INTERNATIONAL JOURNAL OF INNOVATIVE TRENDS IN ENGINEERING (IJITE)
VOLUME 25, NUMBER 01, 2017
ISSN: 2395-2946

Wireless Environmental Sensor Nodes for Subway Stations

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Abstract – In this paper, an IAQ monitoring system, which uses PM_{10} and CO_2 sensor modules and a data processing module with CDMA communication capabilities for the transmission and management of the measurement results, was implemented. Through some 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.

Keywords – IAQ monitoring system, PM_{10}, CO_2, CDMA, subway station.

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. 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 [1-4].

In this study, a PM measurement apparatus using light scattering method was chosen to continuously measure the PM_{10} concentrations in the subway stations. In addition, NDIR based CO_2 sensor networks were implemented to display and monitor the indoor air quality of underground subway stations.

2. NDIR CO_2 SENSOR MODULE

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 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 (Fig. 1), NDIR sensors are more advanced in terms of long-term stability and accuracy during CO_2 measurement (Fig. 2). 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. 3.

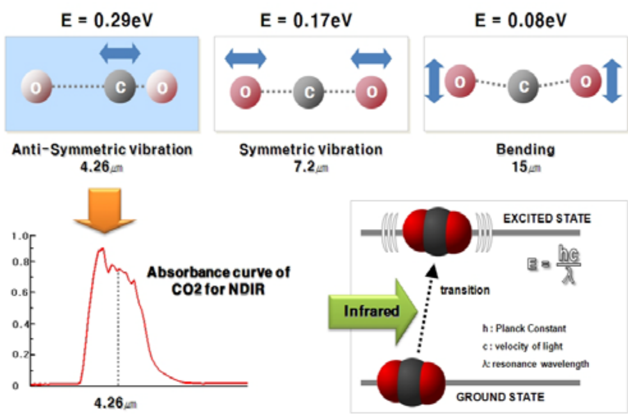


Fig. 1. Absorption wave length of CO_2

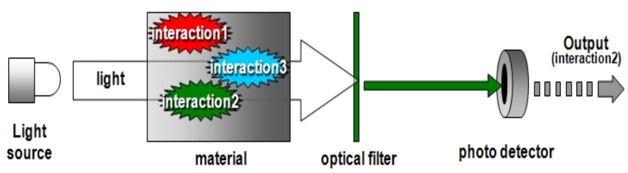
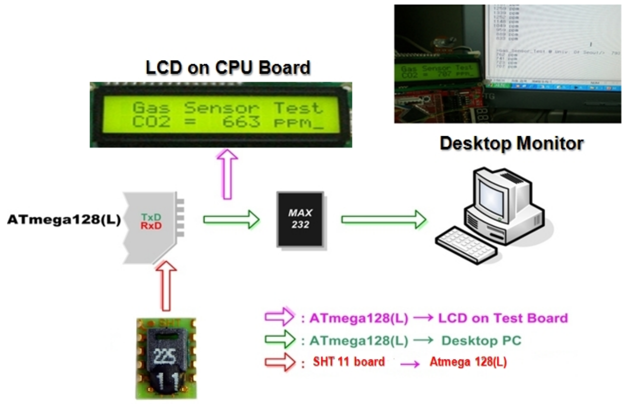
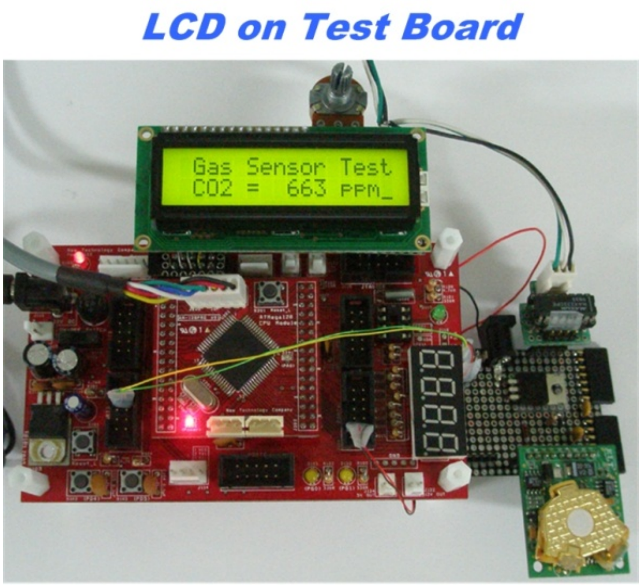


Fig. 2. Principle of NDIR based CO_2 measuring



(a)



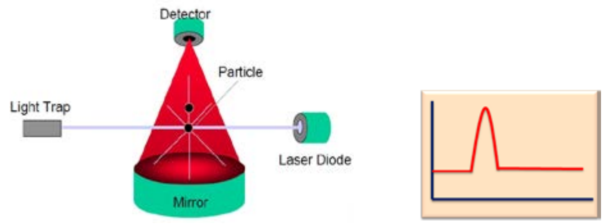
(b)

Fig. 3. NDIR CO_2 sensor connected to Atmega 128L MCU board

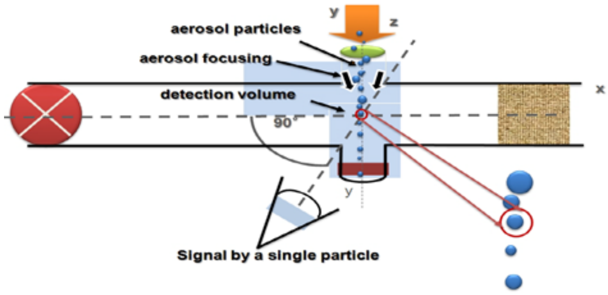
3. PM_{10} SENSOR BASED MONITORING SYSTEM

Particulate matter with an aerodynamic diameter 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 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 has still not been proven since they measure the particle number concentration rather than the mass concentration [5]. Fig. 4 shows the principle of light scattering method.

Fig. 5 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.



(a)



(b)

Fig. 4. Principle of light scattering method

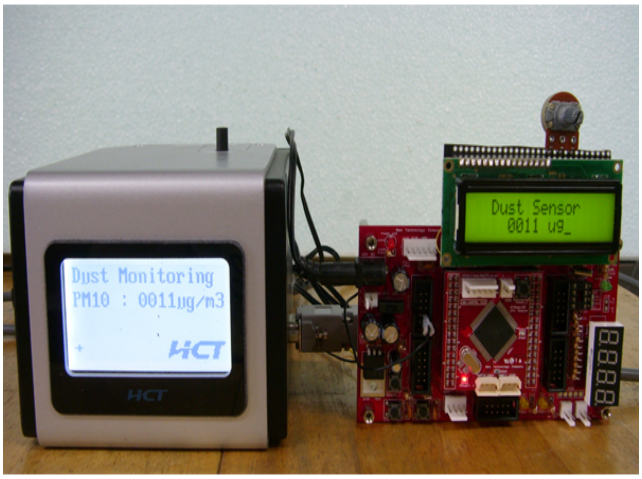


Fig. 5. The PM measuring instrument HCT-PM326 connected to ATmega 128L MCU board.

4. WIRELESS SENSOR NETWORKS

WSNs are formed by a great number of small devices – the so-called sensor nodes or motes – that are able to obtain information from their surroundings by means of transducers
and transmit it towards a sink node using wireless communications. This information, after the suitable data handling, is stored by the sink node on a database, where it is available for use, be it in real time or for statistical analysis. WSNs comprise three different subsystems, namely: sensor nodes; sink node; and, information management system. Fig. 6 shows the structure of a sensor node.

This paper presents the implementation of an IAQ monitoring system, which uses PM_{10} and CO_2 sensor modules and a data processing module with CDMA (Code Division Multiple Access) communication capabilities for the transmission and management of the measurement results [6,7].

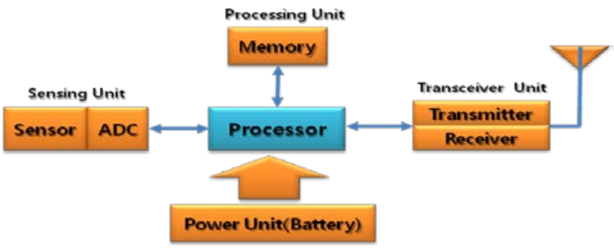


Fig 6. Structure of a sensor node

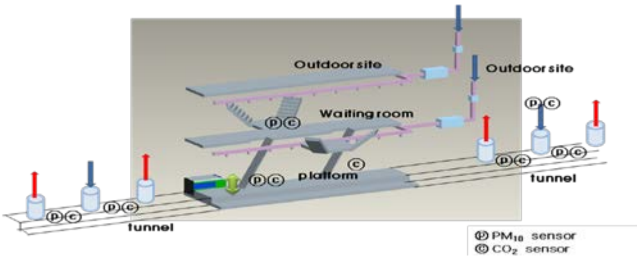
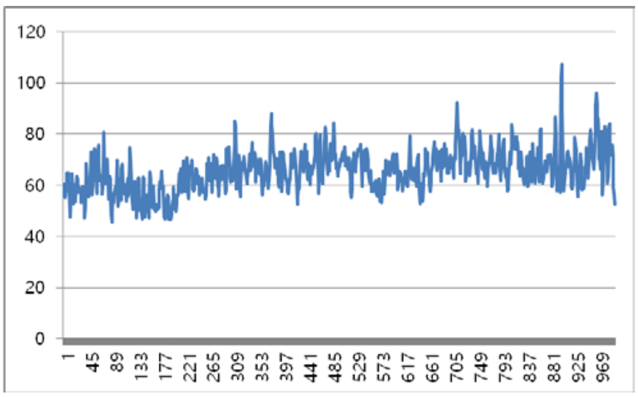


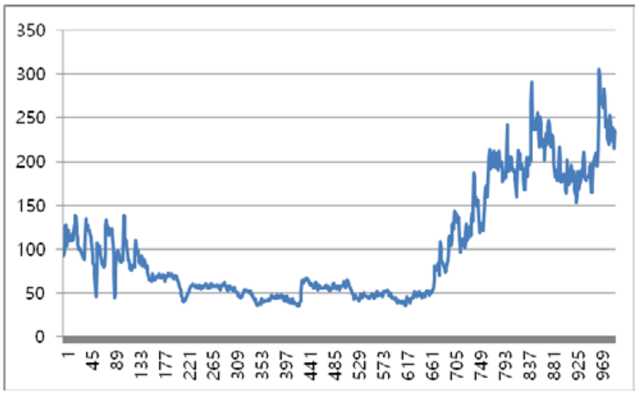
Fig. 7. PM_{10} and CO_2 sensor-based IAQ monitoring system for subway stations

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. 7 shows an air quality monitoring system for subway stations. The sensor and CDMA modules were installed at a waiting room, a platform, an outdoor site, and tunnels. Fig. 8 and Fig. 9 show the measured PM_{10} concentration in an outdoor site and a tunnel of a subway station which were monitored for 1000 minutes. Fig. 10 and Fig. 11 show the measured CO_2 concentration in an outdoor site and a tunnel of a subway station which were monitored for 1000 minutes.



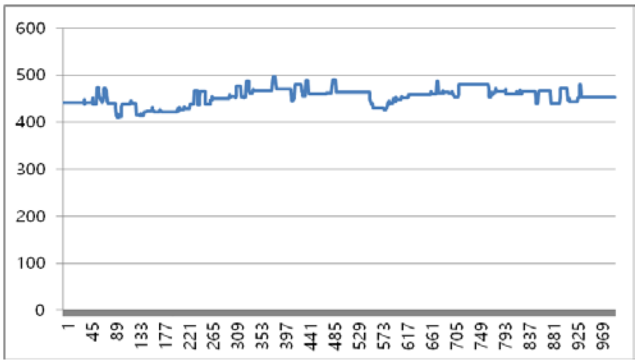
(x-axis : minute, y-axis : μg/m^3)

Fig. 8. PM_{10} concentration in an outdoor site of a subway station



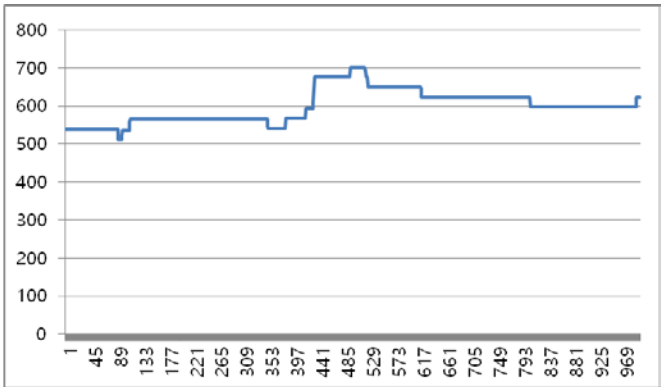
(x-axis : minute, y-axis : μg/m^3)

Fig. 9. PM_{10} concentration in a tunnel of a subway station



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

Fig. 10. CO_2 concentration of an outdoor site of a subway station



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

Fig. 11. CO_2 concentration of a tunnel of a subway station

As for the PM_{10} concentration in an outdoor site of a subway station, it was kept under 120 μg/m^3, which met the KMOE's IAQ standard for PM_{10} concentration (150 μg/m^3). On the other hand, in a tunnel of a subway station, it was over 150 μg/m^3 between 750-1000 min. As for CO_2 concentration, it was kept between 400–500 ppm for an outdoor site and 500-700 ppm for a tunnel, which met the KMOE's IAQ standard for CO_2 concentration (1000 ppm).

5. CONCLUSION

An air quality monitoring system based on environmental sensors was implemented to display and record the data of PM_{10} and CO_2 of waiting rooms, platforms, tunnels and outdoor sites at underground subway stations. In this paper, an IAQ monitoring system, which uses PM_{10} and CO_2 sensor modules and a data processing module with CDMA 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.

5. ACKNOWLEDGEMENTS

This work was supported by the Korea Ministry of Environment (MOE) as ‘‘the Environmental Health Action Program.’’ This work was also supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (No. 2016011249).

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