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Vehicle noise pollution awareness for human health and environmental impacts: A comprehensive review

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ABSTRACT

This comprehensive review explores the extensive and intricate effects of vehicle noise on human health and provides insights into experimental studies using animal models, primarily rats, to understand the impact of low-frequency vehicle noise. Furthermore, the effects of factors such as engine type and size, vehicle speed, air conditions and traffic density on vehicle noise levels are reviewed. The adverse health consequences of vehicle noise include disruptions in sleep patterns, anxiety, mood disorders, cardiovascular risks, noise-induced hearing loss, and gastrointestinal problems. To mitigate these risks, various recommendations and regulations (WHO Environmental Noise Guidelines for the European Region) are put in place, emphasizing the need for noise reduction in transportation and the responsible use of sound-emitting devices. This study serves as a comprehensive resource for understanding the intricate relationships between vehicle noise and human and animal health, emphasizing the importance of addressing vehicle noise pollution for overall well-being and public health.

Keywords: vehicle noise, human health, animal models, low frequency noise

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INTRODUCTION

Vehicle noise from cars, trucks, motorcycles and other transportation and agriculture vehicles has both direct and indirect effects on health. The specific impact on organ health varies depending on factors such as the type and intensity of noise, duration of noise exposure, individual sensitivity and general health status[1]. Vehicle noise can disrupt sleep cycles, especially at night. Poor sleep quality can affect the functioning of various organs and systems, including the brain, immune system and metabolism. Chronic exposure to vehicle noise, especially in densely populated urban areas, has been associated with an increased risk of hypertension. High noise levels can trigger stress responses leading to higher blood pressure levels, which, together with sleep disturbances, can strain the heart and increase the risk of cardiovascular disease[2]. Prolonged exposure to high levels of vehicle noise is associated with an increased risk of heart disease and stroke. Noise, which activates stress response of body and causes the release of stress hormones such as cortisol, can negatively affect various systems, including immune systems. Especially for individuals living near busy roads, prolonged exposure to vehicle noise can cause anxiety and mood disorders[3].

Chronic noise-related stress affects mental health and well-being. High-decibel vehicle noise, such as that produced by motorcycles, modified car engines or loud exhaust systems, can cause noise-induced hearing loss over time[4]. Chronic stress from continuous exposure to vehicle noise can potentially exacerbate gastrointestinal conditions such as irritable bowel syndrome or worsen symptoms of existing conditions. Although vehicle noise can have indirect effects on health through stress responses and sleep disturbance, it is important to note that the primary health risks are usually associated with prolonged exposure to high-decibel noise and the chronic stress it causes[5]. Reducing exposure to vehicle noise, using noise-canceling technologies, and implementing noise mitigation measures in urban planning and transportation infrastructure can help reduce these health risks. Furthermore, maintaining a healthy lifestyle, managing stress and getting medical care, when necessary, can also contribute to the health of people in noisy environments.

Numerous recommendations and legal frameworks have been established, both in Türkiye and globally, with the objective of mitigating the impact of noise exposure on human health. The WHO Environmental Noise Guidelines for the European Region established in 2018 offer recommendations aimed at safeguarding human health against environmental noise exposure stemming from diverse sources, including transportation-related sources such as road traffic, railway, and aircraft noise, as well as noise generated by wind turbines and leisure activities[6]. Recommendations related to road traffic are given below:

- The Guideline Development Group (GDG) strongly advocates diminishing average noise exposure levels caused by road traffic to levels below 53 dB L_{den}. Noise levels exceeding this threshold are linked with detrimental health outcomes, emphasizing the imperative for noise reduction measures in the context of road traffic.
- GDG strongly proposes decreasing nocturnal noise exposure levels resulting from road traffic to levels below 45 dB L_{night}. Noise levels surpassing this threshold during nighttime hours have been correlated with detrimental effects on sleep, underscoring the imperative need for noise reduction measures specific to night-time road traffic.
- To mitigate health-related consequences, GDG highly recommends for policymakers to enact appropriate measures aimed at diminishing noise exposure emanating from aircraft, particularly within populations exposed to noise levels surpassing the stipulated guideline values for both average and nocturnal noise exposure. The GDG further suggests the implementation of specific interventions involving modifications to infrastructure.

The Regulation on Environmental Noise Control, which was enacted in 2022, aims to prevent the negative effects of environmental noise on the environment and human health, to prepare noise maps and noise action plans, to implement noise control measures to reduce environmental noise and to inform the public about environmental noise management works in Türkiye[7].

In this regulation, environmental noise criteria for transportation sources are determined as follows:

- The level of environmental noise emitted from transportation sources shall not exceed 65 dB(A) $LA_{eq.5min}$ during the day, 60 dB(A) $LA_{eq.5min}$ in the evening and 55 dB(A) $LA_{eq.5min}$ at night.
- Transportation vehicles are required to utilize state-of-the-art technologies to minimize environmental noise emissions.
- The noise reduction apparatus installed in the horns and exhaust systems of motor vehicles must not be altered or rendered non-functional.
- Horns or sound-emitting devices on or within motor vehicles should not be operated in a manner that creates noise disturbances, except in cases of mandatory necessity.

METHODOLOGY

Vehicle noise levels and affecting parameters

Today, vehicles, especially transportation vehicles, are an important part of human daily lives. However, the noise emitted by vehicles poses a significant problem for both the environment and human health. The main parameters that cause vehicle noise can be defined as the contact of the vehicle wheels with the ground, engine operation and air resistance. In addition to these basic parameters, vehicle noise is generated and propagated into the environment as a result of the combination of many factors[8,9]. The parameters affecting the levels of vehicle noise are given in Table 1.

Table 1. The effects of different parameters on vehicle noise level

Parameters Affecting Vehicle Noise Level	Comments
Engine Power and Type	Engine power and type of the vehicle is one of the main factors affecting noise levels. Generally, engines with larger cylinder displacement and engines that can produce more power emit more noise to the environment. The noise emitted by a diesel internal combustion engine is considerably higher than the noise emitted by a gasoline engine. The amount of this excess varies depending on vehicle models and engine displacement, but on average diesel engines generate 6 to 10 dB(A) more noise[10,11].
Vehicle Speed	Regardless of the type of vehicle, increasing vehicle speeds have a significant impact on noise levels from vehicles. As the vehicle speed increases, the airflow creates more friction on the vehicle surface, which can lead to an increase in aerodynamic noise. High-speed trains and airplanes in particular can generate high noise levels at high speeds. The influence and importance of vehicle design parameters on aerodynamic noise levels is high. Vehicle designs play an important role in reducing noise level. In addition, wheel noise occurs when the vehicle's wheels come into contact with the road surface. Therefore, as the speed of the vehicle increases, the wheels have the potential to generate more noise[12,13].
Wheel and Road Interaction	The contact of the wheels with the road surface is one of the main sources of noise emission. The roughness of the road surface, type of road surface material, and road maintenance all impact on vehicle noise[14,15].
Tire types	The tires of a vehicle produce noise when they come into physical contact with the road. Factors such as tire patterns, material, pressure, and types have effects on tire-induced vehicle noise[16,17].
Vehicle Technology	Unlike gasoline and diesel engines, recently developed new generation electric vehicle models have engines (electric motors) that operate at lower noise levels and have features such as better noise insulation. This means that new generation vehicles cause less noise pollution[18-20].

Air Temperature	The temperature of the air has an impact on the speed and path of sound spread. Sound waves propagate faster in cold weather, which can lead to an increase in noise levels from vehicles. Hot weather, on the other hand, can cause sound to propagate more slowly[21,22].
Air Humidity	Air density and speed of sound are affected by air humidity. High humidity levels can cause sound to propagate faster and increase noise levels[23,24].
Echoes and Reflections	This issue is related to the reflection and reverberation of sound waves by environmental factors emitted from vehicle noise sources. The echoes and reflections are very significant in terms of noise dispersion. Reflection means that sound waves emitted from a noise source are reflected back when they encounter an obstacle. This reflection can cause the sound to be reflected more than once, resulting in a more complex noise pattern. Environmental echoes and reflections can cause noise levels to increase by reflecting sound waves from nearby environmental features (e.g. buildings, walls and vehicles). These echoes can contribute to the transmission of noise over greater distances. High building density and heavy traffic, especially in urban areas, can cause more of these echoes and increase noise pollution. Therefore, the environmental characteristics of the area through which a vehicle passes influence our level of noise detection[25,26].
Horn Use and Exhaust System	Today, the excessive use of horns by vehicle drivers where they are not needed and the characteristics of vehicle exhaust systems can lead to an increase in vehicle noise levels[27,28].

Traffic density: The presence of too many vehicles on the road causes high levels of noise. Urban traffic density is one of the most important parameters that increase noise from vehicles[29,30]. In road vehicles, each type of vehicle has specific level of noise (dBA). Although the sound pressure levels of all vehicle types vary depending on different parameters, the average vehicle noise levels emitted by different vehicle types was determined in the literature[31]. In addition, sound pressure levels are modeled as a function of vehicle speed for different vehicle types and equations are given in the Table 2 below.

Table 2. Noise level calculations for different vehicle types[31]

Vehicle Class	Equation
Heavy Trucks	12.59logV+60.64
Long Trucks	10.88logV+63.98
Medium Trucks	24.06logV+34.90
Short Trucks	14.60logV+44.69
Cars	30.41logV+13.59
V = Speed of vehicle (km/h)	

The increase of the dB unit, which expresses the level of noise, has a logarithmic character. Therefore, the addition of noise levels cannot be done arithmetically. The summation of sound levels obtained from different noise sources is performed logarithmically. The total sound pressure level emitted by vehicles can be estimated using the following equation:

$$SPL_{total}=10\log_{10}\left[10^{SPL1/10}+10^{SPL2/10}+10^{SPL3/10}+10^{SPLn/10}\right]dB$$

SPL_1: First vehicle sound source

SPL_2: Second vehicle sound source

SPL_3: Third vehicle sound source

SPL_n: nth vehicle sound source

In the above equation, is the total sound pressure level and n is the number of noise sources. The effect of vehicle types and speeds on noise pollution is made more understandable with 7 different models. The effects of various types of vehicles (Heavy Trucks, Long Trucks, Medium Trucks, Short Trucks, and Cars) in traffic on sound pressure levels are compared in terms of different vehicle speeds (10 km/h, 20 km/h, and 100 km/h). In some models, the density of trucks in traffic is low levels (Model 1-5), while in some models this density is quite high levels (Model 6-7). The aim here is to mathematically analyze the effects of various types of vehicles and vehicle speeds on noise levels. In this way, detailed information about the sound pressure levels from trucks and cars can be obtained. Using the equations given in Table 2, the noise levels generated by each vehicle are calculated as a function of vehicle speed. Then, by defining certain ratios for each vehicle type, its density in traffic is simulated. As a result, calculations are performed and the sound pressure levels in different models are determined. Details about the models and results are available in the Table 3.

Table 3. Vehicle noise simulation

Model Number	Distribution of Vehicle Types					Noise Emission Level (dBA)		
	Heavy Trucks	Long Trucks	Medium Trucks	Short Trucks	Cars			
Model 1	%0	%0	%0	%0	%100	54	63	84
Model 2	%0.3	%1.6	%2.5	%3.4	%92.2	88	92	106
Model 3	%1	%3.2	%4.6	%6.3	%84.9	91	95	107
Model 4	%3.5	%4.9	%7.1	%9.6	%74.9	94	97	108
Model 5	%7.2	%6.7	%9.8	%13.9	%62.4	96	99	110
Model 6	%13.2	%16.7	%20.1	%27.8	%22.2	99	103	112
Model 7	%50.3	%29.4	%16.7	%3.6	%0	103	106	115

With only cars in traffic (Heavy Trucks= Long Trucks= Medium Trucks= Short Trucks=0%, Cars=100%), the sound pressure levels emitted for average vehicle speeds of 10 km/h, 20 km/h, and 100 km/h are 54 dBA, 63 dBA, and 84 dBA, respectively. However, as the proportion of trucks in traffic increase, sound pressure levels at all vehicle speeds increase. Especially heavy trucks have a significant impact on vehicle-borne noise generation. In Model 1, the SPL level when there are no heavy trucks is 54dB (10 km/h), while in Model 2, the SPL level increases to 88dB when there are 0.3% heavy trucks in the traffic. In Model 7, where the proportion of heavy trucks is the highest, the SPL levels are quite high for all vehicle speeds (10 km/h, 20 km/h, and 100 km/h). In this model, there are no cars in traffic. Therefore, the emitted noise levels are 103 dBA, 106 dBA, and 115dBA at 10 km/h, 20 km/h, and 100 km/h.

Vehicle noise, commonly referred to as transportation noise, encompasses the sound waves generated during the operation of motorized vehicles, including automobiles, trains, airplanes, ships, and the others. This noise is typically quantified in decibels (dB). While standard conversation registers at approximately 60 dB, the noise level during an aircraft's takeoff can reach 120 dB or even higher. These levels are subject to fluctuations influenced by the factors elucidated above. Trucks and commercial vehicles, due to their larger engine capacities and passenger/cargo-carrying capabilities, generally induce higher noise levels. Noise levels during truck operation frequently range from 85 to 90 dB or beyond. These elevated noise levels contribute to environmental noise pollution, particularly in densely populated urban traffic zones, thereby posing considerable risks to human health. Given its utilization in both freight and passenger transportation, rail transportation raises a distinct and pertinent concern regarding noise levels. High-speed trains may produce less noise compared to traditional locomotives, but even high-speed trains can generate noise levels exceeding 100 dB. Locomotives and freight trains can produce noise levels as high as 110 dB. Aviation noise primarily occurs during aircraft takeoffs, landings, and in-flight operations. The intensity of this noise can exhibit substantial variations contingent upon the aircraft type, engine characteristics, and flight altitude. A commercial passenger aircraft, during takeoff and landing, can generate noise levels ranging from 130 to 140 dB. This can result in serious noise-related health issues for individuals residing in proximity to airports. Maritime transportation noise levels are contingent on factors such as ship type, engine power, and sea conditions. Ships can produce noise levels in the range of 90-100 dB during their engine operations[32-34].

Effects of noise levels on human health

Noise is an important environmental pollution that has been proven to have a significant adverse impact on human health and to which we are highly exposed in our lives. Noise emissions can cause various physical and psychological problems on human health[35,36]. Noise pollution is a growing concern in our increasingly urbanized and modernized world. Noise pollution refers to the situation where environmental sound levels are excessively high and disturbing. While most noise sources did not exist years ago, new noise sources are entering our lives every day. Vehicle noise is one of the main noise sources that have entered our lives in the last century of human history and affect public health. Although vehicle noise seems to be an inevitable part of modern life, its harmful effects on human health cannot be ignored. Table 4 below shows the effects of different noise levels on human health[37]. In addition, Table 5 shows the sound pressure levels that can be legally exposed to in a day in Türkiye[38].

Table 4. Effects of noise levels on human health

Noise Magnitude (dB)	Effects on Human Health
<65 dB	It is not directly harmful to human health.
65 dB – 90 dB	Tension and stress increases in people.
	Respiratory acceleration is observed.
	Tachycardia is observed.
	Blood pressure rises.
90 dB – 120 dB	Damage occurs to cells related to hearing.
<120 dB	Fatal effects may occur.

Table 5. Noise levels that can be legally exposed to in Türkiye in a day

Duration of exposure to noise (h)	Maximum noise level (dBA)
7.5	80
4	90
2	95
1	100
0.5	105
0.25	110
1/8	115

Effects on ear and hearing

Hearing is a vital sense that allows us to connect with the world around us. The hearing system is a complex structure of organs, tissues and sensory receptors that work in harmony to convert sound waves into meaningful information. But this remarkable system is vulnerable to a variety of external influences, including vehicle noise, one of the modern world's forms of pollution. Vehicle noise is a type of noise that can have significant and long-term effects on the hearing system and overall hearing health. Drawing on scientific studies and literature, the multifaceted effects of noise on the hearing system have been examined. Some of the effects of noise on the hearing system are given Table 6[39-43].

Table 6. Effects of vehicle noise on the hearing system

Effects	Comments
Hearing Loss	Noise-Induced Hearing Loss (NIHL) is one of the most direct and alarming effects of noise exposure. The hearing system can be severely damaged by prolonged or intense exposure to loud noise. In particular, it damages the hair cells in the cochlea, leading to permanent hearing loss. NIHL is usually irreversible and hearing loss can range from mild to severe
Hyperacusis	Hyperacusis refers to a condition of increased sensitivity to sounds, especially high-pitched noises. It often occurs after noise trauma and can make every day sounds painfully loud.
Hidden Hearing Loss	Hidden hearing loss is a recently discovered type of hearing loss. This type of hearing loss refers to a condition where traditional hearing tests fail to detect damage to the hearing system, but individuals may have difficulty hearing in noisy environments.
Tinnitus	Tinnitus is defined as a continuous ringing, buzzing or hissing sound in the ears. Noise exposure is associated with damage to the hair cells, especially in the cochlea, and can cause tinnitus to occur. Tinnitus is a distressing condition and can negatively affect a person's quality of life.
Altered Auditory Processing	Chronic exposure to noise can affect how the brain processes sound. This can lead to difficulties in understanding speech and processing complex auditory information.

Tympanic Membrane Damage	Exposure to extremely loud noises, especially aircrafts, can tear the eardrum, causing pain and sometimes permanent damage.
Difficulty understanding speech	Vehicle noise can cause speech comprehension difficulties. With high levels of vehicle noise, speech sounds are masked by the noise. This makes it difficult to understand speech.
Temporary Threshold Shift (TTS)	After exposure to loud noise, individuals may experience a temporary decrease in their hearing sensitivity, known as TTS. This is typically reversible and can recover within a few hours or days, but repeated TTS can contribute to permanent hearing damage over time.

Effects on heart

Vehicle noise directly or indirectly affects our physical health and especially heart health. Detailed ways in which vehicle noise affects the heart are given Table 7[44-46].

Table 7. Effects of vehicle noise on heart

Effects	Comments
High Blood Pressure	Chronic noise exposure is associated with hypertension (high blood pressure). Increased blood pressure, if left uncontrolled, can lead to heart disease, stroke, and other cardiovascular problems.
Disruption of Sleep Patterns	Noise can interfere with quality sleep time, leading to sleep deprivation and poor sleep quality. Inadequate sleep is associated with an increased risk of heart disease and other cardiac problems.
Increased Stress Response	Exposure to high levels of continuous noise can trigger a reaction in the body, causing the release of stress hormones such as cortisol and adrenaline. These hormones can increase blood pressure and heart rate, putting more strain on the heart.
Inflammatory Response	Prolonged exposure to noise can trigger an inflammatory response in the body. Inflammation can lead to the development of atherosclerosis and other heart-related problems.
Endothelial Dysfunction	The inner lining of blood vessels, known as the endothelium, plays a critical role in regulating blood flow. Stress from vehicle noise can lead to endothelial dysfunction, impairing blood vessel function and potentially causing heart problems.
Heart Rhythm Irregularities	Some studies suggest that noise pollution may increase the risk of cardiac arrhythmias (irregular heartbeats), which can be harmful to heart health[47].

Effects on the brain and neural system

The brain is not an organ resistant to the effects of noise pollution. The effects of vehicle noise on the brain and nervous system are given Table 8[48-50].

Table 8. Effects of vehicle noise on the brain and neural system

Effects	Comments
Stress Response	Vehicle noise is a very important stress factor. Prolonged or intense noise exposure can trigger the release of stress hormones such as cortisol and adrenaline. Noise pollution can lead to a range of psychological problems, including chronic stress, anxiety, and depression.
Cognitive Impairments	Chronic exposure to vehicle noise can impair cognitive functions. Some studies have shown that noise can interfere with attention, memory, problem-solving and decision-making abilities[51].
Sleep Disorders	Noise emissions from vehicles can disrupt sleep patterns, leading to sleep deprivation and poor sleep quality. Adequate sleep is vital for cognitive functioning and sleep disturbances can affect memory, learning and general mental state.
Reduced Brain Plasticity	Noise-induced stress can reduce the brain's plasticity, its ability to adapt and reorganize. This can have implications for learning and recovery from brain injuries.
Changes in Brain Structure	Some studies show that chronic noise exposure can lead to structural changes in the brain, including changes in the size of certain brain regions. These structural changes may be linked to cognitive and emotional problems[51].

Effects on the endocrine system

The endocrine system is known as a network of glands and organs in the body. The hormones within this system help the body functions, like metabolism, growth and development, emotions, mood, sexual function, and even sleep quality. The effects of noise pollution on the endocrine system are multifaceted and complex. These effects are listed Table 9[52-54].

Table 9. Effects of vehicle noise on the endocrine system

Effects	Comments
Long-Term Stress	Chronic stress, often triggered by noise pollution, disrupts the balance of hormones in the endocrine system. This can lead to imbalances in various hormones, including insulin, thyroid hormones and reproductive hormones.
Adrenal Gland Function	The adrenal glands, part of the endocrine system, are responsible for the production of stress hormones. Continuous exposure to vehicle noise can lead to overactivity or dysregulation of these glands, affecting hormone balance.
Metabolic Impact	Stress from vehicle noise can interfere with metabolic processes, potentially causing problems such as weight gain and metabolic syndrome.
Thyroid Hormones	Noise-induced stress can affect the function of the thyroid gland, affecting the production of thyroid hormones. This can lead to metabolic problems, fatigue, and psychological problems.
Reproductive Hormones	Noise emissions have been linked in some studies to disruptions in the menstrual cycle and changes in reproductive hormone levels. These changes can affect fertility and reproductive health[55].

Effects on the gastrointestinal system

The gastrointestinal system, also known as the digestive system, includes various organs such as the mouth, esophagus, stomach, liver, gall bladder, pancreas and intestines, and works in harmony to maintain the body's balance of energy and nutrients. Noise pollution can have complex effects on the gastrointestinal system. These effects are listed Table 10[56,57].

Table 10. Effects of vehicle noise on the gastrointestinal system

Effects	Comments
Stress-Induced Digestive Problems	Especially prolonged or intense noise can trigger the stress response of body. This stress can lead to overproduction of stress hormones such as cortisol, which can disrupt normal digestive processes. Chronic stress is associated with problems such as irritable bowel syndrome (IBS), indigestion and changes in bowel habits.
Increased Acidity Level	Stress caused by noise can lead to an increase in stomach acid production. This can exacerbate conditions such as gastritis or gastroesophageal reflux disease (GERD) and cause stomach disorders.
Inflammatory Response	Prolonged exposure to noise can trigger an inflammatory response in the body. Chronic inflammation can lead to the development of IBD, Crohn's disease and ulcerative colitis.
Gut Microbiota	Stress caused by noise pollution can affect the composition and diversity of the gut microbiota. This can affect nutrient absorption, digestion and overall gut health.

Noise studies in experimental animals

The known effects of vehicle noise on human health above were mostly obtained using studies on people known to be exposed to noise. Since the negative effects of continuous or repeated exposure to this type of noise on human health are known, modeling in humans and investigating the unknown effects of noise cannot be widely used. For this reason, vehicle-related noise can be modelled using experimental animals and the effects and mechanism of noise can be investigated.

Noise problems caused by vehicles are generally not observed in high-frequency bands (≥2000 Hz). High-frequency sounds are sounds in which sound waves vibrate faster and create shorter waves. Such sounds are often called "thin" or "treble"[58]. For example, the ringing of a bell or bird calls are high-frequency. These tones are not observed in noise originating from vehicles, instead low-frequency noises are observed. For this reason, low-frequency sounds are used when creating vehicle-related noise models in experimental animals.

Some experimental animal studies that may reflect vehicle noise types and the results obtained from these studies are summarized below.

Vasilyeva et al. investigated the effects of low-frequency noise (LFN) exposure on rats. Rats were exposed to single or multiple LFN sessions with varying sound pressure levels. The results showed a significant increase in chromosomal aberrations in bone marrow cells, along with the appearance of dicentric chromosomes, indicative of DNA double-strand breaks. Additionally, there were significantly elevated levels of low-molecular-weight DNA (lmwDNA) in the blood plasma after LFN exposure, and this effect persisted in the week following exposure. The findings suggest that LFN exposure may have mutagenic effects and cause extensive cell death, possibly through enhancing cellular apoptosis[59].

Venet et al. investigated the alone and combined effects of LFN and carbon disulfide (CS_2) exposure on rat hearing. The study involved exposure to LFN at 106 dB sound pressure level (SPL) and increasing concentrations of CS_2 during four weeks. Exposure to noise alone resulted in auditory deficits in a specific frequency range, indicating the potential to affect cochlear regions detecting mid-range frequencies. When rats were co-exposed to CS_2 at higher concentrations and noise, the damaged frequency range expanded, with significant deficits observed at 9.6 kHz. However, histological examination revealed that neither hair cells nor ganglion cells were damaged by CS_2. This discrepancy between functional and histological data highlights the need to consider CS_2 as a significant factor in hearing conservation regulations[60].

Mancera et al. examined the effects of mining vehicle noise on the behavior and physiological responses of wild mice. The noise was categorized into high-frequency (>2 kHz) and low-frequency (≤2 kHz) ranges. The results showed that exposure to high-frequency noise led to increased stress-related behaviors, such as reduced time spent in nests and increased circling, especially in females. These effects were associated with elevated levels of fecal corticosterone, indicating stress. In contrast, exposure to low-frequency noise reduced grooming and circling, suggesting a milder stress response. Low-frequency noise also increased fecal corticosterone levels in males, potentially due to gender-based differences in frequency sensitivity. The findings highlight the potential impact of different frequency spectra of mining noise on animal welfare and survival[61].

This study investigated the health effects of exposure to inaudible LFN on the inner ear of mice, simulating the levels to which people might be exposed in daily life. The research focused on stress-reactive molecules in the inner ear. Exposure to LFN led to a significant increase (more than 5-fold) in the transcript level of heat shock protein 70 (Hsp70) in the whole inner ear. However, the levels of other stress-reactive molecules were largely unchanged. Specifically, the transcript level of Cebpb, a transcriptional activator for Hsp70, was more than threefold increased by LFN exposure. While Hsp70 levels increased in the vestibule, they remained comparable in the cochleae of LFN-exposed and unexposed mice. These findings suggest that the inner ear may be negatively affected by stress from inaudible LFN exposure, and Hsp70 and Cebpb levels could serve as potential biomarkers for response to LFN exposure[62].

Chalansonnet et al. examined the impact of LFN combined with CS_2 exposure on balance in rats. It found that this combination significantly decreased saccade number and duration, indicating vestibular impairment. However, the effects were reversible and did not result in histopathological changes or behavioral differences. The study suggests that post-rotatory nystagmus, a specific eye movement, could serve as an early, non-invasive indicator of CS_2 intoxication in occupational health monitoring programs[63].

This study investigated the impact of acute LFN exposure on mice. Exposure to LFN at 100 Hz and 95 dB for just 1 hour caused irreversible balance issues in the mice. It also resulted in decreased vestibular function and damage to the otoconial membrane in the vestibule. However, overexpression of the stress-reactive molecular chaperone, heat shock protein 70 (Hsp70), which is induced by prolonged LFN exposure, rescued the LFN-induced imbalance and structural damage to the otoconial membrane[64].

Maes et al. investigated those two experiments examined the impact of irregular, moderate-intensity auditory noise on rats' performance in an operant discrimination task. The first experiment revealed that noise impaired discrimination performance. The second experiment showed that discrimination performance was best when the noise condition at test matched the noise condition at training. The results highlight the importance of considering noise conditions in research, suggesting the need for a 2x2 factorial design with noise presence/absence during training and testing as factors in studies on noise effects in humans and animals[65].

Stewart et al. used a rat model to investigate the effects of noise exposure on the vestibular system. Noise exposure led to hearing loss and caused substantial damage to sensory stereocilia bundles in various parts of the inner ear. Vestibular afferent activity was moderately reduced, and changes were observed in the response to head rotation. However, immediate clinically measurable vestibular signs were not evident. The study suggests that noise exposure can damage the peripheral vestibular system, potentially leading to vestibular disorders over time[66].

McCarthy et al. investigated the impact of noise stress on the biological function of leukocytes involved in wound healing in rats. Rats exposed to 80 dB sound pressure level for 24 hours showed reduced secretion of superoxide radical and interleukin-1 by neutrophils and macrophages compared to control animals. Lymphocyte function remained unaffected. The findings suggest that short-term noise stress can alter the biological functions of specific leukocyte subpopulations[67].

Escabi et al. investigated that rats serve as valuable models for studying noise-induced hearing loss due to their similarities with human auditory physiology. This paper reviews the use of the rat model in researching the effects of noise exposure on the mammalian auditory system, including both hearing loss and central nervous system alterations. It also highlights the rat model's relevance in studying cochlear synaptopathy. The rat model offers insights into the structural, anatomical, physiological, and perceptual aspects of hearing affected by noise[68].

Baldwin et al. exposed rats to daily noise and investigated its effects on microvascular leakiness in the mesenteric microcirculation and mast cell degranulation. Rats exposed to noise had increased microvascular leaks, but those given dietary supplements of vitamin E with α-lipoic acid or Traumeel showed reduced leakiness and mast cell degranulation. This suggests that dietary supplements can mitigate the structural damage caused by excessive noise in rats[69].

RESULTS and DISCUSSION

Noise pollution constitutes a significant component of environmental degradation in both developed and developing nations. It can be regarded as a form of technological residue that extensively contributes to environmental pollution by disturbing the inherent features of the environment. Additionally, noise pollution poses a notable detriment to human health and well-being. In the realm of environmental issues, noise pollution is gaining increasing significance, necessitating urgent efforts for mitigation. Prolonged exposure to noisy environments is observed to lead to severe health issues among individuals[70,75].

This study highlights key parameters influencing vehicle noise, such as engine power and type, vehicle speed, wheel and road interaction, tire types, vehicle technology, air temperature, air humidity, echoes and reflections, horn use, exhaust systems, and traffic density. These factors can lead to considerable variations in noise levels emitted by different types of vehicles, from cars to trucks, helicopters, and jets. The study presents detailed models that simulate noise levels based on the proportion of vehicle types in traffic and vehicle speeds, emphasizing the significant impact of trucks, especially heavy trucks, on overall noise pollution. Moreover, the study underscores the substantial noise levels generated by different modes of transportation, including road vehicles, trains, airplanes, and ships. These noise levels can reach potentially harmful levels, particularly for individuals living near transportation routes and urban centers.

The hearing system is among the most vulnerable, with Noise-Induced Hearing Loss (NIHL) being a primary concern. Prolonged exposure to loud noise can lead to permanent hearing damage, often ranging from mild to severe. This article underscores the urgency of addressing noise pollution to safeguard individuals from hearing-related issues, including hyperacusis, hidden hearing loss, tinnitus, and difficulties in auditory processing. Furthermore, the article delves into the significant repercussions on heart health. Chronic noise exposure is associated with high blood pressure, sleep disturbances, increased stress responses, inflammatory reactions, endothelial dysfunction, and potential heart rhythm irregularities. These findings underscore the importance of noise reduction measures to protect cardiovascular health. The impact on the brain and neural system is equally extensive. Noise pollution serves as a significant stressor, contributing to a range of psychological problems, cognitive impairments, sleep disorders, reduced brain plasticity, and structural changes in the brain. These effects emphasize the necessity of addressing noise pollution for the overall well-being of the nervous system. The article also uncovers the intricate effects on the endocrine system, wherein chronic stress disrupts hormone balance, adrenal gland function, metabolic processes, thyroid function, and reproductive hormones. These disruptions have profound implications for overall health and require urgent attention. Finally, the article addresses the complex consequences of noise pollution on the gastrointestinal system, revealing the potential for stress-induced digestive problems, increased acidity, inflammatory responses, and disruptions in gut microbiota. These issues may lead to conditions such as irritable bowel syndrome and inflammatory bowel diseases, necessitating a comprehensive approach to mitigate noise-induced gastrointestinal complications.

In conclusion, this article provides a comprehensive overview of various experiments conducted on experimental animals, primarily rats, to understand the effects of LFN and noise pollution. These studies shed light on the potential health impacts of noise exposure, covering a range of aspects from genetic and physiological responses to behavioral and auditory changes in these animals. Some key findings include the potential mutagenic effects of LFN exposure, its impact on hearing deficits, the role of different frequency spectra in stress-related behaviors, and the involvement of stress-reactive molecules in the inner ear's response to noise. Furthermore, the article explores the combined effects of LFN with other factors such as carbon disulfide (CS2), shedding light on their influence on balance and vestibular functions in rats. Additionally, it touches upon the potential for dietary supplements to mitigate structural damage caused by noise exposure in experimental animals. Overall, these studies emphasize the intricate interplay between noise and various biological systems in animals, offering insights into potential biomarkers and responses to noise exposure. These animal experiments not only provide valuable insights into the biological and physiological effects of noise but also underscore the importance of considering noise conditions in research design, which has implications for both animal studies and human health research. Moreover, the use of animal models, particularly rats, proves to be a valuable tool for investigating noise-induced hearing loss and other health-related consequences.

To mitigate the health risks posed by vehicle noise, various recommendations and legal frameworks have been established, both globally and in Türkiye. The WHO Environmental Noise Guidelines for the European Region offer specific guidelines to safeguard human health against environmental noise exposure from various sources, with a focus on road traffic, aircraft noise, and more. Türkiye has enacted the Regulation on Environmental Noise Control to prevent the negative effects of environmental noise, including noise maps, noise action plans, and the implementation of noise control measures. These measures and guidelines are crucial for reducing the harmful impact of vehicle noise on public health. They emphasize the need for noise reduction in transportation sources, the use of state-of-the-art noise-reduction technologies, and the responsible operation of sound-emitting devices in motor vehicles. By implementing these recommendations and regulations and by adopting a healthy lifestyle, managing stress, and seeking medical care when necessary, individuals and communities can work together to mitigate the health risks associated with vehicle noise in noisy environments. Official reassessment of road noise occurs under the following circumstances: when a new road is constructed, when new residential properties are built, when alterations are made to an existing road, and when there is an increase in traffic volume on a road. Strategies to mitigate the environmental repercussions of road traffic noise include the adoption of quieter vehicles, installation of noise-absorbing tires, advancement in noise-reducing road surfaces, enforcement of traffic measures such as speed reduction, installation of noise barriers, and enhancement of home insulation.

A significant portion of the populace remains uninformed about the issue of noise pollution, despite its substantial impact on many individuals. The lack of awareness among the general population contributes to the escalation of noise pollution. Therefore, there is a pressing need to raise awareness about the detrimental effects of noise pollution.

STATEMENTS OF ETHICS

This article does not contain any studies with human participants or animals performed by any of the authors.

CONFLICT OF INTEREST STATEMENT

The authors declare there is no conflict of interest associated with this study.

AUTHOR CONTRIBUTIONS

All authors contribute the work equally throughout.

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