong urban air quality monitoring network for the following periods: November 30 to December 1, 2021, February 15 to February 16, 2022, and February 6 to February 7, 2023. The results are presented in Table 7. In Table 7, B-1 represents the measurement data from the mobile air quality monitoring system, while B-2 represents the values recorded by the Daebu-dong urban air quality monitoring network.

This comparison aims to assess the accuracy and consistency of the mobile system's data with that of the established urban monitoring network over different periods.

3.3.1. Improvements in Calibration Devices for Measurement Equipment

To remove harmful gases generated during calibration and to create sufficient workspace for calibration tasks, a water removal system was developed. In order to ensure the accuracy of measurement data, calibration must be performed in the field. Using fixed calibration equipment can lead to high costs and spatial limitations; therefore, mobile calibration equipment was used for these tasks. Mobile calibration devices are particularly sensitive to moisture, making them essential when the ambient humidity exceeds 80%, such as during rain or precipitation events.

Table 7: Daily Average Data of Mobile Air Quality Measurement System, Daebu Community Service Center(Nov 30th~Dec 1th, 2021 & Feb 15th~16th, 2022 & Feb 6th~7th, 2023)

Date Contents	2021		2022		2023	
	Nov 30th~Dec 1th		Feb 15th~16th		Feb 6th~7th	
	B-1	B-2	B-1	B-2	B-1	B-2
SO_2 (ppm)	0.002	0.002	0.003	0.003	0.004	0.004
NO_2 (ppm)	0.012	0.004	0.010	0.005	0.027	0.031
PM-10 (㎍/㎥)	23	16	23	21	78	79
PM-2.5 (㎍/㎥)	11	7	16	15	49	54
O_3 (ppm)	0.032	0.031	0.035	0.041	0.031	0.029

Using WRPLOT, Fig. 10 presents the wind rose for the period from November 30 to December 1, 2021. The dominant wind direction is northwest, and the average wind speed is 9.83 m/s. This wind rose diagram visually represents the wind patterns during the specified period, showing the frequency of wind speeds and directions, which are crucial for understanding pollutant dispersion in the area.

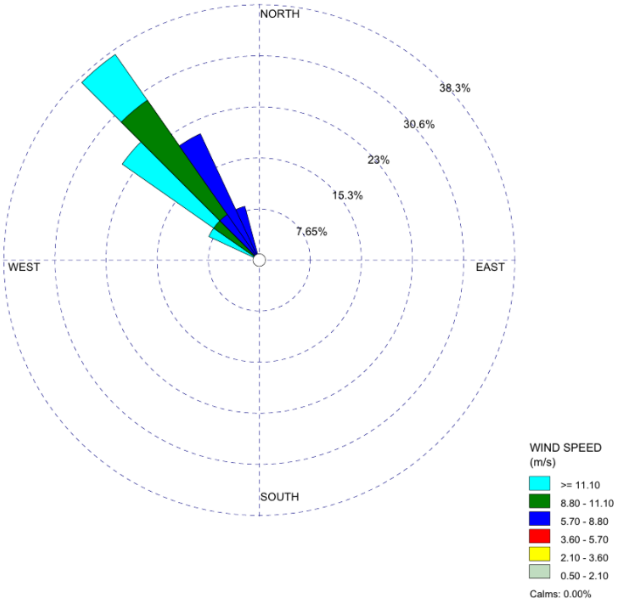


Figure 10: Wind Rose (Nov 30th~Dec 1th, 2021)

Using WRPLOT, Fig. 11 displays the wind rose for the period from February 15 to February 16, 2022. The dominant wind direction is northwest, with an average wind speed of 5.83 m/s. This diagram provides insights into wind patterns during this period, which is essential for analyzing the potential movement and dispersion of air pollutants in the region.

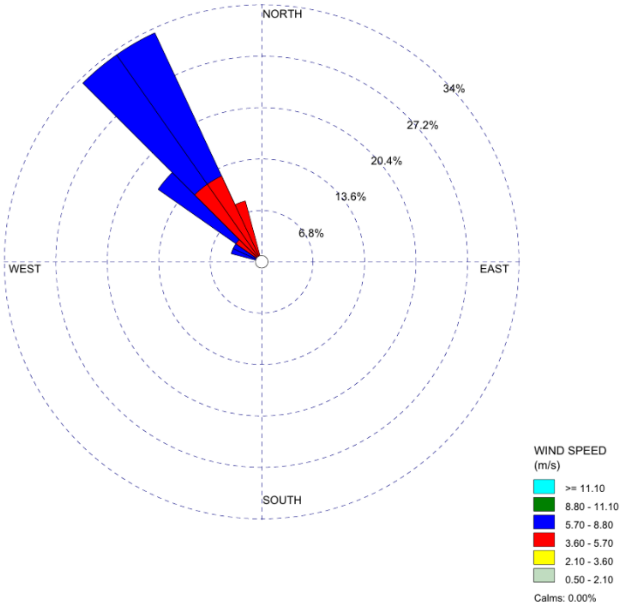


Figure 11: Wind Rose (Feb 15~16th, 2022)

Using WRPLOT, Fig. 12 illustrates the wind rose for the period from February 6 to February 7, 2023. The predominant wind direction is north-northeast, with an average wind speed of 2.33 m/s. This wind rose chart helps visualize the wind patterns during this timeframe, providing valuable information for understanding the dispersion of air pollutants (Kim et al., 2021; Kim et al., 2023) in the area.

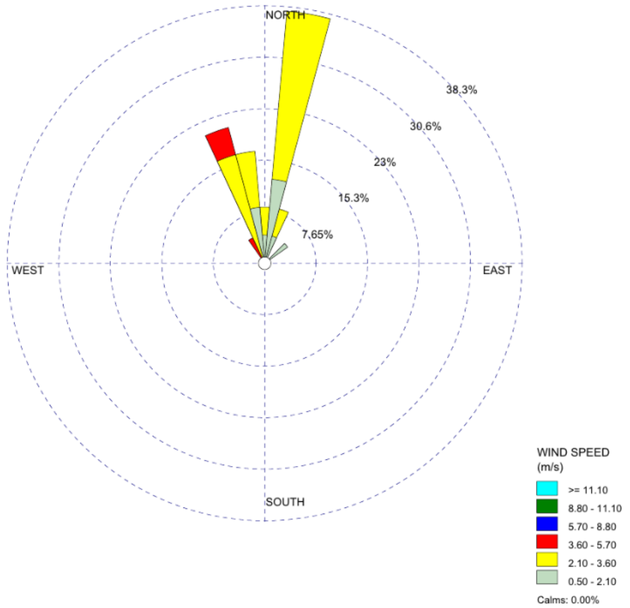


Figure 12: Wind Rose (Feb 6~7th, 2023)

Fig. 13 and Fig. 14 depict the changes in concentration of gaseous and particulate pollutants in response to meteorological factors (Kim, 2020) from November 30 to December 1, 2021. The prevailing wind direction was northwest, with an average wind speed of 9.83 m/s. The area surrounding the measurement (Kim et al., 2021) site consisted of residential and green spaces, with no significant pollution sources, and the low traffic volume on nearby local roads was deemed to have minimal impact.

An analysis of the concentration changes for gaseous pollutants in relation to the wind rose revealed that concentrations of NO_2 and O_3 tended to increase as wind speed decreased. In particular, the higher concentrations observed during daytime suggest that photochemical reactions contributed to the formation of NO_2 and O_3, indicating the influence of these processes on pollutant levels.

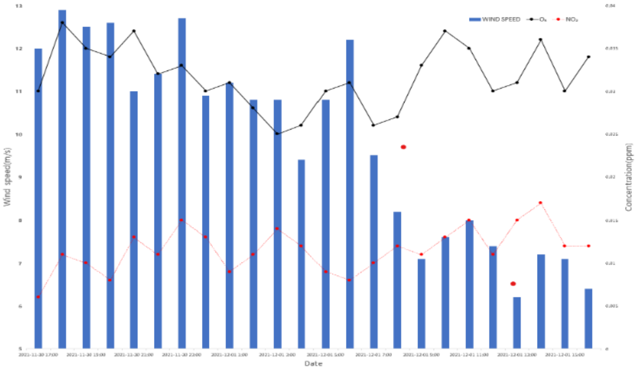


Figure 13: Variation of Gaseous Substances Concentration by Meteorological Factors (Nov 30~Dec 1th, 2021)

An analysis of the concentration changes in particulate pollutants according to the wind rose revealed that both PM-10 and PM-2.5 showed a trend of increasing concentrations as wind speed decreased. This can be attributed to atmospheric stagnation, which occurs when wind speeds are low, leading to higher concentrations of particulate matter (EPA, 2023a: EPA, 2023b) as pollutants are less dispersed and accumulate in the area.

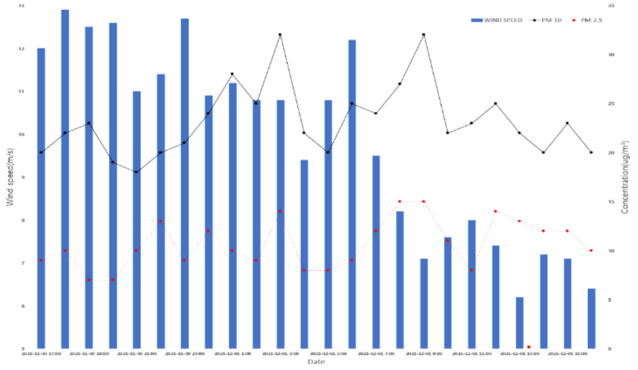


Figure 14: Variation of Particulate Matter Concentration by Meteorological Factors (Nov 30~Dec 1th, 2021)

Fig. 15 and Fig. 16 depict the changes in concentration of gaseous and particulate pollutants in relation to meteorological factors from February 15 to February 16, 2022. The prevailing wind direction was northwest, with an average wind speed of 5.83 m/s. Similar to previous observations, the area surrounding the measurement (Hinds & Zhu, 2022) site consisted of residential and green spaces, with no significant pollution sources, and the low traffic volume on nearby local roads was deemed to have minimal impact.

The analysis of gaseous pollutants in relation to the wind rose showed a repeating pattern in which the concentration of O_3 decreased when NO_2 levels were high, due to the photochemical reactions that produce ozone (Park, 2023) from nitrogen dioxide. As NO_2 levels dropped, O_3 concentrations rose again, reflecting the dynamic interplay between these two pollutants influenced by photochemical processes. This pattern highlights the impact of NO_2 on O_3 formation and the cyclical nature of their concentration changes.

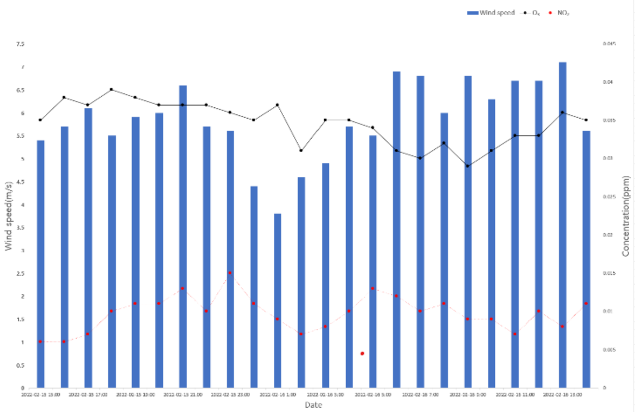


Figure 15: Variation of Gaseous Substances Concentration by Meteorological Factors (Feb 15~16th, 2022)

The analysis of particulate pollutant concentration changes based on the wind rose indicated a trend where concentrations of PM-10 and PM-2.5 increased as wind speed rose. Although there were no significant pollution sources in the vicinity, this increase in particulate matter concentration (Ryoo et al., 2019) is likely due to the movement of fine dust carried by the northwest winds typically observed during the winter months. These winds may transport particulate matter (Park & Lee, 2015; Son et al., 2016) from other regions, resulting in elevated concentrations at the measurement site.

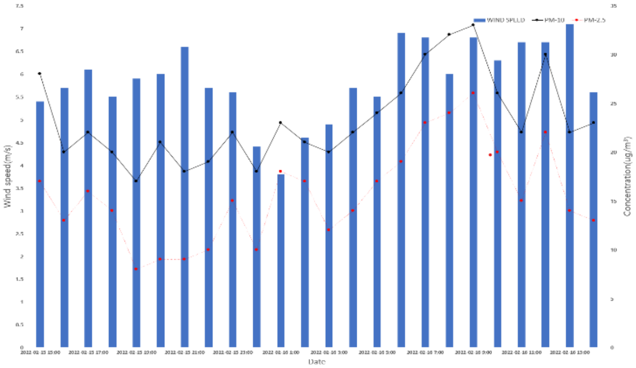


Figure 16: Variation of Particulate Matter Concentration by Meteorological Factors (Feb 15~16th, 2022)

Fig. 15 and Fig. 16 illustrate the changes in the concentration of gaseous and particulate pollutants (Park et al., 2022) in relation to meteorological factors from February 6 to February 7, 2023. The prevailing wind direction was north-northeast, with an average wind speed of 2.33 m/s. The measurement site was located in a residential and green area with no significant pollution sources, and nearby local road traffic was minimal, indicating no substantial impact on pollutant levels.

The analysis of gaseous pollutants based on the wind rose revealed a recurring pattern where O_3 concentrations decreased when NO_2 levels were high, due to the photochemical reactions that generate ozone from nitrogen dioxide. As NO_2 concentrations decreased, O_3 levels rose, indicating the dynamic relationship between these two pollutants influenced by photochemical processes. This cyclical pattern highlights the inverse relationship between NO_2 and O_3 concentrations in the atmosphere.

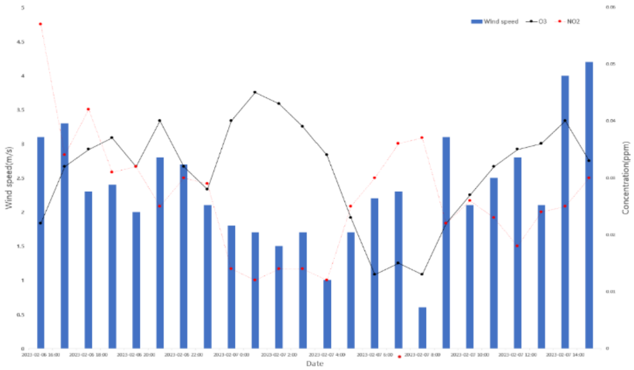


Figure 17: Variation of Gaseous Substances Concentration by Meteorological Factors (Feb 6~7th, 2023)

The analysis of particulate pollutant concentration changes based on the wind rose indicated that both PM-10 and PM-2.5 concentrations increased as wind speed decreased. It is generally known that fine dust levels tend to be high from late autumn to early spring, with high concentrations often occurring when wind speeds are around 1.8 m/s. The high frequency of fine dust concentration peaks in February likely contributed to this trend. The lower wind speeds during this period allow for the accumulation of particulate matter, leading to elevated levels, especially in winter months like February when the occurrence of high-concentration events is most frequent.

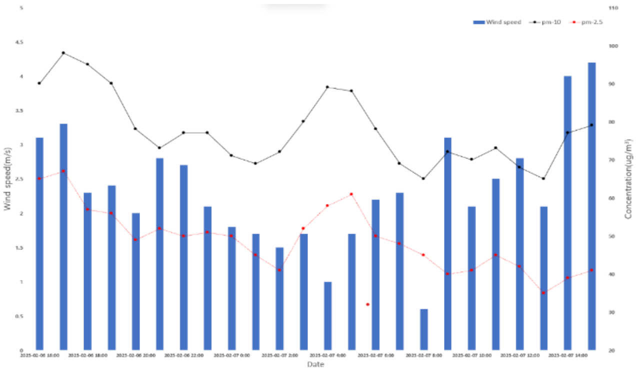


Figure 18: Variation of Particulate Matter Concentration by Meteorological Factors (Feb 6~7th, 2023)

3.5. Data Statistical Analysis: Location B (Interpretation of Correlation Analysis of Samples)

To examine the correlation between the concentrations (Han et al., 2016) of PM-10, PM-2.5, O_3, NO_2, and SO_2 measured at Daebu-dong Administrative Welfare Center and Daebu-dong in Ansan, a Pearson correlation analysis was conducted. The results are presented in Table 8. A total of 70 data points were used in this study, and the correlation coefficients for each substance were as follows: PM-10 = 0.975, PM-2.5 = 0.969, O_3 = 0.073, NO_2 = 0.914, and SO_2 = 0.672.

A correlation coefficient close to 1 indicates a strong positive correlation, while a coefficient close to -1 indicates a strong negative correlation. Except for O_3, all substances showed significant correlations at the 0.01 level. The low correlation coefficient for O_3 is attributed to its high reactivity to ultraviolet light and wind speed, which causes large variations in the data. For SO_2, the correlation coefficient was lower because its background concentration is relatively low, leading to larger data deviations. The other substances exhibited strong positive correlations, indicating that their concentrations tended to increase or decrease together in the study area.

Table 8: Pearson Correlation of Data

N=70

Division		**Daebu-dong, Ansan-si-PM10**	**Daebu-dong, Ansan-si-PM2.5**	**Daebu-dong, Ansan-si-O_3**	**Daebu-dong, Ansan-si-NO_2**	**Daebu-dong, Ansan-si-SO_2**
Daebu-dong Community Service Center - PM10	Pearson Correlation	0.975**				
	Sig.(2-tailed)	<0.001				
Daebu-dong Community Service Center - PM2.5	Pearson Correlation		0.969**			
	Sig.(2-tailed)		<0.001			
Daebu-dong Community Service Center - O3	Pearson Correlation			0.073**		
	Sig.(2-tailed)			0.547		
Daebu-dong Community Service Center - NO2	Pearson Correlation				0.914**	
	Sig.(2-tailed)				<0.001	
Daebu-dong Community Service Center - SO2	Pearson Correlation					0.672**
	Sig.(2-tailed)					<0.001

** Correlation is significant at the 0.01 level (2-tailed)

4. Conclusions

In this study, we improved the accuracy of the existing mobile air quality monitoring system by enhancing the efficiency of span and zero calibrations using mobile calibration equipment, thereby improving precision and accuracy. Additionally, to ensure stable measurements in environments with unstable weather conditions, we installed a portable heating and cooling system. Furthermore, we developed a Moisture Removal System (MCWS), enabling accurate measurements even when humidity exceeds 80% or during precipitation events. To minimize vibrations during vehicle movement, we reinforced the vehicle's underside with vibration-damping devices and modified the equipment racks. For better space utilization and stable sampling, we installed an equipment storage compartment on the roof and reinforced the roof with stainless steel for durability.

The mobile air quality monitoring system was tested and its results were compared with the nearby urban air quality monitoring network using SPSS. The measurement parameters included PM-10, PM-2.5, SO_2, NO_2, CO, and O_3—a total of six pollutants—measured in the Daebu-dong area of Ansan City. When comparing the results from B-1 (Daebubuk-dong, Danwon-gu, Ansan City) and B-2 (Daebu-dong Administrative Welfare Center), all pollutants showed significant correlations at the 0.01 level. The correlation coefficient for O_3 was relatively low due to its high reactivity to ultraviolet light and wind speed, leading to greater variability in the data. For SO_2, the lower background concentration resulted in a larger data variance, lowering the correlation coefficient. Other pollutants demonstrated strong positive correlations.

The advantages of the mobile air quality monitoring system (Kim & park, 2020) developed in this study are as follows:

1. The improved MCWS resulted in reduced initial costs and enabled the collection of high-precision and accurate data.
2. The system was designed to be more compact, expanding the range of areas that can be monitored. It is also suitable for regions where fixed monitoring stations are difficult to install, and for event-specific situations such as fireworks festivals.

In the future, by utilizing data from various regions, further improvements and enhancements can be made to the system, leading to a more efficient and accurate mobile air quality monitoring system (Ghim & Kim, 2013). This study successfully improved the accuracy of the existing system, ma0king it applicable across various fields. With increasing concern over air pollution, this system will also be actively utilized at events like fireworks festivals and construction sites, where temporary air pollution (Finkelstein, 1976) can occur.

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