

**APPLICATION OF A LINEAR REGRESSION ANALYSIS TO AIRTEST PM2500****¹Ha-Young Woo, ²Yong-Cheol Kim, ³Gyu-Sik Kim**¹ Undergraduate student ^{2,3} Professor, Dept. of Electrical and Computer Eng., University of Seoul, Korea

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Keywords: indoor air quality, PM10 concentration, subway system, light scattering, linear regression analysis**Abstract**

Since an individual usually spends most of his/her working hours indoors, the ambient air quality refers to indoor air quality. In particular, PM₁₀ concentration in the underground areas should be monitored to preserve the health of commuters in the subway system. Seoul Metro and Seoul Metropolitan Rapid Transit Corporation measure several air pollutants regularly. In this paper, the accuracy of an instrument for PM measurement using the light scattering method was improved with the help of a linear regression analysis technique to continuously measure the PM₁₀ concentrations in subway stations.

Introduction

People spend most of their time indoors—either at home, in the workplace or in transit. Thus, there has been an increasing concern over indoor air quality (IAQ) and its effects on public health. The US Environment Protection Agency (EPA) reported that in the US, the mean daily residential time spent indoors was 21 h, while the GerES II reported that this duration was 20 h in Germany. Thus, the IAQ has been recognized as a significant factor in the determination of the health and welfare of people [1]. The Korea Ministry of Environment (KMOE) enforced the IAQ act to control five major pollutants, including PM₁₀, CO₂, CO, VOCs, and formaldehyde in indoor environments. Out of these, the IAQ standard for PM₁₀ concentration is 150 µg/m³. The IAQ is critical not only in buildings, but also in underground areas and public transportation systems. Much effort has been made for the improvement of the IAQ in subway stations [2-5]. Among the various types of indoor environments, underground subway stations have especially unique features. The confined space occupied by the underground subway system can accumulate the pollutants entering from the outside in addition to those generated within the system. Therefore, it is likely that the subway system in the Seoul metropolitan area contains different types of hazardous pollutants due to the old ventilation and accessory systems [3, 6]. The IAQ in the subway stations can be affected by many factors, such as the number of passengers, the outside conditions and the natural ventilation rate, etc. The management and monitoring of IAQ in subway stations has become an important issue of public interest. Some environmental sensors are important for monitoring IAQ in subway systems and they provide the data needed for continuous online implementation. In this paper, the accuracy of the instrument for PM measurement using light scattering method was improved with the help of a linear regression analysis technique to continuously measure the PM₁₀ concentrations in the subway stations.

PM measuring instruments

Particulate matter with an aerodynamic diameter less than 10 µm (PM₁₀) is one of the major pollutants in subway environments. The PM₁₀ concentration in the underground areas should be monitored to protect the health of the commuters in the underground subway system. Seoul Metro and Seoul Metropolitan Rapid Transit Corporation measure several air pollutants regularly. As for the PM₁₀ concentration, generally, measuring instruments based on β-ray absorption method are used. In order to keep the PM₁₀ concentration below a healthy limit, the air quality in the underground platform and tunnels should be monitored and controlled continuously. The PM₁₀ instruments using light scattering method can measure the PM₁₀ concentration every once in several seconds. However, the accuracy of the instruments using light scattering method has still not been proven since they measure the particle number concentration rather than the mass concentration [7]. The purpose of this work is to study the accuracy improvement of the instruments which use light scattering method to continuously measure the PM₁₀ concentrations in the underground subway stations. Two different instruments using light scattering method, i.e. Airstest PM2500 (Heyoka solutions, USA) and HCT-PM326 (HCT, Korea) were installed on the platform at a subway station of Seoul metro line number 1 in order to evaluate their dynamic performances (Fig. 1). The specifications of the PM measuring instrument Airstest PM2500 are listed as follows :



- Sampling Method: Laser particle counter;
- Particle Channels: 1.0-5.0 μm , 5.0+ μm ;
- Flow Rate: 0.06 cfm nominal;
- Concentration Limit: Coincidence loss less than 10% at 1,000,000 particles/cubic foot;
- Display Format: Particles/cubic foot (divided by 100) averaged over 1 minute;
- Data Storage: 60 minutes of minute averages, 24 hours of hourly averages, 30 day of daily averages;
- Dimensions: 7.5 x 5.0 x 3.5 inches;
- Weight: Approximately 12 oz;
- Power: 9VDC, 400mA, 110VAC plug-in transformer provided;



Figure 1. The PM measuring instrument Airtest PM2500 installed at a subway station

Performance improvement using a linear regression analysis

A linear regression analysis method was used to improve the accuracy of Airtest PM2500 using the light scattering method. The data measured by this PM measuring instrument had to be converted to actual PM_{10} concentrations using some factors. Two different instruments using light scattering method, i.e. Airtest PM2500 (Heyoka solutions, USA) and HCT-PM326 (HCT, Korea) were installed on the platform at a subway station of Seoul metro line number 1 and measurements were taken for 1350 minutes as shown in Fig. 2.

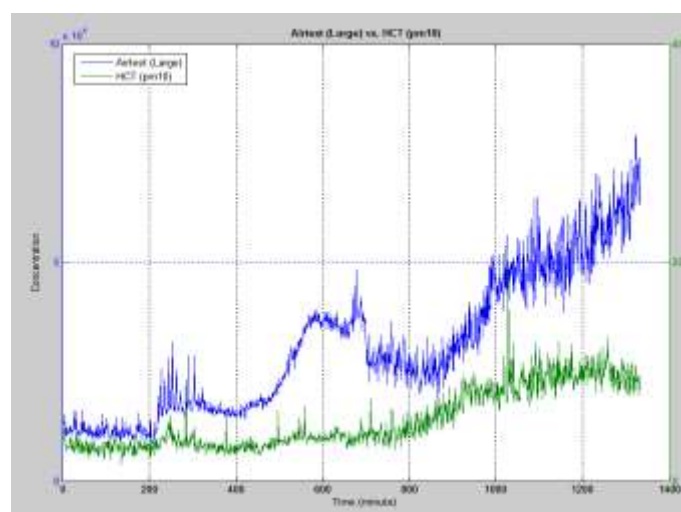


Figure 2. PM_{10} concentrations of Airtest PM2500 and HCT-PM326 measured at a subway station

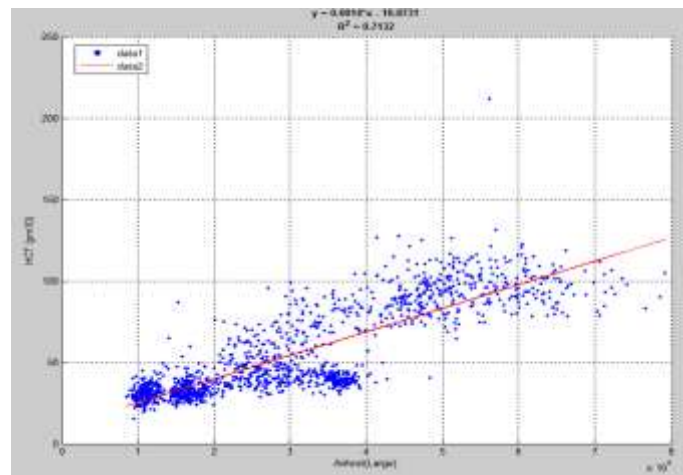


Figure 3. Linear regression analysis

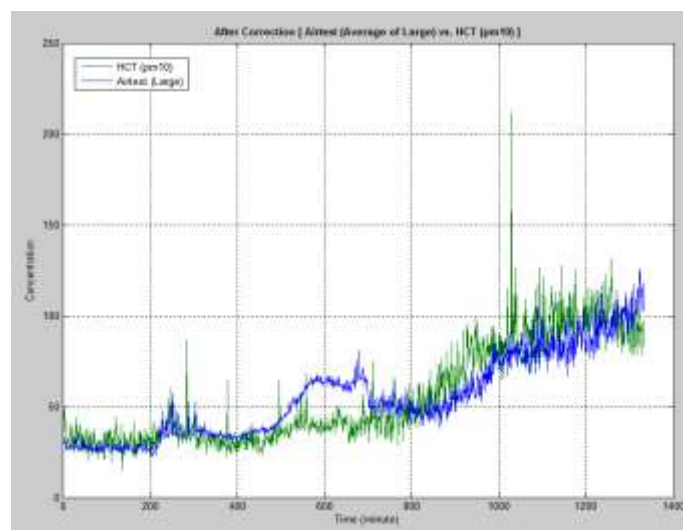


Figure 4. PM₁₀ concentrations corrected using a linear regression analysis

Using the linear regression analysis technique shown in Fig. 3, the measured PM₁₀ concentration of Airtest PM2500 in Fig. 2 can be corrected as shown in Fig. 4. In Fig. 3, the correlation coefficient R² was 0.7132. It can be seen in Fig. 4 that the measured PM₁₀ concentration of Airtest PM2500 is very similar to that of HCT-PM326 if they are corrected using a linear regression analysis technique. This finding suggests that the cheaper PM measuring instrument Airtest PM2500 using light scattering method can be used to measure and control the PM₁₀ concentrations of the underground subway stations.

Monitoring of PM₁₀ in a subway station

The PM measuring instrument Airtest PM2500 was installed in the waiting room, platform, tunnel, and at the outdoor site of a subway station of Seoul Metro line number 1 and PM₁₀ was measured for 10,000 min at a sampling interval of 1 min as shown in Fig. 5 – Fig. 8. As for the waiting room (Fig. 5), the PM₁₀ concentration was kept under 80 µg/m³, which met the KMOE's IAQ standard for PM₁₀ concentration (150 µg/m³). As for the platform (Fig. 6), the PM₁₀ concentration was kept under 70 µg/m³, which was lower than that in the waiting room. This was due to the PSDs, which blocked the dust from the tunnel. In addition, the ventilation fans on the platform were operated more frequently than those in the waiting room because passengers gather at the



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platform. Fig. 7 shows the results for the tunnel of a subway station. The PM_{10} concentration was 20–600 $\mu\text{g}/\text{m}^3$, which was much higher than KMOE's IAQ standard for PM_{10} concentration (150 $\mu\text{g}/\text{m}^3$).

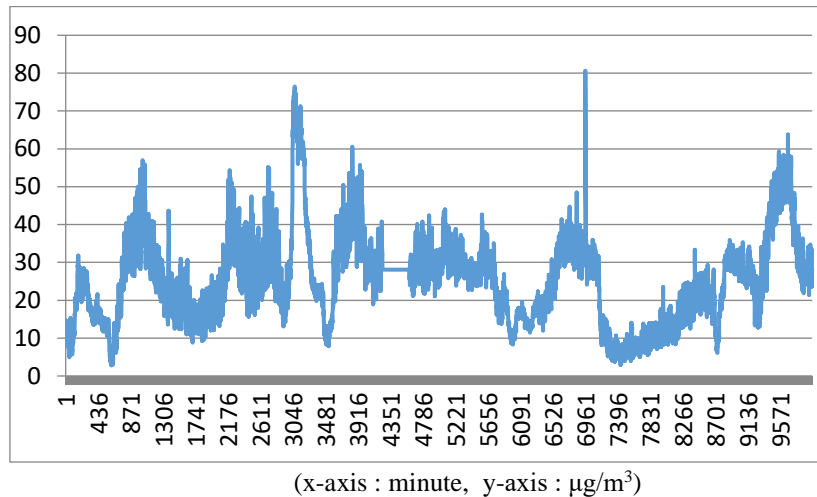


Figure 5. PM_{10} concentrations measured in the waiting room of a subway station

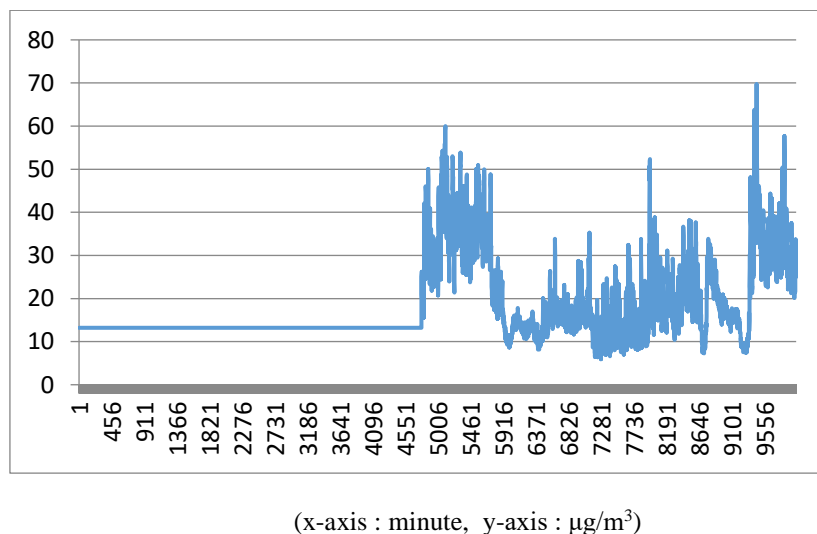
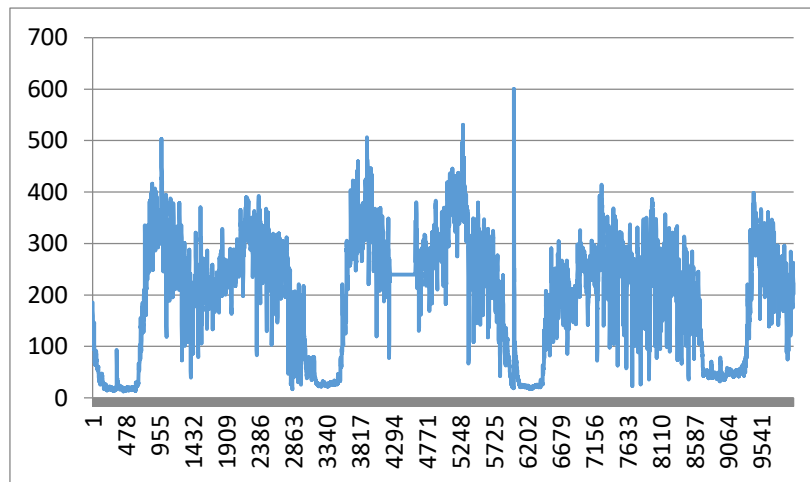


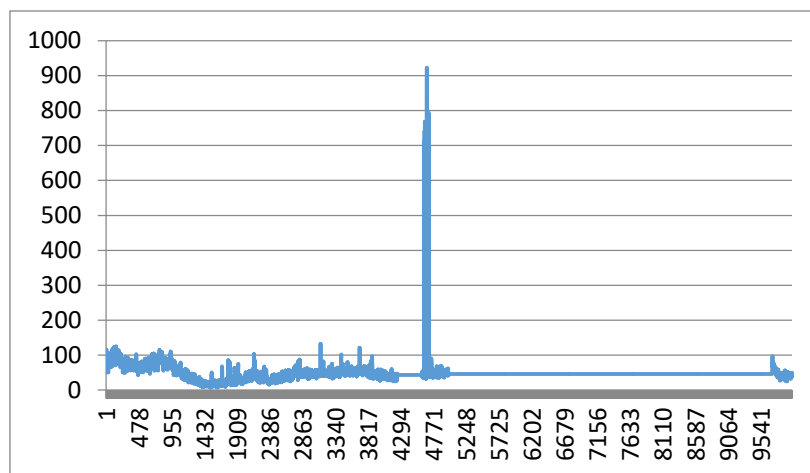
Figure 6. PM_{10} concentrations measured in the platform of a subway station

Most of the ventilation fans may not have been in working condition because of their deterioration and high running cost. Therefore, the PM_{10} concentration in tunnels might have been high for a long period of time. Finally, the data for the outdoor site at a subway station are shown in Fig. 8. The PM_{10} concentration was approximately 10–100 $\mu\text{g}/\text{m}^3$ except for a case in which it was higher than 900 $\mu\text{g}/\text{m}^3$. The air quality of the outdoor site at a subway station was relatively good. The cause of the generation of a pulse data is that the PM_{10} concentration was measured using light scattering method. One of the demerits of light scattering method is that, sometimes, it gives very large values. PM_{10} sensors are important components for monitoring the IAQ in subway systems, as they provide the data needed for continuous online implementation. Sometimes, these sensors suffer from poor data quality and sensor reliability due to the hostile environment in the subway stations in which the measuring instruments are installed for monitoring. They may even fail for a long period of time as Fig. 8. These failures could reduce the accuracy and reliability of the measurement, which may result in an erroneous control action and false perception regarding the performance of the monitoring system. Faulty sensors that have either completely or partially failed could provide incorrect information regarding monitoring and control. Therefore, many researchers have tried to prevent these problems [8–10].



(x-axis : minute, y-axis : $\mu\text{g}/\text{m}^3$)

Figure 7. PM_{10} concentrations measured in the tunnel of a subway station



(x-axis : minute, y-axis : $\mu\text{g}/\text{m}^3$)

Figure 8. PM_{10} concentrations measured in the outdoor site of a subway station

Conclusion

An air quality monitoring system based on environmental sensors was implemented to display and record the data of PM_{10} of a waiting room, a platform, a tunnel and an outdoor site at an underground subway station. The accuracy of the PM measuring instruments using light scattering methods was improved with the help of a linear regression analysis technique to continuously measure the PM_{10} concentrations in the subway stations. Even though the accuracy was greatly improved, this approach had its demerits, such as the generation of very large measured data and the need to repeat the linear regression analysis every time the PM measuring instruments were moved to other places.

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