INDOOR AIR QUALITY AND INTERIOR DESIGN IN WORK PLACE RENOVATION: CASE STUDY OF OPEN PLAN OFFICE

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ABSTRACT
This paper presents about the indoor air quality (IAQ) and how to design and renovate interior space. In this case study, there are two main objectives such as to identify sources of problems and their effects towards employee's health and to provide solution by designing ventilations. IAQ issue is most common in offices or working places; there are proofs of measurement and data records in manuscript and a few renovation and completion with final space. This case study is divided into 3 sections: First, from interviews and information about SBS: Based on the case study, 8 out of 10 persons had indications of sickness such as irritation, nausea, sore throat, sneezing, runny nose, etc. without defined causes. Similarly, Co2: 214 ppm, carbon dioxide, acetic acid, formaldehyde, acetaldehyde, methyl ethyl ketone, methanol, ethanol, isopropanol, butanol, MIBK, chloroform, and trichloroethylene were more than 0.05 ppm. Second, design and management functions from ventilation simulation including selection of materials by user analysis matching with simulation data. Third, 1 (one) month after renovation is finished: Co2: 132 ppm, carbon dioxide, acetic acid, formaldehyde, acetaldehyde, methyl ethyl ketone, methanol, ethanol, isopropanol, butanol, MIBK, chloroform, and trichloroethylene were lower or equal to 0.05 ppm. Generally, there are accepted indoor air standards.

KEYWORDS: *Indoor Air Quality, Interior Design, Office Space, Renovation.*

1. INTRODUCTION

Indoor Air Quality (IAQ) in developed countries is a common concern. In the United States and Europe, there is a greatest concern on health risk problems. This becomes a significant concern when the people spend much time indoors with concentrations of pollutions (US PEA, 1997). It is not only IAQ in living place, but also in working place; it can cause sickness or occupational health problems. As an example, the employee spends time in an office for at least approximately 8-9 hrs. /day while the poor IAQ causes the employee to experience sick building syndromes (SBSs). SBSs (Sick Building Syndromes) include respiratory problem symptoms such as stuffy and irritated nose, rhinitis, cough, sore throat, shortness of breath, skin problem symptoms, and other symptoms like fatigue, headache and fever (Godish T, 1994). However, those symptoms bring serious problems and impact on health, such as, cancer from exposure to carcinogens, increased allergy and asthma from particular matter or mold, lung cancer from radon exposure, carbon monoxide (CO), carbon dioxide (CO_2) poisoning and etc. (Hewett Martha, 2009). Regarding the problem on IAQ in developing countries, there were estimated 1.6 million people died - about 3% of the global burden of disease. There was a high concentration of pollutants and it brought attention and large impact on health (WHO, 2005). There are IAQ reports in Thailand mostly showing result of complaints about indoor air in office environments and work related symptoms (Maneerat, et al., 2012). Since 1992, the legislation for energy conservation in building was implemented; a building in Thailand was adapted to energy saving mode and reduced energy loss. Air – conditioning or chilling system was typically used in approximately 50-60% of energy usage in the building. The energy management by reducing air change rate leads to occupational health problems (Maneerat, 2012). Then, the ventilation has the most important function to contribute to health problems in building (Godish T, 1994). This case study used simulation of new ventilation and design integration as a solution approach. In terms of interior design, the consideration was specific to the issue on “open plan space layout”. An open plan layout was considered in American suburban housing during 1880s in order to create open areas for many activities of every family (Peter Ward, 1999). Until nowadays, an office design supplements an idea of open plan as usual. There are some suggestions for good ventilation related to open plan that it will maximize cross ventilation opportunities by minimizing internal obstacles to breeze such as hallways and internal walls (Cairns Regional Council, 2014).

This project focused on the 8th-floor-renovated-office at King Mongkut’s University of Technology Thonburi as an implementation case theory. Therefore, the project was divided into 3 following phases:

1. Investigation process by using questionnaire to get information about the existing problems of space usage and pre-measurement about VOCs (Volatile Organic Compounds) in interior space,
2. Ventilation simulation and design integration process by collecting all information from the investigation phase and using it to analyze and build 3D model for simulation program, and use of this study as a guideline for interior renovation and construction real space, and
3. Measurement process by having the measurement in the real renovated space, that is, one month after completion of construction.

2. EXPERIMENT

2.1 Experiment apparatus

Section 1: Investigation by questionnaires and measurement. The questionnaires developed by the Department of Occupational and Environmental Medicine, Sweden (Anderson, et al., 1993) was revised to assess in indoor air problems in Bangkok Office Building (Maneerat, 2012). The questionnaire was composed of six parts such as background factors, work environment, work conditions, diseases and symptoms, past /present symptoms and other comments. The questionnaire was distributed to ten officers who have spent their time in the office for more than eight hours/day; they are women aged between 30-60 years old. The period of collecting data was in December 2015 and May 2016.

In measurement process during pre-renovation and after renovation: For monitoring indoor air quality, the measurement was conducted by utilizing FITR (Fourier Transform Infra-Red Spectrometer) method in reference to ASHREA standard. The monitoring equipment was installed in 3 points in terms of plan and average data. The air intake nozzle was located at an approximate height of 1.50 m. above the finished floor and one measurement cycle took between three to five minutes. Due to measurement condition of pre-post renovation, the windows were closed, and the mechanical ventilation and air condition system were not running.

Section 2: In ventilation simulation and design integration process, we focused on natural ventilation after air-condition systems were closed. The pre-simulation test with existing furniture layout and condition for finding an existing ventilation flow with VOCs condition and the post ventilation simulation were used to compare the quality of ventilation flow and to function as the guideline in design process.

Moreover, the design integration process still needs to consider two main issues which are air infiltration control and air removal. In this project, the designer implemented those two main issues in 3 interior design perspectives as mentioned below:

1. Existing opening position such as windows, doors, and voids used by the designer to analyze the potential of natural air ventilation,
2. Lay out of furniture that should respond to the user’s needs and improve natural air ventilation to become better, and
3. Internal wall and partition height that should be lower than 1.2 m. in order to allow the flow of ventilation (Andrew Martin & Jason Fitzsimmons, 2000).

This needs to be associated with positioning of wall and partition design also.

Section 3: Measurement after one month that the renovation is finished and keep the sample by FITR (Fourier Transform Infra-Red Spectrometer) DX 4000.

2.1.1 Data

Section 1: Based on the questionnaires from December 2015 and May 2016 with same populations, there was insignificance ($p>0.05$) which meant that the pair of data had no difference and variation; thus, similar information was provided. Then the data reported that eight out of ten officers in a work place have been sick due to SBSs. Most symptoms were eye irritation, 25%; runny nose, 75%; irritated and stuffy nose, 37.5%; heavy headed feeling, 65%; nauseous, 10%; and scaling/itching, 25%.

Section 2: Based on the first interior design perspective, the designer explored the existing condition of the site, specifically for existing external opening such as windows and doors.

From Figure 1, the designer observed that there had been windows and doors at 4 sides, located in sides A, B, C and D; thus, they would have potential to generate cross ventilation in 2 axes: A to C and B to D.

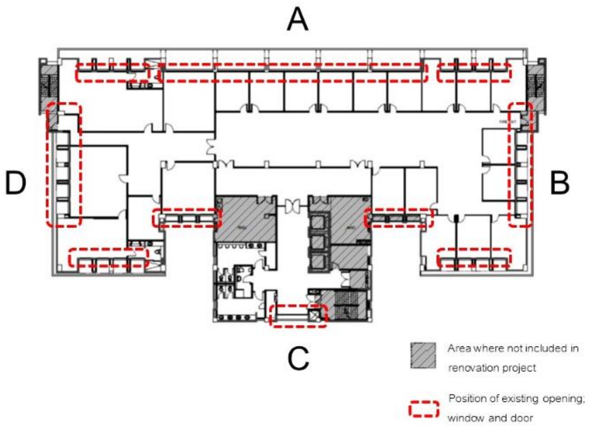

Figure 1. Existing plan shows existing position of external windows and doors.

However, the function and user requirements remained as the important conditions in this project. This affected the renovation of furniture lay out by which the entire upper part of the site (side A) area had mostly been dominated by personnel director rooms which would block natural ventilation from side A to side C when compared with cross ventilation from side B to side D (Figure 2).
Moreover, the designer designed to use the main corridor to separate staff's working area and storage area into 2 sides as it would keep the ventilation flow through side D. Furthermore, the designer tried to integrate the idea of open plan by decreasing the number of director rooms at side B and providing more open meeting areas in the middle and side B areas (Figure 2).

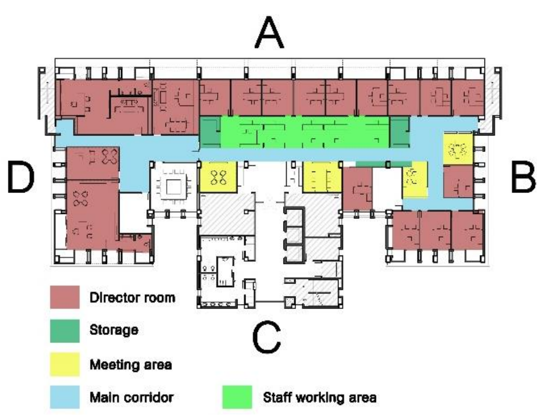

Figure 2. Furniture plan of new renovation

In this project, the designer focused on the partition and wall height intended for work station as it directly affected internal ventilation. Hence, the designer designed the work station by using low partition with 1.2 m. elevation in order to separate functions between private working area and corridor (Figure 3). These low partitions still provided substantial privacy and visual relationship through public corridor and kept the continuous wind flow from side B to side D through the existing windows and door.

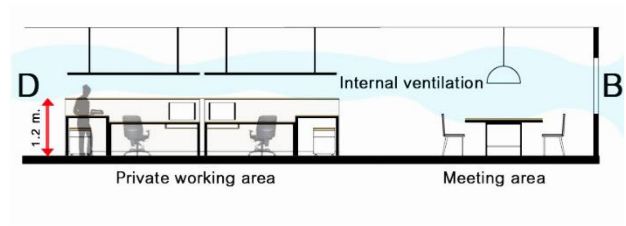

Figure 3. Internal ventilation related to partition height

Moreover, the designer provided additional exhaust fans positioned over all printer station (Figure 4). This would allow reduction of VOCs when printers are used.

Figure 4. Exhaust fan over printing station

Section 3: There were comparisons between monitoring VOCs before, post renovation and one month later in conditions such as close windows, mechanical ventilation and air condition system not running.

Based on Table 1, before renovation monitoring, VOCs components and concentrations were slightly above 0.06 ppm, made up of acetic acid, formaldehyde, acetaldehyde, methyl ethyl ketone, methanol, ethanol, isopropanol, butanol, MIBK, chloroform and trichloroethylene including carbon dioxide which was over 0.2 ppm and over risk unit.

In post renovation monitoring, the components and concentrations were slightly above 0.06 ppm, composed of methanol, ethanol, isopropanol, butanol and MIBK which was over risk unit.

In one month later monitoring, those were all individual compound concentrations which were measured below 0.06 ppm, which was lower risk unit.

Table 1. VOCs (Volatile Organic Compounds) monitoring before, post and 1 month later renovation

Component /ppm.	Before	Post	1 month later
001 Water vapor H2O	0.0039	0.0035	0.004
002 Carbon dioxide CO2	0.2114	0.0268	0.0242
003 Carbon monoxide CO	0.0022	0.0021	0.0019
004 Nitrous oxide N2O	0.0041	0.0024	0.0019
005 Nitric oxide NO	0.0099	0.0037	0.0034
006 Nitrogen dioxide NO2	0.0472	0.0151	0.0115
007 Sulfur dioxide SO2	0.0169	0.0116	0.0074
008 Ammonia NH3	0.0146	0.0038	0.0032
009 Hydrogen chloride HCl	0.0009	0.0004	0.0007
010 Hydrogen cyanide HCN	0.0122	0.0069	0.0056
011 Methane CH4	0.0071	0.0019	0.0021
012 Hexane C6H14	0.0145	0.0019	0.0021
013 Propene C3H6	0.038	0.0137	0.0091
014 1,3-Butadiene C4H6	0.037	0.0139	0.0092
015 Cyclohexane C6H12	0.0065	0.0022	0.0025
016 Benzene C6H6	0.0211	0.005	0.0022
017 Toluene C7H8	0.0211	0.0048	0.0024
018 Styrene C8H8	0.0381	0.0116	0.0114
019 Ethyl benzene C8H10	0.0206	0.005	0.0024
020 m-Xylene C8H10	0.022	0.005	0.0031
021 o-Xylene C8H10	0.038	0.0139	0.0091
022 p-Xylene C8H10	0.0381	0.0139	0.009
023 1,2,3-Trimethylbenzene C9H12	0.0259	0.0047	0.0036
024 1,2,4-Trimethylbenzene C9H12	0.0262	0.0053	0.0036
025 1,3,5-Trimethylbenzene C9H12	0.026	0.0049	0.0036
026 Acetic acid C2H4O2	0.0785	0.0369	0.0317
027 Formaldehyde CHOH	0.1337	0.0183	0.0258
028 Acetaldehyde C2H4O	0.1896	0.0876	0.0587
029 Acrolein C3H4O	0.0339	0.0101	0.0106
030 Acetone C3H6O	0.187	0.087	0.0584
031 Methyl ethyl ketone C4H8O	0.1785	0.0819	0.058
032 Methanol CH4O	0.1855	0.0856	0.0579
033 Ethanol C2H6O	0.1793	0.0811	0.0579
034 Isopropanol C3H7OH	0.1868	0.0855	0.0579
035 Butanol C4H10O	0.1802	0.082	0.0584
036 MIBK C6H12O	0.1874	0.087	0.0586
037 Dichloromethane CH2Cl2	0.0422	0.0115	0.0104
038 Chloroform CHCl3	0.1423	0.0674	0.0506
039 Trichloroethylene C2HCl3	0.0825	0.0388	0.0326
040 Bromoform CHBr3	0.0064	0.0013	0.0016
041 Naphtalene C10H8	0.0025	0.0023	0.0023
042 Ethyl acetate C4H8O2	0.0136	0.0124	0.0087
043 Butyl acetate C6H12O2	0.0091	0.0044	0.0055
044 alpha-Methylstyrene	0.0034	0.0039	0.0026
045 Limonene	0.0036	0.002	0.0021
046 alpha-Pinene	0.0028	0.0019	0.0021
047 beta-Pinene	0.0027	0.003	0.002
048 Chlorobenzene C6H5Cl	0.029	0.0013	0.0015
049 Vinyl chloride C2H3Cl	0.0086	0.0013	0.0022
050 1,1,1-Trichloroethane C2H3Cl3	0.0154	0.0015	0.0017

3. ANALYSIS

Before renovation as shown in Fig.5, there is indication of closed space with air-conditions before renovation and ventilation management from the outside environment. There are not enough ventilation or air infiltration in the side. For final solutions as shown in Fig.6, 7. There are used natural wind the window from south to ventilate space after air-conditions system closed. Table 1 shows high concentration of carbon dioxide, and other VOCs components are over risk unit in general control. Normally, CO_2 is not considered as a pollutant, but it can be used as surrogate in measuring ventilation rates in indoor air quality for investigation.

Post renovation is measured after furniture is settled. Methanol, Ethanol, Isopropanol, Butanol and MIBK are slightly above 0.06 ppm. Components of concentration are higher than the measurement during the time when the officer moved in 1 month later. The amount of concentration is on normal state. Concentration components released are harmless.

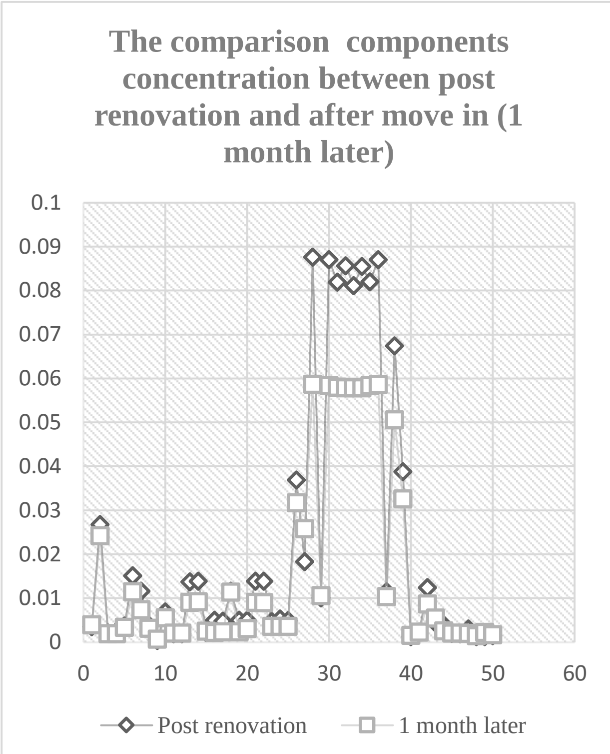

Chart 1. The comparison of concentration between post renovation and after moving in (1 month later)

4. CONCLUSIONS

The case study on indoor air quality and interior design was done. After renovation, the officer moved into the working place with new environment designed to reduce health problems. The result of 1 month after renovation showed that VOCs and CO2 in working space decreased in comparison with the post renovation's result. The main factor might come from air filtration and removal of pollutant.

Furthermore, the interior design and plan function created new activities and new environment that would prevent the workers to indulge in risk activities and produce pollution. Also, there is a need to manage and control air filtration and air removal always. Indoor air quality control and interior design have more positive impact and become effective tools for routine management.

Finally, the user is the most important factor in creating a good environment. Therefore, the concern on indoor air quality and understanding it are salient factors that help the workers to attain better life and good health.

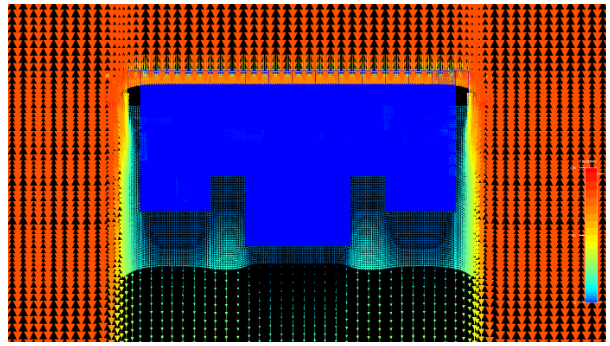

Fig 5. Closed windows / tide space

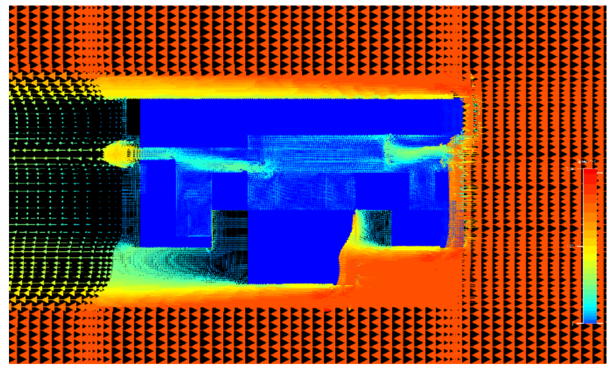

Fig 6. Open window after air condition systems are closed.

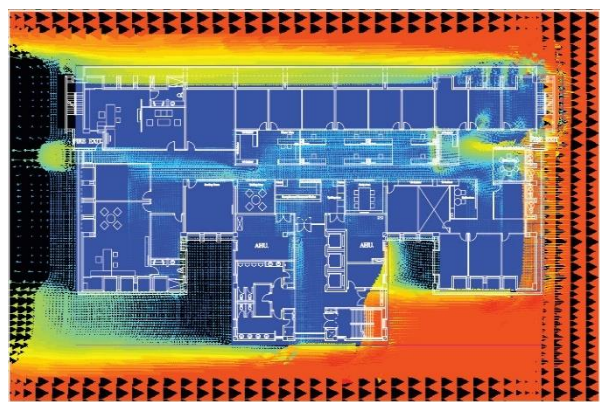

Fig 7. Plan and function after design integrate.

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PHOTOS AND INFORMATION

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