An Approach to the Management of Volatile Organic Compounds (VOC) and Indoor Air Concentration in Tokyo Metropolitan Schools

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The Tokyo board of education sets VOC measurement of indoor air as one of the environmental hygiene activities at all schools. The principals, school personnel, and school pharmacists are taking an unusual approach. Every July, when the indoor concentration of chemicals rises, has been designated "VOC Measurement Month". During VOC Measurement Month, the concentrations of formaldehyde and toluene are measured with a simple measuring instrument at all Tokyo metropolitan schools.
The results of the measurements for the past three years (2006-2008) for a total of 3456 classrooms showed that the concentration of formaldehyde exceeded the standard values (100μg/m^3,0.08ppm) in a few classrooms each year. Naturally, such can be expected immediately after construction or repair work; however, in some cases standard values were exceeded even though many years had passed after repairs etc. Moreover, the concentration of formaldehyde in special classrooms is significantly higher than that in regular classrooms ($p<0.01$). On the other hand, the concentration of the toluene did not exceed the standard values (260μg/m^3) in cases where teaching materials that contain toluene were not used.
It is very important to properly manage the school health environment by monitoring classroom conditions, and it is effective to use simple measuring instruments in summer time, after building or repair work.

Keywords: school environmental hygiene, volatile organic compounds (VOC), indoor air concentration, measurement, formaldehyde

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1. Introduction

Indoor volatile organic compounds (VOC) cause sick building syndrome (SBS), which is a combination of ailments associated with the release of VOCs from building materials in new or remodeled buildings. SBS is often associated with buildings designed to be super-insulated and air-tight for improved comfort and energy control. Improper ventilation in such structures results in increased concentrations of VOCs released from wood materials and paint used in the interior. The symptoms of SBS are characteristically ameliorated by exposure to fresh air. The issue of VOCs has also arisen at school facilities, mainly elementary schools, throughout the nation.

In response, the Tokyo Board of Education has included clear measures for the monitoring and control of VOCs in school health programs as a part of its environmental hygiene activities. Principals, teachers, designated pharmacists, and other staff have worked cooperatively to establish effective approaches to these measures. As one such approach, I report the designation of July, the month during which VOC concentrations tend to rise, as VOC Measurement Month, and the measurement of formaldehyde and toluene concentrations at Tokyo metropolitan schools.

2. Legal consideration for VOC activities at schools

VOC measures are subject to School Health Law, which governs environmental hygiene. The School Health Law was amended in June 2008 and passed

into law on April 1st, 2009. Article 5 of the law stipulates that schools shall establish and carry out environmental hygiene inspection plans. Article 6, Paragraph 1 stipulates that the Minster of Education, Culture, Sports, Science and Technology (MEXT) shall determine the Standards for School Environment and Hygiene regarding ventilation, artificial and natural lighting, heating, sanitation, and other related factors. Paragraph 2 of the same article stipulates that the school authority shall strive to maintain the appropriate environment of the schools under its control in accordance with the Standards for School Environment and Hygiene.

Specific items and methods for environmental hygiene inspection based on Article 5 of the law are stipulated by the Standards for School Environment and Hygiene (March 31st, 2009, MEXT Ordinance No.60). The Classroom Environment section of Ordinance No. 60 includes ventilation, heating, artificial and natural lighting, and noise, as well as six VOCs (shown in **Table 1**). The standard values for each VOC are the same as the guideline values for indoor concentrations stipulated by the Ministry of Health, Labour and Welfare. Each school is legally required to follow Ministry of Health, Labour and Welfare guidelines regarding VOCs.

The 2009 MEXT ordinance was based on the Guidelines for School Environment and Hygiene (introduced by the Ministry of Education's Athletic Director in 1992). The new ordinance represents the first time standard values were clearly stated, a change that promoted legislation of nationwide standards for school environment and hygiene.

Table 1 Standards for School Environment and Hygiene (Abstract)

Volatile Organic Compound (VOC)	Standard Values
Formaldehyde	Less than 100μg/m^3 (Less than 0.08ppm)
Toluene	Less than 260μg/m^3
Xylene (If it is judged to be necessary)	Less than 870μg/m^3
Paradichlorobenzene (If it is judged to be necessary)	Less than 240μg/m^3
Ethylbenzene (If it is judged to be necessary)	Less than 3800μg/m^3
Styrene (If it is judged to be necessary)	Less than 220μg/m^3

3. Approaches by the Tokyo Board of Education

The Tokyo Board of Education established its Measures for VOC at metropolitan schools in July 2002 in response to a partial amendment of the MEXT Guidelines for School Environment and Hygiene in February 2002. The toluene concentration in March 2003 at a Tokyo high school after the remodeling of its practical training building in FY 2002 exceeded the standard value in three out of five target classrooms. Although measures for the reduction of VOC concentration through ventilation, etc., were immediately taken, the values continued to exceed the standard, forcing full-scale use of the practical training building to be postponed to May 14th. In addition, measurement of VOC concentration in 28 classrooms in the practical training building revealed that eight classrooms exceeded the standard value. Measures for ventilation and absorption were taken to improve the classroom environment, and health checkups for students were carried out in cooperation with the Tokyo Medical Association and specialized medical institutions to understand the impact on health.

In addition, the Tokyo Board of Education established the Tokyo Metropolitan School VOC Measures Exploratory Committee in May 2003 for the purpose of thoroughly clarifying the causes, securing student health, and comprehensively examining VOC measures. The Committee examined health management and safety assurance, measures to be pursued at each school site, design and construction for new buildings, remodeling and repair, and manuals on VOC measures for interior construction, and submitted their report in October 2003 (Tokyo Board of Education, 2003).

Based on their findings, the Tokyo Board of Education published Manuals for VOC Measures at Tokyo Metropolitan Schools in December 2003, which includes specific matters to be pursued at each school (Tokyo Board of Education, 2003). The Tokyo Board of Education has updated the content as needed to facilitate the effective use of the manuals at schools. The Tokyo Board of Education made a significant revision to the Manuals Guidelines in February 2004 by stipulating measurement of VOC

concentrations every summer at all schools in the Tokyo Metropolitan District.

The full content of the approaches introduced here can be seen on the following website. (http://www.kyoiku.metro.tokyo.jp/)

4. Measures for VOC at Tokyo Metropolitan Schools

An overview of the Measures for VOCs at metropolitan schools established in February 2004 follows.

The first is the reduction of VOCs. Measures stipulate that schools must choose materials, construction methods and products to minimize VOCs when constructing buildings, and purchasing equipment and school materials.

The second are special and periodic measurements. After construction or total replacement of equipment, construction contractors are required to arrange for special measurement by qualified specialists or with the measurement devices located at each school site. The guidelines also designate July, during which concentrations tend to increase, as VOC Measurement Month and stipulate activities to increase awareness about VOCs among school administrators as well as the need for continued monitoring through periodic measurement.

The third is health management. The guidelines stipulate that each school should improve its health risk management system, effectively monitor student health on a daily basis, and ensure that individuals involved in school administration thoroughly understand the procedures for eliminating VOCs.

Each school developed its own approaches to achieve guideline goals. The specific structure of VOC measures at each school are shown in **Figure 1** Under the direction of individual principals, each school worked toward compliance by (1) clearly including VOC measures in annual School Health Management Plans created for maintenance and promotion of student health, (2) thorough ventilation, and (3) daily monitoring of student health.

Furthermore, results of the periodic measurement of VOCs carried out in July each year have been reported to parents, the School Health and Sanitation Committees, etc. to promote effective risk communication.

Meanwhile, schools also developed a system for emergency VOC measurement, ventilation checks and student health monitoring when SBS symptoms are reported during building construction or equipment updating.

5. Targets and methods of periodic measurements

The results of periodic measurements carried out at each school over the past three years are shown below.

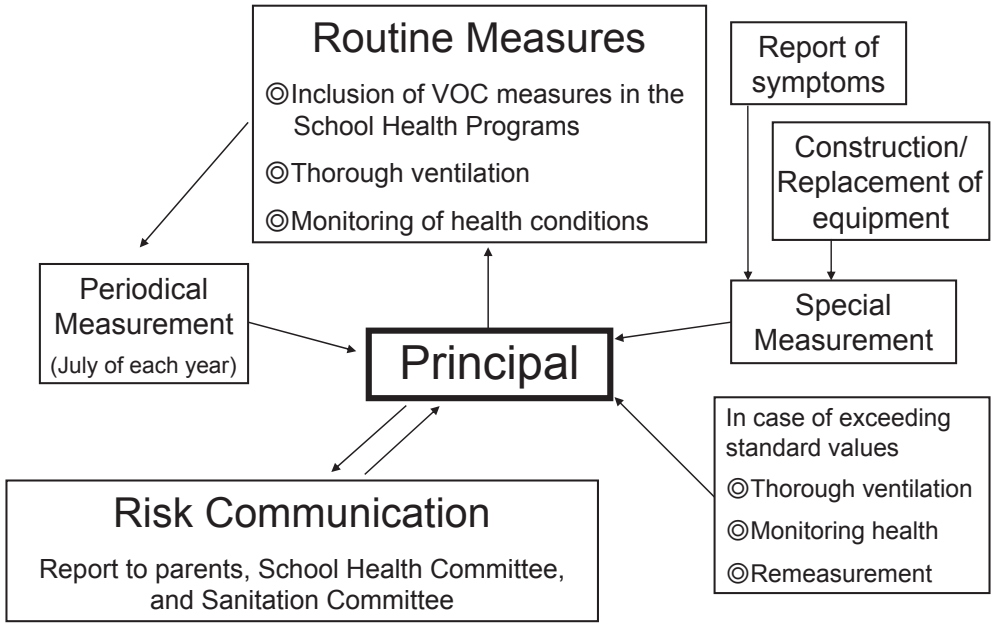


Figure 1 VOC Measures at Schools

(1) Period and targets

July - August 2006/ 240 schools/ 1190 classrooms

July - August 2007/ 209 schools/ 1036 classrooms

July - August 2008/ 246 schools/ 1230 classrooms

* Metropolitan schools include junior high schools, high schools, and special needs schools.

(2) Measurement methods

Designated pharmacists and other staff select five classrooms per school (special classrooms in principle, rotating every year), and measure formaldehyde and toluene concentrations utilizing the measurement devices located at each school (GASTEC Corporation, GSP-300FT pump & detector tube No.91PL, No.122P, flow rate 200ml/ min. for 30 min.),.

Measurement was performed in rooms which had been ventilated for more than 30 minutes and closed for more than five hours in accordance with the directions stipulated in the former guidelines for School Environment and Hygiene (stipulated by the Ministry of Education's Athletic Director in 1992). Ventilation fans were turned on in the rooms equipped with them prior to measurement.

For the purposes of measurement, "a regular classroom" is defined as a classroom used on a daily basis, and "a special classroom" is defined as a classroom not used on a daily basis, such as a music room, audio-visual room, or studio.

6. Measurement results

(1) Formaldehyde

During the three years between 2006 and 2008, 36 classrooms (32 special classrooms and 4 regular classrooms) out of 3456 classrooms (1.0%) exceeded the standard values (100μg/m^3, 0.08ppm) (**Figure 2**). The breakdown of the classrooms by year is 7 in 2006, 9 in 2007, and 20 in 2008.

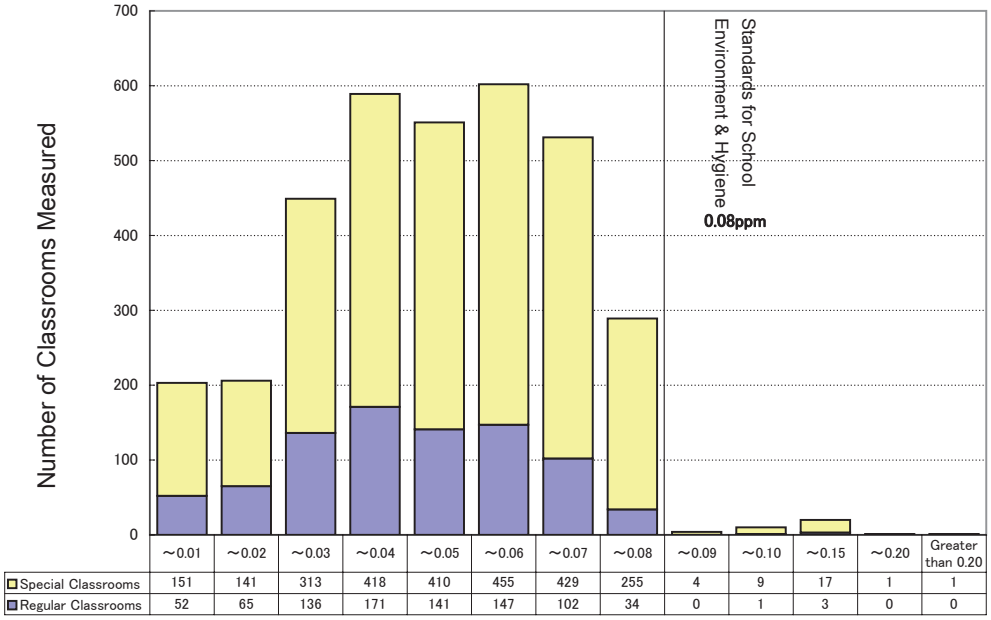
There were 16 classrooms that had been newly built or remodeled within five years among 36 classrooms that registered concentrations beyond the standard values. Eight had been newly built or remodeled within one year (**Table 2**). There were 20 classrooms that were newly built or remodeled more than five years prior.

(2) Toluene

During the three years between 2006 and 2008, there were only two classrooms (shop: 500μg/m^3, regular classroom: 400μg/m^3) that showed toluene concentrations beyond the standard value (260μg/m^3) in 2006.

(3) Comparison of formaldehyde concentration between regular and special classrooms

The results of comparison of formaldehyde concentration between regular and special classrooms are shown in **Table 3**, including the average and median values by year. According to the Mann-Whitney U-test on concentrations of both classrooms, special classrooms were significantly high at 1%.



	～0.01	～0.02	～0.03	～0.04	～0.05	～0.06	～0.07	～0.08	～0.09	～0.10	～0.15	～0.20	Greater than 0.20
Special Classrooms	151	141	313	418	410	455	429	255	4	9	17	1	1
Regular Classrooms	52	65	136	171	141	147	102	34	0	1	3	0	0

Figure 2 Formaldehyde Concentration Distribution Chart (2006 - 2008)

Table 2 Breakdown of Elapsed Years after Construction for New Buildings and Remodeling in Classrooms Exceeding Standard Values (Number of Classes)

Elapsed Years	Special Classrooms	Regular Classrooms	Total
Less than 1 year	6	2	8
1 - 5 years	7	1	8
5 - 10 years	3	0	3
10 years or longer	16	1	17
Total	32	4	36

Table 3 Comparison of Concentrations between Regular and Special Classrooms (Formaldehyde: ppm)

	2006		2007		2008	
	Average Value ± SD	Median Value	Average Value ± SD	Medial Value	Average Value ± SD	Median Value
Regular Classrooms	0.043±0.018	0.042	0.038±0.019	0.039	0.047±0.019	0.048
Special Classrooms	0.048±0.019	0.050※	0.044±0.023	0.042※	0.052±0.020	0.053*

◎ Mann-Whitney's U test Significant difference with regular classrooms (*p<0.01)

7. Causes, responses, and measures for values exceeding the standards

(1) Causes

Formaldehyde concentrations exceeding the standard values were measured in rooms closed for more than five hours, a condition that differed from regular use, and in special classrooms, such as music or audio-visual rooms, which are not used as often as regular classrooms that are full of equipment and materials and closed for a long periods of time during, for example, summer vacation, when the opportunity for ventilation is reduced. Therefore, these factors were assumed to have caused the values for formaldehyde to exceed the standards.

In two classrooms that registered toluene concentrations exceeding the standard value, oil solvent containing toluene was stored regularly and had been used a few days before the measurement. Furthermore, it was determined that ventilation after use had been inadequate. Therefore, these factors were assumed to have caused values of toluene in excess of the standard.

(2) Responses and measures for improvement

Classrooms registering values of formaldehyde and toluene in excess of the standards were temporarily taken out of service to check student health, determine cause, and ventilate thoroughly by natural or mechanical means.

Following ventilation, measurements were once again taken to confirm that concentrations were within normal limits before the affected rooms were cleared for subsequent use. Classrooms whose formaldehyde and toluene concentrations failed to show a decrease on re-measurement underwent further treatment such as the installation of ventilation systems, and were not cleared for use until concentrations were confirmed to have returned to safe levels.

The oil solvent containing toluene stored in classrooms was replaced to higher, sealed locations,

such as in shelves with doors, and proper ventilation was ensured during and after the use of such oil solvent.

8. Discussion

According to a 2001 MEXT survey, 12 classrooms (4.3%) (9 computer classrooms, 2 music classrooms, and 1 art classroom) out of 281 classrooms measured in the morning registered formaldehyde concentrations exceeding the standard values (100μg/m^3, 0.08ppm), and 12 classrooms (4.3%) (9 computer rooms, 2 music classrooms, and 1 art classroom) out of 278 classrooms measured in the afternoon registered formaldehyde concentrations exceeding the standard values. Matsumoto et al. (2003) pointed out that all classrooms whose formaldehyde concentration exceeded the standard values were special classrooms such as music and computer classrooms at elementary and junior high schools. Comparison of median values between regular and special classrooms at elementary and junior high schools showed formaldehyde concentrations in special classrooms to be 2.3 times concentrations in regular classrooms. All classrooms whose measured concentrations of formaldehyde exceeded the standard values were special classrooms and the concentration tended to be higher in special classrooms than that in regular classrooms. It was quite obvious from the survey data that formaldehyde concentrations exceeded standard values in a small number of classrooms each year, that the increased concentrations were noted not only immediately after the completion of new building construction and remodeling, but also regardless of the number of years that had passed after the remodeling, and that the concentrations were found to be significantly higher in special classrooms than in regular classrooms.

Generally, certain school facilities are not used regularly for extended periods of time, such as summer vacation, or are not used frequently, such as special classrooms. Such classrooms remain closed for extended periods of time and do not undergo sufficient ventilation. There were 20 classrooms whose concentrations exceeded the standard values five years from remodeling, etc. The major cause was considered to be the release of formaldehyde along with inadequate ventilation. This indicates that even if the Building Standards Act restricts the use of construction materials that contain formaldehyde or obliges schools to install mechanical ventilation systems when school buildings are designed, concentrations may exceed the standard values over extended periods without appropriate and continued facility management following construction or other work. To address this, maintenance and management of buildings is required on a daily basis. Such measures as encouraging ventilation are very important. In other words, it is important to have measures regarding formaldehyde for both before and after construction.

In order to protect health, it is important for individuals involved in school management to maintain daily awareness of conditions and promote ventilation through the establishment of organizational structures. In addition, it is also important for individuals involved in school management to perform periodic measurements centering on special classrooms to monitor status, and quickly respond with corrective action when necessary.

Meanwhile, according to the 2001 MEXT survey, 3 classrooms (2 art classrooms, 1 computer classroom) exceeded the standard value (260μg/m^3) out of 269 classrooms measured in the morning (1.1%) and one classroom (art classroom) exceeded the standard value out of 271 classrooms measured in the afternoon (0.4%). Toluene is usually detected at high concentrations in new or remodeled buildings immediately after construction. Due to its high volatility, however, thorough natural or mechanical ventilation can effectively reduce concentrations (Tokyo Metropolitan Government Public Health Bureau, 2003). Additionally, the report suggests that VOC concentrations would not exceed standards if no teaching materials containing VOCs were used in the affected rooms because the results showed that the standard values were exceeded only when such VOCs were used immediately before measurements. Therefore, it is important to sufficiently ventilate classrooms prior to use or after the use of materials containing VOCs.

As mentioned above, it is important to monitor VOC concentrations at various times, such as summertime, when levels tend to rise, after construction for new buildings and remodeling are completed, and when updating equipment. The Tokyo Board of Education strives to ensure that all metropolitan schools are thoroughly aware of VOCs and the need to reduce concentrations on an ongoing basis to secure a healthy and safe learning

environment for students.

Note:

A part of this report was presented at the 56th Japanese Association of School Health Conference.

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