Study of the different Cutoff Point of the QEESI Questionnaire as a Screening Tool for Sick Building Syndrome Diagnosis in Taiwan

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Abstract
The Indoor Air Quality Management Act in Taiwan formally came into effect in November 2012 to protect public health. Studies have reported that public and private buildings in Taiwan currently have been facing pollution problems regarding indoor air quality (IAQ), which threatens the health of occupants.1, 2

To clarify the correlation between the indoor air environment and influences on human health by using an economical and efficient method, the United States, Japan, and other countries use screening tools first to understand the health effects on building occupants, and, subsequently, adopt appropriate examination methods once primary influential factors are identified. To enable the integration of research results from Taiwan with those from abroad, this study introduced the quick environmental exposure and sensitivity inventory (QEESI) questionnaire, which the United States, Japan, and other countries have implemented for many years. In this study, the applicability of the QEESI questionnaire in screening sick building syndrome (SBS) in Taiwan was examined by observing the association between the QEESI score and IAQ survey results. The results from Taiwan were compared with those from the United States and Japan. A questionnaire concerning personal and residential environmental factors was also incorporated to identify factors with significant predictive power for the QEESI score.

The following conclusions were derived from this study.
1. The correlation between the IAQ survey values and the QEESI score indicates the capability of the QEESI questionnaire to identify problems related to sick buildings and to serve as a screening tool for SBS in Taiwan.
2. Currently, using the cutoff points proposed by Japanese researchers3-5) to judge the QEESI score can optimally enhance the correlation between the IAQ survey results and the QEESI scores for people in Taiwan.
3. Eight factors with significant predictively power for the QEESI score include gender, age, an understanding of the mechanism of SBS occurrence, allergy history, building type, air ventilation, the use of deodorants and fragrances, and smoking. These factors can serve as key points when performing on-site examinations.

Keywords: QEESI questionnaire; SBS diagnosis; QEESI score; Cutoff Point; concentration in air

1. Introduction
The Indoor Air Quality Management Act in Taiwan came into effect in November 2012 to protect public health. In addition, studies have reported that public and private buildings in Taiwan currently have been facing pollution problems regarding indoor air quality (IAQ), which threatens the health of occupants.1, 2

Clarifying the correlation between indoor air environments and influences on human health requires precise IAQ tests; however, implementing comprehensive testing is time consuming and highly expensive. By using screening tools first to understand health effects on building occupants and subsequently adopting appropriate examination methods once key influential factors are identified, improvement countermeasures can be determined economically and efficiently.
To enable the integration of research results obtained in Taiwan with those reported in international studies, this study introduced the quick environmental exposure and sensitivity inventory (QEESI) questionnaire, which the United States, Japan, and other countries have implemented for several years. The content design of the QEESI questionnaire is stable, and the Chinese version has passed reliability and validity tests.

In this study, the applicability of the QEESI questionnaire in screening sick buildings in Taiwan was examined by observing the correlation between the QEESI score and IAQ survey results. A questionnaire concerning personal and residential environmental factors was also incorporated to identify factors with significant predictive power for the QEESI score. These factors provide key points when performing on-site investigations.

In addition, the QEESI questionnaire can be used in national surveys, in which the results can become crucial references in fields related to architectural research and for policymaking regarding national health insurance programs.

2. Research Design

During the first stage of this study, a nationwide anonymous survey containing the QEESI questionnaire (Chinese version) and a questionnaire on personal and residential environmental factors were conducted. Eight-hundred and fifty questionnaires were distributed and 678 questionnaires were returned (resulting in a response ratio of 80%). After excluding the invalid answers, namely answers that were incomplete for one or more questions, the number of valid questionnaires was 658 (resulting in an effective response ratio of 77%).

During the second stage, IAQ surveys of residences and on-site interviews were conducted. Of the 658 people who returned valid questionnaires during the first stage, those who expressed that they were "willing to cooperate with an IAQ test" were considered possible interviewees. From these samples, the study selected 65 people from 40 households who, at the time the survey was conducted, lived in a new or newly renovated (within 5 years) building in Tainan or Kaohsiung City, where the weather is hot and humid throughout the year, to participate in the interview. The results of the IAQ survey have been published.

During the third stage of the study, the 65 participants were categorized based on their QEESI scores by using cutoff points established in the United States, Japan, and Taiwan. The correlations between the IAQ survey values and the QEESI scores were simultaneously examined to verify the applicability of the QEESI questionnaire for use as a screening tool in diagnosing sick buildings in Taiwan. Moreover, the current optimal cutoff points for the QEESI score as used in Taiwan were identified.

Finally, during the fourth stage, using the 658 valid questionnaires, statistical methods were adopted to identify factors with significant predictive power for the QEESI score. These predictors, which included significant environmental factors that affect human health, can serve as key points when conducting on-site examinations.

The following sections describe the results obtained during the third and fourth stages of this study.

3. Research Methodology
3.1 Questionnaire Survey
3.1.1 Distribution and Recovery of the Questionnaires
An anonymous survey was conducted after the researchers received training from the Institutional Review Board because of ethical considerations. The questionnaire survey had the following characteristics:

1. Time of survey: The survey was administered from November 2008 to December 2008.
2. Survey participants: Because the study questionnaire contained six pages, purposive sampling was adopted to prevent people who could not understand the survey topics and items from participating in the survey and influencing the results. The study researchers were assisted by colleges, public and private offices, and interior decoration companies or relevant vendors to obtain consent from the survey participants. Subsequently, methods for completing the questionnaire were explained to the participants.

3. Methods of questionnaire distribution and recovery: To enhance the valid questionnaire recovery rate, questionnaire distribution and recovery was conducted through personal visits (as often as possible). When this method was unfeasible, questionnaires were sent and returned through registered mail. Regarding the public and private sectors, relevant contact persons were commissioned to explain, distribute, and collect the questionnaires.

3.1.2 Questionnaires

Two types of questionnaire were used. One was used to collect information concerning the occupants and their living environments. (Table 1.) The other was the QEESI questionnaire (Chinese version, Table 1. Survey Items Concerning Volunteers and Their Living Conditions)

<table>
<thead>
<tr>
<th>Survey Items (Number of Questions)</th>
<th>Survey Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Information (7)</td>
<td>Gender, age, allergy history, family history, time spent in the home, understanding SBS</td>
</tr>
<tr>
<td>Information on the Residential Building (6)</td>
<td>Building style, construction year, number of stories, reasons for renovation, floor area, floor materials, ventilation system, and so forth</td>
</tr>
<tr>
<td>Indoor Environmental Conditions and Living Style (6)</td>
<td>Number and type of pets; use of insecticides, aromatics and/ or incense; amount of tobacco smoked</td>
</tr>
<tr>
<td>Surrounding Outdoor Environments (2)</td>
<td>Types of sites surrounding the surveyed house</td>
</tr>
</tbody>
</table>
2.), which comprises five subscales, with 10 questions in each subscale, constituting a total of 50 questions. Among these subscales only Subscale 4, "masking," can be answered with "yes" or "no," which receive a score of one and zero, respectively. Other subscale answers were scored from zero to 10 (zero: unaffected, five: medium, 10: severely affected). The assessment is based on a score ranging from zero to 100.

The original English version,67 translated Japanese version,3-5 and traditional Chinese version8 (used in this study) of the QESI passed reliability and validity tests, indicating that the questionnaires possessed a precise design, complete structure, and applicability to diverse environments and populations. Nevertheless, the questionnaires were distributed to people from different groups, who demonstrated differences in external living environments, internal culture and habits, and ethnicity. Consequently, varying subscales and cutoff points for effectively diagnosing SBS were generated for the three versions of the QESI questionnaire based on local residents. The differences in the subscales and cutoff points are listed in. (Table 3.)

3.3 Methods for Classifying QESI Scores Based on Different Cutoff Points

(1) English version: Effective subscales and cutoff points for diagnosing SBS in citizens of the United States were the "Chemical Intolerance Scale", (Q1): with a cutoff point of 40 points; "Symptom Severity Scale" (Q3) - with a cutoff point of 40 points; and: "Masking Index" (Q4) : with a cutoff point of 4 points.

Furthermore, the QESI scores can be used to evaluate a person's risk of SBS or multiple chemical sensitivity (MCS), which is classified into four stages of "Very Suggestive", "Somewhat Suggestive", "Not Suggestive" and "Problematic". Symptom Severity Scale (Q3): is the primary indicator for this classification (Table 4.).

(2) Japanese version: The effective subscales and cutoff points for diagnosing SBS in Japanese citizens were the Chemical Intolerance Scale (Q1), with a cutoff point of 40 points. Symptom Severity Scale (Q3), with a cutoff point of 20 points; and: Life Impact Scale (Q5), with a cutoff point of 10 points. Moreover, based on QESI scores, a person's risk of SBS or MCS could be categorized into three stages of "probable," "vulnerable," and "healthy." (Table 5.)

Table 4. Screening and Categorization Benchmarks for SBS/ MCS Based on the QESI Questionnaire (Japanese Version)

<table>
<thead>
<tr>
<th>Category</th>
<th>Q3</th>
<th>Q1</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Suggestive</td>
<td>≥ 40</td>
<td>≥ 40</td>
<td>≥ 4</td>
</tr>
<tr>
<td>Very Suggestive</td>
<td>≥ 40</td>
<td>≥ 40</td>
<td>&lt; 4</td>
</tr>
<tr>
<td>Somewhat Suggestive</td>
<td>≥ 40</td>
<td>&lt; 40</td>
<td>≥ 4</td>
</tr>
<tr>
<td>Not Suggestive</td>
<td>≥ 40</td>
<td>&lt; 40</td>
<td>&lt; 4</td>
</tr>
<tr>
<td>Problematic</td>
<td>&lt; 40</td>
<td>≥ 40</td>
<td>≥ 4</td>
</tr>
<tr>
<td>Problematic</td>
<td>&lt; 40</td>
<td>≥ 40</td>
<td>&lt; 4</td>
</tr>
<tr>
<td>Not Suggestive</td>
<td>&lt; 40</td>
<td>&lt; 40</td>
<td>≥ 4</td>
</tr>
<tr>
<td>Not Suggestive</td>
<td>&lt; 40</td>
<td>&lt; 40</td>
<td>&lt; 4</td>
</tr>
</tbody>
</table>

Table 5. Screening and Categorization Benchmarks for SBS/ MCS Based on the QESI Questionnaire (Japanese Version)

<table>
<thead>
<tr>
<th>Category</th>
<th>Q1</th>
<th>Q3</th>
<th>Q5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probable</td>
<td>≥ 40</td>
<td>≥ 20</td>
<td>≥ 10</td>
</tr>
<tr>
<td>Probable</td>
<td>≥ 40</td>
<td>≥ 20</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>Probable</td>
<td>&lt; 40</td>
<td>≥ 20</td>
<td>≥ 10</td>
</tr>
<tr>
<td>Vulnerable</td>
<td>≥ 40</td>
<td>&lt; 20</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>Healthy</td>
<td>&lt; 20</td>
<td>&lt; 10</td>
<td>&lt; 10</td>
</tr>
</tbody>
</table>

(3) Chinese version: Currently, no medical doctor researching SBS is available in Taiwan, and the QESI questionnaire is still in the experimental stages. However, because this study focused on the correlation between the QESI score and the concentration of indoor hazardous substances in the air, the standards for the Chinese version of the QESI questionnaire were also incorporated for cross-country comparisons.

The questionnaire and the classification of groups or categories is based on three subscale cutoff points. The method for categorizing groups is described as follows:
None: None of the scores for the three subscales exceed the cutoff points. That is, Q2 < 25 points, Q3 < 21 points, and Q5 < 13 points.

One: One of the scores among the three subscales exceeds the cutoff point. For example, Q2 > 25 points, Q3 > 21 points, or Q5 > 13 points.

Two: Two of the scores among the three subscales exceed the cutoff points. For example: Q2 > 25 points and Q3 > 21 points, or Q2 > 25 points and Q5 > 13 points.

Three: All the scores of the three subscales all exceed their corresponding cutoff points. That is, Q2 > 25 points, Q3 > 21 points, and Q5 > 13 points. This group contains people who have the highest QEESI scores. (Table 6.)

### Table 6. Screening and Categorization Benchmarks for SBS/MCS Based on the QEESI Questionnaire (Chinese Version)

<table>
<thead>
<tr>
<th>Category</th>
<th>Q2</th>
<th>Q3</th>
<th>Q5</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>&lt;25</td>
<td>&lt;21</td>
<td>&lt;13</td>
</tr>
<tr>
<td>One</td>
<td>≥25</td>
<td>≥21</td>
<td>≥13</td>
</tr>
<tr>
<td>Two</td>
<td>≥25</td>
<td>≥21</td>
<td>≥13</td>
</tr>
<tr>
<td>Three</td>
<td>≥25</td>
<td>≥21</td>
<td>≥21</td>
</tr>
</tbody>
</table>

### 3.4 Observations of QEESI Categories and IAQ Survey Values

Because the survey targets were residences that were in use, and 40 out of 65 residences were surveyed, one residence could contain more than one representative who answered the questionnaire. However, only the highest QEESI score obtained within a residence was used for grouping and classification. For example (English version), for a residence comprising four residents, if one resident was grouped as N (not suggestive), two were P (problematic), and the other was V (very suggestive), the residence would be considered group "V." (Table 7.)

### Table 7. Classification of the Residences by Each Cutoff Point

<table>
<thead>
<tr>
<th>Cutoff point</th>
<th>USA</th>
<th>JP</th>
<th>TW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resident 1</td>
<td>Not suggestive</td>
<td>Healthy</td>
<td>None</td>
</tr>
<tr>
<td>Resident 2</td>
<td>Problematic</td>
<td>Vulnerable</td>
<td>One</td>
</tr>
<tr>
<td>Resident 3</td>
<td>Problematic</td>
<td>Vulnerable</td>
<td>Two</td>
</tr>
<tr>
<td>Resident 4</td>
<td>Very suggestive</td>
<td>Probable</td>
<td>Three</td>
</tr>
<tr>
<td>Overall Classification of the residents</td>
<td>Very suggestive</td>
<td>Probable</td>
<td>Three</td>
</tr>
</tbody>
</table>

After categorizing the 65 participants based on their QEESI scores, their residences were then classified into respective categories. Subsequently, the mean IAQ concentration for each group (N, P, S, and V were used as the x axis) was graphed using a trend line to observe the relationship between the QEESI scores and the concentration of indoor air pollutants.

### 4. Survey Results

#### 4.1 Predictive Capability of Personal and Residential Environmental Factors for the QEESI (Chinese Version) Score

Based on the data collected from the 658 valid questionnaires, multiple regression analysis was performed, with personal and residential environmental factors as the independent variables, and the individual scores for the QEESI subscales as the dependent variables. In this study, eight items were determined to significantly predict the QEESI (Chinese version) score of the user, as described as follows. The personnel who provide SBS diagnosis services can focus on these items during on-site examinations to improve work efficiency. (Table 8.)

1. **Resident Attributes:**
   a. Gender was a significant predictor of "Other Intolerance Scale" (Q2) and "Symptom Severity Scale" (Q3): The scores of the female participants were higher than those of the male participants, and the results were the same as the results of research conducted in Japan.
   b. Age: Age < 20 years was a significant predictor of "Other Intolerance Scale". (Q2)
   c. Understanding of the mechanism of SBS occurrence significantly predicted "Life Impact Scale". (Q5)
   d. Allergy history was a significant predictor of "Other Intolerance Scale". (Q2) : "Symptom Severity Scale" (Q3), and "Life Impact Scale" (Q5). The scores of participants with a history of allergies were higher than those of people without allergies, which is in accordance with the results of research conducted in Japan.

2. **Residence Characteristics:**
   a. Building type could significantly predict Chemical Inhalant Intolerance Scale (Q1) and: Life Impact Scale (Q5).
   b. Air ventilation was a significant predictor of Chemical Inhalant Intolerance Scale (Q1).

3. **Indoor Environment:**
   a. The use of deodorants and fragrances was a significant predictor of "Symptom Severity Scale" (Q3).
   b. The use of tobacco significantly predicted "Chemical Inhalant Intolerance Scale" (Q1). The scores of nonsmokers were higher than those of smokers, which was the same as the results of research conducted in Japan.

4. **Surrounding Environment:**
   None of the factors for surrounding environments were significantly predictive of any of the subscales in the Chinese version of the QEESI questionnaire, suggesting that different residential surroundings did not significantly influence the QEESI score of the respondents. A reason for this tendency could be that the study participants lived in areas (regardless of whether these areas were urban or rural) under similar air pollution conditions, or that, for most of the study respondents, the indoor air pollution in their residence...
was caused mainly by indoor factors. Specifically, the indoor/outdoor (I/O) ratio was greater than 1. These statistical results do not imply that outdoor air quality should be disregarded. Instead, to accurately identify environmental factors that affect the health of residents, the outdoor air quality should be measured during IAQ testing and the I/O ratio should be obtained to identify the sources of pollution correctly.

4.2 The Correlation Between the QEESI Score Categories and IAQ Survey Values

This study adopted the following standards for measuring IAQ: formaldehyde (HCHO) concentrations of 100µg/m$^3$ (Ministry of Health, Labour and Welfare, Japan; Environmental Protection Administration, Taiwan) and a total volatile organic compound (TVOC) concentration of 400µg/m$^3$ (temporary standard; Ministry of Health, Labour and Welfare, Japan).

The researchers used statistical figures to depict the test concentration values in the four QEESI groups and observe whether the concentration of indoor air pollutants increased as the group increase. (N= Not Suggestive, S= Somewhat Suggestive, P= Problematic, V= Very Suggestive, N<P <S<V).

4.2.1 Classification Using the Cutoff Points Established in the United States

Among the 40 study residences, 18 residences (45%) were categorized as the "Not Suggestive" group (Fig.1.).

Regarding the concentration of hazardous substances (µg/m$^3$), the mean/maximal values of HCHO and TVOC were 44/135 and 284/599, respectively. One (5.5%) residence exceeded the standard for HCHO, and three (16.7%) exceeded that for TVOC.

Three residences (7%) were categorized into the "Problematic" group, with the mean/maximal concentration of hazardous substances HCHO and TVOC at 39/49 and 376/430 (µg/m$^3$), respectively. No residence (0%) exceeded the standard for HCHO, and one (33%) exceeded that of TVOC.

Eleven residences (28%) were categorized into group "Very Suggestive", with the mean/maximal concentration of hazardous substances HCHO and TVOC at 55/107 and 331/684 (µg/m$^3$), respectively. One (12.5%) residence exceeded the standard for HCHO, and two (25%) exceeded that for TVOC.

Bar charts of the tested TVOC and HCHO concentrations for the four QEESI groups suggested that the QEESI scores increased as the TVOC concentration increased, and this upward trend was more obvious than that for the HCHO concentration. The $R^2$ values for the TVOC and HCHO trend lines were 0.44 and 0.63, respectively (Figs.2. and 3.).
4.2.2 Results of Using the Cutoff Points Established in Japan for Classification

Three residences (7%) were categorized into the "Healthy" group. Regarding the concentration of hazardous substances observed in these residences (µg/m³), the mean/maximal concentration of HCHO and TVOC were 26/37 and 224/200, respectively. None (0%) of the residences exceeded the standards for HCHO or TVOC.

Thirteen residences (33%) were in the "Vulnerable" group, with the mean/maximal concentration of hazardous substances HCHO and TVOC at 48/135 and 298/599 (µg/m³), respectively. Two (15%) residences exceeded the standard for HCHO, and three (23%) exceeded that for TVOC.

Twenty four residences (60%) were in the "Probable" group, with the mean/maximal concentration of hazardous substances HCHO and TVOC at 52/143 and 352/842 (µg/m³), respectively. One (4%) residence exceeded the standard for HCHO, and seven (29%) exceeded that for TVOC.

Bar charts of the tested HCHO and TVOC concentrations based on the three QEESI groups showed that the QEESI scores increased as both the HCHO and TVOC concentrations increased. These results were more obvious than the results determined using the USA cutoff points for classification. The $R^2$ values for the TVOC and HCHO trend lines were 0.99 and 0.86, respectively (Figs. 5 and 6.)

4.2.3 Results of Using the Cutoff Points Established in Taiwan for Classification

Forty residences were analyzed in this study:

Eight residences (20%) were categorized into the "None" group. Regarding the concentration of hazardous substances observed in these residences (µg/m³), the mean/maximal concentration of HCHO and TVOC was 43/107 and 327/486, respectively. One (12.5%) residence exceeded the standard for HCHO, and one (12.5%) exceeded that for TVOC.

Twelve residences (30%) were in the "One" group, with the mean/maximal concentration of hazardous substances HCHO and TVOC at 55/144 and 327/599 (µg/m³), respectively. Two (15%) residences exceeded the standard for HCHO, and four (31%) exceeded that for TVOC.

Eight residences (20%) were in group "Two", with the mean/maximal concentration of hazardous substances HCHO and TVOC at 53/95 and 393/842 (µg/m³), respectively. No (0%) residence exceeded the standard for HCHO, whereas three (37.5%) exceeded that of TVOC.

Twelve residences (30%) were in the "Three" group, with the mean/maximal concentration of hazardous substances HCHO and TVOC at 53/95 and 393/842 (µg/m³), respectively. No (0%) residence exceeded the standard for HCHO, whereas three (37.5%) exceeded that of TVOC.
substances HCHO and TVOC at 51/144 and 336/544 (µg/m³), respectively. One (8%) residence exceeded the standard of HCHO, and three (25%) exceeded that of TVOC (Fig.7.).

Eight factors with significant predictively power for the QEESI score include gender, age, an understanding of the mechanism of SBS occurrence, allergy history, building type, air ventilation, the use of deodorants and fragrances, and smoking. These factors can serve as key points when performing on-site examinations.

Acknowledgments

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References