Topics: Recent topics in public health in Japan 2020

＜ Review ＞

The state of the indoor air environment in buildings and related tasks in Japan

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Abstract

The law for environmental health in buildings (LEHB) was enacted in1970. It was believed that sick building syndrome could be prevented by LEHB in the1970's. The recent studies showed that the rate of sick building syndrome in offices is not low. One of the factors in this nonconformity rate of indoor air environment is thought to be energy saving in buildings since the 1990's. In this report, the authors showed the state of indoor air environment in specific buildings and the characteristics of the inspection of these buildings by the health centers of local governments. The results showed that though the owner of specific buildings are obligated to follow the law of environmental health in buildings, the nonconformity rates with indoor air environment are increasing and the risk of sick building syndrome may also be increasing. It is clear that some improvement must be done as soon as possible to avoid an architectural health crisis such as sick building syndrome and indoor infections like influenza, etc.

keywords: Environmental health, indoor air quality, building sanitary, health center, energy saving

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I. Introduction

More than 50 years after the enactment of the law for environmental health in buildings (LEHB), building sanitation has recently attracted attention again. In the1970's, it was believed that sick building syndrome could be prevented by LEHB. However, the nonconformity rates of the indoor environment with the standards of LEHB have been increasing over these 20 years. Recent studies showed that the rate of sick building syndrome in offices is not low. One of the factors of this nonconformity rate is thought to be energy saving in buildings since the 1990's. This tendency is thought to continue for a long time because the act of building energy efficiency was enacted in 2017. To reduce environmental load considering health in buildings, it is required to continuously investigate on the necessity of revising LEHB. This report shows LEHB and the results of recent studies on environmental health management of building in Japan, the indoor air environment in specific buildings, inspection of specific buildings by health centers and tasks for better building environments.

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II. Environmental health management of buildings in Japan

Today most of our activities are carried out in buildings, and it is important to ensure a hygienic environment in the buildings. Especially in large-scale buildings that are used by a large number of people, where air conditioning is artificially adjusted and the indoor environment cannot be managed by individual users, the health people in that building may be damaged. Therefore in 1970, the law for environmental health in buildings (LEHB) was enacted. The law is applied to buildings with a total floor area of 3,000

m^2 or more (schools of 8,000 m^2 or more) that are used as entertainment venues, department stores, meeting halls, libraries, museums, art galleries, amusement halls, stores, offices, inns, etc. These are defined as “specific buildings” in the law (LEHB). The LEHB obligates the owner of a specific building to comply with the standards for environment and health management of buildings (SEHMB), report on the building’s management, and appoint a building environmental health management engineer.

1. Standards for environment and health management of buildings

The Standards for Environment and Health Management of Buildings prescribe the adjustment of the air environment, management of the water supply and drainage, cleaning and the prevention of rats and insects and other necessary measures to maintain good conditions in view of environment and health.

Regarding adjustment of the air environment, the amount of suspended dust, CO concentration, CO_2 concentration, temperature, relative humidity, airflow, formaldehyde concentration, etc. are regulated for buildings with air conditioning equipment.

Regarding the management of the water supply, also tap water for drinking and cooking, regular inspection of free residual chlorine, water quality inspection, water tank cleaning, etc. are required. Free water inspection is also required for miscellaneous water, and measures to prevent the occurrence of health damage are required.

As for cleaning, in addition to daily cleaning, regular cleaning is also required.

As for the control of rats and insects, it is stipulated to regularly investigate the presence of rats and their habitat and to take preventive measures.

2. Building Environment and Health Management Engineer

The owner of the Specific Building shall select a building environment and health management engineer from among persons having a license to appoint such an engineer to supervise the maintenance and management of such specific building in view of the environment and health.

3. Instructions for the owner of a specific building

The prefectural governor can request a report from the owner of a specific building when necessary and can conduct on-site inspections. If the maintenance of the specific building that has undergone an on-site inspection is not performed in accordance with the standards for environment and health management of buildings (SEHMB) and may cause health damage, the owner may be ordered to adjust the maintenance method, and in some cases, an order to stop using the building may be issued.

4. Building Maintenance Company registration system

As the number of large-sized buildings increases, the number of business operators who perform maintenance management (building maintenance) in terms of environmental hygiene of buildings such as building cleaning and air environment measurement under the commission of building owners is increasing. It is important to improve the quality of the operators so that these operators can work properly. Therefore, since 1980, a registration system has been established for these building maintenance business operators under the prefectural governor. The necessary equipment (physical requirements) such as machinery and equipment, the qualifications of the workers (personal requirements), etc. for the registration are defined.

III. Indoor air environment in specific buildings

1. Air and hygiene environment in specific buildings

The nonconformity rate of standards for air environment

Table 1 Standards for air environment and health management of buildings

Gross floor space ≧ 3,000 m^2 (exclusively, school ≧ 8,000 m^2)

Measurement / check	Item	Criterion	Remarks
Measured at least every two months or more frequently	Suspended particles	0.15 mg/m^3	
	CO	10 ppm	
	CO_2	**1000 ppm**	
	Air temperature	**17 ℃～28 ℃**	
	Relative humidity	**40 %～70 %**	
	Air stream	0.5 m/sec	
Conditionally measured	Formaldehyde	0.1 mg/m^3 (0.08 ppm)	When newly-built, repaired, reformed
Checking / cleaning	Cooling tower, water for humidifier	Water quality criterion, regular check. Cleaning, exchanging water.	Legionella / microbes
	Drain pan of HVAC	regular check, cleaning	

Figure 1 The air environment should be measured and reported every two months or more frequently

and health management of buildings over the past 20 years has been increasing, particularly concerning humidity, air temperature, and CO_2 concentration. Various concerned reasons include an increase in individual air-conditioning systems, changes to set temperatures, reduction of the ventilation air volume, mainly related to energy and cost saving.

2. Field survey on specific buildings

We surveyed 11 specific buildings in Kanto and Kansai areas in the summer, autumn and winter seasons through 2015 to 2016. Microorganisms were measured by culture method and r-PCR analysis method. A light scattering device was used for $PM_{2.5}$ and other particles. Chemical substances were measured by Tenax-TA-GC/MS and DNPH-HPLC. Air temperature, humidity and CO_2 concentration were measured simultaneously with the factors noted above.

Since CO, air velocity, and SPM (suspended particulate matter) did not exceed the management standards, these three factors were omitted in this report. Instead, we have been investigating chemical substances (VOCs and aldehydes), $PM_{2.5}$, airborne microorganisms (fungi and bacteria), and PMV (Predicted Mean Vote) for overall thermal sensation etc. as air hygiene factors that need to be taken care of in the future. In this article, the results are briefly described.

1) Indoor air temperatures were controlled within a range of 17 to 28°C. Although it did not fall below 17°C in winter, it exceeded 28°C in a few offices in summer. In winter, the mean value was 24.3°C and the minimum was 19.4°C. On the other hand, the values were 26.9 and 27.6°C in summer, indicating that it was significantly affected by Cool Biz 28°C. The fluctuation range of the temperature was within about 3°C in summer, while it largely expanded to 8.2°C in winter.

When evaluating the indoor hygrothermal environment with PMV, which explains thermal comfort within -0.5 to +0.5, the surveyed environments during the work hours were a little warm at 0 to +1 in autumn and warm at +1 to +1.5 in summer, and comfortable at -0.5 to +0.5 in winter.

2) For relative humidity, many offices fall below 40% in autumn and winter. In summer, a few offices equipped with individual-type air conditioners exceeded 70%, and others generally had proper conditions. In winter, both the mean and median values were below 40%, and in the lowest cases it was less than 20%.

3) The maximum value of CO_2 concentration exceeded the standard 1000 ppm, and during the cooling and heating period frequent overruns were observed. Meanwhile the mean and median values were below 1000 ppm, and the daily average satisfied the standard.

4) All chemical concentrations were below the guideline values of the Ministry of Health, Labour and Welfare, and there were also no offices that exceeded the provisional target value of 400 $\mu g/m^3$ for TVOC. Formaldehyde was as low as 30% of the guideline value, even at the highest level. Since acetaldehyde is generated from natural wood and human bodies as well as synthetic wood, it is often troublesome in houses and difficult to control. However, it was as low level as 50% of the guideline in all surveyed buildings.

In recent years, 2E1H has been reviewed as a new candidate for the guideline table, which is a DEHP hydrolyzing component and frequently detected in the office. The MHLW has continued to discuss the health effect and actual state of 2E1H, and it is critical to continue observing it in the future too.

5) Indoor $PM_{2.5}$ was mostly below atmospheric environmental standards and the IO ratio ranged from 0.1 to more than 1.0. An IO ratio of 1.0 or more could be due to a large number of residents, indoor generating and insufficient filter performance of individual air conditioning systems. The results indicated three outstanding concentrations that were affected by the smoking room in the building.

6) With the exception of one office each in Kanto and Kansai, airborne fungi in winter met the academic standard (50 cfu/m^3) of AIJ for indoor and supplied air. In summer, although a concentration of more than 50 cfu/m^3 was observed in many offices, the indoor concentrations were apparently lower than that in the outdoor air (OA), indicating that it was not generated indoors but originated from the outside air.

For the airborne bacteria concentration, more than 350 cfu/m^3 appeared only in one office and the others satisfied the academic standard.

From r-PCR analysis for DNA, all samples defined as pathogenic species were collected in summer, and a substantial portion of the species was resident flora such as human oral cavity and opportunistic species.

The increase in the room temperature in summer and

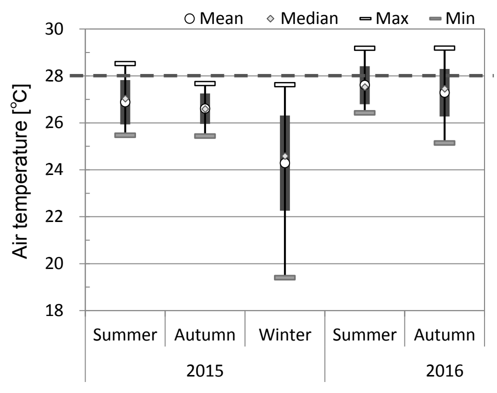

Figure 2　Air temperature

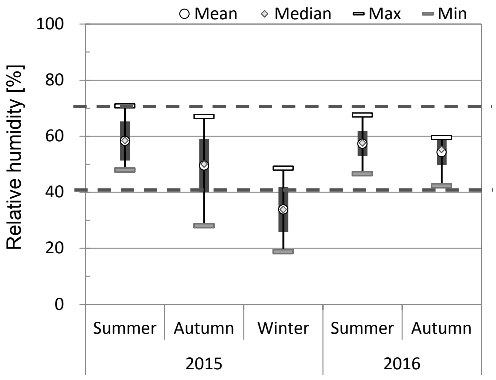

Figure 3　Relative humidity

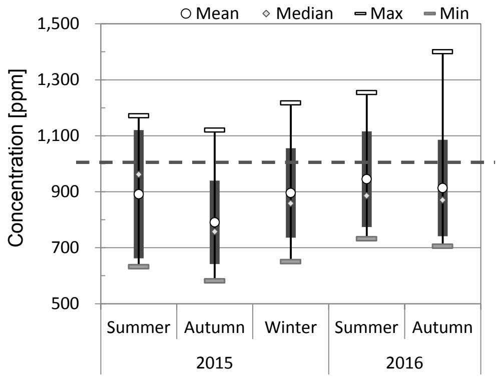

Figure 4　CO_2 concentration

Table 2　Chemical concentration [μg/m³]

	2015 Summer					2015 Autumn					2015 Winter				
	Max	Median	Min	Mean	SD	Max	Median	Min	Mean	SD	Max	Median	Min	Mean	SD
ホルムアルデヒド	26.0	17.2	4.7	16.0	7.8	32.9	13.0	6.1	14.8	6.0	14.3	8.5	5.6	8.8	2.4
アセトアルデヒド	19.0	9.3	2.2	8.6	5.7	17.3	8.2	4.6	9.1	3.3	18.2	6.4	3.9	7.3	3.0
ベンゼン	1.6	1.3	1.2	1.3	0.2	2.3	1.8	0.9	1.7	0.4	1.8	1.2	0.5	1.2	0.5
トルエン	30.0	19.7	6.7	19.9	8.2	57.7	16.6	3.9	19.5	14.5	18.1	9.5	0.9	8.6	4.1
エチルベンゼン	10.0	4.5	3.3	5.9	2.4	14.9	5.1	1.9	6.4	3.9	21.4	3.1	1.4	4.6	4.2
キシレン	9.4	4.1	2.1	5.3	2.5	9.5	4.6	2.5	5.1	2.1	9.9	2.6	2.0	3.3	1.9
スチレン	4.4	3.0	1.8	2.9	1.2	3.8	2.2	1.6	2.4	0.7	4.4	3.5	1.6	3.2	1.1
p-ジクロロベンゼン	2.2	2.0	1.5	1.9	0.3	23.5	1.9	0.7	3.5	6.1	6.5	1.8	1.0	2.7	2.0
テトラデカン	9.4	3.4	1.7	4.5	2.9	8.7	1.8	1.1	2.3	1.8	2.4	1.4	1.2	1.7	0.6
TVOC	320.6	163.9	45.5	175.0	102.2	323.3	98.2	25.5	114.0	71.4	143.8	44.9	5.9	49.4	31.0

	2016 Summer					2016 Autumn					厚生労働省指針値
	Max	Median	Min	Mean	SD	Max	Median	Min	Mean	SD	
ホルムアルデヒド	29.4	22.9	11.9	21.3	5.7	23.3	15.0	11.9	16.0	3.7	100
アセトアルデヒド	23.8	13.9	8.1	14.1	5.0	20.1	8.9	4.7	9.7	3.9	48
ベンゼン	2.0	0.8	0.4	0.9	0.3	1.0	1.0	0.5	0.9	0.2	-
トルエン	14.1	8.5	3.6	8.7	2.7	49.0	10.0	4.0	17.4	14.4	260
エチルベンゼン	5.0	2.9	1.7	3.1	0.9	15.0	2.0	1.0	4.7	4.5	3800
キシレン	18.6	5.9	0.5	7.0	4.4	19.0	6.0	2.0	8.7	5.9	200
スチレン	2.1	2.1	2.1	2.1	-	4.0	2.9	1.8	2.9	1.6	220
p-ジクロロベンゼン	35.3	3.3	1.0	5.8	8.7	13.0	3.0	1.0	4.7	3.6	240
テトラデカン	20.8	1.4	0.7	2.6	4.2	5.0	1.5	0.5	1.9	1.3	330
TVOC	287.0	113.2	31.5	129.5	63.4	351.0	138.0	27.0	141.1	102.7	400 *

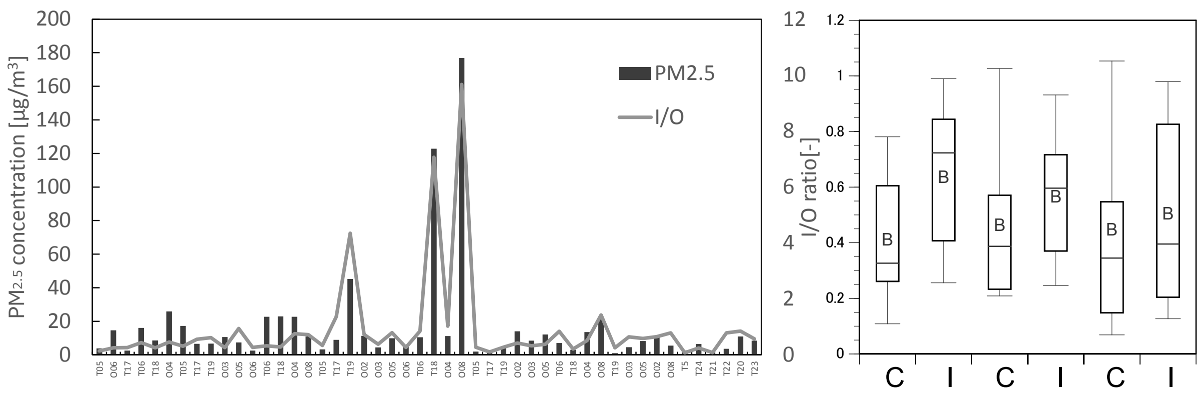

Figure 5　$PM_{2.5}$ concentration (C: central air conditioning system, I: Individual)

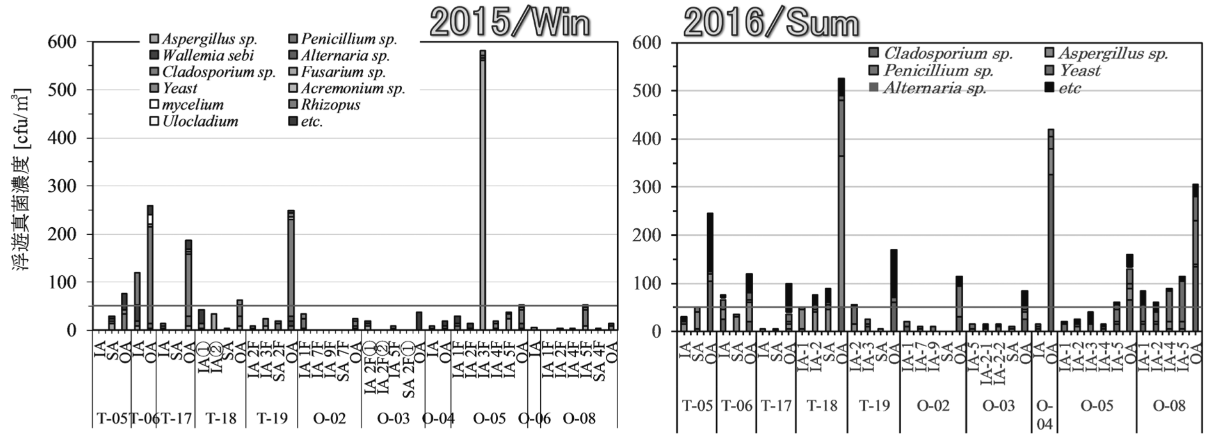

Figure 6　Airborne fungi concentration

the decrease in the relative humidity in winter were remarkable, while an increase in the relative humidity in summer was also observed. CO_2, ventilation, airborne microorganisms, chemicals and $PM_{2.5}$ were at proper levels in most buildings. Although the popularity of individual air conditioner has risen in recent years due to advantages in cost, easing of controls and energy efficiency, this survey has revealed that central air conditioning has an advantage in terms of air quality and hygiene such as ventilation, humidification, microorganisms and PM.

3. Rates of nonconformity with the standards for air environment and health management

Rates of nonconformity with the standards for air environment and health management of buildings in administrative reports by local governments have been decreasing and/or are stable in relation to water services, while the air temperature, humidity, and CO_2 concentration of the indoor air environment have continuously been increasing since 1999. Control and maintenance of the indoor air environment is critical in consideration of health risks caused by buildings, and it is necessary to clarify the cause of the undesirable rate increase and to provide effective improvement measures.

The main causes concern physical factors such as the popularity of individual air conditioners, energy and cost saving, the decrease in ventilation at schools, and an increase in the outdoor CO_2 concentration. It has also been pointed out that the way conformity is judged has changed due to a disproportionate emphasis on the collection of reports rather than on-the-spot inspections by local governments.

From the national statistical data (Fig.7), the mean nonconformity rate of SPM, CO and airflow velocity have been significantly low, while CO_2, air temperature and relative humidity have demonstrated an increasing trend year by year. In particular, the nonconformity rates have increased rapidly after the Great East Japan Earthquake (2011), and in the years after the revision of the energy saving law (1999) and the Law of Environment and Health in Building (2002).

LEHB underwent a major revision in 2002 and the measurement of formaldehyde concentration has also become mandatory in relation to sick house syndrome. Since the revision focused on the abolition of the 10% area exclusive rule and the addition of individual air conditioning systems, the nonconformity rates also rose significantly as the number of buildings that should be listed as covered by the law increased.

Other possible causes mainly concern several revisions of the energy saving law, and it led to the deterioration of indoor air temperature and humidity, as well as a reduction

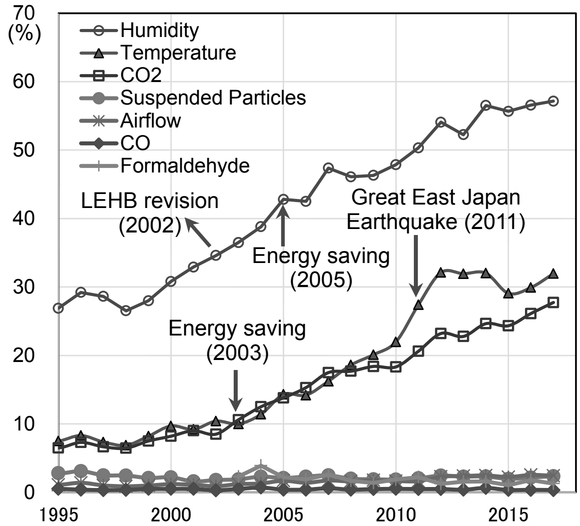

Figure 7　Nonconformity rates of indoor air environmental management standards

Table 3 Societal demands and law revisions

Year	Affair	Remarks
1999	Revision of Energy saving law for residential and nonresidential buildings	Intensification. Full-fledged revision of energy saving for residential buildings
2002	Revision of the Law for Environmental Health in Buildings	・Abolition of 10% excluding stipulation for gross floor area ・Including individual HVAC system ・Adding formaldehyde measurement
2003	Revision of Energy saving law	Non-residential buildings of newly built, extension or reconstruction ≧ 2000㎡
2005	・Revision of Energy saving law ・Manual for IAQ in schools	・Major alterations ・Adding acetaldehyde etc.
2009	Revision of the Standard for School Health and Safety Law	
2011	Great East Japan Earthquake	Saving on electricity

of ventilation (increase in the CO_2 concentration). There has also been a sudden increase in nonconformity rates due to the demand for electricity saving after the Great East Japan Earthquake in 2011. These days, the social demand represented by Cool Biz has justified energy and source saving for the protection of the global environment and improved the recognition of energy saving among administrators and occupants. However, energy conservation should not sacrifice the quality of the indoor environment, and it is fundamental to reduce energy consumption while maintaining a comfortable environment. Various approaches have been made such as the development and improvement of equipment and device technology, operating methods, and changes in work and life styles.

The number of specific buildings has increased at approximately 750 per year in all local governments nationwide. However, the frequency of on-the-spot inspections by local governments has not increased but decreased. From our previous studies inspecting national statistics, it has been found that the significant factor increasing the nonconformity rates stems from the increase of collecting reports rather than on-the-spot inspections by local governments concerning humidity, air temperature and CO_2.

In society today, LEHB is being questioned concerning how the indoor hygiene environment should be controlled and managed in line with the increase in large-scale buildings, the compounding of use, and technological advances in building equipment, diversification and sophistication of monitoring technology etc.

IV. Inspection of specified buildings by the Health Centers

The Health Center's work includes reporting and inspection of specific buildings under the Law for Environmental Health in Building. Specifically, on-site inspections are carried out by "inspecting books and documents kept according to the provisions of Article 10 of the Law for Environmental Health in Building, and inspecting the state of equipment maintenance, based on Article 11, Paragraph 1 of the Law for Environmental Health in Building", and reports are based on "determining the state of equipment maintenance by books and documents kept according to Article 11, Paragraph 1 of the Law for Environmental Health in Building". As a result of these, the proportion of buildings which do not conform to the building environmental health management standards (non-conformity rate) reported in sanitary administration examples is high for some items. This chapter describes the collection of reports and on-site inspection work by local governments as regards 6 air environment items (amount of floating dust, carbon monoxide content, carbon dioxide content, temperature, relative humidity and airflow), and attempts to understand the situation by conducting a survey using a questionnaire targeted at persons responsible for building hygiene.

Questionnaires were sent by postal mail to persons responsible for life hygiene nationwide (municipalities with health centers) as regards 6 items of air environment measurement in building environment sanitation. For 142 questionnaires distributed, 130 (91.5%) valid responses were obtained. There were three survey items: 1) Report collection (report format (exist / non-exist), reasons for building selection, details of deficiencies in report content, judgment of non-conformity based on report content), 2) On-site inspection (Reasons for building selection, increase / decrease of inspection frequency, implementation period, items considered difficult when measuring the air environment, judgment of non-conformity based on the results, items considered difficult to judge non-conformity among the 6 air environment measurement items), and 3) On-site inspections and report collections included in administrative reports (Percentage of non-conforming cases, extent of air environment measurement in buildings included in on-site inspections, details other than air environment measurement in buildings included in on-site inspections). The survey was conducted from January 2016 - December 2017.

Fig.8 and Fig.9 show part of the questionnaire survey results. More than approximately 60% of the respondents answered “non-exist” to whether they had a report format. Regarding the respondents who answered “exist”, it was found that various types of report format were used. In the report, when the respondents reported non-conformity, about half of the respondents answered that “they would judge non-conformity if a building did not meet the standards even once a year”. Approximately 30% of the respondents answered, “Non-conformity depended on the decision of the respondents in view of the building’s condition”, or “It depends on the case”. When the respondents were allowed to freely give their reasons, most local governments which gave the former response stated they wanted to make sure that there was no difference in judgment between the respondents, or that they made their judgment mechanically. On the other hand, most local governments which gave the latter response stated that the influence of the seasons and the building’s condition were added to the basis for their judgment. Hence, as there was a difference in the information obtained from the reported format, it was found that there was also a difference in judgment with respect to subsequent standards.

As regards the period when there were many on-site inspections, “September to November” was the most frequent at approximately 40%, followed by “December to February”. Many of the respondents who answered “September to November” cited they wanted to strike a balance with their other tasks. The respondents who answered “December to February” and “June to August” were predominantly focused on air conditioning and seasonal characteristics. On the other hand, the period when there was few on-site inspections was “March to May”, approximately 70%, which were not preferred for business reasons. In the determination of non-conformity based on on-site inspections, approximately 40% responded that “the building is non-conforming if it does not meet the standards even once a year,” and the next most frequent response was, “non-conformity depended on the decision of the respondents in view of the building’s condition”. Further, “non-conformity depended on the decision of the respondents in view of the building’s condition” and “it depends on the case” together accounted for more than half of the responses. As compared with report collection, it can be

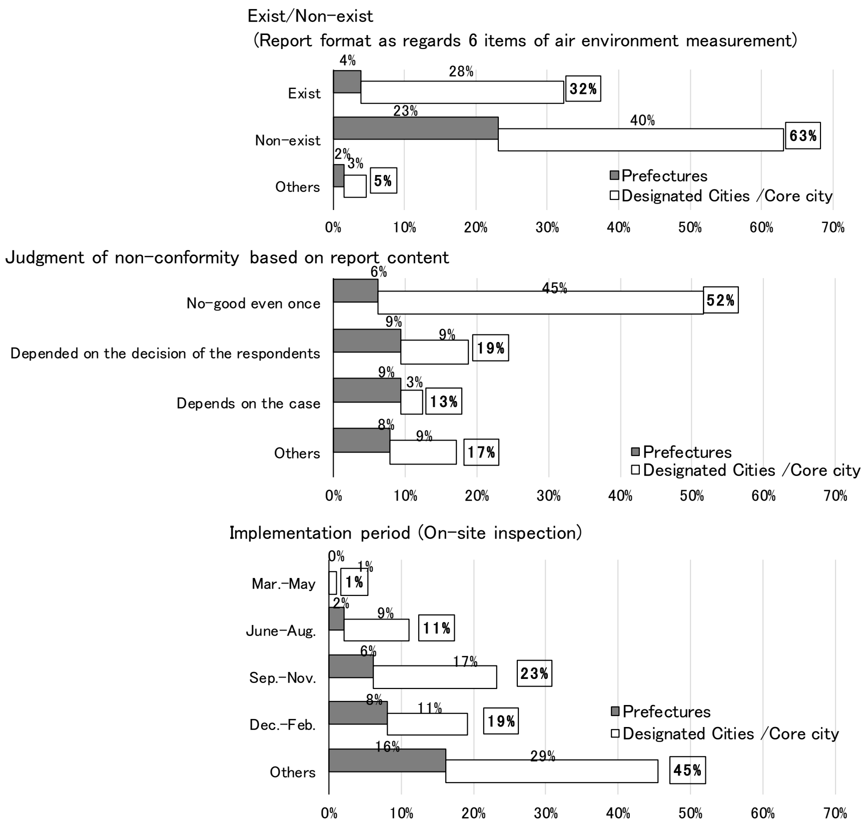

Figure 8 Questionnaire survey results

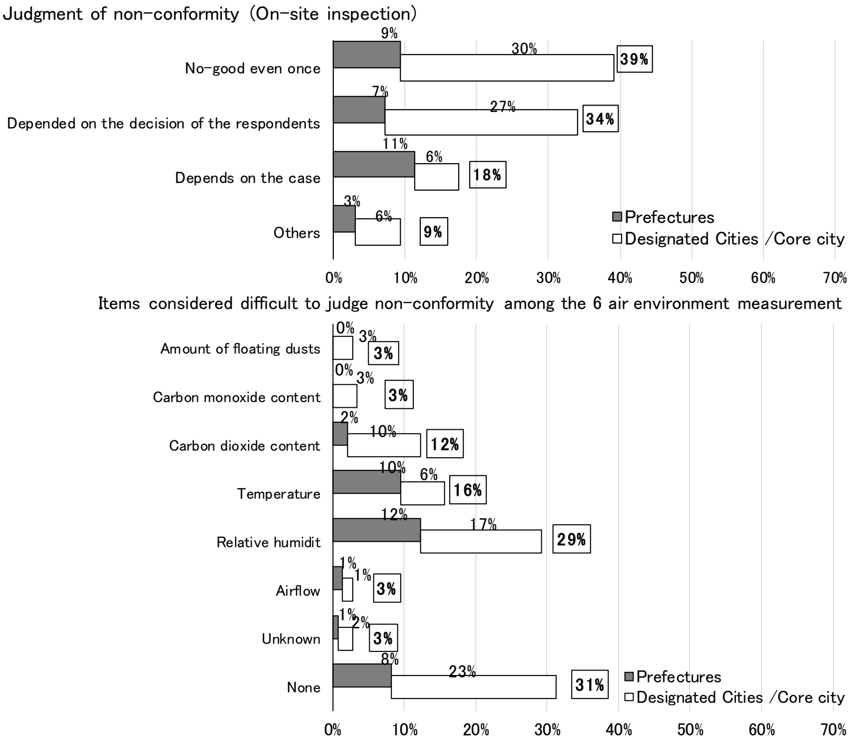

Figure 9 Questionnaire survey results

seen that "the decision of the respondents "and "circumstances of the case" had increased. Of the 6 air environment measurement items that were deemed difficult to judge as non-conforming, "relative humidity" was the highest at approximately 30%, followed by "temperature" and "carbon dioxide". On the other hand, approximately 30% of respondents answered "none". The respondents who answered "relative humidity" or "temperature" often cited the season and the weather, and the respondents who answered "none" often stated that they could not give any reason why they should be uncertain. In addition, the respondents who answered "none", in the judgment regarding maintenance standards when collecting reports or during on-site inspection, often answered, "The building is deemed to be non-conforming if it does not meet the standards even once a year ". In addition, among the buildings that are included in the on-site inspection in administrative reports, the frequency of air environment measurements was "less than 20%", and there were many cases where only books were checked. On the other hand, about half of the respondents answered that the frequency of on-site inspections "had not changed" compared to 10 years ago, but approximately 20% answered that "it had decreased". Thus, it was confirmed that there were differences in the on-site inspection system and the level of information obtained, and that there were also differences in the judgment of non-conformity.

Regarding the administrative monitoring system and its implementation, while it was pointed out that the monitoring staff had changed and technology had been passed on, it was shown that many local governments do not have a fixed form for report collection and on-site inspection, and there were differences in the procedures and information required. It therefore appears that it is necessary to consider unifying the format required to judge conformity / non-conformity with the standards.

V. Conclusions

In this report, the authors showed the state of the indoor air environment in specific buildings and the characteristics of the inspection of these buildings by the health centers of local governments. The results showed that though the owner of specific buildings are obligated to follow the law of environmental health in buildings, the nonconformity rates with the indoor air environment are increasing and the risk of sick building syndrome may be increasing. It is clear that some improvement must be done as soon as possible to avoid the architectural health crisis such as sick building syndrome and indoor infections of influenza, etc.

The Ministry of Health Labour and Welfare has been doing research on effective inspections and guidance according to the law for environmental health in buildings. Such research will clarify the reasons of this increase in nonconformity rates toward the standards of the indoor air environment. In the case of indoor concentrations of carbon dioxide, the conformity rates depend on reduction rates of ventilation rates and the ambient concentrations in urban areas. Indoor temperatures and humidity are also influenced by energy saving and cost saving. This influence is recognized especially in the buildings with separate air conditioning systems. Since separate air conditioning units can only be used when the room is used, the separate system is useful to save energy. However, it is more difficult to control indoor air environments with this system than with a central controlling system.

In above mentioned trends on the environmental operations, the standard on indoor air environment and effective inspection strategies especially for separate air conditioning systems will be investigated for a better building environment.

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日本の建築衛生の現状と課題

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抄録

建築物衛生法（LEHB）の制定から50年を経て，建物の衛生が再び注目されている．1970年代には，LEHBによってシックビルディングシンドロームを予防できると考えられていたが，LEHBの基準に対する空気環境の不適合率は，この20年間増加している．最近の研究では，オフィスでのシックビルディング症候群の発生率は低くないことが示された．この不適合率の要因の１つは，1990年代以降の建物の省エネルギー対策のためであり，この傾向は，2017年に建物のエネルギー効率化が義務付けられたため，今後も続くと考えられている．建物衛生を考慮しつつ環境負荷を軽減するには，建築衛生の実態把握と課題の抽出が必要である．本稿では，LEHBと，日本の建物における環境衛生管理，室内空気環境，保健所による監視指導，建物衛生向上のための課題に関する最近の研究の結果を紹介する．

キーワード：環境衛生，室内空気質，建築衛生，保健所，省エネルギー