Investigation of the Relationship between Noise Controls and Human Behaviours in the General Hospital Buildings of the Central Taiwan

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Noise problem in hospitals is a serious issue. There are two noise sources inside and outside the hospitals. For example, all electromechanical equipment (HVAC system, Laundry… etc.) is noise source of inside the hospital. Outside noise source of the hospital is also important as traffic could cause a lot of high noise level inside the hospital. It can cause nuisance to the doctor, staff and to the patients. People at hospitals need to get rest more than anyone else, but the present noise situation could be very harmful to the patients. In this study, a series of noise level measurements at 11 comprehensive hospitals (single lobby) in central Taiwan have been executed. We found the noise levels are averaged from 60 to 65 dBA through the noise level of equivalent quantity (Leq) using 15 minute integration for 24 hours period. These noise levels are higher than 55 dBA of Noise Control Standards in Taiwan. The noisy level questionnaire was employed to survey how noisy does in the hospital's lobby hall, too. We found the noisy levels derived from psychological survey are correlated well with the noisy cumulated rate (NCR), and the complex functioning of architectural planning in lobby may be in accordance with them.

Key words: Subjective preference, ASW

1. Introduction

People in the hospital require tranquility more than others and noise may cause greater damages to the patients. In general hospital buildings, hospitals need to maintain enormous mechanical facilities, which are the main source of noise in hospitals. Besides the noise made during the daily routine medical treatment activities, such as the noise of carts, furniture, beds, interviews, or even TV, the easy-to-wash hard flooring used in hospitals to prevent the growth of bacteria also increases the decibel value of noise in hospitals. In addition, for the convenience of patients, staff, and visitors to the hospital, more and more convenience stores are opened in hospital lobbies, which in some ways change the complexity of human behaviors in the lobbies. With regard to the ambient noise of hospital buildings, we divide the discussion on noise into two parts: indoor measurement and a psychology questionnaire survey of noise. The subjects under investigation include factors such as the electro-mechanical equipment in hospital lobbies (HVAC systems, laundry rooms, etc.) and noise-related behaviors (including those done by medical personnel, patients, and other staff in the auxiliary spaces of lobbies).

Noise hazards of 11 general hospitals (single buildings) located in central Taiwan was investigated in this study. The results indicate that there is a very high correlation coefficient ($r = 0.826$, $R2 = 0.70$) between the noise concentration rate of noise events and the degree of being agitated by noise in lobbies as shown in the results of the noise psychology questionnaires. Also, a strong connection is observed in the degree of being agitated by noise in lobbies and the diversification of human behaviors in the lobbies. That is, the diversification of lobby functions is one of the reasons that make people agitated by noise.

2. Review prior study results of hospital noise

Professor Yukiko Yamada (1987) at School of Science and Technology, Meiji University has reported the evolution of sound environment in Japanese hospitals. The noise value was measured in 26 hospitals located in the 23 municipalities of Tokyo. The noise volume was recorded based on an average time length of 10 minutes because her study results indicate that an equivalent continuous noise level (LeqA) of 10-15 minutes is the most appropriate for investigating the behavior characteristics of hospital noise. The investigation results

indicate that few hospitals meet the environment quality standards.

Yamada (2003) classified the departments of hospitals into five categories: patient room departments, outpatient departments, external space departments, supply departments, and management departments (according to New Building Science Series 31: Hospital Buildings). She conducted a thorough investigation into the noise conditions based on the outpatient class space of the hospitals, and the questionnaire survey was done primarily among outpatients and medical personnel. Six waiting spaces of three hospitals were investigated for their interior decoration materials and layout plan. All six spaces were not provided with background music facilities. The noise value was measured using the 15-minute equivalent continuous noise level (LeqA) as the reference. To meet the requirements of the regulations of ambient noise control, the measuring time was 06:00-22:00 for the daytime and 22:00-06:00 for the nighttime so as to facilitate comparison with the indoor noise standards (general areas) specified in the regulations, 45 dB and 35 dB respectively. The measurement results indicate that the noise volume of each space is higher than 45dB, the value specified in the regulations, on average during the daytime, and the difference between the noise volume of the daytime and that of the nighttime is more than 15 dB on average due to the outpatient time. As to the questionnaire survey, five scales of reply were provided: quiet, normal, not affected, a little interfered, and noisy. The five scales of reply were also given for the 12 categories of events respectively, including the talking sound and walking sound of patients. The results indicate that the sounds of children and the talking sound of patients were considered the loudest, followed by the sound of printers. However, there are certain differences between the opinions of outpatients and medical personnel, particularly with regard to item 1 and 2. The noise was also louder for medical personnel than for outpatients.

3. Subjects and methods

3.1 Measuring positions and hospital samples

The actual measurement of indoor/outdoor noise included: (1). Two points in the waiting space that are most frequently used by people coming to the hospital (the two ends of a diagonal line chosen from the side by the counter in the hospital lobby) are selected for indoor measurement, and the midpoint of the diagonal line is also chosen for measurement when the area of the lobby exceeds 300 m2; (2). One fixed point on the lot line at the front side of the building facing the main road that does not hinder traffic circulation and is at least 1m away from the outer wall of the building is selected as the outdoor measuring point and the measurement is made simultaneously with the two points inside the lobby. When the outer wall is adjacent to the road or when the distance between the wall and the road is within 1m where the microphone cannot be installed, another side of the outer wall shall be chosen and the measurement shall be made 1m away from the outer wall in principle. In accordance with the requirements of WHO, the noise shall be measured 24 hours a day; the 15-minute continuous equivalent continuous noise level (LeqA: FAST) is obtained for data recording with the limit values (Lmax(A): FAST) of the measuring points and the events are recorded for analysis. The accuracy of the measuring devices must conform to the requirements for noise meters specified in IEC651 TYPE 1 and the ambient accuracy calibration procedures shall be done properly.

The hospitals measured are mostly general hospitals (coded A...K) and they all underwent the screening procedure. Eleven general metropolitan hospitals located in central Taiwan are selected as the investigation objects to achieve the statistical reliability. For the sake of fairness of measurement, the buildings of general hospitals chosen are mostly single buildings (including an inner court design) and large hospital lots with multiple buildings are excluded.

3.2 Measurement standard of indoor noise

Indoor noise is measured abroad mainly according to ISO 1996-1:2003 Acoustics—Description, measurement and assessment of environmental noise – Part 1: Basic quantities and assessment procedures.

a. Measurement standards

Before and after the measurement, the tolerance of the indicated value of the measuring device was calibrated with the sound calibrator to no more than 2 dB(A), or the measurement would be considered invalid. Departments are possible and there is no other intermediary space. Measurements were performed generally on normal workdays from Monday through Friday. The distribution of the measuring points should meet the following requirements: (1) The height from the measuring point to the ground should be 1.2-1.6m; (2) the distance between the measuring point and each reflection surface in the space should be more than 1.0m; (3) the distance between each measuring point should be more than 1.5m; (4) the distance between the measuring point and the noise source in the space should be greater than 1.5m.

b. Production of the on-site indoor/outdoor monitoring conditions (weather, temperature, humidity, wind speed, and special noise events) record.

3.3 Psychology questionnaire surveys of noise-related problems in the hospitals

This work was intended to investigate the psychological response to noise in the hospitals. The number of samples required for each hospital should be determined according to the standard deviation of questionnaire replies and more than 60 questionnaires per hospital have been collected. The samples were taken from people aged above 10 in hospital lobbies and waiting spaces who were willing to participate in the survey (including medical personnel). The subjects include first time patients, reaction patients, doctors or nurses, volunteer worker, companies to patients, the number is totally 681. The main contents of the questionnaire include the psychological judgment of the noise source and the effects of space configuration and material properties on the noise.

4. Results and conclusions

4.1 Discussion based on the average indoor/outdoor noise volume of the first two days in thehospitals

The following results are obtained through variation analysis (2-way ANOVA): (1). There is an obvious difference in the sound pressure level of indoor/outdoor noise for each hospital ($p < 0.001$). (2). There is no obvious difference in the sound pressure level of noise between the two days for individual hospitals (**Fig. 1**). (3). As to the sound pressure level of indoor/outdoor noise of the hospitals, the sound pressure level of outdoor noise is obviously higher than that of indoor noise ($p < 0.001$). Since the indoor/outdoor sound insulation capability of each hospital varies, the binary variation analysis results indicate that there is a strong interference between the 11 hospitals and the sound pressure level of indoor/outdoor noise of the hospitals.

4.2 Discussion based on the concentration rate of indoor noise volume of the hospitals

According to the accumulated percentage of noise shown in the measurement results of the hospitals, the noise in the outpatient time during the daytime appears to be more stable than that in the nighttime. That is, the fluctuations of noise are more identical between 9 am and 5 pm during the outpatient time. Also, based on the frequency distribution of the noise volumes and the variation analysis of the previous result, the distribution of noise events during this period of time tends to be normal distribution. Hence, although there is little difference in the sound pressure level of the noise of the hospitals, the variation of distribution varies widely (**Table 1**). The results of questionnaire surveys carried out simultaneously also indicate that the average of noise value cannot reflect the degree that the subjects are interfered by the noise in the space. However, the noise event variation displays the concentration trend close to the average of noise value (**Fig. 2**). The noise phenomenon under two different noise concentration trends may reflect the concentration rate of noise volume in this space (because the length of observation time is identical). Fifteen minutes of concentration or continuity of noise events can be an invisible noise enhancement to human hearing. That is, continuous noise may increase its level of interference to people. When all noise events in the 11 hospital lobbies measured are put together, the concentration rate is approximately 1.12 dB(A)/hr on average. This concentration rate indicates the frequency of the same noise events in the space, that is, the degree to which the noise persists. Take Hospital B and Hospital C for example, the difference between their average noise volumes is 1.43 dB(A) only. However, their noise concentration rates differ greatly—the noise concentration rate of the former is 1.5 times that of the latter. This concentration rate may be summarized as a so-called noise level in combination with the average noise value and may be used to plan, establish, and improve the noise control policies of hospitals.

Table 1. The mean values and the variation of noise events in the hospital lobbies (Unit: dB(A), data of ten daytime hours)

A	B	C	D	E	F	G	H	I	J	K
59.2	62.9	61.5	61.8	60.6	62.1	59.7	62.5	63.1	61.8	59.1
11.7	8.2	17.7	7.5	14.7	9.4	29.8	26.0	10.6	24.4	17.6

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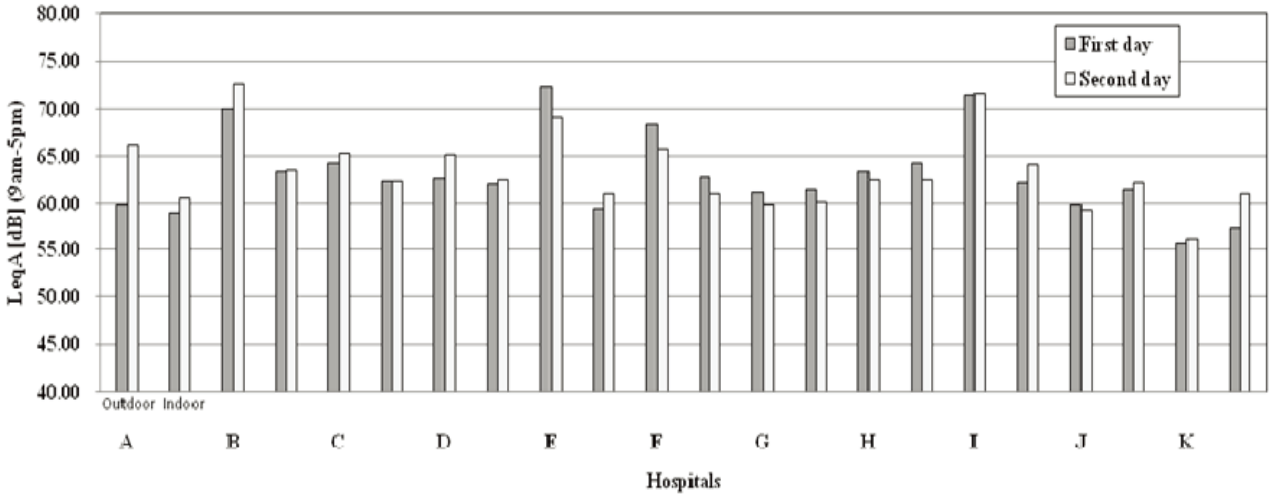

Figure 1. Average sound pressure level of indoor/outdoor noise of the hospitals during the two days

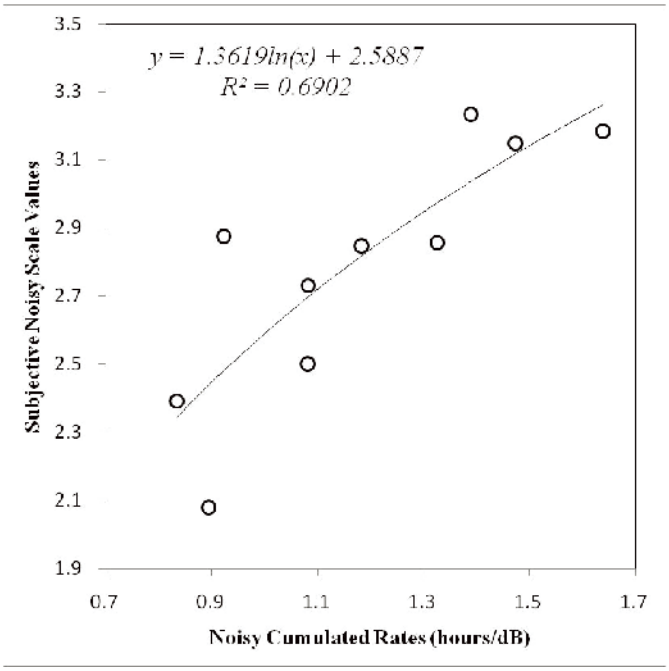

Figure 2. Relationship between the concentration rate of hospital noise during the daytime and the degree of being agitated by noise in the hospital lobbies as shown in questionnaire surveys