A Study on the Characteristics of Indoor Air Quality in Multi-use Facilities Serving Health-Sensitive Populations in Seoul

Jinhyo Lee* · Juhee Hong · Seokryul Oh · Seungmi Kwon (*Seoul Metropolitan Government Research Institute of Public Health and Environment*)

Introduction

❖ Backgrounds

- In modern society, people spend most of their time indoors, where exposure to polluted air can lead to respiratory diseases and other health problems.
- **Indoor air quality is recognized as a key determinant** of public health, and with rising concern for comfort, management has expanded to multi-use facilities and new residential complexes.

❖ Purpose

- This study analyzes indoor air quality in various multi-use facilities serving vulnerable groups, such as child care centers and elderly care facilities, using data visualization. The findings are used **to establish a data framework and propose management strategies** for improving indoor air quality in Seoul.

Material and Method

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- **Study Subjects** : 302 health-sensitive multi-use facilities (638 sampling sites)

Facility(Site)	CCC (child care center)	ICP (indoor children's playground)	PCC (postnatal care center)	ECF (elderly care facility)	HCF (health care facility)
302(638)	69(138)	14(28)	38(76)	37(74)	144(322)

- **Study Period** : January ~ December 2024
- **Methodology** : Standard Test Method for Indoor Air Quality (NIER, No. 2024-70)
  - (Sampling) 2 sites (a total floor area ≤10,000 m²), up to a maximum of 4 sites
  - (Evaluation) Average concentration across all sampling sites within each facility
- **Target Pollutants** : PM10, PM2.5, CO_2, HCHO, TAB(Total Airborne Bacteria)

Parameters	PM10 (㎍/㎥)	PM2.5 (㎍/㎥)	CO_2 (ppm)	HCHO (㎍/㎥)	TAB (CFU/㎥)
National Standard	≤ 75	≤ 35	≤ 1,000	≤ 80	≤ 800

Results & Conclusions

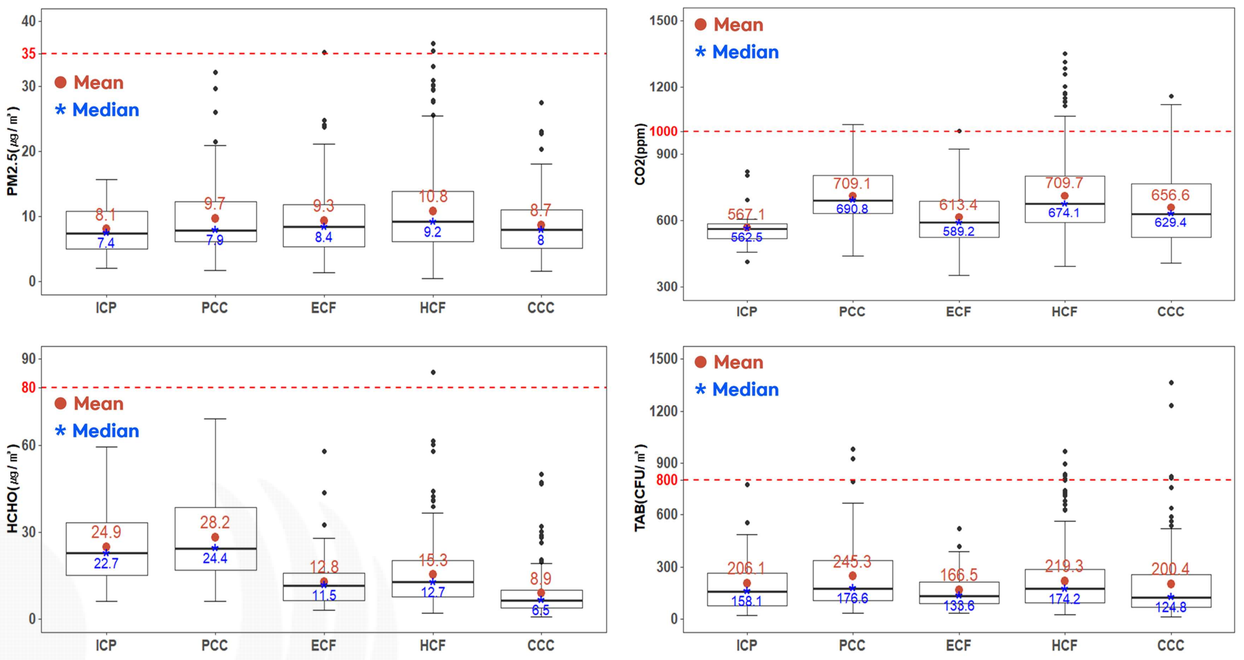
❖ Non-compliance and Indoor Pollutant Levels by Facility Type

- Exceedance of maintenance standards : 3 HCFs (CO_2, 1,051~1,079 ppm)
  - ☞ **Re-inspection results: 3 facilities were within the standard (467~873 ppm)**
- Seasonal variation of target pollutants
  - **(PM10, PM2.5) Higher in spring and winter**, lower in summer (outdoor air)
  - **(CO_2) Highest in summer**, lowest in spring (insufficient ventilation in summer)
  - **(HCHO, TAB) Higher in summer** and lower in winter (hot and humid in summer)

Facility (number)		PM10 (㎍/㎥)	PM2.5 (㎍/㎥)	CO_2 (ppm)	HCHO (㎍/㎥)	TAB (CFU/㎥)
(National Standard)		75	35	1,000	80	800
CCC (69)	Mean	13.9	8.7	657	8.9	199.8
	Min	3.0	1.6	408	0.7	12.5
	Max	51.5	27.5	1,160	50.2	1,364.6
	SD	7.4	4.7	154.4	8.5	213.8
	RSD(%)	53.1	54.2	23.5	95.3	107.0
	95% CI	13.9±1.2	8.7±0.8	657±26.1	8.9±1.4	199.8±35.9
ICP (14)	Mean	12.0	8.1	567	24.9	206.1
	Min	3.0	2.0	412	6.1	20.1
	Max	20.6	15.7	821	59.6	776.8
	SD	5.2	4.1	91.3	14.0	174.3
	RSD(%)	43.2	50.4	16.1	56.4	84.6
	95% CI	12.0±1.9	8.1±1.5	567±33.8	24.9±5.2	206.1±64.6
PCC (38)	Mean	14.5	9.7	709	28.2	245.3
	Min	2.7	1.7	439	6.3	32.7
	Max	50.8	32.2	1,032	69.3	981.5
	SD	9.4	6.0	126.1	14.5	205.7
	RSD(%)	64.8	61.9	17.8	51.3	83.8
	95% CI	14.5±2.1	9.7±1.3	709±28.4	28.2±3.3	245.3±46.2
ECF (37)	Mean	14.9	9.3	613	12.8	166.5
	Min	2.3	1.4	352	3.0	33.4
	Max	45.9	35.2	1,003	58.0	520.9
	SD	7.7	6.1	121.9	9.1	106.3
	RSD(%)	51.3	65.2	19.9	71.4	63.8
	95% CI	14.9±1.7	9.3±1.4	613±27.8	12.8±2.1	166.5±24.2
HCF (144)	Mean	17.6	10.8	709	15.3	219.3
	Min	2.7	0.4	393	2.1	26.3
	Max	69.1	36.6	1,354	85.5	966.2
	SD	10.9	6.9	167.8	10.5	175.2
	RSD(%)	61.8	63.8	23.7	68.8	79.9
	95% CI	17.6±1.2	10.8±0.8	709±18.3	15.3±1.2	219.3±19.3

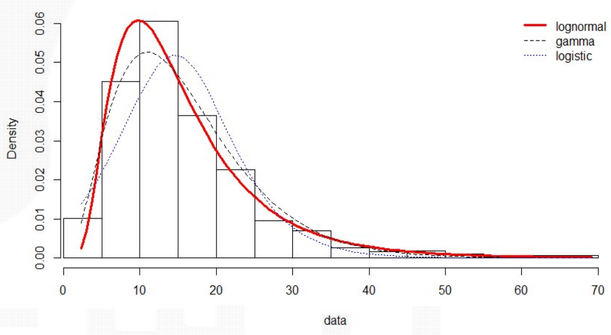
❖ Comparison of Mean Indoor Pollutant Levels by Facility Type

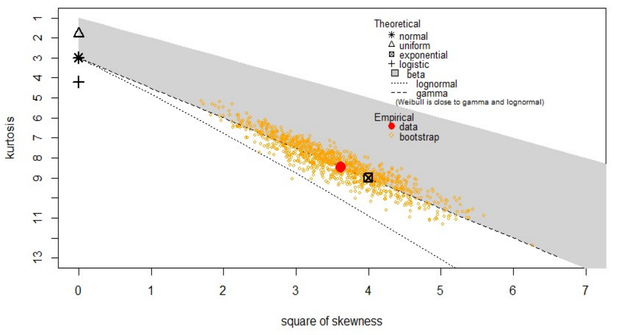
- **(PM10, PM2.5)** Maximum concentrations were within standards / **(CO_2)** Mean and median concentrations across five facilities types were within the standard, suggesting **low health risks**.
- **(HCHO)** Max concentrations were within standard, suggesting **low health risks** / **(TAB)** Maximum concentrations in 5 facilities were within the standard, suggesting that **overall hygienic management levels were satisfactory**.



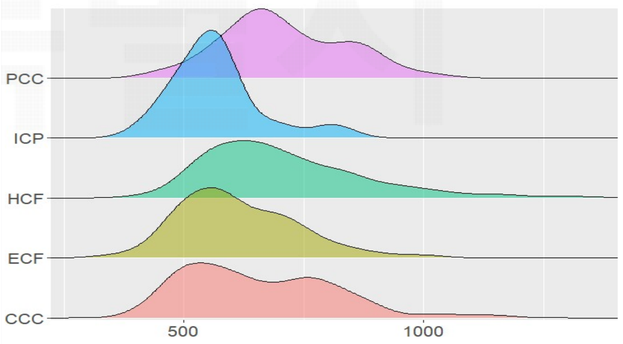
❖ Results from various forms of data visualization

- **(Distributional characteristics)** Normality tests (Shapiro–Wilk, Anderson–Darling, Lilliefors; $p < 0.05$) showed all five parameters were **non-normally distributed**.
- **(Indoor pollution levels) Higher mean pollutant concentrations were found in HCFs and PCCs.** In the star plot, larger semicircles indicate higher pollution, highlighting differences across facility types. These findings underscore the need for facility-specific management and common pollutant controls. (e.g., HCHO)

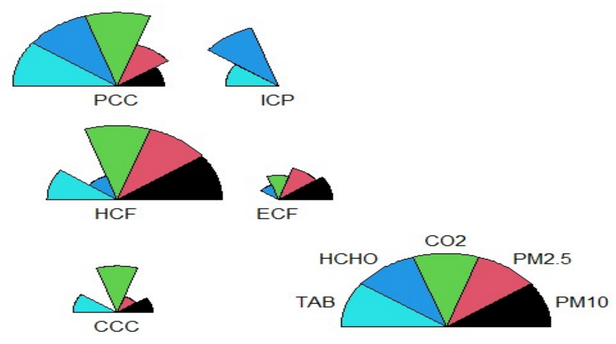




< PM10 - Histogram & Probability Density function, Cullen and Frey graph → Log-normal Distribution >

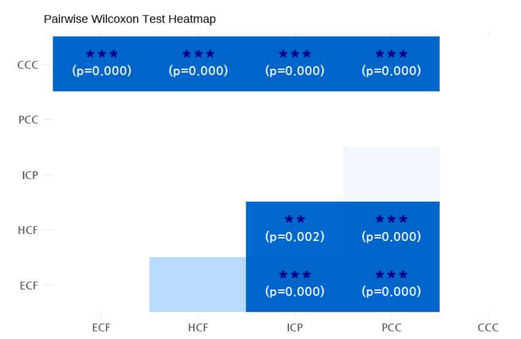


< CO2 – Ridgeline plot >

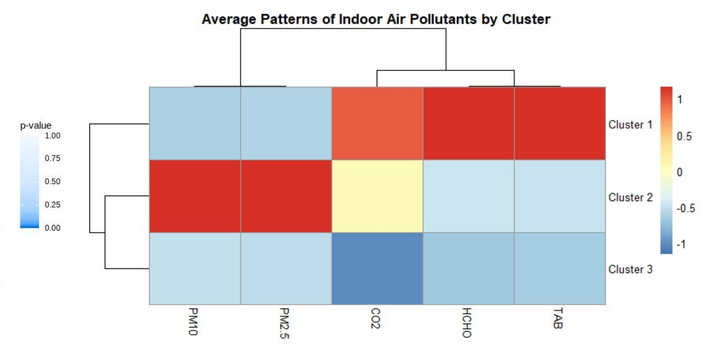


< Star plot by Facility type >

- **(Mean concentration analysis)** Kruskal-Wallis Test & Pairwise Wilcoxon Test
  - ① **(PM10)** Significant difference between **HCFs and CCCs**
  - ② **(CO_2)** Significant differences between **HCFs and ECFs** / **PCCs and ECFs**
  - ③ **(HCHO)** Significant differences between **CCCs and other facility types**
  - ④ (PM2.5, TAB) No statistically significant differences among facility types
- **(K-means clustering analysis)** Cluster 3



< HCHO – Pariwise Wilcoxon Test heatmap >



< Indoor Air Pollutant Patterns by Cluster >

- ✓ **Indoor pollutant concentrations** in five types of multi-use facilities for vulnerable populations in Seoul during 2024 were generally within **acceptable levels**.
- ✓ **Data visualization** enabled a **comprehensive assessment** of indoor air quality and **identification** of critical pollutant-related concerns in these facilities.