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ENVIRONMENTAL NOISE, PERSONAL NOISE EXPOSURE AND PERSONAL RESPONSE TO NOISE

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INTRODUCTION

In spite of the strong administrative measures against noise, complaints are slowly increasing year after year in Japan and the interference with daily life from noise is frequently experienced. When we look at the environment where our houses are located, we hear a lot of complaints against so-called neighborhood noise like that of air conditioning devices, noise from musical instruments, cries of domestic animals, noise of drainage in apartment houses. People themselves produce sounds in their various activities.
At this stage we must know the actual circumstances as to how much and how many sorts of noise the Japanese people are exposed to from day to day, and how they feel about their acoustical environments. Then we can form a scheme to reduce the environmental noise in the future.
From this point of view the authors have carried out the investigation into the daily noise exposure of Japanese city residents,[1] their reaction to environmental noise,[2] and matters concerned.[3]

PERSONAL NOISE EXPOSURE

Daily noise exposure of typical Japanese city residents was investigated and classified depending upon their profession, living environment, method of transit, activity and so on.
The equivalent continuous sound level L_{Aeq} was measured by an integrating sound level meter, which can store L_{Aeq} every ten minutes for 24 hours. The meter is contained in a leather pouch which is worn over the shoulder, the microphone is clipped onto the lapel of a person's jacket. The subject carries the meter for 24 hours, and, at the same time, records his major activities of the day and the times on a sheet of paper. Furthermore, we administered a questionnaire to

the subject in order to examine the relation between his response to noise and exposure to it.
On the basis of our measurements, the cumulative distributions of daily noise exposure, L_{Aeq24}, among 462 workers and 140 housewives were obtained as shown in Fig.1. For workers, the total amount of daily noise exposure varied from 62 dB to 92 dB, and the average noise exposure was 72.7 dB. For housewives, on the other hand, the minimum L_{Aeq24} was 58 dB and the maximum was 82 dB, and the average was 69.9 dB. From these results, we can see that 65.6 percent of workers and 45.7 percent of housewives are exposed to noise over 70 dB in L_{Aeq24} as far as our survey is concerned. As we can expect noise levels to increase in the future, we should strive to decrease noise exposure to protect hearing ability.

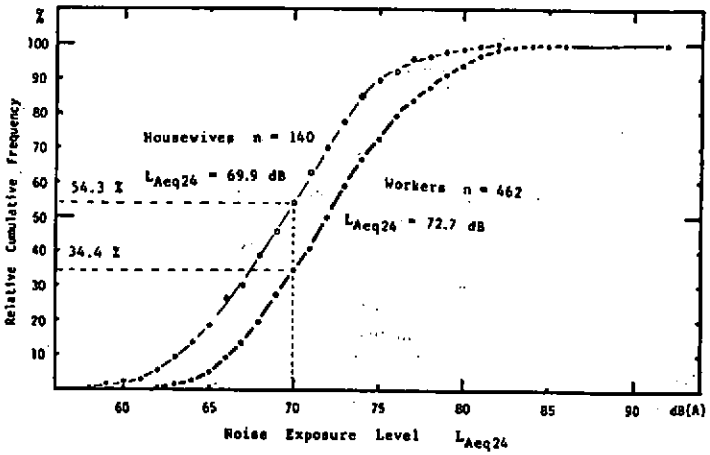

Fig.1 Cumulative distribution of L_{Aeq24} in workers and housewives

Other noticeable results concerning noise exposure of workers are as follows: Among different occupations classified into six categories, the skilled workers show the greatest average L_{Aeq24}, 75.6 dB, and the office workers show the minimum, 70.7 dB. As for various activities, the greatest mean L_{Aeq} is found in commuting and its value is 76.1 dB. Motorbikes show the highest L_{Aeq} (82.2 dB) among different means of commutation.
If we look at the sound environment of workers at home, the quantity of L_{Aeq} after returning home has a significant correlation with that during work. Similarly, housewives with greater L_{Aeq24} show the greater L_{Aeq} while watching TV.

The difference between L_{Aeq24} of workers and L_{Aeq} when they feel annoyed is around 4 - 5 dB whether he works at noisy site or not. This result suggests the existence of a kind of adaptation effect in personal sound exposure.

RELATION AMONG ENVIRONMENTAL NOISE, PERSONAL NOISE EXPOSURE AND RESPONSE OF PEOPLE TO IT

Our next survey was carried out to find the relation among environmental noise, personal noise exposure and response of people to noise. In the survey, the personal noise exposure of people as well as the environmental noise outside their houses was measured by the same type of meters mentioned previously. Subjects' responses to noise were obtained in a questionnaire form. The total number of subjects was 147 including 125 housewives and 22 self-employed males, and all of them lived in the central area of Tokyo.

Relation between environmental noise and personal sound exposure

In a single trial of measurement, two sets of 144 L_{Aeq}'s every ten minutes were obtained: one set was L_{Aeq} of environmental noise around the residence and the other set showed personal sound exposure. We considered here the nine quantities derived from both sets of data respectively. They include the 5-percentile exceeded value obtained from cumulative distribution curve for 144 L_{Aeq}'s, which is indicated here by L_5. Other quantities are L_{10}, L_{90}, L_{95} for the same cumulative frequency distribution curve, the A-weighted equivalent continuous sound level L_d for daytime (7:00 - 22:00), the equivalent sound level L_n for nighttime (22:00 - 7:00), and the 24 hour average sound level L_{dn} obtained after the addition of 10 dB to L_{Aeq} from 22:00 to 7:00.
The mean values for these 18 measures are shown in Table 1, where the number of samples is 147. In the table, data for houses facing the main street and their inhabitants are also shown along with those for houses not facing it and their inhabitants.
As seen from the table, difference in noise level between both

Table 1 Nine values of personal sound exposure and environmental noise.

Level of Noise Exposure		S0	S1	S2	Level of Environmental Noise		S0	S1	S2
	IL_{95}	38.5	40.1	35.8		OL_{95}	57.7	62.1	49.1
	IL_{90}	39.2	40.9	36.5		OL_{90}	58.9	63.4	50.4
	IL_{50}	62.4	62.6	62.3		OL_{50}	65.1	68.9	58.2
	IL_{10}	75.0	74.8	75.4		OL_{10}	70.4	73.9	64.2
	IL_5	77.5	77.2	78.1		OL_5	72.0	75.0	66.5
	IL_n	58.3	58.1	58.7		OL_n	63.7	67.4	56.4
	ILd	73.3	73.2	73.5		OLd	69.3	72.4	63.8
	ILdn	72.8	72.7	73.2		OLdn	71.9	75.4	65.4
	ILeq	71.5	71.4	71.8		OLeq	68.2	71.5	62.4

S0 : Whole Samples

S1 : Samples faced Main Street

S2 : Samples faced Narrow Street

conditions of house location (whether it faces the main street or not) is about 10 dB in each these measures as far as the outdoor noise level is concerned. As to personal sound exposure levels, there is little difference in both house locations except for L95 and L90.

We calculated the correlation coefficients between outdoor average sound level (OL) and personal sound exposure level (IL). Though the correlations are small, in general, IL90 and IL95, which correspond to the lower level in a day, have the largest correlations with the outdoor levels. These IL90 and IL95 are the sound exposure levels in nighttime, as a matter of course, and this fact means that the residents living in noisier area suffer relatively large exposure to noise in nighttime from environs. The contribution of IL90 to the daily sound exposure is small, however, since the sound corresponding to IL90 is negligibly small as compared with the daily exposure.

Contributions of some factors to personal response to noise

Personal response to noise depends not only upon noise level but also upon various factors complicatedly. Seven factors were taken up here, and the dependence of personal responses on them was analyzed with the "theory of quantification (II)". As the levels of noise, some adequate measures were selected from 18 kinds of value shown in Table 1 according to the meaning of each response item. The results for four response items are shown in Table 2.

In the "annoyance of road traffic noise", noise level shows by far the greatest contribution to the inhabitant's response among seven factors.

Table 2 Partial correlation coefficients between four response items and each of seven factors, and the correlation ratio.

	Annoyance for Road Traffic Noise						TV & Radio Interference					
Age	0.27	0.24	0.22	0.25	0.24	0.28	0.12	0.14	0.07	0.16	0.10	0.11
Family Size	0.22	0.13	0.17	0.24	0.16	0.11	0.20	0.14	0.15	0.13	0.16	0.21
Type of House	0.12	0.15	0.11	0.13	0.12	0.18	0.10	0.13	0.09	0.14	0.11	0.08
Type of Window	0.17	0.19	0.18	0.18	0.15	0.27	0.19	0.22	0.18	0.21	0.20	0.13
Direction of Road	0.19	0.19	0.19	0.15	0.20	0.26	0.22	0.25	0.25	0.29	0.20	0.23
Noise Level	0.70 (OL_{90})	0.66 (OL_{50})	0.61 (OL_{10})	0.67 (OLn)	0.69 (OLeq)		0.53 (OL_{90})	0.49 (OL_{50})	0.49 (OL_{10})	0.50 (OLn)	0.48 (OLd)	0.44 (OLeq)
Location of House						0.65						
Correlation Ratio	0.74	0.71	0.68	0.71	0.72	0.70	0.61	0.59	0.58	0.60	0.57	0.56
	Speech Interference						Interference with Falling Asleep					
Age	0.30	0.29	0.27	0.28	0.30	0.28	0.10	0.13	0.02	0.12	0.10	
Family Size	0.25	0.17	0.18	0.19	0.19	0.19	0.24	0.24	0.29	0.24	0.21	
Type of House	0.12	0.16	0.19	0.17	0.19	0.17	0.23	0.32	0.31	0.33	0.29	
Type of Window	0.12	0.12	0.09	0.09	0.09	0.07	0.05	0.09	0.07	0.11	0.02	
Direction of Road	0.12	0.10	0.06	0.11	0.07	0.08	0.11	0.08	0.20	0.22	0.13	
Noise Level	0.52 (OL_{90})	0.48 (OL_{50})	0.45 (OL_{10})	0.51 (OLn)	0.43 (OLd)	0.44 (OLeq)	0.35 (OL_{90})	0.32 (IL_{90})	0.33 (ILn)	0.41 (ILeq)		
Location of House											0.32	
Correlation Ratio	0.63	0.60	0.59	0.61	0.57	0.57	0.49	0.50	0.51	0.54	0.48	

Furthermore, if we adopt OL_{90} among various measures of noise climate, the correlation ratio between measured and predicted responses gives the largest value. OL_{90} can be said, therefore, to be a good measure for predicting the annoyance of road traffic noise.
In the "interference with listening to radio or TV sound" and the "interference with conversation", the contribution of noise level to the inhabitant's response is small as compared with that in the annoyance of road traffic noise. The greatest correlation ratio is obtained here, too, when OL_{90} is adopted as a measure of noise. In the "interference with falling asleep", on the other hand, the sound exposure levels were taken up as the measures of noise, and the adoption of IL_{eq} or IL_n resulted in the greater correlation ratio rather than OL_{90} did.

THE INFLUENCE OF SUBJECT'S OWN VOICE IN HIS NOISE DOSE

In our method of measuring the noise exposure through a microphone put on one's lapel, it inevitably picks up the subject's own voice as well as external sounds. The influence of subject's own voice on his hearing may be different in its character from that of external sounds. We tried to determine the share of subject's own voice in his noise dose and already presented some data on it.[3] In this section we will show somewhat precise data concerning the utterance level and the share of subject's own voice in his daily noise exposure, which were measured by using the newly developed instruments. The daily noise exposure level , the utterance level and the total time of speaking in a day were observed for 24 subjects. The results are shown in Table 3. In this table L0 means $L_{Aeq}24$, which includes the voice of the subject, L1 is the L_{Aeq} excluding the energy of his own voice, and L2 is the L_{Aeq} during his utterance. We can see from the table that each mean level is almost the same between housewives and students. The subject No.24 is a teacher of an elementary school, and every level is the highest among subjects, though the time of her utterance is not so long.
If we calculate the mean of the difference between L0 and L1, it is 2.8 dB for housewives, 1.8 dB for students and 5.8 dB for teachers. Further data will be presented in the near future.

SUMMARY

Outline of our personal noise exposure survey is described above. Some of the results obtained until now are as follows:
1) A large percentage of workers and housewives is exposed to sound over 70 dB in $L_{Aeq}24$, which is the limit recommended by USEPA for the protection of hearing. We must pay attention to our noise exposure in daily life, even though the sound energy of our own voice is eliminated from the sound exposure.
2) The long-term impression of environmental noise around our residences is found to show a large correlation with the residual noise

Table 3 The relation of daily noise exposure level, utterance level and total time of speaking.

Subjects	No.	L0	L1	L2	T(sec)
Housewives	1	75.0	73.7	83.9	3561
	2	71.0	69.9	82.1	2124
	3	64.0	61.9	75.0	3081
	4	69.7	64.5	79.4	7996
	5	71.4	67.2	84.8	3108
	6	76.3	74.4	84.2	6110
	7	69.7	65.3	88.3	1665
	8	69.8	68.1	81.8	2008
	9	69.8	67.5	76.6	8405
	10	70.1	68.9	76.5	5999
	11	73.1	68.0	82.6	7174
	Mean	70.9	68.1	81.3	4657
	S.D.	3.1	3.5	3.9	2410
Students	12	68.9	66.6	81.1	1152
	13	68.6	67.4	76.4	3755
	14	69.0	68.6	75.9	2377
	15	71.6	69.1	83.6	2546
	16	76.7	74.5	84.0	7128
	17	70.2	69.0	81.0	1945
	18	79.3	78.9	87.5	2396
	19	66.7	65.6	79.7	1710
	20	66.6	61.9	77.1	5119
	Mean	70.8	69.1	80.7	3239
	S.D.	4.1	4.7	3.7	1703
Teachers	21	72.9	64.0	83.0	7505
	22	70.5	66.9	83.7	2448
	23	68.1	64.2	77.7	6329
	24	79.7	75.2	89.8	5801
	Mean	72.8	67.6	83.6	5520
	S.D.	4.3	4.6	4.3	1878

outside the house rather than with personal noise exposure.
3) The short-term impression of noise in our daily life is influenced by our noise exposure.
4) Only a small correlation is found between the personal noise exposure of residents and the level of environmental noise around residences except for nighttime.
5) People who work in noisy spot are apt to be exposed to a relatively loud sound at home and to watch TV with a loud sound.
We are still working on our survey. As a result, it is found as a tendency that the difference between the level of noise from external sources observed outside the house and that measured in a bedroom increases along with the increase in noise level outside the house. If this is true, it is suggested that people who live in noisy environmeant contrive to reduce the external noise intruding into the house.

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