An Overview of Noise Related Health Effects

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This paper attempts to summarize those aspects of noise related to health. In a field in which technology is advancing rapidly and where research into noise-induced bioeffects is unable to keep pace with these advances, no attempt has been made to provide details. Instead, an outline of current knowledge in each of the areas concerned and the direction of further research required will be presented. It is planned to publish a document on this background information and to follow it with specific criteria on each of the various health effects of noise.

Much of the impetus for Health and Welfare's involvement comes from the fact that health criteria for noise are largely lacking in Canada, and so noise control has proceeded in a largely uncoordinated fashion, resulting in regulations and bylaws that not only differ across Canada but in some cases are drafted in technically meaningless terms. With more and more reports on the effects of noise becoming available and also workers compensation benefits to employees suffering noise-induced hearing loss increasing rapidly, there is a great need for coordination in noise control. Producing health criteria on noise is one activity towards achieving this goal.

Noise can affect the ability to communicate and/or understand speech and other audio-messages. This may be due to previous impairment of the hearing mechanism or as a result of sufficiently high background noise that speech cannot be understood by the listener. In addition to the direct effect of noise on the auditory mechanism, there are at least three other neural systems that may be affected. These non-auditory effects are not well understood at the present time, but should not be neglected.

Hearing Loss

We will begin by looking at the effects of noise on hearing. Hearing loss may be defined as any reduction in the ability to hear from that of a normal person. There are two general categories of hearing loss: (1) temporary hearing loss (temporary threshold shift or TTS), and (2) permanent hearing loss (which may occur as a result of the aging process, disease, injury, or exposure to loud noises over a long period of time). When from the latter cause, it is generally referred to as noise-induced hearing loss or Noise-Induced Permanent Threshold Shift (NIPTS).

Some factors which create difficulty in assessing the amount of hearing loss caused by noise exposure are: (1) individual susceptibility, (2) presbycusis and (3) sociocusis.

Hearing impairment is a term developed by the American Academy of Ophthalmology and Otolaryngology (AAOO). In 1959 they devised the following formula (see next slide) for assessing a person's impairment of hearing which is still widely used. This formula assumed: (1) the frequencies 0.5, 1, and 2 KHz cover the range of primary importance for hearing and understanding speech; (2) they are given equal weight, and it is the average threshold shift at these three frequencies that is used to measure a person's ability to understand everyday speech; (3) "Impairment" begins after a person has lost an average of 25 dB at the speech frequencies; (4) each decibel loss above 25 dB constitutes 1.5% impairment, so that a loss of 92 dB at the speech frequencies constitutes total impairment.

The problem with this definition is that under very noisy conditions the three and four KHz frequencies become very important and these are not covered by the AAOO formula. This problem is widely recognized. Also this type of definition is really more concerned with hearing as applied to speech communication in optimal conditions, and does not look at the quality of hearing required to enjoy a good orchestra, for instance.

Relation of Hearing Loss to Noise Exposure

Baughn conducted a study in the United States in 1973 that gives strong statistical evidence in favour of an 85 dBA noise limit. A survey of 14 million people in selected industries in the States showed that at that time 1.7 million (12%) would suffer hearing impairment after 40 years of work. If a 90 dBA standard was rigorously enforced, the number would drop slightly to 1 million (7%) whilst an 85 dBA standard would reduce the number that would suffer hearing impairment after 40 years to 200,000 (1-1/2%). The maximum noise limit that would completely eliminate hearing impairment at 4 KHz (the frequency at which the ear is the most sensitive), for the median of the population, is considerably less than 85 dBA. Figure 1 shows this "no effect" level as determined by a number of recent studies.

Thiessen in his report "effects of noise on man" has carefully analyzed data relating hearing loss to noise exposure. His data are mainly based on the EPA Report on the health hazards of noise, which includes results obtained world-wide, and whose general validity and consistency were examined and weighted accordingly. Thiessen's calculation of maximum Noise-Induced Permanent Shift (NIPTS) over 40 year exposure in dB is given in Figure 2. Dr. Thiessen does not make specific recommendations in his report for an occupational noise limit, but he does strongly recommend a 3 dBA higher level for each factor of 2 reduction in exposure time (as opposed to the presently used 5 dBA).

There is at least as much evidence for 3 dBA as 5 dBA. Further the 3 dBA level represent a factor of 2 change in energy. This is supported by recommendations made by the Health and Safety Executive for British Legislation. Some assessment is made of the effect of impulse (very short duration) noise by Dr. Thiessen but, as he says, the areas of ignorance are still great.

Bruel reports in his article "Do we measure damaging noise correctly?" that in the iron and steel industry there are significant peaks of short duration noise containing a significant amount of energy in the 4-6 kHz frequency range. He suggests that since these frequencies are amplified by the outer and middle ear, this explains why hearing loss always starts in this frequency range. The impulse noises found in this industry and similar noise producing environments such as railway shops, may account for the higher risk of hearing loss than that given by the total noise exposure criterion now used.

This view is supported by the World Health Organization who recommends further research in this area.

The premise that occupational noise limits should ensure protection from any measurable degradation of hearing acuity if they are to adequately protect public health and welfare, appears a valid one.

There has been a great deal of controversy over the appropriate limits to be set, particularly in the United States. This is primarily because both the adequacy and interpretation of the scientific data have been disputed.

There is nevertheless enough evidence supporting lower occupational noise limits to make it appear worthwhile revising regulations now. More data is required to assess both the effects of impulse noise and also if there is a better way than the present noise dose criterion to protect hearing.

Audiometric (hearing) testing is conducted for five main reasons:

1. The identification of hearing impairment.

2. As need to the diagnosis of the problem.

3. As a guide to the management of the patient once the problem is found to exist.

4. Monitoring the hearing status of the individual.

5. Indicator of the efficacy of the hearing conservation program.

An audiometer is a frequency-compensated, audio-signal generator. It produces pure tones at various frequencies and intensities for use in measuring hearing sensitivities. It enables the measurement of the minimum audible field for each ear at certain prescribed frequencies. A typical audiogram is shown in Figure 3. The main purposes of such hearing tests are to identify existing or developing hearing impediments and to monitor the effectiveness of hearing conservation programs. The former is referred to as diagnostic audiometric testing and the latter as industrial audiometric testing.

A number of variables exist which can affect the accuracy of audiometric measurements. These are summarized in Figure 4. Not only must care be taken in the type and calibration of the equipment, but also in the test location and procedures. In particular, the instructions to the person taking the test must be carefully given. There are, however, physiological and psychological variables that cannot be controlled and which contribute to the variation in response.

Careful control of audiometric testing is necessary to provide the necessary precision by which hearing loss may be assessed. Whilst over the years this has become better understood and carefully controlled by better equipment, operator training and procedures, improvements in measurement precision are still required.

Personal hearing-protective devices are acoustical barriers that reduce the amount of sound energy transmitted to receptors in the inner ear. The sound attenuation capability of the hearing protective device at threshold may be measured by the difference (in decibels), between the threshold of audibility for an observer with hearing protectors in place (test threshold), and the measured hearing threshold when his ears are open and uncovered (reference threshold).

Hearing protective devices used today are generally inserted into the ears or ear muff types. The insert-type protector attenuates noise by plugging the external ear canal, whereas the ear muff type protector closes the auricle of the ear to provide as acoustical seal. Their effectiveness depends on several factors that are related to the way in which the sound energy is transmitted through or around the device.

In selecting a personal hearing-protective device, several design factors should be considered including the performance, comfort, communications requirements, and appearance.

There are Canadian and other standards for the measurement of the effectiveness of hearing protectors. At the moment, however, none of them adequately account for the importance of the hearing protectors fit to the ear, a subject for further studies. There is also a need for a long term study to assess the effectiveness of the use of hearing protectors in conjunction with careful audiometric testing.

Speech Interference

Speech interference is one aspect of the phenomenon of masking. Masking is an interaction of two acoustics stimuli where one of them:

1. Changes the quality of the other.

2. Shifts its apparent location or loudness.

3. Makes it completely inaudible.

Speech intelligibility and articulation index are two measures of speech interference. They provide a measure of the amount of conversation an alert listener is likely to comprehend at a certain distance. The problem with measures such as these, however is that they do not fully account for the fact that speech consists of a complicated sequence of sounds of varying intensity and frequency distribution. Since speech is not uniform, some sounds will be masked by certain sources but not others. This varies with time, as speech varies in intensity and frequency content with time even in a steady sound field.

Speech interference can be a danger - (when masking warning or emergency signals), or it can be a useful tool, such as masking systems in offices that cover up disturbing noises. It can also be a form of annoyance.

Effect of Noise on Sleep

The effect of noise on sleep is a highly important health effect. We are fortunate in that the acoustics section at National Research Council is amongst the foremost in this field. The following information is based on Thiessen's report on the "Effect of noise on man".

It is known that sleep may be disturbed by noise and that some groups (such as the old, middle-aged and sick) are particularly sensitive to these effects. Sleep is thought to be a restorative process during which the organs of the body renew their supply of energy and nutritive elements. Survey data also indicate that sleep disturbance is often the principal reason given for noise annoyance. Sleep interference thus constitutes a common health hazard.

The interference of sleep is viewed with concern by the individual and health authorities alike. The individual is aware of mainly two effects - a noise induced delay in falling asleep when first retiring, and being awakened by noise during the night.

Medical authorities know that there are different stages of sleep - usually labelled stages 1, 2, 3, 4 and 1 (REM), and that appropriate amounts of sleep are necessary. Noise may cause a shift from a deep level of sleep to a shallower one, thus disturbing the normal apportionment of each stage. Furthermore, sleep progresses during the night in a cyclical pattern consisting of about 3 to 7 cycles, depending on the individuals. Noise may disrupt the cyclical pattern of sleep. Some believe that interferring with this cyclical pattern is in itself deleterious.

In order to monitor sleep in detail, sleep laboratories, such as that at the National Research Council, use the electroencephalograph to monitor sleep. Two or more electrodes are attached to appropriate parts of head and the electrical signal from these are recorded on a chart recorder or on magnetic tape, and these signals may be analyzed by eye or computer. In this way the aforementioned effects of noise on sleep continue to be quantified by laboratories in greater detail.

Non-Auditory Physiological Responses

There is a substantial body of data indicating that noise may have non-auditory physiological effects. The major effect of noise in this area is as a general biological stressor. Significant adverse health consequences are produced by cardiovascular and endocrine effects. Major cardiovascular diseases account for over half of all deaths in North America and noise-induced stress is a contributing factor. A retrospective study carried out in the United States by NIOSH (1973), of medical records of workers for a 5 year period 1966-1970 (Figure 5) indicate a substantial increase in diseases for workers in a high noise environment compared to workers in a low noise environment. There is however, at present, a lack of conclusive evidence for these effects at noise levels of less than those which will cause hearing loss. Further research is required in this area to establish the impact on society.

Annoyance and Other Psychological Effects

Although a highly important area of the effects of noise, this subject is beyond the scope of this paper, which is restricted to more direct effect of noise on health.

Summary

This paper has attempted to summarize the major health effects of noise. It is proposed that there is a great need for health criteria, coordination of Federal noise control programs, revision of present legislation and suggesting areas in which new legislation should be presented. It would seem appropriate that the Department of National Health and Welfare should provide basic health criteria in both occupational and environmental noise. Since noise legislation is enacted primarily to reduce adverse health effects, this would assist in providing coordination in Canadian noise control programs.

"NO EFFECT" LEVEL OF NOISE

(AT 4 KHZ FOR THE MEDIAN OF THE POPULATION)

W. BURNS AND D.W. ROBINSON	78 dBA
W.L. BAUGHN	78 dBA
PASSCHIER - VERMEER	76 dBA
D. WARD ET AL	81.5 dBA
G. THIESSEN	72 dBA

Figure 1

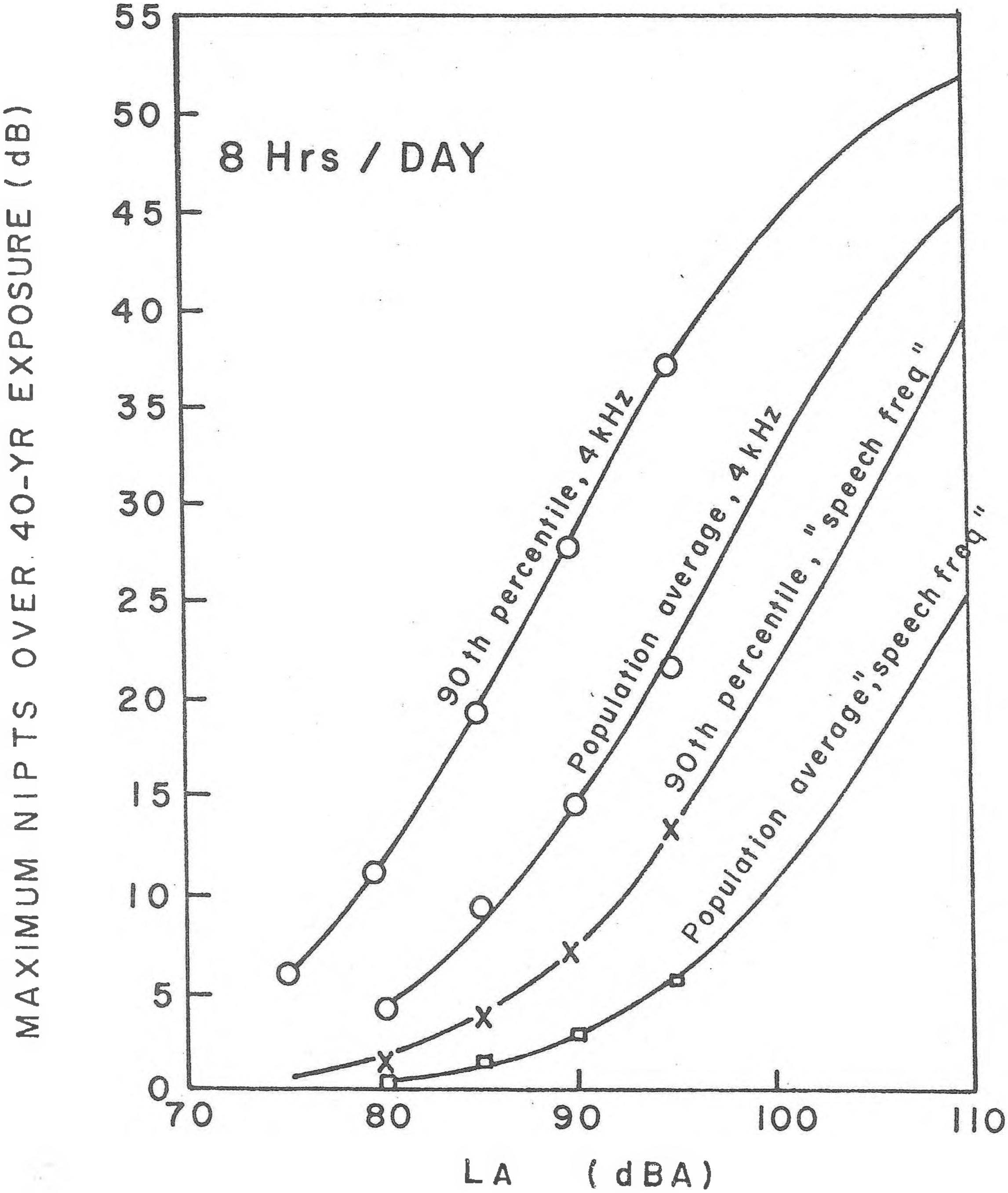
8 Hrs / DAY
MAXIMUM NIPTS OVER 40-YR EXPOSURE (dB)
LA (dBA)
55
50
45
40
35
30
25
20
15
10
5
0
70
80
90
100
110
90th percentile, 4 kHz
Population average, 4 kHz
90th percentile, "speech freq"
Population average, "speech freq"

Figure 2

AUDIOGRAMS

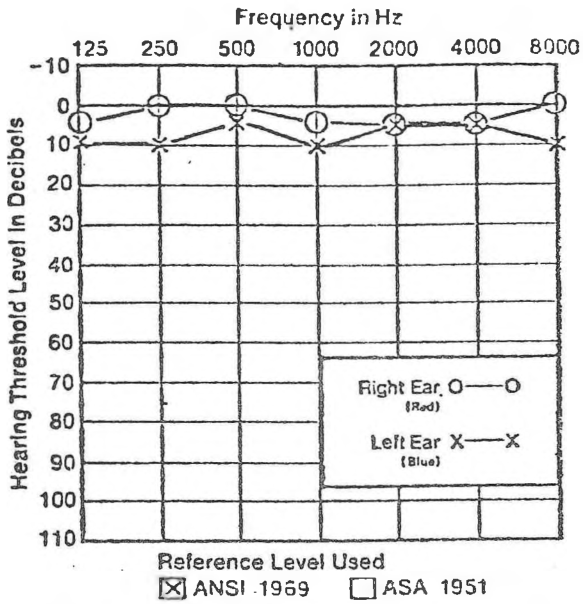

Fig. 25–1.—A typical manual audiogram showing hearing thresholds within the normal range.

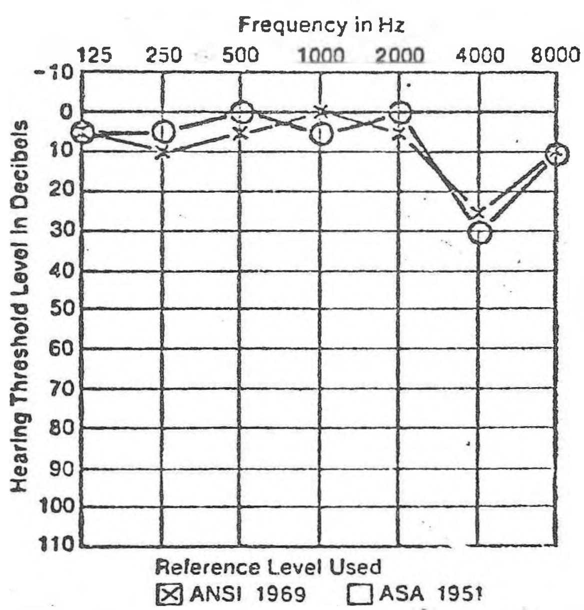

Fig. 25–2.—A typical manual audiogram that was taken immediately after the employee was exposed to excessive noise. Compare the hearing threshold levels shown here with those plotted on the audiogram shown in Figure 25–1. Note the sharp drop at 4000 Hz.

Figure 3

Causes Of Audiometric Changes

Physical Variables

Improper placement of earphones
Ambient noise levels in test room
Equipment variables, such as accuracy of attenuator steps, type of earphone cushions, hum, noise, etc.

Physiological Variables

Age and sex
Pathology of the auditory organs
General health of subject
Temporary threshold shift
Tinnitus and other head noises

Psychological Variables

Motivation of subject
Momentary fluctuations of attention
Attitude toward the test situation
Personality attributes
Intellectual factors
- Comprehension of instructions
- Experience in test taking of any sort

Response conditions
- Type of response required of subject, i.e., button pressing, finger raising, verbal response, etc.

Methodological Variables

Testing technique used
Time interval between successive tests
Instructions to subjects
Order of presentation of frequencies

Figure 4

Numbers of Diagnosed Disorder By Medical Category For Workers in High and Low Noise Groups For 5 Year Period 1966-70

Category of Diagnosed Disorder	Number Afflicted		Number of Occurrences	
	High Noise	Low Noise	High Noise	Low Noise
Respiratory	331	146	2152	590
Allergenic	196	86	358	118
Musculo/Skeletal	75	31	104	47
Cardiovascular	64	37	114	70
Digestive	50	21	66	30
Glandular	39	10	48	14
Neurological	34	11	49	29
Urological	29	14	40	15

Figure 5