The Discussion on the relationship among indoor air quality, environmental cognition and user’s behaviour

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Abstract. Indoor Air quality inspection is an important environmental assessment work before the newly decorated space is open to use. Air quality is a dynamic factor affecting environmental health. It mainly evaluates the concentration of harmful volatile gases such as formaldehyde (HCHO), volatile organic compounds (VOCs) in the air, and the concentration of dust and other indicators. The release of these harmful substances changes with the physical factors of the environment that many studies focus on and explore the complex correlations among them. But as a user in the environment, does the behaviour also affect the air quality? In view of this, the study takes the Master's Research Office of Chaoyang University of Technology in Taichung as an example and tries to explore if the release of formaldehyde (HCHO) and volatile organic compounds (VOCs) has any correlation with the cognitive and behavioural activities of people in their environment. In addition to the measurement of the concentration of formaldehyde (HCHO) and volatile organic compounds (VOCs) under the established conditions in the process of the study, the questionnaire survey was used to know the subject's cognition of the environment, such as the freshness of the air, the ventilation of the space, etc. Through statistical analyses, However, the results showed that there were no significant differences in environmental cognition between the before and after measurements. The results also revealed that there were no change of having bad psychological feeling and only a slight change of having bad physiological feeling between the before and after measurements. The study concludes that the assessment of indoor air quality needs to be based on consideration of people's perceptions of the environment and behavioural activities, not just the level of harmful substances in the air. Through the cognition of the environment and the effective intervention in the behaviour process, the harm caused by the air quality problem to the health of the human being can be alleviated to some extent.

1. Introduction

1.1. Background

The inspection of indoor air quality is an important step to evaluate the health of indoor air before a newly decorated space is open to use. According to the air quality standards set by the local environmental department, they are usually being used as the basis for judging whether the space can
It has been proved that volatile organic compounds (VOCs), formaldehyde (HCHO) and suspended dust are harmful to human health in the air of newly decorated space [1]. So, in the air quality measurement, the values of formaldehyde (HCHO), volatile organic compounds (VOCs) and PM (particulate matter) 2.5 are the main targets. Studies have confirmed that air pollutants, formaldehyde (HCHO) and volatile organic compounds (VOCs) are mainly derived from the release of composite panels used in space [2]. According to the annual climate of Taichung City, the average temperature range from January to December is 18 °C to 30 °C [3], which is a favorable condition for promoting the continuous volatilization of formaldehyde (HCHO) and volatile organic compounds (VOCs) [4]. After the newly decorated space has been passed the test of air quality standards and put into use, it is not uncommon for users to become physically ill due to environmental changes. As air quality is one of the main factors affecting environmental health, related department needs to consider the rationality of its assessment methods and various affecting factors.

1.2. Motivation

WELL Building Standard™ (WELL) [5] was launched by The International WELL Building Institute (IWBI) in 2014, compared with the green building energy conservation and environmental protection standards established by countries in the past to save the earth's resources, many indicators about the people-oriented health have been added in WELL. WELL's seven concepts, including air quality, not only comprehensively address the energy-efficient design and operation of buildings, but also promote and influence human behaviour associated with health and well-being. 90% of human life is spent in indoor space, which has a good air quality environment and keep the indoor space healthy through the user's maintenance and management is the way of sustainable coexistence between human and environment.

In the process of air quality monitoring in space, dynamic data is a comprehensive reflection of the influence of disturbance factors such as environmental space size, congestion level, ventilation, material safety, temperature and humidity on air quality. In addition to the above influencing factors, previous studies may ignore the existence of human being as the leading role of behaviour in space, and the service object of air quality is the user in the environment. Therefore, this study attempts to investigate the correlation between the air quality indicators in space and human environmental cognition or behaviour by taking the space of the master's research office of Chaoyang University of Technology, which was newly completed in September 2018.

1.3. The image of the study

The master's research office of Chaoyang University of Technology completed the interior decoration on September 16, 2018. In the entire space, the main surrounding wall material is painted. The floor and ceiling materials are composite panels. The interior and exterior materials of the desks and cabinets are also composite panels. In addition to the above work area, the space also includes two conference areas and two leisure areas. The actual scene of the office is shown in Figure 1.

![Figure 1. Scene of the master's research office of Chaoyang University](image-url)
2.1. Measurement experiment
This study uses the instruments to measure the indoor air quality of the object space. The research office which completed decoration and cleaning work was sealed for more than 1 hour before tests. Under the established temperature conditions, the concentration of formaldehyde (HCHO) and volatile organic compounds (VOCs) in the space height of 80cm to 150cm was measured twice before and after a week using sensor-type air monitors. At the same time, the formaldehyde (HCHO) and volatile organic compounds (VOCs) concentrations were measured in the internal space of the door cabinet. For the same desk surface, the formaldehyde (HCHO) and volatile organic compounds (VOCs) concentration values with direct sunlight one hour or not were also measured. The measurements have been implemented twice in terms of before and after. The final value is obtained by averaging one hour of data acquisition for each measurement.

2.2. Questionnaire survey
A questionnaire survey was used to understand the daily behaviours such as learning, rest and communication in the experimental space of the users (N=11, male: 5, female: 6, average age: 22), as well as the cognition of the indoor environment such as air freshness and spatial ventilation, etc.

3. Results and discussion
3.1. Air quality and analysis
Through the measurement by several groups of formaldehyde (HCHO) and total volatile organic compounds (TVOC) concentrations under specific conditions in the experimental environment, the corresponding values were obtained and the comparative analysis was attempted.

| Date      | Temperature (℃) | HCHO (ppm) | TVOC (ppm) |
|-----------|-----------------|------------|------------|
| 18-Sep-18 | 28              | 0.03       | 0.26       |
| 25-Sep-18 | 28              | 0.04       | 0.38       |

Note: Air quality standards in Taiwan shows: HCHO≤0.08 (ppm), TVOC≤0.56 (ppm).

The above data shows that the HCHO and TVOC values measured in two experiments have met the air quality standards in Taiwan [6]. The value differences are quite small between the two tests. This may be explained by large space, stable ambient temperature, and insufficient measurement time interval.

| Date      | Temperature (℃) | HCHO (ppm) | TVOC (ppm) |
|-----------|-----------------|------------|------------|
| 18-Sep-18 | 28              | 0.09       | 7.76       |
| 25-Sep-18 | 28              | 0.17       | 9.98       |

Note: Air quality standards in Taiwan shows: HCHO≤0.08 (ppm), TVOC≤0.56 (ppm).

The second set of data shows that the air in the cabinet is seriously exceeded the standard of air quality in Taiwan. It indicates that the harmful gases are easy to exhibit the cumulative effect when the space is small and closed. At the same time, the HCHO and TVOC values in the cabinet (Table 1.) are much higher than the values of space air (Table 2.), because of the composite panels material for the cabinets which is the main release source of the formaldehyde (HCHO) and volatile organic compounds (VOCs).
Table 3. Measurements of HCHO and TVOC of the desk surface with sunlight or not.

| Date     | Sunlight (h) | HCHO (ppm) | TVOC (ppm) |
|----------|--------------|------------|------------|
| 25-Sep-18| 0            | 0.07       | 0.51       |
| 25-Sep-18| 1            | 0.12       | 0.67       |

The last set of data (Table 3.) shows that direct sunlight causes the desktop temperature to rise and promotes the accelerated release of the formaldehyde (HCHO) and volatile organic compounds (VOCs). The desks are layout around the surrounding walls in the room, 60% of the desks without sunlight all day and 40% of the desks with 2-3 hours of direct sunlight every day.

3.2. User’s behaviour

A questionnaire survey on the behaviour of the research office was conducted for the users (N=11) of the experimental space. The results and analysis are as follows:

3.2.1. The using behaviour of cabinets. According to the behavioural survey, cabinets are primarily used to store documents, personal items, and learning tools, each of which has the potential to be opened or repeatedly opened every day. At the same time of opening, high concentrations of formaldehyde (HCHO) and volatile organic compounds (VOCs) which are trapped in the cabinets for a certain period of time are released into the space.

3.2.2. The sitting behaviour. According to the behavioural survey, the user is in a sitting position by the desk or in the sofa for about 93% of the time in the research office, and the height of the breathing apparatus in the adult sitting position by desk or in sofa ranges from 90 cm to 140 cm. Studies have confirmed that the height range of 80 cm to 150 cm in space is a dense suspension area of formaldehyde (HCHO) and volatile organic compounds (VOCs) in the air. Therefore, users in the environment spend most of their time breathing the most polluted air.

3.2.3. The breathing behaviour. According to the behavioural survey, the height of the desktop which is also the major source of formaldehyde (HCHO) and volatile organic compounds (VOCs) is 75 cm. Combined with its release to the final suspension area, the height is 80 cm to 150 cm. In the closed space without obvious influence of ventilation on air flow, the users sit in front of the desk and breathe the volatile formaldehyde (HCHO) and volatile organic compounds (VOCs) from the desk nearly.

3.2.4. The using behaviour on the desks. The desktop temperature is positively correlated with the release rate of formaldehyde (HCHO) and volatile organic compounds (VOCs). Besides direct sunlight, according to the behavioural survey, users usually sit in front of their desks for 78% of the time, and their body contact with the desk for quite long causes heat transfer from body to the desk. Users use laptops for learning and entertainment on their desks for 71% of the time, and laptops placed on the desktop continue to dissipate heat to the desktop, causing significant temperature rise on the desktop. 77% of users drinking hot drinks, dining on the desk are the behavioural factors that cause the desktop temperature to rise. About 45% of users like taking a nap on the desk, and the behaviour of rest will make the respiratory organs close to the formaldehyde (HCHO) and volatile organic compounds (VOCs) release sources, causing people to be seriously affected by dirty air during this behaviour. The above analysis shows that whether the desk is located in a direct sunlight area, the desktop will cause different degrees of warming due to human behaviour, which promotes the volatilization of formaldehyde (HCHO) and volatile organic compounds (VOCs).

3.2.5. Behaviour caused by quiet demand. The behavioural survey shows that 80% of users have a quiet demand for the research office. Referring to the climate characteristics of Taichung City, air conditioning is required indoors for about 35% of the year. The research office is usually in a closed
and non-ventilated state. Combined with the premise that formaldehyde (HCHO) and volatile organic compounds (VOCs) act on the human body and have cumulative effects, users who have been engaged in learning activities for a long time in the space have a certain probability of causing physical discomfort. As the number of people in the enclosed space increases, the rise of the concentration of carbon dioxide (CO2) in the air due to crowding can also cause some physical discomfort. Although dioxide (CO2) is not the object of this study, it is also one of the air quality evaluation indicators.

3.3. Environmental cognition

While measuring the air quality process, an environmental cognition questionnaire on the comfort of the research office was conducted for the user of the experimental space. The results and related analysis are as follows:

Table 4. The before and after measurement of environmental cognitions

| Variable               | Mean (Before) | Mean (After) | t-value | Sig. |
|------------------------|---------------|--------------|---------|------|
| Freshness of the air   | 3.45          | 3.09         | 1.000   | .3410|
| Comfortableness of the air | 3.45       | 3.45         | .0000   | 1.0000|
| Stimulating smell of the air | 3.84        | 3.82         | .0000   | 1.0000|
| Comfortableness of the smell | 3.64       | 3.64         | .0000   | 1.0000|
| Comfortableness of feelings | 3.18        | 3.36         | -.6900  | .506 |
| Learning Efficiency   | 3.55          | 3.18         | .6900   | .506 |

Table 5. The before and after measurement of having bad psychological feeling and having bad physiological feeling

| Variable                         | % (Before) | % (After) |
|----------------------------------|------------|-----------|
| Having bad psychological feeling | No         | 27.3      | 27.3     |
|                                  | Yes        | 72.7      | 72.7     |
| Having bad physiological feeling | No         | 18.2      | 27.3     |
|                                  | Yes        | 81.8      | 72.7     |

According to the statistical analyses, the results (Table 4.) showed that there were no significant differences in environmental cognitions between the before and after measurements. The results also revealed that there were no change of having bad psychological feeling and only a slight change of having bad physiological feeling between the before and after measurements (Table 5.). But as time goes by, the volatilization of formaldehyde (HCHO) and volatile organic compounds (VOCs) will enter a recession period, and the user of the environment will not have any significant difference in the comfort.

4. Conclusions and suggestions

The purpose of this study was to investigate whether people's cognition of the environment and their behaviour in the environment have an impact on air quality in addition to environmental physical factors. After measuring the air quality of the experimental space, investigating the user's environmental awareness and usage behaviour, the conclusions are as follows:

4.1. New perspective on air quality
Air quality acts directly on people. The air quality measurement provided values as a reference is not based on the consideration of users in the environment. This kind of air quality inspection assessment is one-sided. People in different types of space have different behaviours and activities, which requires detailed analysis of the relationship between behaviours and air quality, rather than using the same standards.

4.2. Correlation between behaviour and indoor air quality
In addition to considering the direct correlation between human spatial behaviour interaction and indoor air quality, the indirect correlation between the two is also an important factor leading to air quality, while the temperature is an important indirect factor of human behaviour activity between formaldehyde (HCHO) and volatile organic compounds (VOCs) release.

4.3. Correct cognition and behaviour improve air quality
Timely ventilation is an effective way to improve air quality. The movement of air flow can interfere with the air in the small breathing area in front of the desk and accelerate the dilution of formaldehyde (HCHO) and volatile organic compounds (VOCs) concentration. At the same time, under the condition of no one in the research room, the closed cabinets should be opened while opening the windows for ventilation, and the harmful gas gathered in the cabinets should be discharged in time.

Under the premise of the budget, furniture such as desks and storage cabinets can be replaced with composite panels with high environmental protection level instead of ordinary ones.

Based on the positive correlation between temperature and the release of formaldehyde (HCHO) and volatile organic compounds (VOCs), the blinds can be added to reduce the desktop heating caused by direct sunlight. In order to reduce the long-term contact between the heat source and the desktop, excessive heat transfer to the desktop can be avoided by adding a laptop stand or a heat sink. Hot drinks and food should use trays or heat insulators to reduce heat transfer.

4.4. The disadvantages of this study and further improvement
The purpose of this preliminary study is to raise questions and lead to thinking. Because this research space is exclusive to graduate students in architecture department, the number of users of the experimental space is not big enough, and this experiment adopts the measurement method of before and after comparison, so that the number of sample is limited. It is suggested to try to expand the sample size in future research. The preliminary experiments involved in the process have the disadvantages of single type monitoring equipment and insufficient monitoring time span. The follow-up will be subject to careful experimental design of the research, and the user's behavioural activities need to be reasonably counted and quantified to obtain more accurate experimental results and detailed data analysis.

5. References
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