

Abstract

Development of the indoor air quality monitoring model based on Korea National Health and Nutrition Examination Survey (KNHANES)

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This study was conducted to develop a residential indoor air quality (IAQ) monitoring model that can be applied to the Korea National Health and Nutrition Examination Survey (KNHANES) system; a national cross-sectional surveillance system that has been assessing the health and nutritional status of Koreans since 1998. The KNHANES is conducted by the Korea Disease Control and Prevention Agency (KDCA) and approximately 10,000 persons participate in the survey. The IAQ measurement items selected were PM10, PM2.5, carbon dioxide, formaldehyde, total suspended bacteria, carbon monoxide (IAQ maintenance criteria of the Indoor Air Quality Control Act), nitrogen dioxide, radon, total volatile compounds (TVOC), and fungi (IAQ recommendation criteria) in consideration of domestic and international studies of IAQ. The survey items included 30 questions, including housing-related factors, IAQ management factors such as ventilation, resident behavioral factors such as cooking and the use of air fresheners, and outdoor influencing factors. A preliminary survey was conducted on 60 households among the households subject to KNHANES to examine the applicability of the IAQ monitoring model. The preliminary survey showed that carbon dioxide (35%), TVOC (25%), fungi (13%), and radon (13%) exceeded the IAQ criteria, and PM10, total suspended bacteria, carbon monoxide, and nitrogen dioxide were acceptable for all households. Based on the accuracy and ease of measurement in comparison with domestic and international surveys and the results of the preliminary investigation, four measurements (PM2.5, TVOC, formaldehyde, and carbon dioxide) and 30 survey items were selected by the study's IAQ subcommittee. To characterize the IAQ of Korean homes, this study's model was applied to 1,200 KNHANES households from July 2020 to October 2021.

Keywords : Korea National Health and Nutrition Examination Survey(KNHANES), Indoor air quality measurement, developing model

Table 1. Monitoring methods of indoor air quality (IAQ) in Korean residential households

Measurement items	Reference value	Sampling and analysis*		Sampling time	Note	
PM ₁₀	75 µg/m³	Minivol	Gravimetry	24 hrs	Public use facility's maintenance criteria ('Na' category facilities)	
PM _{2.5}	35 µg/m³					
Carbon Monoxide (CO)	10 ppm	Gas analyzer	Non-dispersive infrared spectrometer	1 hr		
Carbon Dioxide (CO ₂)	1,000 ppm					
Formaldehyde (HCHO)	80 µg/m³	2,4 DNPH Cartridge	LC			
Total Volatile Organic Compounds (TVOC)	400 µg/m³	Sampling tubes for solid thermal desorption	GC/MS			
Total Suspended Bacteria	800 CFU/m³	Impactor	Counting			
Fungi	500 CFU/m³	Impactor	Counting			
Nitrogen Dioxide (NO ₂)	0.05 ppm	Gas analyzer	Chemiluminescence		1 hr	Public use facility's recommendation criteria ('Na' category facilities)
Radon	148 Bq/m³	Continuous radon monitor	Alpha track radon detector		90 days	

*: Indoor air quality testing methods and standards in Korea (Ministry of Environment Notice No. 2017-11).

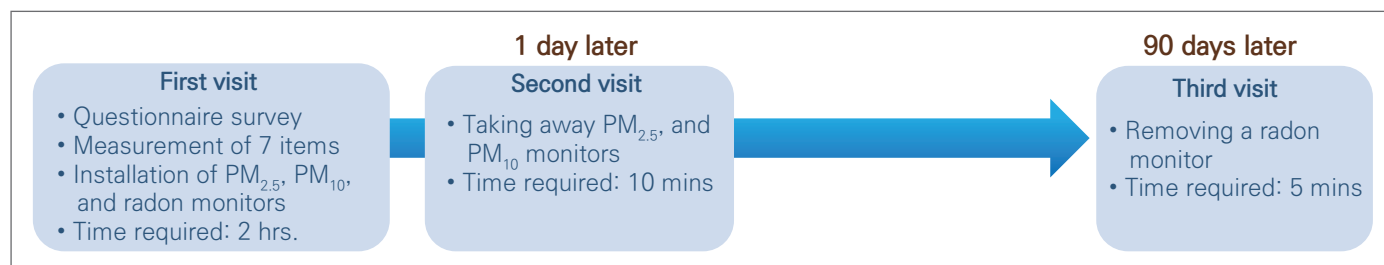


Figure 1. Indoor air quality (IAQ) survey process

Table 2. Summary of indoor air quality (IAQ) monitoring results

Measurement items	GM (GSD)	Min—Max	Q1	Median	Q3	Reference ^a	Evaluation outcome		
							Good ^b	Moderate ^c	In Excess ^d
PM10($\mu\text{g}/\text{m}^3$)	15.2 (1.8)	3.1—48.4	9.6	16.0	22.6	$<75 \mu\text{g}/\text{m}^3$	100%	0%	0%
PM2.5($\mu\text{g}/\text{m}^3$)	8.2 (2.0)	1.1—32.5	5.9	9.9	12.4	$<35 \mu\text{g}/\text{m}^3$	97%	3%	0%
Formaldehyde ($\mu\text{g}/\text{m}^3$)	22.9 (1.8)	7.9—71.5	13.9	20.5	36.6	$<80 \mu\text{g}/\text{m}^3$	95%	5%	0%
Total Volatile Organic Compounds ($\mu\text{g}/\text{m}^3$)	188.7 (2.9)	16.0—2,344.9	85.6	223.6	399.4	$<400 \mu\text{g}/\text{m}^3$	68%	7%	25%
Total Suspended Bacteria (CFU/ m^3)	56 (2.5)	9.0—365	32	47	105	$<800 \text{CFU}/\text{m}^3$	100%	0%	0%
Fungi (CFU/ m^3)	129 (3.0)	11—1,737	65	119	211	$<500 \text{CFU}/\text{m}^3$	83%	3%	13%
Carbon Monoxide (ppm)	0.9 (1.2)	0.5—1.4	0.8	0.9	1.1	$<10 \text{ppm}$	100%	0%	0%
Carbon Dioxide (ppm)	889 (1.4)	384—2465	699	880	1,064	$<1000 \text{ppm}$	40%	25%	35%
Nitrogen Dioxide (ppm)	0.014 (1.5)	0.005—0.03	0.01	0.013	0.018	$<0.05 \text{ppm}$	100%	0%	0%
Radon (Bq/ m^3) ^e	77 (1.7)	27—235	53	70	105	$<148 \text{Bq}/\text{m}^3$	80%	9%	11%

^a Indoor air quality maintenance and recommendation criteria by the Indoor Air Quality Control Act; ^b Measured value of less than 80% of the reference value;

^c Measured value 80% to 100% of the reference value; ^d Measured value exceeds the reference value; ^e 56 out of 60 measured households (3 lost, 1 rejected) analysis results.

Table 3. Categories of information used in the indoor air quality (IAQ) questionnaire

Category	No.	Questionnaire detail/content
Housing related factors	13	When the residents moved in, whether the house was repaired in the last 6 months, whether new furniture/appliances were bought in the last 6 months, whether there is condensation in the winter <u>Items filled out by surveyor:</u> Number of floors in the home, area (m^2) of the home, age of the building, flooring, wall material, living room and kitchen separated by door, water leakage, mold occurrence
Resident behavior related factors	9	Pets (types), whether dry-cleaning was brought in the last week, heating (types and fuels), air freshener usage, cooking (frequency, fuel, time per event, ventilation during cooking), exhaust fan in bathrooms, pesticide usage, humidifier usage (frequency, cleaning), air conditioner usage (cleaning)
Indoor air quality management factors	4	Cleaning (frequency, time per event, how the space is cleaned), how high humidity is managed, ventilation (frequency, time per event, method), air purifier usage
Outdoor factors	1	<u>Items filled out by the surveyor:</u> Classification of the area of use located in the home
Lifestyle	1	How many hours a day are spent at home during the weekdays and weekends
Air quality awareness	2	Satisfaction with indoor and outdoor air quality