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Review Article

Health Impacts of Road Traffic near School – a Narrative Review

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ABSTRACT

Objective: to understand the comprehensive exploration of the stress that road traffic imposes on children, drawing on an extensive literature review that provides a thorough understanding of this issue.

Methodology: A narrative review was meticulously planned, with a focus on selecting high-quality research studies published within the last 20 years. These studies, randomly chosen from reputable sources such as PubMed, Google Scholar, and Embase, provide a robust foundation for our findings. The keywords used for the database search were Road traffic, Health impacts of road traffic, traffic near schools, harms of traffic near schools, and road traffic stress among children. A total of 30 manuscripts, each contributing unique insights, were thoroughly reviewed.

Results: The narrative review underscores the criticality of noise and air pollution, both stemming from road traffic, as significant challenges for the global population. The presence of tyre wear parts and particulate matter in the air, a direct result of road traffic, is linked to a range of health problems, including respiratory issues, immune health complications, and allergies. In children, these pollutants can trigger neurological problems such as ADHD and developmental issues.

Conclusion: It is imperative to address road traffic stress, especially in the vicinity of schools, as it has profound and detrimental effects on children's health. The health challenges faced by children are not to be taken lightly, as they are chronic and can lead to enduring neurological and developmental deficits. Taking steps to reduce traffic near schools is a crucial responsibility we all share.

Keywords: Road Stress, Traffic, Stress, Traffic near School.

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INTRODUCTION OF ROAD TRAFFIC

The movement of cars and people on roads, known as 'road traffic,' encompasses various elements such as automobiles, road design, traffic signals, and driver behavior. Efficient traffic management is crucial for road safety, efficiency, and smooth mobility. However, traffic congestion has escalated into a significant global concern, driven by factors like population growth, the proliferation of automobiles and related infrastructure, the rise of ridesharing and delivery services, and other issues. The impacts of traffic congestion on social, economic, and environmental aspects have amplified in recent years. The urban transportation system, particularly in densely populated areas, bears the brunt of the substantial cost and delay caused by traffic, underscoring the gravity of the situation.[1]

Since the transportation infrastructure—roads, transit networks, spaces, and architectural ideas—shapes the urban environment, mobility is a key component of urbanization. There were roughly 7.5 billion road journeys every day in 2005, Worldwide. Forecasts indicate that by 2050, there will be 3 to 4 times as many passengers per kilometer as there were in 2000 and that freight volume will likely increase threefold. One of the primary causes of air pollution in metropolitan regions is road transportation. Since the beginning of 2013, the number of emissions from road transportation has been rising. The state of the control systems and transportation infrastructure is the leading cause. Road transportation is the primary cause of environmental pollution and accounts for 73% of CO_2 emissions in the EU's transportation sector. Since traffic flows significantly impact corresponding greenhouse gas emissions that influence population health and air quality, they continue to be an issue in the dynamic urban district environment.[2]

Sulfur oxides (SOx) (63%), nitrogen oxides (NOx) (41%), carbon monoxide (CO) and non-methane volatile organic compounds (approximately 86%), and sulfur dioxides (SOx) all had substantial reductions in emissions since 1990 because of the advancement of the transportation industry. Particulate emissions have decreased since 2000 by 40% for PM 2.5 and 34% for PM10. Road transportation comes second to the non-

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transport sector regarding air emissions (excluding SOx).[3] However, over the last 20 years, there has been less of a decrease in road transportation-related emissions than anticipated. This is caused by two factors: first, traffic volume increased more than anticipated; second, compared to gasoline-powered vehicles, diesel vehicles exhibit higher emissions of NOx and PM, among other pollutants, than was anticipated. Furthermore, it is now widely acknowledged that "real emissions" of NOx, particularly from diesel-powered passenger cars and mini busses, are typically above the allowable European emission regulations (EURO).[4]

Health Impact of Road Traffic

The World Health Organization (WHO, 2018) stated that noise, particularly road traffic noise, is the second significant factor adversely affecting health. A comprehensive evaluation of the effects of physical factors can be used to conclude the health-related relevance of acoustic noise, whose limit-exceeding levels continue to grow, particularly in densely developed and populated places. Traffic is the primary source of noise in populated regions, emitting various types of noise such as engine noise, tire noise, and horn noise. Cardiovascular diseases, neurological disorders, and hearing system abnormalities are caused by continuous acoustic pollution of city areas caused by intra-urban traffic, according to the Russian Federation's Ministry of Natural Resources and Environment (2019). The state of traffic infrastructure dramatically influences the state of transportation systems and its effects on the environment. Traffic-related environmental pollution is significantly reduced by efficient infrastructure.[5]

2.1. Noise Pollution

Numerous studies have revealed the expected direct consequences of noise on the auditory system, which include tinnitus, hearing damage, disability, and irreversible loss of hearing—following air pollution in megacities, road traffic noise (RTN), an inescapable byproduct of urbanization and motorized mobility, gained significant attention from scholars and policymakers. RTN affects at least 100 million individuals in the EU. In Western Europe alone, it results in the loss of at least 1.6 million healthy years of life annually, according to the evaluation criteria outlined in the EU's Environmental Noise Directive.[6]

Furthermore, 145.5 million Americans are projected to be exposed to more than 55 dB of noise. In addition to established cardiovascular risk factors, RTN has been associated with an increased risk of anxiety and depression, behavioral and emotional problems, sleep disruptions, obesity and adiposity, hypertension, diabetes, and metabolic syndrome. For instance, a study conducted in [City] found that residents living near a busy highway had a [specific health condition] rate [percentage] higher than those in quieter areas.

It is crucial to reiterate the direct link between noise exposure and these health conditions. Noise pollution has been unequivocally associated with an increased risk of CVD morbidity and mortality.[7] Figure-1 provides a visual representation of the profound impact of noise pollution on human health, underscoring the gravity of the situation.

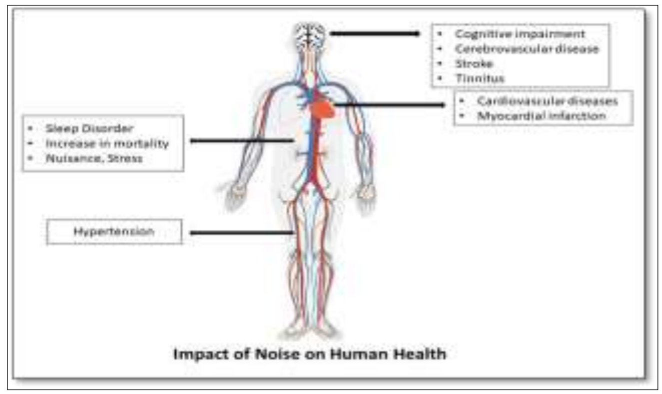

Figure-1: The impact of Noise Pollution on the Human Body

Road traffic noise is a pressing issue in urban contexts due to the high population exposure and extended exposure times. The World Health Organization (WHO) estimates that a significant portion of EU citizens, 20% and 30% respectively, are exposed to noise levels exceeding 65 dBA during the day and 55 dBA at night. Among the nine environmental risk factors that significantly impact health in European countries, road traffic noise ranks second, just after fine particles. This alarming statistic suggests that for every million people, ischemic heart disease claims 400–1500 years of good life.

The lack of extensive research on respiratory morbidity linked to environmental noise is a cause for concern. However, several seminal studies conducted some time ago found significant long-term relationships with respiratory outcomes, including asthma and bronchitis. It's important to note that noise, like any other psychological stimulus, activates the emotional processing of CNS structures and may disrupt homeostasis, potentially leading to anxiety and despair.[8]

2.2. Atmospheric Pollution

Tire and road wear particles (TRWP), produced on roadways during driving operations and linked to micro plastic pollution, are airborne non-exhaust emissions. These particles, dispersed into soils, aquatic compartments, and road surfaces, are a global concern. Tire wear emissions from various nations range from 0.2 to 5.5 kg/(cap*a), significantly contributing to ambient air pollution worldwide. Traffic-related non-exhaust emissions, such as road dust re-suspension and brakes, often exceed the EU's 40 µg/m3 PM101 limit. Synthetic particles can cause food intake loss, energy loss, and leaching into the digestive system.[9]

Urbanization and purchasing power have increased automobile usage, leading to traffic congestion and atmospheric pollution. The health risks associated with long-term exposure to ambient PM 2.5 are alarming. It is linked to increased cardiovascular and respiratory morbidity, premature mortality, and premature death. PM 2.5 is the world's fifth-leading risk factor for mortality, accounting for 4.2 million preventable deaths annually. Despite WHO recommendations, 90% of urban populations live in areas with high PM 2.5 concentrations.[10]

Urban air pollution is primarily caused by road traffic, but introducing three-way catalytic converters on gasoline-powered vehicles has significantly reduced exhaust emissions. Diesel exhausts, however, still contribute to pollution. Recent European regulations mandate using gasoline particle filters to reduce particulate matter emissions from diesel engines. This has significantly decreased non-exhaust emissions from road cars, surpassing exhaust emissions in developed nations. However, the global amount of non-exhaust particulate matter (PM 2.5) generated by passenger vehicles is expected to increase by 53% by 2030. This underscores the need for global regulations to control non-exhaust emissions.[11]

Outdoor air pollution is a significant cause of global illness, with most of the world's population living in areas where pollution levels exceed WHO recommendations. This pollution has damaging consequences on human health, including cancer, making it an urgent global public health concern. Research shows a causal relationship between outdoor air pollution, precisely particle matter (PM), and lung cancer incidence and death. PM air pollution is responsible for hundreds of thousands of lung cancer deaths annually. Major primary air pollutants include gaseous and particulate matter, primarily caused by fossil and biomass fuel combustion. Developed countries have implemented pollution controls to reduce CO levels, but significant amounts can still be found near biomass-burning sources.[12]

Secondary air pollutants, such as gaseous ozone and particle sulfate and nitrate, are created in the atmosphere by reacting nitrogen oxides and hydrocarbons in sunlight. These pollutants contribute to photochemical smog and are particularly concerning for human health due to their deep penetration into the lungs and the presence of hazardous substances like acids and heavy metals. PM 2.5, smaller than primary and secondary combustion particles, significantly contributes to these pollutants.[13] The Table shows that the size of particulate matter differs with the source of its emission and its effect on health.

Table: Classification of Particles Based on Size14

Particles	Diameter	Sources	Health Hazards
Coarse Particulate (PM10)	≤10 µm	Suspension from disturbed roads	Worsening of respiratory diseases, including asthma and chronic obstructive pulmonary disease (COPD)
Fine Particulate (PM2.5)	≤2.5 µm	Residential and Vehicle fuel combustion, tailpipe, and brake emission	Premature mortality, Acute and chronic bronchitis, asthma attacks
ultrafine particles (UFPs)	<0.1 µm	Fuel combustion and tailpipe emission from motor vehicle	Pulmonary inflammation Triggers cardiovascular effects as well as negative impacts on the brain

Schools and Road Traffic

As schools attempt to strike a balance between property, building, and expenses of school transportation in the future with community desires and concerns, decisions about the location of new schools are frequently tricky. The effects of school location on children's exposure to air pollution and their capacity to engage in physical activity by walking and bicycling to school are topics of increasing attention. Decisions about where to locate schools are influenced and frequently complicated by myriad health-related factors. Districts are encouraged by intelligent growth and compact development principles to site schools in walkable areas, frequently close to busy road networks. Public health experts encourage students to travel to school actively to increase their physical activity levels. They also stress the need to reduce air pollution and traffic hazards associated with being close to busy roads.

School locations that are child-walkable and away from busy roads are optimal regarding health exposures; sadly, this is not always possible for many areas. A school's location affects many facets of the lives of the children and the neighbors. School locations impact public sector expenses, transportation choices, local job prospects, and the availability of recreational and educational programs. Strong justifications for innovative school sitting strategies have been compiled by researchers, including the necessity for transportation infrastructure, improved child health outcomes, and financial savings for school districts.[15]

Traffic hazards have always been a factor in health outcomes related to schools. School-related travel accounts for a sizable portion of the motor vehicle collisions involving children in school. According to a 2015 study, local roads and areas with better sidewalk connectivity are less likely to experience collisions linked to school commuting than highways, interstates, arterial roads, and locations with land uses that generate traffic.[16]

During the morning and afternoon rush hours, schools are heavily trafficked as parents drop off and pick up their kids while other kids get to and from school by walking, taking the school bus or public transportation, riding their bikes, or skateboarding. In 2009, students in the United States were dropped off at or picked up from school via 6.6 billion automobile journeys totaling 30 billion miles. Every day in the United States, three children under the age of fourteen die in car wrecks, and about 500 more are hurt, most of them while commuting to or from school. Children between the ages of five and nine crash three times more frequently on their way to or from school than they do at other times, according to research by Toronto, Canada. It should be no surprise that parents frequently state that their children's transportation to and from school is mainly determined by traffic concerns.[17]

Environmental factors can potentially harm developing youngsters. Long-term exposure to traffic air pollution has been linked to changes in children's cognitive development. According to epidemiological research, children may be at risk from high levels of urban air pollution because these pollutants may disrupt the processes involved in brain development.[18]

Numerous investigations in humans and animals have demonstrated a strong correlation between pollutant exposure and degenerative and inflammatory brain pathologies, which lends substantial credence to this idea. Two hundred sixty-three kids between the ages of 8 and 12 were chosen for the group from a more extensive study that evaluated the effects of chronic exposure to urban pollution in school settings in Barcelona.[19]

The more visible morphological and functional maturation processes were thought to reveal the potential effects of air pollution on the brain. Increased relative white matter volumes, more significant choline molecules, and changes in water transport within white matter pathways are all linked to active myelination; developmental changes in gray matter volume are less pronounced at this age. Pre-adolescence is necessary for large-scale functional networks to be assembled at the functional domain in the best feasible way (Menon, 2013). The imaging method includes a high-resolution 3D anatomical capture to assess regional volumes, brain tissue composition, myelination levels, and cortical thickness. Diffusion tensor imaging (DTI) fractional anisotropy data were used to study the architecture of the white matter tract.[20]

Vivo spectroscopy was used to determine a rough estimation of the precursors of membrane components in white matter. Finally, a task activation/deactivation paradigm and resting-state functional connectivity were employed in functional MRI to assess the integrity of pertinent networks. A study using a Thermao-Optical Transmission technique measured the elemental carbon content of particulate matter (PM 2.5) and nitrogen dioxide (NO_2) in Barcelona's schools. Results showed that air pollution levels in the schools may be moderate to high compared to other locations. Elevated pollution levels were linked to increased functional connectivity between the lateral frontal cortex and medial frontal region, while decreased connectivity between angular gyri and the seed. During passive viewing and listening, lower deactivations in the supplementary motor region and somatosensory cortex were strongly correlated with air pollution.[21]

However, the effects of air pollution might be more noticeable when early stages of development are involved. Aprevious research has demonstrated evidence of structural alterations in the brain associated with prenatal exposure to pollutants, which cause damage to notable areas of the white matter in the left hemisphere. These alterations are associated with a less severe consequence associated with postnatal exposures at five years of age.[22]

In traffic pollution, Lead, copper, manganese, aluminum, and other elements have a higher potential for neurotoxicity. Potential residual confounding by sociodemographic variables is a concern in studies on traffic pollution (e.g. when there is a connection between proximity to traffic and poor neighborhoods). Nonetheless, a weak and inverse relationship was found in Barcelona between socioeconomic vulnerability and air pollution, with greater pollution levels in less vulnerable schools.

Even while children's brains are still developing at every stage, pre-adolescence is particularly important for laying the groundwork for large-scale functional network organization. The proto-adult brain's average growth and the maturation of functional networks are severely impacted by urban traffic pollution.[23]

Road Traffic Stress in Children

Stressors, including air pollution, road noise, and artificial nighttime lighting, may be directly or indirectly linked to declines in children's mental health, according to an increasing number of studies. The development of post-traumatic stress disorder (PTSD) or its associated symptoms, such as sadness or anxiety, in children and their parents who survive traffic accidents can be detrimental to both parties' capacity to care for their children and themselves. Even after they have recovered physically, one in six parents and children still struggle with PTSD or another psychological issue. Developmental delays in children can result from PTSD and its associated conditions, such as anxiety and sadness. It is a social issue when children with symptoms associated with PTSD are not treated.[24]

People are known to be exposed to varying amounts of traffic-related air pollutants (TRAP), and higher TRAP concentrations will likely coincide with higher levels of other chronic stressors and adverse socioeconomic determinants of health. Traffic in the vicinity of schools increases children's exposure to TRAP. Black carbon (BC), a particular marker for TRAP produced by diesel engines, is found in considerable quantities in urban environments and is characterized by solid concentration gradients along significant thoroughfares, seaports, and other transportation and trade hubs. Numerous studies have shown significant acute increases in FeNO in children with or without asthma or respiratory symptoms after increasing exposure to BC or closely comparable elemental carbon (EC).

According to epidemiological research, exposure to TRAP may compound the adverse effects on respiratory health by interacting with long-term psychological stress. According to these studies, there are critical linkages between long-term psychosocial stressors, including violence and chronic life stress, and gaseous and particle pollution that affect lung function, asthma risk, and inflammatory marker levels. Children were the subjects of a study to determine BC's direct effects. Findings showed that after six hours of increased exposure to BC, a marker for TRAP, especially diesel exhaust, children with asthma in an environmental justice neighborhood briefly rose in FeNO. The findings show that children with asthma exposed to TRAP experience immediate changes in their airway physiology.[25]

In addition to causing bodily harm, road traffic accidents (RTAs) can have detrimental psychological impacts, such as post-traumatic stress disorder (PTSD). Teenagers and children are some of the most vulnerable road users. However, estimates of the frequency of PTSD in children and adolescents with RTAs varied significantly throughout studies. A comprehensive search was conducted for literature in the electronic databases of PubMed, Web of Science, PsycINFO, and Embase. Heterogeneity was measured using the I2 value and assessed using Cochran's chi-square test. Eleven (11) eligible studies had 1532 children and adolescents participating in RTAs. There was a significant degree of overall heterogeneity ($I2=89.7$, $p<0.001$) among the eligible trials. Following RTAs, 1/5 of children and adolescents experienced PTSD, highlighting the need for quick and efficient psychiatric therapies as well as routine PTSD testing in this population.[26]

The general stress theory explains the biological responses to non-auditory noise, including physical reactions to alertness, resistance, and exhaustion. Since the 1990s, noise pollution has been linked to the cardiovascular system, with the SAM and HPA axis playing crucial roles. Stress hormones like adrenaline, noradrenaline, and cortisol increase blood fat and carbohydrate levels and the risk of coagulation infarction. These changes also affect hemodynamic variables, increasing the risk of arterial and potentially myocardial infarction and hypertension. The limbic system transmits the response to environmental noise to the hypothalamus, releasing stress chemicals. Elevated cortisol levels accelerate adipose tissue metabolism, increasing the body's energy reserves.[27]

Air Pollution, Traffic and Children

Air pollution from transportation is a significant contributor to PM, primarily caused by diesel exhaust (DE). Research on animals and epidemiology has demonstrated that exposure to air pollution may have several detrimental consequences on the central nervous system. Apart from a range of aberrant behaviors, neuro-inflammation and oxidative stress — both observed in humans and animals and bolstered by in vitro research—are the most notable consequences of air pollution.[28]

The most significant factor among those that can influence neurotoxic effects is thought to be age. Air pollution may be neurotoxic to growing brains and may contribute to the emergence of neurodevelopmental disorders like autism spectrum disorder, according to research on both humans and animals. Additionally, exposure to air pollution may contribute to the etiopathogenesis of neurodegenerative diseases, such as ADHD (attention deficit hyperactivity disorder) 28, as it has been linked to increased expression of pathological markers of neurodegenerative diseases, such as beta-amyloid or alpha-synuclein. Parkinson's and Alzheimer's diseases (Figure-2).[29]

In Fresno, California, a study known as the Children's Health and Air Pollution Study (CHAPS) examines the detrimental consequences of childhood air pollution exposure on health. Fresno, a city in the San Joaquin Valley, is known for its severe air pollution, particularly affecting the Hispanic/Latinx population and those with high poverty rates. The CHAPS project, a prospective cohort study, aimed to evaluate the impact of air pollution on children's health in the Fresno metropolitan region, and this study involved 299 children aged 6 to 8 from 2015 to 2017, with 73% of them being 8 to 10-year-olds.

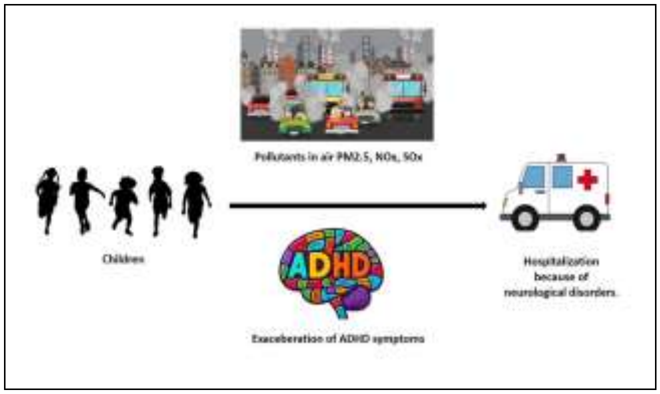

Figure-1: Impact of Pollution on Children's Health

The results showed a strong correlation between NO2, PAH456, CO, and PM2.5 from 1-week to 6-month exposure averages and between NO2, PAH456, CO, and PM2.5. The study also found a consistent pattern of declining HDL with increasing pollutant exposure for metabolic dysregulation biomarkers over several periods. The study suggests that children's metabolic function is impacted by acute exposure to TRAP, which is linked to low-grade systemic inflammation and early atherosclerosis. This suggests that early exposure to ambient air pollution may be a risk factor for cardiometabolic disease in later life.

The study suggests a connection between the biomarkers assessed and TRAP exposure, indicating that air pollution causes aberrant glucose and lipid metabolism in children, potentially increasing the adult risk of metabolic syndrome.[30] Long-term psychosocial stressors, such as chronic life stress, and gaseous and particle pollution, affect lung function, asthma risk, and inflammatory marker levels in children. Further longitudinal and observational studies should be conducted among schoolchildren to discover the challenges children face from traffic near their schools. Internationally, policies related to traffic routes and traffic flow near schools should also be made to prevent accidents and negative health impacts.

CONCLUSION

This study discussed the impact of road traffic stress on students' mental and physical health and academic performance. Health-related factors, such as smart growth and compact development principles, often influence school locations. Public health experts encourage students to walk to school. It can help in reducing air pollution and traffic hazards. School locations that are walkable for children and away from busy roads are optimal for health exposures. Long-term exposure to air pollution from traffic has been linked to changes in children's cognitive development. Noise pollution has been established to impact the cardiovascular system. Stressors like air pollution, road noise, and artificial nighttime lighting may be directly or indirectly linked to declines in children's mental health. Post-traumatic stress disorder (PTSD) can develop in children and their parents who survive traffic accidents.

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Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

IA & AJ: Study design, drafting the manuscript, data interpretation, critical review, approval of the final version to be published.

FM: Data acquisition, data analysis, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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