

Using PM2.5 Automatic Component Analyzer PX-375 Practical Examples of Air Quality DX

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Monitoring of the atmospheric environment has been conducted continuously from the viewpoints of environmental preservation and health hazard prevention, mainly focusing on monitoring nitrogen oxides and ozone, but recently there has been growing interest in the health effects of particulate matter (PM) and heavy metals contained therein. Conventional methods for analyzing particulate matter components require sample pretreatment and expertise, and have real-time performance issues. We propose a monitoring method that utilizes the PX-375 and Eco-WEB: the PX-375 enables continuous measurement of elements contained in particulate matter in a short time, while Eco-WEB realizes real-time data collection and analysis. The Eco-WEB enables quick and efficient environmental monitoring and is expected to contribute to the reduction of environmental burdens in industrial areas and manufacturing industries.



Introduction

Monitoring and management of atmospheric environments are extremely important from the perspectives of environmental conservation and the prevention of health hazards, and such activities have been continuously undertaken to date. The significance of these efforts continues to grow, particularly in industrial regions where the emission of air pollutants is a concern due to their potential impacts on the health of local residents and the surrounding environment. Consequently, the establishment of accurate and continuous monitoring systems is an urgent necessity. Atmospheric monitoring typically involves collecting airborne particulate matter (PM) onto filters using devices such as high-volume air samplers, followed by measurement of the types and quantities of contained elements using techniques

such as ICP-MS (Inductively Coupled Plasma Mass Spectrometry) and ICP-AES (Inductively Coupled Plasma Atomic Emission Spectroscopy).

However, this method requires processing collected samples through multiple steps such as acid digestion and pretreatment over a 24-hour sampling period, necessitating specialized knowledge and expertise for measurement^[1]. As a result, analysis after sampling takes considerable time, making real-time data collection and analysis challenging. Furthermore, the obtained data represent the total amount of particulate matter collected over 24 hours, making it difficult to determine during which specific time periods the particles were captured.

To address these issues, we have proposed an atmospheric monitoring approach utilizing the “PX-375 Automated

PM2.5 Component Analyzer”^{[2],[3]} (hereafter, PX-375) and the atmospheric monitoring system “Eco-WEB” (hereafter, Eco-WEB). This method enables rapid and efficient environmental monitoring through real-time data collection and automated analysis.

PX-375 is an instrument equipped with both mass concentration and elemental concentration analysis units, capable of collecting airborne particulate matter onto tape and continuously measuring both the mass and specific elements contained in the particles at intervals as short as 30 minutes (Figure 1). By analyzing the elements contained in particulate matter, it becomes possible to quickly and easily infer the potential sources of emissions (Figure 2).

Moreover, PX-375 can automatically and continuously measure 15 standard elements, generating a vast amount of data daily. Manual analysis of these data is time-consuming and labor-intensive, making prompt responses

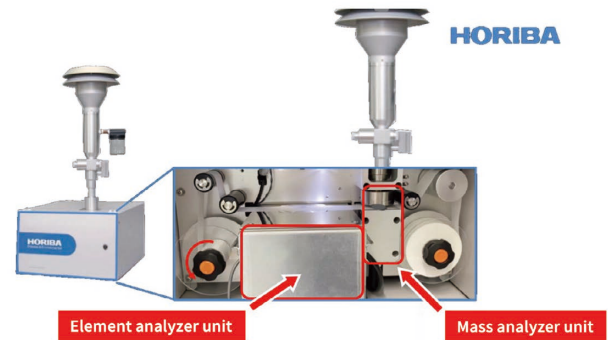


Figure 1 Continuous Particulate Monitor with X-ray Fluorescence PX-375.

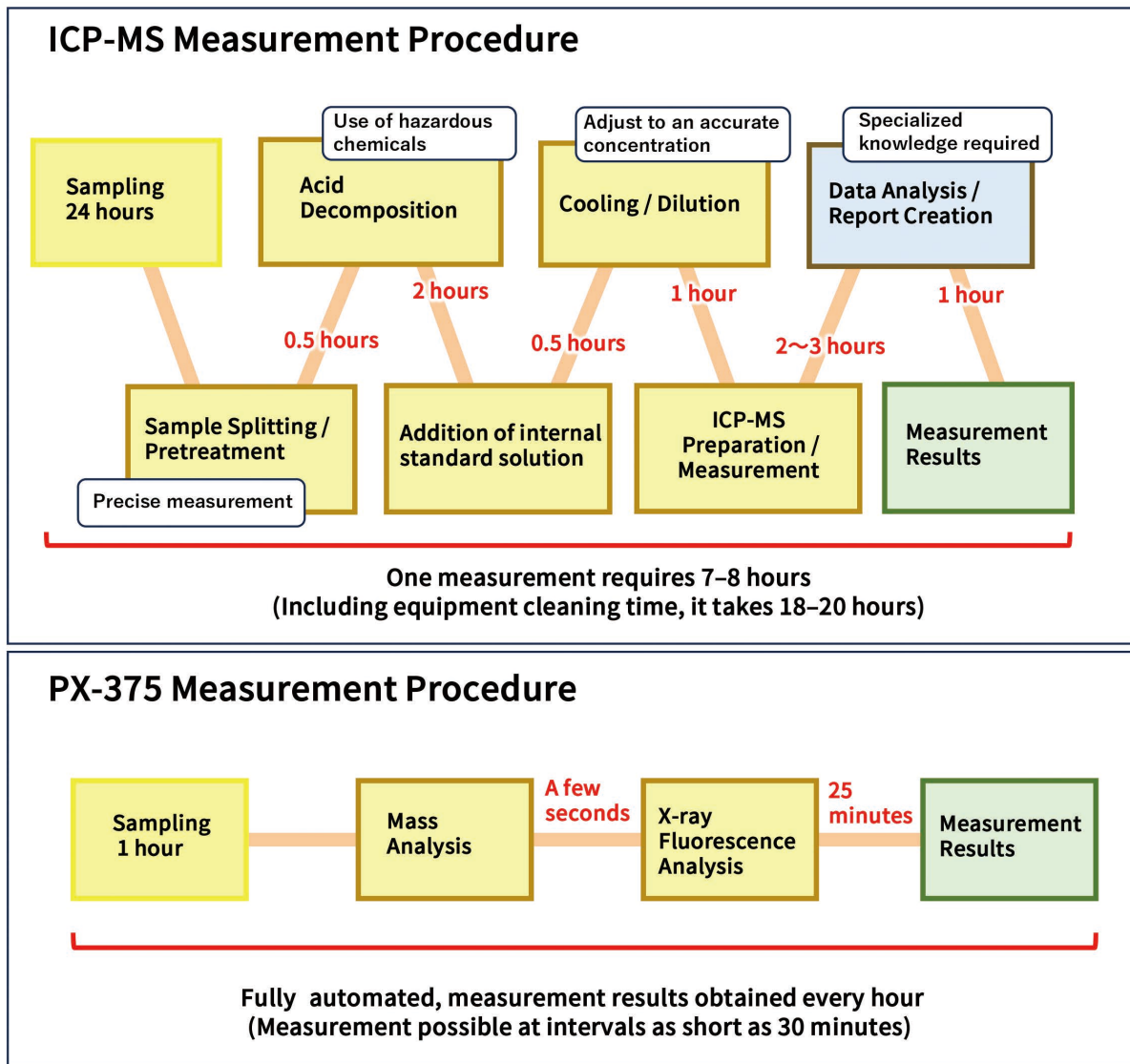


Figure 2 Measurement Procedure Image of ICP-MS and PX-375.

difficult. To resolve this, we have developed “Eco-WEB,” a system that integrally collects and processes PX-375 data. Eco-WEB establishes a measurement network capable of connecting multiple instruments, thereby facilitating the collection and analysis of environmental data (Figure 3).

Through this system, it has become possible to achieve real-time data collection and analysis, which was previously difficult, thereby enabling efficient atmospheric monitoring.

Automated Component Analysis of Particulate Matter Using PX-375

Particulate matter is among the most critical air pollutants, and understanding its composition is essential for identifying

emission sources and elucidating generation mechanisms, which are indispensable for formulating atmospheric environmental measures. Conventional analysis of elements contained in airborne particulate matter has employed highly sensitive ICP-based techniques such as ICP-MS and ICP-AES. However, these methods require hazardous reagents for pretreatment and are time- and cost-intensive, making them unsuitable for rapid trend assessment.

In contrast, PX-375 utilizes X-ray fluorescence (XRF) analysis, enabling fully automated measurement without pretreatment. The instrument supports 15 standard elements (Al, Si, S, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Pb), and additional elements can be included through calibration (Figure 4).

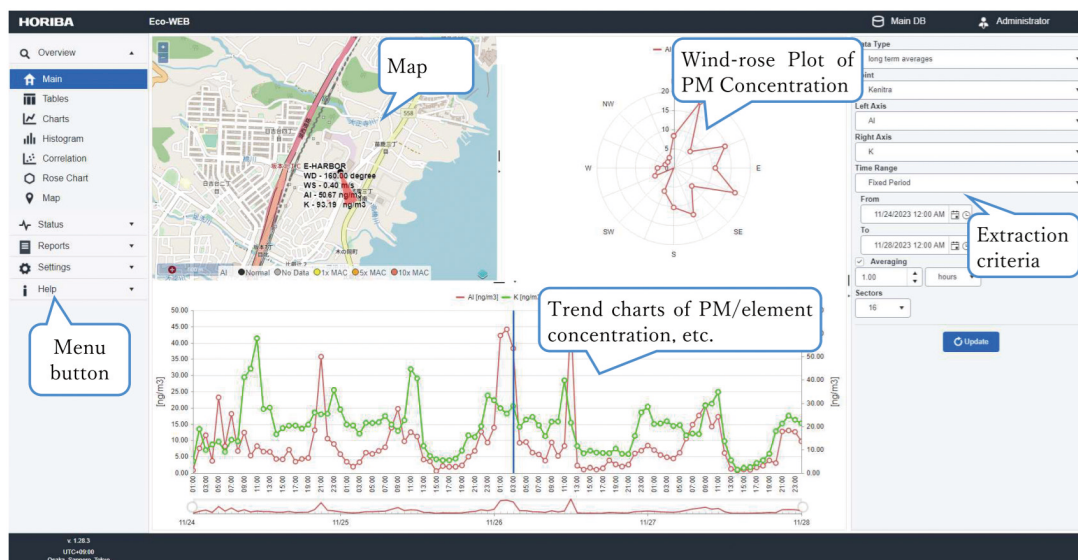
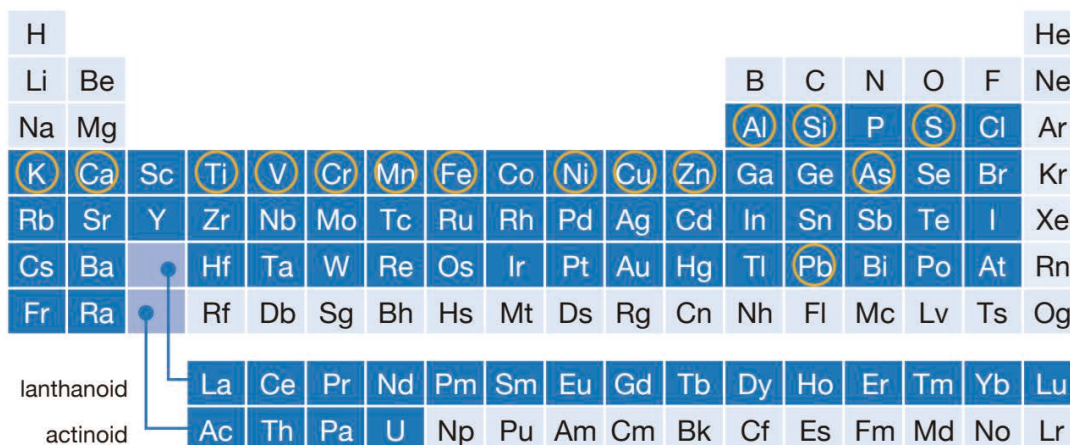


Figure 3 Main Screen of the Air Quality Monitoring System ‘Eco-WEB’.



Detectable Elements

- * —Standard parameters, calibrated by standard calibration materials at factory.
- * To measure element concentration, analyzer needs to be calibrated by standard calibration materials.
- * Please contact separately about elements, marked as non-detectable.

Figure 4 Detectable elements of PX-375

Although XRF is somewhat less sensitive than ICP methods, it allows for direct sample analysis and continuous measurement of elemental concentrations with the same temporal resolution as mass concentration. Due to its reliability and measurement speed, PX-375 has been adopted by air monitoring stations of the Ministry of the Environment, and since April 2017, continuous measurement of 15 elements every four hours has been conducted at four locations nationwide. This has enabled the rapid detection of component fluctuations and emission situations, which were previously difficult to assess.

In the private sector, PX-375 is mainly introduced for monitoring environmental load substances associated with manufacturing processes in company factories, and is utilized for emission management, evaluation of impacts on the surrounding environment, and as part of environmental countermeasures.

Case Studies of PX-375 and Eco-WEB Implementation

PX-375 is an instrument for continuous, rapid measurement of airborne particulate matter, while Eco-WEB is a system for real-time analysis and management of the resulting data. By combining these systems, it is possible to identify emission sources and respond quickly to emissions, thus greatly contributing to the reduction of environmental impact from factories (Figure 5).

In one factory, the urgent issue was to identify sources of chemical emissions and reduce environmental impact. As previously mentioned, the conventional method using

high-volume air samplers and ICP analysis is based on “24-hour average” or “annual average” values, making it difficult to determine the specific time of emission within the 24-hour sample when environmental load substances are detected. Therefore, PX-375, with its excellent real-time capability, was introduced to establish a detailed monitoring system. A mobile monitoring station equipped with PX-375 was installed on a light truck to measure the atmospheric environment at various points within the factory, enabling the identification of elemental emissions and estimation of emission sources.

Measurements revealed that various substances were being emitted from multiple locations within the factory, and in addition to the anticipated emission sources, unexpected sources were also identified. By analyzing the relationship between manufacturing processes and emitted substances, it was possible to accurately estimate which manufacturing processes were responsible for specific air pollutants.

However, instances were observed where high concentrations of metallic elements were detected while the factory was shut down. Initially, external sources were suspected due to the factory’s inactivity, but upon checking onsite activities, it was found that high concentrations of metallic elements were detected during chimney cleaning operations conducted while the incinerator was stopped. During operation, fans in chimneys not in use are inactive, but when these fans are run during cleaning, metallic elements accumulated inside are released.

Furthermore, by combining data from the mobile monitoring station with information on factory processes and wind

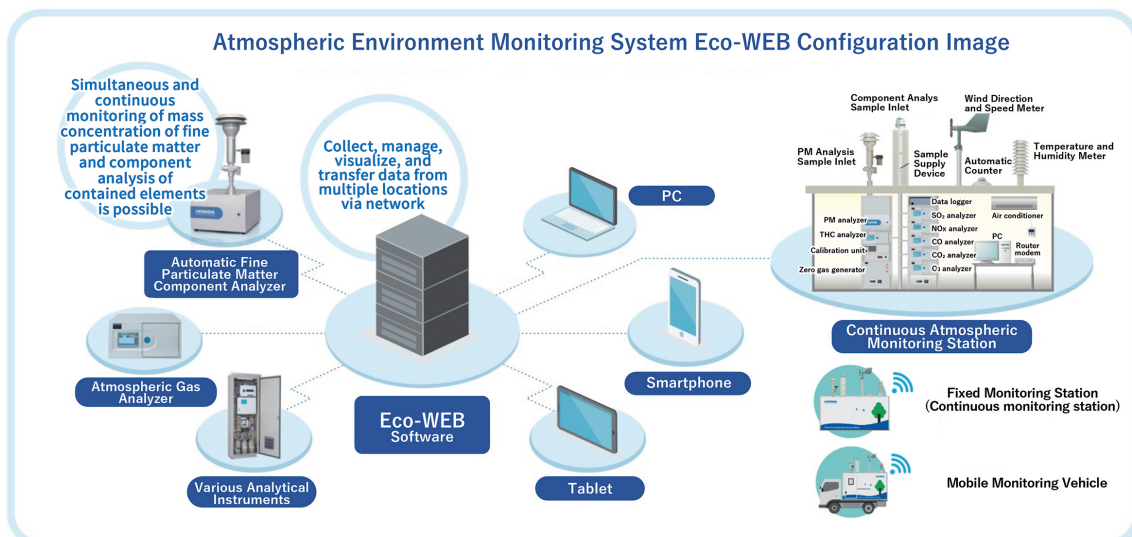


Figure 5 ‘Eco-WEB’ Air Quality Monitoring System Configuration.

direction/speed, statistical analysis showed that certain processes, when active, resulted in detection from specific directions, thereby substantiating the reliability of the data.

This case demonstrated that metallic elements could be emitted from unexpected locations even when the incinerator was stopped, highlighting the importance of continuous monitoring and leading to the installation of a fixed monitoring station.

On the other hand, data collection from the mobile monitoring station was conducted via USB memory and analyzed using spreadsheet software, resulting in operational burdens. To address these issues, the fixed monitoring station was introduced alongside Eco-WEB, which automated data collection and analysis. Eco-WEB automatically collects and organizes data obtained by PX-375 (PM mass, concentration, and elemental concentrations) and visualizes it in real time. Additionally, it features an automatic alert function that sends warning emails to relevant personnel when concentrations exceeding preset thresholds are detected. This enables immediate identification of abnormal values, verification of the relevant time periods and detected elements, and rapid communication with relevant departments to confirm onsite activities.

The integration of PX-375 and Eco-WEB has enabled real-time response, which was difficult with manual data processing. This has facilitated the identification of emission sources and prompt countermeasures, resulting in a substantial reduction of environmental impact across the factory. Furthermore, continuous monitoring has established a mechanism for ongoing evaluation and improvement of the effectiveness of implemented measures.

Data Analysis and Source Estimation Methods

Eco-WEB is equipped with both routine monitoring functions and advanced data analysis capabilities. For daily monitoring, concentration thresholds (alarm values) can be set for each element, and when measurements exceed these thresholds, automatic email alerts are sent to relevant personnel.

For source identification, multifaceted analysis is performed on accumulated measurement data using trend charts, radar charts, correlation graphs, and other visualization tools. For example, the composition ratios of contained elements may differ even at the same PM concentration, and by analyzing these differences, as well as detected directions, time periods, and inter-element correlations, emission sources can be more precisely identified.

The analysis process begins with trend charts to grasp overall tendencies, confirming the dates and times when concentrations of monitored elements are elevated and their fluctuation patterns. Next, correlation coefficients between potentially related elements are checked, and highly correlated element groups are extracted. When specific elements exhibit simultaneous increases, it is likely that they originate from the same emission source.

Focusing solely on total PM concentration may obscure relationships among elements; therefore, understanding inter-element correlations using correlation coefficients and graphs is important. However, high correlation coefficients may be masked by data variability or outliers, and correlations may be non-linear, necessitating direct graph inspection. Excluding outliers enables more accurate evaluation (Figure 6).

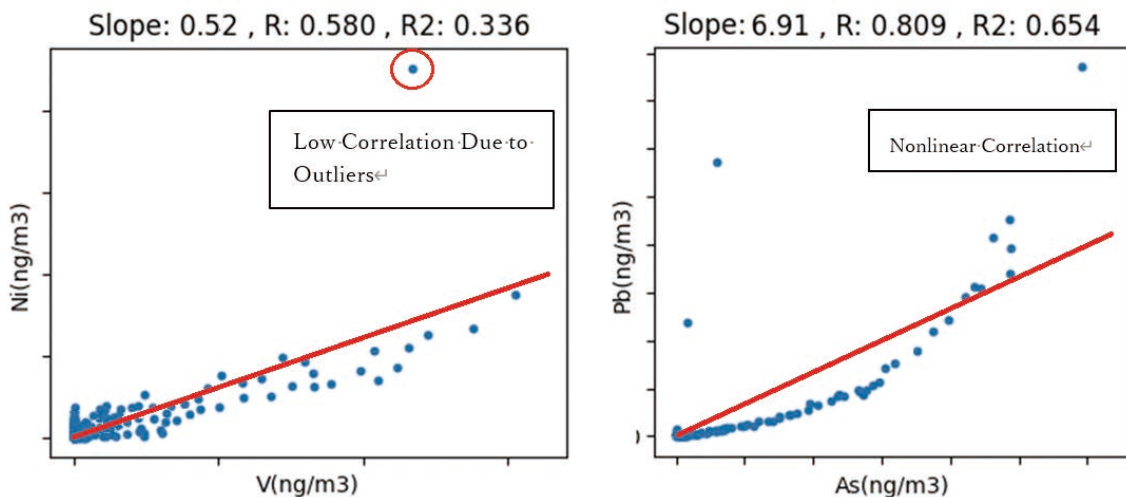


Figure 6 Example of Low Correlation.

When elements with strong correlations are identified, their emission patterns are further analyzed using trend charts and correlation graphs. Moreover, by leveraging wind direction and speed data, the direction of detection for target elements can be determined; if high concentrations are consistently detected from a particular direction, it is highly probable that the emission source is located in that direction. If multiple similar sources exist in the same direction, comparison of element ratios (e.g., Pb/As) can help distinguish them. The ratio may differ depending on whether the source is internal or external, and source estimation can be performed by comparing ratios under specific conditions.

Common source estimation methods include PMF (Positive Matrix Factorization)^[4] and CPF (Conditional Probability Function)^[5], but the CBPF (Conditional Bivariate Probability Function)^[6], which integrates wind direction, wind speed, and concentration data, enables deeper understanding of source locations and contributions*.

Figure 7 shows an example of a graph drawn using the CBPF method, with wind speed plotted on the radial axis, the center representing 0 m/s, and the outer circle representing the maximum wind speed. The colors on the graph indicate increasing observation quantities in the order blue → green → red.

By changing the filtering conditions for displayed data, diverse insights can be gained. For example, if only high-concentration PM is extracted and plotted, and red data appear in the northeast direction, it indicates detection of high-concentration PM from the northeast, with wind

speed serving as a proxy for distance. Cross-referencing with actual maps would suggest a high likelihood of emission sources in that direction. Similarly, plotting for specific heavy metals such as Ni, Cr, Mn is expected to yield additional insights into their respective sources. These analyses demonstrate the effectiveness of the CBPF method for source identification and contribution assessment.

* The CBPF method is currently under development for implementation, and evaluations toward practical application are underway.

Future Prospects

Mathematical processing and analysis of data obtained from measurement instruments enable identification of certain trends and characteristics. However, not all phenomena can be explained by the results, and correct interpretation requires understanding of the data's background and context.

Actual observation data may include substances detected only from specific directions or time periods, as well as substances detected continuously from all directions, each exhibiting distinct characteristics. Moreover, the process of analyzing and interpreting measured data remains difficult to automate, often relying on experience-based judgment, leading to a tendency for analysis tasks to become dependent on individual expertise. The shortage of technical personnel with data analysis expertise is also a challenge.

In view of these circumstances, there is a need to build

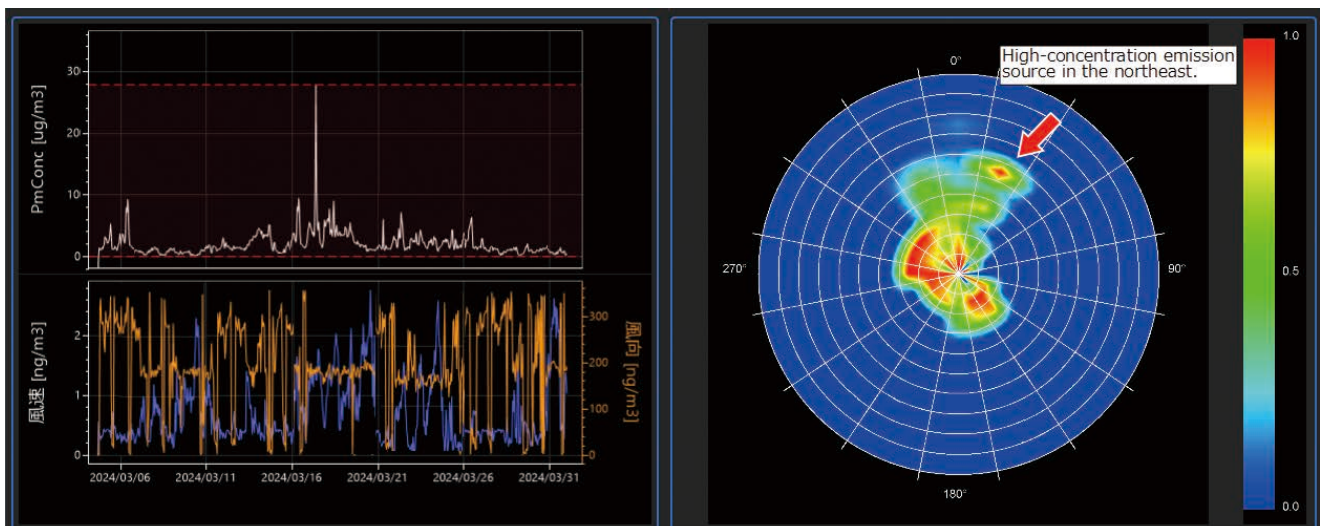


Figure 7 CBPF-Based Distribution of PM Concentration by Wind Direction and Speed.

systems that allow users to comprehensively handle information necessary for data analysis and verify and interpret data from various perspectives. Accurate interpretation of analysis results requires visualization and organization in combination with other relevant information, and the development of platforms to effectively support these processes is an important future challenge.

We aim to evolve systems so that data analysis is not limited to experts but can be performed by non-specialists as well.

Conclusion

As a solution to challenges in atmospheric environmental monitoring, we have proposed a new monitoring method utilizing PX-375 and Eco-WEB. This approach demonstrates the ability to overcome issues inherent in manual data collection and analysis, enabling the construction of a monitoring system that combines real-time capability and efficiency.

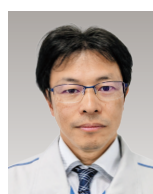
In particular, the automated component analysis of particulate matter by PX-375 and the integrated data collection and analysis functions of Eco-WEB are expected to play a vital role in environmental conservation and the prevention of health hazards. These technologies also contribute to more efficient emission management in industrial regions and manufacturing, supporting the realization of a sustainable society.

Moving forward, we aim to provide comprehensive solutions through further automation of data analysis and the introduction of AI-based predictive analytics.

* Editorial note: This content is based on HORIBA's investigation at the year of publication unless otherwise stated.

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