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Hearing Impairment due to Noise in the Kyung-In Industrial Area in Korea*

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INTRODUCTION

The industrial revolution has brought about the development of machines as well as commodities; however, its by-product, noise, has become an important public health problem.

The amount of hearing loss in industrial environments depends on the level of intensity, frequency distribution, exposure time and individual susceptibility.

Occupational hearing loss falls into the category of noise-induced permanent threshold shift. Since it occurs beyond the conversational range, usually above 4,000 Hz, the early detection of noise-induced hearing loss is quite difficult.

Occupational hearing impairment has been increasing in recent years because of the increase in noise-producing sources.

The present study was carried out in 8 factories of 4 major types of industries in Kyung-In areas.

The various factors were analyzed and the results were reported in the personnel exposed to excessive noise by measuring the sound pressure level as well as by specific physical examinations.

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MATERIALS AND METHODS

1. Material

A total of 2,013 individuals consisting of 1,363 male and 650 female was studied. They were working at 8 different factories in 4 major industrial fields in the Kyung-In area.

2. Period

From July 1, 1975–October 31, 1975.

3. Methods

1. Environmental Survey

a) Noise Characteristics

Industrial noise was classified and surveyed as: continuous, intermittent, repetitive and impulse noise.

b) Overall Sound Pressure Measurement

Average value was calculated after measuring 5 times, using the A and the C setting of the sound level meter (Model 412, H.H. Scott Co.) during the operation of the machinery. Octave band was also analyzed by a sound analyzer (Model 420A, H.H. Scott Co.)

2. Audiometry

Audiograms (H1-B Type, Mico Co.) were obtained on personnel exposed to noise levels exceeding 90 dB. Hearing loss at the frequencies of 125, 250, 500, 1,000, 2,000, 3,000, 4,000, 6,000 and 8,000 Hz respectively were studied

along with the individual threshold audiograms. Average hearing loss was calculated by the $\frac{a+2b+2c+d}{6}$ method.

RESULTS

1. General description

A. Sex Distribution of Workers

Only male workers were employed in the fields of machine manufacture, steel and chemical industries. Female workers were predominant in textile factories(Table 1).

B. Age Distribution of Workers

The youngest age group was found among textile workers and the workers in the machine and steel factories comprised the oldest age group(Table 2).

The workers under age 19 were seen mostly in spinning and weaving shops, while those above 40 were working at hearth steel shops, rolling mill and saw-mill shops.

C. Noise Characteristics

All of the noises were the continuous type

Table 1. No. of Workers by Sex in Eight Factories

T. of Ind. / Factory / Sex	Textile		Machine & Steel			Chemical	Wood		Total
	P.H. Textile	H.D. Textile	H.K. Pipe	H.K. Machine	I.C. Steel	D.Y. Chemical	S.C. Wood	D.S. Wood	
Male	54(10.5)	35(17.3)	20(100)	167(100)	743(100)	15(100)	18(100)	311(93.1)	1,363(67.7)
Female	460(89.5)	167(82.7)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	23 (0)	650(32.3)
Column Total	514	202	20	167	743	15	18	334	2,013

Table 2. Status of Eight Factories by Age Group

Type of Ind. / Factory / Age	Textile		Machine & Steel			Chemical	Wood		Total
	P.H. Textile	H.D. Textile	H.K. Pipe	H.K. Machine	I.C. Steel	D.Y. Chemical	S.C. Wood	D.S. Wood	
<19	181(35.2)	60(29.9)	0 (0)	3 (1.9)	1 (0.1)	0 (0)	0 (0)	10 (3.0)	255(12.9)
20~24	273(53.1)	101(50.2)	0 (0)	9 (5.6)	9 (1.2)	1 (6.7)	0 (0)	19 (5.8)	412(20.8)
25~29	43 (8.4)	11 (5.5)	3(15.0)	35(21.9)	213(29.6)	5(33.3)	3(16.7)	87(26.4)	400(20.2)
30~34	12 (2.3)	13 (6.5)	13(65.0)	34(21 2)	216(30.0)	6(40.0)	8(44.4)	102(31.0)	404(20.4)
35~39	5 (1.0)	11 (5.5)	4(20.0)	59(36.9)	195(27.1)	2(13.3)	4(22.2)	73(22.2)	353(17.9)
40~44	0 (0)	5 (2.5)	0 (0)	20(12.5)	86(11.9)	1 (6.7)	3(16.7)	38(11.6)	153 (7.7)
Column Total	514(100)	201(100)	20(100)	160(100)	120(100)	15(100)	18(100)	329(100)	1,977(100)
M±S.D.	29.4±8.5	20.9±3.3	30.0±3.6	34.9±8.5	34.0±6.7	31.8±5.9	33.6±4.6	32.6±6.9	

Table 3. Proportion of Type of Noise by Type of Industry

Noise / Type of Ind.	Type of noise (%)				Total
	Continuous noise	Repetitive noise	Discont. noise	Impact noise	
Textile	100.0	—	—	—	100
Machine & Steel	22.0	11.0	55.6	11.0	100
Chemical	100.0	—	—	—	100
Wood	41.6	8.3	33.3	16.6	100

Table 4. No. of Workers Exposed to a Scale Noise Level in Industry

Industry / Noise level(A)(dB)	Textile	Machine & Steel	Chemical	Wood	Total
71~ 80	0 (0)	0 (0)	0 (0)	3 (0.9)	3 (0.1)
81~ 90	129(18.0)	192(20.6)	0 (0)	170(48.3)	491(24.4)
91~100	363(50.7)	124(13.3)	15(100.0)	179(50.9)	681(33.8)
101~110	224(31.3)	614(66.0)	0 (0)	0 (0)	838(41.6)
Total	716(35.6)	930(46.2)	15 (0.7)	352(17.5)	2,013(100.0)
Mean±S.D.	98.7±4.4	99.0±6.4	93.6±1.6	92.4±7.1	97.7±6.4

Table 5. No. of Workers Exposed to C Scale Noise Level in Industry

Industry / Noise level(C)(dB)	Textile	Machine & Steel	Chemical	Wood	Total
71~ 80	0 (0)	0 (0)	0 (0)	3 (0.9)	3 (0.1)
81~ 90	202(28.2)	238(25.6)	11(73.3)	207(58.8)	658(32.7)
91~100	514(71.8)	476(51.2)	4(26.7)	142(40.3)	1,136(56.4)
101~110	0 (0)	216(23.2)	0 (0)	0 (0)	216(10.7)
Total	716(35.6)	930(46.2)	15 (0.7)	352(17.5)	2,013(100.0)
Mean±S.D.	100.9±3.5	102.9±6.9	100.3±0.5	97.1±4.6	101.1±5.9

Table 6. Duration of Services by Type of Industry

Type of Ind. / Year	Textile	Machine & Steel	Chemical	Wood	Total
<1.0	183(25.6)	51 (5.5)	0 (0)	10 (2.8)	244(12.1)
1.1~3.0	361(50.4)	397(42.7)	2(13.3)	124 35.2)	884(43.9)
3.1~5.0	107(14.9)	68 (7.3)	4(26.7)	77(21.9)	256 (2.7)
5.1~7.0	54 (7.5)	143(15.4)	6(40.0)	70(19.9)	273(13.6)
>7.1	11 (1.5)	271(29.1)	3(20.0)	71(20.2)	356(17.7)
Column Total	716	930	15	352	2,013(100.0)
Mean±S.D.	2.4±1.7	5.5±4.7	5.7±1.0	5.3±4.1	4.4±4.1

in textile and chemical industries. Noise was variable in the machine and steel factories (Table 3).

D. Noise by A and C Scales

75.4% of all workers exposed to A scale noise beyond 91 dB, while it was 67.1% in C scale(Table 4, 5).

E. Duration of Services

The longest duration was noted in chemical workers and the next longest was seen among machine and steel workers. The shorter duration was noted in textile workers(Table 6).

2. Hearing Loss

A. Hearing Loss at 4,000 Hz

In male workers, the highest occurrence of hearing loss was seen in the machine factories while in the female textile workers hearing loss was the highest at the P.H. factory (Table 7).

In right ear hearing loss above 31 dB, the

Table 7. Mean of Hearing Loss by Factory, Sex and Side of Ear (4,000Hz)

Factory \ Sex / Side	Male		Female	
	Rt.	Lt.	Rt.	Lt.
P.H. Textile	33.0±15.3	30.7±13.6	26.4±9.5	26.6±10.1
H.D. Textile	27.6±16.4	30.4±17.4	22.1±4.0	21.8± 5.0
H.K. Pipe	38.0±11.1	36.5±15.0		
H.K. Machine	43.3±20.9	44.3±20.9		
I.C. Steel	31.6±16.8	31.6±16.8		
D.Y. Chemical	29.0±12.0	33.0±15.9		
S.C. Faniture	39.7±17.3	36.9±18.1		
D.S. Wood	28.6±12.8	27.8±12.7	22.2±4.5	22.2±5.4

Rt: Right., Lt: Left.

Table 8. Number of Hearing Loss by Work Place and Age Group in Machine & Steel Industry

Work place \ Side / Serv. year	Rt.					Lt.				
	<19	20~29	30~39	>40	Total	<19	20~29	30~39	>40	Total
Rolling mill	0 (0)	6 (5.5)	60 (55.1)	43 (39.5)	109 (100.0)	0 (0)	9 (7.5)	66 (55.0)	45 (37.5)	120 (100.0)
Forging shop	0 (0)	3 (15.8)	8 (42.1)	8 (42.1)	19 (100.0)	0 (0)	5 (25.0)	7 (35.0)	8 (46.0)	20 (100.0)
Openhearth steelmaking	0 (0)	2 (18.2)	5 (45.5)	4 (36.4)	1 (100.0)	0 (0)	3 (13.0)	12 (52.1)	8 (34.7)	23 (100.0)
Electric Furnace	0 (0)	10 (25.0)	25 (62.5)	5 (12.5)	40 (100.0)	0 (0)	13 (30.2)	24 (55.8)	6 (13.9)	43 (100.0)
Wire & rod	0 (0)	4 (40.0)	6 (60.0)	0 (0)	10 (100.0)	0 (0)	7 (45.7)	8 (53.3)	0 (0)	15 (100.0)

highest value was seen in the machine and steel workers and the next highest in the chemical workers. Hearing loss above 41 dB in the right ear was seen among machine workers.

In the left ear, the highest hearing loss was noted in workers at steel and machine factories, the next being in chemical workers.

B. By Sex and Duration of Services

Among textile workers, the incidence of hearing loss in males with less than 5 years of service was high. However, hearing loss was remarkably higher among female workers with less than 5 years of service. (Table 13) Among the machine and steel workers, hearing loss tended to increase with the rise of the service duration. (Table 8)

C. Hearing Loss at 4,000 Hz by Age

Among the machine and steel workers, there was no relation between hearing loss and the increase of age. Hearing loss seemed to be increasing in the period between the 2nd and 3rd decades. (Tables 9 & 10)

3. Average Hearing Loss

A. Average Hearing Loss by Industry

In the right ear, the highest hearing loss was seen in the machine and steel workers. Average hearing loss above 31 dB was seen in 3.9% of the total workers studied. The highest average hearing loss of 915±13.5 dB was noted among the machine and steel workers.

In the left ear, it was highest in the machine

Table 9. Number with Hearing Loss by Work Place, Sex and Duration of Services (Textile)

Sex	T. of W.	Rt. <1	Rt. 1.1~5	Rt. >5.1	Rt. Total	Lt. <1	Lt. 1.1~5	Lt. >5.1	Total
M.	Spinning	0 (0)	4(80.0)	1 (20.0)	5(100.0)	0 (0)	4(100.0)	0 (0)	4(100.0)
	Weaving	2(11.7)	8(47.0)	7 (41.1)	17(100.0)	2(13.3)	7 (46.6)	6(40.0)	15(100.0)
	Machinary	0 (0)	0 (0)	5(100.0)	5(100.0)	0 (0)	5(100.0)	0 (0)	5(100.0)
	Total	2 (7.4)	12(44.4)	13 (48.1)	27(100.0)	2 (8.3)	16 (66.6)	6(25.0)	24(100.0)
F.	Spinning	2(11.7)	12(70.5)	3 (17.6)	17(100.0)	0 (0)	10 (83.3)	2(16.6)	12(100.0)
	Weaving	15(28.8)	36(69.2)	1 (1.9)	52(100.0)	15(28.3)	38 (71.6)	0 (0)	53(100.0)
	Machinary	2(66.6)	0 (0)	1 (33.3)	3(100.0)	2(66.6)	0 (0)	1(33.3)	3(100.0)
	Total	19(26.3)	48(66.6)	5 (7.1)	72(100.0)	17(25.0)	48 (70.5)	3 (4.4)	68(100.0)

Note: No. of this table means No. of Workers with hearing loss above 31 dB.

Table 10. Number with Hearing Loss by Work Place, Duration of Service (Machine & Steel Ind.)

Work place	Right <1	Right 1.1~5	Right >5.1	Right Total	Left <1	Left 1.1~5	Left >5.1	Left Total
Rolling mill	1(1.0)	28(27.7)	72(71.3)	101(100.0)	3 (3.0)	28(28.0)	69(69.0)	100(100.0)
Forging shop	0 (0)	6(33.3)	12(66.7)	18(100.0)	0 (0)	6(31.5)	13(68.4)	19(100.0)
Steel making	0 (0)	4(44.4)	5(55.6)	9(100.0)	2(10.5)	5(26.3)	12(63.2)	19(100.0)
Electric Furnace	0 (0)	18(56.3)	14(43.7)	32(100.0)	0 (0)	21(60.0)	14(40.0)	35(100.0)
Wire & Rod	0 (0)	7(63.6)	4(36.4)	11(100.0)	0 (0)	9(69.2)	4(30.8)	13(100.0)
Total	1(0.6)	63(36.8)	107(62.6)	171(100.0)	5 (2.6)	69(37.1)	112(60.2)	186(100.0)

Table 11. Number with Average Hearing Loss by Industry (Rt.)

Av. H.L.(dB)	Textile	Machine & Steel	Chemical	Wood	Total
<10	641 (89.5)	578 (62.1)	7 (46.7)	299 (84.9)	1,525 (80.3)
11~30	71 (9.9)	280 (30.1)	8 (53.3)	51 (14.5)	410 (20.4)
>31	4 (0.6)	72 (7.7)	0 (0)	2 (0.6)	78 (3.9)
Total	716 (100)	930 (100)	15 (100)	352 (100)	2,013 (100)
Mean±S.D.	2.3±7.5	9.5±13.5	9.3±9.5	3.5±8.3	6.0±11.4

No. in parenthesis are ratio of workers against to the total No. of workers of the industry.

Table 12. Number with Average Hearing Loss by Industry (Lt.)

Av. H.L.(dB)	Textile	Machine & Steel	Chemical	Wood	Total
<10	638(89.1)	565(60.7)	6(40.0)	295(83.8)	1,504(74.7)
11~30	70 (9.8)	274(29.5)	9(60.0)	56(16.0)	409(20.4)
>31	8 (1.1)	91 (9.8)	0 (0)	1 (0.3)	100 (5.0)
Total	716 (100)	930 (100)	15 (100)	352 (100)	2,013 (100)
M±S.D.	2.6±8.4	10.7±14.5	12.4±10.4	3.5±8.0	6.6±12.2

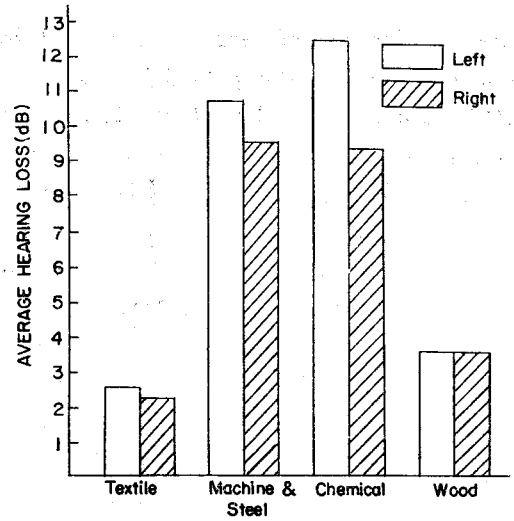

Fig. 1. Average Hearing Loss by Type of Industry.

and steel workers. 5.0% of the total showed hearing loss above 31 dB. In chemical workers the highest loss of 12.4±10.4 dB was seen. (Table 11 & 12, Fig. 1)

D. By Sex, Side of Ear and Average Hearing Loss:

1) Textile: Among male machinary workers the highest value of average hearing loss was noted. (right 9.3±22.7, left 10.7±23.0) In females the highest hearing loss was seen among weaving workers. (right 4.6±9.3, left 5.4±10.2)(Table 13).

2) Machine and steel: The highest average hearing loss was in the rolling mill workers. (right 12.8±14.5, left 13.1±14.9)(Table 14)

DISCUSSION

Hearing loss due to noise was first described by Alberti (1591). Fosbroke (1831) later pointed out the fact that hearing disturbance occurs among industrial workers. Noise deafness was extensively studied by Larsen, Bunch, Davis and Glorig(1961).

Impairment of hearing among industrial workers was thought to be noise-induced. It is related to overall noise level, frequency spectrum, period of exposure and total work duration. It is also related to ear diseases, age, duration of service, and individual susceptibility.

Noise is one of the physical factors. Even in the same types of industries with the same working processes, it varies according

Table 13. Average Hearing Loss by Work Place, Sex and Side of Ear (Textile)

Side / Sex / Work place	Rt.		Lt.	
	Male	Female	Male	Female
Spinning	2.2± 6.5	0.4±2.9	2.4± 7.4	0.7± 4.8
Weaving	7.5±10.2	4.6±9.3	7.0±11.2	5.4±10.2
Machinary	9.3±22.7	1.2±5.2	10.7± 2.3	1.1± 4.7

Table 14. Average Hearing Loss by Work Place, Sex and Side of Ear (Machine & Steel Industry)

Side / Sex / Work place	Rt.		Lt.	
	Male	Female	Male	Female
Rolling mill	12.8±14.5	—	13.1±14.9	—
Forging shop	9.3±12.3	—	9.5±12.0	—
Open hearth steel making	6.7±12.9	—	10.4±15.3	—
Electric furnace	5.5±10.6	—	5.6±11.7	—
Wire and rod	8.9±15.2	—	9.4±15.2	—

to the working conditions, operating status of machinery, place and time when noise is measured.

Methods of measuring noise vary in different countries.

Sound level A is more closely similar to the sensible sounds and noise level of the A scale has the highest correlation which allows weighting to different parts of the spectrum. In evaluating T.L.V. of industrial noise, the standard exposure of 8 hours per work day is usually implied. Industrial noise is related to sound energy from the source of noise.

Kryster, Stermer and the American Society of Ophthalmology and Otolaryngology recommended the limit of 80~85 dB. A standard of 90 dBA/8 hours per day is set by the Intersociety Committee on Guidelines for Noise Exposure Control.

In the present study, noise above 90 dB with sound level A or C weighting in the different industrial environment was compared and analyzed.

As to noise characteristics, all noise was continuous in textile and chemical industries. In machinery industries 55.6% of noise was intermittent. With intermittent noise exposures, the magnitude of similar effect is predictable by adding 15 dB of sound pressure as cited by Joseph, S. (1969).

It is well known that occupational hearing loss is characterized by C_5-dip formed from tone gape curve (V shape) at the frequency of 4,000 Hz. A long-standing exposure to noise exceeding TLV will result in hearing loss extending to lower frequencies.

Incidence of noise-induced hearing loss is associated with the type of industry, noise producing environment and various other factors.

Its increase is consistent with aging and extended duration of service, as studied by Goldner (1953), Glorig (1961) and Sakai (1976). According to Rosenblith, increase in the hearing loss of more than 10 dB was noted at the period of 5 years before and after 20 years of service. In the mine workers studied by T.J. Lee, the incidence of hearing loss was 6.1% within 5 years of service. It increased to 8.7% during 5~10 years and 9.1% beyond 10 years of service. K.H. Park reported an average hearing loss of 14.2 dB within 5 years of service with increments of loss of 3.4 dB and 3.8 dB at the lapse of every 5 years.

A high degree of hearing loss was reported within 3 years of initial exposure to noise by Sataloff (1953).

Our results also indicate the increase of hearing loss in both ears especially among the machine and steel workers with the increase of time in duration of service.

Reger (1958) and Watson (1967) reported that the left ear is more susceptible to hearing loss at higher frequencies. As suggested by Ward and Chaney, the cerebral dominance factor was thought to be related. No difference was noted in our present study.

CONCLUSION

A total of 2,013 individuals working at 8 different factories in Kyung-In industrial area were studied. The following results were obtained.

1. Male workers numbered 1,363 (67.7%) and female workers were 650 (32.3%). In 5 factories all of the workers were male. Both male and female workers were working at textile and wood factories.

2. The oldest age group was seen at machine and steel factories (34.9±8.5 years). 33.7% of the textile workers were under 19 years of age,

with the youngest age group (20.9±3.3 years) seen at the H.D. textile factory.

3. In the textile workers, 76% of the workers had less than 3 years of service with an average duration of 2.4±1.7 years. 25.6% of the workers had less than 1 year of service. More than 60% of the workers in chemical industries had over 5 years of service.

4. Hearing loss of more than 31 dB at 4,000 Hz was noted as follows: In the right ear, 34% were seen in the machine and steel workers while 26.6% were seen in the chemical workers. In the left ear, 19.8% and 16% were in the steel and machine workers and chemical workers respectively.

5. Average hearing loss of more than 31 dB was noted as follows: In the right ears, 11.1% were seen among the workers of the S.C. wood factory, while in the left ear 11.0% was noted at I.C. steel factory.

As to the type of industry, in the right ear, 7.7% were seen in the machine and steel workers and 0.6% in the textile workers respectively. Average hearing loss was highest in the machine and steel industries (9.5±13.5 dB). In the left ear, the highest of 9.8% was seen at the machine and steel industries with the highest average hearing loss of 12.4±10.4 dB in the chemical industry.

6. Continuous noise was 100% in the chemical and textile industries. In the wood and machine factories, it was 41.6% and 18.1% respectively; 33.3% of intermittent noise was noted in the wood industry.

7. A-scale noise level above 91 dB was seen 100% in the chemical industry and 82% in the textile industry. 74.4% of machine and steel workers and 71.8% of textile workers were exposed to C-scale noise. 67.1% of the total workers were exposed to C-scale noise.

8. Hearing loss in both ears at 4,000 Hz as well as an average hearing loss tended to increase at the age of 30 and beyond.

9. Hearing loss of more than 31 dB in both ears among machine and steel workers was consistently proportional to the increase of the duration of service.

10. There was no difference in hearing loss in either right or left ears.

From these conclusions it is desirable that an accurate survey of industrial noise, early detection of noise-induced hearing impairment, and protective measures against increased duration of service years of the workers must be considered in preventing occupational health problems.

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