Investigation of road traffic noise and annoyance in Beijing: A cross-sectional study of 4th Ring Road

Hui-Juan Li, Wen-Bo Yu, Jing-Qiao Lu, Lin Zeng, Nan Li, Yi-Ming Zhao

Research Center of Occupational Medicine and Research Center of Clinical Epidemiology, Peking University Third Hospital, Beijing, P. R. China

Address correspondence to: Hui-Juan Li, Research Center of Clinical Epidemiology Peking University Third Hospital, 49 North Huayuan Road, Haidian District, Beijing, 100083, P.R. China. Tel (Fax) : +86-010-62017691 ext 2732, E-mail:elegancelhj@hotmail.com

ABSTRACT

The aim of this study was to evaluate traffic noise level and noise annoyance in Beijing and the impact of the noise on quality of life of the residents. A cross-sectional study had been carried out in a 12-floor college dormitory near 4th Ring Road in Beijing. The north-side rooms of the building were noisy with windows facing the road. Both indoor and outdoor noise was measured. A sample of 1293 college students living in the dormitory were questioned about their response of road traffic noise annoyance using both a five-item verbal scale and a 0-11 numerical scale. The results showed that average outdoor day-night noise level (L_{dn}) in the noisy rooms was 79.2 dB(A), and 64.0 dB(A) in the quiet rooms. Nearly 39 % respondents living in the noisy rooms indicated that they were highly annoyed by traffic noise according to the response on the verbal scale, and 50 % respondents living in the noisy rooms were highly annoyed according to the numerical scale.

Keywords: noise, road traffic, annoyance, Beijing

INTRODUCTION

Traffic noise tends to be a dominant noise source in urban area. Most of today's research on noise control is focused on noise from transportation of urban traffic. An amount of literature was written on the subject of the various effects of traffic noise on people. Traffic noise interferes with basic activities such as sleeping, resting, studying and communicating, it can also cause heart disease, mental health problems and hearing damage (Stansfeld et al. 2000; Ohrström 2004; Lundqvist et al. 2000; Babisch et al. 2005).

Noise annoyance is seen as the major effect of noise, which can include feelings of nuisance or disturbance (Passchier-Vermeer & Passchier 2000; Guski & Felscher-Suhr 1999). Existing evidence indicates that traffic noise is the most important source of environmental annoyance, such studies have found a positive correlation between annoyance and sound level (Ali 2003; Fidell 2003; Ising & Kruppa 2004; Michaud et al. 2005; Miedema 2004; Ouis 2002; Yano & Ma 2004). The simplest and most widespread scheme in use is the presentation of a self-reported scale of annoyance (Fields 1984; Fields et al. 2001). With the exception of Japan, all of these regions were Euro-American. In 2004 Yano and Ma have translated the standardized 5-point verbal noise scale into Chinese (Yano & Ma 2004).

There is growing recognition of the importance of environmental noise pollution in Beijing, capital of China. Heavy traffic flows have lead to high noise pollution levels in these areas. The maximum Leq reaches 79.5 dB(A) with an average L_{eq} of 75.6 dBA at the monitoring locations surrounding main roads (Li et al. 2002; Li & Tao 2004). Some studies reported that about 16 % of the people (1 million) live in the areas surrounding main roads in Beijing (Wang et al. 2000; Wang & Liu 2004). So far, very few studies have been carried out to investigate and assess noise annoyance in Beijing.

A cross-sectional study was carried out in a 12-floor college dormitory nearby north 4th Ring Road in Beijing to assess traffic noise level and noise annoyance degree. Both indoor and outdoor noise of this building was measured, and two standardized questions were used for noise annoyance survey in accordance with the recommendations provided by ICBEN and Yano's study.

METHODS

The 12-floor dormitory was 20 meters away from the north 4th Ring Road. There were 50 rooms on each floor. The north-side rooms of the building were noisy with windows facing the road, and the south-side rooms were relatively quiet (Figure 1).

We selected two rooms from each floor (one room on the noisy side, the other on the quiet side), with a total of 24 rooms. The selected noisy room number was N42 and the quiet room was N43 in each floor (N=floor number), made sure all of the rooms were in the same vertical section (Figure 1). If the pre-selected room was absent, the room next it on the same side was measured. For example, if room 842 was absent when we conducted the measurement, then room 844 or 846 next to it would be measured randomly.

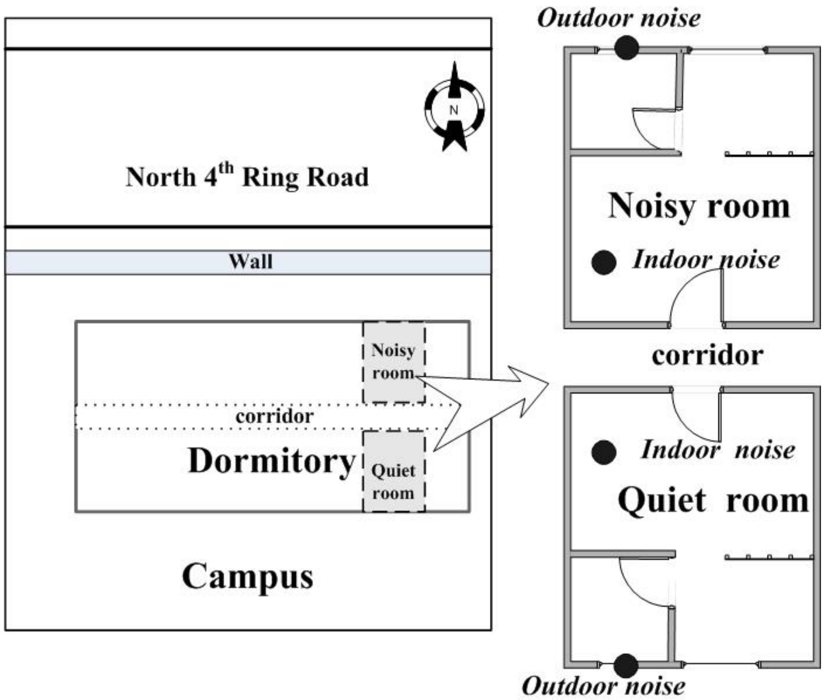

Figure 1: Sketch map of noise assessment on one floor of the dormitory

Indoor and outdoor noise was measured in the 24 rooms from 22:30 to next day 21:00 using 24 noise dosimeters (AWA5610E, Hang Zhou Ai Hua Instruments Co. Ltd., Hangzhou, China) in two days. In the first day, both indoor and outdoor noise of 12 rooms on the 1, 3, 5, 7, 9, 11 floors were measured, and in the second day those of the 2, 4, 6, 8, 10, 12 floors were measured. The dosimeters meet the requirements of IEC61672-2002 standard for class 2 integrating sound level meter, Chinese National Standards (GB) of sound level meter GB3785-1983 and personal noise dose meter standards GB/T15952-1995.

Equivalent A-weighted sound pressure level (L_{Aeq}) was computed with a sample interval of 4 seconds. Day-night noise levels (L_{dn}) have been calculated from the formula:

$$L_{dn} = 10\lg[\frac{1}{22.5}14.5*10^{L_d/10} + 8*10^{(L_n+10)/10}]$$

where L_d and L_n represent the daytime and night-time equivalent noise level, respectively. The daytime period was from 06:30 to 21:00 and the nighttime period was from 22:30 to 06:30.

Dosimeters measuring outdoor noise were located in the windowsills of these rooms. Make sure the microphones pointed to the outside and windows were open all the day. Dosimeters for indoor noise were located on the top of wardrobes (2 meters height) inside these rooms with microphones exceeding the wardrobes 3 to 5 cm and pointing to the center of the room (Figure 1).

The survey was performed all by volunteer distributors who were members of the environmental protection association in this university. Questionnaires were distributed to each room of the dormitory. The questionnaires were completed by the respondents in their dorms and were collected one hour later. Out of 1560 questionnaires distributed, 1463 were filled, giving the response rate 93.8 %. 170 questionnaires were excluded in which both of the noise annoyance questions were not filled. The final sample consisted of 1293 respondents, 720 in the quiet rooms, 573 in the noisy rooms.

The questionnaire comprised demographic characters (age, sex, period of residence), noise annoyance degree and noise sensitivity score.

In accordance with the recommendations provided by ISO/TS-15666 the following two questions were asked about road traffic noise annoyance. One question is: Thinking about the last 12 months or so, when you are at home, how much dose noise from road traffic bother, disturb, or annoy you? The subjects were asked to response with a 5-point verbal scale. We used the standardized noise annoyance scales in Chinese14 in which not at all was translated to yi dian ye bu, slightly to hao xiang you dian, moderately to bi jiao, very to xiang dang, extremely to te bie.

The second question is: Thinking about the last 12 months or so, what number from zero to ten best shows how much you are bothered, disturbed or annoyed by road traffic noise ? The answer is a 0-10 numerical scale that zero is equivalent to “not at all bothered” (yi dian ye bu fan in Chinese) and ten is equivalent to “extremely bothered”(te bie fan in Chinese).

Noise sensitivity is an intervening variable between noise exposure and annoyance (Belojevic et al. 2003; van Kamp et al. 2004; Job 1999). In our study, we used a Swedish version of the Weinstein Noise Sensitivity Scale to assess noise sensitivity, which consists of 16 items with a 7-point scale to response (Vastfjall 2002). Higher scores indicate higher sensitivity to noise.

ANOVA was used to compare noise from different positions, followed by Fisher’s protected least significant difference (LSD) if significant. Student’s t-test was used to compare age, years of residence between noisy and quiet rooms. $\chi 2$ test was used to compare gender. Correlation between 5-point verbal scale and 0-10 numerical scale was computed using Pearson correlation coefficients. Multiple logistic regression analysis was used to investigate the association of possible factors for noise annoyance. All analyses were performed using SPSS version 13.0 for Windows.

RESULTS

Both indoor and outdoor noises were measured on every floor. The results of the average noise levels are shown in Table 1. The average L_{dn} of outdoor noise is 79.2 dB(A) in the noisy rooms, which is 15 dB(A) higher than in the quiet rooms. No significant differences of indoor noise L_{dn} were observed between the noisy and quiet rooms. Noise in the night was about 2-6 dB(A) lower than in the day of each position. The outdoor noise in the night was very high in the noisy rooms, which was 72.6 dB(A). We also computed equivalent noise levels from 2:00 to 5:00 in the morning when every resident was sleeping. The result showed that the average indoor noise of the noisy rooms was 4.8 dB(A) higher than of the quiet rooms in the wee hours. In short, the results supported that road traffic noise highly affected outdoor noise environments in the noisy rooms. Indoor noise during sleep time in the noisy rooms was also influenced.

Table 1: Noise from different positions in the 12-floor dormitory (unit: dB)

Positions		N (floors)	Daytime $L_{Aeq,14.5h}$	Nighttime $L_{Aeq,8h}$	Day-night level L_{dn}	wee hours $L_{Aeq,3h(2:00\text{-}5:00)}$
Noisy	outdoor	12	74.4 ± 3.5[a]	72.6 ± 3.0[a]	79.2 ± 3.1[a]	71.1 ± 3.0[a]
	indoor	10	59.1 ± 3.2[b]	53.4 ± 4.0[b]	61.5 ± 3.1[b]	45.8 ± 4.6[b]
Quiet	outdoor	12	61.0 ± 2.4[b]	56.3 ± 3.1[b]	64.0 ± 2.4[b]	52.4 ± 1.6[c]
	indoor	10	59.8 ± 2.5[b]	54.7 ± 5.3[b]	63.4 ± 2.4[b]	41.0 ± 0.5[d]
P-value			< 0.01	< 0.01	< 0.01	< 0.01

Results marked with different letters are significantly different for each index, LSD test, $P<0.05$. Indoor noise of two noisy rooms and two quiet rooms were not measured because of residents' disagreement.

All of the 1293 respondents were college school students living in the 12-floor dormitory. The time of residence varied from 1 month to 6 years. The average age was 20.9 years old, ranging from 16 to 30. About 75.9 % of the respondents were female and 24.1% were male.

The comparison of general characteristics between noisy and quiet rooms are shown in Table 2. There were no significant differences in gender and years of residence between the two sides. Respondents from the noisy rooms showed more sensitive to noise (P=0.002) and they were a little younger (P=0.045).

Table 2: General characteristics

General characteristics	Position		P-value
	quiet	Noisy	
No. of residents	720	573	
Age (mean ± SD, y)	21.0 ± 1.7	20.8 ± 1.6	0.045
Men (%)	24.7	22.0	0.238
Years of residence (mean ± SD)	1.9 ± 1.4	1.8 ± 1.4	0.228
Noise sensitivity score (mean ± SD)	69.7 ± 13.9	72.1 ± 13.4	0.002

The correlation between the verbal scale and 0-10 numerical scale was high (Pearson correlation coefficient=0.923, P<0.01). In this survey, significant differences were found on both noise annoyance scales between respondents in the noise and quiet rooms (Mann-Whitney's U-test, P<0.001). Respondents in the noisy rooms were clearly more disturbed by traffic noise than those in the quiet rooms.

Those who answered "very" or "extremely" on the verbal scale or score >6 on the 0-10 numerical scale were considered "highly annoyed". (On the 0-10 numerical scale: 0+1=not at all; 2+3=slightly; 4+5+6=moderately; 7+8=very and 9+10=extremely). Nearly 39 % of the respondents in the noisy rooms indicated that they were highly annoyed by traffic noise according to the response on the verbal scale, but only 6 % in the quiet rooms (Figure 2). Percent of highly annoyed responses was even higher on the 0-10 numerical scale, which was 50% in the noisy rooms and 9% in the quiet rooms (Figure 2).

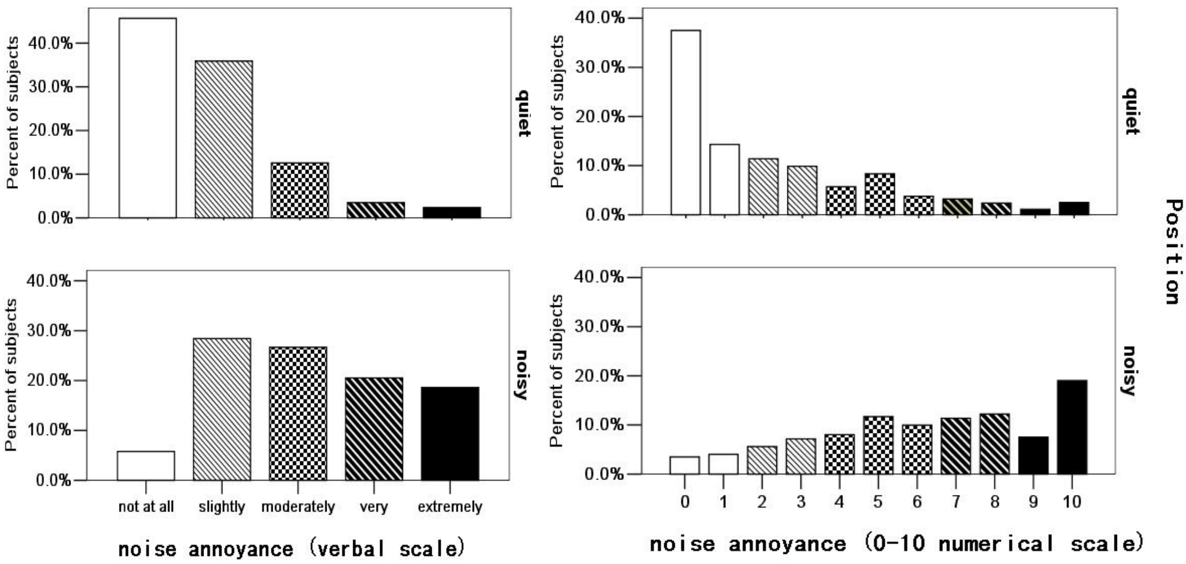

Figure 2: The distribution of road traffic noise annoyance on the verbal and numerical scale among respondents in the noisy and quiet rooms of the dormitory

Two models were used to evaluate the factors which might affect the annoyance levels of the subjects with both of the annoyance scales. After adjusting for years of residence, living floor and gender, the multivariate logistic regression analysis demonstrated that residence in noisy rooms was identified as an important predictor for the occurrence of highly annoyed response (OR=12.42, P<0.05, in model 1;

OR=12.95, P<0.05, in model 2; Table 3). Residents with higher noise sensitivity showed more highly annoyed response (OR=1.07,P<0.05, in model 1&2). There were no differences between the two models except the years of residence was significant in model 2 (0-10 numerical scale) (OR=0.88,P<0.05).

Table 3: Multivariate logistic regression analyses showing ORs (95 % CIs) of highly annoyed response

Variables	Model 1 (verbal scale)		Model 2 (0-10 numerical scale)	
	OR (95 % CI)	P-value	OR (95 % CI)	P-value
Position (noisy vs quiet)*	12.42 (8.40-18.37)	< 0.001	12.95 (9.17-18.28)	< 0.001
Noise sensitivity score	1.07 (1.06-1.09)	< 0.001	1.07 (1.06-1.08)	< 0.001
Years of residence	0.94 (0.83-1.06)	0.325	0.88 (0.78-0.99)	0.028
Floor	0.95 (0.89-1.02)	0.137	0.96 (0.90-1.03)	0.234
Gender (female vs male)	1.34 (0.78-2.31)	0.291	1.08 (0.65-1.79)	0.769

* Noisy: Outdoor L_{dn}=79.2 dB, Quiet: Outdoor L_{dn}=64.0 dB

DISCUSSION

In this study, high level of road traffic noise was observed near the 4th Ring Road in Beijing, which was in accordance with previous study (Li et al. 2002; Li & Tao 2004). The average noise level during night time (22:30-nextday 06:30) was 72.6 dB(A), which exceeded the national standard of 45 dB(A) (GB3096-93) by 27.6 dB(A) (EPA China 1993). Big trucks were allowed to come into the urban area only from 23:00-06:00 in Beijing, which was the main reason of noise pollution during nighttime.

Indoor noise exposure assessment was conducted in this study, which could reflect the real noise environment where people live. But there were no significant differences of indoor noise between the noisy and quiet rooms except for the sleeping time (Figure 2, Table 1). Indoor noise was also influenced by people’s conversation and other activities. So we computed indoor noise levels from 2:00 to 5:00 a.m., the result showed that the average indoor noise of the noisy rooms was 4.8 dB(A) higher than of quiet rooms in the wee hours. Indoor noise measurement during the sleeping time might be ideal to evaluate how much traffic noise affected people’s life. The outdoor noise was 10 dB(A) larger than indoor noise for the quiet rooms from 2:00-5:00 a.m. The outdoor noise might be affected by traffic noise diffraction from 4th Ring Road, for the quiet rooms only faced a small footpath in the college and there was no noise source during this 3-hour period.

In our study we used both a five-item verbal scale and a 0-10 numerical scale. The correlation between the two scales was high (Pearson correlation coefficient=0.923, P<0.01), and the percents of highly annoyance were different which were 39 % on the verbal scale and 50 % on the numerical scale in the noisy rooms. ISO 1996-1:2003 gives guidance on predicting the potential annoyance response of a community to long-term exposure from various types of environmental noises. To compare which scale was more believable, we used the ISO standard for assessment procedures for environmental noise the percent highly annoyed is obtained from the rating level (RL) using equation:

$$\% \text{ highly annoyed} = 100/[1+\exp(10.4-0.132*RL)]$$

The relationship for road traffic noise is obtained when RL equals L_{dn} .The number of daylight hours is 15, defined as hours from 07:00-22:00 (ISO 2003; Michaud et al. 2005). Outdoor noise L_{dn} in the noisy rooms in the present study was 79.4 dB(A), the calculated percent of highly annoyed was 51.36 % according to the equation. It indicates that the result of the numerical scale is closer to 51.36 % and maybe more comfortable for the evaluation of road traffic noise annoyance.

The logistic regression analysis demonstrated that residents in noisy rooms and those with higher noise sensitivity showed more highly annoyed response in model 1 & 2. Years of residence was only significant in model 2 (0-10 numerical scale) (OR=0.88, P<0.05) which means that subjects living longer time in this residence showed less annoyance. It might because the 0-10 numerical scale was more accurate than the 5-point verbal scale. In our study the average year of residence was less than 2 years, so we need to evaluate more groups of people with different ages to testify.

To our knowledge, the present study is the first to evaluate level of annoyance to traffic noise in Beijing. We found that 50 % respondents living in the noisy rooms were highly annoyed by road traffic noise (using numerical annoyance scale). Authorities in Beijing have increased aware of the effects of road traffic noise in urban areas, soundproof windows have been built in several districts along 4th Ring Road. Reducing traffic volume is another method to solve noise pollution problem (Ohrström 2004). In recent years, the government in Beijing keeps on developing urban public traffic and begins to restrict the increase of private cars. In order to greet the Beijing 2008 Olympic Game, Beijing will still shoulder heavy responsibilities to improve acoustical environment.

Our study has one limitation that we only focused on a certain group of college students in Beijing, and the noise observation targets the north 4th Ring road. To form a whole picture of people's noise annoyance in Beijing, we need to select different groups of people in different spots of the city, and according to the noise map in Beijing we can establish the relationship between road traffic noise level and percentage of respondents that feel "highly annoyed".

REFERENCES

Ali S (2004). Investigation of the dose–response relationship for road traffic noise in Assiut, Egypt. Appl Acoust 65: 1113-1120.

Babisch W, Beule B, Schust M, Kersten N, Ising H (2005). Traffic noise and risk of myocardial infarction. Epidemiology 16: 33-40.

Belojevic G, Jakovljevic B, Slepcevic V (2003). Noise and mental performance: personality attributes and noise sensitivity. Noise & Health 6 (21): 77-89.

EPA, China (1993). GB3096-93: noise standard in urban environment. Beijing: Publishing House of China Environmental Sciences.

Fidell S (2003). The Schultz curve 25 years later: a research perspective. J Acoust Soc Am 114: 3007-3015.

Fields JM (1984). The effect of numbers of noise events on people's reactions to noise: An analysis of existing survey data. J Acoust Soc Am 75: 447-467.

Fields JM, De Jong RG, Gjestland T, Flindell IH, Job RFS, Kurra S, Lercher P, Vallet M, Yano T, Guski R, Felscher-Suhr U, Schümer R (2001). Standardized general-purpose noise reaction questions for community noise surveys: research and a recommendation. J Sound Vibr 242: 641-679.

Guski R, Felscher-Suhr U (1999). The concept of noise annoyance:how international experts see it. J Sound Vibr 223: 513-527.

Ising H, Kruppa B (2004). Health effects caused by noise: evidence in the literature from the past 25 years. Noise & Health 6 (22): 5-13.

ISO, International Organization for Standardization (2003). Acoustics-Description, measurement and assessment of environmental noise, Part 1: Basic quantities and assessment procedures. ISO 1996-1: 2003 (E).

Job RF (1999). Noise sensitivity as a factor influencing human reaction to noise. Noise & Health 1 (3): 57-68.

Li BG, Tao S (2004). Influence of expanding ring roads on traffic noise in Beijing City. Appl Acoust 65: 244-249.

Li BG, Tao S, Dawson RW (2002). Evaluation and analysis of traffic noise from the main urban roads in Beijing. Appl Acoust 63: 1137-1142.

Lundqvist P, Holmberg K, Landstrom U (2000). Annoyance and effects on work from environmental noise at school. Noise & Health 2 (8): 39-46.

Michaud DS, Keith SE, McMurchy D (2005). Noise annoyance in Canada. Noise & Health 7 (27): 39-47.

Miedema HM (2004). Relationship between exposure to multiple noise sources and noise annoyance. J Acoust Soc Am 116: 949-957.

Ohrström E (2004). Longitudinal surveys on effects of changes in road traffic noise-annoyance, activity disturbances, and psycho-social well-being. J Acoust Soc Am 115: 719-729.

Ouis D (2002). Annoyance caused by exposure to road traffic noise: an update. Noise & Health 4 (15): 69-79.

Passchier-Vermeer W, Passchier WF (2000). Noise exposure and public health. Environ Health Perspect 108 (Suppl 1): 123-131.

Stansfeld S, Haines M, Brown B (2000). Noise and health in the urban environment. Rev Environ Health 15: 43-82.

van Kamp I, Job RF, Hatfield J, Haines M, Stellato RK, Stansfeld SA (2004). The role of noise sensitivity in the noise-response relation: a comparison of three international airport studies. J Acoust Soc Am 116: 3471-3479.

Vastfjall D (2002). Influences of current mood and noise sensitivity on judgments of noise annoyance. J Psychol 136: 357-370.

Wang Y, Liu JL (2004). Urban area acoustic environment reviews and prospects of Beijing. Noise Vibr Contr 5: 23-25.

Wang Y, Song FX, Xu H. (2000). Investigations and countermeasures for pollution on the traffic noise Ii Beijing area. Noise Vibr Contr 3: 31-35.

Yano T, Ma H (2004). Standardized noise annoyance scales in Chinese, Korean and Vietnamese. J Sound Vibr 277: 583-588.

Yoshida T, Osada Y, Kawaguchi T, Hoshiyama Y, Yoshida K, Yamamoto K (1997). Effects of road traffic noise on inhabitants of Tokyo. J Sound Vibr 205: 517-522.