



COMPARISON OF COMMUNITY NOISE RATINGS BY L_{50} AND L_{Aeq}

M. OMIYA

*Nagoya City Environmental Science Research Institute 16-8, Toyoda 5, Minami-ku,
Nagoya 457, Japan*

K. KUNO

Department of Electrical and Electronic Engineering, Mie University, Tsu 514, Japan

Y. MISHINA AND Y. OISHI

Daido Institute of Technology, Nagoya 457, Japan

AND

A. HAYASHI

Suzuka University of Medical Science and Technology, Suzuka 510-02, Japan

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A survey of daily noise exposure of residences and inhabitants' reactions was conducted in the city of Nagoya. More than 1000 samples have been acquired since 1987. The stored data are used to examine dose-response relationships and ratings of environmental noise by L_{50} and L_{Aeq} . The levels above 60 dB(A) in L_{50} and 65 dB(A) in L_{Aeq} are unacceptable for noise environments, irrespective of the time of day and land use. We propose a criterion based on L_{50} and L_{Aeq} . The values of the criterion are consistent with Japanese quality standards on L_{50} in residential areas, but not with those in commercial and industrial areas. The values based on L_{Aeq} are in agreement with standards in other countries. A criterion for a roadside area is obtained by adding 5 or 10 dB(A).

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1. INTRODUCTION

Environmental quality standards for noise in Japan were established in 1971 to protect public health and to conserve the daily living environment. The standard values for environmental noise are based on the median value L_{50} of A-weighted sound pressure level. Many measurements and monitorings of the environmental noise have been carried out by many local governments in Japan. However, seldom have the measurements and monitorings been conducted with surveys of residents' reactions to the noise environment. In 1987, a social survey on the environmental noise in the city of Nagoya was started to investigate the relation between noise levels and the reactions of inhabitants. In the study, noise levels in L_{50} and L_{Aeq} are measured and the inhabitants' reactions against the environmental noise are obtained by a questionnaire on loudness, annoyance, sleep disturbance, etc. The survey is reported here and the criterion for the environmental noise based on L_{50} and L_{Aeq} discussed.

2. METHODS

The social survey of noise environments of residences and inhabitants' reactions was conducted in the city of Nagoya. The city, which has a population of 2.1 million, is one of the three largest metropolitan regions in Japan, along with Tokyo and Osaka. It has highly advanced traffic networks and has developed as a nucleus city with industry such as automobile and machinery. The city area has been categorized according to city planning law of land use into eight zoning areas. These areas were reclassified into different zones as shown in Table 1. The number of samples acquired in each zone is given in the table and is nearly proportional to the area covered. Noise measurements over one day and night were carried out at dwelling sites. The microphone of the measuring instrument was set at a place where the noise condition was typical, such as on the balcony, railing, porch, near the flower pot, etc. The equivalent sound level $L_{Aeq}1/6$ as well as the median $L_{50}1/6$ of fluctuating noise level was measured in ten-minute time intervals during one day and night, and 144 pairs of $L_{Aeq}1/6$ and $L_{50}1/6$ were recorded automatically.

According to the Japanese standards for environmental noise, one day and night is divided into four time sections: morning (06:00–08:00), daytime (08:00–19:00), evening (19:00–22:00) and night-time (22:00–06:00). The L_{Aeq} 's for these time sections are expressed by $L_{Aeq}M$, $L_{Aeq}D$, $L_{Aeq}E$ and $L_{Aeq}N$, respectively. The corresponding L_{50} 's are denoted by $L_{50}M$, $L_{50}D$, $L_{50}E$ and $L_{50}N$, which are obtained by arithmetic average of $L_{50}1/6$ in the respective time sections. $L_{Aeq}24$ and $L_{50}24$ were also calculated for a 24 h period. Several questions on daily life were also posed to inhabitants. The respondents were mainly housewives (about 60%). The contents of the measurement and the questions are given in Table 2. The questions on the noise environment are listed in Table 3. The authors have constructed the survey files and stored more than 1000 samples in a large computer.

3. RESULTS OF MEASUREMENTS

3.1. ENVIRONMENTAL NOISE PATTERN OVER 24 HOURS

Both $L_{50}1/6$ and $L_{Aeq}1/6$ in each ten-minute interval are arithmetically averaged over all samples. Figure 1 shows the averaged time patterns of $L_{50}1/6$ and $L_{Aeq}1/6$ of environmental noise over 24 hours. $L_{50}1/6$ rises about 12 dB(A) from 05:00 to 08:00 and holds an almost constant level of 54 dB(A) during the daytime and falls gradually from 18:00 to 01:00 reaching its lowest level of 43 dB(A) during the period 01:00 to 04:00. The time pattern of $L_{Aeq}1/6$ is almost the same as that of $L_{50}1/6$, but higher by about 6 dB(A). The standard deviation (S.D.) of $L_{50}1/6$ around the above pattern is about 7 dB(A) for the entire day.

TABLE 1
Distribution of samples in different zoning areas in the city of Nagoya

Zoning areas	Land use		Samples	
	Area (km ²)	Proportion (%)	Number	Proportion (%)
Exclusively residential	81.9	25.1	254	21.7
Residential	104.4	32.0	434	37.2
Commercial	47.9	14.7	118	10.1
Industrial	67.2	20.5	348	29.8
Unclassified	25.0	7.7	14	1.2
Totals	326.4	100.0	1168	100.0

TABLE 2

Contents of survey file obtained from measurement of noise over 24 h and questionnaire to inhabitants

Noise level measurement	$(L_{Aeq}1/6, L_{50}1/6) \times 144$ (every 10 min intervals over 24 h)
Residence	Building (stand alone or collective, structure, window frame, floor) Countermeasure for noise, type of noise source Surroundings (road, railroad, land use, density of buildings)
Respondent	Respondent (sex, age, vocation, family) Length of time living in current residence, comfortability of living Reactions to noise (indoor, outdoor) Sleep disturbance by noise
Secondary data	$L_{Aeq}24, L_{Aeq}M(06:00-08:00), L_{Aeq}D(08:00-19:00)$ $L_{Aeq}E(19:00-22:00), L_{Aeq}N(22:00-06:00), L_{dn}, L_{den}$ $L_{50}24, L_{50}M(06:00-08:00), L_{50}D(08:00-19:00)$ $L_{50}E(19:00-22:00), L_{50}N(22:00-06:00)$
Others	Date, time, device number, location, weather

The S.D. of $L_{Aeq}1/6$ is larger at night, however, where L_{Aeq} is sensitive to sudden noises from vehicles, etc.

3.2. NOISE LEVELS IN DIFFERENT TIME SECTIONS

Distributions of L_{50} for different time sections as well as for one day are given in Figure 2. The distribution of $L_{50}24$, which ranges from 30 dB(A) to 71 dB(A) with a mean value of 50 dB(A), is consistent with those of $L_{50}M$ and $L_{50}E$. Comparing the above distributions shows that those of $L_{50}D$ and $L_{50}N$ are shifted higher by 4 dB(A) and lower by 6 dB(A), respectively. The mean value of $L_{50}D$ is 54 dB(A), which is 2 dB(A) lower than the one obtained by the Nagoya city government at pavements, parks, etc., in 1989. Figure 3 shows

TABLE 3

Questionnaire on noise environment

IA	How do you find the noise around your residence? 1: loud (+) 2: medium (0) 3: low (-)
IB	Are you annoyed by the noise? 1: very annoyed (+) 2: annoyed (+) 3: little annoyed (0) 4: not annoyed (-)
IC	Do you feel it is noisy around your residence? 1: very noisy (+) 2: pretty noisy (+) 3: noisy (+) 4: little noisy (0) 5: quiet (-) 6: very quiet (-)
ID	What do you think about the noise? 1: should be abated 2: desirable to be abated (+) 3: pay little attention (0) 4: pay no attention (-)
IIA	How do you find the noise in your residence including that from outside? 1: loud (+) 2: medium (0) 3: low (-)
IIB	Are you annoyed by the noise? 1: very annoyed (+) 2: annoyed (+) 3: little annoyed (0) 4: not annoyed (-)
III	Have you ever been disturbed by the noise in your sleep? 1: often (+) 2: sometimes (+) 3: scarcely (-)

The answer for each question is labeled as follows, according to degree of complaints: (+), positive reaction; (0), neutral reaction; (-), negative reaction

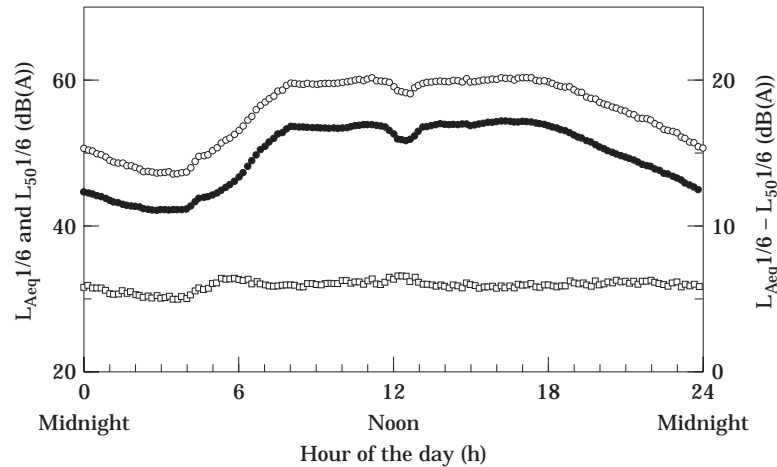


Figure 1. Average time patterns of daily noise exposure of residences in the city of Nagoya. \circ , $L_{Aeq}1/6$; \bullet , $L_{50}1/6$; \square , $L_{Aeq}1/6 - L_{50}1/6$.

L_{Aeq} 's distributions, which are about 8 dB(A) higher as compared with the corresponding ones of L_{50} .

3.3. NOISE LEVELS IN DIFFERENT ZONING AREAS

The noise environment in an urban area is largely affected by road condition around the residences. The zones within 20 m of trunk roads are distinguished as a roadside area from the other zoning areas (general areas). The averaged time patterns of $L_{50}1/6$ and $L_{Aeq}1/6$ in a roadside area are given in Figure 4. The level difference of $L_{50}1/6$ between day and night time is large as 16 dB(A), but the one of $L_{Aeq}1/6$ is about 9 dB(A). And the difference between $L_{Aeq}1/6$ and $L_{50}1/6$ is 5 dB(A) in daytime and 10 dB(A) at night. The distributions of $L_{Aeq}24$ in a roadside area as well as general areas classified by land use are shown in Figure 5. We summarize the average L_{50} and L_{Aeq} for different time sections

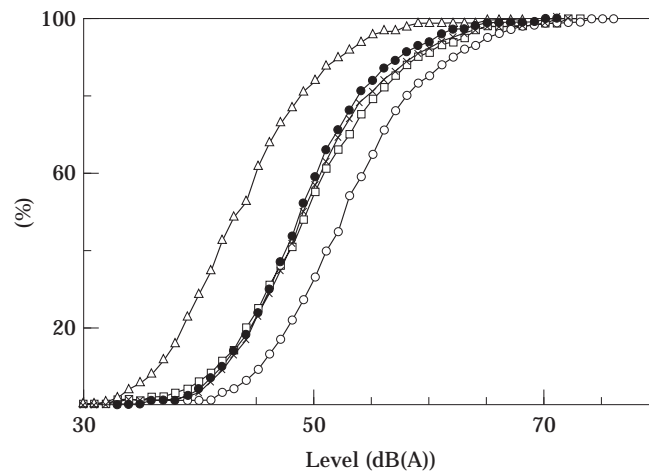


Figure 2. Cumulative distributions of noise levels in L_{50} for different time sections during a day. Key with time section, mean and standard deviation: \square , morning, 50.4, 7.1; \circ , daytime, 53.6, 6.6; \times , evening, 50.3, 6.5; \triangle , night-time, 44.2, 6.2; \bullet , 24 h, 49.8, 6.1.

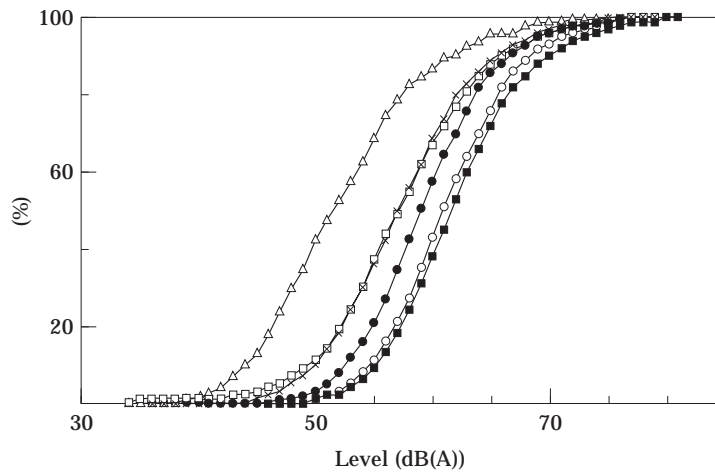


Figure 3. Cumulative distributions of noise levels in L_{Aeq} for different time sections during a day. Key with time section, mean and standard deviation: \square , morning, 58.0, 5.5; \circ , daytime, 61.8, 6.9; \times , evening, 57.9, 5.8; \triangle , night-time, 52.6, 6.7; \bullet , 24 h, 59.8, 5.5. \blacksquare , L_{dn} , 62.7, 5.8.

in each zoning area in Table 4. The average level in a roadside area is 10 dB(A) higher than that in general areas. The level difference in L_{50} among different land use in general areas is less than 5 dB(A) for each time section. The level differences in L_{Aeq} among zoning areas are less than those in L_{50} .

4. RESIDENTS' REACTIONS TO ENVIRONMENTAL NOISE

The answers to each question on the noise environment (i.e., residents' reactions) are summarized in Figure 6. The positive reactions are above 30% for outdoor noise, but only 20% for indoor noise. About 30% of people complain of sleep disturbance by noise in Nagoya, as in other cities in Japan [1].

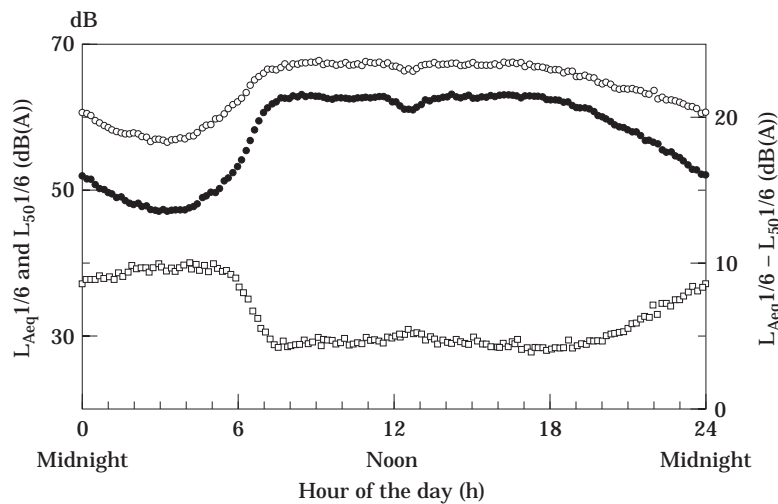


Figure 4. Average time patterns of daily noise exposure of residences in a roadside area. \circ , $L_{Aeq} 1/6$; \bullet , $L_{50} 1/6$; \square , $L_{Aeq} 1/6 - L_{50} 1/6$.

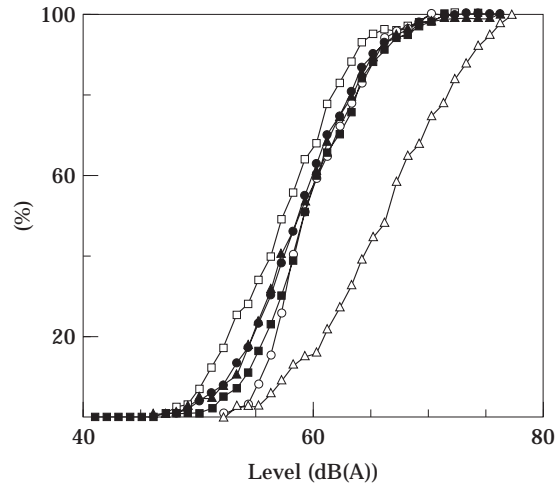


Figure 5. Cumulative distributions of noise level in $L_{Aeq,24}$ in different zoning areas. Refer to mean levels in Table 4. □, Exclusively residential; ▲, residential; ○, commercial; ■, industrial; △, roadside; ●, all areas.

4.1. LOUDNESS

About 30% of residents feel that their outdoor noise is loud. The corresponding distribution of $L_{Aeq,D}$ ranges from 52 dB(A) to 79 dB(A) with a mean value of 64.2 dB(A) as shown in Figure 7. The level differences in L_{Aeq} between positive and negative reactions are 4 dB(A) in the daytime and 5 dB(A) at night. The corresponding differences in L_{50} are 7 dB(A) and 4 dB(A), respectively. Table 5 gives the average outdoor noise level for each time section of a day against which people are seen to react positively (i.e., they consider it to be loud). The level difference between roadside and general areas is as much as 10 dB(A), but the level difference among the general areas is about 4 dB(A) in L_{50} and almost less than 1 dB(A) in L_{Aeq} .

TABLE 4

Average levels in L_{50} and L_{Aeq} for each time section in different zoning areas (in dB(A))

	General areas†					Total
	Exclusively residential	Residential	Commercial	Industrial	Road side area‡	
$L_{50,24}$	46.5	48.7	51.4	50.3	57.8	49.8
$L_{50,M}$	46.5	49.3	51.8	50.9	59.8	50.4
$L_{50,D}$	50.1	52.2	55.2	54.4	62.5	53.6
$L_{50,E}$	47.5	49.1	52.4	49.9	59.3	50.3
$L_{50,N}$	41.3	43.5	45.6	44.7	50.5	44.2
$L_{Aeq,24}$	57.7	59.1	60.2	59.9	66.2	59.8
$L_{Aeq,M}$	54.8	57.0	58.7	58.3	66.3	58.0
$L_{Aeq,D}$	59.8	61.1	62.0	62.0	67.8	61.8
$L_{Aeq,E}$	56.1	57.1	58.9	57.5	64.9	57.9
$L_{Aeq,N}$	49.7	51.7	53.6	52.5	61.1	52.6
L_{dn}	60.2	61.8	63.2	52.7	69.8	62.7
Samples	241	386	103	311	116	1168

† areas beyond 20 m from trunk roads

‡ area within 20 m of trunk roads

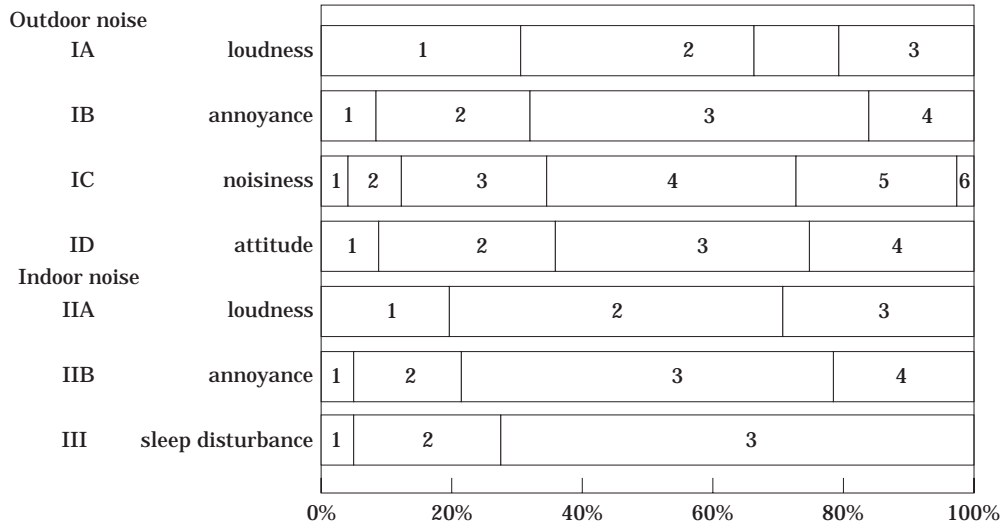


Figure 6. Response ratio of residents to each answer for various questions on noise environments. See Table 3 for questions (IA, IB, etc.) and answers (1,2,3, · ·).

4.2. ANNOYANCE AND SLEEP DISTURBANCE

The mean value of L_{50} for residents who are annoyed by outdoor noise is almost the same as that for residents who feel the noise to be loud. The level difference in L_{50} between positive and negative reactions regarding annoyance is 6 dB(A) in the daytime and 4 dB(A) at night. The corresponding differences in L_{Aeq} are 4 dB(A) and 6 dB(A), respectively. As for sleep disturbance, the mean values of outdoor noise in $L_{50}N$ and $L_{Aeq}N$ for residents who complain are 47 dB(A) and 56 dB(A), respectively. Corresponding values for undisturbed residents are 44 dB(A) and 52 dB(A).

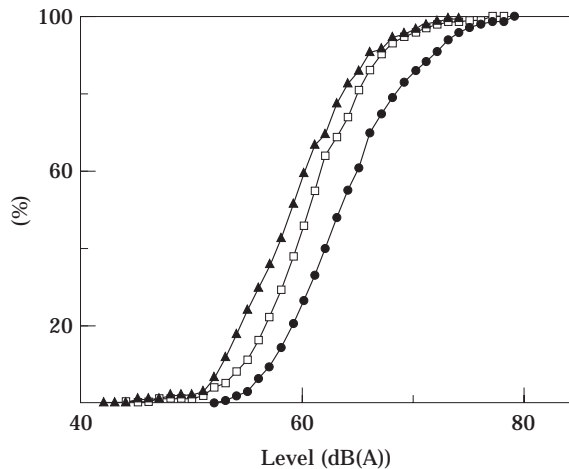


Figure 7. Cumulative distributions of L_{Aeq} during the daytime for different reactions to loudness of outdoor noise. Key with reaction, mean and standard deviation: ●, positive, 64·2, 5·4; □, neutral, 61·2, 5·2; ▲, negative, 59·5, 5·3.

TABLE 5

Average levels in L_{50} and L_{Aeq} corresponding to positive reaction to loudness in different zoning areas (in dB(A))

	General areas					Total
	Exclusively residential	Residential	Commercial	Industrial	Road side area	
$L_{50}24$	49.2	50.3	52.9	51.4	61.1	52.8
$L_{50}M$	49.8	51.6	53.3	52.1	62.7	53.9
$L_{50}D$	53.2	54.2	56.8	56.0	66.0	57.1
$L_{50}E$	50.5	51.1	54.1	50.8	62.1	53.3
$L_{50}N$	42.9	44.2	47.1	45.2	53.8	46.3
$L_{Aeq}24$	60.8	60.8	61.1	61.0	69.3	62.3
$L_{Aeq}M$	58.7	59.6	60.0	59.4	69.4	61.2
$L_{Aeq}D$	62.8	62.7	63.1	63.2	70.8	64.2
$L_{Aeq}E$	59.9	59.6	59.6	58.4	67.8	60.7
$L_{Aeq}N$	53.1	53.6	55.2	53.3	64.6	55.6
L_{dn}	63.5	63.6	64.4	63.7	73.1	65.4
Samples	33	88	35	126	74	360

5. DISCUSSION

By using the results of the survey, a criterion based on L_{50} as well as L_{Aeq} can be examined with respect to environmental noise. The scalings of reactions were carried out by using various methods. In some cases, a criterion for noise environments is obtained from the noise levels which correspond to 30% in cumulative distributions of annoyed inhabitants (i.e., those who express a positive reaction). The values of L_{50} and L_{Aeq} thus obtained in the present survey are given in Table 6. These values are then rounded down by 5 dB(A) steps, and the criterion based on L_{50} and L_{Aeq} for noise environment in different zoning areas is proposed in Table 7. Another criterion which corresponds to the median values

TABLE 6

Levels corresponding to 30% in cumulative distributions for positive reaction to loudness of outdoor noise in different zoning areas (in dB(A))

	General areas					Total
	Exclusively residential	Residential	Commercial	Industrial	Road side area	
$L_{50}24$	47	47	50	48	56	49
$L_{50}M$	45	48	50	49	58	49
$L_{50}D$	50	51	54	52	61	53
$L_{50}E$	46	48	51	47	58	49
$L_{50}N$	40	40	44	41	48	42
$L_{Aeq}24$	58	58	58	58	65	59
$L_{Aeq}M$	55	56	58	56	65	57
$L_{Aeq}D$	60	60	60	60	67	61
$L_{Aeq}E$	56	56	56	55	64	57
$L_{Aeq}N$	49	50	53	49	60	51
L_{dn}	60	61	62	60	69	62

TABLE 7

A proposed criterion based on L_{50} and L_{Aeq} for environmental noise in city areas (in dB(A))

	General areas					Total
	Exclusively residential	Residential	Commercial	Industrial	Road side area	
L_{50} 24	45	45	50	45	55	45
L_{50} M	45	45	50	45 (50)	55	45
L_{50} D	50	50	50 (55)	50	60	50
L_{50} E	45	45	50	45	55	45
L_{50} N	40	40	40	40	45	40
L_{Aeq} 24	55	55	55	55	65 (60)	55
L_{Aeq} M	55	55	55	55	65 (60)	55
L_{Aeq} D	60	60	60	60	65	60
L_{Aeq} E	55	55	55	55	60	55
L_{Aeq} N	45 (50)	50	50	45	60 (55)	50
L_{dn}	60	60	60	60	65	60

of L_{50} and L_{Aeq} for neutral reaction is also examined. This criterion is consistent with the one above with the exception of a few values shown in parenthesis in Table 7.

The results are summarized as follows.

(1) The values of the criterion among daytime, morning (evening) and night-time in each zoning area differ by about 5 dB(A).

(2) The values in a roadside area are greater by about 5 or 10 dB(A) than those in general areas.

(3) The values among different areas of land use of each time section in the general areas are almost the same with the exception of the L_{50} values in the commercial area which are about 5 dB(A) higher.

(4) The differences between L_{Aeq} and the corresponding L_{50} is about 10 dB(A).

(5) The values of L_{50} in residential areas are consistent with the ones in A (i.e., primarily residential) area defined in the quality standards for noise in Japan. In addition, the L_{50} values at a roadside area are almost equal to those in A area bordering on a more than two-lane road defined in the above standards.

(6) The levels higher than 60 dB(A) in L_{50} and 65 dB(A) in L_{Aeq} are unacceptable for noise environments, irrespective of the time of day and area.

(7) The values (i.e., criterion) based on L_{Aeq} are consistent with standards in other countries [2]. These values also confirm those obtained in our previous studies [3, 4].

6. CONCLUSION

Measurements of daily noise exposure of residences and a survey of inhabitants' reactions to the noise environment have been conducted since 1987 in the city of Nagoya. Community noise ratings by L_{50} and L_{Aeq} were examined using stored data. A criterion based on L_{50} is obtained and compared with the environmental quality standards for noise in Japan. The values of the criterion are consistent with the standards in residential areas. However, the values are almost the same in other zoning areas where the standards are different. A criterion based on L_{Aeq} is also obtained, which is in agreement with standards in other countries. A criterion for a roadside area is 5 or 10 dB(A) higher than the one in general areas.

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