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Air Pollution Monitoring System for Underground Shopping Center Using Environmental Sensors

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Abstract

An air quality monitoring system based on environmental sensors was implemented to display and record the data of PM_{10}, CO_2, CO, temperature, and humidity of underground shopping centers. 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 underground areas. Some experimental results are presented to verify the practical feasibility of our monitoring system.

Keywords: *air quality monitoring, environmental sensor, PM_{10}, CO_2, CO, temperature, humidity, underground shopping center*

1. 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]. According to a report from WHO, the number of deaths caused by air pollution per year is amounting to 6 million people and especially the death caused by indoor air pollution is estimated to be 2.8 million people. The Korea Ministry of Environment (KMOE) enforced the IAQ act to control five major pollutants, including PM_{10}, CO_2, CO, VOCs, and formaldehyde in indoor environments. Out of these, the IAQ standard for PM_{10} concentration is 150 $\mu g/m^3$. 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 [2-7].

In this study, 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 PM_{10} concentrations in the underground shopping centers as shown in Fig. 1 [8]. In addition, the air quality monitoring system based on environmental sensors was implemented to display and record the data on PM_{10}, CO_2, CO, temperature, and humidity [9, 10].

Fig. 1 Underground shopping center

2. Environmental Sensors

Particulate matter with an aerodynamic diameter less than 10 μm (PM_{10}) is one of the major pollutants in underground environments. The PM_{10} concentration in the underground areas should be monitored to protect the health of the commuters. The facilities management cooperation for underground shopping centers measures several air pollutants regularly. As for the PM_{10} concentration, generally, measuring instruments based on β-ray absorption method are used. In order to keep the PM_{10} concentration below a healthy limit, the air quality in the underground areas should be monitored and controlled continuously. The PM_{10} instruments using light scattering method can measure the PM_{10} 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

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rather than the mass concentration [11].

In this paper, the accuracy of the instruments which use light scattering method is improved to continuously measure the PM_{10} concentrations in the underground areas. Fig. 2 shows the PM measuring instrument HCT-PM326 connected to the ATmega 128L CPU board, which is used to display the measured data and transfer them to an m2m wireless modem.

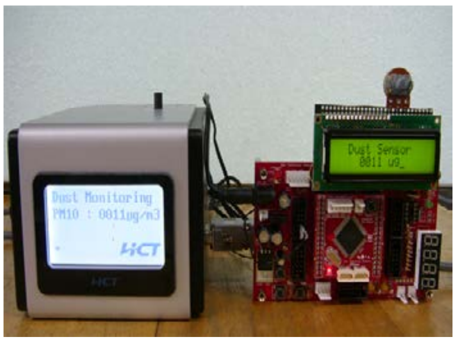


Fig. 2 The PM measuring instrument HCT-PM326 connected to ATmega 128L CPU board

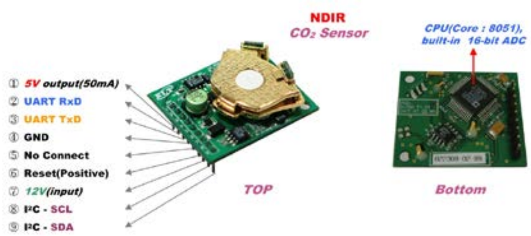


Fig. 3 Pin assignment of the NDIR CO_2 sensor H-550 (ELT, Korea).

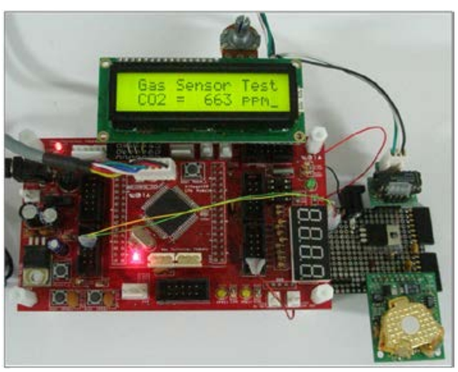


Fig. 4 The NDIR CO_2 sensor H-550 connected to ATmega 128L CPU board.

Of late, the monitoring of carbon dioxide (CO_2) has been considered very important for passengers and employees in underground areas due to the health risks associated with carbon dioxide exposure. For instance, headache, sweating, dim vision, tremors and loss of consciousness are caused by exposure to high CO_2 concentration for a long time. CO_2 gas sensors being used presently can be divided into two types. The first one is NDIR (Non-Dispersive InfraRed) method and the second one is a chemical method. They are commonly available for monitoring CO_2 concentrations indoors. However, chemical CO_2 sensors have many limitations that prevent their application to a variety of practical fields. The obvious drawbacks of chemical CO_2 sensors are short-term stability and low durability. This is because chemical sensors are easily deteriorated by heterogeneous gases and minute particles in the ambient polluted air. On the other hand, since the NDIR method uses the physical sensing principle, such as gas absorption at a particular wavelength [12], NDIR sensors are more advanced in terms of long-term stability and accuracy during CO_2 measurement. Hence, NDIR CO_2 sensors are the most widely applied for real-time monitoring of CO_2 concentration [13]. The pin assignment of the NDIR CO_2 sensor H-550 manufactured by ELT Co. Ltd, Korea and its connection to ATmega 128L CPU board are shown in Fig. 3 and Fig. 4, respectively.

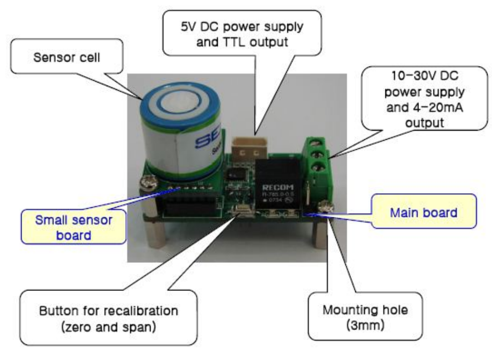


Fig. 5 Senko CO sensor module SS2128

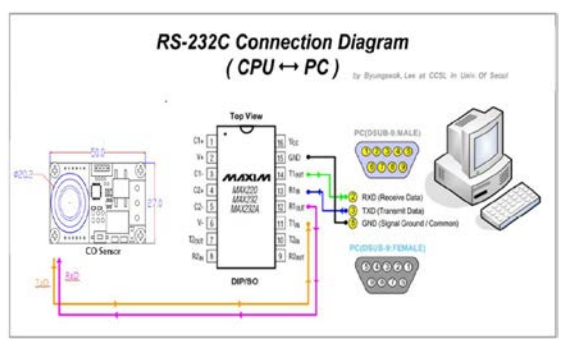


Fig. 6 CO sensor module and its RS232C connection to PC

Fig. 5 shows the Senko CO sensor module SS2128 which is chosen in this paper for monitoring of CO concentration. Fig. 6 shows the RS232C connection to PC of SS2128 module. As for temperature and humidity sensors, the

SHT11 manufactured by Sensirion was chosen in this study. It is a single chip relative humidity and temperature multi sensor module, comprising of a calibrated digital output. It is coupled to a 14-bit analog to digital converter and the 2-wire serial interface and internal voltage regulation, which allow easy and fast system integration. The pin assignment of SHT11 is shown in Fig. 7. Fig. 8 shows that the SHT11 is connected to ATmega 128L CPU board, which transmits temperature and humidity data to the desktop PC using RS232C interface.

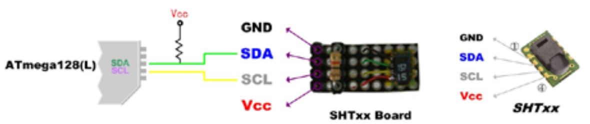


Fig. 7 Pin assignment of the temperature and humidity sensor SHT11

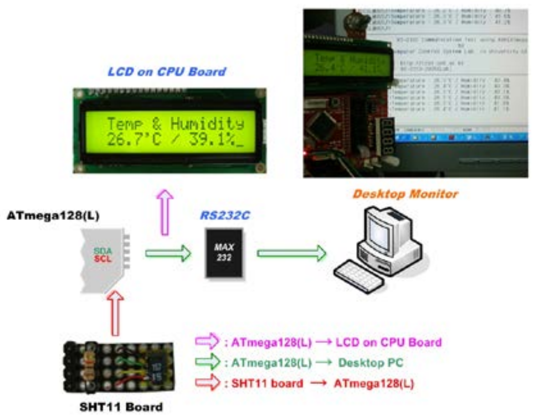
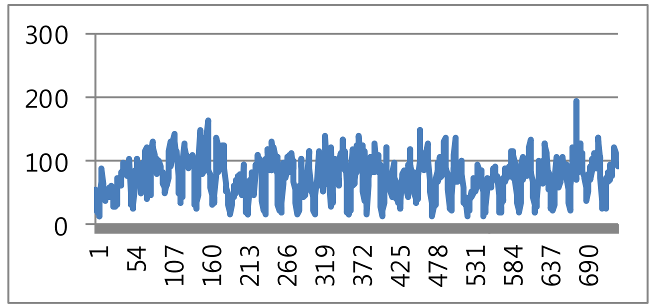


Fig. 8 The temperature and humidity sensor SHT11 connected to the ATmega 128L CPU board

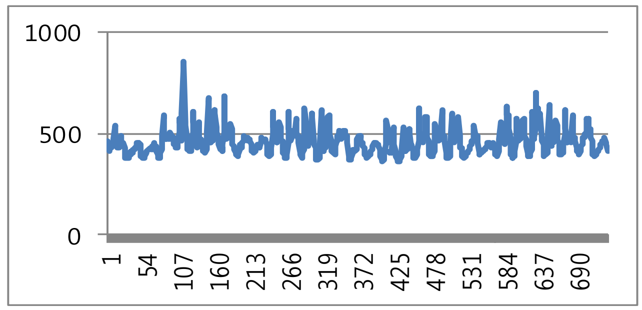
3. Experimental Results

In this paper, an air pollution monitoring system for the underground shopping center which is near Seoul City Hall is implemented using environmental sensors. The measured sensor data were transmitted to a server system via wireless communication and internet every one hour. The PM_{10} concentration, CO_2 concentration, CO concentration, temperature, and relative humidity are monitored for one month as shown in Fig. 9 to Fig. 13. As for the PM_{10} concentration, it was kept under 150 μg/m^3, which met the Korea Ministry of Environment (KMOE)'s IAQ standard for PM_{10} concentration (150 μg/m^3). As for CO_2 concentration, it was kept between 400–600 ppm, which met the KMOE's IAQ standard for CO_2 concentration (1000 ppm). As for CO concentration, it was kept under 2.5 ppm. The temperature was 25–33^{o}C and the relative humidity was 37–70%.



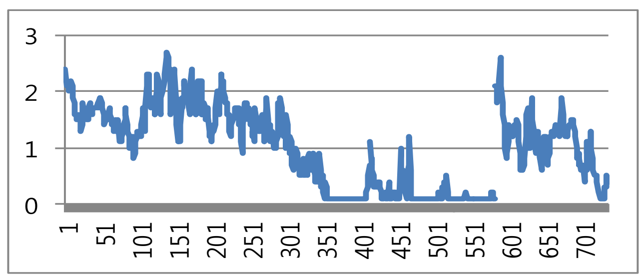
(x-axis : hours, y-axis : μg/m^3)

Fig. 9 PM_{10} concentration

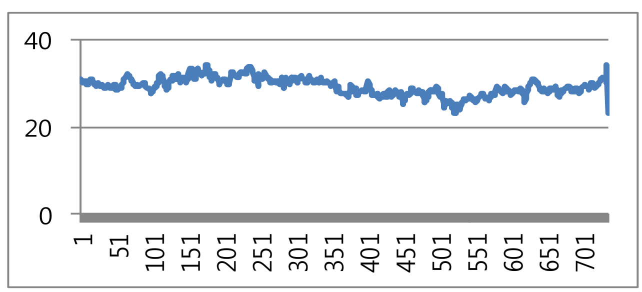


(x-axis : hours, y-axis : ppm)

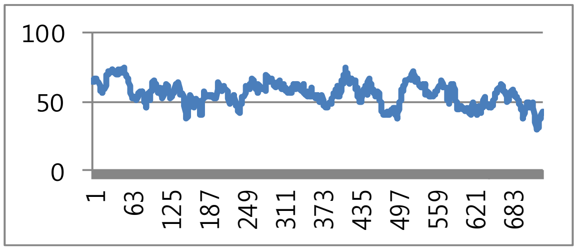
Fig. 10 CO_2 concentration



(x-axis : hours, y-axis : ppm)
Fig. 11 CO concentration



(x-axis : hours, y-axis : ^{o}C)
Fig. 12 Temperature



(x-axis : hours, y-axis : %)
Fig. 13 Relative humidity

4. Conclusions

An air quality monitoring system based on environmental sensors was implemented to display and record the data of PM_{10}, CO_2, CO, temperature, and humidity of underground shopping centers. 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 underground areas. 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.

Acknowledgments

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References

[1] http://www.euro.who.int/__data/assets/pdf_file/0009/128169/e94535.pdf.

[2] Jihan Song, Heekwan Lee, Shin-Do Kim, and Dong-Sool Kim, "How about the IAQ in subway environment and its management," *Asian Journal of Atmospheric Environment*, vol.2, no.1, pp.60-67, June, 2008.

[3] Youn-Suk Son, Young-Hoon Kang, Sang-Gwi Chung, Hyun Ju Park, and Jo-Chun Kim, "Efficiency evaluation of adsorbents for the removal of VOC and NO_2 in an underground subway station," *Asian Journal of Atmospheric Environment*, vol.5, no.2, pp.113-120, June, 2011.

[4] Kyung Jin Ryu, MakhsudaJuraeva, Sang-Hyun Jeong, and Dong Joo Song, "Ventilation efficiency in the subway environment for the indoor air quality," *World Academy of Science, Engineering and Technology*, vol.63, pp.34-38, March, 2012.

[5] Youn-Suk Son, Trieu-Vuong Dinh, Sang-Gwi Chung, Jai-hyo Lee, and Jo-Chun Kim, "Removal of particulate matter emitted from a subway tunnel using magnetic filters," *Environmental Science & Technology*, vol.48, pp.2870-2876, Feb., 2014

[6] Ki Youn Kim,, Yoon Shin Kim, Young Man Roh, Cheol Min Lee, Chi Nyon Kim, "Spatial distribution of particulate matter (PM_{10} and $PM_{2.5}$) in seoul metropolitan subway stations," *Journal of Hazardous Material*, vol.154, pp.440-443, June, 2008.

[7] Hae-Jin Jung, BoWha Kim, JiYeon Ryua, Shila Maskey, Jo-Chun Kim, Jongryeul Sohn, Chul-Un Ro, "Source identification of particulate matter collected at underground subway stations in Seoul, Korea using quantitative single-particle analysis," *Atmospheric Environment,* vol.44, pp.2287-2293, 2010.

[8] Seber, G.A.F., Linear Regression Analysis, John Wiley & Sons, New York, pp.80-130, 1997.

[9] Dong-Uk Park and Kwon-Chul Ha, "Characteristics of PM_{10}, $PM_{2.5}$, CO_2 and CO monitoring in interiors and platforms of subway train in Seoul, Korea," *Environment International*, vol.34, no.5, pp.629-634, 2008.

[10] Anuj Kumar, Hiesik Kim, and Gerhard P. Hancke, "Environmental monitoring systems: A review," *IEEE Sensors Journal*, vol.13, no.4, pp.1329-1339, April, 2013.

[11] Hans Grimm, Delbert J. Eatough, "Aerosol Measurement: The Use of Optical Light Scattering for the Determination of Particulate Size Distribution, and Particulate Mass, Including the Semi-Volatile Fraction," *Journal of the Air & Waste Management Association*, vol.59, pp.101-107, Jan., 2009.

[12] Byungseok Lee, KyoungHonn Kim, YoungDeok Yeom, HyunTae Kim, JoonHwa Lee, Gyu-Sik Kim, Chung Hyuk Lim, "A study on CO_2/CO dual sensor module by NDIR method," *Advanced Engineering Forum*, vol.2, pp.541-546, 2012.

[13] Jong-won Kwon, Gwang-hoon Ahn, Gyu-Sik Kim, Jo-Chun Kim, Hiesik Kim, "A study on NDIR-based CO_2 sensor to apply remote air quality monitoring system," *Proc. of ICROS-SICE International Joint Conference*, pp.1683-1687, August, 2009.

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