Maslow's hierarchy of needs as a model for the process of the development of national noise regulations

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INTRODUCTION

The subject matter of this paper arose out of a request received to write an article on international noise regulations for the Encylopedia of Environmental Health. The author's initial thought was to update Appendix 2, Examples of Regional Noise Situations, in the World Health Organization (WHO) Guidelines on Environmental Noise (Berglund et al. 1999). However, upon revisiting the WHO Appendix, which covers Latin America, USA, South Africa, the Eastern Mediterranean, Southeast Asia and the Western Pacific, no unifying principles were apparent. In an attempt to find a unifying organizing principle, the author turned to a psychological theory known as Maslow's hierarchy of needs.

METHOD

The idea that the psychological development of humans proceeds from concern with basic physiological needs to self-actualization was introduced in 1943 by an American behavioral psychologist, Abraham Maslow. Dissatisfied with the concept of American academic psychology that the end goal of the organism is homeostasis as well as Freud's concept that the end goal of psychotherapy is the resolution of neurotic symptoms, Maslow argued that all human beings operate out of what he termed "an inborn hierarchy of needs." The five stages of this hierarchy are physiological needs (breathing, food, water, sex, sleep, homeostasis, excretion), safety needs (security of body, employment, resources, morality, family, health and property), love and belonging needs (friendship, family, sexual intimacy), need for esteem (self esteem, confidence, achievement, respect for others, respect by others), and self-actualization (morality, creativity, spontaneity, spiritual enlightenment). Fulfillment of a lower stage in this hierarchy is a prerequisite for an individual to move toward fulfillment of the next higher stage. Although Maslow intended his framework to apply to individuals, several social scientists have used it to predict developments within individual nations. Recent examples include strategies for eco-development in national parks in India (Rishi et al. 2008), institutional child care in developing countries (Tanner 2005) and annual quality of life in 88 countries over the period 1960 to 1994 (Hagerty 1999). Hagerty's analysis confirmed that quality-of-life improvements within nations proceed along a temporal sequence of developmental stages. The temporal sequence of developmental stages is an essential element of Maslow's theory, and the method used here was to look at the dates of milestones in the development of global noise regulations. A review of reviews was conducted (Bragdon 1970; Burton 2004; Concha-Barrientos et al. 2004; Flindell & McKenzie 2000; Finegold 2002; Johnson et al. 2001; Schwela 2000; Noise News International Editorial Staff 2000; Schultz 1982; Tachibana & Lang 2007; Wikipedia 2008). From these reviews, the correspondences between Maslow's hierarchy and categories of noise regulation listed in Table 1 were developed.

Table 1: Comparison of the proposed stages of national noise regulations and Maslow's hierarchy of needs

Maslow's Hierarchy	Individual Needs	Corresponding Noise Regulations
Physiological	Sleep	Sleep disturbance
Safety	Security of body	Occupational hearing loss
Love/Belonging	Friendship and family	Community and low noise products
Esteem	Respect of others	Protecting children, noise sensitive
Self-actualization	Creativity and spontaneity	Preservation of natural quiet

RESULTS

Regulating Sleep Disturbance

Regulations against sleep disturbance predated the technology for noise measurement (Bragdon 1970). Chariots in ancient Rome were banned from the streets at night to prevent the noise of iron rims on paved streets that disrupted sleep. Similarly, in Beverley, England, a market town which drew buyers and sellers from all over medieval England, a fine was imposed on persons driving iron-wheeled carts wherever stone pavement existed. By the thirteenth century, some English towns enacted laws prohibiting blacksmiths from working in the early morning hours because of sleep disturbance from noise.

In Japan, a country which was relatively isolated from the European technology until the rise of modern industrialization during the Meiji Restoration in 1868, the first nuisance noise ordinance was enacted by Tokyo in 1871. This ordinance, which was the beginning of noise ordinances in Japan, prohibited unacceptable behaviors such as breaking serenity by unnecessarily loud sounds in the street or in other public places after midnight. After World War II, such nuisances as loud voices, loud music performances and loud radio sounds were restricted by the Minor Offenses Act in 1947.

In the United States, the first attempts to deal with urban noise (including sleep disturbing noise) began after the Civil War (Smilor 1979). The most prominent and successful of these efforts was led by a physician, Julia Barnett Rice, in New York City, who, in 1906, founded the Society for the Suppression of Unnecessary Noise.

Even after technology for noise measurement became available, non-quantitative regulation of nighttime noise, such as curfews, are common. The reason is that sleep disturbance is difficult to predict on the basis of noise measurements. Two major problems are the context effect and the definition of sleep disturbance.

(1) Context Effect: Meta-analyses of field and laboratory studies have established that normal subjects are most likely to awaken to a specific decibel value of aircraft sound when sleeping in a sleep laboratory and least likely to awaken when sleeping in their own bedrooms in the vicinity of an airport. Subjects sleeping in their own bedrooms but not accustomed to nighttime aircraft sounds fall between those two extremes.

(2) Definition of Sleep Disturbance: Within the U.S.and U.K, there is a tradition of defining sleep disturbance as an awakening in which the subject is alert enough to push a button indicating a wakened status. Within Germany and some other European countries, there is a tradition of defining sleep disturbance as a physiological arousal,

such as a shift in EEG toward a shallower stage of sleep. Use of physiological arousal is justified by evidence that subjects experience aftereffects during the next day, such as irritability and fatigue, even if they never fully awaken. At the same time, this difference has led to more conservative guidelines in some European countries than in the U.S.

Regulating Hearing Hazardous Noise

Concerns about noise-induced hearing loss arise with industrialization. The recognition that excessive exposure to noise in the workplace can lead to permanent loss of hearing appears to have first emerged during the 1870's with the observations of English physicians (Roosa & St John 1873) in regards to "Boilermakers' Deafness", but a critical mass of patients with noise-induced hearing loss did not emerge until World War I. Shortly before World War I, German researchers were on the cutting edge of understanding noise-induced hearing loss (Hawkins 1976), but their progress was limited by not having effective technology to measure sound or to evaluate hearing sensitivity. Both technologies became available in the U.S. and U.K. during World War II. At the Harvard Biological Laboratory, Dr. Hallowell Davis' wartime experiments in noise-induced hearing loss were facilitated by the availability of the sound level meter and the audiometer (Western Electric 6-B). In addition, the burst of research initiated by Bell Laboratories and other innovators in electro-acoustics during the inter-war period allowed access to oscillators, amplifiers, attenuators and earphones of sufficient quality for scientific work.

At the end of WW II, the U.S. had a legacy of veterans with hearing loss, an active duty military force which was continuing to develop hearing loss, and a military budget with the luxury to address the problem. Consequently, world leadership in this stage of regulation came out of the U.S. Department of Defense. The Air Force published the first hearing conservation regulation which set limits to noise exposures from jets and rocket power plants, and mandated audiometric testing procedures (US Air Force 1948) and the Navy published a comparable regulation (US Navy 1953). DoD funded a group of experts to come together as the Armed-Forces National Research Council Committee on Hearing and Bio-Acoustics who issued their first report in 1954 (CHABA 1954). In October 1956, AFR 160-3 was updated and titled, "Hazardous Noise Exposure". This publication became the first recognized comprehensive hearing conservation program (HCP), both within and outside the military and served as the template used by successive government and non-government organizations for establishing HCP's within their respective agencies.

The first U.S. legal limits for industrial noise exposure were not written into the Walsh Healy Public Contracts Act until 1969. This long standing resistance of the U.S. industrial base to noise regulation was aided and abetted by two scientific issues. The first was the definition of "normal hearing." European data on the sensitivity of the healthy young ear showed greater sensitivity than U.S. data. This resistance was broken through political maneuvering by the Executive Secretary of CHABA, a maneuver referred to as "tricky Hallowell's end run" (Washington University 1977).

The second scientific issue was the mathematical model used to predict hearing loss. In AFR 160-3, the U.S. Air Force adopted a model published by W.A. Rosenblith and K.N. Stevens in 1953 who adopted their model from earlier work by Dr. Karl Kryter in 1950 on using the "critical band concept" as a predictor of hearing hazard. The limits specified by AFR 160-3 for life-time exposures to broad band noise included four octave bands: 300-600. 600-1200, 1200-2400. and 2400 to 4800 Hz. The risk of hearing impairment was stated to be slight if the octave-band level did not exceed 85 dB, but to be excessive at 95 decibels (dB) Within the private sector, the mathematical model adopted in AFR 160-3 was considered to be inadequate. For example, in 1954, an exploratory committee (Z24-X-2) of the American Standards Association surveyed all available data on hearing loss among the industrial workforce and concluded that the data could not be sufficiently validated for regulating industrial noise exposures of the U.S. workforce.

The mathematical model of hearing loss which became incorporated into the 1969 amendment to the U.S. Walsh-Healy Act required that hearing protection be worn when average noise levels exceeded 90 decibels, A-weighted (dBA) in an 8 hour period (using a 5 dB exchange rate), and when impulse/impact noise exceeded 140 dB Peak. In 1971, this standard was incorporated into the Occupational Safety and Health Act of 1970, eventually leading to the OSHA Hearing Conservation Amendment in 1983. The theoretical basis for this model was the observation by Dr. W. Dixon Ward and others that the amount of temporary threshold shift at two minutes after the cessation of an exposure to a continuous noise (TTS_2) could be mapped onto the amount of permanent threshold shift (PTS) among factory workers after a lifetime of exposure to workplace noise of a comparable spectrum and level. In laboratory experiments, recovery from TTS_2 was observed to proceed as a function of the logarithm of post-recovery time, and experimentation with different exposures led to the 5 decibel rule. Thus, an 8 hour exposure to 90 dBA was considered to be equally hazardous as a 4 hour exposure to 95 dBA and a 2 hour exposure to 100 dBA. The mathematical model was clearly superior to the Rosenblith-Stevens model, and in 1970, the Navy adopted the OSHA noise standard as part of their HCP in BUMEDINST 6260.6B, mandating enrollment in HCPs when the noise levels exceeded 90 dBA.

Subsequently, dozens of laboratory tests of the 5 dB rule in which multidisciplinary teams looked at the behavioral thresholds, electrophysiological functioning and cochlear histology of noise-exposed animals failed to demonstrate the reliability of the 5 dB time-intensity relationship, and the majority of experts came to support a 3 dB rule for continuous noise exposures, which is known as the “equal energy rule” or “equivalent noise level (Leq).”

Regulating Community Noise Exposures

Quantitative national laws for community noise tend to begin at the municipal or provincial level prior to enactment of national occupational noise laws, later culminating in national community noise guidelines. For example, the U.S. Congress passed the Noise Control Act in 1972, five years after the occupational noise amendment to the Walsh Healy Act. Japan’s Occupational Health Association set down permissible noise criteria consisting of three band levels (500 – 2000 Hz) in 1966; the Basic Law for Environmental Pollution was issued in 1968 with guideline values for general environmental noise, aircraft noise and Shinkansen railway noise in 1971, 1973 and 1975, respectively. Although South Africa had provided community noise guidance to local jurisdictions in the Environment Conservation Act of 1989, their first national noise law was the Occupational Health and Safety Act of 1993. Australia published the National Code of Practice for Noise Management and Protection of Hearing at Work in 1992 but did not introduce the Sydney Airport Demand Management Plan until 1997.

As with the third stage of Maslow’s hierarchy, the focus of most community noise regulations is the family and community and, typically, the first sources to be addressed are motor vehicles and aircraft.

The historical record suggests that the first country to consider a methodology for regulating the noise of motor vehicles was the U.K. in 1934 (Berry 1998). Interrupted by World War II, National Physical Laboratory researchers did not return to this subject until 1959. In the meantime, the growth of the commercial airline business, particularly in the U.S., led to a new regulatory challenge.

The history of regulations for aircraft noise began with a single question asked (at the municipal level) by the New York Port Authority in 1956, "How loud is the Boeing 707 jet aircraft compared with the propeller-driven airplanes which have been using the New York International Airport at Idlewild, now JFK, Airport?" (Beranek 2007). The Boeing Company, which had compared the noise levels of both types of aircraft using the linear scale of the sound level meter, concluded that there was not a significant difference between aircraft. However, the acoustical engineering firm, Bolt, Beranek and Newman, which employed a psychologist, Dr. Karl Kryter, to compare the two types of aircraft, concluded that the jet aircraft would be perceived as significantly louder than the propeller-driven aircraft. Kryter based his analysis on the loudness model developed by another psychologist, Dr. S.S. Stevens of the Harvard Psycho-acoustic Laboratory. This application yielded the basic measure, Perceived Noise Level (PNL) which was later improved to become the Effective Perceived Noise Level (EPNL) and incorporated into a technology for land-use planning, Noise Exposure Forecast (NEF).

When, sixteen years later, the U.S. Congress authorized the US Environmental Protection Agency to regulate community noise, EPNL was set aside in favor of a more convenient European approach, the Equivalent Level, a measure which achieved nearly global acceptance toward the end of the 20th Century.

Protecting the Most Vulnerable

As a human matures to a stage where he or she experiences self esteem, a concern for others, particularly for the most vulnerable, also emerges. Similarly, as a safe and secure society matures, there is a growing concern for the most vulnerable members of that society. In regards to noise exposures, two vulnerable groups are children and people who are "noise-sensitive."

Within the U.S., the first experimental demonstration that noise has an adverse impact on children in classrooms was published in 1932 (Hartmann 1946), but over 25 years passed before a municipal government in the U.S. used its regulatory powers to protect children from noise (Bronzaft 1981). At the U.S. Federal level, the USEPA never addressed the needs of this vulnerable group, despite a credible body of scientific literature. Not until the adoption of the Americans with Disabilities Act (ADA) of 1990 was there an opportunity for noise regulation benefiting children. The trigger was a petition from a parent of a child with hearing loss who requested that the ADA Accessibility Guidelines be amended to include acoustical standards for classrooms. In June 1998, the ADA Board requested public input on this issue, a request answered by the Acoustical Society of America. The result was American National Standard S12.60-2002 on Classroom Acoustics. Although the standard is voluntary, it was written to be easily incorporated in building codes, and some U.S. cities and states have done so.

As to the needs of the approximately one-in-five adults who can be categorized as "noise-sensitive", there has been no activity whatsoever by any level of government within the United States. With the exception of an influential study by an American psychologist in the late 1970's (Weinstein 1978), the research in this area has been dominated by scientists from Europe and the Western Pacific regions. A search of the American Psychological Association's PsycNet data base suggests that the earliest reference to noise sensitivity came from a Spanish journal (Suils 1942), but the first serious consideration of the subject appears to have developed in the UK (Broadbent 1972).

Although it would be economically infeasible for any society to tailor community noise regulations for this most vulnerable segment of the population, it is still possible to give consideration to the noise-sensitive within a regulatory environment. For example, the Sydney Airport supplements Australian Noise Exposure Forecast maps with maps showing areas where the levels of individual flights are in excess of 70 dBA (Southgate 2000). These maps include information on the number of daily flights and the times of day when the flights occur. Although such maps are not used to prohibit people from living in a noise-exposed neighborhood, the information facilitates noise-sensitive persons in making informed decisions about choosing a residence. This approach to protecting the noise-sensitive individual is consistent with the political philosophy known in the U.S. as "libertarian" government.

Preservation of Natural Quiet

The preservation of the natural quiet and natural soundscapes is a relatively recent development in noise regulation. It is the last stage of development, and it is unlikely to be undertaken unless a country is relatively wealthy and contains a critical mass of citizens who will lobby to preserve natural quiet. Anecdotal evidence suggests that creativity and spontaneity, characteristics of Maslow's self-actualization stage, are important to these citizens.

Within the U.S., the initiative for the regulation of noise in quiet outdoor areas came from Public Law 100-91, The National Park Service Overflights Act of 1987. This initiative was driven by citizens concerned about Grand Canyon National Park, which, within the span of a single generation, has suffered visual degradation from air pollution and noise pollution from tour aircraft, particularly helicopters.

The passage of PL 100-91 led to a burst of creativity among experts in noise regulation. Up to that point, noise regulations had been focused on achieving a specific decibel value while following a measurement procedure prescribed in a national or international standard. For the regulation of natural quiet, there cannot be a single number. In Table 4-1 of its Guidelines for Community Noise, the WHO recommends that existing quiet outdoor areas should be preserved and that the ratio of intruding noise to natural background sound be kept low. This goal precludes using Leq, because a single value cannot preserve the fine structure of the soundscape.

With two decades having passed since the passage of PL 100-91, it is clear that some progress has been made. The noise signatures of touring aircraft and helicopters in U.S. National Parks have been greatly reduced. New computer models have been introduced which provide more accurate predictions of the spectra of aircraft at longer distances than had been available from the older computer models used to calculate average noise levels around airports (e.g. the U.S. Federal Aviation Administration's INM). Measurements and analyses of the propagation of sound through various terrains have been published, to include studies of natural masking sounds (e.g. wind in the trees). Because of the large expanse of U.S. National Parks, National Forests and designated wilderness areas, there is a growing consensus that management and preservation of the soundscape can only be achieved through computer modeling. Using Geographical Information System (GIS) technology, it has been demonstrated that the probability of noticing highway traffic, rail traffic or jet aircraft traffic during the daytime can be calculated by county across the entire U.S. (Miller 2003). In Europe, which has relatively few areas of natural quiet compared to North America, the emphasis has been on a companion concept, the soundscape. The technology for the analysis of soundscapes is applicable to urban as well as rural areas (Schulte-Fortkamp et al. 2007).

Lessons learned in the preservation of natural quiet and soundscapes are applicable to unique acoustic environments, such as found in Australia, Africa and South America. To date, grass roots efforts in this direction have been sporadic (and undocumented in published literature). Examples include an attempt to address the impact of the noise from tourist boats in the Periyar Tiger Reserve in India (Sidhu & Sebastian 1998) and activism over the noise of helicopter flights in the Capertee Valley, New South Wales, Australia (Hut News 2007).

CONCLUSIONS

Within the U.S., the development of noise regulations followed the sequence outlined in Table 1. Specifically, Stage 1 (sleep disturbance) took place during the period 1865-1930, Stage 2 (hearing loss) during the period 1953-1969, Stage 3 (community) in 1972, Stage 4 (protection of the most vulnerable) in 1981, and Stage 5 (Protection of natural quiet) in 1987. Similar sequences of development have been observed among many of the countries in the European and Western Pacific regions. It is logical to expect that this sequence will be followed in other nations. At the same time, developing countries have the opportunity to benefit from the lessons already learned from successes and failures in Europe and North America.

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