March - April 2020
ISSN: 0193 - 4120 Page No. 3833 - 3839

Characteristics of Exposure to Environmental Factors Evaluated Using IoT-Based Monitoring in Homes

Hyo-Sun Lee[1], Jung-Heum Jo[2], Young Yoo[3], Chae-Bong Kim*4

[1,3*,4]Environmental Health Center for Asthma, Korea University, South korea

[1]Department of Health Science & 3D Printing, Dongnam Health University, South Korea

[2]National Institute of Environmental Research, South Korea

[3]Department of Pediatrics, Korea University College of Medicine, Seoul, Korea

rosalee0228@naver.com[1]hmmgoon@korea.ac.kr[2], yoolina@korea.ac.kr[3], bbp62@nate.com (Corresponding Author)[4]*

Article Info
Volume 83
Page Number: 3833 - 3839
Publication Issue:
March - April 2020

Article History
Article Received: *24 July 2019*
Revised: *12 September 2019*
Accepted: *15 February 2020*
Publication: *23 March 2020*

Abstract:

Population groups sensitive to pollutants need to be managed when they are exposed to indoor air pollution. This study is aimed at identifying characteristics of environmental hazards within households using IoT-based environmental measurement. Environmental measurement was conducted in homes and offices, where data about volatile organic compounds (VOCs), PM1.0, PM2.5, PM10, CO2, temperature, and humidity were collected from September to December 2017. The IoT-based measurement was made for 24 hours and classified according to times of the day. It was reported that the concentration of fine dust increased during family gatherings, especially in the evening (18:00-24:00). CO2 and VOCs showed increasing concentrations from 18:00 pm to dawn. In this study, it was shown that the increase in indoor air pollutants at homes was related to the lifestyle of family members

Keywords: *exposure trends, indoor air pollution, environmental pollution, Internet of Things.*

I. Introduction

Air pollution is known to be involved in the development and aggravation of symptoms of allergic diseases [1]. Avoiding air pollution contributes to preventing allergic diseases. Many studies on the association between exposure to air pollution and allergic diseases have been reported. Harmful air particles indoors have been shown to negatively affect the development of allergies [2]. Moreover, continuous exposure to contaminated indoor air increases the likelihood of developing lung and respiratory diseases [3]. Due to the westernized lifestyle, people are exposed to pollutants from various sources such as building materials, so it is necessary to manage air pollution indoors. Most studies examining the association between indoor air pollution and allergy have reported results using cross-sectional models and direct-reading methods.

Due to the recent developments in science and technology, it is possible to measure in real time the impact of air pollution using Internet of Things (IoT) equipment [4]. IoT has the advantage of easy access regardless of place and real-time check from outside through smart phones [4]. However, there is still controversy about the reliability and validity of academic studies on IoT-based environmental measurement and evaluation. So far, information on IoT technology trends, IoT monitoring system development, IoT system implementation, and IoT fine dust system development has been mainly reported [5,6,7,8,9]. There was a domestic study experimenting with measurement errors and recognition rates of IoT-based indoor air measurement system. The study generally showed less than error of basic specification of sensor, and the error rate was 0.00% [4]. However, this result represents only a single line of evidence, and various experimental results are needed in the future. Despite the obvious limitations of IoT sensors, we suggest that the results of the existing complementary measurement methods are needed. In addition, it was reported that it is necessary to understand and cope with the status of indoor air pollution by measuring and collecting polluted indoor air in real time [10].

Although outdoor air pollution is getting worse and is causing increasing damage to human health, indoor air pollution is becoming equally dangerous and there is lack of awareness of indoor air pollutants [11]. In particular, allergic patients are known to be sensitive to low-quality indoor air. Therefore, it is necessary that sensitive groups in the general public understand the implications of exposure to indoor hazardous substances and should be given instructions that such substances must be avoided. Among its various environmental characteristics, indoor air is known to be partly related to seasonal factors. Indoor air quality is higher in winter than in summer [12]. In recent years, the importance of ventilation has been emphasized in order to improve the quality of indoor air [13,14]. Harmful air generated outdoors or indoors requires exposure conditions over time because indoor air quality varies depending on the lifestyle of people, but studies showing such results are insufficient. In addition, although IoT-based indoor air quality experiment research is continuously required to implement real-time monitoring, the results are insufficient due to reliability and validity issues. However, the collection of basic data is necessary because it can monitor the environmentally harmful factors in homes in real time. Therefore, this study examined the tendency of exposure to harmful indoor factors in households of allergic patients over time. This study aims to raise awareness of indoor air quality management and to use this as basic data for minimizing damage to people sensitive to indoor air pollution.

II. Methods

Research Subjects

The households of pediatric allergy patients were selected from the population sensitive to indoor air. Study subjects were patients with respiratory allergies and children recommended by the Department of Pediatrics, Korea University Guro Hospital. However, households were restricted to those with real homes in the capital area. Of the 20 households selected, 12 households eventually participated in the study, and a control group was selected in one office where healthy adults stay.

Methods

In order to identify the characteristics of each household under the same conditions, furniture of the living room was selected, and measurement items were volatile organic compounds (VOCs), two types of ultrafine dust (PM1.0, particulate matter less than 1.0 μm and PM2.5, particulate matter less than 2.5 μm), fine dust (PM10, particulate matter less than 10 μm), and carbon dioxide (CO_2). Temperature and humidity were also investigated. Moreover, the

TEST Engineering & Management

March - April 2020
ISSN: 0193 - 4120 Page No. 3833 - 3839

control office also had the same measurement items as the household.

The measurement used indoor air quality IoT equipment (CESCO Air IAQ Monitor EM 200I). The measurement period was from September to December 2017, and the research team visited 12 households and one office to install the measuring equipment. Data about exposure concentration was collected using the IoT sensor over the course of 4 months, and the exposure concentration was stored in the server every 10 minutes. The measurement sensor used the method of monitoring the concentration information of the measurement item and storing it in the gateway connected to the application server using wireless communication (Kim, 2007). The 24 hours of exposure were classified according to time intervals: dawn (from 24:00 to 06:00), morning (from 06:00 to 12:00), afternoon (from 12:00 to 18:00), and evening (from 18:00 up to 24:00).

Statistical Analysis

Data collected from September to December 2017 were processed for missing values and outliers, and then the differences in concentrations between households (experimental) and offices (control) were measured using SPSS Statistics 23 for Windows (IBM, USA). Trends for exposure concentrations are expressed as box plots. In the box plot, the middle line means median, the upper and lower values represent confidence interval, and Student's t-test was conducted based on the significance level of 5%.

III. Result

Exposure Characteristics in Homes

Average exposure and standard deviation for PM1.0 were 22.9 μg/m3 and 34.8 μg/m3, PM2.5, 29.5 μg/m3 and 38.8 μg/m3, and PM10, 57.0 μg/m3 and 68.4 μg/m3, respectively. The average exposure to VOCs was 180.9 ppb (45.8 ppb) and to CO2 was 923.4 ppm (387.6 ppm).

Table 1. Exposure Characteristics in Homes

Measurement	Average	S.D
$PM_{1.0}$ ($\mu g/m^3$)	22.9	34.8
$PM_{2.5}$ ($\mu g/m^3$)	29.5	38.8
PM_{10} ($\mu g/m^3$)	57.0	68.4
VOC_S (ppb)	180.9	45.8
CO_2 (ppm)	923.4	387.6

24-Hour Exposure Trends in Homes and Offices

In the case of households, PM10 had a high concentration of 50 μg/m3 in the evening (from 18 to 24 hours) and a low concentration of 23 μg/m3 in the morning (from 24 to 6 hours). The concentration tended to increase to 38 μg/m3 on average in the morning (from 6 to 12 hours).

PM2.5 and PM1.0 tended to have higher average concentrations in the evening and morning time intervals. The concentrations of VOCs and CO2 were 165 ppb and 750 ppm on average in the evening (18:00 and before 24 hours), compared to the afternoon hours (from 12:00 and before 18:00 o'clock). Maintaining high concentrations after 6 o'clock tended to decrease slightly in the morning (after 6 o'clock-12 o'clock). The survey showed that PM concentrations were high in the morning and evening hours when family members are all at home, and CO2 and VOCs tended to maintain concentrations from evening to dawn.

The results of office measurements showed that CO2 and VOCs showed similar concentration trends to those in home from 12:00 to 18:00 o'clock, but decreased after 20:00 o'clock. In addition, the concentration was gradually increased from 8:00 o'clock while maintaining low concentration until dawn.

March - April 2020
ISSN: 0193 - 4120 Page No. 3833 - 3839

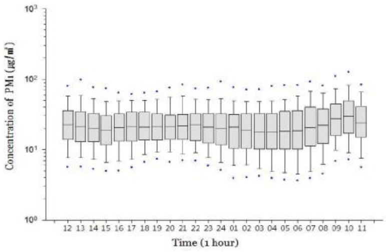
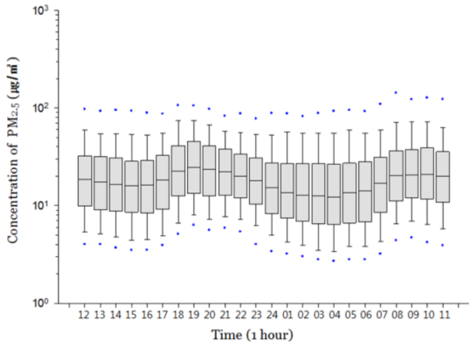


Figure 1. 24-hour exposure trends of PM1.0 in homes and offices



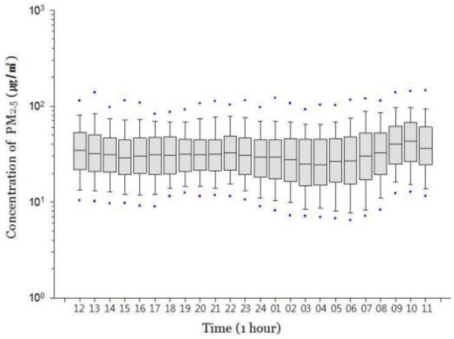
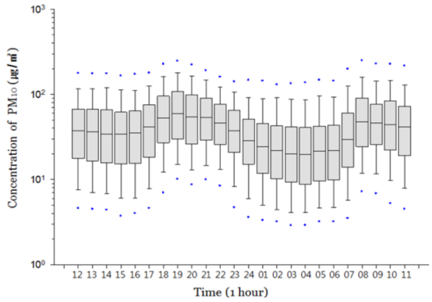
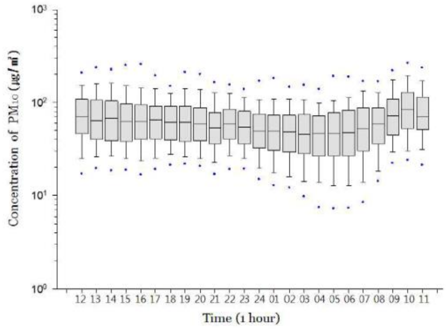
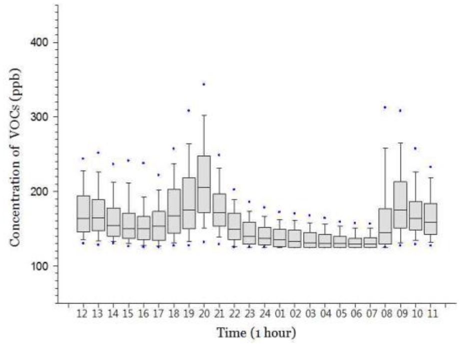
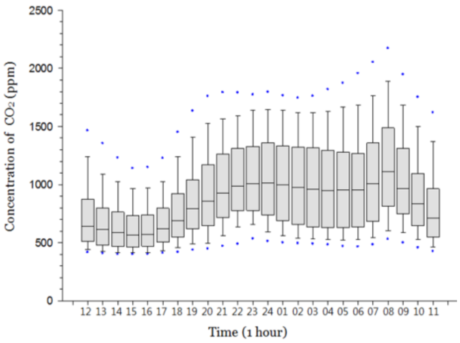


Figure 2. 24-hour exposure trends of PM2.5 in homes and offices









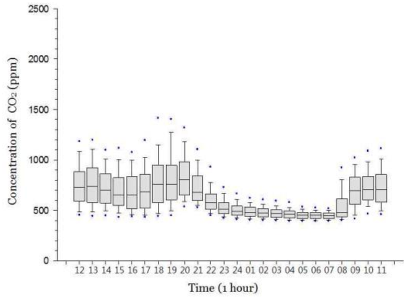


Figure 3. 24-hour exposure trends of PM10 in homes and offices.

Table 2. Comparison of PM10, CO2, and VOCs Average Exposure Concentrations in Homes and Offices according to Time of Day.

Time	PM_{10} (㎍/㎥)			CO_2 (ppm)			VOCs (ppb)		
	Home	Office	p-value	home	office	p-value	home	office	p-value
24:00 –06:00	22.7	47.3	< 0.0001	976.3	470.9	< 0.0001	183.0	132.7	< 0.0001
06:00 –18:00	38.3	63.9	0.0012	931.3	580.5	0.0196	181.0	150.2	0.0445
12:00 –18:00	36.4	64.9	< 0.0001	599.2	692.5	< 0.0002	144.0	156.0	0.0047
18:00 –24:00	50.6	57.6	0.00511	876.5	876.5	0.0875	177.7	168.0	0.4505

Time Interval Exposure Trends in Homes and Offices

TEST Engineering & Management

March - April 2020
ISSN: 0193 - 4120 Page No. 3833 - 3839

he concentrations of PM10, CO_2, and VOCs, which were meaningful between the experimental group and the control group, were classified according to morning time, afternoon time, and evening time. In the case of PM10, the concentration in offices was higher and the difference was statistically significant in the morning and afternoon hours. In contrast, in the evening hours, there was no statistically significant difference in concentration levels in homes and offices. CO_2 concentrations were higher at home than at office at all time points, with statistically significant differences. VOCs were higher at home than at office in dawn and morning. In the afternoon, however, the concentration was somewhat higher in office. In the evening hours, there was no statistically significant difference in concentration levels in homes and offices.

IV. Conclusions

At home, fine dust was highest in the evening (18:00-24:00) and lowest in the early morning (24:00-06:00). Compared with PM1.0 and PM2.5, the change in concentration was significantly higher in PM10. In contrast, the concentrations of VOCs and CO_2 increased gradually in the evening and were maintained until dawn (24: 00-06:00). CO_2 and VOCs levels remained low from 10:00 to 17:00 o'clock, when family members did not have much indoor activity. This may be due to the activity pattern of family members and lack of ventilation after household activities. According to a previous study that measured indoor air pollutants in a multi-use facility in real time, the concentration of CO_2 increased at the beginning of the class, but the concentration of CO_2 dropped sharply after ventilation [10]. The results of this study are consistent with those of the current study, where the concentration of CO_2 in the evening was increased, but not decreased. In addition, the results of VOCs measurement in child care centers showed that the concentration was up to four times higher indoors than outdoors. In addition to the high interest in air pollution, interest in reducing indoor air pollution is increasing. Previous studies on indoor air pollution emphasized that indoor air quality management should be given special attention because air circulation and contaminant concentrations accumulate over time compared to air pollution [2,4,10]. In modern society, people are more exposed to indoor air pollution, especially children and the elderly who stay longer times indoors [15]. In addition, building syndromes are among the health risks caused by indoor air pollution. CO_2, PM10, PM2.5, and VOCs measured in this study are the causes of building syndromes [16]. This study investigated the concentration and trends of exposure in households of children with allergy, but did not suggest any association between allergies and exposure. In addition, although there were limitations of examining the trend of exposure from September to December, the seasonal change in the concentration of VOCs in child care centers showed the highest VOCs exposure concentration in summer followed by autumn, as the frequency of ventilation was low [17]. Since there are differences in indoor air concentrations and indoor activities according to seasons, subsequent studies will require a 12-month research model. According to a study reported in Japan, it is possible to collect accumulated data through real-time monitoring because the variation of concentration of VOCs is large according to season, measurement location, and ventilation condition [18]. In this study, the IoT-based measurement equipment was used to identify the exposure trends over time, and the importance of indoor air in homes was reflected by reflecting the season after summer.

This study was able to confirm the indoor air quality concentration pattern over time in general homes and offices, and it was confirmed that time-of-day management is necessary to maintain high-quality indoor air. In the early years of development of indoor air measurement based on IoT, equipment was difficult to install in general homes due to the problem of system volume [10,19] reported the establishment of a real-time air quality management system focusing on the need for ventilation to alleviate indoor air pollution and reported facilities that are vulnerable to air pollution. In the future, research on environmentally harmful factors based on real-time environmental measurement data will help prevent diseases related to indoor air pollution.

References

[1] Hyo-mi, K., Jin-ah, H., Yun-hyung, P., & Jong-tae, L. (2012). The Effect of Air Pollution on Allergic Diseases Considering Meteorological Factors in Metropolitan Cities in Korea. Korean Society of Environmental Health, 38(3), 184-194.

[2] Lee, S. Y., Chang, Y. S., & Cho, S. H. (2013). Allergic Diseases and Air Pollution. Asia Pacific Allergy, 3(3), 145-154.

[3] Ackermann-Liebrich, U., Leuenberger, P., Schwartz, J., Schindler, C., Monn, C., Bolognini, G. & Grize, L (1997). Lung Function and Long Term Exposure to Air Pollutants in Switzerland. Study on Air Pollution and Lung Diseases in Adults (SAPALDIA) Team. American Journal of Respiratory and Critical Care Medicine, 155(1), 122-129.

[4] Kim, U., Kim, Y.-C., & Kwak, S (2016). Iot Based Indoor Air Quality Monitoring System. The Korea Contents Society, 16(2), 143-151.

[5] Heon, L. T., & Kyung, M. M. (2016). Design and Implementation of Portable Air Quality Measurement System Based on IoT Platform. Korean Institute of Next Generation Computing, 12(3), 75-84

[6] Seo, M.-S., Oh, C.-S., Kim, S.-H., Lee, J.-H., Kim, Y.-D., Lee, C.-S., & Park, H.-J. (2014). A Study on Indoor Air Quality Monitoring Systems in the IoT Environment. Korean Information Science Society, 963-965.

[7] Jin-ho, R., & Han-ho, T. (2017). The Implementation of the Fine Dust Measuring System Based on Internet of Things (IoT). Korean Institute of Information and Communication Sciences, 21(4), 829-835.

[8] Su, Y. K., Pil, L. J., Gwang, L. J., Seong, L. H., Hyeok, L. J., & Kwang, L. J. (2018). Air Quality Analysis Using IoT Sensor in Laboratory Environment. Journal of the Korean Institute of Communication Sciences, 420-421.

[9] Kim, H.-S. (2017). IoT-Based Air Meter Status and Development Direction. Korean Society of Environmental Health Conference, 175-175.

[10] Oh, C.-S., Seo, M.-S., Lee, J.-H., Kim, S.-H., Kim, Y.-D., & Park, H.-J (2015). Indoor Air Quality Monitoring Systems in the IoT Environment, Journal of the KICS, 40(5), 886-891

[11] Choi, Y. J. (2013). A Study on Improvement of Indoor Air Quality in Homes. Policy Study Report, 59, 1-201.

[12] Jang-won, S., Byeong-cheol, M., Suk-man, J., Sang-hoon, L., & Deuk-hyun, Y. (2017) A Study on the Characteristics of Major Indoor Pollutants in Multi-Use Facilities by Season. Korea Society of Environmental Health Conference, 114-114.

[13] Na, J. J., Lim, J. H., & Son, J. Y (2008). Effects of Air Purifiers and Ventilation on Indoor Air Quality in Child Care Facilities. Proceedings of the Architectural Institute of Korea Conference, 28(1), 719-722.

[14] Choi, S. W. (1997). Evaluation of Ventilation System Performance Using Indoor Air Quality Model. Journal of Environmental Health Sciences, 23(4), 57-66.

[15] Nieuwenhuijsen, M. J. (2015). Exposure Assessment in Environmental Epidemiology. Oxford University Press, USA

[16] Kim, K. W., Jun, H. D., & Park, J .C. (2009). A Study on the Survey Indoor Environment in Child Care Center (1). Proceedings of 2009 Architectural Institute of Korea, 29(1), 705-708.

[17] Sung-ki, J., Jae-young, C., Seong-yeon, K., Sook-young, P., Jeong-min, R., Jung-yeon, L., & Woo-suk, L. (2007). Seasonal Variations of Volatile Organic Compounds (VOCs) in Indoor Air of

March - April 2020
ISSN: 0193 - 4120 Page No. 3833 - 3839

Daycare Centers. Analytical Science & Technology, 20(5), 474-482.

[18] University, Environmental Health and Preventive Medicine, 18(4), 285.

[19] Ye, S. H., & Han, S. (2013). Indoor Environment Monitoring System Using Short-Range Wireless Communication in Mobile Devices, Journal of the Korean Institute of Information and Communication Engineering, 17(9), 2167-2173.