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STUDY ON SUBJECTIVE RESPONSES ACCORDING TO FACILITY EQUIPMENT NOISE IN APARTMENTS

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As functions required by apartments are expanded, installed facility equipment has also been diversified. Facility equipment requires a low noise level due to difficulties in control of operation time and running 24-hour a day to create a comfortable residential environment. Furthermore, it is difficult for residents in apartments to select optional facilities because facilities are already installed before live in. Which is why facility equipment should emit low noise. The present study aims to propose a noise standard for facility equipment. For facility equipment, boiler, heat exchanger, and kitchen range hood were selected and annoyance and loudness were analysed according to noise level through seven-point scale. Moreover, a level of facility noise where residents can perform various activities (TV watching, reading, study, work, dining, sleeping, and household chores) without difficulty was investigated.

Keywords: Facility equipment, Subjective response, Apartments, Annoyance

1. Introduction

With the expansion of functions in apartments, household facility equipment has become diversified. As an interest in quality of life has increased, quiet residential environments have been demanded so a low noise level has also been required in facility equipment. The Ministry of Environment in Korea has initiated a low noise mark scheme to induce noise reduction in indoor electronics and providing information about noise level of vacuum cleaners and washing machine to consumers. However, a low noise mark scheme is only applied to some electronics and its utilization is low.

A variety of facility equipment have been installed as built-in type in recently built apartments. Thus, it is necessary to investigate a level of noise occurrence since it is difficult for residents in apartments to choose built-in equipment selectively. A number of studies on proposal of noise standards have been underway to protect residents from noise generated from facility equipment. Jeon et al studied a rating standard that evaluated daily living noise including drainage noise generated in apartments complexly [1]. Shin et al studied annoyance level of toilet water noise to suggest a standard of noise level, which has been the most complaint in apartments [2]. Hutt et al examined a standard according to various service noises occurred in apartments and proposed an appropriate noise standard [3]. Although research on proposal of standards on facility noise has been performed in Korea, it is necessary to investigate whether common noise standards can be proposed since facility equipment noise is various and noise characteristics are different.

The present study investigated subjective response according to noise occurrence in facility equipment, which has been built in in recent apartments. The subjective response according to noise occurrence was evaluated in terms of loudness and annoyance, and a noise level that can ensure residents' activities (sleeping, reading, and dining etc.) was investigated. Furthermore, a deviation of subjective response according to noise from various types of facility equipment was investigated to examine the possibility of providing common noise standards.

2. Study method

2.1 Overview of the subjects and survey

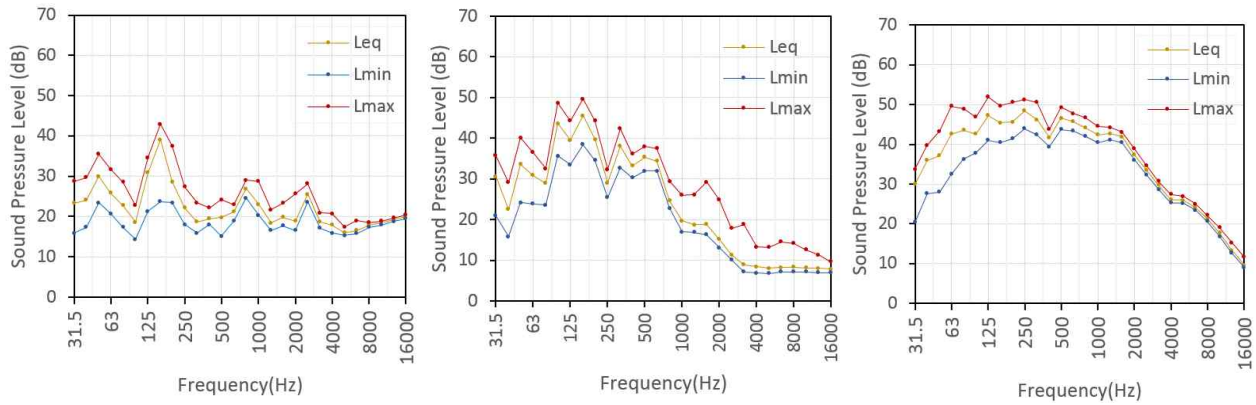
The subjective response was studied with regard to 39 subjects whose hearing ability was normal and a range of ages was between 20s and 50s.

The psycho-acoustics experiment was conducted in psycho-acoustics room inside the anechoic room that simulated a living room in apartments. A background noise in the psycho-acoustics room was set to 15dB(A). Prior to the psycho-acoustics experiment, ages, resident type (apartment, villa etc.) of residential household area, presence of facility equipment, and noise sensitivity etc.) were surveyed.

2.2 Overview of the used sound source

Noise generated from the kitchen range hood, boiler machine, and heat exchanger in the indoor of the apartment was recorded using a head and torso simulator (HATS). A level of operation in the facility equipment was set to the maximum and noise transmitted to the center of the living room was recorded. The boiler and heat exchanger were located in a space for the facility equipment where a door is separately installed whereas the kitchen range hood was exposed to the location nearby the living room.

The characteristics of the sound source recorded from the facility equipment are shown in Figure 1. Although the noise from the boiler showed a high sound pressure level around 200 Hz band, it showed a flat and low sound pressure level mostly. The maximum noise level was 35.5dB(A). The heat exchanger revealed a high sound pressure level at a frequency band range of 63–500Hz but a low sound pressure level was revealed higher than 2,000 Hz. The maximum noise level was 41.5dB(A). The kitchen range hood produced a high broadband noise. The maximum noise level was 52.8dB(A), which was the highest among the three sound sources. All three sound sources showed no significant fluctuation of noise level over time.



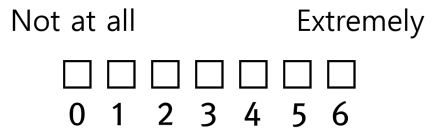
(a) Boiler (b) Heat exchanger (c) Kitchen range hood

Figure 1: Noise characteristics of the facility equipment

2.3 Overview of the psycho-acoustics experiment

The survey used in the psycho-acoustics experiment consisted of questionnaire that determined annoyance and loudness felt by the subject, and questionnaire to have responses from the subject to understand whether activities can be performed under the noise level. When noise from the kitchen range hood, boiler machine, and heat exchanger was emitted, respectively, a level of annoyance and loudness was answered. The subjects were informed of a type of the sound source generated from facility equipment prior to the experiment. The residents answered the following questions: "How much did you feel annoyed by the noise?" and "how loud was the noise?" suggesting situation that the subjects were taking a rest in the living room. The response scale used was a seven-point scale which is edited method of ICBEN suggested [4]. In the seven-point scale method, the more the subjects felt the noise was annoyed or loud, the closer the scale to six and the less the subject felt the noise was annoyed or loud, the closer the scale to zero.

The survey questionnaire regarding activities under the noise level is shown in Figure 2. The subjects marked their answers to the questions whether they could perform activities (TV watching, reading, study or work, dining, sleeping, and household chores) even under the generated noise level without too much care about the noise. The subjects were allowed to answer multiple responses or no response.



(a) Questionnaire to evaluate annoyance and loudness

TV watching	Reading	Study or work	Dining	Sleeping	Household chores

(b) Questionnaire to evaluate activities under the noise level

Figure 2: Survey to evaluate subjective responses

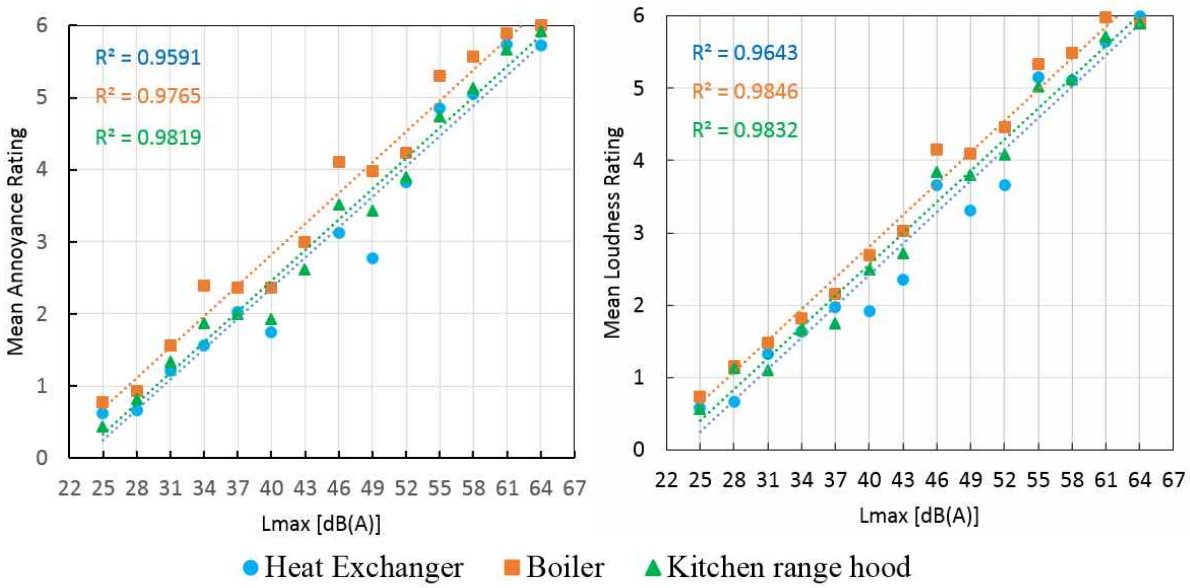
3. Evaluation result

3.1 Annoyance and loudness according to the noise generated from facility equipment

The evaluation results of annoyance and loudness according to noise generated from the facility equipment are shown in Figure 3. A mean value of annoyance and loudness under the maximum noise showed that noise from the boiler was the most annoying sound when the same level of noise was generated. Noise from the kitchen range hood was more annoying or comparable than that from the heat exchanger. When the same level of noise from the sound sources was presented, a mean value of annoyance revealed a difference in 0.23 – 1.21 point and more annoyance deviation was found in the mid-noise level than in a level of 30 dB(A) or lower or a level of 55 dB(A) or higher.

The survey result showed that loudness was more closely related to the noise level than annoyance was. It also showed that even if subjects recognized a noise level differently, they felt a similar level of annoyance at the certain range of noise level.

The maximum noise level of the boiler in the recorded sound sources was 35.5 dB(A) and a mean of annoyance was 2.3. The maximum noise level of the heat exchanger was 41.1 dB(A) and a mean of annoyance was 1.7–3.0. The maximum noise level of the kitchen range hood was 52.8 dB(A) and a mean of annoyance was 3.9. The kitchen range hood produced the largest maximum noise level as well as the largest annoyance level.



(a) Annoyance (b) Loudness

Figure 3: Annoyance and loudness according to the noise generated from facility equipment

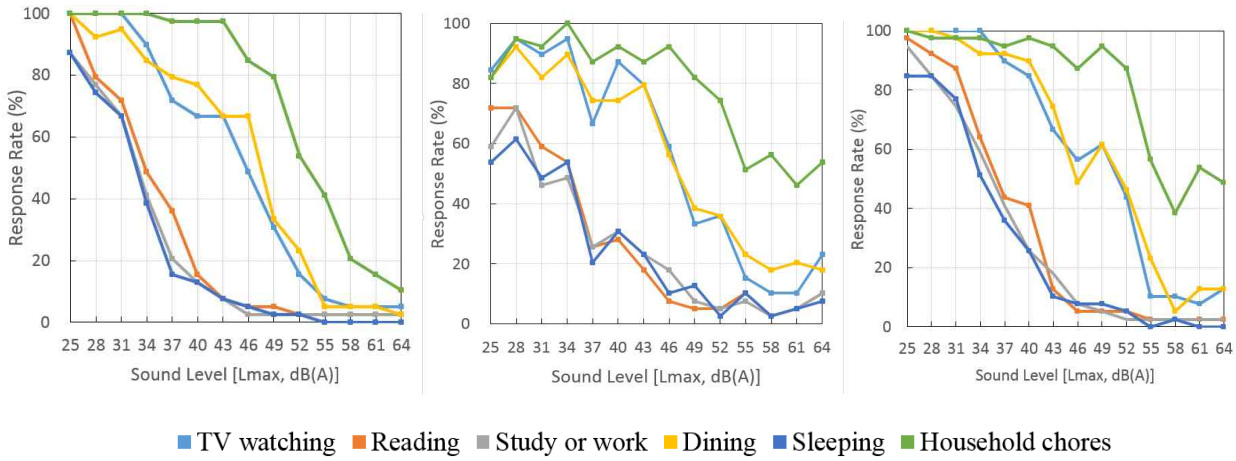
3.2 Survey results of activities under the noise

The psycho-acoustics experiment was conducted to identify the restriction of activities under the noise generated from facility equipment in households of apartment. The subjects answered possible activities without significant restriction due to noise generated from the facility equipment. The survey results are shown in Figure 4. The most affected activity by noise was sleeping followed by study and work, reading, TV watching, dining, and household chores.

A noise level of 50% of the subject answered they able to perform activities without significant restriction was identified. The survey results showed that sleeping, study and work, and reading activities can be done under the noise below 31 dB(A) approximately from the facility equipment while TV watching or dining can be done under 46 dB(A) noise level. For household chores, 50% of the subjects responded that they can do household chores without too much concern about the noise if a noise level was 52dB(A) or lower. As revealed in the result of the heat exchanger or kitchen range hood, even if a noise level increased, the response rate did not decrease significantly.

Among the facility equipment, it is difficult to adjust an operating time for boiler and heat exchanger to maintain a comfortable environment. Although noise should be generated at a level that is not interruptible to any activities including sleeping or study, a noise level of boiler and heat exchanger was 35.5 dB(A) and 41.1 dB(A), respectively in the household of the recorded sound source, resulting in only 13% to 30% residents were not bothered by the noise for sleeping.

When a noise level was increased, a response rate of possible activities was not decreased linearly. This was because every activity had a different level of obligation and needs. Furthermore, it was limited for the subjects to respond to six activities consistently when subjects heard the generated sound source in the psycho-acoustics experiment.



(a) Boiler (b) Heat exchanger (c) Kitchen range hood

Figure 4: Response of possible activities under the noise generated from facility equipment

4. Result

The present study aimed to produce foundational data to propose a noise standard of facility equipment inside households of apartments, which has become built-in more and more in recent years. This study surveyed annoyance and loudness according to the maximum noise level through the psycho-acoustics experiment.

The survey used seven-point scale and a noise level that corresponded to a median value(3) of annoyance was found as 43–46 dB(A). When noise was generated from the boiler, the subject felt more annoyance than noise generated from the heat exchanger or kitchen range hood but the difference between them was minimal. A mean value of annoyance varied (0.23–1.21) depending on facility equipment despite that the same level of noise was generated.

Furthermore, a noise level, under which subjects had no significant interruption in various activities, was also investigated. Since it is difficult for facility equipment to adjust an operating time to maintain comfort inside apartments, it is necessary to provide a standard of noise level through the subjective response survey as conducted in the present study.

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