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# THEMATIC ISSUE:
# **Noise impacts on health**

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*Environment*

## Science for Environment Policy

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## EDITORIAL

# Environmental Noise

*Our ears are constantly exploring our living environment for potential threats and opportunities. They are a vital part of the body's defense mechanism: preparing our brains for fight-or-flight if needed and, as such, affecting many bodily functions. The plasticity of the human hearing system and the ability of the brain to block out irrelevant information from this permanently alert sensory system are remarkable.*

However, this perfectly evolved hearing system is under threat. Many people's modern living environments are filled with low-quality sound that has little or no importance. The sounds of cars, planes, trains, cooling systems, ventilation, machines, electronically amplified music and announcements – or simply the sound of living closer together in a 24/7 city – are constantly present. Gating out these sounds can consume a significant fraction of cognitive resources and the body is frequently triggered in vain to prepare for fight-or-flight. Moreover, the information carried by this sound – mainly related to its source – influences our appraisal of our person-environment relationship. The feeling of not being in control of one's living environment can lead to additional stress particularly in the absence of coping resources or mechanisms. Both the autonomous response and stress path could eventually lead to negative effects on health and wellbeing, such as an increased risk of high blood pressure or circulatory disease, as explained in this thematic issue.

Health effects related to environmental noise result in a cost for society. The loss of healthy life years is often valued in euros, but there are also indirect and hidden costs, such as the cost of medical treatment (e.g. medication for hypertension or mental illness); loss of efficiency at work due to illness or fatigue resulting from sleep deprivation or ineffective resting periods; reduced creativity and learning – and even less prosocial behaviour – caused by noise stress, resulting in safety and security costs. It is therefore essential that environmental sound is included in different policy areas effectively and efficiently: in particular, at a preventive stage.

The papers presented in this Science for Environment Policy Thematic Issue explore research into the threat to health posed by environmental noise. They cover topics such as the link between environmental noise and serious health issues like cardiovascular disease and stroke; the effect of noise on vulnerable people and how sound affects our state of mind.

In the EU, exposure to excessive noise is becoming recognised as a large environmental health concern. Estimates from available data suggest that 65% of Europeans living in major urban areas are exposed to high noise levels exceeding Lden 60 dBA (which could be due to attendance at social activities, such as bars and concerts), and that more than 20% are exposed to night-time noise levels exceeding 55 dBA, (the level at which there is an increased risk of adverse health effects occurring, according to the WHO). Although exact numbers are not available, recent estimates suggest that one to two million disability adjusted life years (DALYS) are lost to environmental noise every year in the EU. Nevertheless, health extends beyond the lack of disability: quality of life is also relevant here, so methodologies for determining optimal conditions may need to be adjusted accordingly.

Currently, the European Commission is committed to meeting challenging targets on noise reduction through the 7th Environment Action Programme[1]. In addition, the World Health Organization (WHO) is revising the Community Noise Guidelines[2] for the European region. The Guidelines will include a review of evidence on the health effects of environmental noise to incorporate significant recent research.

The EU's Environmental Noise Directive (2002)[3] aims at protecting people from the adverse impacts of noise and has triggered many new initiatives and raised awareness of noise at the urban and citizen level. Understanding how different soundscapes and, in particular, tranquil areas in the urban environment affect overall health and wellbeing is allowing for new types of urban design. These improvements may limit health effects from noise annoyance and improve wellbeing, while allowing noise activities in appropriate contexts – but will inevitably require an understanding of the spatial and temporal details at a finer granulation.

Prevention-oriented health systems are crucial to meeting Europe's challenges of the 21st century. And noise policy should also be strongly directed at avoiding any additional and preventable health effects. Accurate knowledge of noise's effects on human health will help policymakers to decide whether limited resources should be focused on black spots – the highest exposure – or on reducing overall levels of unwanted sound.

But opportunities for innovative, micro-policies should also be created. Exposure-aware citizens can play a crucial role in noise policymaking,

1 http://ec.europa.eu/environment/noise/directive.htm
2 http://www.euro.who.int/en/health-topics/environment-and-health/noise/activities/development-of-who-guidelines-for-community-noise-for-the-european-region
3 http://ec.europa.eu/environment/newprg/index.htm

both as observers using monitoring equipment or their own ears, and as solution providers – and scientific research will help policymakers and citizens to understand these dynamics and optimal conditions. Direct involvement of individuals through social media and monitoring could lead to new fine-grained solutions. This level of detail and citizen participation might also extend the concept of 'vulnerable groups' to the individual, as there is a growing body of evidence that health sensitivity to noise has a strong genetic component.

The studies presented in this Thematic Issue, alongside future scientific research, will help decision makers to develop more effective policies based on recent scientific results. It is essential that environmental sound is considered by a range of different policy areas such as mobility planning, urban development, housing and preventive health, and that noise policy is based on the assessment of all possible impacts.

**Professor Dick Botteldooren, Department of Information Technology, University of Ghent, Belgium**

# Summary of the articles in this Thematic Issue

Two articles in this Thematic Issue describe how stress and sleep disturbance resulting from environmental noise are pathways to cardiovascular disease. Research summarised in '**Transport noise mitigation must consider the medical impacts'** reveals that night-time noise may have more of an impact on cardiovascular health than day-time noise. Noise exposure at night is a particular problem because it disturbs sleep. The researchers recommend that noise reduction policies consider the medical effects of noise and suggest targeting noise problems at their source.

The second article, '**Loss of healthy life due to UK noise exposure valued at €1.34 billion**' is based on a study in which researchers evaluated how exposure to day-time noise above recommended levels affected the blood pressure and associated health complications of the UK population. They found a marked increase in three health problems most strongly associated with high blood pressure: heart disease, stroke and dementia; this increase has a significant cost to society.

The effects of night-time noise on health are also examined in **'Aircraft noise at night can damage blood vessels and cause long-term cardiovascular disease',** which reports on a study of 75 healthy volunteers aged between 20 and 60 years. Researchers monitored the blood pressure and heart rate of the volunteers during the night and found that those exposed to greater amounts of night-time aircraft noise suffered disturbed sleep, damaged blood vessels and increased levels of stress hormones in the body. These physical changes can lead to high blood pressure, heart and circulatory disease over the long term.

Vulnerable groups of people (such as those with mental illness, shift workers and those with tinnitus) may be at increased risk from exposure to environmental noise. The article '**Health of vulnerable people exposed to noise is under-researched'**, reports that although children's health is less likely to be affected by environmental noise than adults', it has been observed to lead to hyperactivity and inattention. Based on a German study, the article **'Children are more hyperactive if they live near busy roads'** reveals that in addition to an increased risk of hyperactivity, children living close to busy roads may also have more emotional problems, especially if they are exposed to higher levels of noise during the night.

Research into noise pollution and health is outlined in **'Reviewing the multiple impacts of noise pollution'**. This focuses on studies on the health impacts of noise – including environmental and social (via headphones) noise. Hearing impairment as a result of noise exposure presents a serious public health problem - The World Health Organization (WHO) estimates that 10% of the global population are currently exposed to noise levels that could lead to hearing impairment.

The article **'Preserving quiet areas improves health'** provides evidence of the beneficial effects of access to tranquil places. The researchers took data from those living in rural and urban locations and found that those living in so-called 'noisy' urban areas were more likely than those in 'quiet' urban areas to be very annoyed by noise.

'**How sounds affect our state of mind'** examines research which finds that a diversity of acoustic environments is preferable over more uniform acoustic environments that comply with certain legal noise limits. Therefore tranquil places as well as more lively places should be found in our cities.

Knowledge about the source of a noise (e.g. wind turbines) has been shown to influence people's judgement of noise annoyance. Motorways have been proposed as good locations for turbines, partly because the traffic could help conceal turbine noise. Based on a Belgian study, the final article '**Are motorways the best spot for wind turbines?'** describes a listening experiment in which participants detected turbine noise even when it was 23 dBA quieter than accompanying motorway noise, and they could hear turbines above any volume of noise from local roads.

# Transport noise mitigation must consider the medical impacts

***People living close to road, rail and aircraft noise are likely to experience negative health effects. Long-term noise exposure may lead to problems with their heart and circulatory (cardiovascular) system and night-time noise is particularly disruptive of sleep patterns, which in turn may lead to cardiovascular health problems, a review of research into the effects of noise on cardiovascular diseases has found.***

*"Night-time noise may have more of an impact on cardiovascular health than day-time noise, and noise exposure at night is a particular problem because sleep is disturbed."*

In addition to annoyance and a perception of a lower quality of life, long-term exposure to environmental noise can affect people's health in other ways. This study, based on current literature, reviewed research into the impact that exposure to transport noise has on the cardiovascular system, to help improve noise mitigation policies.

Night-time noise may have more of an impact on cardiovascular health than day-time noise, and noise exposure at night is a particular problem because sleep is disturbed. Exposure to noise may lead to changes in the way the body functions: laboratory studies have demonstrated that the body reacts to acute noise exposure by releasing stress hormones, such as adrenaline. As shown by field studies, these acute effects occur not only at high sound levels in workplace settings, but also at relatively low environmental noise levels when concentration, relaxation, or sleep is disturbed. This flight-or-fight reaction is automatic and does not even require a conscious awareness to occur. As a result, people do not get enough sleep and their sleep pattern is broken - disrupted sleep can lead to cardiovascular health problems.

For example, exposure to aircraft noise at night was linked with increased blood pressure. If night-time noise levels stimulate high blood pressure – preventing blood vessels from relaxing in order to restore themselves overnight – this can lead to continued high blood pressure, hardening of the arteries and cardiovascular diseases such as heart attacks and strokes in people who have long-term exposure to high enough noise levels.

Population studies on long-term exposure to road, rail traffic and aircraft noise have used different research methods, but in general reveal a link between noise exposure and raised blood pressure, heart attacks and strokes.

The World Health Organisation (WHO) considers night-time noise levels of less than 55 dBA to be necessary to prevent adverse health effects from noise in the short term, although the long-term goal is 40 dBA. Around 40% of the European population is exposed to road-traffic noise of more than 55 dBA $L_{DN}$, according to the WHO. Results from a number of studies suggest that the risk of heart disease increases for people exposed to road traffic noise of between 55 and 60 dBA. The risk of having a stroke was also found to increase, particularly in the elderly.

Several studies on people living near airports have found a link between increased exposure to aircraft noise and the risk of having high blood pressure. Recent studies have also associated exposure to day and night-time aircraft noise with an increased risk of heart disease and strokes in people living close to airports.

The researchers suggest that the association between road, rail and aircraft traffic noise with adverse health effects requires policies to reduce the burden of noise that take into account the associated medical effects. They suggest that noise should be targeted at source, for example take-off and landing procedures of aircraft should be controlled to reduce noise levels, traffic curfews could be imposed, and better sound insulation could be installed where source control measures are not feasible.[4]

**Source:** Münzel, T., Gori, T., Babisch, W. and Basner, M. (2014) Cardiovascular effects of environmental noise exposure. *European Heart Journal.* DOI:10.1093/eurheartj/ehu030

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**Themes:** Environment and health, Noise

4 The energy-equivalent average A-weighted *SPL* (LAeq) as expressed in decibels is the most commonly used indicator of the noise exposure that people perceive outside and inside their homes. The A-weighting accounts for the different sensitivity of the human ear at different sound frequencies.

**SPL: The sound pressure level (SPL) is a logarithmic measure of the effective pressure of a sound relative to a reference value. It is measured in decibels higher than a reference level. The reference sound pressure in air is 20 µPa ($2\times10^{-5}$ Pa), which is equivalent to the human hearing threshold at a sound frequency of 1000 Hz.**

# Loss of healthy life due to UK noise exposure valued at €1.34 billion

***Exposure to environmental noise levels above recommended levels results in 1169 cases of dementia, 788 strokes and 542 heart attacks every year in the UK alone, new research suggests. Valuing a year of healthy life at £60 000 (€74 002) means that these health impacts together have a 'cost' of £1.09 billion (€1.34 billion), the study's authors conclude.***

*"...the researchers set out to evaluate how exposure to day-time noise above recommended levels affected the prevalence of abnormally high blood pressure and associated health complications of the UK population"*

Exposure to noise pollution is a widespread problem - in 1996 the European Commission estimated that 20% of the EU population were likely to suffer negative impacts to their health or well-being due to noise. In the UK, a government study estimated that 54% of the population was exposed to day-time noise pollution above recommended levels of $L_{Aeq\ 16hr}$ 55 A-weighted decibels – a unit which measures sound in a way similar to the human hearing system, averaged over a 16-hour period.

Environmental noise has been linked to a number of different health problems including high blood pressure. This can, in turn, increase the risk of other health problems such as heart disease or stroke. For this study, the researchers set out to evaluate how exposure to day-time noise above recommended levels affected the prevalence of abnormally high blood pressure and associated health complications of the UK population. They focused on three health problems most strongly associated with high blood pressure: heart disease, stroke and dementia (vascular dementia and Alzheimer's disease).

To estimate levels of noise pollution, 1160 sites were monitored across the country between 2000 and 2001[5]. These data were then combined with information on the age and sex of UK residents, as these factors can influence health risk. The researchers then calculated the added health problems that were predicted as a result of the noise pollution exposure for groups of different ages or sexes and multiplied this by the number of people in each group.

The results suggested that exposure to noise levels above recommended levels resulted in an additional 1169 cases of dementia, 788 cases of stroke and 542 cases of heart attack in the UK over the course of a single year.

To calculate the cost of these health impacts the researchers used 'quality adjusted life years' (QALYs). The QALY takes into account quality of life by assessing not only the total number of years of life but also how many years might be spent coping with a non-life threatening illness. For example, an individual who lives for 70 years but only has 60% of full health would have 42 QALYs.

Using a standard government figure of £60 000 (€74 002) for the 'value' of a single year of healthy life, the researchers calculated that the health impacts of exposure to noise above $L_{Aeq\ 16hr}$ 55 A-weighted decibels cost £1.09 billion (€1.34 billion), with dementia accounting for 44% of this figure.

The researchers note that these are intangible, or invisible, 'costs' arising from loss of a healthy life (see standard figure above), rather than the wider costs to society, such as healthcare. If these latter costs were to be included, the figures would likely be substantially higher; for instance, previous research has estimated that 99% of the costs of dementia are associated with healthcare and informal care and only 1% with loss of healthy life.

**Source**: Harding, A-H, Frost, G. A., Tan, E. & Tsuchiya, A. (2013). The cost of hypertension-related ill-health attributable to environmental noise. *Noise & Health.* 67 (15): 437-445. DOI: 10.4103/1463-1741.121253.

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**Theme(s):** Noise, Environment and health

5 These sites were monitored by the Building Research Establishment (BRE)

# Aircraft noise at night can result in dysfunction of blood vessels and cause long-term cardiovascular disease

***Recent research into the impact of different levels of noise on 75 volunteers, reveals that disturbed sleep caused by night-time aircraft noise can damage blood vessels and increase the levels of stress hormones in the body. As these physical changes are potential pathways to high blood pressure, heart and circulatory disease over the long term, reducing night-time aircraft noise is important for preventing cardiovascular disease in people living near airports.***

*"Reducing noise from aircraft at night would help prevent heart and circulatory problems in people living near airports."*

Aircraft noise tends to be more annoying and disruptive to sleep than road and rail traffic noise, and long-term night-time exposure to aircraft noise is implicated in cardiovascular disease (such as heart attacks and strokes) more than day-time exposure to aircraft noise.

People need sleep to maintain normal good health and this depends not only on the length of a night's sleep but also its quality. Repeated noise disturbances, with or without waking up, interrupt the restorative powers of sleep, and cause a person's blood pressure to fluctuate in response to the noise.

In this study, the researchers tested the impact of night-time aircraft noise on 75 healthy volunteers aged between 20 and 60 years. All the participants were exposed to recordings of different patterns of aircraft noise in their own homes. On one night the volunteers were exposed to background noise, as a control, and on the other two nights they were exposed to repeated aircraft noise either 30 or 60 times during the night. Volunteers kept to their normal sleep patterns and on the nights of exposure to aircraft noise, the noise event sequence lasted for 415 minutes. The researchers monitored the blood pressure and heart rate of the volunteers during the night.

The following morning, the volunteers visited a laboratory where the researchers used ultrasound to measure changes to the diameter of the main artery in the arm, which affects blood flow. The results revealed that the arteries were stiffer (also called endothelial dysfunction) after an aircraft noise night, and the more severe the noise, the less flexible the blood vessels became. This suggests that the blood vessels were affected by poor sleep as a result of the aircraft noise.

In those volunteers who were first exposed to 30 episodes of aircraft noise, the effect on their arteries became worse (the arteries became less flexible) when they were then exposed to 60 noise episodes during the night. Thus, the vessel does not adapt to noise, and becomes more sensitive. Moreover, blood pressure increased in response to the aircraft noise.

The researchers also tested the volunteers' blood for stress (fight-or-flight) hormones, and found there was a significant increase in adrenaline levels after exposure to nights where the volunteers were exposed to the aircraft noise. Volunteers also reported poor sleep quality on the noise nights. Over a long period of time, this repeated exposure to aircraft noise can result in permanently high blood pressure due to more rigid blood vessels leading to cardiovascular disease.

In further tests, five volunteers, who had been exposed to a 60-event aircraft noise night, were given Vitamin C in the laboratory. The researchers detected an improvement in arterial flexibility. Vitamin C is a powerful anti-oxidant, and the researchers suggest the mechanism by which the arteries become less flexible is related to oxidative stress of the blood vessels as a result of exposure to the aircraft noise.

Taken together, the observed stiffening of the arteries (even in young healthy adults), and the increase in adrenaline levels, combined with volunteers' reported poor sleep quality, indicate that their raised blood pressure was most likely related to the aircraft noise at night, suggest the researchers. As this can lead to cardiovascular disease, night-time aircraft noise may be considered as a new risk factor. Reducing noise from aircraft at night would help prevent heart and circulatory problems in people living near airports.

**Source**: Schmidt, F.P., Basner, M., Kröger, G. *et al.* (2013) Effect of nighttime aircraft noise exposure on endothelial function and stress hormone release in healthy adults. *European Heart Journal*. DOI:10.1093/eurheartj/eht269

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**Themes**: Environment and health, Noise

# Health of vulnerable people exposed to noise is under-researched

*Vulnerable groups of people, including those with long-term illnesses, those sensitive to noise or tinnitus (ringing of the ears), people with mental health problems and unborn and newly born babies, are often more susceptible to physical and emotional stresses. So, vulnerable groups of people may be more at risk from exposure to environmental noise than healthy adults, say researchers after reviewing the health impacts.*

*"Several studies suggest that schoolchildren exposed to noise from aircraft and road traffic experience learning and comprehension difficulties."*

However, there is comparatively little research focusing on the adverse health effects of noise on vulnerable people. This study reviewed 62 papers, published from April 2006 to April 2011, which included the impact of environmental noise on the health of vulnerable people, including primary school children, young adolescents, preschool children, the elderly, and children with autism, asthma and attention deficit hyperactivity disorder.

One study linked hospital admissions for respiratory diseases and pneumonia for young children (less than 10 years old) with exposure to road traffic noise, and another found that girls with asthma were prone to asthma attacks if they had been annoyed by night-time noise.

The most common effects of noise on the vulnerable identified by the studies included:

1. **Annoyance**. Several studies found that schoolchildren (aged between eight and 14) are less annoyed by aircraft and road traffic noise then adults. One paper, reviewing multiple studies, found that both the youngest and people over 60 are the least likely to be highly annoyed by air and road traffic noise, irrespective of the level of noise or how sensitive to noise they were.

2. **Sleep disturbance**. Results from several studies indicate that children are less likely than adults to be woken by noise, but they tend to experience more physical reactions, including raised blood pressure. Studies have not found evidence of the long-term health effects of sleep disturbance for vulnerable groups, including people sensitive to noise.

3. **Heart and circulation problems**. Research on the impact of aircraft and road traffic noise on the cardiovascular health of schoolchildren shows that the main effect appears to be short-term raised blood pressure, although the strength of the association between noise exposure and cardiovascular effects is inconsistent between studies because of differences in the methods used.

4. **Quality of life**. Several studies have linked noise exposure at school to children having more headaches, being more tired and having raised stress hormone levels in the blood. One study associated deterioration in physical and mental quality of life in people over 60 with exposure to road traffic noise.

5. **Cognitive processes**. Several studies suggest that schoolchildren exposed to noise from aircraft and road traffic experience learning and comprehension difficulties. One study found that noise at work affected the job performance of teenage boys.

6. **Hearing**. Little is known about the impact of noise on the hearing of children, although it is likely any effects will be cumulative over the long term. Research has been done on the impact of loud noise from concerts, discotheques and listening to music from headphones on teenagers, with the most common effects being short-term tinnitus and hearing loss.

The researchers advise that more research is needed, especially on little studied groups of vulnerable people, including those with mental illness, shift workers and those with tinnitus.

**Source**: van Kamp, I. and Davies, H. (2013). Noise and health in vulnerable groups: A review. *Noise and Health*. 15(64): 153-159. DOI: 10.4103/1463-1741.112361

**Available from:** http://www.noi-seandhealth.org/text.asp?2013/15/64/153/112361

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**Themes**: Environment and health, Noise

# Children are more hyperactive if they live near busy roads

***Children living close to busy roads may have an increased risk of hyperactivity. They may also have more emotional problems, especially if they are exposed to higher levels of noise during the night, according to research carried out on children's health in Germany.***

*"...night-time exposure to noise may have more adverse effects than exposure to day-time noise, because the body needs adequate sleep to remain healthy."*

Research on the negative health effects of noise on children has mainly focused on aircraft noise at school, but less is known about the impact of road traffic noise on children at home.

In this study, the researchers investigated the impact of road traffic noise at home on 10-year-old children's mental health and behaviour, including problems of hyperactivity or inattention and emotional problems such as being anxious, easily scared or unhappy. Information on the 872 children in this study came from two ongoing German population-based studies, LISAplus[6] and GINIplus[7], which are following the physical wellbeing of healthy children, from birth to the age of 10 years, and assessed behavioural problems at the age of 10.

Using data from existing noise maps, the researchers assigned maximum and minimum levels of noise at the exterior wall exposed to the most noise (facing the street) and the exterior wall exposed to the least noise, at each child's home. The researchers chose two noise indicators, the night noise indicator to assess the disturbance of children's sleep by night-time noise and the day-evening-night noise indicator to measure overall noise annoyance.

The researchers assessed the children for behavioural problems using a standardised questionnaire and various aspects of their behaviour were categorised as normal, borderline or abnormal.

The study concluded that being exposed to higher noise levels was associated with significantly greater problems of hyperactivity and inattention. The researchers also found that children were more likely to display emotional problems if they were exposed to higher noise levels.

In particular, night-time exposure to noise may have more adverse effects than exposure to day-time noise, because the body needs adequate sleep to remain healthy. The researchers also assessed the impact of night-time noise exposure on sleeping problems in 287 of the children, as this data was available for this subgroup. Children appeared to have more sleeping problems, especially falling asleep, with increasing exposure to night-time noise levels. It is possible that road traffic noise levels that the researchers used do not necessarily reflect the actual noise levels the children were exposed to – for example the researchers had no information about any noise insulation that had been installed in the houses.

This study focused on the environment where the children spent most of their time – at home, which the researchers highlight as a major strength of the study.

**Source**: Tiesler, C.M.T., Birk, M., Thiering, E. *et al.* (2013). Exposure to road traffic noise and children's behavioural problems and sleep disturbance: Results from the GINIplus and LISAplus studies. *Environmental Research*. 123: 1–8. DOI:10.1016/j.envres.2013.01.009

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**Themes**: Environment and health, Noise

6 LISAplus: The Influence of Life-style factors on the development of the Immune System and Allergies in East and West Germany Plus the influence of traffic emissions and genetics
http://www.helmholtz-muenchen.de/en/epi1/research/research-units/research-unit-1-environmental-epidemiology/projects/lisa-plus/index.html

7 GINIplus: German Infant Study on the influence of Nutrition Intervention Plus environmental and genetic influences on allergy development.
http://www.helmholtz-muenchen.de/en/epi1/research/research-units/research-unit-1-environmental-epidemiology/projects/giniplus/index.html

# Reviewing the multiple impacts of noise pollution

*While occupational exposure to noise has declined, 'social' exposure in the form of personal music players or rock concerts is estimated to have tripled for young people since the 1980s. A new review examines studies that have investigated noise sources including environmental (e.g. traffic) and social (e.g. via headphones). The review also explores research into the range of health effects beyond hearing impairments, such as annoyance and cardiovascular problems.*

*"In addition to hearing problems, the non-auditory health impacts of noise exposure, including annoyance, sleep disturbance, heart disease and cognitive impairment, are all causing increasing concern."*

Noise is ubiquitous to everyday life. Exposure in the workplace is a common problem and as a result many countries have developed legislation to protect employees. The increase in social exposure to noise is worrying, say the review's authors, as there is now evidence that noise exposure when young can contribute to hearing loss in later life.

Hearing impairment as a result of noise exposure presents a serious public health problem; it is estimated that worldwide 1.3 billion people suffer from this condition and the World Health Organisation (WHO) estimates that 10% of the global population are currently exposed to noise levels that could lead to hearing impairment. However, new treatments are under development. An oral drug, D-methionine, has shown good protection against hearing loss in animals and the review's authors predict that these kinds of treatments will be available for human use in the next 10 years.

In addition to hearing problems the non-auditory health impacts of noise exposure, including annoyance, sleep disturbance, heart disease and cognitive impairment, are all causing increasing concern. Annoyance, which could be thought of as trivial, can in fact lead to anger, stress and exhaustion and, because of the large number of individuals affected, is estimated to be the second most important cause of health impacts due to environmental noise.

Sleep disturbance is thought to have the greatest effect on health because it can have impacts on alertness, performance at work and general quality of life. In fact, studies have suggested that noise levels at night may have a greater impact on long-term health than noise exposure during the day.

Cardiovascular disease, which includes high blood pressure, heart disease and stroke, has been clearly linked with long-term exposure to environmental noise. For instance, an analysis combining the results from many different studies found that an increase of 10 dB of transport noise (traffic and aircraft) can lead to an increase in risk of high blood pressure or heart disease of between 7 and 17%.

Finally, the results of over 20 studies have shown that environmental noise can affect children's learning and cognitive development. Exposure to road, rail and aircraft noise over long periods can reduce memory, reading ability and test performance. For example, as part of the EU-funded RANCH project[8], a study was carried out on 2844 9-to-10 year-olds attending 89 schools near major airports in London, Amsterdam and Madrid. After accounting for variables such as socioeconomic status, the results showed a clear link between noise exposure and reduced reading comprehension and memory.

**Source**: Basner, M., Babisch, W., Davis, A. *et al.* (2014). Auditory and non-auditory effects of noise on health. *The Lancet*. 383: 1325-1332. DOI: 10.1016/S0140-6736(13)61613-X.

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**Theme(s):** Noise, Environment and health

8 The RANCH (Road traffic and Aircraft Noise exposure and children's Cognition and Health) project was supported by the European Commission. See: http://ec.europa.eu/research/quality-of-life/ka4/pdf/report_ranch_en.pdf

# Preserving quiet areas improves health

*Living in a quiet area has a positive impact on health. A study assessed quality of life for people living in quiet and noisy locations and found that those who lived in quiet locations – particularly in rural areas – had a better quality of life.*

*"About 15% of those living in the noisy city location said they were very annoyed by transport-related noise. This is similar to European cities, where 10-35% of people are severely or very annoyed by traffic noise."*

The EU's Noise Directive exists to protect people from the adverse impacts of noise and preserve the health benefits of quiet spaces. However, while there have been many studies on the negative impacts of noise, such as annoyance and lost sleep, there have been relatively few studies on the positive impacts of quiet spaces.

Noise impacts – positive or negative – can be measured and compared by using health-related quality of life (HRQOL), which asks people to rate how satisfied they are with numerous aspects of their health. Other measures can be used to express health impacts in terms of the healthy days or years of life that are lost. For example, in Europe each year, the equivalent of a million healthy years of life are thought to be lost due to traffic noise. The authors decided to adopt a HRQOL approach to compare the health impacts of noise in 'noisy' versus 'quiet' areas in New Zealand.

They used data from studies on noise-related health carried out in four different areas, described as: 'quiet rural', 'noisy rural', 'quiet city' and 'noisy city'. The noisy rural location was near to a wind farm, while the noisy city locations were near an airport or major motorways. Both quiet locations were situated away from busy roads and industry. A total of 823 people were surveyed in these four locations.

The authors found that quality of life increased as noise levels decreased – health-related quality of life was highest in the quiet rural location. But while there was a clear association between transport noise and HRQOL, the relationship between neighbourhood noises such as dogs barking and lawn mowers was less clear. The researchers suggest this may be because such noises are less constant and so have a smaller impact on health, even if they are sometimes very annoying.

About 15% of those living in the noisy city location said they were very annoyed by transport-related noise. This is similar to European cities, where 10-35% of people are severely or very annoyed by traffic noise. People living in the quiet city location and the two rural areas were less annoyed by noise. However, of the two so-called noisy areas, the rural location was home to more people who were 'very annoyed' by noise compared to the city location. This suggests that unnatural sounds, such as those of wind turbines, are more annoying in the context of green areas and perhaps mask other natural sounds.

Overall, the researchers say their research justifies the aims of the European Noise Directive in preserving quiet spaces for health. Some of the more specific health impacts of living in noisy or quiet areas require further study. For instance, how much does traffic noise disturb sleep and how much do quiet areas reduce stress levels? There were also no data on the differences in actual sound levels between the four sites. However, the authors note that decibel measurements can be misleading as they are heavily influenced by the setting.

**Source:** Shepherd, D., Welch, D., Dirks, K.N. *et al.* (2013). Do Quiet Areas Afford Greater Health-Related Quality of Life than Noisy Areas? International Journal of Environmental Research and Public Health, 10, 1284-1303. DOI: 10.3390/ijerph10041284

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**Themes:** Environment and health, Noise

# How sounds affect our state of mind

*Sounds affect our state of mind differently depending on whether they are pleasant or annoying. In a theoretical study, researchers developed a model for exploring human responses to sound. Their work may help us to understand better the health impacts of long-term exposure to noise, as well as the potential benefits of spending time in quiet spaces.*

*"People can become finely attuned to the sounds that most disturb them, heightening their annoyance."*

It seems clear that there are health benefits to living in a quiet, pleasant environment. But the researchers wanted to consider what 'quiet' actually means. Within policy contexts, 'quiet' may be interpreted as meaning little or no noise. However, other interpretations may have less to do with sound levels than with a lack of disturbances in a given location or a level of control that people feel they have over the sounds.

While pleasant, natural sounds make us feel calm and safe and allow us to remain in a tranquil state of mind, sudden 'loud' and 'annoying' sounds made by machines or other people may force us out of this tranquil state and become the focus of our attention. We may even have evolved – like other animals – to pay attention to the annoying sounds, because they indicate danger. People can become finely attuned to the sounds that most disturb them, heightening their annoyance. In the same way, an absence of pleasant sounds may also put us on high alert, because it offers no guarantees of safety.

After reviewing existing studies on the way that people react to pleasant and annoying sounds, the authors developed their own model, focusing on the influence of sound on 'mind states'. Their model draws on theories from different disciplines, including psychology and neurobiology. They describe four possible states of mind: 1. maximally restoring (sleep); 2. restoring; 3. effortful (requiring focused attention); and 4. inefficient and more effortful.

When we are in environments that make us feel safe, according to the model, our state of mind is restorative. Therefore, in the second, 'restoring' waking state, we have freedom in our thinking and behaviour. However, if we feel threatened by our environment, we have to pay more attention to it and – in the authors' fourth state - switch constantly between thoughts about the tasks we're trying to get on with and potential external threats. Continually being in this state of high alert and carrying out such mental switching means not only that we can't focus on specific thoughts, but that we miss out on the restorative benefits of free thinking. These various states of mind may be strongly influenced by the 'soundscapes' (acoustic environments) we are exposed to.

However, the researchers also think that people may benefit from changes in soundscapes – from spending time in lively places as well as quiet places. They say a diversity of acoustic environments is preferable over more uniform acoustic environments that comply with certain legal noise limits. Such an approach might also be less costly than trying to keep sound levels uniformly low.

**Source:** Andringa, T. C., & Lanser, J. J. L. (2013). How pleasant sounds promote and annoying sounds impede health: a cognitive approach. *International Journal of Environmental Research and Public Health*, *10*(4), 1439–61. doi:10.3390/ijerph10041439

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**Themes:** Environment and health, Noise

# Are motorways the best spot for wind turbines?

***Wind turbine noise can be detected at low levels, even when it is heard alongside motorway traffic noise, a study finds. It is possible for louder motorways to drown out turbine noise, however. The participants in this listening experiment could easily detect wind turbine noise, but only once they knew it was present in recordings of environmental noise.***

*"...turbines could be detected at all volumes when combined with local road traffic, which suggests that road traffic is not suitable for masking turbines."*

Public annoyance with wind turbine noise is rising with the increasing number of turbines installed. Previous studies have suggested that people are more annoyed by wind turbines than other sources of environmental noise, such as road traffic, even if they are equally as loud. Research has also indicated that masking turbine noise with other sounds could reduce annoyance.

This Belgian study adds to the body of research into turbine noise. Motorways have been proposed as good locations for turbines, partly because the traffic could help conceal turbine noise. Fifty people participated in a listening test in which they were asked to identify and detect wind turbine noise when heard alongside traffic noise. None of the participants held negative attitudes towards wind energy, and only one was particularly familiar with turbine noise.

The researchers first played recordings of noise at realistic indoor sound levels (40 A-weighted decibels (dBA)) to participants while they read at leisure in an otherwise quiet room. At this stage, the participants did not know the true purpose of the study or that they were going to be played recorded noises.

There were four types of recording: pure wind-turbine noise, pure motorway noise, combined motorway traffic and wind turbine noise, and combined local road traffic and wind turbine noise. Motorway noise was continuous, whereas local road noise was intermittent and individual vehicles could be heard driving past.

The researchers asked participants to rate how annoying they found the noise recordings, without telling them what the recordings actually were. Participants considered local road traffic recordings much more annoying than motorway and turbine recordings. There was little difference in annoyance levels for motorway and turbine recordings, whether in isolation or combined.

When asked to name what they had heard, nearly all participants correctly identified road traffic noise. Just under half said they had heard wind turbines. A number of incorrect answers were given, including air traffic (48% of respondents) and sea waves (28%).

In a second stage of the experiment, the researchers explored how loud traffic noise would have to be in relation to turbines, to mask their noise effectively. The participants were asked to deliberately listen for turbines in recordings, which had an overall volume of around 40 dBA, but with varying ratios of turbine and traffic noise.

At this stage, the listeners easily detected turbine noise in combined recordings, now they knew it was present. Those who detected it most easily tended to be the same people who had rated it as annoying in the first part of the experiment.

Listeners started to detect turbine noise when it was 23 dBA quieter than accompanying motorway noise. The turbine noise's acoustical energy was thus 200 times lower than the motorway's. In contrast, turbines could be detected at all volumes when combined with local road traffic, which suggests that road traffic is not suitable for masking turbines.

The researchers caution that the study was small-scale and short-term; some patterns they observed here might be different if they had conducted a long-term study.

**Source**: Van Renterghem, T., Bockstael, A., De Weirt, V., Botteldooren, D. (2013) Annoyance, detection and recognition of wind turbine noise. *Science of the Total Environment*. 456-457: 333-345. DOI: 10.1016/j.scitotenv.2013.03.095.

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**Themes**: Environment and health, Noise

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# Further Reading

You may also be interested in reading the following publications from Science for Environment Policy.

## News Alert articles

### Traffic noise pollution mapped with new mobile phone app (Nov 2014)

**A new mobile phone application** which can help monitor traffic-noise exposure is presented in a recent study. The app, '2Loud?', can measure indoor night-time noise exposure and, given large-scale community participation, could provide valuable data to aid urban planning, the researchers say. In an Australian pilot study, nearly half of participants who used the app found that they were exposed to potentially unhealthy levels of night-time noise.
http://ec.europa.eu/environment/integration/research/newsalert/archive/noise.htm

### Both traffic noise and air pollution linked to stroke (Oct 2014)

Road traffic noise and air pollution both increase the risk of having a stroke, recent research from Denmark suggests. The results suggest that traffic noise is more strongly associated with ischaemic stroke, whereas only air pollution appears to be linked with more serious, fatal strokes.
http://ec.europa.eu/environment/integration/research/newsalert/pdf/traffic_noise_air_pollution_links_strokes_390na7_en.pdf

### Aircraft noise at night may lead to long-term health impacts (Feb 2014)

**Exposure to aircraft noise** at night for more than 20 years could increase the risk of heart disease and stroke, according to research conducted around six European airports. Risk also increased for those constantly exposed to road traffic, but this may have been caused by air pollution rather than noise.
http://ec.europa.eu/environment/integration/research/newsalert/pdf/363na1_en.pdf

## Thematic issues

### Environmental Noise (Nov 2011)

Noise pollution is among the most common complaints regarding environmental issues in Europe, especially in densely populated and residential areas near major roads, railways and airports. But noise - unwanted sound - is more than a mere annoyance, even at levels below ear damaging volumes. The EU's Environmental Noise Directive (END) has initiated action plans in Member States to reduce environmental noise exposure and its effects. This Thematic Issue reports on recent research to help guide effective noise action plans throughout Europe.
http://ec.europa.eu/environment/integration/research/newsalert/pdf/29si.pdf

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