한국산업보건학회지, 제33권 제3호(2023) ISSN 2384-132X(Print) ISSN 2289-0564(Online)
Journal of Korean Society of Occupational and Environmental Hygiene, 2023: 33(3): 308-316
https://doi.org/10.15269/JKSOEH.2023.33.3.308

Original Article

아파트 건설노동자 소음 노출평가

강태선*
서울사이버대학교 안전관리학과

Assessment of Apartment Building Construction Workers' Noise Exposure

Taesun Kang*
Department of Safety Management, Seoul Cyber University

ABSTRACT

Objectives: The aim of this study is to measure and assess the occupational noise exposure levels among construction workers at apartment building construction sites in South Korea.

Methods: Noise exposure assessments were conducted for 139 construction workers across 10 different trades at 53 apartment building construction sites in the northern part of Gyeonggi-do. Assessments were carried out using a noise dosimeter set with a 90 dB criterion, an 80 dB threshold, and a 5 dB exchange rate over a period of more than 6 hours(L_{MOEL})

Results: The mean L_{MOEL} (equivalent continuous noise level over 8 hours) for the 139 dosimeter samples was 87.8 ± 4.3 dBA. The mean noise exposure level for each construction trade, referred to as the trade mean, was also calculated. Significant differences in noise exposure levels were observed between construction trades (ANOVA, $p < 0.001$). The highest L_{MOEL} values were recorded for concrete chippers (93.2 ± 2.6 dBA), followed by ironworkers (88.4 ± 0.7 dBA), concrete finishers (88.3 ± 2.7 dBA), masonry workers (87.7 ± 1.9 dBA), pile driver operators (85.6 ± 1.7 dBA), concrete carpenters (84.9 ± 2.4 dBA), interior carpenters (83.5 ± 2.1 dBA), and other groups (81.4 ± 2.2 dBA).

Conclusions: The findings suggest that nearly all construction workers in this study are at risk of Noise-Induced Hearing Loss (NIHL). Moreover, the study establishes that construction trades can serve as a useful metric for assessing noise exposure levels at apartment construction sites.

Key words: apartment, construction trade, construction worker, noise exposure, trade mean

I. Introduction

In the realm of occupational sectors, construction is a notably characterized by its exposure to elevated noise levels, leading to documented proven cases of noise-induced hearing loss (NIHL) in developed countries. More than half of construction workers are exposed to hazardous noise levels and about 14 % of all construction workers suffer from hearing difficulty (Kerns et al, 2018). Scientific research has substantiated that such exposure leads to a notable elevation in the hearing threshold level (HTL), even when accounting for age-related effects and nonoccupational noise exposure (Seixas et al., 2012). Notably, there is a dearth of studies addressing the prevalence of NIHL among Korean construction workers. The sole accessible data stems from official records of workers' compensation insurance, indicating that, on average, 5 out of an estimated 1.7 million

*Corresponding author: Taesun Kang, Tel : 02-944-5137, E-mail: kangts@iscu.ac.kr
Department of Safety Management, Seoul Cyber University, 60, Solmae-ro 49-gil, Gangbuk-gu, Seoul
Received: June 12, 2023, Revised: July 30, 2023, Accepted: September 18, 2023
Taesun Kang http://orcid.org/0000-0002-3876-8539

construction workers receive compensation due to NIHL annually (Korea National Statistical Office, 2013a). Per the findings from the 2nd Korean Working Condition Survey conducted in 2010 (Korea National Statistical Office, 2013b), 56% of construction workers reported exposure to noise levels so pronounced that they were compelled to raise their voices significantly to communicate with colleagues working in close proximity. In comparison, this percentage is notably significant when juxtaposed with the 68% reported among mining workers. The 2004 revision of the Occupational Safety and Health Act mandates the construction industry to conduct both noise exposure assessments and health examinations (Ministry of Government Legislation, 2013). Yet, the actual implementation rate on construction sites remains disappointingly low (Kim et al., 2010; MoEL, 2011). Within Korean construction sites, the primary emphasis of occupational safety control is on averting work-related accidents, with noise exposure often overlooked as a potential hazard. Consequently, construction workers in Korea represent a more underserved population in terms of noise-related occupational health compared to their counterparts in the USA (Suter, 2002).

The noise exposure assessment at construction sites presents challenges distinct from those in the manufacturing industry, attributable to the inherent characteristics of construction environments. While the manufacturing industry tends to maintain consistency in operators and processes, the construction sector frequently experiences changes in both workers and procedures. Put differently, establishing a homogeneous exposure group, deemed fundamental and crucial for a comprehensive hazard exposure assessment, becomes unfeasible in this sector (ACGIH, 2012). In the sector of construction, various trades often operate concurrently or sequentially on a single site, contingent upon the specific process and within a constrained timeframe. Given these conditions, the trade mean (TM) method has been employed to assess exposure to hazards, including noise. Historically, most studies have utilized the trade mean approach across diverse construction settings (Neitzel et al., 2011). While each construction trade possesses distinct operations, the nature of construction and the trades collaborating on a project can vary based on the site. Consequently, the exposure of construction workers to hazards might differ, even within the same trade, contingent on the nature of the construction. For this study, the focus was narrowed down to apartment construction sites to minimize variables. Apartment complexes, representative of the predominant housing style in Korea, engage a significant workforce. Such constructions predominantly utilize reinforced concrete, and various operations, such as pile driving, chipping, and stone working, are executed within a comparatively confined space.

The aim of this study is to obtain foundational data to enhance the occupational health management of construction workers. This will be achieved by analyzing noise exposure levels of workers at typical Korean apartment construction sites, taking into account factors such as the specific construction trade, company size, overall workforce on the site, and the number of workers representing each trade.

Ⅱ. Material and Methods

1. Subjects

Data was sourced from 53 apartment construction sites located in the northern region of Gyeonggi-do between 2005 and 2008. This data was procured from an institute recognized by the MoEL as a working environment measurement entity, which has been actively involved in such measurement activities. According to the Occupational Safety and Health Act, working environment measurement should be conducted for processes with a

Table 1. Subjects of noise exposure monitoring

Construction trade	Job description	Main noise sources	No. of samples	No. of companies	No. of construction sites	No of workers
Pile driver operator	To operate a pile driver, a piece of heavy construction equipment	Hammer impact on pile, diesel engine	20	6	8	148
Concrete carpenter	To set up or remove concrete	Hand hammer, impact of pipe support, prying of crowbar	28	7	10	523
Concrete chipper	To chip or cut concrete structures	Jackhammer,	37	17	14	82
Concrete finisher	To finish and repair concrete	Grinding	23	12	10	79
Masonry worker	To cut and attach stone to outer wall	Masonry saw	10	6	6	119
Interior carpenter	To install interior doors, cabinets, flooring etc.	Nail gun, hammer	13	6	6	166
Ironworker	To erect and dismantle structural steel	Cutter	3	2	2	9
Other groups*	Tile setter, waterproofer worker and facility worker	Hammer etc.	5	3	3	62
Total			139			1,188

* Other groups : Tile setter, waterproof worker and facility worker

Time-Weighted Average (TWA) of 80 dBA or above. Consequently, the institute's industrial hygienists selected construction trades that met this criterion based on a preliminary survey. In total, 10 construction trades across 53 apartment construction sites were evaluated, with 139 out of 1,188 construction workers from these sites undergoing measurements. Table 1 delineates the sample count for each construction trade, site, and company. Specifically, 20 out of 148 pile driver operators, 28 out of 1,199 concrete carpenters, 37 out of 82 concrete chippers, 23 out of 79 concrete finishers, and 12 out of 119 masons were assessed for noise exposure. Furthermore, 11 interior carpenters from a pool of 166, 3 ironworkers out of 9, and 5 workers from a combined group of 62 tile setters, waterproof workers, and facility workers were evaluated for their noise exposure levels (Table 1).

2. Noise exposure measurement

The noise exposure measurement and assessment were carried out in compliance with the working environment measurement and quality control guidelines stipulated by the MoEL. The assessment employed a noise dosimeter (TES 1355, TES Electrical Electronic Corp. Taiwan) and measurements were conducted under ‘Property A’. Criteria was 90 dB, the threshold was 80 dB, the exchange rate was 5 dB. The entire assessment spanned a duration of 6 hours (L_{MOEL}).

3. Statistical analysis

The measured noise levels, both overall and within each construction trade, exhibited a normal distribution. Consequently, the mean value and standard deviation were presented as representative metrics. To discern differences in noise exposure based on construction trade, the size of the construction company, and the number of workers on each site, an ANOVA was performed. The statistical analyses were conducted using SAS 9.3 (SAS Institute, US).

Ⅲ. Results

1. Noise exposure by construction trade

Table 2 presents the noise exposure data for 139 construction workers engaged in apartment construction. The 139 workers were exposed to a mean noise level of 87.8 dBA, with a minimum of 78.3 dBA and a maximum of 99.3 dBA. Among these, 101 cases (72.7%) exceeded 85 dBA, and 38 cases (27.3%) even surpassed 90 dBA. Breaking it down by construction trade, pile driver operators had a mean exposure of 85.6 dBA, with 17 out of 20 cases (85.0%) exceeding 85 dBA; none exceeded 90 dBA. Concrete carpenters had a mean exposure of 84.0 dBA, with 12 out of 28 cases (42.9%) exceeding 85 dBA; again, none exceeded 90 dBA. Concrete chippers were exposed to a mean of 93.2 dBA, and all 37 cases (100%) exceeded 85 dBA, with 19 cases (89.1%) surpassing 90 dBA. Concrete finishers had a mean exposure of 88.3 dBA, with 20 out of 23 cases (87.0%) exceeding 85 dBA; 4 cases (17.3%) exceeded 90 dBA. Masons had a mean exposure of 87.7 dBA, and all 10 cases (100%) exceeded 85 dBA; one case (10.0%) exceeded 90 dBA. Interior carpenters had a mean exposure of 83.5 dBA, with only 1 out of 13 cases (7.7%) exceeding 85 dBA; none exceeded 90 dBA. Ironworkers had a mean exposure of 88.4 dBA, and all 3 cases (100%) exceeded 85 dBA; however, none exceeded 90 dBA. Tile setters, facility workers, and waterproof workers had a mean exposure of 87.8 dBA, but none of the 5 cases exceeded 85 dBA (refer to Table 2).

2. Comparison of noise levels between noise factors

Table 3 delineates the noise exposure levels segmented by company size, total number of workers at the construction site, and the number of workers per sampled work unit. Construction companies were categorized into three groups based on their construction capacity ranking as of 2007: large corporations (top 20), mid-tier companies (ranked 21 to 50), and small enterprises (ranked below 50). These rankings are annually published by the Ministry of Land, Infrastructure, and Transport, and are based on the previous year's business performance of the construction companies. The mean noise exposure levels were 87.7 dBA for large corporations, 87.4 dBA for mid-tier companies, and 88.7 dBA for small enterprises. No significant difference was observed between these groups (p=0.35).

For each construction site, the total number of

Table 2. Noise exposure level for construction workers by construction trade

Job	N	Mean (SD), dBA	Range, dBA	N (%)>85 dBA	N (%)>90 dBA
Pile driver operator	20	85.6 (1.7)	80.3~87.4	17 (85.0)	0 (0.0)
Concrete carpenter	28	84.9 (2.4)	79.1~89.2	12 (42.9)	0 (0.0)
Concrete chipper	37	93.2 (2.6)	87.7~99.3	37 (100.0)	19 (89.1)
Concrete finisher	23	88.3 (2.7)	83.2~94.1	20 (87.0)	4 (17.3)
Masonry worker	10	87.7 (1.9)	85.9~90.8	10 (100.0)	1 (10.0)
Interior carpenter	13	83.5 (2.1)	81.0~89.2	1 (7.7)	0 (0.0)
Ironworker	3	88.4 (0.7)	87.8~89.2	3 (100.0)	0 (0.0)
Other groups	5	81.4 (2.2)	78.3~83.6	0 (0.0)	0 (0.0)
Total	139	87.8 (4.3)	78.3~99.3	101 (72.7)	38 (27.3)

Table 3. Noise exposure level segmented by company size, total workforce on construction site, and number of workers per work unit

Variables		N	Mean	SD	95% CI	F	p
Company size	Large	46	87.7	4.5	86.4~89.1	1.04	0.35
	Middle	63	87.4	4.0	86.4~88.4		
	Small	30	88.7	4.5	87.1~90.4		
Total workforce	≤100	59	88.0	4.4	86.9~89.2	0.50	0.61
	101~ 499	64	87.4	4.3	86.3~88.5		
	≥500	16	88.4	4.3	86.1~90.7		
No. of worker per work unit	≤5	69	90.2	3.8	89.3~91.1	34.78	<0.001
	6~10	22	86.9	4.2	85.0~88.7		
	≥11	48	84.7	2.7	83.9~85.5		

workers was categorized into three groups: 100 or fewer, 101-500, and 501 or more. The mean noise exposure levels for these groups were 88.0, 87.4, and 88.4 dBA, respectively, and no significant difference was found between them (p=0.61). The work units within each construction trade were further divided into three groups based on the number of workers: 5 or fewer, 6-10, and 11 or more. The noise exposure levels were then compared. The group with 5 or fewer workers had a mean noise exposure level of 90.2 dBA, the 6-10 group had 86.9 dBA, and the 11 or more group had 84.7 dBA. A significant difference was observed between these groups in terms of noise exposure levels (p<0.001).

Table 4 presents the noise exposure levels segmented by construction trade. According to the ANOVA Bonferroni analysis, significant differences were observed in noise exposure levels across the various construction trade groups. Concrete chippers exhibited the highest noise exposure levels, registering 7.6 dBA higher than pile driver operators (p<0.001), 8.3 dBA higher than concrete carpenters (p<0.001), and 4.9 dBA higher than concrete finishers (p<0.001). Additionally, their exposure was 6.1 dBA higher than masonry workers (p<0.001), 9.8 dBA higher than interior carpenters (p<0.001), 4.8 dBA higher than ironworkers (p=0.03), and 10.7 dBA higher than other specialized groups (p<0.001).

Ironworkers had a noise exposure level that was 5.0 dBA higher than interior carpenters (p=0.044) and 5.9 dBA higher than other specialized groups (p=0.018). Concrete finishers had a noise exposure level that was 2.7 dBA higher than pile driver operators (p=0.011) and 3.4 dBA higher than concrete carpenters (p<0.001). Their exposure was also 4.9 dBA higher than interior carpenters (p<0.001) and 5.8 dBA higher than other specialized groups (p<0.001). Masonry workers had a noise exposure level that was 3.7 dBA higher than interior carpenters and 4.6 dBA higher than other specialized groups (p=0.005).

Ⅳ. Discussions

While environmental noise is actively monitored at Korean construction sites to mitigate potential complaints from local residents, there has been less emphasis on the assessment of occupational noise exposure. A dearth of research exists regarding noise exposure among workers at apartment construction sites, a common type of construction site in Korea. This study assessed the noise exposure of 139 workers across 10 construction trades at these apartment construction

Table 4. The noise exposure level by construction trade (ANOVA Bonferroni analysis)

Job (A)	Job (B)	Difference (A-B)	95% CI	p
Concrete chipper	Pile driver operator	7.6	5.4~9.7	<0.001
	Concrete carpenter	8.3	6.4~10.3	<0.001
	Concrete finisher	4.9	2.9~6.9	<0.001
	Masonry worker	6.1	3.5~8.6	<0.001
	Interior carpenter	9.8	7.2~12.4	<0.001
	Ironworker	4.8	0.2~9.4	0.030
	Other groups	10.7	7.3~14.0	<0.001
Ironworker	Pile driver operator	2.8	−2.0~7.5	1.000
	Concrete carpenter	3.6	−1.1~8.2	0.444
	Concrete finisher	0.1	−4.6~4.8	1.000
	Masonry worker	1.3	−3.6~6.2	1.000
	Interior carpenter	5.0	0.1~10.0	0.044
	Other groups	5.9	0.5~11.3	0.018
Concrete finisher	Pile driver operator	2.7	0.3~5.0	0.011
	Concrete carpenter	3.4	1.3~5.6	<0.001
	Masonry worker	1.2	−1.5~3.9	1.000
	Interior carpenter	4.9	2.1~7.7	<0.001
	Other groups	5.8	2.3~9.3	<0.001
Masonry worker	Pile driver operator	1.5	−1.3~4.3	1.000
	Concrete carpenter	2.3	−0.4~4.9	0.193
	Interior carpenter	3.7	0.6~6.9	0.007
	Other groups	4.6	0.8~8.4	0.005
Pile driver operator	Concrete carpenter	0.8	−1.5~3.0	1.000
	Interior carpenter	2.3	−0.6~5.1	0.359
	Other groups	3.1	−0.4~6.7	0.156
Concrete carpenter	Interior carpenter	1.5	−1.2~4.2	1.000
	Other groups	2.4	−1.1~5.8	0.848
Interior carpenter	Other groups	0.9	−3.0~4.7	1.000

sites, finding an average noise exposure of 87.8±4.3 dBA. This indicates an exceedance of the Korean Occupational Exposure Limit by at least 27%. Given that exposure to noise levels of 85 dBA or higher carries a substantial risk for NIHL, it's inferred that a minimum of 71.9% of the assessed construction workers may be at risk. This number could potentially increase when different assessment methods are applied. For instance, Neitzel et al. evaluated the noise exposure of a construction worker cohort in Washington using both the NIOSH method and the OSHA method, the latter of which was utilized in this study. The noise exposure measured by the NIOSH method was approximately 7.7 dBA higher, suggesting that the subjects of this study could exceed exposure standards if these criteria were implemented (Figure 1) (Neitzel et al., 1999)

The Washington construction worker cohort assessed the noise exposure levels of 730 workers across 9 construction trades, yielding a mean level of L_{OSHA}=82.1±5.7 dBA. This is notably lower than the findings of the current study. Given the differences in the number of construction trades

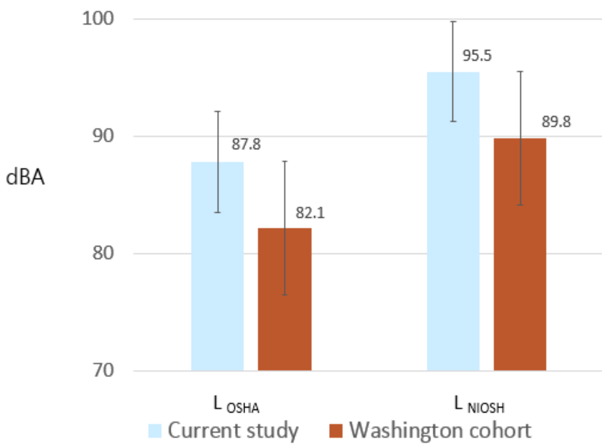

Figure 1. Comparative analysis of mean noise exposure levels between construction workers in the current study and the Washington cohort

and sample sizes between the two studies, a trade-specific comparison is warranted. In trades that are directly comparable—such as carpenters, masonry workers, and ironworkers—the noise exposure levels in the current study were generally 2-5 dBA higher. This discrepancy is not fully accounted for by the difference of 5 dB or more in the mean values. One plausible explanation for this divergence could be the application of a worst-case investigation methodology in the current study, as it was conducted under legal measurement protocols. Specifically, electricians, who generally have lower exposure levels, constituted the largest segment of the Washington cohort. In contrast, concrete chippers made up the largest proportion of subjects in the current study (Seixas et al., 2005).

In the Washington cohort, ironworkers and operating engineers exhibited the highest levels of noise exposure, a trend similarly observed among ironworkers and pile driver operators in the current study. However, unlike the Washington cohort where the variation in exposure levels across construction trades was not statistically significant, the current study found significant differences. This can be attributed to the inclusion of a large number of concrete chippers and concrete finishers in the current study, trades that were not represented in the Washington cohort. Chipping and grinding are generally corrective measures employed to address defects in concrete work on construction sites, and these processes can be minimized on well-designed sites. The prevalence of such activities on Korean construction sites suggests that the design and construction processes may not be as organically managed as they are in the USA. Additionally, the notably high noise exposure levels in construction trades with smaller workforces can also be linked to chipping and grinding activities, as these tasks are typically performed by a minimal number of workers, primarily to correct concrete defects.

The noise exposure levels for concrete carpenters and interior carpenters are relatively low, but they are not a level that can be disregarded. This holds particular significance for occupational health management, especially given the large number of workers employed in these two construction trades. Therefore, even moderate levels of noise exposure in these trades warrant attention for effective occupational health management and risk mitigation. In the Washington cohort study, electricians were anticipated to experience very low levels of noise exposure. However, their actual exposure was only 2-3 dBA lower than those in construction trades known for high noise exposure, such as ironworkers. This discrepancy is attributed to their exposure to background noise while working in close proximity to trades with higher noise levels (Seixas et al., 2001).

In the Washington cohort, approximately 40 % of workers exposed to noise levels of 85 dBA or higher utilized earplugs (Edelson et al., 2009). In stark contrast, none of the subjects in the current study used earplugs. This discrepancy can be attributed to the focus of occupational safety and health measures in Korean construction sites, which primarily aim to prevent accidents and disasters, often neglecting basic occupational health issues like noise exposure. The Occupational

Safety and Health Act requires workplaces of a certain scale to appoint a health manager, yet construction sites were notably exempt from this requirement at the time of this study. Consequently, the level of occupational health management remains uniform across both large and small companies, a fact corroborated by the lack of variation in noise exposure levels based on company size. To better protect the hearing health of construction workers in the future, there is an urgent need for authorities to more rigorously enforce relevant laws and regulations on construction sites. Concurrently, it is imperative to expand the scope of assessments to include noise exposure levels across a broader range of construction trades and sites, complemented by audiometric testing.

Additionally, the presence of significant differences in noise exposure levels between various trades suggests that the construction trade itself serves as a useful metric for exposure assessment. This lends credence to the applicability of the TM method for assessing noise exposure on construction sites.

However, there are some limitations to this study that should be acknowledged. First, the focus on apartment construction, which is predominantly undertaken by large corporations in Korea, means that the findings may not be generalizable to all construction sites or to sites constructing different types of buildings. Second, the measurements obtained in this study represent worst-case scenarios and should not be considered as reflective of average noise exposure levels across most apartment construction sites.

V. Conclusions

In conclusion, our findings suggest that the majority of construction workers participating in this study are at risk of Noise-Induced Hearing Loss (NIHL). This underscores the relevance of construction trade as an exposure metric within the context of apartment construction sites. Consequently, it is imperative that authorities more rigorously enforce laws and regulations pertaining to exposure assessment and hearing examinations, with a view to better safeguard the hearing health of construction workers. Furthermore, the promotion of ongoing research in this area is also essential.

Conflict of Interest

The authors declare they have no conflicts of interest.

Acknowledgement

Acknowledgment is extended to the Kyeonggi Industry Health Center for the provision of data for this study.

References

ACGIH. 2012 TLVs® and BEIs®: Based on the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices. ACGIH; 2012

Edelson J, Neitzel R, Meischke H, Daniell W, Sheppard L et al. Predictors of hearing protection use in construction workers. Annals of Occupational Hygiene. 2009;53(6):605-615 doi information (https://doi.org/10.1093/annhyg/mep039)

Kerns E, Masterson EA, Themann CL, Calvert GM. Cardiovascular conditions, hearing difficulty, and occupational noise exposure within US industries and occupations. American journal of industrial medicine. 2018;61(6):477-491.doi information (https://doi.org/10.1002/ajim.22833)

Kim KS, Kim EA, Kim GH, Kim DS. Study on health effects associated with hazards exposure using work environment monitoring data and special health examination. Incheon: Korea Occupational Safety and Health Agency; 2010

Korea National Statistical Office. 2001~2011 Occupational

Disease Compensated by Industrial Accident Compensation Insurance.: 2013a [Accessed 2023 Jun 10]. Available from URL: https://kosis.kr/statHtml/statHtml.do?orgId=118&tblId=DT_11806_N055&vw_cd=MT_ZTITLE&list_id=118_11806_cole6857&seqNo=&lang_mode=ko&language=kor&obj_var_id=&itm_id=&conn_path=MT_ZTITLE

Korea National Statistical Office. 2010 Korea Working Condition Survey.: 2013b

MoEL. 2010 Annual Report of Work's Health Examination. Gwacheon, Kyungido: 2011

Ministry of Government Legislation. Korea Natinal Legal Information Center.: 2013

Neitzel R, Seixas NS, Camp J, Yost M. An assessment of occupational noise exposures in four construction trades. American Industrial Hygiene Association Journal. 1999;60(6):807-817 doi information (https://doi.org/10.1080/00028899908984506)

Neitzel RL, Daniell WE, Sheppard L, Davies HW, Seixas NS. Evaluation and comparison of three exposure assessment techniques. Journal of occupational and environmental hygiene. 2011;8(5):310-323 doi information (https://doi.org/10.1080/15459624.2011.568832)

Seixas N, Neitzel R, Sheppard L, Goldman B. Alternative metrics for noise exposure among construction workers. Annals of Occupational Hygiene. 2005;49(6):493-502 doi information (https://doi.org/10.1093/annhyg/mei009)

Seixas NS, Neitzel R, Stover B, Sheppard L, Feeney P et al. 10-Year prospective study of noise exposure and hearing damage among construction workers. Occupational and Environmental Medicine. 2012;69(9):643-650 doi information (http://dx.doi.org/10.1136/oemed-2011-100578)

Seixas NS, Ren K, Neitzel R, Camp J, Yost M. Noise exposure among construction electricians. American Industrial Hygiene Association Journal. 2001;62(5):615-621 doi information (https://doi.org/10.1080/152986 60108984661)

Suter AH. Construction noise: exposure, effects, and the potential for remediation; a review and analysis. American Industrial Hygiene Association Journal. 2002;63(6):768-789. doi information (https://doi.org/10.1080/15428110208984768)

<저자정보>

강태선(교수)