거주자 안전을 고려한 친환경건축자재의 HCHO등급에 관한 고찰

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A Study on the HCHO Grade of Architectural Material's Standard for Greenness with Consideration for Residents' Safety

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Abstract : According to Tokyo protocol which suggests the prevention of global environmental pollution, Korean government establishes the standard of architectural materials emission consistency with best effort to decrease the environmental pollution. But many current architectural materials which are used for constructing and remodeling buildings are composed of a variety of chemicals. These include stimuli bad for the residents' health and safety and harmful discharged air polluting substances such as volatile organic compounds(TVOCs) and formaldehyde(HCHO) that in tern include a variety of carcinogen substances. These discharged substances are also researched into inducing 'sick building syndrome' which induces headache, dizziness, vomiting and concentration failure among residents. But the standard of architectural materials according to the Korean apartment provision is limited to emission factors: HCHO and TVOCs. So the aim of this study is to present a standard of functional material's emission consistency about TVOCs including glues and paints, and a certification grade for green building by instituting a materials standard for green building which has consideration for the residents' safety.

초 록 : 1997년 도쿄의정서(protocol)에서는 지구환경오염에 대한 오염원방지를 제안하는 협정으로 우리나라에서도 배출기준에 감소하기 위한 노력의 일환으로 건축자재에 대한 방출농도 기준을 마련하고 있는 실정이다. 그러나, 최근 건축공사에는 많은 종류의 건축자재와 내장재료가 사용되고 있으며, 특히 화학기술의 발달로 복합재료로 구성된 건축재료들에 대한 사용이 증가하고 있다. 실내건축자재에서 방출되는 물질로 인하여 재실자들에게 두통, 현기증, 메스꺼움, 졸음, 집중력 감퇴 등의 각종 질병을 불러 일으키는 '새집 증후군'과 같은 현상을 야기 시켜 건강상 많은 영향을 주고 있는 것으로 조사되고 있으며, 이러한 문제 해결을 위해서는 각 나라마다 건축물에 사용되어지는 건축자재에 대한 유기 화합물의 방출농도를 최소화 하는 친환경 건축자재의 선정을 권고하는 실정이다. 이에 본 연구에서는 건축자재의 TVOCs에 대한 HCHO의 등급기준을 제안하고자 한다.
Key Words : resident's safety, construction materials, volatile organic compounds, formaldehyde(HCHO)

1. Instruction

According to Tokyo protocol which suggests the prevention of global environmental pollution, Korean government establishes the standard of architectural materials emission consistency with best effort to decrease the environmental pollution. But the theory of green building system and conservation of environment are being raised as new and urgent problems, because of abuse of energy and materials, disturbance of nature and the ecosystem, environmental destruction and weather disasters caused by the development of

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technology and growth in economy that threatens the survival of human beings. Various architectural resources and interior materials are used in current construction and, the use of these materials, which are composed of various substances with the development of chemical technology, is rising. A great deal of studies and research about recycling of materials, development of non-toxic materials and control of materials which emit polluting substances have been conducted by architectural companies, materials producers, and construction companies all over the world according to the acceleration of campaigns about green architecture. Recently, the standard of indoor air quality(IAQ) was established in 2003 and studies have been conducted in Korea. The selection of the right architectural materials is the most important design element because the emission amount and characteristic of polluting substances are different from each other according to the type of architectural materials in view of IAQ.

In particular, interior architectural materials are composed of various chemical compounds and they emit air polluting substances. These include stimuli bad for the residents' health and safety and harmful discharged air pollution substances such as volatile organic compounds(TVOCs) and formaldehyde(HCHO) that include a variety of carcinogen substances. These discharged substances are also researched for their influence on 'sick building syndrome' which induces headache, dizziness, vomiting and concentration failure among residents. As such many countries are recommending the selection of green building materials which emit pollution substances shortly in the part of architecture. Thus, this study aims to suggest the standard grade of TVOCs and HCHO of architectural materials.

2. The pollution of IAQ caused in architectural materials composed of chemical compounds

2.1. Classification of TVOCs

Organic compounds are classified into 3 parts: 'volatile', 'semi volatile', and 'nonvolatile', according to the characteristics of steam pressure and boiling point. TVOCs are above the steam pressure 10^{-2} kPa, SVOCs $10^{-2}\sim10^{-8}$kPa, and NVOCs below 10^{-8}. The World Health Organization classifies the TVOCs below 10 0℃, and SVOCs and NVOCs above 100℃(Table 1).

2.2. Important architectural materials and pollution emission

Various materials are inserted into the construction process according to the construction types, and these materials are mostly industrial organic compounds. Polluting substances are emitted because organic compounds are largely composed of TVOCs. Table 2 describes architectural materials according to important construction types. It is obvious that most of materials

Table 1. The classification of organic compounds in air(WHO)

Classification	Abbreviation	Range of boiling point	Method of capture
very volatile organic compounds	VVOC	< 0℃~50 - 100℃	absorption by activated carbon
volatile organic compounds	VOC	50~100℃ - 240~260℃	absorption by solidity absorbent
semi-volatile organic compounds	SVOC	240~260℃ - 380~400℃	absorption by polyurethane form or XAD-2
particle-bound organic compounds	POM	> 380℃	absorption by filter

Table 2. Important architectural materials on construction types

Construction types	Important material
Structural material	RC (reinforced concrete structure), PC structure, ALC (autoclaved lightweight concrete structure)
Outdoor finishing material	wood keeping material, caulking material, sealant, window frame, putty, gasket
Insulating material	insulating material, fireproof covering material, sound material
Air conditioning equipment	pipe, duct lagging material, duct sealant, cooling water addition, refrigerant
Interior finishing	floor structure, floor material, carpet & glues, floor vinyl material, textile, veneer particle board, hard board, chip board
Partition wall	finishing wallpaper & textile, adhesive & glues, paint, wood keeping material, panel, veneer board
Ceiling material	tile, panel

Table 3. Important architectural materials and emission of pollution substance

	Architectural material	Cause	Emission of pollution substance
Insulating material	1. textile insulating material (glass wool, rock wool)	adhesive resin, textile substance	aldehydes, ketones, solvents
	2. polyurethane insulating material	substance before treating, amine, blowing agent (CFC)	FCs (chlorofluoro-hydrocarbons)
	3. insulating material	(pentane), styrene residual oil	styrene
Interior finishing material	1. water-soluble lacquer, latex	hardener, solvents	texanol, glycols, glycol ethers
	2. oil paint, lacquer	solvents, monomers	solvents
	3. carpet-textile	solvents, addition and supplement, textile treat resin	Formaldehyde (HCHO)
	4. pine tree block	wood extract	pentanal, hexane pinene, camphene, 3-carene, HCHO, etc. (34 components identified)
	5. piece of wood material	wood extract, lacquer, adhesive, glue	HCHO, solvents, terpenes, aldehyde (12 components identified)
	6. linoleum	fatty acid	fatty acids, toluene, 3-methypentanes (12 components identified)
	7. cork tile	wood extract, synthetic resin	1,2propandiol, 4-methyldioxalan, HCHO, 2,4,6-pentamethylheptane (25 components identified)
	8. PVC floor material	hardener, supplement, solvents	TXIB (2,2,4-triethyl-1), 2-ethyl-1-hexanol, aromatic and aliphatic hydrocarbons, phenol (17-58 components identified)
	9. rubber floor material	oxidizer, hardener, supplement	styrene, isododecene
Caulking, sealant material	1. silicon caulking material	acetic acid	acetic acid
	2. acrylic caulking material	solvents	solvents
	3. polyurethane	hardener, solvents	solvents
	4. polyester polymerization concrete	polyester resin, styrene	styrene residue, phallic acid
Others	1. clipboard	urea formaldehyde resin	HCHO
	2. adhesive, glue	solvents	2-ethyl-1-hexanol

are composed of organic compounds.

Table 3 details pollution sources and pollution emissions from architectural materials. The classification items are 'insulating material', 'interior finishing material', and 'sealant material'. Important causes and emissions of TVOCs are presented in architectural materials, which are composed of TVOCs substances: paint, adhesive & glues, particle board, insulating material, caulking material, carpet, and wood preservative(Table 3).

2.3. The influence of architectural materials emission on human body

Sick Building Syndrome(SBS) is an illness symptom such as irritation of eyes, skin eruption and vomit in newly constructed buildings. Formaldehyde(HCHO) is one of the main substances causing a SBS and is the most widely used material in construction and furnishing. The concentration of its standard is < 0.1 mg/L in the majority of countries. The U.S. EPA(1991) reported that it generates health disorders(irritation of eyes, nausea, headache, fatigue, dullness and thirst). Major sources of formaldehyde are from plywood, particle board and adhesives for wallpapers(Sekine and Nishimura, 2001). The influence of architectural materials emission on the human body is fatal because it has a very bad effect on blood, internal organs, and nerves(Table 4).

3. A proposal of grade and standard of architectural materials

3.1. Foreign standard suggestion

EU and Finland established division standard of indoor environment and finishing materials with the full use of characteristic of pollution emission degree

Table 4. Important causes of TVOCs and influence on human body

Important substance of TVOCs	Important cause	Influence of human
benzene	smoke, washing and cleaning material, paint remover, adhesive, particle board	bone-marrow damage, lack of blood platelet, leukopenia, poverty of blood
halogenations hydrogen		virulence of liver, kidney and heart
methanol		loss of sight, scrotal hernia
formaldehyde	wood preservative, cosmetic, furniture, veneer board, insulating material, adhesive	allergic dermatitis, fall of liver performance
hexane		obstacle of peripheral nerves
toluene	paint, adhesive, heat apparatus, carpet, insulating material, wax, caulking materials	virulence fatigue of liver, blood, nerve, mental storm: strong virulence
xylene	paint, adhesive, heat apparatus, carpet, caulking materials, dye coloring agent	virulence of nerve
ethyl benzene	furniture brightener, paint, floor wax, electric materials	virulence of nerve
pentachloro benzene	wood preservative, fungicide, insectifuge	emotion unrest, nerves distraction, fatigue
dichloro benzene	aromatic material, fungicide, mothball	vertigo, damage of nerve, fatigue
butyl acetate	lacquer	
styrene	cigarette smoke, caulking materials, foaming insulating material, textile board	

about architectural materials and have used by design instruction. SCANVAC(Scandinavia Nation society) divides architectural materials into 3 grades follow as: low-emission building materials, moderately emitting building materials and heavily emitting building materials. Table 5 is a presentation of emission degree by stages. An emission degree of A stage is 0.04 mg/m^3(Table 5).

Finland classifies architectural interior finishing materials into 3 stages and accepts M1 grade in standard of pollution emission about architectural materials. Table 6 shows VOCs consistency and related materials classified in Finland Architectural Information Center. The consistency of 1st grade is 0.2mg/m^2h(Table 6).

Table 5. Materials grade with the emission degree

Emission degree	Maximum emission degree(20℃, RH 50%)
MEC-A	40$\mu g/m^3$ (m^2h)
MEC-B	100$\mu g/m^3$ (m^2h)
MEC-C	450$\mu g/m^3$ (m^2h)
MEC : Material Emission Class	

Table 6. Materials Grade with VOCs consistency in Finland

Division	M1	M2	M3
VOCs	0.2mg(m^2h)	0.4mg(m^2h)	above 0.4mg(m^2h)
Materials	flooring material, paint, varnish, board, mineral fiver, plaster, additional material etc.		

Many companies which make adhesives in Germany established the nonprofit organization GEV, and have carried out environmental labeling system. Now 30 companies, 5 countries in Europe are granting EMICODE grade about 400 products (2000 year standard). Table 7 shows the range of TVOCs emission about architectural materials. Standard of primer is most hard in the aspect of same grade and mortar, adhesive according to emission degree. Each 1st grade about architectural materials is follows as: primer (0.1mg/m^3), mortar(0.2mg/m^3) and adhesive(0.5mg/m^3). The total amounts of VOCs are measured 10 days later according to chamber method(Table 7).

And Federal Environmental Agency and Federal Institute For Materials in Germany established Eco-Label(RAL-UZ38 rev) system about wood products together. This system contains certification standard

Table 7. Grade of materials according to TVOCs in Germany (EMICODE)

Grade	Rangy	TVOCs (Primer)	TVOCs (Mortar)	TVOCs (Adhesive)
EMICODE EC1	Very low	Below 100$\mu g/m^3$	Below 200$\mu g/m^3$	Below 500$\mu g/m^3$
EMICODE EC2	Low	100-300$\mu g/m^3$	200-600$\mu g/m^3$	500-1500$\mu g/m^3$
EMICODE EC3	A little high	Above 300$\mu g/m^3$	Above 600$\mu g/m^3$	Above 1500$\mu g/m^3$

Table 8. Eco-Label of wood product in Germany

Division	Plane shape materials (door, panel, laminate floor, wood floor)		Cube shape materials (Furniture etc.)	
	First data 24 hours later	Last data 28 days later	First data 24 hours later	Last data 28 days later
VOCs	-	300μg/m^3	-	600μg/m^3
SVOCs	-	100μg/m^3	-	100μg/m^3

of indoor environmental pollution substances, covering, using rate of recyclable materials and post treatment. The amount of VOCs emissions are measured chamber method and judged by air consistency after regulation time(Table 8). The VOCs data of plane shape materials is regulated to 0.3mg/m^3 but cube shape materials is regulated to 0.6mg/m^3(Table 8).

"Green Environment Organization" and "Green Guard: certification program of architectural materials" which are established by nonprofit organizations in U.S present the detail standard of TVOCs of architectural materials. Test method is same as above method, and judged by 96 hours' consistency(Table 9).

Environmental Agency in Canada gives a green environmental mark to 29 living supplies by evaluating harmfulness degree to human and environment, recycling possibility, and waste recycling since 1988. The standards of VOCs content among architectural materials: adhesive, paint, carpet and others are specified(Table 10).

Table 9. TVOCs Standard of Green Guard in U.S.

Division	Standard (mg/m^3)
adhesive, normal architectural material, floor material	0.50
home facilities	0.50
ceiling material, insulating material	0.50
office furniture (chair, desk, table etc.)	0.25
paint	0.50
wallpaper, textile, furniture(work station)	0.50

Table 10. TVOCs Standard of architectural materials in Canada

Type	Ingredient	Standard	Remark
Paint	VOCs content	Below 200g/L	
Carpet	TVOCs	0.25mg/m^{2}h	24 hours later
Carpet adhesive	TVOCs	0.05mg/m^{2}h	72 hours later

Table 11. Standard of architectural in Japan

Grade	Emission velocity(μg/m^{2}h)	Remark	Test
F☆☆☆☆	Below 5	-	JIS A 1901
F☆☆☆	Below 20	Land restriction	
F☆☆	Below 120		
Others	Above 120	Forbidden	
Materials	6 adhesives used for(floor finishing, wood block, wall, ceiling and board, plastic lagging panel, manufacture, floor knot) 3 insulating materials(artificial mineral textile, artificial mineral textile for house, textile for blowing)		

Grade	Emission velocity(mg/L)	Remark	Test
F☆☆☆☆	Below 0.12	-	JIS K 5601-4-1
F☆☆☆	Below 0.35	Land restriction	
F☆☆	Below 1.8		
Others	Above 1.8	Forbidden	
Materials	11 types of Paints(aluminum paint, oil paint, synthetic resins paint, phthalic resins vanish paint, phthalic resins enamel paint, oil foundation paint, normal waterproof paint, various shape paint, house wood shape paint, house wood and metal paint, building floor paint) * materials which regulate only F☆☆☆☆ grade 16 types of paints(varnish, nitro cellulose lacquer, lacquer, foundation paint in lacquer, poly vinyl resins vanish paint, poly vinyl resins enamel paint, poly vinyl resins primer paint, acrylic resins vanish paint, acrylic resins enamel paint, architectural polyurethane resins paint, glossy poly resins emulsion paint, emulsion paint, poly resins emulsion paint, poly resins emulsion shape paint, emulsion pate paint, acrylic resins paint, house wall paint)		

Many organizations such as "Ministry of Land, Infrastructure and Transport", "Ministry of Health, Labor and Welfare" and "Ministry of Agriculture, Forestry and Fisheries" In Japan are established the standard of IAQ(Indoor Air Quality) pollution, and divided materials into 3 grades according to HCHO contents.

3.2. Korean certification grade of green building

The certification grade is divided in Table 12 through emission of HCHO according to the introduction of a green labeling system in architectural materials. The Korean standard certification system of architectural materials is being studied and researched by Korean Agency for Technology and Standards for the preparation of a counterplan about pollution substances emission.

Table 12. Standard of grade about architectural material's HCHO emission by KS

Architectural material	Grade	Emission of formaldehyde (mg/L)	
		average	maximum
Veneer board (KS F 3101) & other board	F1	0.5	0.7
	F2	5	7
	F3	10	12
Particle board (KS F 3104) Fiberboard (KS F 3200) Flooring board (KS F 3126)	E0	0.5	
	E1	1.5	
	E2	5	
Wood chip decorated flooring board(KS F 3111)	general	10	12
	general	5	7
Wallpaper (KS M 7305)	-	2	
Starch adhesives for wallpaper(KS F 3217)	-	5	

The Korean Agency for Technology and Standards is also establishing and presenting a standard for architectural materials regarding TVOCs and HCHO, which are indoor polluting substances because of the classification counterplan of materials. These activities are methods for the selection of low emission materials and improvement of IAQ through the selection good material in construction.

Table 13. Certification standard of TVOCs about architectural materials (unit: mg/m^3)

Division		General material	Paint	Adhesive
indication (5) *****	TVOC	Below 0.10	Below 0.10	Below 0.25
	HCHO	Below 0.03	Below 0.03	Below 0.06
indication (4) ****	TVOC	0.10~0.20	0.10~0.20	0.25~0.50
	HCHO	0.03~0.05	0.03~0.05	0.06~0.12
indication (3) ***	TVOC	0.20~0.40	0.20~0.40	0.50~1.50
	HCHO	0.05~0.12	0.05~0.12	0.12~0.40
indication (2) **	TVOC	0.40~2.00	0.40~2.00	1.50~5.00
	HCHO	0.12~0.60	0.12~0.60	0.40~2.00
indication (1) *	TVOC	2.00~4.00	2.00~4.00	5.00~10.00
	HCHO	0.60~1.25	0.60~1.25	2.00~4.00

***** : Excellent
**** : Very Good
*** : Good
** : General I
* : General II

Table 14. Standard of TVOCs about architectural material (mg/m^3)

Country	SCANVAC	Finland	Germany	U.S.	Canada	Korea
TVOCs	1 grade : 0.04 2 grade: 0.10 3 grade: 0.45 (20℃, RH 50%)	1 grade: 0.2 2 grade: 0.4 3grade: above 0.4 (flooring material, paint, varnish, board, mineral fiber, plaster, addition)		0.50 (paint, home furniture, ceiling material, insulating material, wall paper, textile, furniture) (96 hours later)	Below 0.2 (paint) 0.25 (carpet: 24 hours later)	1 grade: below 0.10 2 grade: 0.10 - 0.20 3 grade: 0.20 - 0.40 4 grade: 0.40 - 2.00 5 grade: 2.00 - 4.00 (general material, paint)
TVOCs (primer)	-	-	1 grade: below 0.1 2 grade: 0.1-0.3 3 grade: above 0.3 (final result: after 10 days)	-	-	-
TVOCs (mortar)	-	-	1 grade: below 0.2 2 grade: 0.2-0.6 3 grade: above 0.6 (final result: after 10 days)	-	-	-
TVOCs (adhesive)	-	-	1 grade: below 0.5 2 grade: 0.5-1.5 3 grade: above 1.5 (final result: 10 days later)	0.50 (adhesive, general material, flooring material) (96 hours later)	0.05 (carpet adhesive: 72 hours later)	1 grade: below 0.25 2 grade: 0.25 - 0.50 3 grade: 0.50 - 1.50 4 grade: 1.50 - 5.00 5 grade: 5.00 -10.00 (adhesive)
Wood products (plane shape)	-	-	TVOCs: 0.3 SVOCs: 0.1 (final result: 28 days later)	-	-	-
Wood products (cube shape)	-	-	TVOCs: 0.6 SVOCs: 0.1 (final result: 28 days later)	0.25 (office furniture: chair, desk, table) (96 hours later)	-	-

The Korean standard is divided into 5 grades. The effectiveness could be said to be low because the range of grades is larger than others. Namely, it is thought that the division and grade of architectural materials must be established effectively according to the IAQ.

3.3. Comparison with standard grade of architectural material classified by country

The results of analyzing each country's standard regarding TVOCs are as follows. In SCANVAC and Finland, are preserved the standard data about architectural materials are preserved in a lump. However, in Germany, the U.S and Canada, the data are preserved through the classification of detailed materials. Used materials are different from each other by part, and it is thought that detailed material classification and standard of enforcement are necessary to restrict the TVOCs data because each material is composed of different components.

3.4. A proposal of HCHO standard grade about Korean architectural materials

Korean Ministry of Environment and related association has conducted certification work for 553 green materials which have been registered to the association since 2004. The 553 green materials are classified as follows: adhesive(194), paint(78), flooring materials (83), wallpaper(55), wood & board(28), and others(95). The emission of HCHO is not a serious problem according to the certificated data of general architecture green materials (Fig 1), but it is thought that much effort in the development of materials which emit low TVOC because of many materials are obtained in 3-5 grades in case of TVOC. In the case of HCHO, many products are evaluated as higher grades, but not in the case of TVOC(Fig 2).

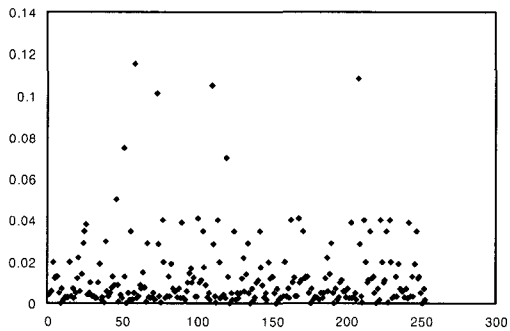

Fig. 1. HCHO according to greenness architecture general materials.

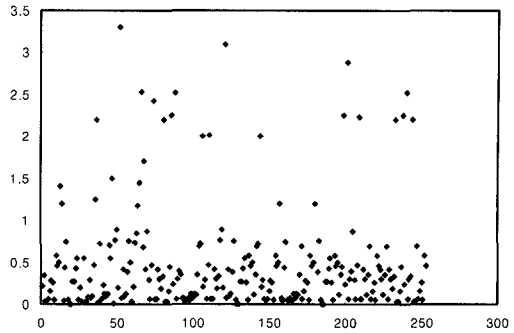

Fig. 2. TVOCs according to greenness architecture general materials.

Evaluation results for HCHO are different from the result of TVOC. As such, re-establishment is essential and necessary through the strengthening of evaluation standards according to the guideline of WHO standard.

4. Conclusion

According to the "management law of indoor air quality for multitude using facilities" in operation in Korean government since 2004, the best efforts have been made to use architectural green materials by government and construction companies for the residents' safety to make clean indoor spaces. It is thought that the green materials for the residents' safety lowers emitting pollution grades without increasing the amount of materials used. This study analyzed certification standard grades and polluting emission substances and

Table 15. HCHO standard grade and restriction of used area

Division		Emission consistency				
Korean standard	[mg/L]	~0.03	0.03~0.05	0.05~0.12	0.12~0.6	0.6~1.25
	Grade	Excellent	Very Good	Good	General I	General II
Investigation standard	[mg/L]	~0.005	0.005~0.03	0.03~0.12	0.12~0.30	0.30~1.25
	Grade	Grade I	Grade II	Grade III	Grade IV	Grade V
Used area	Area restriction	Whole possibility	1/2 of area possibility		1/4 of area possibility	Restrictive possibility

compared the Korean standard of green materials with those of other countries. This study also presented a new Korean architectural materials standard grade. However it is thought that the following items must be preceded first to resolve the environmental problem:

1) It is thought that total amount of TVOCs must be decreased by amending 0.03ppm: current minimum standard of HCHO to 0.005ppm. And restriction of using area about General I and General II is necessary.

2) Most of all, the certification standard grade regarding pollution emitting materials, testing method and credit verification of testing organization which are mixed complicatedly and in a non-systemic was must be unified by a national standard. Especially, the actualization of emission grade which considers IAQ consistency interrelationship after construction is necessary because HCHO and TVOCs have different harmful performances and characteristics of consistency change.

3) Realignment is needed through various documents which analyze the interrelationship of architectural materials and IAQ by season and construction work types. The improvement of house furniture which makes IAQ worse is an urgent problem. A national standard and counterplan for pollution emitting substance of furniture sold in markets and including built-in drawers are needed. The management of the manufacturing process of basic materials must be optimized.

4) Offering a certification standard system of architectural materials and useful information obtained by understanding maleficence about life products(furniture, textiles and cleaning materials) are needed.

5) Accumulation of data is needed urgently because data about correlation of pollution substances is insufficient.

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