Personal noise exposure assessment of overhead-traveling crane drivers in steel-rolling mills

Lin Zeng[1], Dong-liang Chai[2], Hui-juan Li[1], Zhuo Lei[2], Yi-ming Zhao[1*]

[1] Research Center of Clinical Epidemiology, Peking University Third Hospital, 49 Huayuan road, Haidian District, Beijing 100083, China

[2] Department of Occupational Health, Center for Disease Control and Prevention, Taiyuan Iron & Steel (Group) Company LTD., 332 Datong road, Taiyuan, Shanxi province 030003, China

*corresponding author: Zhao Yi-ming e-mail: yimingzhao115@163.com

INTRODUCTION

Noise is one of the most widespread occupational hazardous agents. It's attributable for 16 % mortality and morbidity due to occupational exposures for global burden of occupational disease and injury (Nelson et al. 2005). According to the World Health Organization (WHO), noise-induced hearing impairment is the most common irreversible (and preventable) occupational hazards world-wide. And in most developing countries, industrial noise levels are higher than those in developed countries (Nelson & Schwela 2001). Many countries around the world had developed Hearing Conservation Programs to protect the workers. Noise exposure assessment is the first step in a Hearing Conservation Program. Noise exposure in steel plants is well known for being one of the highest among all industries both in developed and developing countries. According to International Labour Organization (ILO), the iron and steel industry is the most important industry in China. Overhead-traveling cranes are widely used in this industry, but few studies characterizing overhead-traveling crane drivers' noise exposure levels have been published so far. According to Legrisa and Poulinb, personal noise exposure levels among crane drivers they had measured using noise dosimeters ranged from 74 to 97 dB(A), depending on the carrying capacity and whether the crane had an insulated cab or not (Legrisa & Poulinb 1998).

Noise dosimeters are usually small and easily carried on workers' waist or put into their dungarees pocket, so that they can collect full-shift noise exposure data by moving together with the workers. Thus, they have been used extensively in the past two decades to measure noise exposure of workers who work in non-steady noise environments where sound pressure levels shift significantly during the period of observation. Increasingly, investigators have used noise dosimeters to evaluate occupational and environmental exposure to noise (Ahmed et al. 2001; Sadhra et al. 2002; Neitzel et al. 2004; Reeb-Whitaker et al. 2004; Landon et al. 2005; Cesar Diaz & Antonio 2006). Moreover, personal noise dosimeters have been used internationally for large-scale noise surveys (Kock et al. 2004; Daniell et al. 2006).

As there are few data on noise exposure of overhead-traveling crane drivers, in this study, we used personal noise dosimeters to assess full-shift noise exposure of overhead-traveling crane drivers in a hot steel-rolling mill and a cold steel-rolling mill of the same steel plant. We would like to describe the characteristics of noise exposures and examine if the noise exposures of these crane drivers exceeds the limit value of 85 dB(A) for 8 hour work shift or daily personal noise exposure recommended by US National Institute of Occupational Safety and Health (NIOSH) (NIOSH 1998) and Chinese criterion of Occupational Exposure Limit for Noise in Workplace (MOH P.R. China 2002).

SUBJECTS AND METHODS

Subjects

This study was conducted in two steel-rolling mills of the same steel plant. This plant is over 80 years' old and is the largest stainless steel manufactory in China, which produces over five million tons of steel each year. One of the two mills is hot rolling and the other is cold rolling. This study was conducted in fall 2005.

There were 17 overhead-traveling cranes in the hot steel-rolling mill and 24 cranes in the cold one, all of which were 17 meters high. According to locations and tracks, overhead-traveling cranes in the hot and cold steel-rolling mill gathered and formed six lines and nine lines respectively. Loads of the cranes were between 15 tons and 100 tons. The crane operating cabins were built of steel plates, with a dimension of 1.5×1.8×2m (W×L×H). There were three windows in the operating cabin. One was opposite to the door; the other two were in front of and at the back of the operating panel. There were no noise insulating measures in operating cabins.

All overhead-traveling crane drivers of the two mills were enrolled in this survey, 92 overhead-traveling crane drivers in the cold steel-rolling mill and 56 in the hot one. After exclusion of workers who were absent (on vacation, taking sick leave, or out for job training), the exact number of the participants was 76 in the cold steel-rolling mill and 48 in the hot one. Most of the overhead-traveling crane drivers are male. Gender proportions of male to female crane drivers in both of the rolling mills were approximately the same (p=0.977), about 8 to 2 (Table 1).

Table1: Gender of the participants in the tow steel rolling mills

	Participants n (%)			Absent n (%)	Total number of crane drivers
	Male	Female	Total		
Hot rolling mill	38 (79.2)	10 (20.8)	48	8 (14.3)	56
Cold rolling mill	60 (78.9)	16 (21.1)	76	16 (17.4)	92
Total	98 (79.0)	26 (21.0)	124	24 (16.2)	148

Gender proportions χ^2=0.001 P=0.977

Overhead-traveling crane drivers in these mills worked 8 hours a shift with an average of 5.25 shifts a week. Each crane was operated by one driver at a time, but some drivers might operate more than one crane during a shift. That is, crane drivers might change lines in their work shifts.

Noise exposure measurement

Personal noise dosimeters (AIHUA Instruments Model AWA5610e, Hangzhou, China) were used to collect full-shift noise exposure data for the participants. The dosimeters meet the International Electrotechnical Commission (IEC) standard IEC61672-2002 class 2, Chinese national standards (GB) of sound level meter GB3785-1983, and personal noise dose meter standards GB/T15952-1995. Dosimeters collected noise exposure data according to Chinese national standard (85 dB(A) criterion, 3 dB exchange rate). Dosimeters were fitted and removed by the researchers at subjects' workstations. Microphones were covered with windscreens and placed near subjects' collars. Dosimeters were calibrated before each measurement. The logging period was two seconds, allowing for the collection of 14400 2-second A-weighted equivalent continuous sound levels ($L_{Aeq.2s}$) data for an 8-h work shift.

Crane drivers were asked to fulfill work logs about their activities during work shifts. Contents included date, crane code, working activities and time and location of activities (Hung et al. 2003; Chen et al. 2003). 124 work logs were collected in total. Researchers checked whether the noise data of each crane drivers was consistent to his work log after noise exposure measurement. If they didn't match, the driver would be measured again.

Data analysis and statistical methods

8-hour A-weighted equivalent continuous sound levels ($L_{Aeq.8h}$) were computed by commercial software AWA5610e (AIHUA Instrument, Hangzhou, China). In order to estimate noise exposure in different lines, A-weighted equivalent continuous sound levels (L_{Aeq}) based on lines were obtained through analyzing personal noise exposure data according to work logs. So if a driver changed lines during his work shift, personal noise exposure data would be divided into segments based on the lines in which they worked[14]. Each L_{Aeq} based on lines was considered to be a measurement of noise exposure for a line. A-weighted equivalent continuous sound levels, $L_{Aeq.8h}$ and L_{Aeq} based on lines, were calculated according to the equal energy principle, using the following formula (Kryter 1985; Malchaire & Piette 1997)

$$L_{Aeq} = 10 \times \log\left[\frac{1}{n}\left(10^{\frac{L_{eq1}}{10}} + 10^{\frac{L_{eq2}}{10}} + \ldots + 10^{\frac{L_{eqn}}{10}}\right)\right]$$

where n=number of 2 second measurements, and L_{eq1}, L_{eq2} … L_{eqn} are the average noise levels during each measurement 2 second interval.

Personal noise exposure levels ($L_{Aeq.8h}$) were presented by arithmetic mean and standard deviation, geometric mean and median etc. Noise levels based on lines were presented by arithmetic mean and standard deviation, minimum, maximum and range. Furthermore, we assess exposure to high noise levels by computing the percentage of workers and lines above 85 dB(A). Student t-test was used to determine differences in $L_{Aeq.8h}$ of crane drivers between the two steel-rolling mills. Nested design analysis of variance (nested design ANOVA) was used to compare the noise exposure levels based on different lines in the two mills. A two-tailed P-value less than 0.05 was considered statistically significant. All statistical analyses were done using SPSS13.0. Typical personal noise exposure level figures of overhead-traveling crane drivers were drawn by using R2.3.0.

RESULTS

Personal noise exposure level

The average personal noise exposure ($L_{Aeq.8h}$) of overhead-traveling crane drivers in the hot and the cold steel-rolling mills was 85.03 ± 2.25 dB(A) and 83.05 ± 2.93 dB(A) respectively. Personal noise exposure level in the hot steel-rolling mill was higher than that in the cold one, and the difference was statistically significant ($p<0.001$). The arithmetic mean, geometric mean and median of $L_{Aeq.8h}$ in hot steel-rolling mill were approximate the same, but the $L_{Aeq.8h}$ median in cold steel-rolling mill was a little smaller than the arithmetic mean and geometric mean. The range of noise level in the cold steel-rolling mill was almost twice as large as the hot one. 54.2 % personal noise exposure measurements in the hot steel-rolling mill and 23.7 % in the cold one were over the 85 dB(A) criteria (Table 2). Most measurements of $L_{Aeq.8h}$ of crane drivers in the hot steel-rolling mill were between 83 and 87 dB(A). The distribution of measurements in the hot steel-rolling mill was approximately normally distributed. The shape of personal noise exposure in the cold steel-rolling mill was right skewed and spread much wider than that in the hot one (Figure 1). Hence, the $L_{Aeq.8h}$ median in the cold steel-rolling mill was smaller than arithmetic mean and geometric mean.

Table 2: $L_{Aeq.8h}$ (dB(A)) of overhead-traveling crane drivers in two steel-rolling mills)

Mill	Measure-ments	Arithmetic Mean (SD)	Geometric mean	Median	Min	Max	Range	Measurements over 85 dB(A) n (%)
Cold steel-rolling mill	76	83.05 (2.93)	83.00	82.05	77.0	94.1	17.1	26 (54.2)
Hot steel-rolling mill	48	85.03 (2.25)	85.00	85.20	79.1	89.9	10.8	18 (23.7)

t=4.25, df=117.2, p<0.001

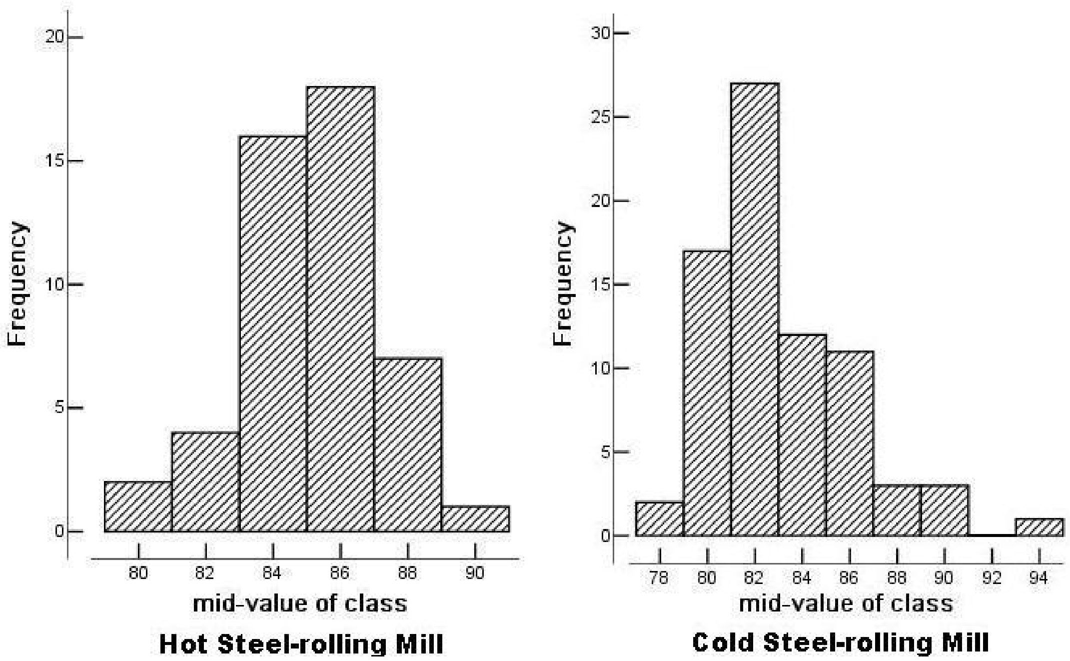

Figure 1: Distribution of personal noise exposure ($L_{Aeq.8h}$) among crane drivers in the two steel-rolling mills; left section of Figure 1 is distribution of $L_{Aeq.8h}$ in the cold steel-rolling mill. Right section is that in the hot steel-rolling mill. Class interval of the frequency distribution is 2 dB.

Overhead traveling cranes in the two mills

There are 17 overhead traveling cranes in hot steel-rolling mill and 24 cranes in the cold one. Carrying capacities of these cranes vary from 15 tons to 100 tons. According to the locations and tracks, cranes form six lines in hot steel-rolling mill and nine lines in cold one (Figure 2). There are no partition walls among lines. Hence, in addition to the noise generated from the cranes themselves (e.g. crane engines), noise exposure of overhead-traveling crane drivers was also influenced by all other noise sources in the entire work place.

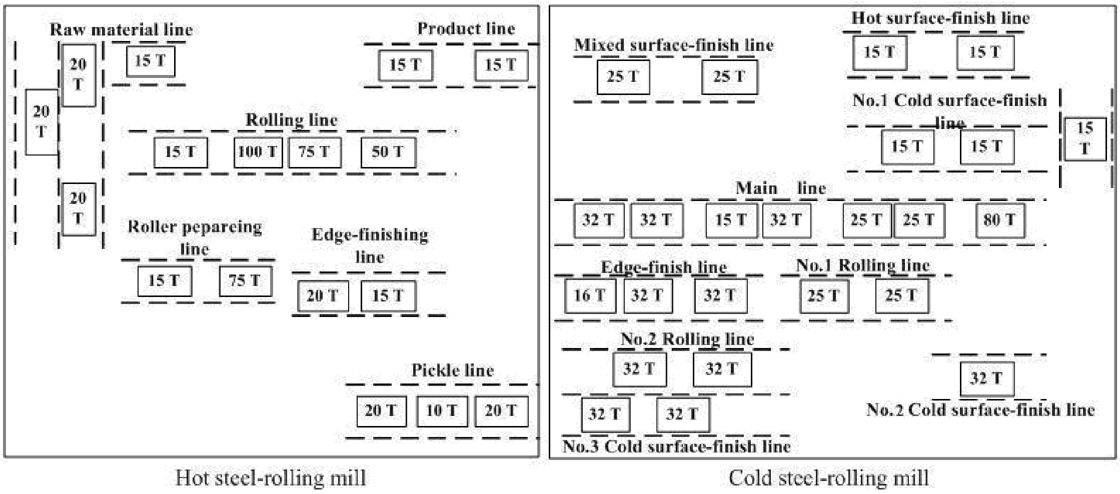

Figure 2: Location of overhead-traveling cranes in the two steel-rolling mills;
the left section of this figure is sketch map of the hot steel-rolling mill. Right section is that of the cold steel-rolling mill. The broken lines in the map are the tracks of overhead traveling cranes. Panes in the broken lines are overhead-traveling cranes. Numbers in the panes are the loads of cranes (T=tons).

Figure 3 presents the changing noise exposure levels of overhead-traveling drivers during their work-shifts. The upper part of the figure illustrates personal noise exposure data of a crane driver in the hot steel-rolling mill. According to the work log recorded by the driver, he had worked in three lines during his work-shift. The lower part of the figure illustrates data of a driver in the cold steel-rolling mill who had worked in two lines during his work shift. From this figure, it can be seen that noise exposures were unstable in both mills. Noise exposure at lunch time and the time when drivers stayed in their work stations was much lower than when they worked in the lines. In the hot steel-rolling mill, the rolling line was noisier than the pickle and edge-finish lines, and noise exposure in edge-finish line was more unstable than the other two lines. In the cold steel-rolling mill, noise exposure in the hot surface-finish line was higher than the cold surface-finish line.

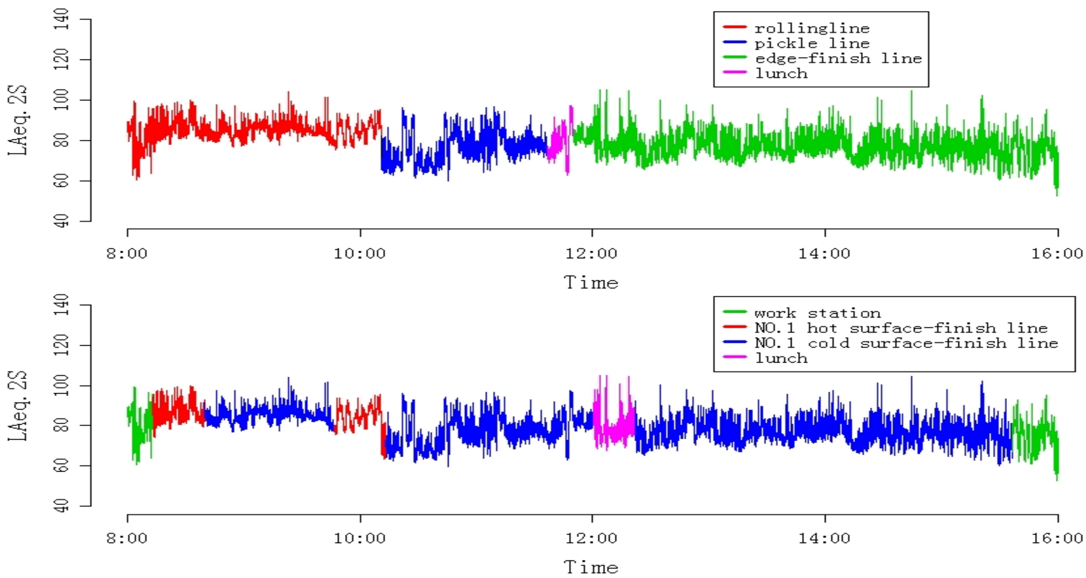

Figure 3: Typical personal noise exposure of overhead-traveling crane drivers in the two steel-rolling mills; the upper section in the figure illustrates personal noise exposure data of a crane driver in the hot steel-rolling mill. The lower section illustrates that in the cold steel-rolling mill. Different colors represent different activities of drivers during a work shift.

Noise exposure level based on lines

Overhead-traveling crane drivers might operate more than one crane during a work shift. And the cranes they steer may be in different lines (e. g. Figure 3). In order to estimate noise exposure for lines, personal noise exposure data were divided into different segments based on lines in which drivers worked during the work shift. Each segment was regarded as one noise exposure measurement of a particular line. Table 3 shows the noise exposures for the various lines in the hot and cold steel-rolling mills.

Table3: Noise exposure levels of overhead-traveling cranes in the two steel-rolling mills based on lines (dB(A))

mill*	Lines**	Measure -ments (n)	L_{Aeq} Mean(SD)	Min	Max	Range	Measurements over 85 dB(A) n (%)
Hot steel-rolling mill	Pickle line	9	83.9 (3.50)	79.1	89.0	9.9	4 (44.4)
	Roller preparing lie	4	84.7 (2.39)	82.8	88.1	5.3	1 (25.0)
	Rolling line	12	85.0 (3.00)	79.5	89.9	10.4	6 (50.0)
	Edge-finish line	11	85.3 (1.79)	81.0	87.9	6.9	8 (72.7)
	Raw material line	13	85.8 (2.10)	81.4	89.9	8.5	10 (76.9)
	Product line	3	87.8 (1.40)	86.7	89.4	2.7	3 (100.0)
	Total	52	85.2 (2.61)	79.1	89.9	10.8	32 (61.5)
Cold steel-rolling mill	No.2 cold surface –finish line	6	81.6 (1.99)	78.8	84.6	5.8	0 (0)
	No.1 rolling line	6	81.7 (1.56)	79.7	83.7	4.0	0 (0)
	No.1 cold surface –finish line	10	82.1 (1.95)	79.8	86.2	6.4	1 (10)
	Main line	22	82.3 (2.49)	77	88.1	11.1	4 (18.2)
	Edge-finish line	12	83.3 (2.58)	80.5	89.8	9.3	3 (25)
	No.3 cold surface –finish line	8	84.2 (2.13)	81.0	86.6	5.6	4 (50)
	No.2 rolling line	9	85.0 (3.13)	80.9	90.4	9.5	3 (33.3)
	Mixed surface-finish line	12	85.2 (3.93)	80.4	94.1	13.7	5 (41.7)
	Hot surface-finish line	4	85.5 (6.57)	79.7	94.0	14.3	2 (50)
	Total	89	83.3 (3.10)	77.0	94.1	17.1	22 (24.7)

Nested design ANOVA, $*F_{mill}=12.673$, $P_{mill}=0.001$ $**\ F_{lines}=2.061$, $P_{line}=0.021$

The average noise exposure level based on lines in hot steel-rolling mill and the cold one were 85.2 ± 2.61 dB(A) and 83.3 ± 3.10 dB(A), respectively. Noise exposure levels based on lines were similar to personal noise exposures (85.03 ± 2.25 dB(A) and 83.05 ± 2.93 dB(A)) in both mills. Total mean noise level of lines in the hot steel-rolling mill was obtained by enrolling all 52 measurements of noise exposure based on lines in this mill. And that in the cold steel-rolling mill was obtained by enrolling all 89 measurements in this mill.

The average noise exposure level based on lines in hot steel-rolling varied from 83.9 to 87.8 dB(A). The “noisiest” line in hot steel-rolling mill was the product line (87.8 ± 1.40 dB(A)), which hoisted finished products to the packaging area. And the “quietest” line was the pickle line (83.9 ± 3.50 dB(A)), which hoisted steel plates to the pickling pool. Noise levels in four out of the six lines were above 85 dB(A) stated in the Chinese national standard. Over 60 percent of the measurements exceeded this criterion. The mean noise exposure level based on lines in the cold steel-rolling varied from 81.6 to 85.5 dB(A). Most noise exposures of lines in this mill were below 85 dB(A). Only 24.7 percents of the measurements were above the Chinese national criterion. Differences among the noise exposure of lines were statistically significant between mills and lines (nested design ANOVA: $p_{mill}=0.001$ and $p_{line}=0.021$). The means of noise exposure levels for these lines were varied from each other.

DISCUSSION

Overhead-traveling crane drivers are exposed to many safety and health risks. Since operating cabins are high above the ground and crane drivers have to keep looking down during their work shift, they may suffer from neck and shoulder pain, work injury and fatality. Furthermore, crane drivers may be exposed to risk agents which exist in their workplace, such as noise, dust, and heat. It is difficult to assess exposure levels for these risks without portable measurement devices. As a result, there are not many published data about occupational risk factors exposure for overhead-traveling crane drivers.

This survey is a study to estimate the noise exposure levels of overhead-traveling crane drivers by using personal noise dosimeters. There are two ways to evaluate noise exposure (Cheng et al. 2001). One way is based on measuring the workplace environment, while the other is based on measuring workers individually. Noise assessment based on environmental measurement may be sufficient if noise is stable. However, since noise in most workplaces is inconsistent and workers are mobile in the workplace, noise assessment based on measuring the environment is not always sufficient to reflect their true exposure. Personal assessment by portable devices is one of the most suitable methods for this situation. The overhead-traveling crane driver is a typical example. They work in an operating cabin 17 m high and move during the work shift in these two mills. Noise in these two mills is inconsistent (Figure 3). Using noise dosimeters, we measured the noise exposure levels of the drivers and lines in two steel-rolling mills. Noise exposure of more than half of the drivers in the hot steel-rolling mill and less than 30 percents in the cold steel-rolling mill had exceeded the 85 dB(A) criterion. These workers should have been included in the Hearing Conservation Program.

In our previous study in the cold steel-rolling mill, personal noise exposures of workers who worked on the ground varied from 81.2 to 100.0 dB(A) (Chai et al. 2006). Personal noise exposures of overhead-traveling crane drivers in this mill varied form 77.0 to 94.1 dB(A). The range of personal noise exposure levels was approximately the same for workers who work on the ground and overhead-traveling crane drivers in this mill. Noise in this mill which mostly came from rolling machines and edge-finishing machines was unstable. Because of the distance to the sound resources, personal noise exposure of overhead-traveling crane drivers was about 5 6 dB(A) lower than that of workers on the ground. It suggests that noise exposure of overhead-traveling crane drivers are dependent upon background noise levels of the mill and noise levels on the ground in the workshop.

Average personal noise exposure levels of overhead-traveling crane drivers in the hot steel-rolling mill was significantly higher than that in the cold one. But before drawing a conclusion, background noise should be taken into account. Actually, the background noise levels in the hot steel-rolling mill were higher than that in the cold one due to the following reasons. Firstly, there was airflow dynamic noise from the large-scale heater which heated the steel plates before rolling in the hot mill, while the steel coils rolled in cold steel-rolling mill were not heated before rolling. Noise exposure of the heating and rolling procedure on the ground in the hot steel-rolling mill was above 95 dB(A) on average (from our unpublished research) and that of the rolling procedure in the cold steel-rolling mill was 89 dB(A) (Chai et al. 2006). Secondly, the raw material of steel plates is much thicker than the steel coils. The thicker the raw material is the higher the noise level will be, especially in the edge-finish process, which means that noise levels in edge-finish area of the hot steel-rolling mill are higher than that in the cold one. Noise exposures of the edge-finishing procedure on the ground in the hot steel-rolling mill was above 96 dB(A) on average (from our unpublished research) and that in the cold steel-rolling mill was 89-92 dB(A) (Chai et al. 2006).

In this survey we included as many overhead-traveling drivers in these two mills as possible, and each one of them had completed personal noise exposure measurement in one of their work shifts. Noise exposure data in the hot steel-rolling mill indicate that the noise exposure levels of the drivers in the mill were quite similar. Assuming that noise exposure levels of the overhead-traveling drivers in this mill are the same, it might not be necessary to measure personal noise exposures of all the drivers in this mill for exposure assessment. Overhead-traveling crane drivers in this mill could be regarded as one job-exposure group (Roach 1991), and we should be able to evaluate their noise exposure levels by sampling some drivers (e. g. three or four drivers), which can save time and resources. But in the case of the cold steel-rolling mill, the variation in noise exposure among overhead-traveling drivers was much larger than that in the hot one. Drivers in this mill can not be regarded as one job group. Since noise exposure of overhead-traveling crane divers is mostly from the environment they work, drivers in the cold steel-rolling mill might be divided into several job groups by lines in which they work. In order to characterize noise exposure levels in a complex workplace, proper grouping and sampling are of prime importance. Since there are no well-established principles of grouping and sampling, more work should be done to solve these problems.

CONCLUSION

Noise dosimeters as potable instruments are suitable for assessing noise exposure level of overhead-traveling crane drivers. Noise exposure of these drivers in the two steel-rolling mills was inconstant. And it was dependent upon background noise levels and noise levels on the ground in the mill. As the noise exposure levels of some of these workers and some of the lines were above the 85 dB(A) criteria, these drivers should be involved in a Hearing Conservation Program to protect their hearing.

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