Community Aircraft Noise: A Public Health Issue

Karen Bowman, MN, RN, COHN-S
Karen Bowman & Associates, Inc.

Introduction

Protecting and promoting population health are the defining goals of public health practice. Within this framework, public health encompasses a broad array of scientific disciplines, including occupational and environmental health. From an occupational health perspective, noise exposure is a hazard that poses a significant public health risk for hearing loss, hypertension and stress.[1] [2] In effort to reduce and eliminate this hazard, state and federal regulations have been established to address, prevent and reduce occupational noise exposure. Beyond the work setting and within communities, noise exposure from industrial operations, traffic and aircraft is a growing concern. Community based-environmental noise exposure contributes to sleep disruptions stress and cardiovascular disease related hospital admissions. [3] [4]

As a supportive document to Coupeville's community project, this manuscript will discuss the health effects of community noise exposure including aircraft noise. For the development of this document a review of scientific research (qualitative and quantitative) was conducted. For this paper, the selected studies dating from 1972 to 2013 reveal a wide range of potential health impacts from exposure to loud environmental noise in particular loud aircraft noise. Drawing from this literature review on environmental noise in general, and loud aircraft noise in particular, this document's purpose is to shed light on the real and potential health effects of military aircraft noise on community health for Coupeville Washington. Beginning with background information on the Coupeville community, this discussion will entail an overview to the problem of noise exposure particularly related to aircraft related noise, define hearing loss, provide a discussion of the anatomy and physiology of the ear and hearing, identify the health impacts of noise induced hearing loss (NIHL), along with the epidemiology of hearing loss specifically focusing around aircraft noise. This paper will conclude with recommendations for community actions for noise abatement and specific areas of future research related to environmental noise exposure from aircraft/military aircraft noise.

Worldwide, residential exposures to aircraft noise have sparked frustration and distress.[5] [6] [7] Addressing military aircraft related noise poses a particular challenge for typical community abatement because military aircraft are exempt from Federal and State noise control regulation.[8] In the Washington state community of Coupeville, a project is currently underway to address the health impacts incurred by community members from exposures to military aircraft noise. From 1942 through 2013, the Outlying Field has been used by the U.S. Navy Air Station Whidbey for touch and go flights but as the years progressed so did the number of flights and noise exposure. The Navy is now using EA-18G military jets which are louder than the older EA-6B military jets they've replaced. On May 7, 2013 jet noise studies were conducted at (5) locations near the touch and go landing strip called "Outlying Field" (OLF) on Whidbey Island 3 miles southeast of Coupeville, WA. Positions 1-4 were outside locations; position 5's noise measurements were inside a community member's home. All the locations are in populated community locations where citizens may be exposed to military aircraft noise and without hearing conservation training nor

the proper training and fitting of hearing protection, may sustain sensorineural noise induced hearing loss[9] among a host of other diseases and conditions. The JGL noise studies determined that maximum sound levels were clearly above levels requiring hearing protection[10] and they surpassed Washington State, the U.S. Environmental Protection Agency and the World Health Organization community noise protection guidelines.[11] [12] [13] [14]

Overview: Environmental Noise Exposure as a Public Health Issue

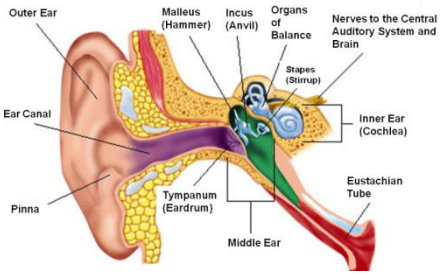
Loud noise exposure at anytime during the lifespan can have deleterious results. Although noise-NIHL is often associated with adults especially in the occupational setting, it is important to note that childhood noise exposure may potentiate hearing loss later in life. Animal studies show that if exposed to loud noise early in life mice were more disposed to age related hearing loss. [15] Therefore, it is critical to protect vulnerable populations like children from loud noise to protect adult hearing and future consequences of the loss of this vital sense.
Environmental noise is different from workplace noise in that it is often intermittent, is usually 24 hour hours a day 365 days a year in contrast to roughly 2,080 hours of work in a typical year. The Environmental Protection Agency (EPA) has determined that to protect 95% of the people, an environmental noise level limit of Leq(24) , which equals 70dB is effective in preventing hearing loss of greater than 5dB at the 4000 frequency.[16] Environmental and occupational noise exposures are major contributors to NIHL but it is not the only health effect that has been associated with loud noise. In fact loud noise has been shown to contribute to: cardiac problems including myocardial infarction, elevated triglycerides and cholesterol; immunotoxicity; cognitive impairment including slowed learning, performance and memory issues; psychosocial problems stemming from the lack of ability to communicate; sleep disturbances; exacerbation of depression and anxiety and overall general annoyance.[17] [18] Moreover, not only have such health effects been associated with noise exposure aircraft noise has been identified as a major offender.[19] One study determined substantial disturbance is reached with flight noise of 55 dBA in the daytime and 45dBA at night outside.[20] The pain and suffering associated around hearing loss is overwhelming. What is more saddening is noise induced hearing loss and other noise-induced health related impacts can be prevented.

Defining Noise

According to the United States Environmental Protection Agency (EPA), noise is defined as, "unwanted or disturbing sound."[21] Sound becomes unwanted when it either interferes with normal activities such as sleeping, conversation, or disrupts or diminishes one's quality of life."[22] Though this can be considered annoying for some, many suffer serious health effects as a result of "disturbing noise."[23] "The World Health Organization (WHO) guidelines for community noise recommend less than 30 A-weighted decibels dB(A) in bedrooms during the night for a sleep of good quality and less than 35 dB(A) in classrooms to allow good teaching and learning conditions.[24] The WHO guidelines for night noise recommend less than 40 dB(A) of annual average (L_{night}) outside of bedrooms to prevent adverse health effects from night noise.[25] In 2012, WHO identified the magnitude of disabling hearing loss from research accumulating through 2010 determined 360 million people (or 5.3% of the world's population) suffer from disabling hearing loss. Three hundred and twenty eight million (91%) of these are adults (183 million males, 145

million females). Thirty-two million of these are children.[26] Around 22 million (10%) of adults between the ages of 20 and 69 have permanent hearing loss do due occupational or leisure activity exposure to loud noise.[27]

Anatomy and Physiology of the Ear and Hearing Synopsis



Hearing is one of our incredible senses that help us enjoy the "music" of life, helps us with communication and other social activities and alerts us to danger and harm and it all starts with the ear. Hearing is 10 times more sensitive than eyesight and is the primary sense for conveying danger. Unlike the human eye which has a lid to stop visual sensation, the ear cannot shut itself off from hearing. This presents a unique problem especially when sleeping which is discussed later in this document.[28]

The ear is subdivided into three auditory parts: the outer, middle and inner ear chamber and the acoustic nerve (8th cranial nerve)[29]. The outer ear functions as a funnel which carries sound vibrations to the ear drum or tympanic membrane. The middle ear is an air filled cavity that connects to the inner ear. It contains those tiny bones, known as the ossicles, which conduct the sound waves to the inner ear. The inner ear, locate directly behind the eye socket, consists of the vestibular system that contribute to equilibrium and the cochlea for hearing conduction. The cochlea is responsible in part for our hearing because it houses the *organ of Corti*.[30] This tiny organ contains 16,000 hair-like cells or sensory cells which are found on the basilar and tectorial membranes Sound waves vibrate the membranes which stimulate the hair cells that generate nerve impulses to the brain. It is how we translate sound into recognized hearing.

Measurement and Mitigation of Noise Exposure

As mentioned prior, *the quality of the noise; whether it is continuous, interrupted, loud impact etc. and how it is influenced by intensity, duration and frequency composition determines the severity of injury or illness; e*ssentially, the dose-response relationship between the health effects and increasing sound level exposure. In the environment, noise measurement (noise pitch (frequency) and loudness (intensity)) is defined in terms of a logarithmic decibel scale (dB). Specifically, the dB scale is the logarithm of the ratio of the sound pressure of the signal to a reference pressure.[31] Environmental noise assessment and measurement is always A-weighted. Using the glossary of terms found in the WHO document, *Occupational Noise: Assessing the Burden of Disease from Work Related Hearing Impairment at National and Local Levels* (2004), "A-weighted decibel defined is a measure of sound levels humans hear, calculated using a spectral sensitivity factor (A-filter) that weights sound pressure levels by frequency to correspond to the sensitivity of the human ear." [32] Though as mentioned above, outdoor environmental noise is typically based on the A-weighted sound pressure level some hearing damage criteria is based on the un-weighted peak sound pressure level.[33]

Abating or mitigating any occupational and environmental hazard necessitates health and safety professionals to implement one or more of the standard industrial hygiene control measures consisting of: elimination or substitution, engineering, administrative or personal protective equipment (the former control measure being more health protective than the later). The Occupational Safety and Health Act (OSHA) and subsequently the Washington State Department of Labor and Industry requires the implementation of a Hearing Conservation Program, as an administrative control, when employees are subjected to noise at or equal to 85dBA with an 8 hour Time Weighted Average (TWA) along with requiring employees to be trained in hearing conservation and how to don and doff hearing protection. At 90dBA with a TWA of 8 hours, engineering controls are required.[34] At 110dBA maximum exposure is 1 minute 29 seconds. Continued exposure over time at 85dBA will cause hearing damage. At 140 dB one exposure may cause permanent damage and pain.[35]

The Minnesota Pollution Control Agency (1999) has provided a table of common noise sources.[36] As cited, jet engine and jet aircraft have a dB (A) rating of 130-140, which causes pain and permanent hearing damage at 1.29 seconds.

Decibel Levels of Common Noise Sources

Sound Pressure Level (dBA)	Noise Source
140	Jet Engine (at 25 meters)
130	Jet Aircraft (at 100 meters)
120	Rock and Roll Concert
110	Pneumatic Chipper
100	Jointer/Planer
90	Chainsaw
80	Heavy Truck Traffic
70	Business Office
60	Conversational Speech
50	Library
40	Bedroom
30	Secluded Woods
20	Whisper

Health Effects of Noise Exposure

Hearing Loss

There are numerous factors that can cause damage to the delicate hair cells of the cochlea; disease, age, medication, toxic chemicals, and loud noise. There are three types of hearing loss; conductive, sensorineural and the combination of both. *Conductive hearing loss* occurs when sound is not effectively conducted from the outer to inner ear specifically the ossicles. It often presents as a reduced sound level. Causes can be as simple as wax in the ear canal to more serious conditions as infection, tumor or perforation of the eardrum. Conductive hearing loss can often be corrected. *Sensorineural hearing loss* the most common type of hearing loss is usually not repairable and it involves the inner ear and often the auditory nerve. It occurs over time when the hair cells become damaged from prolonged exposure to loud noise.[37] *The quality of the noise; whether it is continuous, interrupted, loud impact etc. and how it is impacted by intensity, duration and frequency composition determines the severity of the injury or hearing loss.* The hair cells cannot keep up with the continued onslaught. Once hair cells for a certain frequency are permanently damaged you may no longer hear that frequency. Sensory cells do not regenerate. Symptoms of NIHL often include tinnitus, muffled sound and inability to understand conversation.[38] [39] One of the biggest concerns with NIHL is that it rarely causes pain. Individuals often cannot discern if they are losing their hearing. As an analogy, think of a city park with a beautiful green and healthy lawn; a mass of individual blades. When a person walks across the lawn just once, the blades of grass bend over but eventually straighten back up. When many people start to use the area as a shortcut, the grass lies down permanently, never straightens back up and is eventually destroyed. Such is the fate of sensory hair cells. Sensorineural hearing loss may be genetic or age related, however it may also be due to exposure(s) to loud noise, chemicals and/or drugs. , The result is a reduction in the ability to hear faint sounds and even though one might be able to hear

conversation, it could be muffled and unintelligible. Sensorineural hearing loss is the topic of this paper as it relates to environmental noise annoyance especially aircraft noise.

Psychosocial Impacts of Noise Exposure

The impact of hearing loss directly affects how individuals interact within their family, workplace and community and can lead to psychosocial impairment. The inability to hear affects not only the individual but family members, co-workers and community members with whom he/she is trying to communicate with. The inability to communicate can disrupt activities of daily living and can even present a safety hazard if you cannot hear a warning.[40] The ability of a nurse or family care provider to be vigilant in listening for vocalized alarms from a patient's room is compromised when environmental noise is so loud she/he cannot hear the patient. The same example is illuminated with a parent's vigilance with their children.

Environmental noise exposure effects memory, memory recall and the way we strategize our activities of daily living. It can reduce our willingness to help, reduce ways we identify social cues for performance and can increase aggression. Noise effects how we live. It affects our activities of daily living (ADL), and the ability to actualize our "activities of daily living" is a marker for our mental and physical health. The most documented subjective response to noise is annoyance. Aircraft noise has been noted to interfere with ADLs such as conversation, watching TV or listening to the radio, and it is dose-response related. Therefore the louder the aircraft noise the less an individual is able to adapt.[41]

As noted in this document, occupational noise and subsequent health effects have been greatly researched. We know that noise impairs performance. A study conducted by Nassiri, et al. (2013) exposed 40 healthy male university students, to loud "real" occupational noise and assessed their performance using a series of standardized tests. Their results revealed that treble noise, intermittent noise and high pressure levels severely reduced performance at the worksite when exposed to loud noise.[42] There is additional evidence that noise exposure may augment other stressors on an individual's health thereby reducing performance.[43]

In general, research shows a better link to aircraft noise and psychological symptoms such as anxiety and stress rather than psychiatric disorders, though there may be a link with higher noise levels.[44] [45]There is a consensus among researchers that further research in this area is critically needed. Some studies around commercial airports identified higher psychiatric admissions, others identified higher prescription dispensation but these studies were not replicable. Another study cited a dose-response association with higher levels of military aircraft noise and depressiveness and nervousness.[46]

Noise, Stress Hormones and Health

Noise is a biological stressor. Excessive exposure to noise, as in aircraft or military aircraft noise, is a health risk and may be contribute to sleep disturbances, cardiovascular disease, hypertension[47], myocardial infarction, gastrointestinal disease, migraine headaches and immunotoxicity.[48]

When looking at the body holistically, it is easy to understand how environmental noise exposure disrupts the body's homeostasis. Homeostasis defined is "a tendency of biological systems to maintain stability while continually adjusting to conditions that are optimal for survival." [49]One core component of non-auditory related health effects begins with stress. Hans Selye first coined the phrase "stress" and spent much of his career defining and researching the health effects associated with it. The stress reaction occurs when the body is exposed to physiological and/or psychological stimuli which Dr. Selye defined as "the general adaptation syndrome." A simpler definition of stress from Dr. George Chrousos is "an animal's state of threatened homeostasis." [50] Much of the reviewed research shows that prolonged environmental noise, especially aircraft noise, causes enormous stress. A common question asked by researchers is there a particular personality type that complains of loud environmental noise and the answer is complicated? The answer is no. Individuals who have been identified as "noise sensitive" seem to not complain of health effects related to loud environmental noise anymore than other individuals. However, some studies have indicated that if an individual has a perceived internal locus of control they tend to adapt better over time.[51]

Stress creates a cascade of releasing "fight or flight hormones" such as cortisol, adrenalin, epinephrine and norepinephrine which affect multiple systems in the body. When a person is exposed to loud noise a series of physiological responses occur; Adrenalin is released which increases the heart rate, blood pressure and breathing, blood is shunted to the vital organs like the brain and heart, reduced in less vital areas like the gastro-intestinal track, vasoconstriction occurs and muscles constrict, our mind becomes alert and focused. Continued releases of cortisol and other stress hormones leads to stress induced disease such as sleep disturbance, myocardial infarction, atherosclerosis and immunosuppression.[52]

Immune Disturbance

The immune system is a complex mechanism that keeps our body in homeostasis. Studies have shown that certain T cells (white blood cells that protect the body from disease organisms and other foreign bodies known as antigens) become suppressed with psychological stressors thereby reducing immunity. Chronic stress also affects the inflammatory response which raises the risk of viral infection. Stress has also been shown to exacerbate other diseases as well such as asthma and diabetes, and it increases the risk of certain gut conditions that affect the production of gastric acid thereby increasing the risks of ulcerative colitis, stress and peptic ulcers.[53] One study found that environmental noise impaired the immune system of workers which potentially put them at a higher risk of experiencing negative health effects from toxic chemical exposures, though further research is needed in this area.[54]

Aircraft Noise and Health

An exhaustive literature search found few articles related to military aircraft flight noise. None were noted earlier than 1990. H. Ising and E. Rebentisch et al (1990) conducted noise studies in the Federal Republic of Germany; Munsterland and Franken. The document determined that the physical characteristics of military low-altitude flight noise are different in terms of other aircraft flight noise; the extremely high maximal sound level and the very rapid increase in sound level

during direct over-flights. This combination increases community annoyance and health symptoms. Low altitude over-flight noise has been associated with cardiovascular problems and sleep disturbances even during the "quiet" nights that follow over-flights.[55]

Research conducted by W. C. Meecham and W. Shaw shows a link with jet noise and mortality rates.[56] One study conducted by Meister and Donatelle (2000), using four neighborhoods exposed to commercial aircraft airports and two control group communities (no aircraft noise), found noise annoyance very stressful for the exposed neighborhoods. All health measures were significantly worse in the exposed communities than the control communities. This study confirmed the strong link between aircraft noise, stress load and decreased health consequences. It also confirms aircraft noise seriously affects a person's sense of well being as measured by a "sense of vitality." Below, the Generalized Etiology Framework (Meister & Donatelle 2000) adeptly uncovers the etiology of commercial aircraft noise on human health.

Chronic Commercial Aircraft Noise Exposure → Increased Stress Load → Chronic Psycho-physiological Stress Activation → Adverse Health Effects + Reduced Quality of Life[57]

Stress hormones are also sensitive to light and dark and awake-sleeping patterns consequently affecting our sleep. According to Prasher (2009) sleeping individuals cannot determine what the noise is so noise is therefore interpreted as "danger." The conclusion derived is that the level of noise is not necessarily the predictor of the stress reaction but the rather the meaning of the noise for that individual. Aircraft noise is interpreted as danger thereby effecting cortisol levels. Aircraft noise has been associated with sleep disturbances and increased night time cortisol levels.[58] A study included in Deepak Prasher's (2009) research found that even loud noise exposure during the day reduced effective sleep patterns down to 80%, and the rapid eye movement (REM) phase of sleep associated with dreaming was critically affected.[59]Sleep is the time the body repairs and without it the body cannot survive.

Perhaps one of the most studied health effects of environmental and aircraft noise is cardiovascular disease. As mentioned prior, environmental and aircraft noise creates stress and chronic stress, which in turn increases the heart rate, pulse and blood pressure while creating vasoconstriction. It also clogs the arteries with plaque causing atherosclerosis which often causes angina or myocardial infarction.[60] The Los Angeles Airport Study determined that chronic exposure to aircraft noise raised systolic and diastolic blood pressure. These results were significant even though the blood pressure numbers remained within normal limits. Another study in Munich linked chronic noise exposure to both baseline systolic blood pressure and lower reactivity of the systolic blood pressure when doing a cognitive task under acute noise. After the new airport opened a significant increase in the systolic blood press was noted proving that there was a causal link between the airport noise and a rise in blood pressure.[61]

The HYENA study (2008) is the first study that assessed the relationships between the risk of hypertension (high blood pressure) and exposure to aircraft noise and traffic noise around the airport using 4,861 people between the ages of 45-70 who had lived for at least 5 years around six major European airports. When adjusted for demographic and other confounders, nighttime aircraft noise of 10 dB(A) (L_{night}) was associated with hypertension. The study's principle

investigators used the WHO *L*AEQ-T indicator of exposure which is the A-weighted equivalent continuous noise level over a specific time period. Specific times both for night and day were assigned. The document also cited previous research that found aircraft noise as a hazard risk for high blood pressure which is a major risk factor for cardiovascular disease including stroke.[62]

One study (Huss, et al. 2010) used the Swiss National Cohort and the national census which included demographic data on where citizens lived as its cohort. The study included hospitalizations and ICD-9 codes in the identified areas. It also included 65 airports and airfields in Switzerland. Zurich, the largest airport had a dedicated noise exposure model, the other 64 used an exposure model from the Federal Office of Civil Aviation. The study was adjusted for confounders and it was determined that acute and chronic noise exposure in particular aircraft noise is associated with high blood pressure, heart attacks, increased cardiovascular medication and cardiovascular morbidity and mortality. The risk of death from heart attacks was higher in individuals exposed to aircraft noise of 60 dB(A) or more and when you combined aircraft noise when associated with particulate matter PM10 exposure and adjusted for socio-demographic and geographical variables. [63]

Lastly, a multi-airport retrospective study of approximately 6 million older people residing near airports in the United States utilized 2218 zip codes surrounding 89 airports in the contiguous states was conducted in 2009. The researchers used ICD-9 codes from hospital admissions to determine if groups exposed to commercial aircraft around commercial airports were at higher risk for negative cardiac outcomes and despite limitations related to potential misclassification of exposure there was a statistical significance relating airplane noise and cardiovascular disease related hospitalizations among older people living around airports.[64]

Summary

This document articulates the serious health effects of environmental noise exposure in particular aircraft and military aircraft noise at the community level. Health effects range from sleep disturbance, depression, anxiety and cognitive impairment to atherosclerosis, cardiac disease, myocardial infarction and even death. Cardiovascular disease, including hypertension and myocardial infarction has the most statistically significant data and sadly it is the most serious of the negative health effects associated with aircraft noise. The continued over activation of stress hormones are not only key factors in cardiac disease but also in immune-toxicity causing a host of other conditions ranging from the increased probability of accidents to the development of other acute and chronic diseases.

Aircraft noise, especially as a night time exposure, exacerbates the release of the hormones which dramatically throws the body out of homeostasis and health. Aircraft noise, in particular low-altitude over-flights, is a public health issue that must be addressed to reduce the negative health outcomes of community members for generations to come. Current mitigation strategies for low flying aircraft according to Hartmut Ising, et al (1990) should range from reducing over-flight noise levels to 115db(A), a maximum sound level increase speed of 60 dB(A) and a reduction of over-flights.[65]

The community of Coupeville has sustained noise levels above "community noise exposure levels" for State and National guidelines and law. The Washington State (Chapter 70.107 RCW NOISE CONTROL/WAC 173-60) state that the maximum noise in a residential setting should be no greater than 55dBA and between 10pm-7am the maximum noise should be reduced by 10dBA = 45dBA. The JGL Acoustics study confirmed Position (5), which was a private residence, had noise measurements of L_{max} 81.1 dBA at 8:30pm; surpassing state guidelines.[66] The EPA sets noise standards as 70 dBA 24 hour $L_{eq.}$ JGL Acoustics noise measurements for Coupeville were: L_{max} levels ranged from 119.2-113.4dBA and predicted $L_{average}$ over 24 hours 64.1-75.0; again over guidelines established by Washington State and the EPA.[67] The World Health Organization recommends no more than <30dBA inside the bedroom for good quality sleep and no higher than<40dBA outside the bedroom to prevent adverse health effects.[68]

The citizens of Coupeville Washington are chronically exposed to loud, low-flying military aircraft. Studies confirm a host of diseases and injuries are associated with this type of noise hazard such as but not limited to: stress, psychosocial trauma, increased potential for accidents, decreased memory and cognitive function and lastly cardiac disease ending in potential death by myocardial infarction. Recommendations include implementing industrial hygiene control measures starting with eliminating the hazard or closing the OLF. Further recommendations include conducting a well thought out Environmental Impact Statement in conjunction with a Health Impact Assessment. Both must have stakeholder involvement including Coupeville citizens to fully assess determinants of health and community impact. Doing so will promote health and homeostasis not only for individuals, but for the community as a whole. Further research is needed to address the health effects associated with military aircraft and military low-altitude flight noise especially using current military aircraft/jet technology to not only protect citizens but Navy personnel as well. Additionally, further research is needed to critically assess all human and environmental health impacts associated with this phenomenon and more importantly development of control measures to abate the effects of this chronic environmental noise exposure.

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