Characterizing the Hearing Comfort in Intensive Care Unit Using Objective and Subjective Evaluation

Joko Sarwono[1],Ezra Tandian[1],Andika Rizki[1] ,Sentagi Utami[2] and Ressy Yanti[2]
[2]Department of Engineering Physics Institute Technology of Bandung, Bandung, Indonesia
(Tel: + 62 22 2504424;E-mail: jsarwono@tf.itb.ac.id)
[1]Department of Engineering Physics, Universitas Gadjah Mada, Yogyakarta, Indonesia
(Tel: +62 -274 - 580882;E-mail: sentagi@ugm.ac.id)

Abstract - Hospital is a place that should be free of acoustic problems. According to previous researches, these acoustic problems are responsible for 20.9% - 26.2% of the ICU patient's recovery process. A research based on soundscape of a hospital was done through objective, subjective and simulation methods. The result has shown that the most perceived loud sound is from the ventilator at 4000 Hz with loudness level of 60 phon. The L90 score is between 55-59 dBA. The Leq ranged between 50.78-67.49 dBA at the left ear and 60.07-76.55 at the right ear from the first receiver position. From the second measuring point, L10 score is around 52.08-72.19 dBA at the left ear and 61.91-78.94 at the right ear. This value indicates that the noise level in the ICU is high enough, and caused discomfort for human hearing. Installation of panels on ceiling at the nurse ward can reduce the intensity level up to 3 dBA. Meanwhile, relocation of nurse ward can reduce up to 4 dBA.

Keywords: ***Hospital, ICU, soundscape, noise***

I. Introduction

Hospital is one of the working places that require conducive condition, which is free from environental problems either it is thermal, visual, or acoustic problem. Acoustics problem can affect ICU patients rest as much as 20.9%-26.2% [1]. Besides having negative effect on patient, it also has a negative effect on the work performances of the nurses and doctors'. Research that was done in Brazil shows that high noise level in hospital will cause 44.20% of patients having rest difficulties, 34.78% having a low concentration level, 18.12% feeling inconveniences and 7.97% experiencing hearings impair.

In the past few years, soundscape concept has been developed. The soundscape concept states that the acoustical quality of a room is judged not only from the sound pressure level, but also how sounds can be perceived by human. Researches on soundscape at hospital have been done and the patients are the research objects [3]. Meanwhile, very few researches that focus on the physicians as the research object. This research explored the nurse perception in order to find out what is the strong, weak, and important and unimportant disturbance for nurses in performing their work. Besides that the relation of sound pressure level and perception of the nurses in that room will be studied. Nowadays, soundscape has become an important application in environment quality evolution of a park and protected area, city planning and designing, etiology and anthropology, and long term supervision to climate changes [4].

II. Theoretical Background

Some parameters that were used in this research are percentile level, equivalent sound level (L_{eq}), sound level and reverberation time. Percentile level is a sound level exceeded for n% of the measurement time. Percentile level is usually symbolized with L_x where x is a presentation of measurement length. L_{90} can be used as background noise indicator that comes from unknown sources. L_{50} which can be defined as median level is used to define noise limit, while L_{10} is used to show the presence of loud noises.

The L_{10} value of 92 dB is obtained from the SPL values that exceed 10% from the total measurement time. Similar to it are the L_{50} and L_{10}, where these values are 78 dB and 61 dB, obtained from sound pressure level that is more than 50% and 90% of the total measurement time, as shown in Figure 1.

Equivalent sound level is sound level that comes from average sound energy in certain time span. Equivalent sound level (L_{eq}) is also known as time average sound level [6].

$$L_{eq} = 10 \log \frac{1}{N} \sum_{i=0}^{N} 10^{0.1 Li} \quad (1)$$

Li is individual sample of sound level (dB).

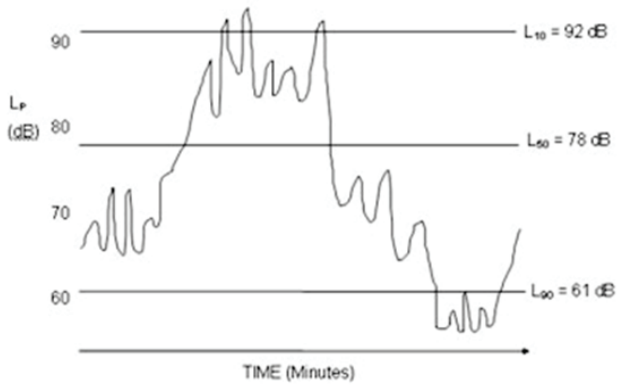

Figure.1 Percentile Level [5]

III. Method

Soundscape evaluation of ICU's nurse room was carried out with three methods, which were objective measurement,

subjective observation, and computer simulation. Objective measurement was done by measuring SPL of each frequency every second at 2 measurement points. The two measurement points are measured using microphones attached to a computer with Yoshimasa software through a BSWA sound card, and microphones that are placed on a dummy head. Measurements were done by taking a recording every second for 15 minutes at each point in 24 hours. The microphones on the dummy head were positioned 1.2 m above the floor. Figure 2 shows the measurements arrangements.

Figure 2. Dummy head with microphones attached

Subjective observation was done using questionnaires and noise sources observation. Simulation method was done by ray-tracing analysis with CATT-Acoustics v9.0 software. The simulation was intended to obtain values that were unable to be collected from objective measurement such as when buzzing noise occurred and also used to map SPL of the room noise.

IV. RESULT

A. Objective Data

The loudest noise that was perceived by the human ears from the measurement was 60 phone at 4000 Hz, as it is shown in Figure 3.

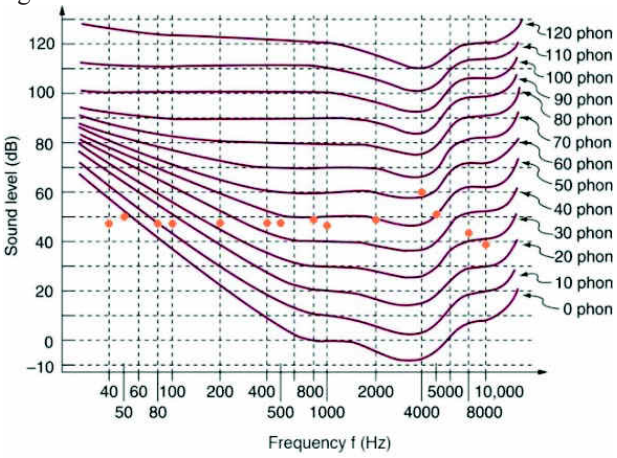

Figure 3. Pressure Level Plot Result at Equal Loudness Contour Curve

Other high SPL were noise perceived at 800 Hz, 2000 Hz, and 5000 Hz frequency with a loudness level of 50 phon. Results of the SPL values obtained during measurement show that ventilator alarm noise was the source of the 60 phon noise at 4000 Hz frequency.

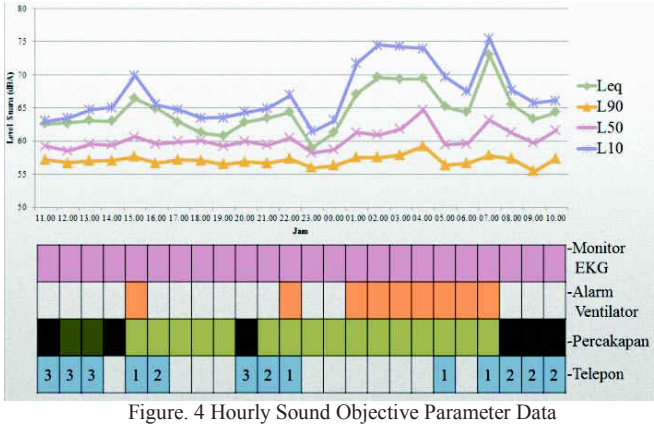

Figure. 4 Hourly Sound Objective Parameter Data

Figure 4 shows that the L_{90} values were quite constant with values between 55-59 dBA. It shows that the average background level in the ICU room is around 57 dBA. Meanwhile, according to World Health Organization on Specific Effect: Problems with Communication, relaxed conversation can be understood completely at 35 dBA and can be understood fairly at 45 dBA [7]. The L_{10} obtained from the measurement reached above 77 dBA. Meanwhile, the L_{eq} at the ICU room according to the calculation was 65.20 dB (A-weighting). The L_{eq} value is larger than the standard L_{eq} value, both for WHO and Ministry of Health standards. This shows that the ICU room is very noisy and in need for acoustics improvement.

The L_{90} score is between 55-59 dBA. The L_{eq} ranged between 50.78-67.49 dBA at the left ear and 60.07-76.55 at the right ear from the first receiver position. From the second measuring point, L_{10} score is around 52.08-72.19 dBA at the left ear and 61.91-78.94 at the right ear. This value indicates that the noise level in the ICU is significantly high, and may produce discomfort for human hearing.

B. Subjective Data

The number of respondents in this research were 11 people and all of them are nurses working at the hospital ICU's room.

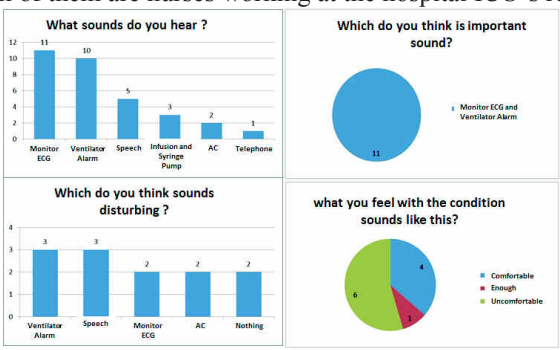

Figure 5. Subjective data result

Sound sources which had the biggest impact to nurses or had the most appearance frequency were ventilator monitor and alarm sounds. According to survey (in Bahasa Indonesia), it shows that acoustic condition in the ICU room according to the nurses was classified as uncomfortable. The resume was shown in Figure 5.

The acoustic in the ICU room can be improved to an acoustically comfort space for both the patients and the physicians by reducing noise level utilizing variety of architectural elements. Room acoustics simulation using CATT-Acoustic was done in order to understand the acoustic conditions before and after adding architectural elements.

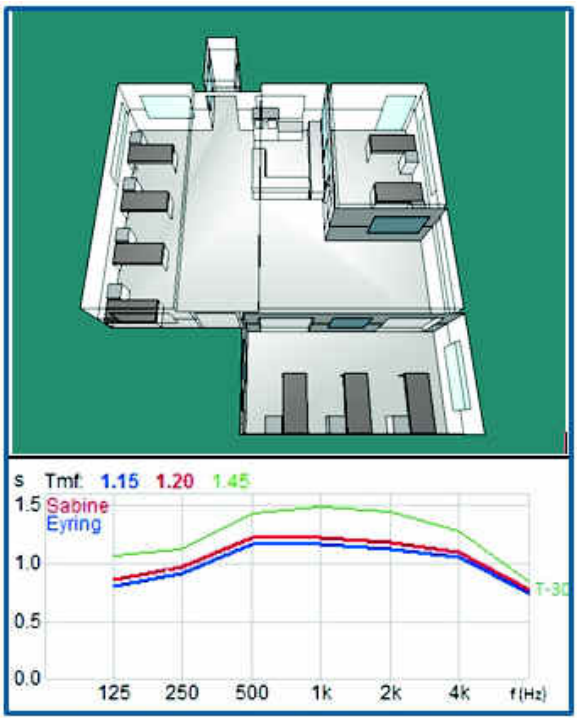

Figure 6. Modeling result by using CATT-Acoustic

The ICU room size at X hospital observed in this research is 538 m^3. Therefore, optimum reverberation time in this space is 0.8 sec - 1.08 sec at mid-frequency, as shown in Figure 6. Meanwhile, the reverberation time value measured exceeded the optimum reverberation time for conversation and therefore, caused unclear conversations. This might create problems since information from the conversation between nurses should be delivered clearly in order to avoid mistakes during performing the medical treatment.

C. Simultion Data

Installation of diffuser and absorber on the nurse ward ceiling can reduce the sound pressure level approximately 3 dBA and change the ceiling and wall materials surrounding the patients' area can decrease the SPL from 59-66 dBA to 55-63 dBA, as shown in Figure 7.

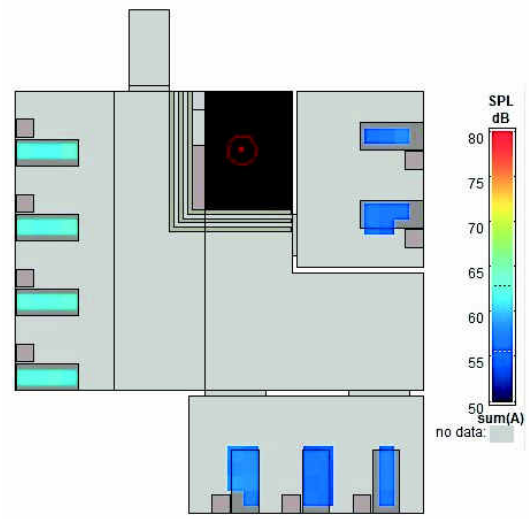

Figure 7. Mapping Result in Beds with Installation of diffuser and absorber on the nurse ward ceiling

Relocation of the nurse ward can also decrease the SPL from 59-66 dBA to 54-62 dBA. By isolating patients that require ventilator in a same area can reduce the SPL from 67-81 dBA to 64-72 dBA. This is shown in Figure 8. A decrease in the noise level can improve hearing comfort in the ICU.

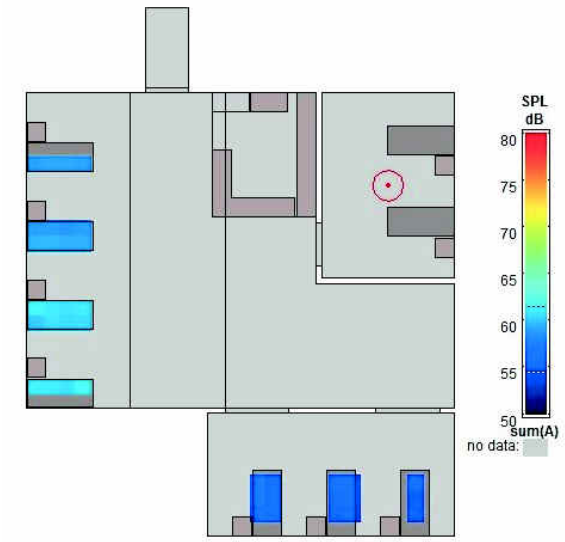

Figure 8. Mapping Result in Beds with Displacement nurse ward

V. Conclusion

The result has shown that the loudest sound perceived by nurses is coming from the ventilator at 4000 Hz with loudness level of 60 phon. It is however, it was not perceived as discomfort sound since they need it to monitor patient conditions. The overall acoustics condition in the ICU has not conform the standards and need some improvements. Installation of panels on ceiling at the nurse ward can reduce the intensity level up to 3 dBA. Meanwhile, relocation of nurse ward can reduce up to 4 dBA.

ACKNOWLEDGMENT

The authors would like to thanks the management of a hospital in Cimahi Bandung for their supports. This research was funded by ITB Research Grant with contract number 1763/I1.B04.1KU/2015

REFERENCES

[1] M. Park, A. Kohlrausch, and W. De Bruijn, "Analysis of The Soundscape In an Intensive Care Unit Based On The Annotation of an Audio Recording," vol. 135, no. 4, pp. 1875–1886, 2014..
[2] G. D. L. Costa, A. Bender, M. De Lacerda, and J. Marques, "Noise on the Hospital Setting : Impact on Nursing Professionals' Health Ruído no contexto hospitalar : impacto na saúde," pp. 642–652, 2013.
[3] IOM, Keeping Patients Safe: Transforming the Work Environment of Nurses. Washington DC: National Academy Press, 2004.
[4] A. Farina, Soundscape Ecology. 2014.
[5] "Percentile Level." [Online]. Available:http://www.castlegroup.co.uk/2012/06/30/percentile-levels/. [Accessed: 23-Feb-2015].
[6] ASTM International, "E 1686 - 03: Standard Guide for Selection of Environmental Noise Measurements and Criteria.pdf." West Conshohocken, pp. 1166–1167, 2003.
[7] B. Berglund, T. Lindvall, and D. H. Schwela, "Guidelines for Community Noise." WHO, Geneva, 1999.