Recently issues on Indoor air quality in Korea

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I. Introduction

Now days, the air quality in the indoor environment has a significant impact on human health and comfort. Because most people spend most of their time in indoor, poor indoor air quality can lead to discomfort, ill health, absenteeism, and low productivity. Good indoor air quality safeguards the health of indoor occupants and contributes to their comfort and well-being.

Indoor air pollution has received little attention in past compared with the outdoor air pollution in Korea like other nations. It is now become main topic of increasing public concern, prompted partly by the isolation of the indoor environment from the natural outdoor environment in tight-sealed commercial building, and by the investigation of so-called Sick Building Syndrome, and Sick House Syndrome.

The potential problems of exposure in poor indoor air are much less well understood and more difficult to handle. This is due to the shortage of reliable health effect data, difficulties in quantifying the concentration of air pollutants at low level, potential interactions between pollutants, wide variation to which indoor occupants are susceptible to air pollutants.

The concentration of indoor pollutant is much low level to that of the workplace. Unlike health effect by exposure of workplace, the health effects by poor indoor air quality are dependant on several factors such as the effect of each air contaminant, concentration, duration of exposure, and individual sensitivity.

Indoor air quality is not only technical complex but also complex from an administrative point of view. The many factors to be taken into consideration and strategies required to maintain good indoor air quality cut across a variety of disciplines; industrial hygiene, public health, engineering, and responsibility of several departments of the governmental section.

Since the WHO and the U.S EPA have warned the relationship between indoor air pollution and human health risk, the national interest regarding control and management of the indoor air quality is being augmented, especially in advanced countries. The US OSHA is presuming that the American workers suspected as Sick Building Syndrome are from thirty millions to seventy millions. Also the US EPA suggests that indoor air pollution is one of environment problems to be controlled urgently.

During that time there were discussion reports against the indoor air pollution problems. The mass communication report such as the high concentration of radon and asbestos in subway gave rise to the social interest. The radio, TV and press reports on health risk by indoor air pollution in the newly constructed apartments, and commercial buildings have been becoming the opportunities which recognize the importance of the indoor air quality.

The increasing of well-being expectation takes a growing interested in Sick Building Syndromes, and Sick House Syndromes, which leads the government to have made regulations for control and management of indoor environment quality.

Consequently, the four departments of government related indoor air quality such as the department of labor, the department of environment, the department of construction and transportation, and the department of health and welfare in Korea are established or to in the process of establishing the regulation, or guideline for managing the indoor air quality. This presentation introduces the several regulations specifically addressing the issue of indoor air quality, and related research activities in Korea.

II. Regulations

The first regulation on IAQ was the Public Sanitation Act promulgated in 1986 by the Ministry of Health (now Ministry of Health and Welfare), which had sanitation standards for indoor air of the public facilities, such as commercial office building, wedding ceremony hall, theater, physical training facility.

The second regulation on IAQ was the Organic Act of Construction Facility released in 1992 by Ministry of Construction (now Ministry of Construction and Transportation), which had a standard for ventilation system.

The third regulation on IAQ was the Underground Air Quality Management Act enacted in 1996 by Ministry of Environment, which had air quality standards (SO_2, CO, NO_2, PM10, CO_2, HCHO, Pb) in the underground, such as subway station, underground commercial quarter.

Although the law on IAQ had been enacted early than other countries, these laws were not executed effectively. Recently the increasing of the public expectation for the good indoor air quality induces the several government branches to promulgate the Act of managing IAQ. The following are current regulations for managing indoor air quality according to the braches of the government in Korea.

1. Ministry of Labor

Almost any discussion about air quality in the workplace will include the Ministry of Labor like U.S. OSHA, the standard it sets, and its enforcement policies. In 2003, the Ministry of Labor promulgated the regulation of preventing health impediment by office air pollution, which applies to office controlled by central air management system, such as HVAC. This regulation requires employer to control office air quality to meet the standards (see Table 1), to have a measurement of office air quality when being necessary, and to carry on necessary measures for improvement the air quality not in case of meet the standards.

Table 1 Air quality standard in the office

Contaminant	Concentration	Averaging
Respirable dust	150 ㎍/㎥	8 hour
CO	10 ppm	8 hour
CO_2	1000 ppm	8 hour
Formaldehyde	0.1 ppm	8 hour

2. Ministry of Environment

In 2003, Ministry of environment revised the Underground Air Quality Management Act into the Indoor Air Quality Management Act in the Public Using Facility. The revised Act has magnified not only the scope of the law application from two public facilities to ten public facilities, but also the number of standard for pollutants from seven to ten.

The revised Act presents two types of standard according to pollutants, which is the mandatory standard and the recommended standard. If the employer violates the mandatory standards of PM10, CO, CO_2, HCHO, and total airborne bacteria the employer would receive a fine for default. Five pollutants classified as the recommended standard are NO_2, Rn, TVOC (total volatile organic compounds), asbestos, and ozone, which is outdoor contamination source or relatively less health risk than the mandatory standard pollutants.

Table 2 Mandatory standard of the Indoor Air Quality Management Act in the Public Using Facility

<table>
<tr><th>Pollutants
Public facility</th><th>PM10
μg/㎥</th><th>CO_2
ppm</th><th>HCHO
ppm</th><th>Bacteria†
CFU/㎥</th><th>CO
ppm</th></tr>
<tr><td>Underground station and commercial quarter</td><td rowspan="8">150</td><td rowspan="10">1000</td><td rowspan="10">0.10</td><td rowspan="8">-</td><td rowspan="8">10</td></tr>
<tr><td>Waiting room at transportation terminal</td></tr>
<tr><td>Traveler terminal at airport</td></tr>
<tr><td>Waiting room at harbor facility</td></tr>
<tr><td>Waiting room at train station</td></tr>
<tr><td>Library, Museum, Gallery</td></tr>
<tr><td>Business facility</td></tr>
<tr><td>Public performance facility, Department store, Underground shopping center</td></tr>
<tr><td>Medical facility, Nurture facility
Old person welfare facility, Commercial education facility</td><td>100</td><td>800</td><td>10</td></tr>
<tr><td>Indoor garage</td><td>200</td><td>-</td><td>25</td></tr>
</table>

†: Total airborne(suspended) bacteria.

Table 3 Recommended standard of the Indoor Air Quality Management Act in the Public Using Facility

<table>
<tr><td>Pollutants
Public facility</td><td>NO_2
ppm</td><td>Rn
pCi/ℓ</td><td>TVOC
㎍/㎥</td><td>Asbestos
Fiber/cc</td><td>O_3
ppm</td></tr>
<tr><td>Underground station and commercial quarter</td><td rowspan="8">0.05</td><td rowspan="10">4.0</td><td rowspan="8">500</td><td rowspan="10">0.01</td><td rowspan="8">0.06</td></tr>
<tr><td>Waiting room at transportation terminal</td></tr>
<tr><td>Traveler terminal at airport</td></tr>
<tr><td>Waiting room at harbor facility</td></tr>
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<tr><td>Public performance facility, Department store, Underground shopping center</td></tr>
<tr><td>Medical facility, Nurture facility
Old person welfare facility, Commercial education facility</td><td>0.05</td><td>400</td><td>0.06</td></tr>
<tr><td>Indoor garage</td><td>0.30</td><td>1000</td><td>0.08</td></tr>
</table>

The revised Act of Ministry of environment specify the assessment strategy for evaluating the compliance of standard, such as, the sampling and analytical method, and sampling time, sample size, sampling location etc. The Gas phase pollutants (TVOC, Formaldehyde, CO, CO_2, NO_2, O_3) should be sampled one hour, the PM10 and radon should be sampled eight hour continuously during a day working time (from 8 AM to 7 PM) by area sampling. Table 4 shows the sampling method and time defined by the revised Act. The employer or stack holder shall measure the pollutants having the mandatory standard one time every year, keep the record of the monitoring results by the Act.

Table 4 Sampling method and time of pollutants by the Indoor air Quality Management Act in the Public Using Facility

Pollutants	Sampling method and time	Analytical Method
TVOC	Sampler: adsorbant (charcoal or Tenax etc) Sampling time: 30 minute, 2 times	GC-FID or GC-MS
HCHO	Sampler: 2,4-DNPH coated silicagel Sampling time: 30 minute, 2 times	HPLC
PM10	Sampler: Filter	Gravimetric

	Sampling time: 8 hour	
Asbestos	Sampler: Filter Sampling time: one hour	PCM or TEM
CO	Direct reading instrument Sampling time: one hour	-
CO_2		
O_3		
NO_2		
Rn	Continuous Radon Monitor, etc Sampling time: 8 hour	-
Bacteria	Anderson cascade impactor, etc Total sampling volume: 200 – 1000 L , one times	-

Building and furnishing materials may be important sources of indoor air pollutants. To achieve good indoor air quality against chemical emissions, building designer should limit the use of high emitting building and furnishing materials. Materials with the lower emission rates of chemicals should be selected if provided that they meet all relevant statutory requirements. This is particularly important when a large amount of the materials is used in an area. To provide information of chemical emission rate of construction materials, the ministry of environment by the revised Act has an obligation for the defining a construction materials emitting heavy pollutants, and notifying the construction materials in an official gazette. Table 5 presents the standard of the pollutants emitting construction materials defined by the revised Act.

Table 5 Standard of the construction materials emitting pollutants

(Unit: ㎍/㎥·h)

Item / Pollutant	Adhesive material	Construction material
Formaldehyde	Not less than 4	Not less than 1.25
TVOC	Not less than 10	Not less than 4

Also the revised Act gives a builder of apartment an obligation of the monitoring the indoor air quality and reporting the results to the self-government such as a mayor, a country headman, etc. Also a builder of apartment should give out a public notice of the measurement results at a notice board before moving into the apartment. The pollutants be measured are formaldehyde, benzene, toluene, ethyl benzene, xylene, and stylene.

3. Ministry of Health and Welfare

The Public Sanitation Act promulgated in 1986 had been revised into the Public Sanitation Management Act in 1999. The Act revised again in 2005 specified the standard of pollutants in the public using facility. If the employer or stack holder of the public using facility violates the standard he could be punished by a fine. But this revised Act do not define the periodic monitoring and the record keeping by employer or stack holder. Table 6 shows the type of pollutants and its standard by the Public Sanitation Management Act.

Table 6 Indoor air quality standard in the public using facility

Pollutants	Concentration	Averaging
PM10	150 ㎍/㎥	24 hour
CO	25 ppm	1 hour
CO_2	1000 ppm	1 hour
Formaldehyde	120 ㎍/㎥	8 hour

4. Ministry of Construction and Transportation

The Organic Act of Construction Facility specified ventilation standard for improving the indoor air quality had been revised into the Construction Act in 1996. In the revised Act, the ventilation standard was abolished. Currently the ventilation standard of the public using facilities is specified in the Indoor Air Quality Management Act in the public using facility by ministry of environment. This standard is presenting two types of ventilation rate by mechanical ventilation according to kinds of the public using facilities. One is a air change requirement per hour(ACH), and another is fresh outdoor air requirement per person and hour (㎥ of fresh air/person·hour), which is similar to ASHRAE Standard 62 “Ventilation for Acceptable Indoor Air Quality”.

Ventilation in its dilution, displacement, and replacement aspects causes changes in chemical composition and environmental factors in the air environment of ventilated spaces. Only the Indoor Air Quality Management Act in the Public Using Facility by the ministry of environment specifies a specific ventilation standard, the Act related IAQ by other governmental branches do not defined any particular ventilation standard.

5. Ministry of Education and Human Resources Development

The Health Act in School by the ministry of education and human resources development levies the principal the duty of maintaining air quality standard in a classroom and attached facility which is specified in the Act. Table 7 shows the air quality standard specified in the Health Act in School.

Table 7 Air quality standard in classroom

Contaminant	Concentration	Application facility
PM10	100 ㎍/㎥	All classroom
CO_2	1,000 ppm	
Formaldehyde	100 ㎍/㎥	
Total airborne bacteria	800 CFU/㎥	
Temperature	18-28 ℃ Summer: 26-28℃ Winter: 18-20℃	
Relative humidity	30-80 %	
CO	10 ppm	Classroom near vehicle road
NO_2	0.05 ppm	
Rn	4.0 pCi/L	Underground classroom
TVOC	400 ㎍/㎥	New Construction school not passed three years
Asbestos	0.01 fibers/cc	School with using asbestos containing construction materials.
O_3	0.06 ppm	A staff room in school
Mite	100 head/㎥	A nursing room in school

The standard of indoor air in Health Act in school, such as PM10, CO, Formaldehyde, is more strict than any other standard of indoor air in Korea. That reason is the main purpose of setting these standards protects health of children in school. For all that, the weak point of this Act is that there is no penalty if the principal violate the duty for maintaining indoor air quality to meet the standard.

6. Exposure standard or guideline of indoor pollutants in other countries

The standards of indoor air quality are very similar values in all of countries having the IAQ standards. So most of countries present the standard of carbon dioxide used an indicator of estimating the indoor air quality as 1,000 ppm.

Although many countries define the standard of indoor air quality, main difference is that a few countries such as Korea and Japan present the standard as a regulation, most of countries suggest the standard as a guideline.

Table 8. IAQ standards or guidelines established by other countries

Pollutant	Korea	Japan	Hong Kong	USA	Australia	Finland
CO_2(ppm)	1000	1000	1000	1000 (ASHRAE)		1200
CO (ppm or ㎍/㎥)	10 ppm	10 ppm	10,000 ㎍/㎥	EPA:9 ppm (8 hr)	9 ppm	7 ppm
HCHO(ppm)	0.1ppm	0.08ppm	0.08 ppm		0.1 ppm	0.08 ppm
PM10 (㎍/㎥)	150	150	180	EPA:150 (24h)	90	50
NO_2 (ppm)	0.05		0.08	0.055(yr)		
O_3 (ppm)	0.06		0.06	0.05 (ASHRAE)	0.12	0.04
TVOC (㎍/㎥)	500	400	600		500	600
Asbestos (fibers/cc)	0.1			0.1(OSHA) 0.2 (ACGIH)		
Rn (pCi/L)	4		5.4	EPA: 4(yr)	5.4	5.4
Bacteria (CFU/㎥)	800		1000			
Temperature (℃)	18-28(W) 26-28(S), school	17-28, office	Less than 25.4	ASHRAE: 21-23(W) 23-26(S)		20-23(W) 22-27(S)
Humidity (%)	30-80, school	40-70, office	Less than 70	ASHRAE: 20-30(W) 50-60(S)		

III. Research activity related IAQ

The indoor environment results from the interaction of the site, the climate, the building system, the potential contaminant sources, and building occupants. During the last two decades there has been increasing concern within the scientific community over the effects of indoor air quality on health in the world. Changes in building design devised to improve energy efficiency have meant that modern public using facilities, home, and offices are frequently more airtight than old structure. Furthermore, advances in construction technology have caused a much greater use of synthetic building materials.

Figure 1, 2 categorizes the IAQ related researches studied by indoor air pollutants since twenty century inside and outside country, respectively. The researches on VOCs, NO_2, and SO_2 has been carried out mainly from outside country, but mainly researches on IAQ in domestic country are PM, NO_2, CO.

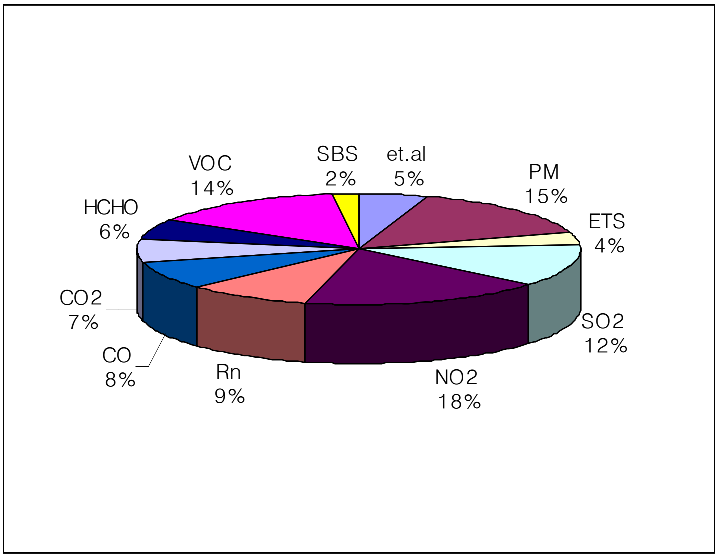

Figure 1 Distribution of IAQ researches by indoor air pollutants in foreign countries(source: Kim, 2005)

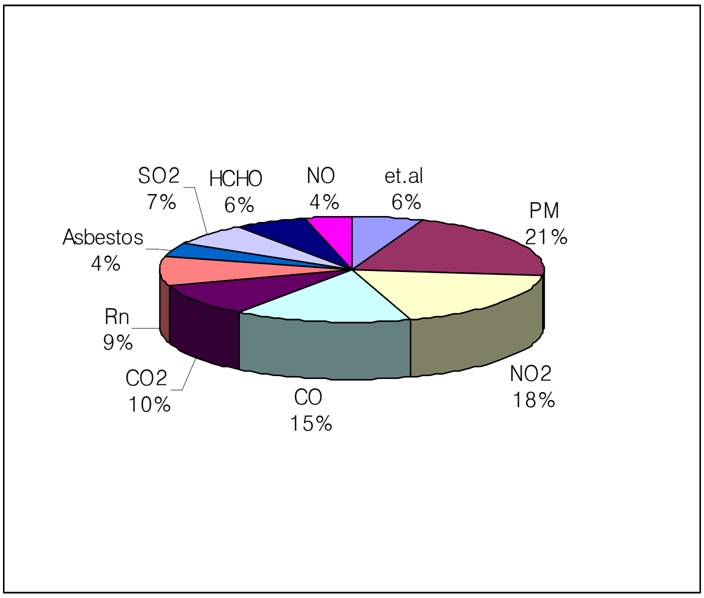

Figure 2 Distribution of IAQ researches by indoor air pollutants
in domestic country(source: Kim, 2005)

There are so many fields IAQ related research activities in domestic country like outside world, which is very difficult to introduce the summary results of IAQ research activities. So, this paper presents the research activities around especially office air quality in Korea. Although many IAQ related research activities in Korea were accomplished the relatively large and well designed researches focusing office air have been carrying out recently by KOSHA, Ministry of Labor, and Associate of Workplace Measurement Institutes. The following results came from these studies.

1. Particulate matters

There has been many researches of correlation between the exposure of PM10(less than 10 um diameter) and health effects since 1980. After that many countries has set standard for controlling particulate such as PM10. The U.S UPA promulgated the air quality standard for fine particulate matter (known as PM2.5) in 1997. The standard of PM2.5 is correlated with increased mortality and a range of serious health effects, including aggravation of lung disease, asthma attacks, and heart problems.

The indoor air standard for particulate matters is not PM2.5 but PM10 in almost countries. In Korea, only the ministry of labor has a standard (150 ㎍/㎥) of the particulate matters as the respirable dust defined by ACGIH but the other branches of government has set the standard (150 ㎍/㎥) of PM10. But the ministry of labor is in processing of changing the standard into PM10.

Table 9 shows the concentration of airborne particulate matters in commercial office buildings in Korea, USA, and Japan. The Korean data for the particulate matters had been sampled at thirty six office rooms located in four commercial buildings in 2004. The USA data was the airborne particulate matters in 100 randomly selected office building following a standardized protocol developed for the Building Assessment Survey and Evaluation Study by the US EPA from 1994 to 1998. The Japan data was the survey results which was sampled at the specific buildings (defined as total area of office floors is more than 3,000 ㎡ by the ministry of health welfare and labor) in 1997.

Table 9 Concentration of the airborne particulate matter in Korea, USA, and Japan (unit: ㎍/㎥)

	Korea			USA			Japan		
	N†	GM‡	Range	N	GM	Range	N	GM	Range
PM10	93	58.9	47.7-185.3	588	11.4	1.3-35.4	335	20	0-260
Respirable	167	37.0	20.3-42.4	-	-	-	-	-	-
PM2.5	-			453	7.2	1.3-24.8	-	-	-

† : The number of samples, ‡: Geometric mean.

The geometric mean PM 10 concentration of office air in Korea, USA, and Japan was 58.9 ㎍/㎥, 11.4 ㎍/㎥, and 20 ㎍/㎥, respectively. Mostly, the office indoor air concentration of PM10 in three countries was higher than the PM10 concentration in outdoor air. There were correlation of PM10 and PM2.5 in indoor air, but not in outdoor air, which means the indoor air concentration of PM10 influenced not only the particulate concentration of outdoor air but also the indoor source of particulate.

2. CO_2, CO

The primary source of CO_2 in office building is respiration of building occupants. CO2 concentration in office buildings typically range from 350 to 2,500 ppm. At concentrations occurring in most indoor environment, CO_2 buildup can be considered as a surrogate for other occupant-generated pollutants, particularly bioeffluents, and for ventilation rate per occupant, but not as a casual factor in human health responses. The Korean Occupational Exposure Standard and the Threshold Limit Value for 8-hour time-weight-average exposure to CO_2 is 5,000 ppm. Currently, the American Society of

Heating, Refrigeration, and Air-Conditioning Engineers(ASHRAE) recommends a minimum office building ventilation rates of 10 L/s·person, corresponding to an approximate steady state of indoor concentration of 1,000 ppm, based on the assumptions that outdoor CO_2 is 350 ppm and indoor CO_2 generation rate is 0.31 L/min • person. The CO_2 standard in indoor environment is 1,000 ppm in most of countries including Korea

Figure 3 shows the mean CO_2 concentration changing patterns of offices in four different commercial buildings which were monitored in the winter season, 2004. The CO_2 concentration of B building offices showed the typical changing pattern of CO2, that is the CO_2 concentration was increasing with working time increased, and it was peak concentration around 11:30 AM, and leaving for lunch induced the decreasing of CO_2 concentration, and at afternoon the concentration increased again, arrived at peak concentration around 4:30 PM. The office air heating of B Building offices in the winter season was provided by mainly fan coil unit which couldn't supply fresh outdoor air into office rooms by the mechanical ventilation. The office air heating of A, C, and D building in the winter season was got by the air handing unit of HVAC system. The air CO_2 concentration pattern of office air in those buildings was influenced by the operation condition of the HVAC system.

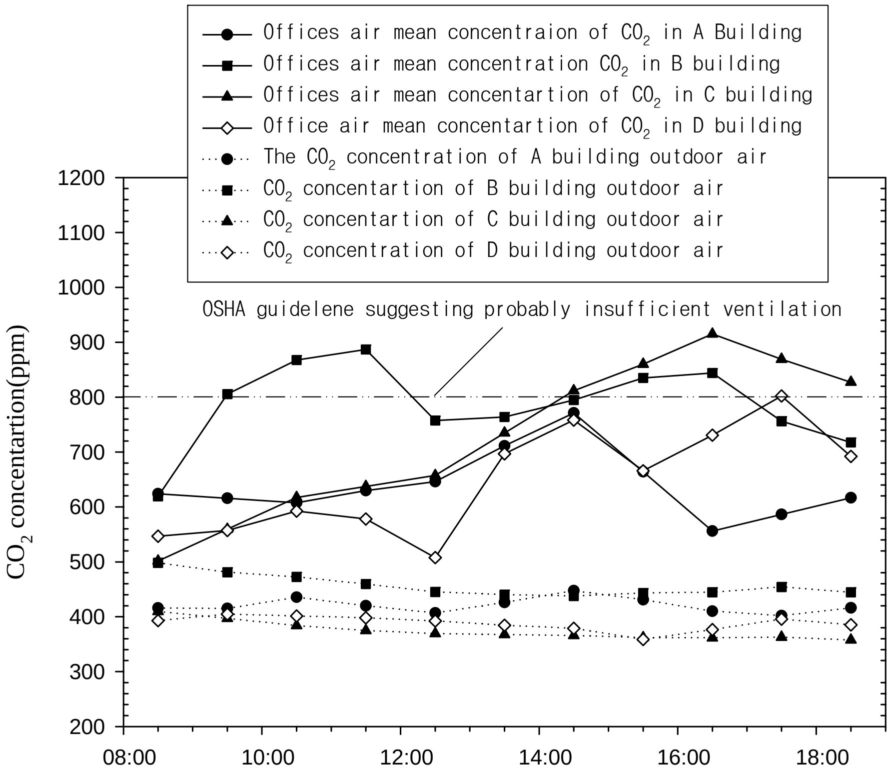

Figure 3. Changing patterns of the office air CO2 concentration at commercial buildings in the winter season, Korea.

The CO_2 concentration in Figure 2 was the mean concentration of many offices in each building. Figure 4 showed the changing pattern of CO_2 concentration at nine offices in B building. The eight offices among total nineoffices exceeded 800 ppm, which means probably insufficient ventilation. Especially one office exceeded 1,000 ppm, which means surely insufficient ventilation. In a recent review about SBS symptoms in office building found that increased indoor CO_2 level were positively associated with a statistically significant increase in the prevalence of one or more SBS symptoms. SBS symptoms associated with CO_2 included headache, fatigue, eye symptoms, nasal symptoms, respiratory tract symptom, and total symptom scores. Fifty to sixty percent office workers in B building reported one and more symptoms in this study using the SBS symptoms questionnaire.

The survey were performed in 136 commercial office buildings in the metropolitan New York region between 1997 and 1999 showed that the indoor CO_2 ranged from 370 to 2040 ppm with a mean value of 621 ppm and standard deviation of 138 ppm. Approximately 2.07% of all CO_2 concentrations exceeded 1000 ppm. Outdoor air concentrations, measured during the same time period, ranged from 335 ppm to a maximum of 619 ppm, with an average of 448 ppm.

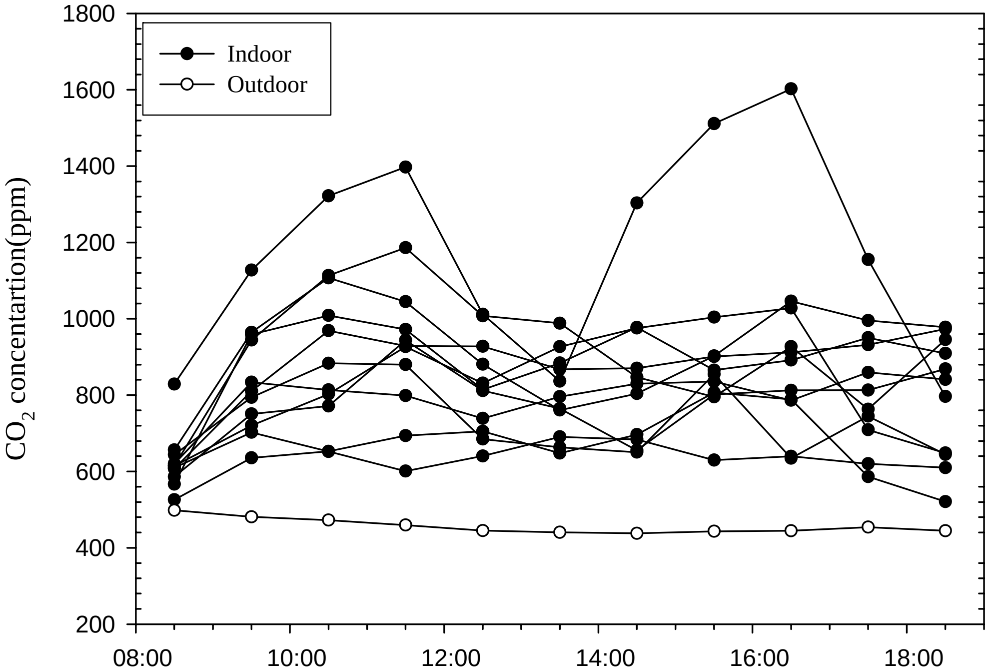

Figure 4. Changing pattern of CO_2 in nine offices located in B building

The survey were carried out in specific office building in 1997 by the ministry of health welfare and labor of Japan presented that the indoor CO_2 ranged from 370 to 1650 ppm with a mean value of 753 ppm and roughly 8% of all CO_2 concentrations exceeded 1000 ppm.

Carbon monoxide is an extremely toxic gas which interferes with the oxygen transport capacity of blood. It cause cardiovascular disease and symptoms such as headaches, concentration problems, flu symptoms, nausea, fatigue, rapid breathing, chest tightness and impaired judgment. The burning gas or so-called combustion gas such as carbon monoxide is a result of incomplete combustion by gas cooking and spacing heating. Other important sources of combustion gas in the indoor environment are tobacco smoking and vehicle exhaust fumes entering the building from the outside environment of indoor car parking lots

Smoking in all commercial buildings including office building in Korea like USA or Japan is prohibited by law, and mostly heating of office air is accomplished by central heating system. Now days, there are no local spacing heating devices in offices, and tobacco smoke source in offices. The main source of indoor carbon monoxide is vehicle exhaust fume coming from a road and indoor car parking lot. If the concentration of carbon monoxide exceeds the 5 ppm there is a possibility of existing the carbon monoxide source in or near office.

Table 10 shows the indoor CO concentration which monitored at the same time period of CO_2 sampling in Table 9. The mean concentration of CO in the office air was 2.0 ppm which was slightly higher than 1.7 ppm of CO concentration in USA, 1.2 ppm of CO concentration in Japan. But these concentration was much lower that the indoor standard of CO, 10 ppm.

Table 10. Office air carbon monoxide concentrations in three countries, Korea, USA, and Japan

(unit: ㎍/㎥)

Pollutant	Korea			USA			Japan		
	N†	GM‡	Range	N	GM	Range	N	GM	Range
CO	396	2.6	1.6-4.7	15,094	1.7	0.2-10.3	335	1.2	0.3-3.0

†: The number of samples, ‡: Geometric mean.

3. Formaldehyde

Formaldehyde is a VOC and a chemical ingredient used in many building materials and fabrics, cleaning fluids and adhesives. The most common sources of formaldehyde emissions in buildings are plywood, particle board, carpets and urea-formaldehyde foam insulation.

In very high concentrations it gives off a strong chemical smell. Unusually high concentrations of formaldehyde are known to cause eye, nose and respiratory irritation and sensitization. Formaldehyde is also a suspected human carcinogen.

Table 11 presents the airborne formaldehyde concentrations of commercial office building in the summer and winter season.

Table 11. Airborne formaldehyde concentration of offices in the summer and winter season

HCHO	Summer				Winter			
	NO	NS	AM	SD	NO	NS	GM	GSD
Indoor	109	278	0.03	0.024	36	151	0.032	1.91
Outdoor	109	52	0.01	0.004	36	42	0.007	1.63

NO: Number of offices, NS: Number of samples, AM: Arithmetic mean, SD: Standard deviation, GM: Geometric mean, GSD: Geometric standard deviation

The airborne formaldehyde mean concentration of offices air in the summer and winter season was almost 0.03 ppm, at that same period, the outdoor airborne mean concentration of formaldehyde was three times lower that the concentration of indoor.

In the summer season survey two offices of total 109 offices exceeded the formaldehyde standard of 0.1 ppm, one office of total 36 offices exceeded the formaldehyde standard in winter seasons survey.

Table 12 shows another survey result of formaldehyde concentration in the office air by the completion year of commercial office building. The number of sampling offices with less than one year, 1 to 3 years, and over 3 years after completion of the building was 8, 8, and 15 respectively.

Table 12. Formaldehyde concentrations by elapsed time after the completion year of office building

Pollutant	Elapsed time			Total (N=62)
	Less than 1 year (N=16)	From 1 to 3 years (N=16)	More than 3 years (N=30)	
HCHO	0.043 ppm	0.055ppm	0.041 ppm	0.046 ppm

The formaldehyde concentrations of offices with less than one year, 1 to 3 years, and over 3 years after completion of the building were 0.043, 0.055, and 0.041 ppm, respectively, which wasn’t significant statistically($p>0.05$). Five samples (8.1%) among the sixty two samples exceeded the standard of formaldehyde in this study.

The results suggested in Table 12 had been sampled in the summer season, which is slightly higher than the results of Table 11(winter season). The level of formaldehyde concentration depends on the age of the source, air flow, temperature and humidity, and may vary during the course of a day or from season to season. Although new office buildings have many the young age of the formaldehyde sources, but these building could supply the fresh outdoor air with the well designed ventilation system. Otherwise, there could be new interior renovations in old office building with the poor ventilation system. The formaldehyde concentration in an office with new interior renovation presented in Table 8 exceeded the standard limit of 0.1 ppm. These Korean studies suggested that the formaldehyde concentration was depended on multiple factors such as the age of the formaldehyde sources, ventilation system, and temperature and humidity.

4. Temperature and Humidity

Physical factors, such as temperature and humidity are important indoor air quality parameters as they could affect people's perception of the indoor air quality. Air temperature in office has the most direct effect on thermal comfort. Humidity influences thermal comfort by affecting the human body's ability to lose body heat through perspiration. Many researches on temperature and humidity as indoor air quality showed that air is perceived as very fresh and acceptable when it is cool and dry, while warm and humid air is always perceived as stuffy and unacceptable even if the air is clean.

Table 13. Temperature and relative humidity of office air in summer and winter season

Parameter	Summer			Winter				
	N	Outdoor		N	Indoor		Outdoor	
		AM	SD		AM	SD	AM	SD
Temperature (℃)	61	25.5	1.8	20	23.9	2.0	7.3	4.8
Humidity (%)	61	61.6	13.3	20	20.7	4.3	26.6	2.4

N: Number of offices, AM: Arithmatic mean, SD: Standard devistion

The mean temperature and relative humidity of offices air surveyed in summer season was 25.5℃, 61.6%, respectively, which was satisfied with the recommended standard of ASHRAE 55-1992(Summer season; temperature: 23-26℃, humidity: 50-60%). But the mean temperature of offices air surveyed in the winter season was slightly higher than the recommended standard of ASHRAE 55-1992(21-23℃), and the humidity of office air was almost lower limit of the recommended standard(20 – 30%). There is four seasons such as a brief spring and fall period, relatively long summer and winter period in Korea. In summer season there wasn't nearly existed the problems of temperature and humidity in offices with HVAC system. But the trouble season is a winter. In our country, most of HVAC system in office buildings controls only the temperature of air, and in winter season the humidity of outdoor air is much lower than any other season. Figure 3 showed the air temperature and humidity of two offices among the twenty offices surveyed in winter season (presented in Table 10). In case of B office the relative humidity was almost 10% during the working period.

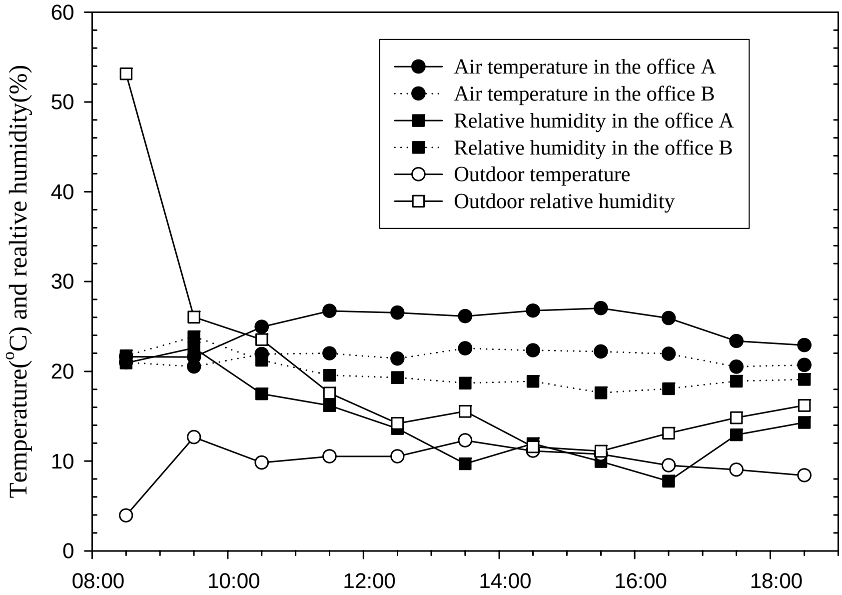

Figure 3. The changing patterns of the temperature and humidity of office air in the winter season

High humidity encourages the growth of mildew and other fungi on building fabric and furnishings. Low relative humidity causes eyes, noses and throats to dry which may lead to discomfort, irritation and increased susceptibility to infection. Extremely low humidity can also cause static electricity which is uncomfortable for indoor occupants. The workers in office B complained strongly these uncomfortable symptoms. The Health Act in School by the ministry of education and human resources provides the standard of the temperature and relative humidity in indoor air, the ministry of labor and the ministry of environment don’t specify the standard of temperature and humidity.

5. VOCs

Volatile Organic Compounds (VOCs) are chemical compounds that contain one or more carbon atoms and tent to evaporate at room temperature. Over 900 different VOCs in the indoor identified at concentrations higher than 1ppb. There are so many sources of VOCs in the indoor. It may enter from the outdoor environment, or be emitted from building materials, cleaning agents, cosmetics of occupants, waxes, carpets, furnishings, laser printers, photocopiers, adhesives and paint used in indoor.

Table 14 shows the concentrations of VOCs in the office air by the completion of office buildings. The VOCs concentration of the office air with less than one year after the completion was much higher than that of the office with 1 to 3 years. The percentage of exceeding the standard of VOCs by the ministry of environment, 500 ㎍/㎥, was 28.6% (four offices among fourteen offices sampled). It seemed that new offices buildings had more strong emission sources than the older office buildings. In this study major VOCs were benzene, toluene, xylene, styrene, and ethyl benzene, the VOCs concentration of indoor air in new constructed office building was almost 5 times higher than that of outdoor air.

Table 14. VOCs concentrations of office air by the completion of the office building

Pollutant	Elapsed time		Total	The % of exceeding the VOCs standard
	Less than 1 year	1 to 3 years		
VOCs ㎍/㎥	762.2±1121 (N=7)	248.1±1.25 (N=2)	648.0±997.3 (N=9)	28.6

6. Bioaerosol

Bioaerosols indoor air quality, especially bacterial and fungi, are another potential source of indoor air pollution, and can cause more serious problems than some chemical air contaminants. Although these bioaerosols are important factor in the indoor environment, so far the research activities related the bioaerosol, especially in office air, were feeble in Korea.

By the study surveyed at office building on July - September in 2004 -2005 the range of the mean concentrations of the total suspended bacteria were from 50 to 200 CFU/㎥, main genus of these bacteria were Staphylcoccus spp., Bacillus spp., Micrococcus spp., Corynebacterium spp., and Actinibacillus spp. In case of fungi, the range of the mean concentrations were from 5 to 15 CFU/㎥, main genus were Aspergillus, Fusarium, Roseum, Mucor, Rhizopus, and Alternaria.

IV. Conclusions

Current laws issues of governmental branches related on Indoor air quality, and research activities, especially office air quality, in Korea has been introduced in this paper. If it sees from law aspect, only a few countries including Korea has the standard of indoor air pollutants as regulation, but most of countries in world has it as recommendation or guideline. But if those regulations are not enacted actually, or if the inspections of the governmental whether or not employer and stack holder conforms to the standard are weak the objective of the laws establishment could not be accomplished.

Indoor air quality is not only technically complex, it is also complex from an administrative point of view. For preventing indoor air quality problems, and solve the problems promptly if they arise the coordination of the inter-department in a government is very important and necessary. Recently our country has set or setting the legislation schemes of indoor air quality by several governmental branches, such as ministry of labor, ministry of environment, ministry of construction and transportation, and ministry of education and human resources. For guarantee the good indoor air quality in Korea there should exist strong legal enactment of IAQ for checking employer's observance of the standards, and the coordination and information exchanges and coordination between inter branches of government

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