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Influence Factors and Management based on Phase of Building Construction for the Improvement of Post Occupancy Indoor Air Quality

Lim, Hyoung-Chul*

Department of Architectural Engineering, Changwon University, Uichang Gu, Changwon, 641 773, Korea

Abstract

In recent years, pollution in residential spaces has been a significant area of concern. In particular, the indoor air quality (IAQ) of an apartment building before occupancy, which is related to the interior material, is a serious problem. Unlike previous research, which has mainly focused on pollution control after construction, this study has derived influencing factors and priority of management with a controlling schedule for IAQ. The objectives of this research are 1) control of schedule or improvement of management for IAQ, 2) distribution of responsibility to the parties concerned (factory, material company, construction company, design and engineering, occupancy). The results show the relative priority of the four major items in wall based apartment buildings and in column based apartment buildings. An analysis of the parties responsible for improvement based on the IAQ results shows more efforts to improve IAQ are needed in material factories and engineering/design companies.

Keywords : IAQ (indoor air quality), influencing factor, phase of building construction, apartment building

1. Introduction

1.1 Research background and objective

As the interest in the toxic substances generated in residential spaces has been on the rise, many efforts have been made to reduce the presence of such toxic substances in newly built apartment buildings by raising awareness, reinforcing regulations and distributing responsibility appropriately among participants in the construction industry. In particular, it should be noted that unlike other building structures, apartment buildings have a small area exposed to external air, which is recognized as disadvantageous in terms of ventilation. Increased demands from residents and advances in construction-related technology have led to a deteriorated IAQ even before occupancy due to a shortened construction period as well as an increase in toxic substances emitted and different types of interior finishing materials [1].

For this reason, many different methods have been attempted based on the reinforced system, including the introduction of building material grades such as 'E-Mark' and 'HB Building Material Grades,' so that builders can select more eco-friendly materials that are known to release less toxic substances[2].

As part of this trend, more and more attempts to develop pollution reduction technologies and eco-friendly materials continue to be made in the medium and long term; however, regardless of whether the approach is one of using eco-friendly materials and treatment after completion, or one of processing after completion, such as the early release of pollutants and ventilation before occupancy, these approaches cannot be solely depended on due to the

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* Corresponding author : Lim, Hyoung-Chul
[Tel: 82-55-213-3803, E-mail: hclim@changwon.ac.kr]

characteristics of apartment housing [3].

This research, therefore, aims not only to derive the influencing factors that can lead to improvements in operation and management at the site and changes in the schedule of the interior finishing work, but also to determine the relative priority of managerial and applicable procedures in order to improve the IAQ not the conventional research areas, including the elimination of pollutants from the construction materials used in the apartment building and their control after completion, and the development and use of eco-friendly materials.

Through the appropriate management and application of these influencing factors, this research aims to present a fundamentally improved method at the managerial level that can control the schedule of construction, improve schedule management and enhance the responsibility for pollution prevention by appropriately distributing the responsibility among the parties concerned (material manufacturers, factories, logistics companies, subcontractors, and person(s) in charge of material storage at the site).

1.2 Research scope and method

As preliminary research, a review of previous literature, actual conditions, and practical data was carried out to analyze the influence of each material used in an apartment building. The category of the air quality control for the finishing work was prepared, and a process model was drawn to determine the relationship between the interior finishing work and deterioration of the air quality.

To improve the air quality shown in the process model by securing manageability and improving effects, two surveys were conducted: one to derive the managerial priority and the other to adjust the process managing body. Based on the surveys, a management improvement plan was prepared to distribute the responsibility for reducing the pollutants among the parties concerned, including material manufacturers, factories, logistics companies, subcontractors, and person(s) in charge of storage at the site.

The research scope is limited to the finishing work of an apartment building, and it is performed based on the category derived from the linking analysis of the standard specification and the master format.

The following describes the methods in detail.

First of all, for the theoretical review on the air quality of apartment buildings, pollutants were analyzed by performing an analysis of previous research, not only on the development of eco-friendly materials and chemical treatments, but also on bake-out and cases of practical applications.

Then, the Finish System Breakdown Structure (FsMS) was drawn by conducting a linking analysis of the standard time schedule, the standard specification and the master format in order to classify the interior finishing work by process and consider the factors for process change. A standard process model is developed for the IAQ based on the category, and surveys are conducted to analyze factors influencing the IAQ and derive the relative management priority.

To perform an analysis of factors for process change and the effects resulting from management control by the participants, the participants for management are selected based on the critical path management technique; managerial priority is derived according to float time and relative amount of pollutants released at a given work section; a survey of the participants on the effect of the IAQ is conducted; and a prior control model for each participant is developed.

2. Theoretical research

2.1 Review of the related research

First of all, domestic and overseas criteria and research that can be applied to apartment buildings

were reviewed. The pollution characteristics and the possibility of pollution by the processing of Volatile Organic Compounds (VOCs) and formaldehyde that are identified in previous research as the main causes of deteriorating IAQ are investigated through a review of the literature, the cases of practical application, various criteria and standards. The research findings include statistic/practical results of pollution for each finishing material, pollutants, development of eco-friendly materials, chemical post-treatment and the need for diverse approaches.

Table 1. Previous research

Researcher	Index	Contents
Choi YJ [1]	Material of Reducing IAQ pollution	Investigation on IAQ after renovation of apartment housing
Kim CN [2]	Managing IAQ	Estimation of IAQ based on ventilation at finishing work of apartment housing
Lee YK [3]	Material of Reducing IAQ pollution	Research of developing construction technology of reducing pollution of IAQ
Han KW [5]	Managing IAQ	Investigation of IAQ on Apartment housing newly constructed
Yeo MS [6]	Material of Reducing IAQ pollution	Research of experiment about material of reducing pollution
Shin BS [8]	Managing IAQ	Research of improving IAQ from analysis on request of occupancy

Related research can be largely divided into material-related research and IAQ management technique-related research.

The material-related research on pollution reduction is mainly limited to the premise that it is necessary to improve materials based on an actual survey and analysis of materials that can induce pollution. The IAQ management technique-related research is mainly limited to a description of the effects of materials that emit less pollution.

As discussed in the research recently done by Lee, YG and Kim, JW, changes in the working schedule and construction technologies have been partly incorporated in the IAQ management technique, including pollution control. Despite such attempts, most of the research is limited to the amount of pollutants that are emitted, either after the pollution reduction treatment or after the 'bake-out' immediately before occupancy.

Such measures and improvement plans are usually performed after the finishing material work, or even immediately after extensive ventilation or bake-out, so it seems difficult to consider them as a fundamental solution to the issue of pollutants[4].

2.2 Review of the cases of practical application

The cases of practical application reviewed include a study on the ventilation system done by Seong, KC (DW Construction), a study on the bake-out done by Kim, MW (SS Construction), a study on influencing factors on the IAQ done by Hong, GP (DS Construction), and an experimental study on pollutants (SA Construction), all of which have been conducted by construction companies to improve the IAQ and are actually applied to new apartment buildings.

Despite the fact that improving the IAQ should be considered from the material design stage to the construction cost estimation stage, apartments are mainly sold by constructors based on their unique characteristics. Constructors should consider improving the IAQ as a design change that can differentiate their apartments from a marketing perspective.

For this reason, improvement of the IAQ has long been a social interest, and has also been requested by residents of apartment buildings, and construction companies have steadily applied eco-friendly materials and materials that release less pollutants. However, efforts to improve and review the applicability of such materials should be made due to realistic problems related with construction schedule, a lack of awareness among participants, and concerns about increased construction costs[5].

Table 2. Case study of practical fields

Company	Index	Contents
SA	Material of Reducing IAQ pollution	Developing analysis of cause of IAQ pollution in newly constructed building
DS	Managing IAQ	Investigation of IAQ influence factors on apartment housing
SS	Managing IAQ	Investigation of effectiveness of bake out ventilation at post construction
DL	Material of Reducing IAQ pollution	Research of experiment about material of reducing pollution
DW	Material of Reducing IAQ pollution	Research of experiment on effectiveness of vetilation facility for apartment housing

Therefore, as described in the previous cases, most construction companies in Korea take an approach to IAQ management in addition to an approach to materials. According to the studies done by Seong, KC and Hong, GP, while bake-out and ventilation seem to greatly improve the IQA in the short run, the results are not equal in effect, and the IAQ deteriorates over time.

Based on practical studies and previous research, government bodies and research centers conducted research on actual conditions and actual surveys, a review of the actual condition research performed by the Ministry of Environment in 2005 and by the National Environmental Protection Institute in 2004 shows that the pollutants that deteriorate the IAQ most are toluene, formaldehyde, and xylene, in that order. In particular, the average of toluene stood at 1003$\mu g/m^3$, which shows a relatively higher concentration in air than other pollutants, and which is also above the acceptable level of exposure to toluene. For this reason, it is important to control the level of toluene in order to improve the IAQ[6].

2.3 Research differentiation and requirements for improvement

Based on a review of the existing research on IAQ techniques, including pollution reduction processing, factors for process change and a management system were derived.

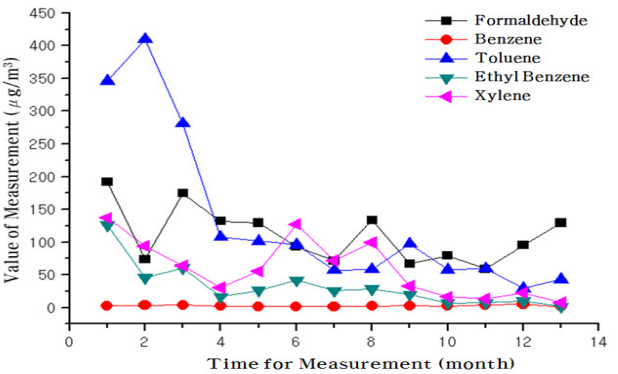

Figure 1. Density of IAQ pollution substance [3]

From the review, it was also found that ethyl benzene and styrene are around the acceptable exposure levels. However, formaldehyde and toluene are prone to deteriorate the IAQ more than other pollutants, so the need for prioritization to manage and control them in the course of construction work should be understood.

In order to establish the validity and research direction based on the review results, the need for and feasibility of changes in the schedule at the site to improve the IAQ after occupancy were studied as follows.

The research subjects consisted of 5 schedule managers in charge of the site process of apartment buildings with more than 300 households that are now under construction (denoted as S in Figure 2), and 5 construction managers (denoted as C in Figure 2), and Figure 2 shows the research results.

Both schedule and construction managers positively responded to the need for the IAQ in many different fields, while the construction mangers gave a strongly negative response to questions about its feasibility.

Therefore, the research results revealed that it is needed to take an procedural approach through prioritization and minimize the changes taking into account the conditions of the site where the finishing work is done.

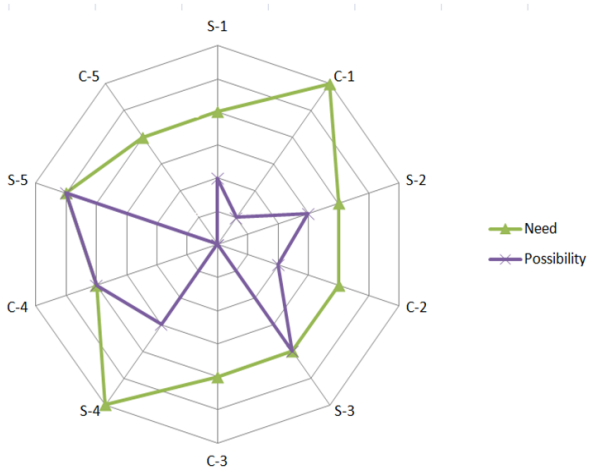

Figure 2. Results of survey

3. Classification of the finishing work and factors for process change

3.1 Breakdown of the interior finishing work for apartment buildings

As the designs of apartment buildings have been diversified, the materials and techniques used for the finishing work have varied accordingly, which makes them important factors to be managed[6].

Therefore, a system to break down the finishing work by type (FsMS : Finish System Breakdown Structure) is presented in this research to enable

Table 3. Comparative analysis of finishing work with FsBS

Level 1		Wall based Slab Apartment House		Column based Slab Apartment House	
		Level 2	Desc.	Level 2	Desc.
1.	Masonry	1.1 Mortar. 1.5 Grout. 1.6 Reinforcement	Water based work (Cement block, ALC etc)	1.2 Unit Masonry. 1.3 Erection 1.4 Ties & Anchor	Heavy dry wall, ALC board, Stone panel Dry wall based Work
2.	Flooring	2.1 General Flooring 2.2 Wood Flooring	Wood Flooring or Linoleum Finish	2.1 General Flooring 2.2 Wood Flooring	Wood Flooring or Linoleum Finish (Adhesive Material)
3.	Ceiling		at papering (4.3)	3.1 Texture Ceiling 3.2 Ties & Anchor	Paper, Tex Ceiling Adhesive or Mortar based work
4.	Finishing	4.1 Plaster Finishing 4.3 Papering 4.4 Tile 4.5 Terazzo	Direct Influence of IAQ Paper, Mortar Finish, Tile Finish Adhesive or Mortar based work	4.2 Board Finishing 4.3 Papering 4.4 Tile 4.5 Terazzo 4.6 Painting	Direct Influence of IAQ Paper, Dry Wall, Gypsum Board Adhesive and Painting Material based work
5.	Thermal Moisture Protection	5.1 Panel Heating 5.2 WaterProofing 5.3 Insulation	Panel Heating with Air contained concrete	5.1 Panel Heating 5.2 WaterProofing/ Damper 5.3 Insulation 5.4 Caulking & Sealing	Many part of dry works, direct influence at IAQ with Water Proof, Caulking, Sealing
6.	Wood & Plastics	6.2 Store Furniture 6.3 Kitchen Furniture 6.4 Other Wood & Plastic Fabrications	Direct Influence of IAQ in fabrication work using Adhesive material	6.1 Wood Panel & Framing 6.2 Store Furniture 6.3 Kitchen Furniture 6.4 Other Wood & Plastic Fabrications	Direct Influence of IAQ in fabrication work using Adhesive material
7.	Doors & Windows	7.1 Metal Door 7.2 Wood Window/door 7.3 Al Window/door	Direct Influence of IAQ from fabrication Adhesive material in wood win/door	7.1 Metal Door & Frame 7.2 Wood Win/Door 7.4 Specified Win/Door 7.5 Unit Curtain wall 7.6 Stick Curtain wall 7.7 Punched Windows	Many case of column based building, use curtain wall Influence at IAQ with Water Proof, Caulking, Sealing
8.	Mechanical & Electrical System	8.1 Plumb/LevelPipe 8.2 Heating System 8.5 Fire Sprinkler 8.6 Lighting System	Work using less influencing material to Indoor Air Quality	8.1 Plumb/Level Pipe 8.2 Heating System 8.3 Ventilation System 8.4 Air Conditioning 8.5 Fire Sprinkler 8.6 Lightening System	Work using less influencing material to Indoor Air Quality
9.	Specified Item			9.1 FireProof System (Steal Structure Only)	In case of Steel Structure System, direct influence in IAQ from FireProof Material

managers to effectively control and manage the process and the pollutants generated from the process in the future. For the convenience of an actual survey, apartment buildings are categorized into wall-based apartment buildings for general apartment buildings and column-based apartment buildings for mixed-use high-rise residential buildings.

In order to classify the possibility of emitting pollution by process item, 9 main categories and 39 divisions (FsBS) are derived based on a review of the literature on pollution inducement and the development of eco-friendly materials and the case studies on practical application, and then determined through the course of interviews with specialists and persons in charge (Table 3).

To make it possible to apply both to domestic and to overseas processes, the classification system is not only based on the standard specification for building construction but is also based on the master format that is currently used in North America.

That is, the standard process table for the apartment buildings generally used by the persons in charge is now being applied variably to each project depending on its conditions. A redefinition of the process flow in the standard specification is required depending on the development and application of new material, since the items in the standard specification are classified based on materials and work sections. As a result, an upper category like the UCI-Division generally utilized in the master format is needed.

Based on this, the standard schedule for the finishing work of apartment buildings was drawn

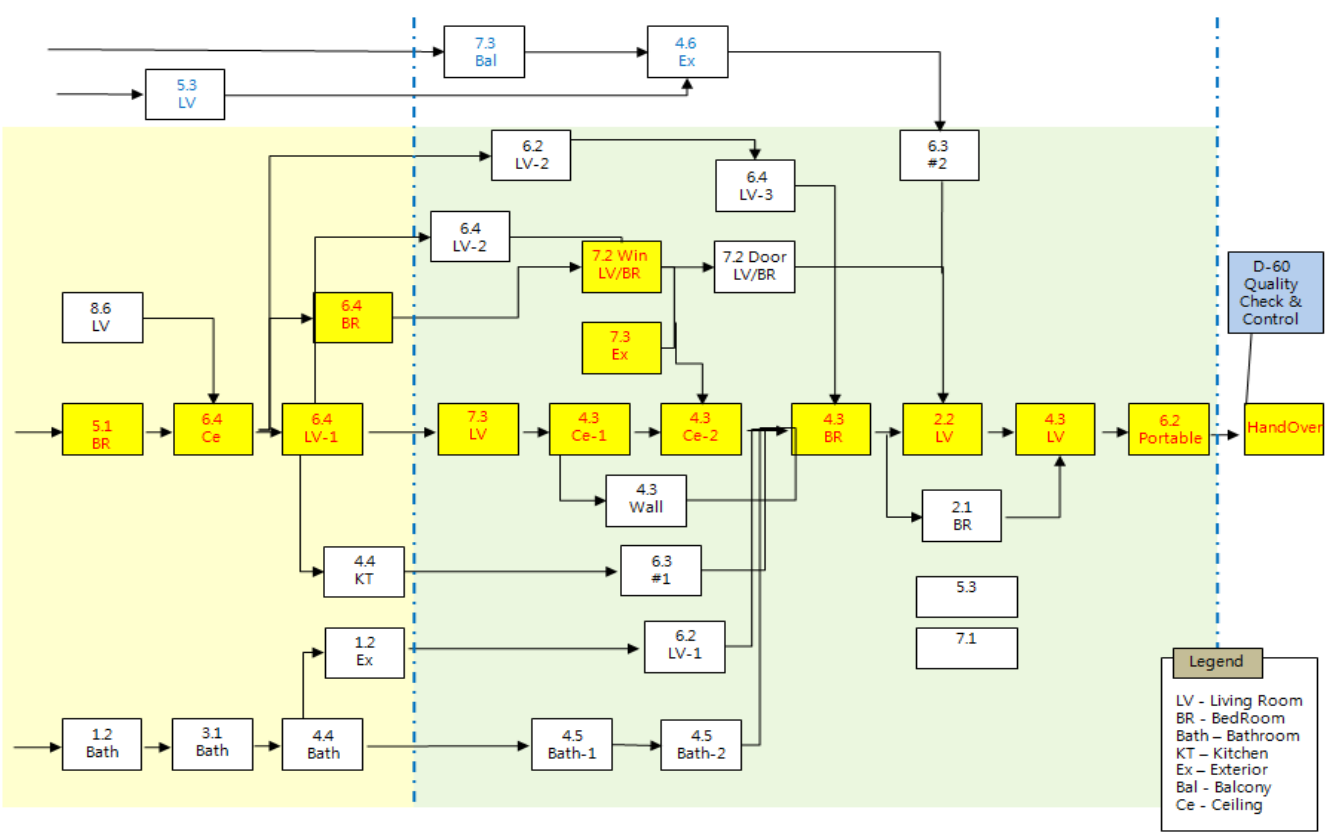

Figure 3. Standard schedule for finishing work of apartment house
(partly referred from Korea Land & Housing, 1998, Research of Efficiency in Construction Schedule of Apartment [7])

up, as shown in Figure 3. This logic is made by referring to the general information of the cases of practical application based on the standard schedule as part of the 'systematic organization of the process management of apartment buildings' by Korea Land and Housing Corporation. The codes for the process items refer to the categories, and the order of the working process by part is expressed[5].

3.2 Relative priority based on an analysis of the IAQ by schedule

As is already known, since internal factors such as materials, construction and design factors including selection of materials, ventilation volume, and pollutants are intertwined with the external factors, which affect the processes of Level 2 in Table 3, it is hard to assume that such factors affect all processes at a consistent level[6].

Therefore, a paired comparison interview was conducted among professionals and persons in charge using a 5-point scale. The interview covered the categories of the FsBS, which is the relative schedule management that should be generally considered for air quality control; as well as the question of which party should be responsible for the improvement of the IAQ, by dividing the participants into designer, material producing company, construction company, and resident.

To determine the priority between the items of the questionnaire, an AHP-based survey was conducted. However, this method was applied only to the processes in Level-1, which are newly composed by putting more weight on relative priority than quantitative preference value of each work type, rather than the sub-tiers including those in Level-2, because the conditions can vary depending on the selection of materials and the site itself.

In addition, Table 4 shows a summary of the survey conducted in this research, including the relative priority, the establishment of a classification system, and an analysis of the cases of practical application.

Table 4. Summary of survey

Stakeholder	Participants	Valid Check
Design /Engineering	Manager of engineering	4
	Construction Superviser	1
Material /Factory	Manager of related subcontractor	3
Construction	General Contractor Manager	6
	Subcontractor of finishwork	3
Occupancy	Column based apartment	2
	Wall base apartment	4

The survey results are shown in Table 5, Figure 3 and Figure 4. It is found that for wall-based apartment buildings, a relative priority was put on finishing work, floor work, masonry work, and furniture work, in that order, while for column-based apartment buildings a relative priority was put on finishing work, furniture work, floor work, and masonry work, in that order. Although the relative priority of the work processes appeared to be similar in both types of buildings, there are some differences in the reinforced concrete protective covers, ceiling panel work for the Rahmen structure, and curtain wall caulking of the curtain wall. However, there are wide variations in priority among items.

Table 5. Comparative analysis of finishing work with FsBS

Level 1	Relative priority	
	Wall based Slab Apartment House	Column based Slab Apartment House
Masonry	0.13	0.14
Flooring	0.17	0.16
Ceiling	0.12	0.10
Finishing	0.20	0.23
Thermal Moisture Protection	0.09	0.04
Wood & Plastics	0.14	0.16
Doors & Windows	0.08	0.06
Mechanical & Electrical System	0.08	0.05
Specified Item		0.07

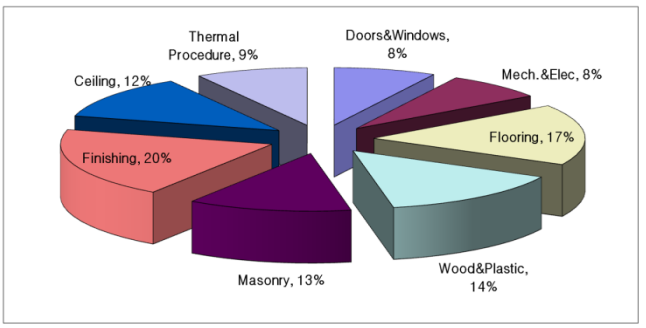

Figure 4. Relative priority in wall based apartment building

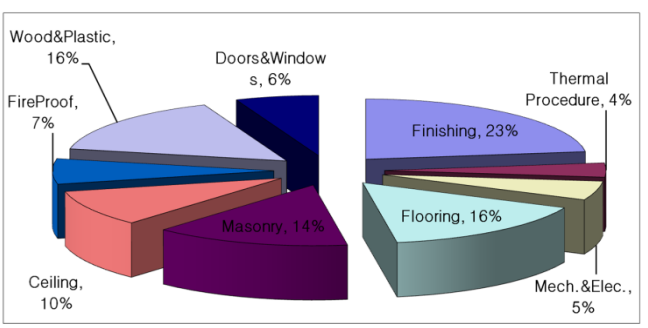

Figure 5. Relative priority in column based apartment building

4. Analysis of the process control effect by relative priority of releasing pollutants

4.1 Analysis of the process control effect by relative priority

Finishing work can be divided into two different paths: the critical path including masonry, papering, and flooring, and the general path including doors and windows work, tiling and furniture work. Masonry work is the framework, the schedule of which cannot be changed. The schedule control effect was analyzed by limiting the milestone activities to two types of work in the critical path and three types of work in the general path.

The analytical results of schedule management with no change in paths are as follows. The float time of the critical path is '0,' and the schedule is impossible to change. As a result, the doors and windows work, tiling and furniture work in the general path are analyzed, and then the float time and intensity of pollutants of individual work are enumerated.

However, it is assumed that 6.3 kitchen furniture work with the mark '*' is completed in a two-step installation, and that individual processes do not have any relation with other households and buildings. If it is possible to work on each part, the factors to restrictively interfere with work are not taken into account. For instance, the sequence of work sections is not considered, including papering after the installation of a windowsill, baseboard work after papering, and wall tiling after floor tiling.

As you can see in Table 6, the relative intensity of any release of pollutants is shown to be high, in the order of papering, furniture work, doors and windows work and tiling. Of these, some papering and plastering is included in the critical path, and the schedule of the works can be changed. The float time of the front door work and the aluminum doors and windows work is long, but pollutants are not emitted during such work. Taking the float time and the relative intensity of releasing pollutants into account, one can change the schedule of furniture (90 days), wood doors and windows (75 days), and tiling (150 days) to control the period of time of releasing the substances.

Table 6. RD and float of finishing work except critical path (RD : Relative Priority of Releasing pollution Substance)

Desc.	Level	Float	Period to End		Time	RD
			Early Start	Late Start		
4. Finishing	4.1 Plaster Finishing	0	220	220	wall : after masonryFloor : after air contained concrete after plastering after waterproof	5
	4.3 Papering	0	120	120		1
	4.4 Tile (KT-Wall)	50	150	100		4
	4.4 Tile (Bath-Wall,Floor)	50	150	100		
6. Wood/ Plastics	6.2 Store Furniture	90	160	70	after plastering	
	6.3 Kitchen Furniture (#1)*	55	140	85	after wall tile, plumb	2
	6.3 Kitchen Furniture (#2)	25	95	65		
7. Doors Windows	7.1 Metal Door	150	210	60	after Masonry or structural work	6
	7.2 Wood Window/Door	75	135	60		3
	7.3 Al Window/Door	150	210	60		

Table 7. The result on investigation of main agent for IAQ management

FsBS	Wall based Slab Apartment House			Column based Slab Apartment House		
Work Category	Work Package	Main Agent of IAQ Management		Level	Main Agent of IAQ Management	
		Current	Need to Improve		Current	Need to Improve
1. Masonry	1.1 Mortar. 1.5 Grout. 1.6 Reinforcement	Construction	Design & Engineering Factory	1.2 Unit Masonry. 1.3 Erection 1.4 Ties & Anchor	Occupancy	Factory
2. Flooring	2.1 General Flooring 2.2 Wood Flooring	Occupancy,Construction	Design & Engineering,Construction	2.1 General Flooring 2.2 Wood Flooring	Occupancy Construction	Design & Engineering Construction
3. Ceiling	N/A			3.1 Texture Ceiling 3.2 Ties & Anchor	Occupancy	Factory, Construction
4. Finishing	4.1 Plaster Finishing 4.3 Papering 4.4 Tile 4.5 Terazzo	Occupancy,Construction	Design & Engineering Factory	4.2 Board Finishing 4.3 Papering 4.4 Tile 4.5 Terazzo 4.6 Painting	Occupancy,Construction	Factory, Construction
5. Thermal & Moisture Protection	5.1 Panel Heating System 5.2 Water Prf. / Damp prf. 5.3 Insulation	Occupancy	Design & Engineering Construction	5.1 Panel Heating System 5.2 Water Prf. / Damp prf. 5.3 Insulation 5.4 Caulking & Sealing	Occupancy	Construction
6. Wood & Plastics	6.2 Store Furniture 6.3 Kitchen Furniture	Occupancy,Construction	FactoryConstruction	6.1 Wood Panel & Framing 6.2 Store Furniture 6.3 Kitchen Furniture 6.4 Other W&P Fabrications	Occupancy,Construction	Factory, Construction
7. Doors & Windows	7.1 Metal Door & Frame 7.2 Wood Window & Door 7.3 Al Window & Door	Occupancy	FactoryConstruction	7.1 Metal Door & Frame 7.2 Wood Window & Door 7.4 Specified Window/Door 7.5 Unit Curtain Wall 7.6 Stick Curtain Wall	Occupancy	Factory, Construction
8. Mechanical & Electrical System	8.1 Plumbing/Levelness Pipe 8.2 Heating System 8.5 Fire Sprinkler(일부) 8.6 Lightening System 8.7 Miscellaneous	Occupancy	Occupancy	8.1 Plumbing/Levelness Pipe 8.2 Heating System 8.3 Ventilation System 8.4 Air Conditioning 8.5 Fire Sprinkler 8.6 Lightening System	Occupancy	Factory, Construction
9. Specified Item	N/A			9.1 FireProof System (Steal Structure Only)	Occupancy	Design & Engineering Construction

Also, in terms of work sections such as kitchen furniture and storage furniture work, which have a long float time and release large amounts of pollutants, the work should not solely depend on the float time in consideration of the fact that the work sections done immediately before and after the furniture work are done en bloc, by floor or by building. The efforts to improve the IAQ should be distributed among material factories, logistics companies, and even the person(s) in charge of the storage at the site.

In the schedule management, the float time should be considered not as a time slot in the schedule during which nothing needs to be done, but as a kind of buffer during which the variations of sequential works can be dealt with depending on the field conditions. From this perspective, it is necessary to manage the schedule in a way that is flexible and can suit each household rather than to manage it en bloc. Furthermore, it is desirable to selectively apply the flexible schedule to the work sections that can greatly improve the IAQ by doing so.

According to 'Figure 1. Density of IAQ pollution substances,' toluene is found to be released most

in the initial two months but declines to approximately 20 percent of the maximum level after four months, while formaldehyde is released from various items, and the amount released does not show any clear relationship with the time elapsed.

Therefore, based on the idea that a large amount of toluene is released from one to four months after work is done, the work that has a long float time should be done as early as possible in order to allow the pollutants to be released for a relatively long time prior to habitation.

4.2 Adjustment of managing body by process

As discussed above, since the incorporation and separation of a process or the utilization of the float time in the schedule should be performed after taking complex conditions into account, there is the potential to improve the IAQ with the materials produced in a factory by distributing the responsibility for reducing the amount of pollutants to each party in charge of design, production, logistics, and storage.

Therefore, as described above, we conducted a survey to identify the party in charge of IAQ improvement, as well as the relative priority of schedule management, in order to improve the IAQ. The parties can be broadly divided into designer, manufacturer, constructor and resident. The results are as follows.

The current status of the party responsible for the IAQ improvement and the future direction of the research were investigated. Table 7 shows the survey result.

Resident and constructor were identified as the parties currently responsible for the most of the schedule, which means other parties need not make any efforts to reduce the pollutants. That is, as the resident and constructor cannot change anything in the process of design, manufacturing, and logistics, the only way to improve the IAQ is reduction of the substances over time. Moreover, the only responsible party to improve the IAQ is the constructor.

As indicated in the objective of this research, the parties responsible for improving IAQ should be diversified through the systematic management of materials and pollutants, and the improvement of construction and work section. In particular, the responsibility of parties in charge of design and manufacturing should be enhanced.

Since design improvement has been achieved in the areas of masonry, finishing, and floor heating work, consideration of the IAQ can be an additional means of design improvement. It was also found that masonry, doors and windows, and finishing can be greatly improved through the systematic management of production, materials and inventory.

5. Conclusion and future research direction

In order to develop a management method and model based on changes in the schedule and responsible bodies, we conducted research on actual condition and reviewed practical applications and the previous research. Based on the research, pollutants and current state of the pollutants by material were analyzed.

The most influential pollutants that deteriorate the IAQ most are found in the order of toluene, formaldehyde, and xylene. In particular, the average of toluene stood at 1003$\mu g/m^3$, which is relatively higher in density than other pollutants and which is also above the acceptable level of exposure to toluene. For this reason, it is important to control the level of toluene in order to improve the IAQ.

As the designs of apartment buildings have been diversified, the materials and techniques used for the finishing work have varied accordingly, which makes them important factors to manage. Therefore,

a system to break down the finishing work by type (FsMS : Finish System Breakdown Structure) is presented in this research to enable managers to effectively control and manage the process and the pollutants generated from the process in the future. For the convenience of an actual survey, apartment buildings are categorized into wall-based apartment buildings for general apartment buildings and column-based apartment buildings for mixed-use high -rise residential buildings.

It is found that for wall-based apartment buildings, a relative priority was put on finishing work, floor work, masonry work, and furniture work, in that order, while for column-based apartment buildings a relative priority was put on finishing work, furniture work, floor work, and masonry work, in that order. Although the relative priority of the work processes appeared to be similar in both types of buildings, there are some differences in the reinforced concrete protective covers, ceiling panel work for the Rahmen structure, and curtain wall caulking of the curtain wall. However, there are wide variations in priority among items.

From the analytical results, constructors and residents were responded as the party responsible for improving the IAQ among the 4 participants, Overall, other parties except for constructors pay little attention to improving the IAQ. Therefore, cooperative efforts should be made by factories and designers in order to reduce the pollutants.

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