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A Study on the Improvement of Comfortable Living Environment by Using real-time Sensors

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Abstract

Purpose: This study was conducted to identify indoor air quality in various living spaces using sensors that can measure noise, vibration, fine dust, and odor in real time and to propose optimal indoor air quality maintenance management using Internet of Things(IoT). **Research design, data and methodology:** Using real-time sensors to monitor physical factors and environmental air pollutants that affect the comfort of the residential environment, Noise, Vibration, Atmospheric Pressure, Blue Light, Formaldehyde, Hydrogen Sulfide, Illumination, Temperature, Ozone, PM10, Aldehyde, Amine, LVOCs and TVOCs were measured. It were measured every 1 seconds from 4 offices and 4 stores on a small scale from November 2018 to January 2019. **Results:** The difference between illuminance and blue light for each measuring point was found to depend on lighting time, and the ratio of blue light in total illumination was 0.358 ~ 0.393. Formaldehyde and hydrogen sulphide were found to be higher than those that temporarily attract people in an indoor office space that is constantly active, requiring office air ventilation. The noise was found to be 50dB higher than the office WHO recommendation noise level of 35 ~ 40dB. The most important factors for indoor environmental quality were temperature> humidity> illumination> blue light in turn. **Conclusions:** Various factors that determine the comfort of indoor living space can be measured with real-time sensors. Further, it is judged that the use of IoT can help maintain indoor air quality comfortably.

Keywords : Indoor air quality, IoT, Real-time sensor, Comfort

JEL Classification Codes : I00, I10, I30, I31

1. Introduction

With the increase in an economic activity, modern people spend more than 90% of their time indoors, so comfortable air quality in the indoor space has become a very important issue (Ministry of Environment, 2002). The human comfort of the indoor air environment is greatly affected by the indoor furniture, household items, and pollutants generated by human activities in living as well as the air quality flowing in from the outdoors. When Indoor Air Quality(IAQ) is polluted, room ventilation has been proposed as a way to reduce indoor air quality pollution concentration (Choi & Ko, 2013). However, recently, the harmfulness of particulate matter is known, and it is very difficult to ventilate the outside air indoors due to air pollutants generated in Korea and air pollutants flowing from China.

The Ministry of Environment in Korea also forecasts the weather and particulate matter concentration in the atmosphere of air. When the air containing substances harmful to health generated due to rapid industrial development in China flows into the Korean Peninsula, the concentration of fine dust in Korea increases and the forecast of ‘bad fine dust’ is becoming more frequent (Kang & Choi, 2015). Indoor Air Quality Control(IAQC) is in accordance with the 『Indoor Air Quality Control Act』. In other words, public-use facilities used by an unspecified number of people, such as underground stations, underground shopping malls, libraries, art galleries, medical clinics, and indoor parking lots, as well as apartments and row houses larger than the size prescribed by the Presidential Decree, fulfill the 5 criteria for maintaining IAQ and 5 criteria for the recommendation. It is managed through regular inspections. However, for newly built apartment houses, 7 items of recommended Indoor Air Quality Standards(IAQS) are set and inspection results are required to be submitted 7 days prior to resident move-into (Ministry of Environment, 2018).

According to the United States Environmental Protection Agency(US EPA), the Indoor Air Pollutants Concentration(IAPC) is 2 to 5 times higher than that of Outdoor Air Pollutants Concentration(OAPC), and when it is high, more than 100 times higher(Haldane, 2018). According to the World Health Organization(WHO), 7 million people die annually from air pollution on environment, and more than 80% of people living in urban areas are exposed to Air Quality Standards(AQS) that exceed the standard. In countries with low or middle income levels every year, 3.8 million people die prematurely due to indoor air pollution exposure at home(WHO, 2019), indicating that the risk of Indoor Air Pollution(IAP) is high. In Korea, IAQC is being strengthened through continuous revision of the Indoor Air Quality Control Act(IAQCA). However, it is limited to public-use facilities that fall under the law, and management in other residential spaces can be said to be in a blind spot. Although the public-use facility is subject to the law, it is difficult to say that this facility is continuously air quality controlled because it is subject to an indoor air quality monitoring once for a set period (Ministry of Environment, 2018).

Since many people are constantly living in indoor spaces, IAQ must also be continuously managed, but both the state and local governments cannot manage it. As mentioned above, since Indoor Air Pollution(IAP) affects a serious risk to human health, sustainable IAQC in public-use facilities subject to the Indoor Air Quality Control Act and other residential spaces not subject to the Act is very important. This study intends to utilize a sensor that can measure noise and vibration, fine dust, and odor, etc. in real time. Through this, this study tries to identify the IAQ of a residential space and propose a way to maintain and manage IAQ at all times by using the Internet of Things(IoT).

2. Research Methods

2.1. Overview of Measurement

This study conducted sensor-type Indoor Air Quality Monitoring Equipment(IAQME) (Rubix, POD, size 14×14×12.7cm, weight 430g) from November 2018 to January 2019 in 1 office, 2 laboratories, 1 measurement data monitoring rooms, and 4 stores on small scale sites was measured. Measurements include atmospheric pressure, blue light, illuminance, formaldehyde, temperature, humidity, hydrogen sulfide, ozone, PM10, noise, vibration, human comfort. In addition, aldehyde, amine, Low Volatile Organic Compounds(LVOCs), Total Volatile Organic Compounds(TVOCs) were measured using a sensor that applied oxidation-reduction potential reaction. It was measured at 1 second intervals by the measuring equipment and stored in Cloud Server. For this measurement analysis, correlation analysis and regression analysis were applied.

2.2. Characteristics of POD Gaseous Pollutants Measurement Sensors

In the Metal Oxide Sensor(MOS) of the POD measuring equipment used in this study, oxidation and reduction occur on the surface sensing when volatile substances come into contact with the surface sensing. This measuring equipment is the principle of generating a signal by converting the resistance value generated during measurement into a conductivity value. The degree of oxidation-reduction depends on the material coated on the surface sensing, and the reactivity appears regardless of a specific component. This measuring equipment is suitable for the detection of total VOCs, and by analyzing the pattern with array technology of different types of MOS, finger printing of volatile components is possible. Electro Chemical Sensor(ECS) uses the movement of electrons on the surface sensing when it encounters a specific component. This sensor generates a conductivity value, and the sensing electrode that generates conductivity only by contact with a specific component is the most different from MOS. Table 1 shows the service life and measurement range for each item.

Table 1: Sensor Performances of Measurements Devices

Type	Sensor	Life time		Range		Resolution
MOS	Aldehyde	3 years		0 to 1000 ppm		< 20 ppb
	Amine	3 years		0 to 500 ppm		< 20 ppb
	LVOC	3 years		0 to 30 ppm		< 20 ppb
	TVOC	5 years		0 to 400 ppm		< 20 ppb
Electro-chemical	Sensor	Range (ppm)	Detection limit(ppb)	Resolution (ppb)	Accuracy reading	Expected life(month)
	H_2S	0-100	45	15	± 2%	>24
	Ozone	0-20	20	1	± 2%	>24
	Formaldehyde	0-50	10	50	± 5%	>24

Note: Specific gas concentration levels are measured under controlled conditions. Ultra Clean Synthetic air at 25 ± 0.5℃, 1 atm ± 0.2 atm and 50 ± 10% RH. Data produced with MOS does not use units.

3. Research Results

3.1. Comparison of Indoor Air Quality in Points

The office group refers to the living environment analysis room, office, microbiological laboratory, and data monitoring room, and was measured from November 9, 2018 to January 22, 2019. The store group on a small scale consisted of 3 restaurants and a billiard room, and the results measured from January 23 to January 30, 2019 are shown in Tables 2 and 3.

Table 2: Statistics of Indoor Air Quality according to Store Sites

Site	Statistics	Atmospheric pressure (hpa)	Blue light intensity (lux)	Comfort	Form-Aldehyde (ppm)	Humidity (%)	Hydrogen sulphide (ppm)	Light intensity (lux)	Ozone (ppm)
A Restaurant	N	169	169	169	169	169	169	169	169
	Mean	1023.5	5.6	41.6	0.29	27.6	0.060	14.6	0.040
	Std. dev.	2.8	2.2	10.6	0.30	7.7	0.066	7.0	0.062
B Restaurant	N	169	169	169	169	169	169	169	169
	Mean	1024.0	18.0	38.8	0.12	30.9	0.019	49.8	0.023
	Std. dev.	2.8	16.4	6.8	0.12	7.8	0.029	47.7	0.009
C Restaurant	N	169	169	169	169	169	169	169	169
	Mean	1024.0	4.1	46.4	0.12	36.2	0.011	10.5	0.000
	Std. dev.	2.8	1.6	4.8	0.12	6.5	0.012	5.5	0.001
D Billiards hall	N	160	160	160	160	160	160	160	160
	Mean	1021.8	27.2	37.2	0.03	20.4	0.022	70.7	0.006
	Std. dev.	2.7	29.1	10.3	0.05	3.0	0.048	78.6	0.003

Site	Statistics	PM10 (μg/㎥)	Aldehyde	Amine	LVOC	TVOC	Sound level (dB)	Temperature (℃)	Vibration (m/s^2)
A Restaurant	N	169	169	169	169	169	169	169	169
	Mean	1.549	4.131	4.870	4.132	-2.313	56.0	23.1	204.7
	Std. dev.	1.226	0.549	0.721	0.651	1.376	5.3	3.1	24.8
B Restaurant	N	169	169	169	169	169	169	169	169
	Mean	3.012	0.949	4.517	4.743	-1.380	50.7	18.4	228.8
	Std. dev.	2.822	0.938	0.740	0.808	0.760	5.0	3.7	133.0
C Restaurant	N	169	169	169	169	169	169	169	169
	Mean	1.342	1.817	5.064	5.834	-1.590	49.6	18.7	127.8
	Std. dev.	2.464	0.873	0.677	0.998	0.973	4.8	1.2	14.8
D Billiards hall	N	160	160	160	160	160	160	160	160
	Mean	1.237	0.405	4.574	3.855	-1.577	50.0	17.2	227.8
	Std. dev.	1.135	1.070	1.017	0.947	0.731	3.7	2.6	33.1

Table 3: Statistics of Indoor Air Quality according to Office Room Sites

Site	Statistics	Atmospheric pressure (hpa)	Blue light intensity (lux)	Comfort	Form-Aldehyde (ppm)	Humidity (%)	Hydrogen sulphide (ppm)	Light intensity (lux)	Ozone (ppm)
Life Environ. Lab	N	967	967	967	967	967	967	967	967
	Mean	1024.3	87.8	46.8	0.01	26.4	0.006	300.8	0.000
	Std. dev.	4.9	78.9	14.9	0.02	10.9	0.011	269.9	0.000
Microbial Lab	N	952	952	952	952	952	952	952	952
	Mean	1024.3	104.2	46.6	0.12	21.4	0.017	289.9	0.022
	Std. dev.	5.0	120.8	11.0	0.23	8.5	0.021	322.9	0.005
Monitoring room	N	967	967	967	967	967	967	967	967
	Mean	1024.2	12.4	42.6	0.00	22.3	0.013	31.5	0.002
	Std. dev.	5.0	18.1	9.7	0.02	8.4	0.016	59.6	0.001
Office room	N	967	967	967	967	967	967	967	967
	Mean	1023.8	183.8	50.7	0.01	23.2	0.043	511.3	0.007
	Std. dev.	5.0	118.0	13.5	0.02	9.3	0.082	315.9	0.003

Site	Statistics	PM10 (μg/㎥)	Aldehyde	Amine	LVOC	TVOC	Sound level (dB)	Temperature (℃)	Vibration (m/s^2)
Life Environ. Lab	N	967	967	967	967	967	967	967	967
	Mean	1.270	-1.921	3.008	1.902	-1.036	46.6	18.2	224.2
	Std. dev.	2.225	0.983	1.434	1.079	0.793	0.9	3.3	132.2
Microbial Lab	N	952	952	952	952	952	952	952	952
	Mean	1.283	-2.460	4.082	4.173	-0.920	47.8	20.2	287.9
	Std. dev.	1.748	1.639	1.263	0.983	1.067	1.4	3.0	121.4
Monitoring room	N	967	967	967	967	967	967	967	967
	Mean	0.879	-0.783	1.778	2.210	-2.166	50.0	19.6	297.1
	Std. dev.	1.195	1.030	1.214	0.558	0.589	1.1	2.9	67.2
Office room	N	967	967	967	967	967	967	967	967
	Mean	1.412	-0.157	2.896	3.244	-1.993	46.7	20.5	408.2
	Std. dev.	1.752	1.223	1.292	1.069	1.182	1.0	3.6	112.7

Ultraviolet rays, which are known to have a bad effect on the eyes, do not have high transmittance, so they affect the cornea and the lens part that serves as the camera of the eye, that is, the front part of the eye (Kim, 2005). However, blue light is a ray between 380 and 500 nm among the light (visible light) area that the eye can see, and it affects the retina at the back of the eye, which is the most important part of the eye, and can lead to retinal diseases such as macular degeneration.

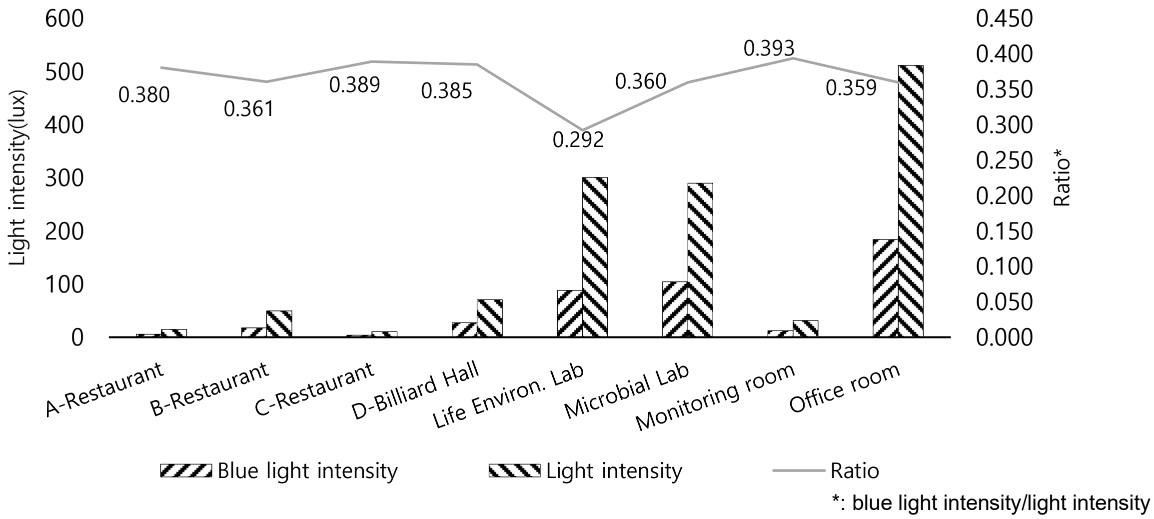


Figure 1: The Comparison of Blue Light and Light Intensity

This type of macular degeneration is a disease caused by the death of retinal cells, and is one of the leading causes of blindness in the elderly over 65 years old (Kirk, 2013 ; Lee, 2003). Although life has become more convenient and better with the development of technology, blue light has an adverse effect on human eyes and is exposed more frequently. The health of the eyes is constantly being damaged as people watch TV or smart phones on the subway and bus, monitor at the office, and fall asleep while returning home. Figure 1 shows the average value of all time values, and the illuminance of the office group was higher than the illuminance and blue light of the store group on a small scale. This difference is due to the fact that the store group on a small scale turns on the lights at a time when visitors are concentrated, and it is found to be at a level similar to the monitoring room of the office group that does not turn on the lights. Blue light was generally classified as 0.292 in the life environment lab with the lowest ratio of blue light and 0.358 ~ 0.393 in other places.

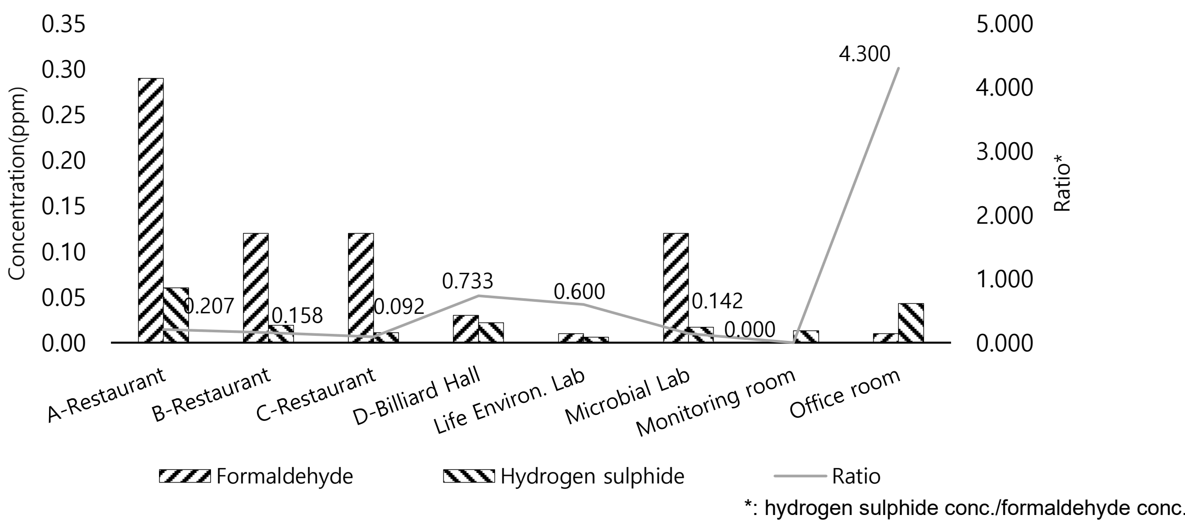


Figure 2: The Comparison of Formaldehyde and Hydrogen Sulfide

Formaldehyde is mixed in indoor air environment, but it is contained in construction materials and adhesives in new houses and new furniture, and it is also generated when a solid fuel mixed with trioxane and hexamine is used in the kitchen (Sohn, 2013). Hydrogen sulfide, mercaptans, and amines are substances that occur frequently in daily life among odor generating substances (Kim & Kang, 2014), and were measured using a sensor capable of detecting hydrogen sulfide, a representative substance. As shown in Figure 2, excluding monitoring room and office room, formaldehyde concentrations were higher than hydrogen sulfide concentrations. The concentration of formaldehyde was 0.00 ~ 0.029 ppm, and hydrogen sulfide was 0.006 ~ 0.060 ppm. The ratio of the two substances ranged from 0.092 to 4.300 and was the highest in the office room. This is due to continuous human activity in the office, and it was found that office air ventilation is necessary.

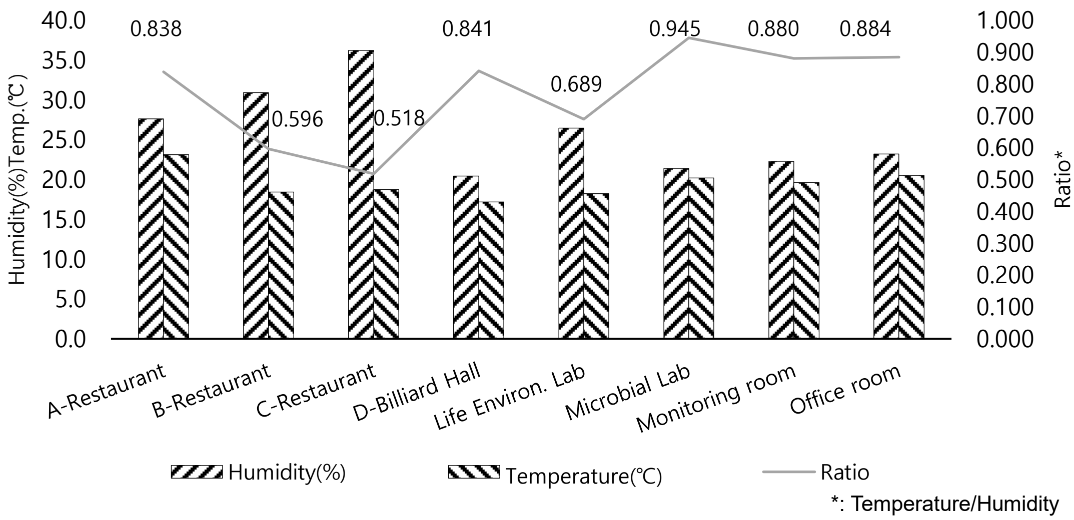


Figure 3: The Comparison of Humidity and Temperature

The temperature and humidity ratios were similar in the three office groups, where people were continuously occupant from work to the end of the workday at 9 am. The stores on the ground showed a similar rate, but the basement restaurants B and C showed higher humidity compared to the temperature. It can be seen that the room temperature rises during cooking and is maintained even during non-business hours, and the humidity is maintained as well.

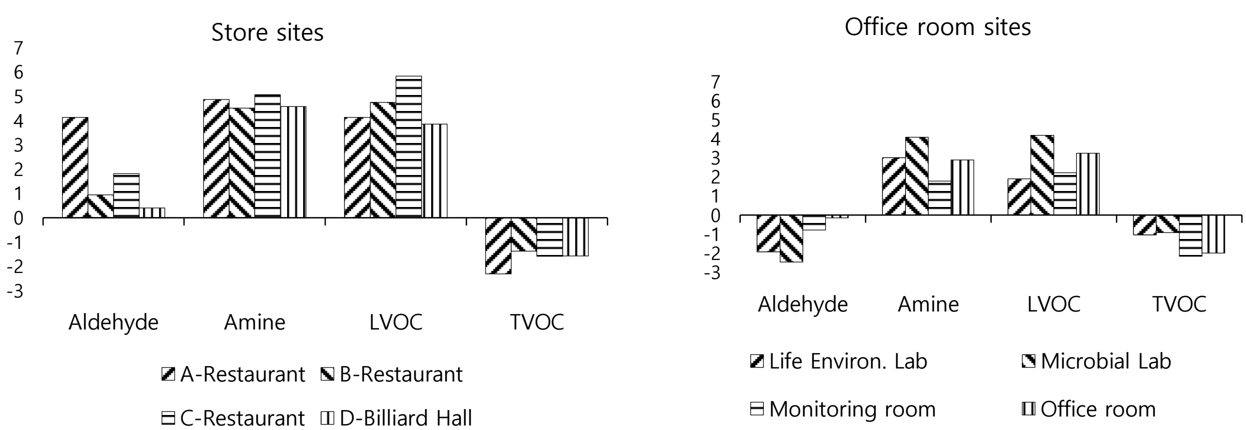


Figure 4: The Comparison of Aldehyde, Amine, LVOCs and TVOCs Measured with a MOS Sensor

Aldehyde, amine, LVOCs, and TVOCs, which are odor-causing volatile organic compounds(VOCs), are the values measured by measuring the reaction with an oxidation-reduction potential sensor(MOS type) that does not use a unit. This material can be used to characterize the air quality pattern at the monitoring point by combining the above four components. Figure 4 is a diagram showing the distribution of VOCs in the store on a small scale and office groups. In this figure, it is shown that a pattern different from the indoor air quality of the store is shown because aldehyde and amine are generated a lot among the four components in a relatively the store on a small scale, and a lot of amine is generated in the office group.

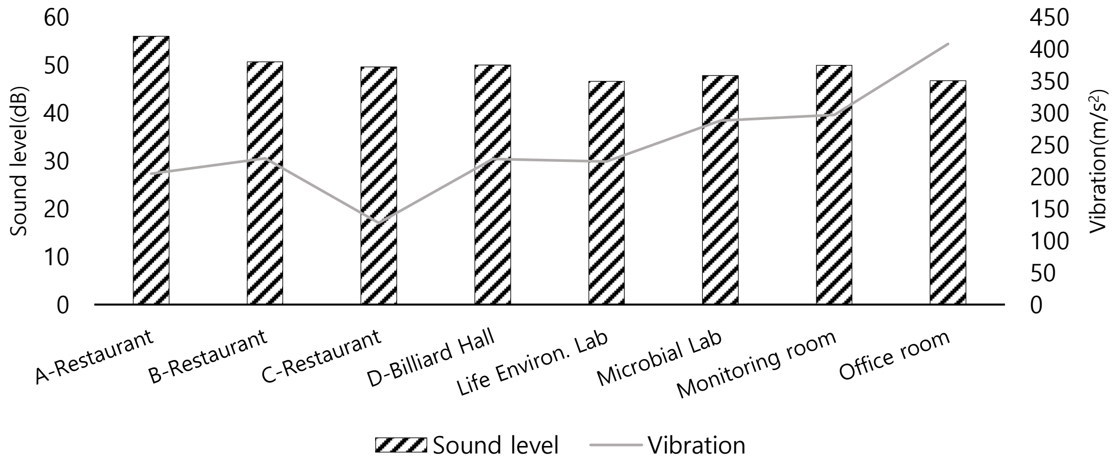


Figure 5: The Comparison of Sound Level and Vibration

Among the measurement points, the indoor sound level was the highest at restaurant A at 56 dB, and at other points it was around 50 dB. The sound level in this range exceeded the recommended noise standard(30~35 dB) for small offices, reception rooms, and small conference rooms with anround 20 people, and was higher than the sound level of medium offices or factory offices that required a 35~40 dB sound level. Vibration can be provided as anti-vibration data for the lowest vibration at the measurement site by identifying the quiet time period and vibration pattern.

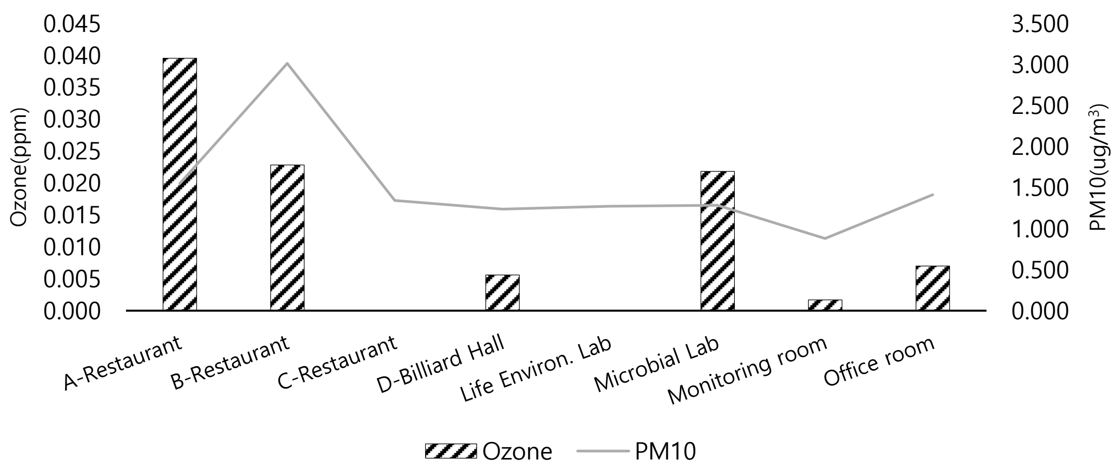


Figure 6: The Comparison of Ozone and PM10

The high concentration of particulate matter in the air also affects the rise in indoor particulate matter concentration. Indoors, outside air flows into the room through ventilation or gaps or openings in buildings, affecting indoor air quality and mixing with pollutants generated from indoor activities (Lee et al., 2015; WHO, 2019). In Figure 6, the particulate matter concentration was the highest at 3.012 ㎍/㎥ at point B, and about 1 μg/㎥ at other points. Point B is a restaurant located in the basement, and it is judged that ventilation systems should be operated in addition to natural ventilation through a small entrance. On the other hand, the ozone concentration was highest at 0.040 ppm at point A. point A is located on the first floor and is relatively spacious compared to other stores on a small scale, but it is judged that the cause is the combustion gas generated from the kitchen due to continuous business activities.

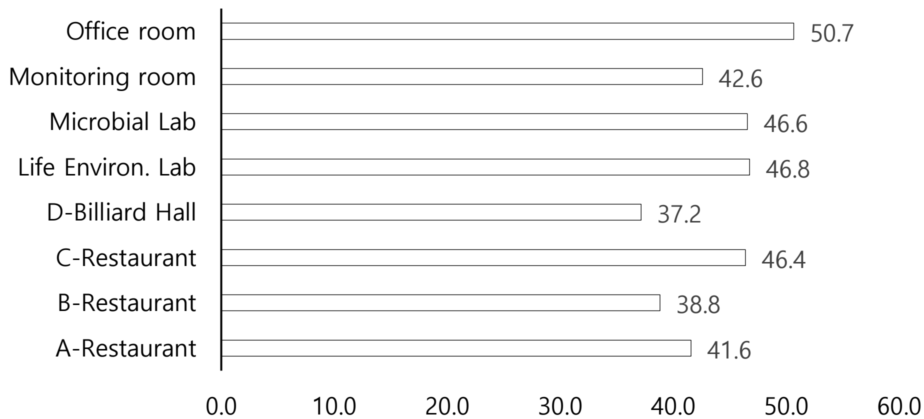
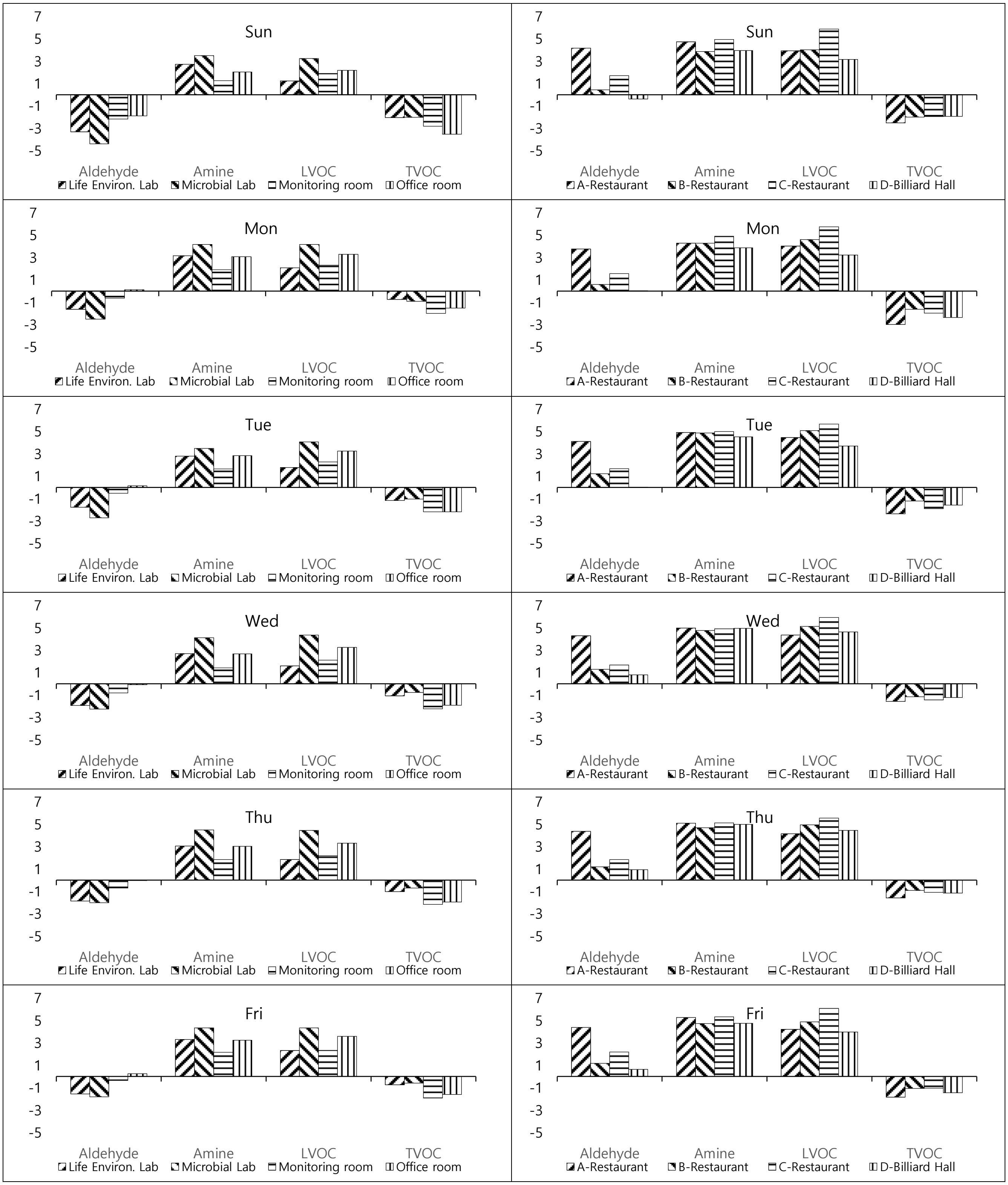


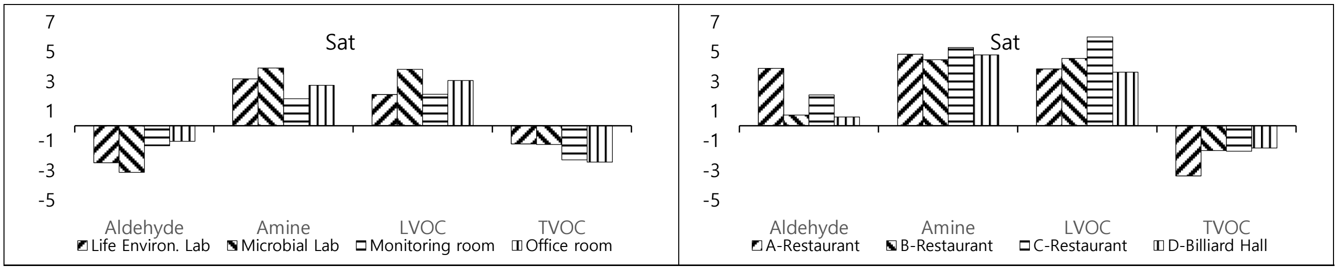
Figure 7: The Comparison of Comfort depending on Sites

In Figure 7, there was an explanation from the manufacturer of the measuring equipment that the Comfort score is given as the temperature approaches 21℃, relative humidity 50%, CO2 500ppm, illuminance 500 lux, and noise 50 dB. However, since the CO2 sensor was not set in the measuring equipment used in this study, it was calculated without including CO2 data. The higher the value, the higher the comfort. The Comfort score of each measurement point was higher in the office group than in the store group on a small scale. In the office group, the office room showed the highest comfort at 50.7, followed by the life environment laboratory > microbial laboratory > monitoring room in turn. In the store group on a small scale, restaurant C had the highest level of comfort at 46.4, but it was found to be less pleasant than the office group.

3.2. Comparison of Odors and VOCs by Life Pattern

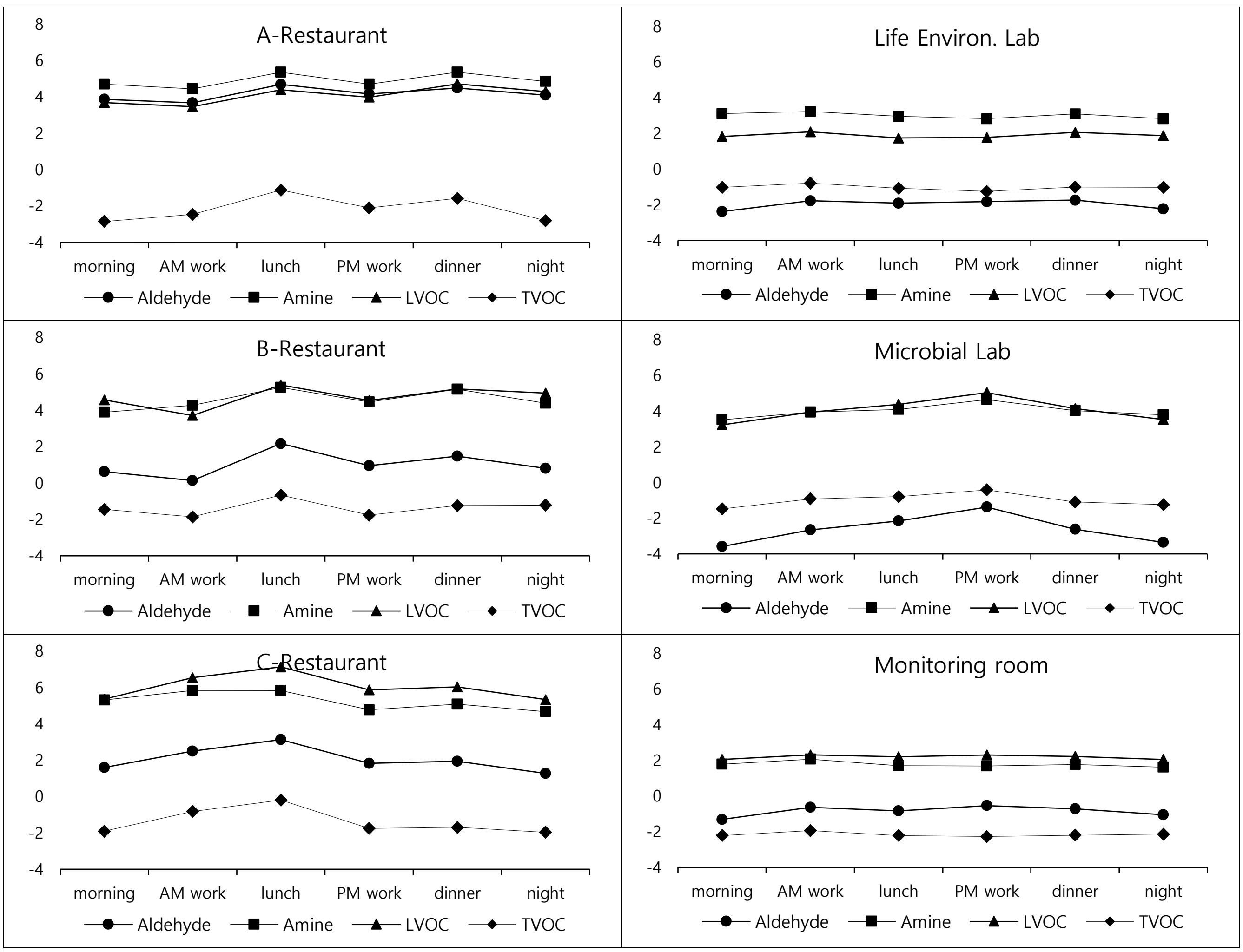
Figure 8 shows the weekly changes by measuring Aldehyde, Amine, LVOCs, and TVOCs with MOS sensors divided into office group and store groups on a small scale. Odor and VOCs substances were generated relatively less on Sunday and Saturday than on other days of the week, and a similar trend was also observed in the office group. Amine and LVOCs components were relatively higher than Aldehyde and TVOCs components. Also, the Aldehyde component was higher in the store group on a small scale than in the office group. In Figure 9, the human activity time zone is 6 to 9 in the morning, 9 to 12 in the morning, 12 to 14:00 in the afternoon, 14 to 18 in the afternoon, 18 to 22:00 in the evening, 22 to the next day in the night time. Divided into 6 o'clock. This figure shows the distribution of Aldehyde, Amine, LVOCs, and TVOCs for each measurement point. For restaurants, all four items were higher during lunch time than other time zones, and for billiard hall, dinner time was higher than at other times. On the other hand, the morning time of the office group was higher than that of other time zones, and the life environment laboratory showed weak changes by time compared to other offices.


Sun
Aldehyde Amine LVOC TVOC
Life Environ. Lab Microbial Lab Monitoring room Office room
Sun
A-Restaurant B-Restaurant C-Restaurant D-Billiard Hall
Mon
Mon
Tue
Tue
Wed
Wed
Thu
Thu
Fri
Fri
7 5 3 1 -1 -3 -5



(a) Office group (b) Store group

Figure 8: Weekly Change of Aldehyde, Amine, LVOCs and TVOCs by Life Group



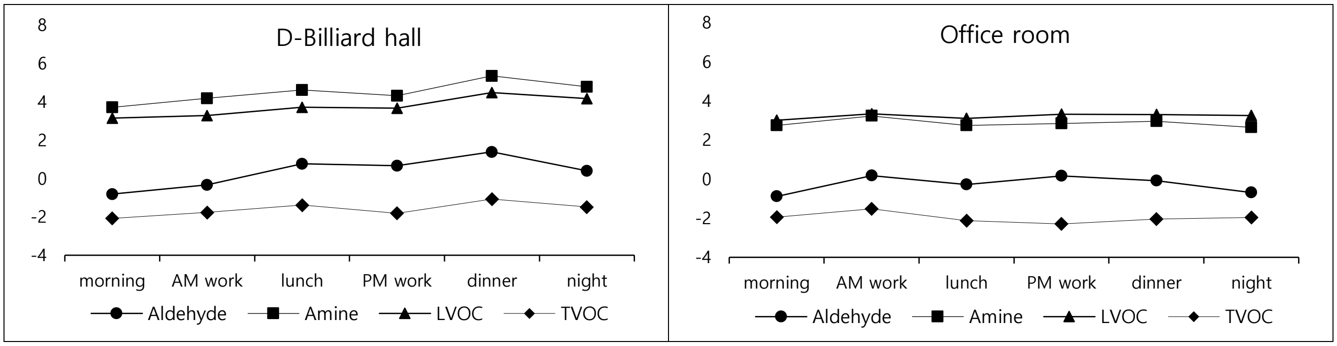


Figure 9: Changes of Aldehyde, Amine, LVOCs and TVOCs according to Life Time

3.3. Analysis of Comfort factor for improving indoor environment

Principal component analysis and forward elimination regression analysis were applied to investigate the effect on the comfort level of the indoor air environment. Principal component analysis was performed with an initial eigenvalue of 1 and factor analysis was performed according to the correlation matrix and total variance. As shown in Figure 10, a scree diagram with 5 components as the main components and the regression analysis results as shown in Table 3 were derived.

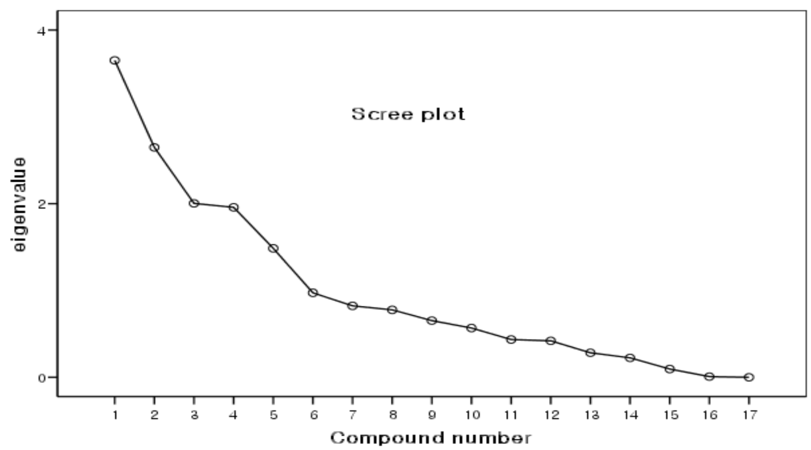


Figure 10: Scree Plot of Main Component Analysis

Table 4: Main Factors Indoor Air Quality Management Model

Model	Item	Non-std factor		Std factor	T	P value
		B	Std. error	Beta		
1	Constant	5.242	0.900		5.827	0.000
	Temperature	2.070	0.045	0.563	45.761	0
2	Constant	-7.232	0.979		-7.390	2E-13
	Temperature	2.239	0.043	0.609	52.166	0
	Humidity	0.380	0.015	0.293	25.091	4E-130
3	Constant	43.240	2.230		19.392	2E-80
	Temperature	2.616	0.043	0.711	60.794	0
	Humidity	0.411	0.014	0.317	28.835	6E-168
	Sound level	-1.212	0.049	-0.287	-24.838	9E-128

4	Constant	36.728	2.307		15.917	2E-55
	Temperature	2.417	0.047	0.657	51.100	0
	Humidity	0.419	0.014	0.323	29.672	6E-177
	Sound level	-1.026	0.052	-0.243	-19.730	3E-83
	Light intensity	0.005	0.001	0.119	9.681	6E-22
5	Constant	32.874	2.223		14.789	2E-48
	Temperature	2.421	0.045	0.658	53.339	0
	Humidity	0.401	0.014	0.309	29.518	3E-175
	Sound level	-0.944	0.050	-0.224	-18.861	2E-76
	Light intensity	0.061	0.003	1.484	21.149	1E-94
	Blue light intensity	-0.160	0.008	-1.378	-19.735	3E-83

As shown in the model, the most important factor for indoor human comfort was temperature > humidity > noise > illuminance > blue light in turn, and the constants and coefficients for each model are shown in Table 4. Therefore, it can be said that the control of the indoor environment consists of proper heating and cooling, humidity control, a calm environment, and lighting control to prevent eye fatigue. In addition, 11 variables out of 16 variables were included in the model application, in the order of formaldehyde > hydrogen sulfide > amine > LVOCs > TVOCs > Ozone in turn, followed by 5 major variables followed by odor-causing substances.

4. Discussions

4.1. Exploring Ways to Maintain a Comfortable Indoor Environmental Quality

In the residential space where people live continuously, it is necessary for a healthy life to maintain the comfort of the indoor air environment, not only in public-use facilities subject to legal management, but also in small businesses or private residential spaces that are not subject to the law. As communication technologies and uses of the Internet of Things (IoT) and smart phones have been greatly developed, it is intended to improve the quality of the indoor air environment or propose a maintenance plan by utilizing these technologies.

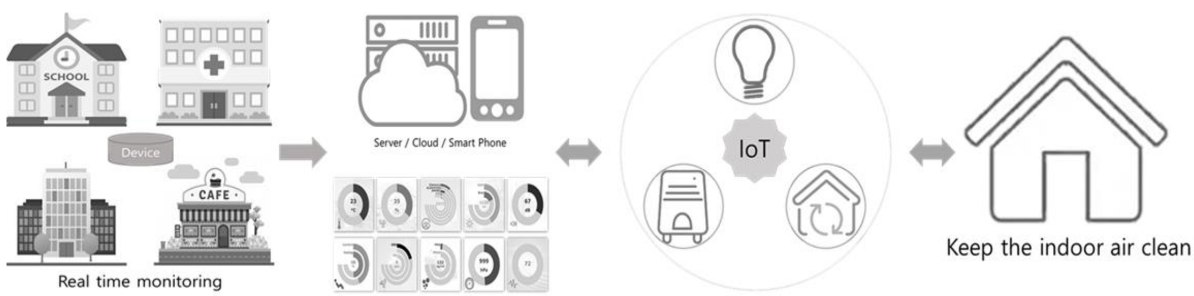


Figure 11: Flowchart of Improving Indoor Air Quality

Recently, as sensor technology capable of detecting various environmental pollutants has rapidly developed, a technology that can be combined with IoT may be used. Figure 11 shows the air flow diagram. Schools where children and students study, hospitals that treat the sick, offices where ordinary people spend most of their day, and coffee shops where they spend their leisure time are important daily living spaces. Here, noise and vibration, the physical environment, and environmental pollutants are factors that affect the indoor environment. Here, a sensor that can measure in real time may be installed. And this data is stored in the cloud server and the data being measured is checked with a smart phone. If this data exceeds the comfort maintenance standard entered in advance in the smart phone or measuring equipment, an alarm should be set. In addition, according to this alarm, the air purifier, ventilation systems, and lighting in the living space are adjusted to maintain a comfortable living environment.

5. Conclusions

This study used a sensor that can monitor physical factors and environmental pollutants that affect the comfort of a residential environment in real time. The results of measurement and analysis of noise, vibration, atmospheric pressure, blue light, formaldehyde, hydrogen sulfide, illuminance, temperature, ozone, PM10, Aldehyde, Amine, LVOCs, and TVOCs in 4 offices and 4 stores on a small scale were as follows.

1) The difference between illuminance and blue light for each measurement point was found to depend on the time the lighting was turned on. The ratio of blue light among the total illumination was 0.358 ~ 0.393. Formaldehyde and hydrogen sulfide were found to be higher than offices temporarily crowded in office spaces with continuous activity, suggesting that office air ventilation is required. It was found that the temperature and humidity were maintained together in the restaurant in the basement compared to the office or store on small scale on the ground. The noise was found to be about 50 dB, which is higher than the office WHO recommended noise standard of 35 to 40 dB. It was found to be higher in stores with many customers during business hours and in the microbiological analysis room where experiments were conducted continuously. The amenity level was higher in the office than in the store, but there was no clear difference between the ground level and the basement level.

2) Aldehyde, Amine, LVOCs, and TVOCs were measured with a MOS sensor. As a result of the measurement, it was found that on Sundays and Saturdays, odors and VOCs substances were relatively low compared to other days of the week, and Aldehyde and TVOCs components were relatively higher than Amine and LVOCs components. In restaurants, all four items were higher in lunch time than in other time zones, and in billiard room, dinner time was higher than in other times.

3) The most important factor for indoor comfort was temperature > humidity > noise > illuminance > blue light in turn.

4) A sensor that can measure the comfort of a living space in real time is installed. This measurement data is checked with a smart phone, and the IoT in the residential space can be operated according to the alarm exceeding the comfort maintenance standard to improve and maintain a comfortable living environment.

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