The Relationship between Low Emission Building Material Used and Sick House Syndrome in Southern Taiwan

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SUMMARY
Taiwan is located in the subtropical climate region. It's hot and humidity on summer, in addition to the cold and humidity winter have significant effects in dwelling buildings. Single houses in southern Taiwan are renovate with large amount of building materials in indoor, which causes formaldehyde and VOCs emissions from these building materials. Although Green Building Materials Labels provide a category for Low-Emission Materials in Taiwan, but the labels are only for encouragement purposes and are rarely being used. This research investigates new, renovated and re-built dwellings with indoor air sampling method to monitor indoor environment. The Result shows ventilation rates have the greatest effect on the relationship between low-emission material used and Sick House Syndrome in southern Taiwan, followed by the quantity of low-emission material used.

KEYWORDS
Low Emission Materials, VOCs, Sick House Syndrome , Formaldehyde , renovate

INTRODUCTION
The problems with indoor environment pollution are especially severe in developed countries located in temperate regions. Existing buildings currently take up 97% of total buildings. The functions of Existing buildings decline as they approach the end of their cycles; diseases such as sick building syndrome (SBS), sick house syndrome (SHS), building related illness (BRI), etc,(Molhave,2003;Wolkoff and Nelsen,2001; Wieslander et al.,1997). Sick buildings and sick houses often develop during the "completion of new construction" or "renovation of building construction" stages(WHO,1989). Studies on Taiwanese sick houses and buildings show exceeding levels of methanol hazardous to health; the risk of cancer development by methanol is 100~1000 times greater than that of cancers caused by other mean(Wu,et al. ,2003).

Taiwan is located in the subtropical climate region. It's hot and humidity on summer, in addition to the cold and humidity winter have significant effects in dwelling buildings. Single houses in southern Taiwan are renovate with large amount of building materials in indoor, which causes formaldehyde and VOCs emissions from these indoor building materials to accumulate inside. Although Green Building Materials Labels provide a category for Low-Emission Materials in Taiwan, but the labels are only for encouragement purposes and are rarely being used. In a hot and humid environment with low ventilation, Sick House Syndrome(SHS) or Multi-Chemicals sensitivity(MCS) to chemical substances often affect dwellers. Therefore, this research investigates dwellings renovated with both Low Emission Material and High Emission Material and establishes the relation between the SHS and the quantity of the building materials used.

Figure 1. Residential building in Southern Taiwan

METHODS

(1) This research investigates new, renovated and re-built dwellings in southern Taiwan with B&K 1302/1303、SHIBATA IES 2000 to monitor indoor environment, such as TVOC, formaldehyde, CO_2, temperature, humidity, etc, for a long period of time.

(2) for testing the emission rate of formaldehyde and VOCs for low-emission wood materials in accordance with ASTM D6670-01.

(3) uses Quick Environment Exposure and Sensitivity Inventory (QEESI) questionnaire to survey dweller of sick house, and assess their MCS reactions from the chemical exposure

RESULTS

(1) Tests were conducted on 13 individual resident buildings built within 1 year or recently renovated(Table 1). Both low and high emission indoor building materials were used along with partial air conditioning system and natural ventilation. After 8 hours of testing in summer climate, the level of methanol and TVOC were 0.28 ppm and 1.61 ppm respectively. (Fig 2) Building material played an important emission factor. Resident buildings built with low emission material showed far more less emission level than those built with high emission material.

Table 1. 13 individual resident buildings studied

Building	Total floor	Structure	Flooring	wall	ceiling	Furniture*	TVOC (ppm)	HCHO (ppm)
CASE-A	5	SRC	Wood	Water paint	plaster board	Low	3.178	0.693
CASE-B	5	SRC	Wood			Low	3.163	0.656
CASE-C	5	RC	Marble			High	2.37	0.8
CASE-D	5	RC	Wood			Low	1.45	0.17
CASE-E	5	RC	Tile			Low	2.08	0.296
CASE-F	18	SRC	Marble			Low	0.972	0.063
CASE-G	6	RC	Tile			Low	0.929	0.131
CASE-H	5	RC	Wood			Low	0.837	0.0639
CASE-I	5	RC	Marble			High	1.06	0.28
CASE-J	18	SRC	Wood			Low	1.03	0.0507
CASE-L	4	RC	Wood			Low	0.994	0.153
CASE-M	4	RC	wood			Low	1.88	0.181
CASE-N	5	RC	wood			Low	1.06	0.223

(*LOW: low emission (TVOC<0.19mg/m^2*H^{-1}, HCHO<0.08 mg/m^2*H^{-1}) , *High: High emission)

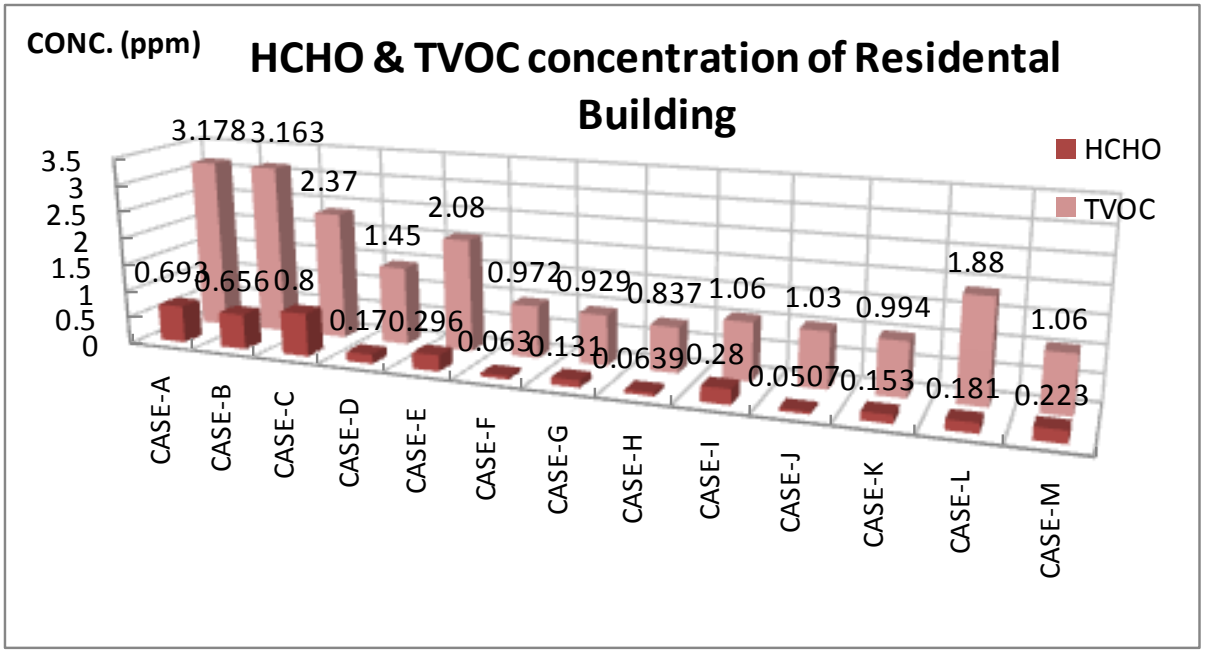


Figure 2. The mean concentration value of TVOC and HCHO in residential Buildings

(2)The loading factor of areas such as walls, wardrobe and cabinets, furniture, ceiling, etc, using low emission materials was 1.57 (m^2/m^3) with an average methanol level of 0.44 ppm, (Table 2)(Fig 3) (Fig 4) which exceeds health level. The indoor pollution mostly came from the high emission wooden floors used(Table 3).

Table 2. 6 individual resident buildings the mean concentration value of TVOC and HCHO

Building	floor	Area (m^2)	Loading Factor* (m^2/m^3)	TVOC (ppm)	HCHO (ppm)	TVOC Std	HCHO Std	TVOC (Open window)	HCHO (Open window)
CASE-A	5F	45.24	1.82	3.178	0.693	0.72	0.24	0.049	0.72
CASE-B	4F	54.38	1.92	3.163	0.656	0.649	0.228	0.05	1.68
CASE-C	2F	30.44	1.74	2.37	0.8	0.05	0.06	2.27	0.73
CASE-D	4F	31.9	1.28	1.45	0.17	0.14	0.13	0.04	1.36
CASE-H	4F	35.94	1.55	0.837	0.0639	0.09	0.05	0.04	0.8
CASE-I	2F	45.27	1.12	1.06	0.28	0.18	0.13	0.04	0.75

(* Loading Factor=Building materials Used Area / Room Volume)

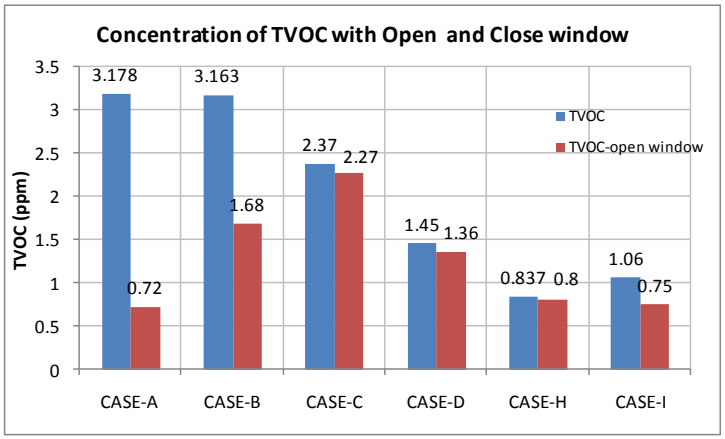


Figure 3. Concentration of TVOC with Open and Close window in residential Buildings

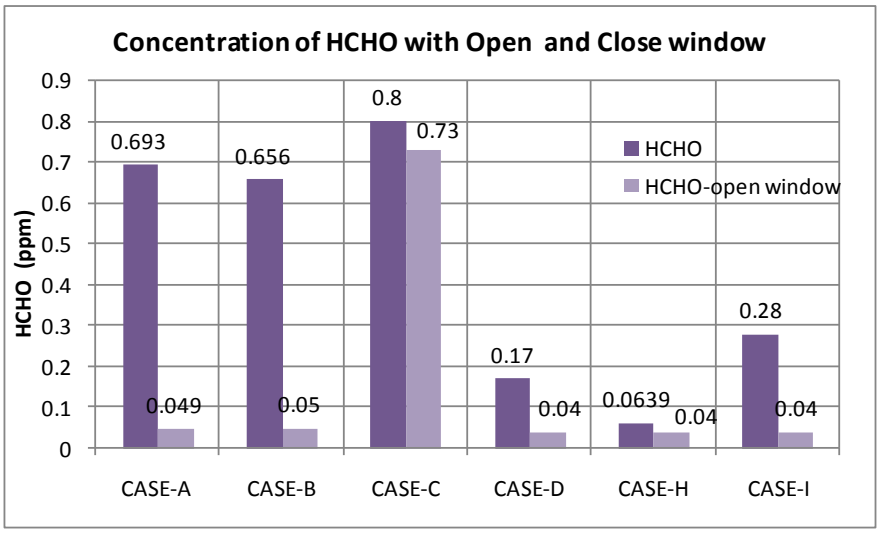
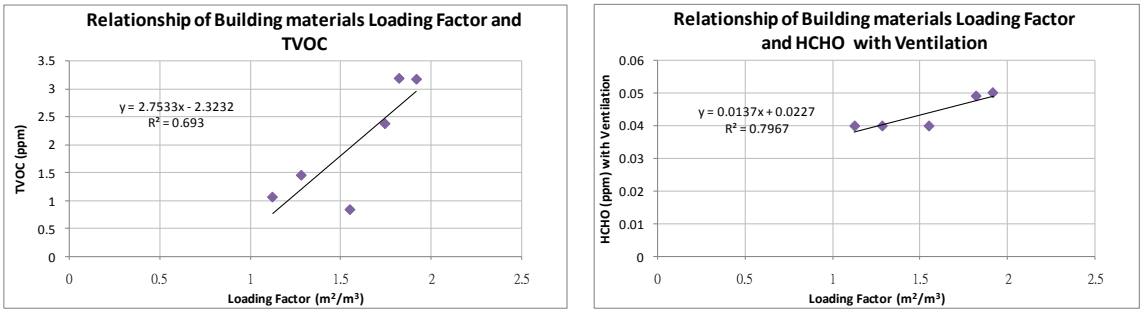


Figure 4. Concentration of HCHO with Open and Close window in residential Buildings

Tested the states of closed-window and open-window. Result shows, the low emission case, under closed window and air conditioning system turned on, had a methanol level of 2 ppm. However, once the windows were opened allowing natural ventilation, a low methanol level of 0.1 ppm was achieved in short period.(Fig 5)

Table 3. 6 individual resident buildings used Building Materials

Building	floor	Area (m^2)	Loading Factor* (m^2/m^3)	Building Materials used area (m^2)	High Emission Materials Used Ration	Low Emission Materials Used Ration	Low Emission Materials Furniture Used Ration
CASE-A	5F	45.24	1.82	206.04	29.43%	70.57%	25.99%
CASE-B	4F	54.38	1.92	260.66	25.11%	74.89%	34.62%
CASE-C	2F	30.44	1.74	132.71	23.70%	76.30%	0.00%
CASE-D	4F	31.9	1.28	112.58	25.01%	74.99%	14.38%
CASE-H	4F	35.94	1.55	150.50	10.71%	89.29%	31.44%
CASE-I	2F	45.27	1.12	149.69	39.06%	60.94%	0.00%



a) b)

Figure 5. Relationship of Building materials Loading Factor with Ventilation ,a) TVOC ,b) HCHO

(3)The research found homes that use high emission materials (>0.19mg/m^2*hr) have an average formaldehyde concentration of 0.8±0.05 ppm (8hr), TVOC concentration of 2.37±0.05 ppm (8hr) and CO_2 concentration of 480±65 ppm (8hr). The indoor concentration of formaldehyde is 0.08ppm higher than the W.H.O suggested health standard. Houses that use low-emission materials have an average formaldehyde

concentration of 0.656±0.228 ppm and 3.163±0.649 ppm for TVOC. When the air exchange rate was increased from 3.7(h^{-1})ACH to 8.5 (h^{-1})ACH, (Fig 6) the indoor chemical concentration was instantly lowered to 0.01ppm for formaldehyde and 1.5ppm for TVOC.

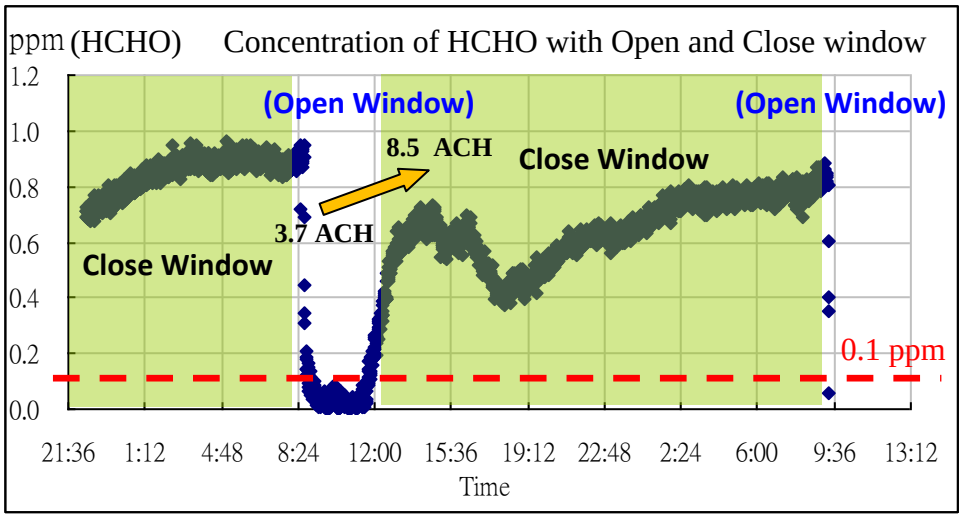
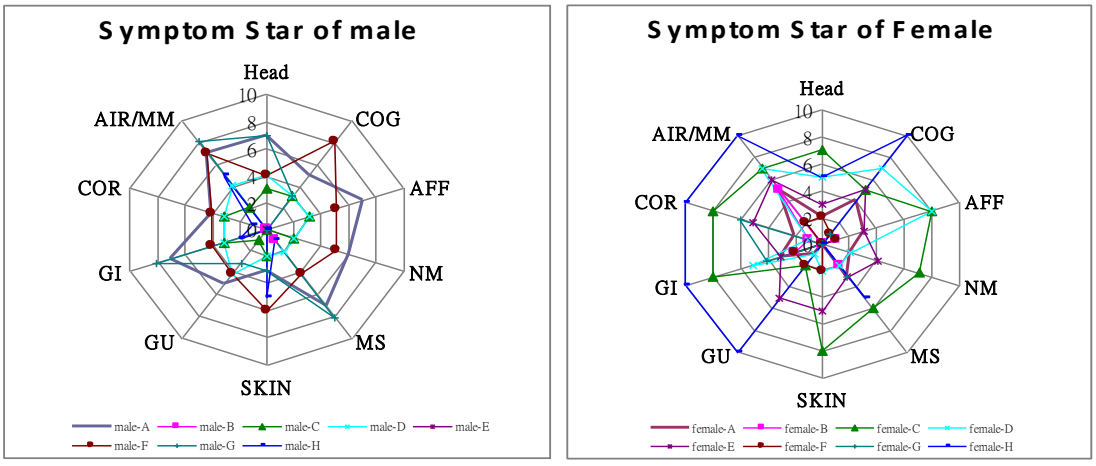


Figure 6. Concentration of HCHO when Ventilation Value Increase

(4)The research then conducted a health survey on the residents of the 6 buildings using the QEESI method. A total of 6 male and female were surveyed. Result shows, residents living in sick houses were exposed to an average allergy level between 50pt ~ 70pt. The symptoms of male and women residents included headaches, discomforts to the eye, unsteady moods, aching muscles, etc.(Fig 7) New furniture and perfume played a major role in causing chemical exposure syndromes. As for daily life allergies, the residents were most susceptible to the indoor renovation.



a) b)

Figure 7. The Symptom Star of QEESI. a）Male , b）Female.

The results of the 6 research cases show, indoor air quality is dramatically affected by the use of low emission building material. Indoor methanol level increases as the ratio of using low emission material drop below 30%. However, using low emission material does not fully guarantee low methanol level. Indoor methanol level increases over 0.1ppm as time elapses if windows were closed and the air conditioning system is turned on. Once the windows are

opened allowing natural ventilation, indoor methanol level drops below 0.1ppm within 10 minutes.

DISCUSSION

The concentration is effected by air exchange rates in houses of southern Taiwan. The air-exchange rate had the greatest effect on the concentration of formaldehyde. The source of formaldehyde concentration mainly came from the wooden floors, walls, and adhesives used. In the survey of Sick House Syndrome, dwellers in houses with high concentrations of formaldehyde and TVOC, in addition to low air-exchange rate, show the most obvious symptoms.

CONCLUSIONS

Ventilation rates have the greatest effect on the relationship between low-emission material used and Sick House Syndrome in southern Taiwan, followed by the quantity of low-emission material used. Therefore, it is concluded that in Taiwanese climate conditions, low-emission materials should be used with adequate air exchange rate, in order to reduce indoor chemical concentration and protect indoor air quality.

The OEESI test shows, residents living in buildings with a ratio of low emission material higher than 30% along with open window and natural ventilation did not show any health concern. Most residents showing severe health concerns had been exposed to cabinets and wardrobes, walls, furniture, wall paper, flooring, etc built from high emission building materials. Their symptoms remain even if the windows were opened and natural ventilation was allowed.

ACKNOWLEDGEMENT

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REFERENCES

ASTM D6670-01, 2001, Standard Practice for Full-Scale Chamber Determination of Volatile Organic Emissions from Indoor Materials/Product.

Chiang C. M., Chou P. C., and Wang W. A.l. 1996 , A study of the impacts of outdoor air and living behavior patterns on indoor air quality - case studies of apartments in Taiwan, INDOOR AIR ’96, Vol. 3, pp. 735-740.

EURO,2006,“Housing and health regulations in Europe.” EUROPEAN CENTRE FOR ENVIRONMENT AND HEALTH BONN OFFICE ,Final report.

Jarnstrom H, Saarela K, Kalliokoski P,. Pasanen A-L,2006, Reference values for indoor air pollutant concentrations in new , residential building in Finland,Atmospheric Environment,(40) 7178-7191

Molhave L. and Thorsen M.,1991, A Model for Investigations of Ventilation Systems As Sources for Volatile Organic Compounds in Indoor Climate, Atmospheric Environment, 25A ：2, 241-249.

Molhave L.,2003, Organic compounds as indicators of air pollution.,Indoor Air 13 (6),12-19

Wolkoff Peder.,1998, Impact Of Air Velocity, Temperature, Humidity, And Air On Long-Term VOC Emission From Building Products, Atmospheric Environment, Vol. 32, No. 14/15, pp. 2659-2668.

Wu P.C., Li Y.Y., Lee C.C., Chiang C.M., Su H.J. ，2003 ，Risk Assessment of Formaldehyde at Typical Office Buildings in Taiwan, 《Indoor Air》 Vol.13,No.4, pp.359-363.

Wu P.C., Li Y.Y., Lee C.C., Li F.C., Huang C.Y., Chiang C.M., Su H.J., 2005, Changing microbial concentrations associated with ventilation performance in Taiwan’s air-conditioned office buildings, 《Indoor Air》, Vo15., No.3-1, pp.19-26

WHO,World Healthy Organization ,2001, 〝Housing and health Programmes〞 Report

WHO,World Healthy Organization ,1989,Indoor Air quality : Organic Pollutants ,Copenhagen,EURO Reports and Studies No.111

WHO,World Healthy Organization ,2000,Air Quality Guidelines for Europe, second ed. European series 91.

Wolkoff,P., Nielsen,G.D.,2001 , Organic compounds in indoor air – their relevance for perceived indoor air quality?Atmospheric Environment 35,4407-4417

Wolkoff,P. ,2003, Trends in Europe to reduce the indoor air pollution of VOCs,Indoor Air (13) 5-11

Wieslander,G. Norrack,D.,Bjornsson,E.,Janson,C.,Boman,G.,1997 Asthma and the indoor environment : the significance of emission of formaldehyde and volatile organic compounds from newly painted indoor surfaces . International Archives of Occupation and Environment of Health 69,115-124