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# Neighborhood Noise

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## Abstract

Listening to sounds in everyday life is an important factor in a human life. You can talk, listen to music, and enjoy nature through sound. However, due to adverse effect, listening to unwanted sounds continuously may cause noise-induced health disorders. Noise is an inevitable pollution factor in modern society, and its severity is increasing day by day. In addition, as the improvement of the economic level and the demand for the calm quality of life are increasing, the noise-related problem is emerging as a continuous social issue. Most of the problems associated with noise are mental, especially in developed countries, where social issues with the neighborhood noise are getting worse. The severity of noise-related problems is associated with the characteristics of noise, personal sensitivities, and vulnerable groups, but continued exposure can adversely affect not only health but also sociocultural, ethical, and economical aspects. However, the knowledge of the direct and indirect effects of noise pollution on health is still insufficient. Due to these limitations, it is difficult to establish reasonable standards for resolution and therefore requires more scientific research works.

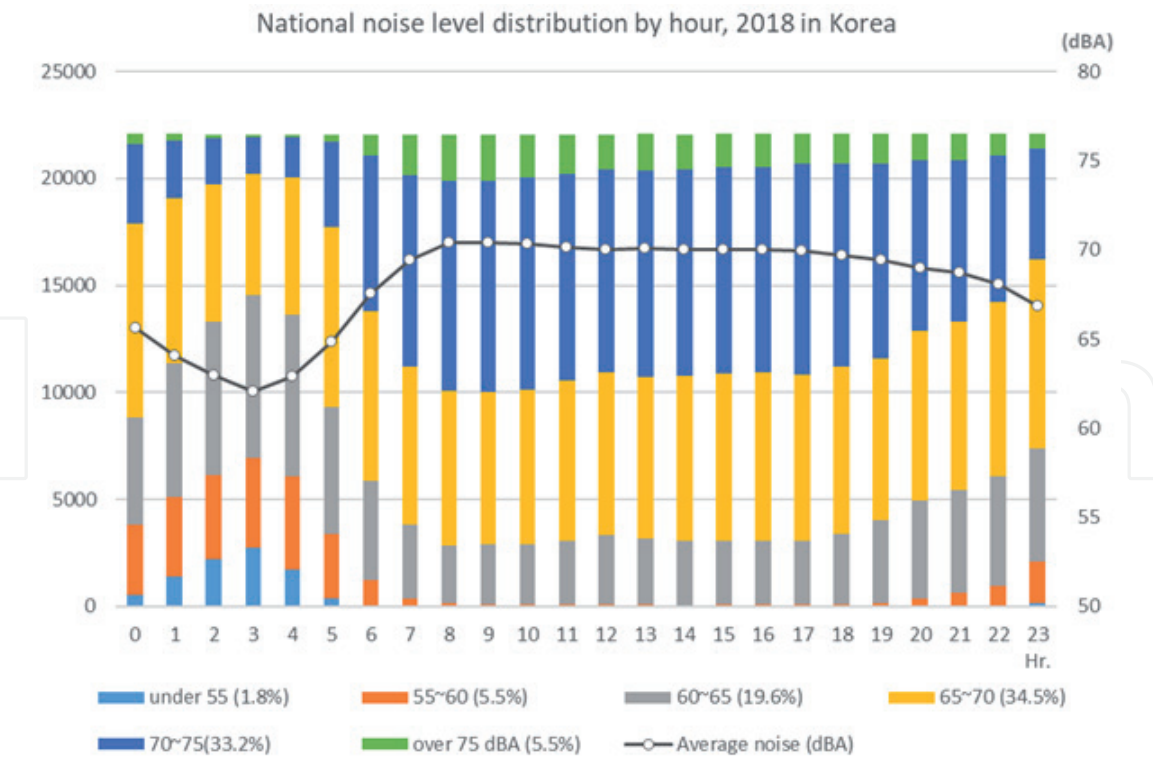
**Keywords:** neighborhood noise, annoyance, health effects, environmental burden, mediation, social issue

## 1. Noise pollution becomes a main problem

With the improvement of living standards, urbanization, and industrialization, noise pollution has become an environmental factor that is most frequently encountered by anyone, anytime, and anywhere in everyday life. Unlike other environmental problems, noise pollution tends to increase continuously, and the sufferings of the residents exposed to noise also increase gradually. In particular, in a rapidly developing society, poor buildings' quality, poor urban planning, and traffic noises generate more exposed to noise pollution.

Korea is successfully industrialized country. With the industrialization, noise complaints began to emerge. Noise and vibration make up 90% of the environmental disputes. Most metropolitan residents in Korea are suffering from noise pollution. And 88% of metropolitan residents expected that noise level would get worse.

The data of the nationwide environmental noise through automatic measurement network in 2018, which included major cities in Korea, were as follows (**Figure 1**). The distribution of noise level was 84.5% in the case of over 55 dBA at night (23–7 hours) and 99.9% in the daytime (8–22 hours), and some cases exceeded 75 dBA (0.95% at night, 4.54% during the day). The national average noise level was 64.6 dBA (54.6–69.9 dBA) during the night and 69.6 dBA (55.1–74.3 dBA) during the day, 5 dBA higher than during the night. Most of results exceeded the domestic standard for residential areas, 50 dBA at night and 55 dBA during the day. Because such noise level is a result of outdoor measurement, the indoor noise level might be



**Figure 1.**  
*Distribution and mean noise levels of nationwide automatic measurement system in 2018, in Korea: Data from <http://www.noiseinfo.or.kr>.*

10–15 dBA lower than outdoor level usually [1]. The nationwide environmental noise level and noise-related problems in Korea are not getting better than before.

According to the International Program on Chemical Safety [2], an adverse effect of noise is defined as a change in the morphology and physiology of organism that results in an impairment of functional capacity, or an impairment of capacity to compensate for additional stress, or increases the susceptibility of organism to harmful effects of other environmental influences. This definition includes any temporary or long-term decrement of physical, psychological, or social function of humans or human organs.

Environmental noise exposure is responsible for range of health effects, including increased risk of ischemic heart disease as well as sleep disturbance, cognitive impairment among children, annoyance, stress-related mental health risks, and tinnitus. Taken together, these risks in high-income European countries account for a loss of 1–1.6 million disability adjusted life years (DALYs) – a standardized measure of healthy years of life lost to illness, disability, or early death.

The health effects of noise depend on its complexity such as time variation, frequency content, loudness, ambient noise level, type of noise, and individual difference. The lack of sufficient knowledge about the direct and indirect effects of these noises on health is limiting the provision of reasonable regulatory standards for living noise.

**2. Neighborhood noise is increasing**

A rapid increase in population in the city and urbanization in 1960s and 1970s prompted the need for residential construction. To cope with the demand, high-rise flats were built. Regulation on building at that time did not include the test on sound insulation in residential building, so standards were often not adequate

to protect people from everyday sounds from their neighbors made [3]. Although there were some differences by country, neighborhood noise issues were mostly published after the 1980s. They revealed that economic growth and urbanization affected the neighborhood noise issues.

According to the special report of New York City in 2005, there were 410,000 noise complaints to 311. New Yorkers perceived much more from neighborhood noise and also suffered more behavioral and emotional consequences, such as difficulty sleeping and relaxing and feeling annoyed, angry, or upset compared to the nationwide population. New Yorkers were especially bothered by neighbor noises such as inadequate floor covering and slamming of doors. Of those, young children running around excessively were noise complaints that were best handled by clauses in apartment leases. These findings demonstrated that New Yorkers could not find the requisite peace and quiet in their homes that they deserve [4].

The European quality-of-life surveys were carried out examining both the objective circumstances of lives of European citizens and how they felt about those circumstances and their lives in general. The last (fourth) survey in 2016–2017 involved nearly 37,000 citizens, and respondents were asked whether they had major, moderate, or no problems with noise from the immediate neighborhood of their home. Almost one third (32%) of them reported problems with noise (ranging from 14 to 51% in individual countries), mainly in cities or city suburbs (49%) [5]. The neighborhood noise problem accounted for a large proportion of complaints related to noise and its proportion increased despite the government efforts such as campaign and legislation.

Neighborhood noise may stem from various potential sources of noise (such as ventilation systems; church bells; animals; neighbors; commercial, recreational and occupational activities; or shooting/military). As the sources might be located in close proximity to where people live, they could cause considerable annoyance even at low levels.

The main background factors of noise issues include overcrowding, developing urbanization, sprawling development, building of apartments and houses with inadequate sound insulation, increased use of electric equipment at home, increased number of recreation facilities, and lack of communication among neighbors. In addition, the calmness of a residential area depends on the noises outside the house. These main noise issues simply divided neighborhood noise into three categories: (1) noise produced by using loudspeakers, (2) noise produced during the nighttime operation of commercial facilities, and (3) daily life noise [6].

According to the report of Right to Peace and Quiet Campaign (RPQC) in 1994, at least five people a year died from noise-related conflicts between neighbors in the UK [3]. Also, 18 people had serious social problems in 2010–2020 such as arson and murder followed by conflicts related to neighborhood noise in Korea.

People could feel more annoyed if they believe the noise might harm our health or put us in danger. They could be particularly disturbed when their neighborhoods suddenly become noisy. When noises become really disturbing, it could dominate every aspects of our lives. The desire to get rid of the offending noises by almost any means possible could be overwhelming. Murder or suicide is just the end point of that process. Although only a small number of people resort to suicide or murder, many lives could get altered forever by noise problems [3].

### **3. Neighborhood noise problem and the related efforts in Korea**

According to mediation center report, of the 137,813 telephone consultations (2012–2018), there were severe conflicts among neighbors, and 39,950 cases

(29.0%) were requested for onsite diagnosis and measurement. The mediation service demand has increased by 3.2 times from 8795 cases in 2012 to 28,231 cases in 2018. 12493 cases required on-site diagnosis and measurement. Even though the construction year varied among those cases, the slab thickness of the apartments estimated to be less than 120 mm. Of the 1271 noise measurements, 1177 (92.6%) were within the standard, and only 94 (7.4%) exceeded the regulatory standard in 2018. Of the number of onsite diagnoses and measurements received, the floor impact sound distribution was 82.8%, and in particular, “children’s running or footsteps” accounted for 70.6%, followed by hammering, furniture pulling, door closing, vibrating machines, and exercise equipment. The most common air transmitted noise was generated by household appliances, followed by musical instruments, argument, pets, toilet drains, and air conditioner outdoor units.

Most of the damages reported to the Mediation Center were sleep disturbance, followed by rest disturbance, excessive protest from the victim, emotional anxiety, and learning disturbance. In case of the conflict period between neighborhoods, less than 6 months was the most frequent, and it tended to decrease over time until 2 years but increased after that.

These results showed that the victim initially responds to the neighborhood noise sensitively due to unfamiliar state of the living environment, but eventually the pattern of response improved due to changes in behavior attitude, improvement of mutual relations, and habitualization of noise. However, it is estimated that if the period gets prolonged, the damage is re-recognized when the subjective tolerable limit is exceeded (**Table 1**).

If the noise exposure persists over an extended period of time, increasing evidence suggests that more severe health consequences, such as cardiovascular diseases, may emerge as a result of prolonged physiological stress [7, 8].

Korea’s standards of Environment Noise were first established in 1964 as “Pollution Prevention Act” and have gone through several revisions in the following order, Environmental Protection Act (1978), Noise and Vibration Control Act (1991), and still the revision is ongoing. The intent of the law is to preserve proper environment, which requires the establishment of various measures, such as setting

Type of impact	Conflict period between neighborhood (years)							Others
	Total (%)	>0.5	0.5–1	1–1.5	1.5–2	2–3	3<	
Total (%)	4684 (100.0)	1281 (27.3)	1114 (23.8)	809 (17.3)	269 (5.7)	452 (9.6)	538 (11.5)	223 (4.8)
Sleep disturbance	2865 (61.2)	838	705	489	163	275	333	64
Rest disturbance	662 (14.1)	160	109	118	35	63	90	87
Excessive protest	590 (12.6)	182	136	109	32	56	48	27
Emotional anxiety	315 (6.7)	55	98	56	20	36	41	9
Learning disturbance	94 (2.0)	16	28	22	4	9	13	2
Others	159 (3.4)	30	39	15	15	13	13	34

**Table 1.**  
*The receipt situation of mediation center for neighborhood noise by conflict period and type of impact in Korea (2017–2018).*



environmental standards, designating an area requiring countermeasures against noise, and setting rational permissible emission standards necessary to protect the health, property, and pleasant natural environment of the people. The law determines the regulation area of living noise where control standards are needed to impose adjustment of working hours, suspension of noise producing activities, and installation of soundproofing facilities. In addition, for those who fail to fulfill the act, it enables to prohibit the use or closure of the industry. In 2010, the revised enforcement rules have stipulated the range of noise generated by human activities (**Table 2**).

As the problem of neighboring noise became more serious, the government prepared comprehensive plans to reduce living noise in 2010. The related contents are in the following paragraphs.

First, strengthening the precautions prevention: provision of regulations for surrounding noise sources for quiet facilities (schools, libraries, hospitals, elderly facilities, childcare facilities, apartment houses, etc.), recognition of the amount of the fine caused by the noise and vibration dispute; second, management of new noise sources and living noise: present management standards for the floor impact noise and noise rating system for home appliances, preparing low frequency noise management guidelines; and third, traffic noise management: expanding the supply of low-noise cars and low-noise pavement and designating traffic noise management areas.

As a result of these efforts by government departments, the standard for neighborhood noise was more strengthened than the first one. The following shows the standards for interlayer noise implemented since 2014 (**Table 3**). The inter-floor noise-related policies of other countries are centered on lightweight impact noise, and the recommendation to the perpetrator (the UK) and fine imposition (the USA and Germany) is the main method. The allowable range varies from 65 dB in Spain

Target areas	Noise source		Morning (05–07) Evening (18–22)	Day (07–18)	Night (22–05)
Living area*	Loudspeaker**	Outdoor	60	65	60
		Transmitted to indoor	50	55	45
	Factory		50	55	45
	Industry	Same building†	45	50	40
		Others	50	55	45
	Construction		60	65	50
	Other area	Loudspeaker	Outdoor	65	70
Transmitted to indoor			60	65	55
Factory			60	65	55
Industry		Same building	50	55	45
		Others	60	65	55
Construction			65	70	50

\*Area straightly within 50 m from boundary of a general hospital under the Medical Act, schools under the Elementary and Secondary Education Act and the Higher Education Act, and public libraries under the Library and Reading Promotion Act.  
\*\*The loudspeaker installed outdoors should be used within 3 minutes at once with at least 15-minute interval.  
†The term “Same building” refers to a building in accordance with Article 2 of the Building Act, which has a roof, pillar, or wall as a whole.

**Table 2.**  
Noise and vibration control act and related standards (dBA SPL).

Classification of neighborhood noise		Standard for neighborhood noise	
Parameter	Measuring unit (dBA)	Daytime (6 am to 22 pm)	Night (22 pm to 6 am)
Direct impact noise	Equivalent noise level ( $L_{eq}$ ) for 1 minute*	43	38
	Maximum noise level ( $L_{max}$ )**	57	52
Air transmission noise	Equivalent noise level ( $L_{eq}$ ) for 5 minutes*	45	40

*\*The equivalent noise level ( $L_{eq}$ ) for 1 minute and the equivalent noise level ( $L_{eq}$ ) for 5 minutes are the highest values measured in accordance with Note 3.*

*\*\*The maximum noise level ( $L_{max}$ ) is considered to have exceeded the standard if the value exceeded three times per hour.*

**Table 3.**  
Supplementary standards for neighborhood noise (Note 3).

<b>First-step service</b>	1. Telephone counseling	National noise information system and nationwide call center After determining the cause of neighborhood noise, conflict resolution and mitigation measures are presented
	2. Confirm respondent onsite diagnosis and related measurement acceptance	Accept: Implementation of second-step service Refuse: Noise reduction, conflict mitigation measures postal notice (end)
<b>Second-step service</b>	1. Additional telephone counseling	In-depth consulting on both sides If satisfied or self-solve the problem then finish
	2. Onsite diagnosis	Consultation of mitigation measures after understanding housing structure, causes of conflict, and degree of conflict Write the consultation report
	3. Onsite measurement of noise	Measurement of noise level with equipment 24 hours Completion of the consultation report

**Table 4.**  
Work processing flows of neighborhood noise mediation center.

to 53 dB in Finland. In Korea, the law related to interlayer noise, which is stricter than that of the other countries, was enacted considering heavyweight shock, lightweight impact noise, and maximum time-weighted noise level ( $L_{max}$ ).

According to a 2013 National Human Rights Commission survey, 88% was stressed by interlayer noise. The response choices included were patience (46%), request to visit (25%), report to the guard (19%), protest after visit (7%), and report to police and neighboring centers (1%).

The Neighborhood Mediation Center opened in March 2012 to prevent neighborhood noise from social issue of multiunit apartments and to settle disputes reasonably (Table 4).

4. Environmental noise indicators of the health impacts

The suitable indicators for policy making on the basis of the most frequently used average noise indicators in Europe are  $L_{den}$  and  $L_{night}$ . These are used widely for exposure assessment in health effect studies and noise impact assessments.

The  $L_{\text{den}}$  indicator is day-evening-night-weighted sound pressure level as defined in Section 3.6.4 of ISO 1996-1:2016. It is calculated by the A-weighted average sound pressure level measured over a 24-hour period, with a 10 dB penalty, a 5 dB, and no penalty, each added to the average level at night, evening, and the daytime period, respectively [9]. The penalties considered people's extra sensitivity to noise during the evening and night. The  $L_{\text{night}}$  indicator is the equivalent continuous sound pressure level when the reference time interval sets during the night.

In general, environmental noise is composed of complexed component such as impact sounds and impulse sounds, which make the  $L_{\text{den}}$  or  $L_{\text{night}}$  indicators hard to represent a particular noise effect. For single-event noise indicators, the maximum sound pressure level ( $L_{A,\text{max}}$ ) and its frequency distribution can be more appropriate in specific situations, such as in the context of night-time railway, aircraft noise events, and neighborhood noise that can clearly elicit awakenings and other physiological reactions that can be determined by  $L_{A,\text{max}}$ . The  $L_{A,\text{max}}$  indicator is maximum time-weighted and A-weighted sound pressure level within a stated time interval starting at  $t_1$  and ending at  $t_2$ , expressed in dB [10]. Nevertheless, the assessment of the relationship between different types of single-event noise indicators and long-term health outcomes at the population level remains tentative.

All noise exposure prediction models used today estimate free-field exposure levels outdoors, and most noise abatement regulations refer to outdoor levels as well. Nevertheless, in certain cases, it would be helpful to estimate indoor levels based on outdoor values. The differences between indoor and outdoor levels are usually estimated at around 10 dB for open, 15 dB for tilted or half-open, and about 25 dB for closed windows [1].

Regarding the night noise impacts on health, below the level of 30 dB  $L_{\text{night}}$ , no effects on sleep are observed except for a slight increase in the frequency of body movements during sleep due to the night noise. There is no sufficient evidence that the biological effects observed at the level below 40 dB  $L_{\text{night}}$  are harmful to health. However, adverse health effects are observed at the level above 40 dB  $L_{\text{night}}$ , such as self-reported sleep disturbance, environmental insomnia, and increased use of somnifacient drugs and sedatives. Therefore, 40 dB  $L_{\text{night}}$  is equivalent to the lowest observed adverse effect level (LOAEL) for night noise. Above 55 dB, the cardiovascular effects become the major public health concern, which are likely to be less dependent on the characteristics of the noise. Closer examination on the precise impact will be necessary in the range between 30 and 55 dB because most will depend on the detailed circumstances of each case. The causal link between immediate physiological reactions and long-term adverse health effects is complex and difficult to prove [11, 12].

Since most of the problems of neighborhood noise are generated during the evening or at night, it is reasonable to estimate physical health effects using the noise indicators presented above. However, the actual field noise measurement results showed a few cases that exceeded the regulatory standards, and collisions among neighbors occurred even at relatively low noise levels. This means that the problems related to neighborhood noise are largely responsible for mental health effects such as annoyance and sleep disorders. It also suggests that the effects of "effect modifiers," such as differences in noise levels from the ambient noise, socioeconomic status, and personal susceptibility to noise, should be considered.

## 5. Health outcomes of the noise exposure

Exposure to noise can lead to auditory and nonauditory effects on health. Through direct injury to the auditory system, noise exerts auditory effects such as



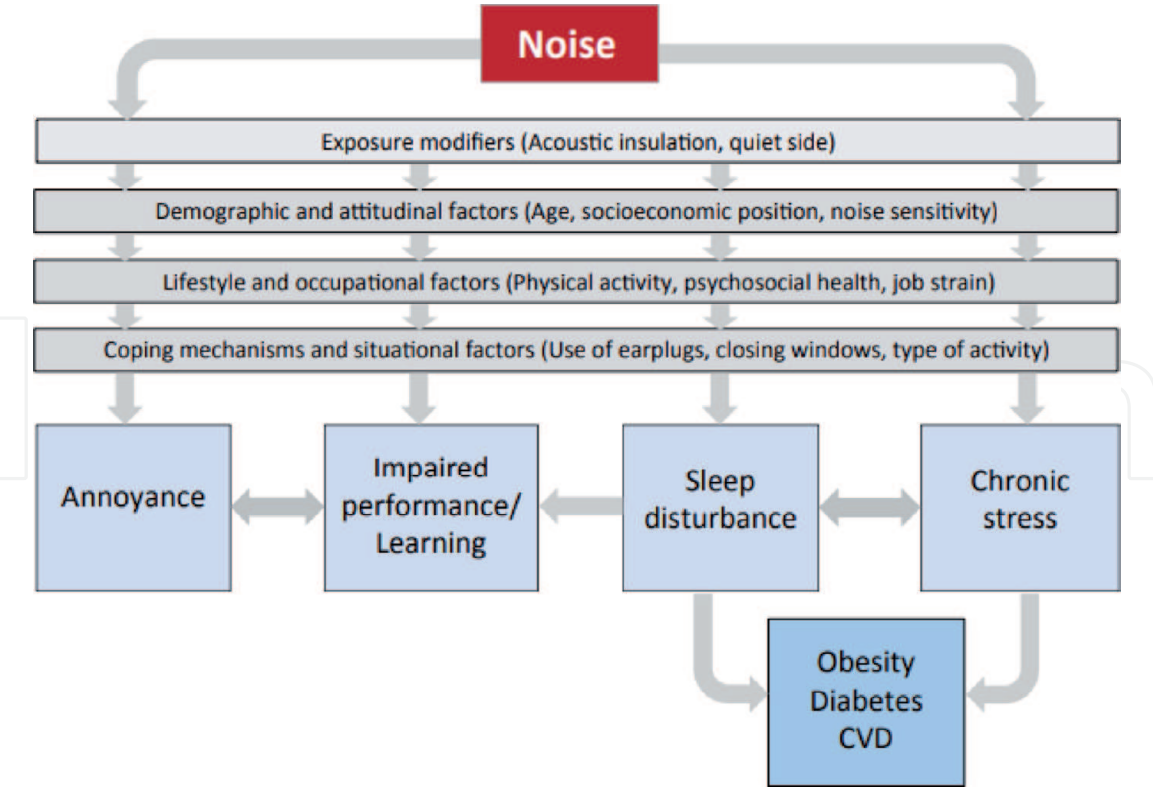
hearing loss and tinnitus. Noise is also a nonspecific stressor that has been shown to have an adverse effect on human health, especially following long-term exposure. These effects are the result of psychological and physiological distress, as well as disturbing homeostasis of an organism and increasing allostatic load [13].

The most common noise-related health effect is annoyance. Noise annoyance is caused by noise-related disturbances of the individual's speech communication, concentration, and performance of tasks, and it is commonly associated with negative emotional reactions, such as feelings of displeasure, anger, and disappointment. Furthermore, annoyance may give rise to physiological symptoms, including tiredness, stomachache, and stress symptoms. In fact, noise annoyance is a symptom of stress building up inside as a consequence of signals transmitted from the auditory system to the nervous system, stimulating several subsequent reactions in our bodies [14].

Since endocrine changes manifesting physiological disorders come first in the chain of cause effect for perceived noise stress, noise effects on stress hormones may therefore be detected in populations after relatively short periods of noise exposure. This makes stress hormones a useful stress indicator but in terms of the risk assessment, usually the quantitative interpretation of endocrine noise effects is often a quantitative one rather than qualitative one. The most well-known mechanism mediating the response to stress is the hypothalamic-pituitary-adrenal (HPA) axis. When the HPA axis receives a signal of a stress response, corticotropin-releasing factor is secreted from the hypothalamus, which in response releases adrenocorticotrophic hormone from the pituitary gland. Adrenocorticotrophic hormone then promotes the secretion of cortisol from the adrenal cortex through the blood, which triggers responses to various kinds of stress. The secretion of cortisol in response to stress inhibits the function of the HPA axis to disrupt the secretion of neurohormones and neurotransmitters as well as influencing the endocrine system, thereby disturbing homeostasis of the body, which can induce the development of various stress-related diseases [15]. Recent studies have also reported that sleep quality and noise sensitivity are not related to vascular function, but rather that night noise increases the risk of cardiovascular disease due to the increased blood pressure [7].

The associations between noise and health could be modified by several factors (effect modifiers), so individuals may therefore be more or less affected by the noise. These so-called "effect modifiers" can be demographic factors, for instance, age, sex, and socioeconomic position; personal or attitudinal factors, such as noise sensitivity and fear of the noise source; or related to the individual lifestyle and occupation, including physical activity, psychosocial health, and job strain. In addition, coping mechanisms, such as use of ear plugs or window opening behavior, and situational factors, including time of day and type of activity, may modify the effect of exposure (**Figure 2**) [16]. Identification of risk groups, individuals who are particularly vulnerable to noise, is important for assessments of public health impact and can serve as a basis for preventive measures. For each specific health outcome, one should consider not only the available factors that may modify the effect of noise but also the annoyance rating of noise sensitivity as the most important individual characteristic when predicting dissatisfaction with the noise [14, 17].

The health outcomes influenced by possible nonacoustic factors may include gender, age, education, subjective noise sensitivity, extroversion/introversion, general stress score, comorbidity, length of residence, duration of stay at dwelling in the day, window orientation of a bedroom or living room toward the street, personal evaluation of the source, attitudes toward the noise source, coping capacity with respect to noise, perception of malfeasance by the authorities responsible,



**Figure 2.**  
*The framework of health effects of noise according to environmental noise and health – current knowledge and research needs ISBN 978-91-620-6553-9.*

body mass index, and smoking habits. In noise annoyance studies, nonacoustic factors may explain up to 33% of the variance [18].

According to WHO report, the key health outcomes associated with environmental noise exposure based on the seriousness and prevalence and the anticipated availability of evidence were in the following. The health outcomes were divided as either critical or important for developing recommendations on the health impacts of environmental noise. The selection of health outcomes was based on the available evidence for the association between the environmental noise and the specific outcome, as well as public concern about the health outcome resulting from noise exposure. The critical health outcomes associated with environmental noise included such as cardiovascular disease, annoyance, sleep disturbance, cognitive impairment, and hearing impairment and tinnitus. In addition, the important health outcomes were adverse birth outcomes, metabolic outcomes, quality of life, well-being, and mental health [19].

The following health outcomes were based on the evidence-based association between the environmental noise and the specific outcome, as well as public concern about the health outcome resulting from noise exposure. These health outcomes can be measured in various ways, and their prioritization was based on the impact of the disease and the disability weights (DWs) associated with the health outcome measure. A disability weight is a weight factor that reflects the severity of the disease on a scale from 0 (perfect health) to 1 (equivalent to death). Years Lost due to Disability (YLD) are calculated by multiplying the incident cases by duration and disability weight for the health condition [8]. In case of cardiovascular disease, DW of IHD is 0.405, DW of hypertension is 0.117, and the severity of the disease itself is high in IHD. However, the incidence rate varies depending on the survey area or country, the results of YLD may be different. The critical health outcomes, identification of the priority outcome measures, and justifications for their selections are listed in **Table 5** [19].

Critical health outcome	Critical health outcome measures	Justification for selection
Cardiovascular disease ( $L_{den}$ )	<p>Self-reported or measured prevalence, incidence, hospital admission, or mortality due to:</p> <ul style="list-style-type: none"><li>• ischemic heart disease (IHD) (including angina pectoris and/or myocardial infarction)</li><li>• hypertension</li><li>• stroke</li></ul>	<p>Except for self-reports, these are objective measures of the outcome, affect a large proportion of the population, have important health consequences, and can lead to more severe diseases and/or mortality.</p> <p>DW for IHD: 0.405</p> <p>DW for hypertension: 0.117</p>
Effects on sleep ( $L_{night}$ )	<ul style="list-style-type: none"><li>• Percentage of the population highly sleep-disturbed (%HSD), self-reported, assessed with a standardized scale</li><li>• Polysomnography measured outcomes (probability of additional awakenings)</li><li>• Cardiac and blood pressure outcome measures during sleep</li><li>• Motility measured sleep outcomes in adults</li><li>• Sleep disturbance in children</li></ul>	<p>This is the most meaningful, policy-relevant measure of this health outcome. Self-reported sleep disturbances are a very common problem in the general population: they affect quality of life directly and may also lead to subsequent health impediments. Effects on sleep may be in the causal pathway to cardiovascular disease. This measure is not a proxy for physiological sleep quality parameters but is an important outcome in its own right.</p> <p>DW for %HSD: 0.07</p>
Annoyance ( $L_{den}$ )	<ul style="list-style-type: none"><li>• Percentage of the population highly annoyed (%HA), assessed with standardized scale</li><li>• Percentage annoyed, preferably assessed with standardized scale</li></ul>	<p>This is the most objective measure of this health outcome. Large proportions of the population are affected by noise annoyance, even at relatively low exposure levels. Annoyance may be in the causal pathway to cardiovascular disease.</p> <p>DW for %HA: 0.02</p>
Cognitive impairment ( $L_{den}$ )	<ul style="list-style-type: none"><li>• Reading and oral comprehension, assessed with tests</li><li>• Impairment assessed with standardized tests</li><li>• Short- and long-term memory deficit</li><li>• Attention deficit</li><li>• Executive function deficit (working memory capacity)</li></ul>	<p>This outcome measure is the most meaningful: it can affect vulnerable individuals (children) and has a significant impact later in life.</p> <p>DW for impaired reading and oral comprehension: 0.006</p>
Hearing impairment and tinnitus ( $L_{Aeq}$ and $L_{AF,max}$ )	<ul style="list-style-type: none"><li>• Permanent hearing impairment, measured by audiometry</li><li>• Permanent tinnitus</li></ul>	<p>This outcome measure can affect vulnerable individuals (children) and has a significant impact later in life. It is the most objective measure for which there is an ISO standard (ISO, 2013), specifying how to estimate noise-induced hearing loss.</p> <p>DW for mild severity level (threshold at 25 dB) for childhood onset: 0.0150</p>

DW: A disability weight is a weight factor that reflects the severity of the disease on a scale from 0 (perfect health) to 1 (equivalent to death).

**Table 5.**  
Critical health outcomes, outcome measures identified, and justifications for selection according to the WHO Environmental Noise Guidelines for the European Region.

6. The burden of environmental noise and adverse health outcome

The disability weight (DW) is used to rank the priority critical health outcome measures. DWs are ratings that vary between 0 and 1, in which 0 indicates no disability and 1 indicates the maximum amount of disability. The DWs have been proven useful in calculating the burden of disease (**Table 6**).

Priority health outcome measure (associated with DW)	Relevant risk increase considered for setting of guideline level
Incidence of IHD (DW: 0.405)	5% RR increase
Incidence of hypertension (DW: 0.117)	10% RR increase
%HA (DW: 0.02)	10% absolute risk
%HSD (DW: 0.07)	3% absolute risk
Permanent hearing impairment (DW: 0.0150)	No risk increase due to environmental noise
Reading and oral comprehension (DW: 0.006)	One-month delay in terms of reading age

**Table 6.**  
*Priority health outcomes and relevant risk increases for setting guideline levels according to the WHO Environmental Noise Guidelines for the European Region.*

Important health outcome	Health outcome measures reviewed
Adverse birth outcomes ( $L_{den}$ )	<ul style="list-style-type: none"><li>• Pre-term delivery</li><li>• Low birth weight</li><li>• Congenital anomalies</li></ul>
Quality of life, well-being, and mental health ( $L_{den}$ )	<ul style="list-style-type: none"><li>• Self-reported health and quality of life</li><li>• Medication intake for depression and anxiety</li><li>• Self-reported depression, anxiety, and psychological distress</li><li>• Interviewer-assessed depressive and anxiety disorders</li><li>• Emotional and conduct disorders in children</li><li>• Children’s hyperactivity</li><li>• Other mental health outcomes</li></ul>
Metabolic outcomes ( $L_{den}$ )	Prevalence, incidence, hospital admission, or mortality due to: <ul style="list-style-type: none"><li>• type 2 diabetes</li><li>• obesity</li></ul>

**Table 7.**  
*Important health outcomes and health outcome measures reviewed according to the WHO Environmental Noise Guidelines for the European Region.*

For cardiovascular disease, the DW value (DW: 0.405) specifically applied to acute myocardial infarction in the publication outlining the data sources, 5% increase of relative risk in ischemic heart disease (IHD) and 10% in hypertension. The DWs for high sleep disturbance (DW: 0.07), high annoyance (DW: 0.02), and impaired reading and oral comprehension (DW: 0.006) were developed in the context of calculating the burden of disease from environmental noise. According to the WHO night noise guidelines, there were observed adverse health effects at levels starting from 40 dB  $L_{night}$ , and self-reported sleep disturbance (HSD) and



annoyance should not exceed 3 and 10% to be health protective, receptively. The DW for hearing impairment was available from the technical paper on the burden of disease from environmental noise; a DW of 0.0150 for moderate severity level “has difficulty following a conversation in a noisy environment, but no other hearing problems.” For cognitive impairment, the DW was derived from a very conservative value (DW: 0.006) for noise-related impairment of children’s cognition, equivalent to a DW for contemporaneous cognitive deficit in the context of a range of cognitive impairments in children. This impact cannot be predicted accurately [9].

Also, WHO provides a list of the important health outcomes along with the reviewed measures. There was no prioritization of health outcome measures leading to justification of selection, since important health outcomes had less impact on the development of recommendations. In **Table 7**, the health outcome-related noise indicator was  $L_{den}$ , and the most common health outcomes were relevant to psychoacoustic problems such as quality of life, well-being, and mental health [20].

## 7. Mental health impacts of noise

Environmental noise is not believed to be a direct cause of mental illness, but it is assumed that it accelerates and intensifies the development of latent mental disorder. Studies on the adverse effects of environmental noise on mental health cover a variety of symptoms, including anxiety, emotional stress, nervous complaints, nausea, headaches, instability, argumentativeness, sexual impotency, changes in mood, increase in social conflicts, and general psychiatric disorders such as neurosis, psychosis, and hysteria [17, 21].

Then, even when exposed to lower noise levels than outdoor, why the problems of neighbor noise are taken so sensitively and seriously? This is because it is contrary to the expectation that home is a place of rest and a comfortable, quiet place.

New Yorkers, like citizens in the quietest towns of the country, expect less noise when they close the doors to their apartment and homes. They may willing to deal with the noisy street traffic, crowds, and subways, as they transverse the city but they are less tolerant of noisy intrusions into their homes (Why noise matter chap 2) [3].

It turned out that psychiatric disorders are associated with noise sensitivity, rather than with noise exposure level, and the association was found to disappear after adjustment for the baseline trait anxiety. These and other results show the importance of taking vulnerable groups into account because they may not be able to cope sufficiently with unwanted environmental noise. This is particularly true of children, the elderly, and people with preexisting illnesses, especially depression. Despite the weaknesses of the various studies, the possibility that community noise has adverse effects on mental health is suggested by studies on the use of medical drugs, such as tranquilizers and sleeping pills, on psychiatric symptoms and on mental hospital admission rates. About 1 of 10 people are particularly noise sensitive. These people will become 10% more annoyed by noise than general population [22].

After adjustment of noise-related variables, sociodemographic factors, medical illness, and duration of residence, subjects in the high noise-sensitive (NS) group were more than 2 times more likely to experience depression and insomnia and 1.9 times more likely to have anxiety, compared to those in the low NS group. The levels of noise recognition and psychological discomfort are affected by various factors,



including individual components (e.g., age and effects of traits) and environmental factors, including contextual aspects and noise parameters (e.g., source, attitude toward noise, and amplitude modulation). Not all people exposed to environmental noise suffer from a disease or health problem, and the effects of noise differ among individuals [23].

Hearing noises above the perceived normal threshold, higher noise sensitivity, and continuous noises were associated with higher levels of displaced aggression (DA). It occurs when a person is provoked, is unwilling or unable to retaliate against the original provocateur, and subsequently aggresses against a seemingly innocent target. Low frequency and high intensity noises were also associated with higher DA scores. DA score was higher in women and in older people living in the neighborhood for a longer time, in people with better education, and in those reporting poorer health. Moreover, low frequency and continuous noises resulted in higher DA. The frequency of hearing noises above the normal threshold was positively correlated with DA as was noise annoyance [24].

## 8. Conclusion

The laws related to noise are increasingly being strengthened, and the actual noise level is decreasing compared to the past with the improvement of building technology and the reinforcement of regulatory standards. However, social problems related to noise have become more serious and are now an important part of the psychoacoustic problems related to the environment. This is also related to the expectation of a better quality of life as a result of the improvement of the economic level and the desire for home comfort. Also, even when the actual noise level is not high compared to other external environments and problems occur between neighbors. Therefore, it means that the problem of neighborhood noise should be discussed not only at the physical level but also at the psychoacoustic aspects, and the individual's sensitivity and cultural difference should be considered. In particular, it needs to be treated more seriously, considering that health problems (especially mental problems) related to neighborhood noise may occur at a lower level than actual measured noise levels. Also, neighborhood noises tend to provoke the existing mental health problems related to noise more easily. Identifying the physiological and psychological effect of environmental noise precisely and making it recognized broadly comprise the essential part of solving the environmental noise problem to create better living environment. The neighborhood noise issues were in part due to the lack of communication between and among neighbors. Lack of contact within the community affected people's perception of the loudness of daily life sounds [6]. Furthermore, intense emotional conflicts between and among some neighbors were also found to be one of the major sources of daily life noise. Even though the neighborhood noise annoyance will always be an issue, we want to be good neighbors and also hope to have good relationship with neighbors. Consideration of neighborhood, social responsibility, and changes in social behavior are important factors in addressing neighborhood noise. In addition, it is necessary to understand a scientific basis for the health impact of noise and to provide national support for noise reduction.

## Conflict of interest

The author declares no conflict of interest.

## Thanks

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