International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 3 Issue 5, August 2019 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Indoor Air Quality Monitoring System for Underground Subway Stations

Tae-In Hyon[1], Gyu-Sik Kim[2]

[1]Linc Industry, University Cooperation Group, Jeonju University, Jeonju, Korea
[2]Department of Electrical and Computer Engineering, University of Seoul, Seoul, Korea

How to cite this paper: Tae-In Hyon | Gyu-Sik Kim "Indoor Air Quality Monitoring System for Underground Subway Stations" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-3 | Issue-5, August 2019, pp.1054-1058, **https://doi.org/10.31142/ijtsrd26603**

IJTSRD26603

ABSTRACT
The IAQ has been recognized as a significant factor in the determination of the health and welfare of people. In this study, the air quality monitoring system based on environmental sensors was implemented to display and record the data on PM10, CO2, radon concentration, temperature, and humidity. In addition, a USN monitoring system is implemented to display and record the environmental sensor data measured in an underground subway station. To transmit and receive these measured sensor data, Wi-Fi wireless communication is applied.

KEYWORDS: *IAQ, environmental sensor, PM10, CO2, radon concentration, temperature, humidity, USN*

I. INTRODUCTION

The IAQ (Indoor Air Quality) 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 some pollutants, including PM10, CO2 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].

Radon is a natural, inert, invisible, odorless, chemically inactive, and radioactive gas emitted by the earth. Because it is inert and does not chemically bond to elements, it is released from soil into the atmosphere. Because inhaling radon and its radioactive-decay products cause irradiation of lung tissue, prolonged exposure to a high concentration of radon significantly increases the risk of developing cancer [7,8].

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 [9, 10], etc. The management and monitoring of IAQ in subway stations have become an important issue of public interest [11-13]. Some environmental sensors are important for monitoring IAQ in subway systems and they provide the data needed for continuous online implementation. Sometimes, these sensors in subway stations suffer from poor quality of data and the unreliability of the sensor due to the highly deteriorated and polluted environment, which may cause the measuring instruments installed for monitoring to malfunction. The quality of the online measurement can determine the failure or success of IAQ monitoring and assessment.

In this study, the air quality monitoring system based on environmental sensors was implemented in an underground subway station to display and record the data on PM_{10}, CO_2, radon concentration, temperature, and humidity. In addition, a Wi-Fi wireless communication was applied in order to transmit and receive these measured sensor data.

II. Environmental Sensors

2.1. Radon sensors:

The RD200M is the new innovative fastest radon sensor, which has the highest sensitivity, 30 cph/pCi/L on the market today. This sensor is optimized for the IAQ monitor, air purifier, radon detector and auto ventilation system. A breakthrough in FTLAB's patent technology which received a New Excellent Technology certification in 2015, the RD200M uses a dual probe structured pulsed ionization chamber and a special high impedance differential amplifier circuit to offer the highest signal to noise ratio. It effectively detects the secondary charges which were generated from collisions with air and α-particle caused by radon or radon's progeny. The accuracy and precision of the RD200M are ±10% at 10pCi/L, which has been tested by the international standard Radon Testing Laboratory in KTL. Each sensor has been individually calibrated by equipment which is already calibrated to traceable international standards. Fig. 1 shows the ion chamber-type radon counter: RD200, made by FTLAB, Korea. Table 1 shows the specifications of the RD200.

Fig.1. Ion chamber-type radon counter: RD200

2.2. PM_{10} sensors: Particulate matter with an aerodynamic diameter of less than 10 μm (PM_{10}) is one of the major pollutants in subway environments. The PM_{10} 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 PM_{10} concentration, generally, measuring instruments based on the β-ray absorption method are used. In order to keep the PM_{10} concentration below a healthy limit, the air quality in the underground platform and tunnels 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 still has not been proven since they measure the particle number concentration rather than the mass concentration.

Table1. Specifications of RD200

Descriptions	RD200 is a real-time smart radon detector for homeowner which has the high sensitivity 0.5cpm/pCi/L, about 20~30 times more than conventional radon detector by FTLAB's high stable circuit technology
Type	pulsed ion chamber 200cc
First reliable data out	< 60min
Data interval	10min update (60min moving average)
Sensitivity	0.5cpm/pCi/L at 10pCi/L (30cph/pCi/L)
Operating range	10~40℃, RH<90%
Range	0.1~99.99pCi/L
Precision	<10% at 10pCi/L
Accuracy	<±10% (min. error <±0.5pCi/L)
Power	DC 12 ± 0.1V, 65mA (12V DC adapter)
Size	Φ80(mm) x 120(mm), 240g
Data Communication	Bluetooth LE (Android/iOS)
Data log	max 1year(1h step)
Display	0.96 inch OLED

In order to continuously measure the PM_{10} concentrations in the underground subway stations, Airtest PM2500 (Heyoka solutions, USA) was installed on the tunnel at a subway station of Seoul metro line number 1. The specifications of the PM measuring instrument Airtest PM2500 which is shown in Fig. 2 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 of 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 days 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;

Fig.2. The PM measuring instrument Airtest PM2500 installed at a subway station

2.3. Temperature and humidity sensors:

Seoul Metropolitan Rapid Transit Corporation measures temperature and humidity as well as PM_{10} and CO_2 in the subway stations regularly. Temperature and humidity can also be used for the analysis and prediction of IAQ in a subway station. 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. 3. Fig. 4 shows that the SHT11 is connected to the ATmega 128L CPU board, which transmits temperature and humidity data to the desktop PC using the RS232C interface.

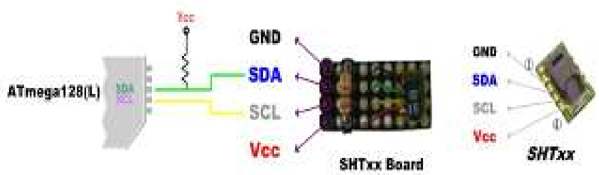


Fig.3. Pin assignment of the temperature and humidity sensor SHT11.

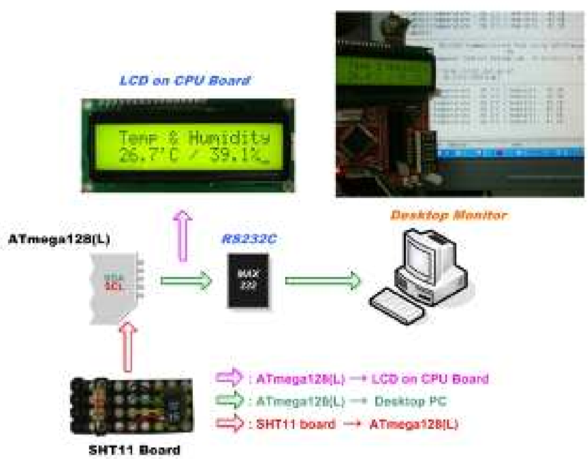


Fig.4. The temperature and humidity sensor SHT11 connected to the ATmega 128L CPU board.

2.4. NDIR CO_2 sensors:

Recently, the monitoring of carbon dioxide (CO_2) has been considered very important for passengers and employees in underground subway stations 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 the 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, 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. The NDIR CO_2 sensor H-550 manufactured by ELT Co. Ltd, Korea and its connection to ATmega 128L MPU board is shown in Fig. 5.

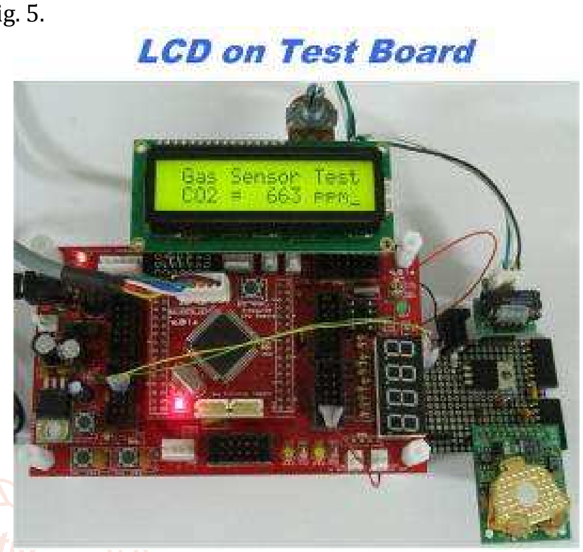


Fig.5. NDIR CO_2 sensor connected to Atmega 128L MCU board

2.5. IAQ monitoring system:

This study presents the implementation of an IAQ monitoring system, which uses sensor modules for measuring PM_{10}, CO_2, radon concentration, temperature, humidity and a data processing module with Wi-Fi communication capabilities for the transmission and management of the measurement results. The need for air quality measuring over large underground subway areas, such as waiting rooms, platforms and tunnels, necessitates wireless connectivity for the measuring device. Wireless sensor networks represent a vast and active research area in which a large number of applications have been proposed, including indoor air quality monitoring and control, structural health monitoring, and traffic monitoring. Fig. 6 shows an air quality management system for subway stations. Fig. 7 shows the web page of the air quality management system.

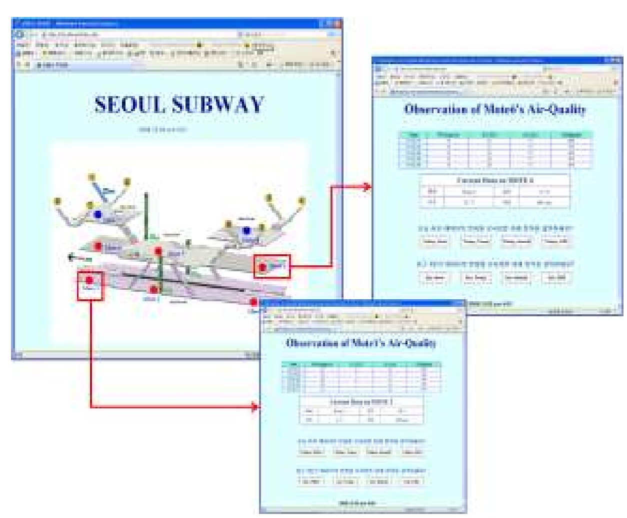


Fig.6. Air quality management system

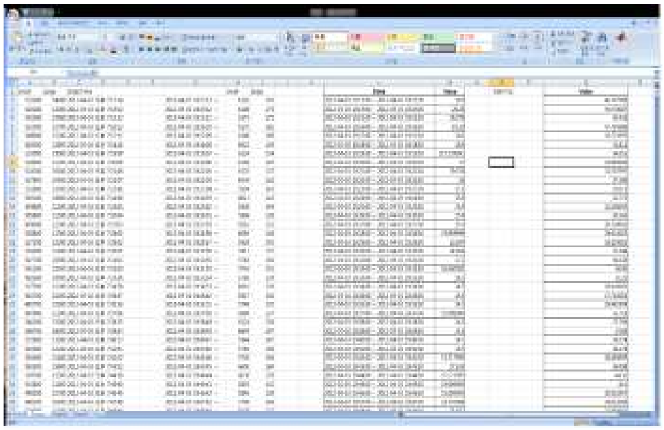
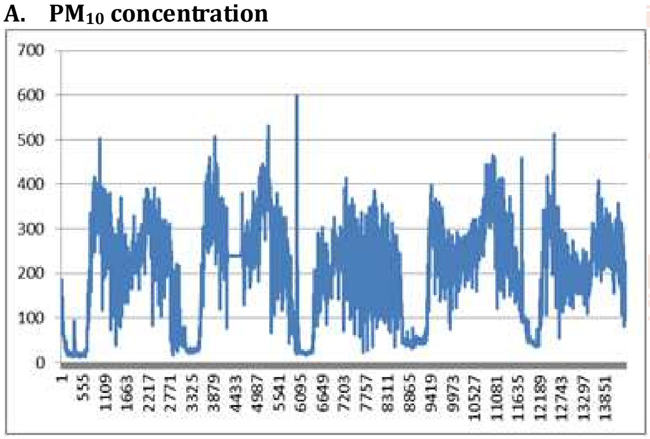


Fig.7. Web page of the air quality management system

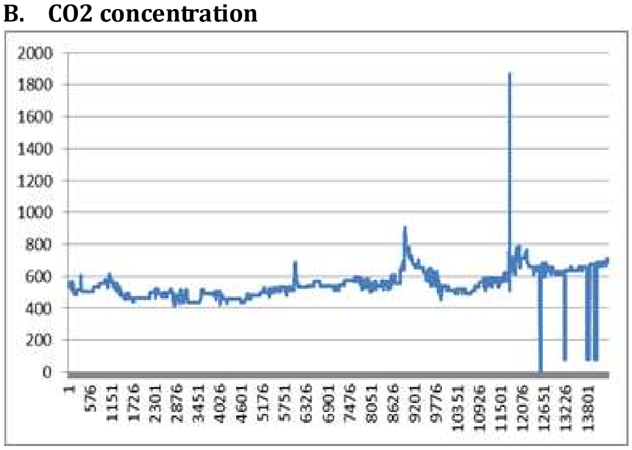
The PM_{10}, CO_2, temperature, humidity, and radon concentration data which were measured in the tunnel of a subway station for 5 days are shown in Fig. 8. The PM_{10}, CO_2, temperature, and humidity were recorded at a sampling interval of 30 sec. On the other hand, the radon concentration was recorded at a sampling interval of 1 hour. As for the PM_{10} concentration, it was mainly over 150 μg/m^3, which was the KMOE's IAQ standard for PM_{10} concentration. As for CO_2 concentration, it was kept between 400–800 ppm, which met the KMOE's IAQ standard for CO_2 concentration (1000 ppm). The temperature of the waiting room was 27 ~ 30^{o}C and the relative humidity was 50 ~ 80%. The radon concentration was under 70 Bq/m^3. It was under 148 Bq/m^3, which was the KMOE's IAQ standard for radon concentration.

A. PM_{10} concentration



(x-axis: sampling number, y-axis: μg/m^3)

B. CO2 concentration

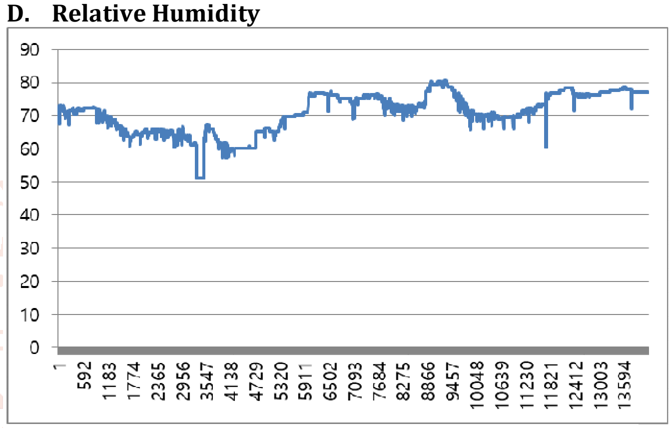


(x-axis: sampling number, y-axis: ppm)

C. Temperature

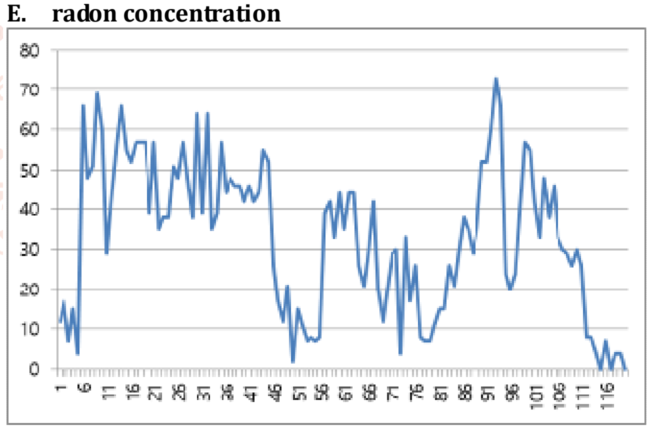
(x-axis: sampling number, y-axis: ^{o}C)

D. Relative Humidity



(x-axis : sampling number, y-axis : %)

E. radon concentration



(x-axis: sampling number, y-axis: Bq/m^3)

Fig. 8. PM_{10}, CO_2, temperature, relative humidity, and radon concentration in the tunnel of a subway station.

III. Concluding Remarks

An air quality monitoring system based on environmental sensors were implemented to display and record the data of PM_{10} and CO_2, temperature, humidity, and radon concentration of the tunnel of an underground subway station. In this study, an IAQ monitoring system, which uses PM_{10} and CO_2, temperature, humidity, and radon sensor modules and a data processing module with Wi-Fi communication capabilities for the transmission and management of the measurement results, was implemented. Through these experimental studies, we believe that the implemented IAQ monitoring system would be helpful in protecting many people from the dangers associated with indoor pollutants exposure.

Acknowledgment
This work was supported by the 2019 Research Fund of the University of Seoul

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] Gyu-Sik Kim, Jae-Hak Kim, "Low-end real-time radon detector," *Global Journal of Engineering Science and Researches*, vol. 4, no.2, pp.1-5, Feb., 2017.

[8] Chungyong Kim, Gyu-Sik Kim, "Implementation of a radon counter measuring apparatus using CCD image sensor module," *International Journal of Trend in Scientific Research and Development*, vol. 2, no.4, pp.1194-1197, May-Jun, 2018.

[9] Soon-Bark Kwon, Youngmin Cho, Duckshin Park, Eun-Young Park, "Study on the indoor air quality of Seoul metropolitan subway during the rush hour," *Indoor Built Environment,* vol.17, no.4, pp.361-369, 2008

[10] Soon-Bark Kwon, Duckshin Park, Youngmin Cho, Eun-Young Park, "Measurement of natural ventilation rate in Seoul metropolitan subway cabin," *Indoor Built Environment,* vol.19, no.3, pp.366-374, 2010

[11] Harrison R.M., A.R. Deacon, and M.R. Jones, "Sources and processes affecting the concentration of $PM_{2.5}$ and PM_{10} particulate matter in Birmingham (U.K.)," *Atmospheric Environment*, vol.31, no.24, pp.4103-4117, 1997

[12] Aarnio, P., et al., "The concentrations and composition of exposure to fine particle ($PM_{2.5}$) in the Helsinki subway system," *Atmospheric Environment*, vol.39, pp.5059-5066, 2005

[13] Branis, M., "The contribution of ambient sources to particulate pollution in spaces and trains of the Prague underground transport system," *Atmospheric Environment*, vol.40, pp.348-356, 2006