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# PERFORMANCE IMPROVEMENT OF PM10 SENSORS USING LINEAR REGRESSION ANALYSIS

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## ABSTRACT

The PM10 concentrations in the underground should be monitored for the health of commuters on the subway system. Seoul Metro and Seoul Metropolitan Rapid Transit Corporation are measuring several air pollutants regularly. In this paper, the performance of PM10 sensors is improved using linear regression analysis. To demonstrate the practical significance of our results, some experimental studies are presented.

***Keywords-*** *PM10 concentrations, subway, air pollutants, PM10 sensors, linear regression analysis.*

## I. INTRODUCTION

The PM10 concentrations in the underground should be monitored for the health of commuters on the underground subway system. Seoul Metro and Seoul Metropolitan Rapid Transit Corporation are measuring several air pollutants regularly. As for the measurement of PM10 concentrations, instruments based on beta-ray absorption methods are being used generally. In order to keep the PM10 concentrations under a healthy condition, the air quality of the underground platform and tunnels should be monitored and controlled continuously. The PM10 instruments using light scattering method can measure the PM10 concentrations every less than one minute. However, the reliability of the instruments using light scattering method is still not proved.

**Fig. 1 PM measuring instruments in a subway station**

**Table 1. Spec. of PM measuring instruments**

| | E-BAM | E-sampler | HCT |
|---|---|---|---|
| Measuring method | Beta-ray absorption | Light scattering | Light scattering |
| Measuring range | 0~100 $mg/m^3$ | 0~ 65 $mg/m^3$ | 0~1 $mg/m^3$ |
| Sampling flow rate | 16.7 L/min | 2 L/min | 0.8 L/min |
| Sampling period | 60 min | 1 sec | 6 sec |

The purpose of this work is to study the reliability of the instruments using light scattering method to measure the PM10 concentrations continuously in the underground platforms. One instrument using beta-ray absorption method and two different instruments using light scattering method (Airtest, HCT) were placed at the platform of a subway station of Seoul Metro for 10 days as shown in Fig. 1. A linear regression analysis method is used to improve the performance of the instruments using light scattering method. The data measured by these instruments have to be converted to actual PM10 concentrations using some factors. These findings propose that the instruments using light scattering method can be used to measure and control the PM10 concentrations of the underground subway stations. The specifications of the three PM measuring instruments are listed in Table 1.

## II. PERFORMANCE IMPROVEMENT OF PM10 SENSORS

Generally, a linear regression straight line is expressed as eq (1).

$$y = \hat{m}x + \hat{b} \quad (1)$$

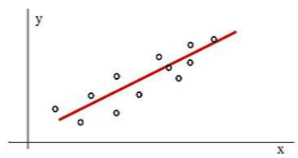



**Fig. 2 Approximation to a straight line**

In Fig. 2, the data dotted in small circles can be approximated to a straight line using a linear regression analysis method. The error $e$ can be expressed in eq (2)

$$e = \sum_{i=1}^{N} (y_i - (\hat{m}x_i + \hat{b}))^2 \quad (2)$$

In order to find the unknown variables $\hat{m}$ and $\hat{b}$ which minimize the error $e$, the partial differentiations are use d as

$$\frac{\partial e}{\partial \hat{m}} = -2\sum_{i=1}^{N} x_i(y_i - (\hat{m}x_i + \hat{b})) = 0$$
$$\frac{\partial e}{\partial \hat{b}} = -2\sum_{i=1}^{N} (y_i - (\hat{m}x_i + \hat{b})) = 0 \quad (3)$$

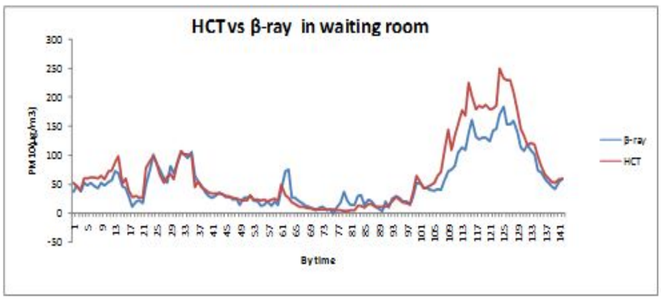
From eq (3), we can get eq (4).

$$\hat{m}\sum_{i=1}^{N} x_i^2 + \hat{b}\sum_{i=1}^{N} x_i = \sum_{i=1}^{N} x_i y_i$$
$$\hat{m}\sum_{i=1}^{N} x_i + \hat{b}N = \sum_{i=1}^{N} y_i \quad (4)$$

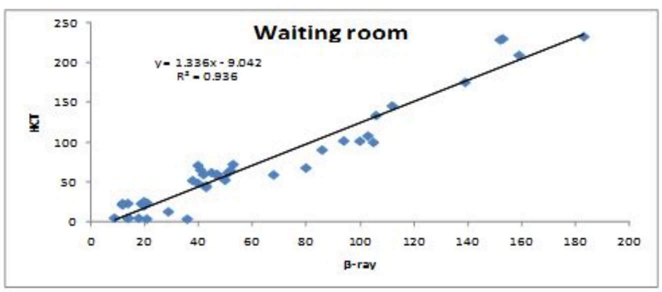
Eq (5) can be obtained using eq (4).

$$\hat{m} = \frac{N\sum_{i=1}^{N} x_i y_i - \sum_{i=1}^{N} x_i \sum_{i=1}^{N} y_i}{N\sum_{i=1}^{N} x_i^2 - (\sum_{i=1}^{N} x_i)^2}$$
$$\hat{b} = \frac{1}{N}(\sum_{i=1}^{N} y_i - \hat{m}\sum_{i=1}^{N} x_i) \qquad (5)$$

One instrument using beta-ray absorption method (E-BAM) and the other instrument using light scattering method (HCT) were installed and measured at the waiting room and the platform of a subway station of Seoul Metro line Number 1 for 5 days. The measured data are shown in Fig. 3 and Fig. 4, respectively.

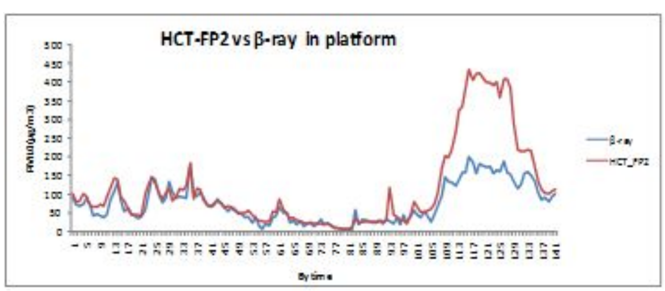



(a) **PM10 concentrations**

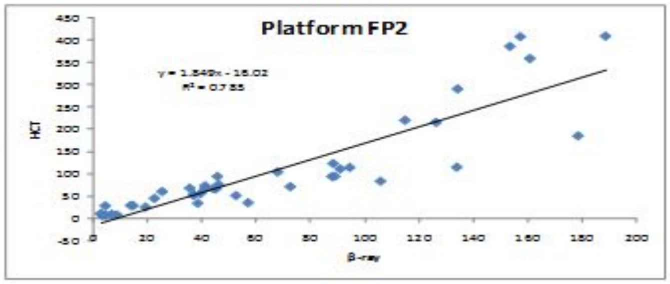



**(b) Linear regression analysis**

**Fig. 3 PM10 and linear regression of waiting room**



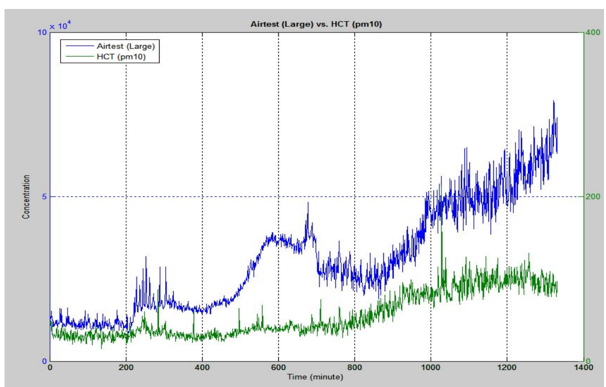

(a) **PM10 concentrations**




**(b) Linear regression analysis**

**Fig. 4 PM10 and linear regression of platform**

In Fig. 3, the correlation coefficient $R^2$ was 0.936. On the other hand, in Fig. 4, $R^2$ was 0.785. The correlation between E-BAM and HCT in the waiting room was higher than that of platform. Two instruments HCT and Airtest using light scattering method were also measured similarly. The measured data are shown in Fig. 5. Using the linear regression analysis technique shown in Fig. 6, the measurement data of Airtest in Fig. 5 can be corrected as shown in Fig. 7. In Fig. 6, the correlation coefficient $R^2$ was 0.7132. It can also be seen in Fig. 7 that the measurement data of Airtest was closely similar as those of HCT if they were corrected using a linear regression technique.




**(upper line : Airtest lower line : HCT)**
**Fig. 5 Measurement data of HCT and Airtest (Before correction)**

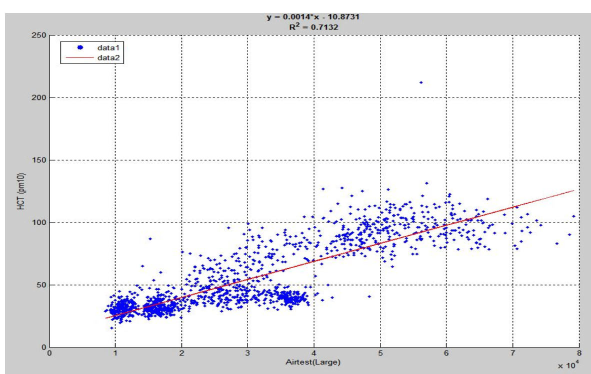



**Fig. 6 Results of linear regression analysis of HCT and Airtest**

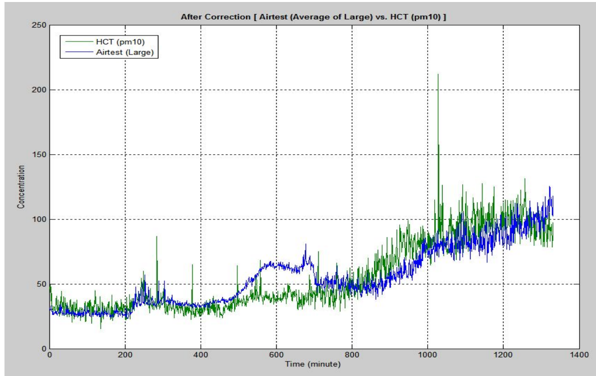



**Fig. 7 Measurement data of HCT and Airtest (After correction)**

## III. CONCLUSIONS

As for the measurement of PM10 concentrations, instruments based on using beta-ray absorption method and light scattering methods are being used. But the beta-ray instruments can measure the PM10 concentration every one hour. In order to keep the PM10 concentrations under a healthy condition, the air quality of the underground platform and tunnels should be monitored and controlled continuously. The PM10 instruments using light scattering method can measure the PM10 concentrations every less than one minute. However, the reliability of the instruments using light scattering method is still not proved. So, the purpose of this work is to study the reliability of the instruments using light scattering method to measure the PM10 concentrations continuously in the underground platforms. We found through some experimental studies that the measurement data of Airtest was closely similar as those of HCT if they were corrected using a linear regression technique. These findings propose that the instruments using light scattering method can be used to measure and control the PM10 concentrations of the underground subway stations.

## IV. ACKNOWLEDGEMENT

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