Special Report

Noise Exposure Guidelines

Don't Let Noise Insidiously Steal Your Precious Hearing

Neil G. Bauman

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Introduction

Over the years I have been asked a lot of questions regarding noise exposure and how it relates to hearing loss. Most people know that you need to protect your ears from loud sounds if you want to preserve your hearing over your lifetime. However, there is a lot of confusion about just how much sound exposure is safe for your ears and at what level sounds begin to cause hearing loss.

For example, a young man asked me, "What is the safe range of sounds for human ears? How long can a person be in a dangerous range before damage occurs? Are we talking about hours, minutes or just seconds?"

In a similar vein, a hard-of-hearing person wanted to know, "How much noise can my ears stand without causing additional hearing loss? Should I wear ear protectors when I am around noise or not?"

Another person wanted to know why he was still losing more of his hearing even though he was following the Occupational Safety and Health Administration (OSHA) regulations regarding wearing hearing protection.

Yet another puzzled person explained, "While doing research, I have found that many websites have different views on safe exposure times regarding loud sounds. Some web sites say that you should not be exposed to noises that exceed 80 dB for more than 8 hours, others say 85 dB and some say 90 dB. I don't know which one is right." Then he asked me, "Do you have a reliable safe-exposure time-table?"

These are all excellent questions and reflect the lack of knowledge and high degree of confusion concerning louder sounds causing hearing loss and what we can do to protect our precious hearing from the ravages of noise.

One important reason for the various conflicting noise standards is because there isn't a single safe threshold for everyone below which noise has no effect. This is because each of us both hear and perceive sounds differently from each other. This variation is both in sensitivity to given frequencies of sound and to given levels of sound. Thus, a sound at a given level and frequency that may damage my hearing may not damage your hearing (and vice versa).

Over the years, researchers have developed a number of guidelines to try to help us avoid noise-induced hearing losses by limiting noise exposure for the theoretical "average" person but none of them work perfectly for everyone since none of us is that theoretical average person.

Another reason for the various noise guidelines is that some of these guidelines apply to everyone while others exclude certain classes of people or people that are more sensitive to noise damage than the general population.

Furthermore, each of these different noise-exposure guidelines vary because they have different purposes. Therefore, unless you understand the purpose behind each of these noise guidelines, you can easily get confused about which one best applies to your ears in a given situation.

Note that throughout this article, I will be using the words "sound" and "noise" interchangeably since they are really the same. It's just that noise is unwanted sound, and sound is wanted noise. The truth is that loud sounds whether wanted or unwanted still can cause hearing loss.

Understanding Sound Exposure Tables

Weighted Scales

You measure sound loudness with a sound meter. The sound meter shown in Fig. 1 can measure sounds between 30 and 130 decibels. When measuring sound levels, be aware that sound meters typically have two weighting scales, the "A" weighted scale and the "C" weighted scale. Normally

Fig. 1. VLIKE Model VL6708 digital sound meter.

you use the "A" weighted scale. It basically discounts low-frequency noise and focuses on sounds more in the speech range where your ears are most sensitive to sound.

In contrast, you would use the "C" weighted scale for noise sources with a large proportion of low-frequency sounds, very intense levels of sound and/or high intensity impulse noise such as may be heard in in factories and on construction sites.

Notice the "A" weighting button (A/C) second button from the bottom on the right side and the fast/slow button (center). Normally you would use the "A" weightied scale and the "slow" response setting unless you are trying to measure short-lasting peak sounds.

This SPL Meter (Fig. 2) is one of the 20 or so Sound Meter Apps I have on my iPhone. This meter has the "A" or "C" switch on the left below the meter and the fast/slow response switch below it. Typically, you would compare/calibrate any on-line meter with a stand-alone factory-calibrated meter like the VLIKE meter (Fig. 1) before trusting it to give accurate sound level measurements although some sound meter apps are surprisingly accurate from the get go.

Fig. 2. The SPL Meter App for an iPhone.

Understanding Decibels (dB)

In order to understand how loud sounds need to be in order to damage your hearing, you need to understand the basics of decibels. The intensity of sounds is measured in decibels. The unit of sound intensity is the Bel, named after Alexander Graham

Bell. Since this is a large unit, we normally use the decibel, which is a tenth of a Bel. It is abbreviated dB (with a small d and a capital B since the "B" is the abbreviation for Bell's name).

Zero dB is not the absence of sound. Rather, it is the faintest sound that a person with normal hearing typically can detect. If your ears are even more sensitive than "perfect hearing" (0 dB) on your audiogram it shows as a negative number above the 0 dB line. Some younger people can hear above -10 dB.

When I was younger, and because I had an extreme reverse slope hearing loss, I could hear up to an incredible -30 dB, which is far beyond what audiometers are set to measure and yet I was the "deaf guy".

To give you an idea of sound levels, a typical conversation measures around 50 to 65 dB. According to my sound meter, when I am giving presentations, I typically speak a bit louder than normal—around 65 to 70 dB. In my house when everything is quiet, my sound meter still reads around 35 dB, yet I hear nothing even with my hearing aids set to their normal volume, so you can imagine how soft a sound at 0 dB must be.

The sound of traffic on a busy road reaches about 80 dB. Sound discomfort typically begins around 100 to 110 dB, but if you have loudness hyperacusis you could experience discomfort or pain to sounds at 50 dB or even lower. The threshold of pain typically begins around 110 to 130 dB.

Sustained noise louder than 70 dB can result in gradual hearing loss over your lifetime, while very loud sounds—louder than 120 dB or so can cause immediate hearing loss.

Note that decibels are not linear units of measurement. Rather, they are logarithmic units just like the open-ended Richter scale used for measuring earthquakes. Furthermore, decibels are ratios, just like percentages are ratios—not discrete numbers. Thus, a 10 decibel increase on the logarithmic decibel scale represents a ten-fold increase in sound energy.

This means a sound intensity of 10 dB takes ten times the energy to produce as a sound intensity of 0 dB. Likewise, a sound intensity of 30 dB takes ten times the energy to produce as does a sound intensity of 20 dB while a sound intensity of 30 dB takes 1,000 times the energy needed to produce as does a sound intensity of 0 dB.

Don't get confused between the terms "sound intensity" and "sound volume". Sound **intensity** is the **energy** (power) needed to produce a given level of sound measured in decibels, while sound **volume** is the level at which we **perceive** the resulting sound.

Table 1 shows the energy needed to produce a given intensity of sounds. These numbers rapidly get enormously big.

Table 1 Relative Energy Needed to Produce Various Intensities of Sound

Decibel Value	Increase in Sound Intensity
0 dB	—
10 dB	10 times the sound intensity
20 dB	100 (10 x 10)
30 dB	1,000 (10 x 10 x 10) etc.
40 dB	10,000
50 dB	100,000.
60 dB	1,000,000
70 dB	10,000,000
80 dB	100,000,000
90 dB	1,000,000,000
100 dB	10,000,000,000
110 dB	100,000,000,000
120 dB	1,000,000,000,000 (1 trillion)

As you can see, if you had a profound hearing loss of 120 dB at a certain frequency, in order to hear a sound at that frequency, the sound intensity would have to be 1 trillion **times** as intense, that is, it would require 1 trillion times more energy to produce it as would be needed for a person who had "perfect" hearing and thus could hear this same sound at an intensity level of 0 dB.

I find it totally amazing that God made our ears so incredibly sensitive that they can hear a sound at 0 dB, yet they are so robust that they are not instantly smashed with a sound 1 trillion times as intense.

Fortunately for us, our ears don't perceive volume linearly, rather, they hear logarithmically. This means that although the sound intensity, i.e. the energy needed to increase a sound by 30 dB (10 x 10 x 10 = 1,000) takes 1,000 times more energy to produce the sound, we only perceive it as 8 times as loud (2 x 2 x 2 = 8).

Table 2 shows the increase in sound intensity between 0 dB and each of the values listed and beside each value is how much louder we perceive (hear) that sound.

Table 2 Sound Intensity vs. Perceived Volume

Decibel Value	Increase in Sound Intensity	Perceived Increase in Sound Volume
0 dB	—	—
10 dB	10 times the sound intensity	2 times as loud
20 dB	100 (10 x 10)	4 (2 x 2)
30 dB	1,000 (10 x 10 x 10) etc.	8 (2 x 2 x 2) etc.
40 dB	10,000	16
50 dB	100,000	32
60 dB	1,000,000	64
70 dB	10,000,000	128
80 dB	100,000,000	256
90 dB	1,000,000,000	512
100 dB	10,000,000,000	1024
110 dB	100,000,000,000	2048
120 dB	1,000,000,000,000	4096

Note this well. Since our ears **perceive** sound logarithmically, we do not perceive a sound of 120 dB as being 1 trillion times louder than a sound of 0 dB. Rather, as Table 2 shows, we perceive it as 4,096 times louder.

Furthermore, note that this is the theoretical relationship. In actual fact, since we are all different, we each perceive the volume of sound somewhat differently than this theoretical figure and also somewhat differently from each other. That is why one person may comfortably stand a given sound while another person finds it uncomfortably loud and still another person finds it too soft.

Now, let's dig a bit deeper into decibels. If you are used to working with regular (linear) numbers, you will get a shock as working with logarithms look like "funny math".

For example, when adding 20 dB + 20 dB, in other words, multiplying 20 x 2, the answer is **not** 40 dB as you would get if you were using regular linear units, but 23 dB since we are using decibels which are logarithmic numbers.

The important thing to understand and remember is that for every 3 dB increase in sound intensity shown on your sound meter, the energy needed to produce this increase in sound is doubled, or put the other way, when you double the intensity of a sound, the result is always 3 dB greater (see Table 3 in the next section).

This means that if you measure a very loud sound such as 110 dB, just increasing the sound by 3 dB to 113 dB means the energy needed to produce this sound will be twice as much. Thus, in like manner 50 dB + 50 dB = 53 dB and 100 dB + 100 dB = 103 dB.

Now let's try something a bit different. When adding 30 dB to 90 dB the answer is what? I'll give you a clue. It's not 120 dB.

Actually, the result of adding 30 dB to 90 dB is surprise—still 90 dB. Why? Because when compared to 30 dB, 90 dB is 6 orders of magnitude greater—namely 1,000,000 times as intense. Thus, the difference between 90 dB and 90 dB plus 30 dB (90.000001 dB) is so small (0.000001) so as to be negligible.

You can understand this better when thinking of earthquakes and the Richter scale. Do you remember the massive earthquake of 9.2 they had in Alaska back in 1964? Now let's pretend there was another earthquake occurring in the same area at the same time, but it only measured 3.2 on the Richter scale. You wouldn't even feel this small tremor because the massive 9.2 earthquake would totally overpower it since it would be 6 orders of magnitude stronger—namely 1,000,000 times as strong.

That's exactly the way decibels are when adding two significantly-different sound intensities together. I warned you that working with logarithms such as decibels is "funny math".

Converting Decibels to Sound Intensities

This next section is for those of you that are reading this article and would like more in-depth information on converting decibels to sound intensities. Otherwise skip this section.

A person asked, "How do I calculate the difference in sound intensity in decibels between any two sound intensities. For example, how do I calculate the increase in sound intensity between 0 dB and 15 dB or between 52 and 94 dB?"

First, to review, there is a mathematical relationship between decibels (dB) and sound intensities. It works like this. Each 10 dB increase in sound volume results in a **10-fold** increase in sound **intensity** which we **perceive** as a **2-fold** increase in sound **volume**.

Thus, from 0 dB to 10 dB there is a 10-fold increase in sound intensity, just as there is from 10 dB to 20 dB or from 34 dB to 44 dB.

Now let's proceed with the details of how to calculate the differences in sound intensities and relate them to decibel values.

Unfortunately, far too often people assume that there is a simple linear interpolation between any two decibel values. Thus, since there is a 10-fold increase between 10 dB and 20 dB in sound intensity, they assume the increase at the half-way point (at 15 dB in this case) is a 5-fold increase. If you assumed this, you would be wrong. Even hearing health care professionals that should know this don't always get it right.

This is because of the logarithmic relationship between such values. It is not the linear relationship we are used to. Therefore, to find the increase in sound intensity between 10 dB and 15 dB, you first subtract the higher dB value (15) from the lower value (10) which equals 5. Then you divide the result by 10 to get the exponent. Calculating (15 – 10)/10 gives you an exponent value of 0.5. Raising 10 to the 0.5 power ($10^{0.5}$) gives 3.162. Thus, the increase in sound intensity between 10 dB and 15 dB is 3.162 **times** greater (see Table 3).

Table 3 Increase in Sound Intensity from 0 to 10 dB

dB Difference	x-fold Multiplier
0	1.000
1	1.259
2	1.584
3	**1.995 (rounded to 2)**
4	2.512
5	**3.162**
6	3.981
7	5.011
8	6.309
9	7.943
10	10.000

In like manner, to calculate the difference in sound intensity between 52 dB and 94 dB, just follow the same procedure and use the same formula. (94-52)/10 gives an exponent of 4.2 and $10^{4.2}$ = 15,848.9. Thus, the increase in intensity between 52 dB and 94 dB is 15,848.9-fold. To put it another way, it takes 15,848.9 **times** as much energy to produce a sound of 94 dB than it takes to produce a sound of 52 dB.

It's easy to check your work to be sure you are in the right ballpark. You know the difference you are working with is 42 dB (94 – 52 = 42). You already know that for a 40 dB increase, the intensity value is 10,000 times higher (10 x 10 x 10 x 10 = 10,000) and that for a 50 dB increase, the value would be 100,000 times higher (10 x 10 x 10 x 10 x 10 = 100,000). (Refer back to Table 2.) Thus, your answer must lie somewhere between these two values, and sure enough, it does.

To make things simple, in case you don't have a fancy calculator, Table 3 will give you this information.

Note: if you have an iPhone, you have a fancy built-in calculator. Swipe down from the top and you'll see it there with your flashlight, timer and camera. When you hold your iPhone vertically you have a simple calculator. Turn your phone on its side and it automatically switches to a fancy scientific calculator where you have the 10^x and x^y functions you'll need.

In order to use Table 3, just take the multiplier figures for values between 1 and 10 and then move the decimal point to the right one place for each whole 10 dB difference.

Thus, if you want to find the difference in sound intensity between 3 dB and 9 dB, and since the value is less than 10 dB, just read off the value from the table for a 6 dB difference, namely 3.981. Thus, for a 6 dB increase, there is a 3.981-fold increase in intensity.

And if you ever want to calculate how much louder you **perceive** one sound as compared to another, you can do it by using the following formula.

perceived x-fold volume increase = $2^{(\text{ending dB value} - \text{starting dB value})/10}$

Therefore, to find the perceived increase in sound volume between 10 dB and 15 dB, you simply subtract the lower dB value from the higher value and divide the result by 10 to get the exponent (15 – 10)/10 gives you an exponent of 0.5. So far, everything is the same as calculating intensity differences. Now comes the change—you use base 2 rather than base 10. Raising 2 to the 0.5 power ($2^{0.5}$) gives 1.4. Thus, you would perceive the sound as being 1.4 times louder.

In like manner, to calculate the difference in perceived sound volume between 52 dB and 94 dB, just follow the same procedure and use the formula.

(94 - 52)/10 gives an exponent of 4.2. $2^{4.2} = 18.4$. Thus, you would perceive this change in sound as 18 times louder.

Note: Perceived volume varies from person to person so the calculated results may not agree with any given person's subjective results, but it certainly puts you in the right ballpark.

Time-Weighted Average

The safe sound exposure tables we'll be discussing shortly are based on the concept of time-weighted averages (TWA).

You typically use time-weighted averages rather than just measuring the instantaneous sound level unless you are deliberately taking instantaneous peak sound levels. This is because noise is seldom constant in both volume and frequency.

In order to generate safe noise-exposure tables, there are two factors you have to consider—the intensity of the sound you hear and the length of time you expose your ears to that level of sound. Taken together, these two factors give you a time-weighted average (TWA).

The time-weighted average sums sound energy over time. This involves specifying an exchange rate. The exchange rate is the increase in allowable sound exposure level with each halving of sound exposure duration. Most guidelines specify a 3 dB exchange rate since that is how our ears work.

The Equal Energy Principle

The equal-energy principle is used to construct time-weighted average tables for safe sound exposure times at various intensities of sound. In order to keep the time-weighted average the same, whenever you increase the sound intensity by 3 dB you need to cut the time your ears are exposed to that level of sound by half.

The key point is that each line in these tables has the same effect on your ears. Notice that when the sound intensity doubles (increases by 3 dB), the safe exposure time is cut in half as you go down the table line by line. This lets you know how long you can safely expose your ears to a given sound intensity (Table 4).

There are a number of additional factors that go into designing the various sound safety schedules that are in use. These include such things as how long the sound exposure table is designed for, such as 24-hour limits, day/night limits, sound intermittency and the main frequency of sounds your ears are being exposed to.

Table 4 Sound Level Tabel Showing Equal Energy Principle in Action

Average Sound Level	Exposure Time
85 dB	8 hr
88 dB	4 hr
91 dB	2 hr
94 dB	1 hr
97 dB	30 min
100 dB	15 min

The Four Main Safe Sound-Exposure Guidelines

There are four main safe noise exposure guidelines in common use. Each of these different noise-exposure guidelines vary because they use different algorithms to serve somewhat different purposes.

1. The Occupational Safety and Health Administration (OSHA)

The Occupational Safety and Health Administration is a regulatory agency that sets and enforces workplace safety standards. It may surprise you but the OSHA 90 dB (A) standard which is used in the workplace here in the USA does not totally protect against hearing loss, nor is it designed to. The OSHA standard limits time-weighted sound levels in industry to 90 dB or less for 8 hours a day over a 30-year work career. Even so, you will have some degree of hearing loss after that time. Furthermore, it does not take into account all the noise your ears are exposed to at home and from recreational activities such as noisy bars, loud music, using chainsaws, skill saws, snowmobiles, ATVs, shooting guns and rifles, attending ball and hockey games etc. that are not a part of the normal working day, but still damage your ears.

Note that the OSHA standard uses 90 dB as its safe limit for an 8-hour day's exposure to sound, and they use a 5 dB exchange rate, that is, they cut the time in half for every 5 dB above that level.

The problem with this is that as we just saw, sound intensity levels **double** with each 3 dB increase, not with every 5 dB increase, so using the 5 dB exchange rate isn't scientifically valid in the first place. It may look good on paper, and is easy to calculate, but it doesn't reflect reality. However, using this higher 5 dB exchange rate allows for the intermittency of sounds, which reduces risk. The OSHA scale looks like this using a 5 dB exchange rate (Table 5).

Table 5 OSHA Safe Noise Exposure Table

Average Sound Level	Exposure Time
90 dB	8 hrs
92 dB	6 hrs
95 dB	4 hrs
97 dB	3 hrs
100 dB	2 hrs
102 dB	90 min
105 dB	60 min
110 dB	30 min
115 dB	15 min

According to OSHA, unprotected exposure to continuous noise above 115 dB of any duration is not permitted.

(Note that in this and all the following tables, I have rounded the numbers, so the precise figures are slightly different—but this is so much easier to read, understand and remember.)

Also, note that in Canada the equivalent government agency to OSHA is OHSA, the Occupational Health and Safety Act. Don't get them mixed up as OHSA and OSHA look similar, it's just that they have the two middle letters reversed.

2. The National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limits (REL).

The National Institute for Occupational Safety and Health (commonly called NIOSH) focuses on research and recommendations to improve worker safety and health.

The NIOSH recommended sound exposure limits of 85 dB (A) average sound exposure is clearly targeted toward workers whose noise exposures typically last 8 hours a day, 5 days per week. It aims to protect workers from developing a material hearing loss, that is, a hearing loss great enough to impact understanding speech over their working lifetime which is assumed to be 40 years. At average noise exposures of 85 dB, this NIOSH REL standard estimates that 92% of workers exposed 240 days per year for 40 years would be protected from developing a material hearing loss.[1] The NIOSH scale looks like this (Table 6).

Table 6 NIOSH Safe Noise Exposure Table

Average Sound Level	Exposure Time
85 dB	8 hr
88 dB	4 hr
91 dB	2 hr
94 dB	1 hr
97 dB	30 min
100 dB	15 min
103 dB	8 min
106 dB	4 min
109 dB	2 min
112 dB	1 min
115 dB	30 sec
118 dB	15 sec
121 dB	8 sec
124 dB	4 sec

3. The World Health Organization (WHO)

The WHO 80 dB (A) standard limits sound exposure to 80 dB averaged over a maximum of 40 hours per week. This guideline targets the general population whose exposures can occur 24 hours a day, 7 days per week, but with more presumed intermittency. Note that this guideline was set to a level that presumably would avoid any increased risk of permanent hearing loss due to environmental noise exposure and would presumably protect 100% of the population. The WHO scale looks like this (Table 7).

1 Eichwald, 2022. p. 20.

Table 7 WHO Safe Noise Exposure Table

Average Sound Level	Exposure Time
80 dB	8 hrs
83 dB	4 hrs
86 dB	2 hrs
89 dB	1 hr
92 dB	30 min
95 dB	15 min
98 dB	8 min
101 dB	4 min
104 dB	2 min
107 dB	1 min
110 dB	30 sec
113 dB	15 sec
116 dB	8 sec

3a. The World Health Organization's (WHO) 100 dB (A) limit.

The WHO 100 dB (A) venue and event guidelines are for loud venues and events. It recommends a 100 dB (A) average sound exposure limit to 15 minutes at noisy venues such as loud concerts, sports events, etc. It is targeted at adults attending concerts and other loud events and aims to prevent hearing loss by reducing unnecessarily-hazardous sound levels at such events. This 100 dB (A) limit does not, and cannot, eliminate all risk of an individual audience member from suffering sound-induced hearing loss.

Therefore, note that you may acquire hearing loss even at venues meeting this criterion. These guidelines are not necessarily safe, but the WHO did not lower the criterion further because they felt that reducing the sound to a limit that would eliminate hearing risk would be unacceptable to both performers and spectators. Thus, they leave the safe sound limit to 15 minutes at 100 dB whereas their main table sets the limit to 4 minutes.

4. The Environmental Protection Agency (EPA)

The Environmental Protection Agency (EPA) has set their average safe noise level to a level they thought was sufficient to protect public health and welfare against hearing loss with an adequate margin of safety.

The EPA 70 dB (A) standard is the most conservative (and thus the safest) standard at a daily level of 70 dB and considers **all** sounds reaching our ears. It targets the general population whose exposures can occur 24 hours a day, 7 days per week, but with more presumed intermittency. For example, occasional higher noise levels would be consistent with a 24-hour energy average of 70 decibels, as long as there are sufficient lower-level periods of time such that the average sound level remains below 70 dB. It seeks to protect against a hearing change of more than 5 dB at 4 kHz over a lifetime and is designed to protect 96% of the population.[2] This conservative EPA scale looks like this (Table 8).

Table 8 EPA Safe Noise Exposure Table

Average Sound Level	**Exposure Time**
70 dB	24 hrs
73 dB	12 hrs.
76 dB	6 hrs
79 dB	3 hrs
82 dB	1.5 hrs
85 dB	45 mins
88 dB	22 mins
91 dB	11 mins
94 dB	6 mins
97 dB	3 mins
100 dB	1.5 mins
103 dB	45 secs
105 dB	22 secs
107 dB	11 secs
110 dB	6 secs
113 dB	3 secs
116 dB	1.5 secs.
119 dB	0.75 sec
122 dB	0.4 sec

Note that the EPA 70 dB(A), WHO 80 dB(A) and the NIOSH 85 dB(A) REL exposure limits were established to prevent hearing loss. However, their definitions of hearing loss vary across the different guidelines.

Another factor that creates differences across noise exposure guidelines is the level of acceptable risk that is incorporated in the recommendation.

2 Eichwald, 2022. p. 20.

Lower noise limits generally protect more people. However, remember that people differ in their susceptibility to noise damage.

Also note that some of these “guidelines” have the force of law. For example, OSHA and the EPA create legally enforceable noise regulations and standards which set limits on exposure to hazardous noise. In addition, state and local governments may pass legislation to regulate noise exposure.

In contrast, other governmental, professional or standards organizations such as NIOSH and the WHO propose voluntary guidelines and recommendations on noise exposure limits.

I need to emphasize that these standards only apply to the **average** person. If you have more sensitive ears, you could still acquire hearing loss, so don’t take these standards as set in stone. You need to modify them for your ears.

In contrast, some people have what I call “cast iron” ears. It seems they can abuse their ears with very loud sounds for a long time and do not seem to suffer hearing loss, at least not for many years.

For example, one man told me he was a professional competition skeet shooter and had fired off more than 1,000,000 rounds of 12 gauge. I asked him whether he had used ear protection as 12 gauge is very loud (I only ever shot off 1 round of 12 gauge, and that was already too much for my ears.) He told me he didn’t wear ear protection for the first 600,000 rounds. That man **had** to have cast iron ears!

Peak Sound Levels vs. Average Sound Levels

Time-weighted average guidelines assume that peak levels are not excessive compared to the average sound level, but this is not always true. These guidelines can fail when the average sound level, although at 70 dB or below, are interspersed with sudden, excessively-loud sound peaks.

For example, the average sound-level may be only 50 dB and thus be perfectly safe for your ears, but if there are sudden, short peaks of 120 dB or louder you could still experience instant or delayed hearing loss.

Noise Exposure and Hearing Loss Over a Lifetime

Up to now we have been discussing using the time-weighted average guidelines and standards to prevent hearing loss basically on a day by day or hour by hour basis. However, we seldom, if ever, see anything said about the safe lifetime cumulative effects of sound and typically blame it on presbycusis.

Presbycusis vs. Socioacusis

Presbycusis is generally defined as, "Gradual hearing loss, especially in the high frequencies, due to aging". This is because as we get older, we typically notice that we don't hear higher-frequency sounds well anymore, giving our audiograms the typical ski-slope hearing loss shape. Thus, we logically assume that as we age, the resulting hearing loss is due to the effects of aging.

However, the truth is that much of what we call presbycusis isn't inevitable. We don't have to lose hearing just because we are getting older. It is true that some fraction of our lost hearing is due to the effects of aging on our bodies, but blaming all hearing loss on presbycusis leaves out the main part of the story.

A better term that more correctly explains this loss of hearing over a lifetime is the term "socioacusis". We can define socioacusis as a "hearing loss produced by a lifetime of exposure to non-occupational louder sounds". Basically, it is the cumulative hearing loss due to everyday living in our noisy world combined with hearing loss due to taking more and more ototoxic drugs as we age.

The Pasque: Measuring Cumulative Safe Lifetime Noise Exposure

In order to measure the cumulative amount of sound our ears have absorbed over a given period of time, or over our lifetimes, researchers came up with a new term, the "Pasque"[3]. Pasque stands for Pascals-squared-seconds and rhymes with "task" and is pronounced "pask".

If you are like the average person, the decibel (dB) scale makes it difficult for you to understand just how much the actual impact of increasingly-loud sound has on your ears over your lifetime.

For example, as we learned earlier, a sound of 100 dB is not just 30 linear units louder than a sound of 70 dB, nor is it 30 **times** louder. In actual fact, it is 3 orders of magnitude or 1,000 **times** louder. The Pasque makes it easier to put these numbers into perspective. The Pasque basically converts the logarithmic decibel scale to a linear scale and then uses it to calculate the impact of louder sounds per second on our ears over a lifetime. The Pasque scale looks like this (Table 9).

3 Drott, 2011. pp. 34-36.

Table 9 Pasque Scale Multipliers

Average Sound Level	Pasque per second	Multiplication factor
70 dB	0.004	1
80 dB	0.04	10
90 dB	0.4	100
100 dB	4	1,000
110 dB	40	10,000
120 dB	400	100,000

Using Table 9 you can see that a time-weighted average sound intensity of 70 dB gives a sound exposure of 0.004 Pasques per second, whereas a one-second sound at 120 dB is 400 Pasques which is 5 orders of magnitude or 100,000 times as intense.

Calculating your safe lifetime exposure at any given sound intensity is a simple matter. Let's use the Environmental Protection Agency (EPA) 70 dB time-weighted average scale for our example.

For the purposes of this exercise, let's make our lifetime a modest 70 years. Next, what we need to do is calculate the number of seconds in 70 years since the Pasque is based on the intensity of sound per second. The calculation is 60 seconds/min x 60 min/hr x 24 hr/day x 365.242 days/yr x 70 years in a lifetime which equals 2,208,983,616 seconds. At 70 dB we just multiply this by the number of Pasques at 70 dB shown in Table 9, namely 0.004 Pasques. The result is 8,835,934 Pasques. This gives us our maximum safe lifetime time-weighted noise exposure at 70 dB.

Remember, the EPA guideline should give us a minimal hearing loss of only 5 dB at 4,000 Hz over a lifetime. Thus, if we are exposed to a 70 dB sound 24/7 for 70 years, we should at the most, have a resulting noise-induced hearing loss of 5 dB which is still within the "normal" hearing range. Therefore, you should neither have presbycusis nor socioacusis due to excessive sound exposure.

Now, watch what happens to this 70-year safe lifetime sound exposure when we increase the exposure level by just 10 dB to 80 dB time-weighted average. Since 80 dB is a ten-fold increase from 70 dB, we just divide the safe time by 10. Now, instead of a 70-year safe time without damaging our hearing, the safe time dramatically shrinks, and we now only have 70/10 = 7 years of safe time remaining. In other words, we have used up 63 years of our safe 70-year lifetime noise exposure limit by exposing our ears to 80 dB time-weighted sounds rather than 70 dB.

At 90 dB your safe lifetime exposure limit is now down to 8 months and 15 days instead of 70 years. And if you increase your average sound exposure to 100 dB, your safe time limit plummets to 25 days and 13 hours from 70 years! That's how dramatic the changes in sound level can be in eating up your safe lifetime exposure to sounds.

If you work in a noisy environment such as in certain mills or on construction sites for 8 hours a day a question is, "What is the maximum safe time (number of hours per year) you can expose your ears to without damage?"

According to the EPA guidelines, if the sound level was 70 dB, you could expose your ears to it for 2000 hours each year (a typical work year) supposedly with little hearing loss for a working lifetime of 30 years. That would be equivalent to a yearly sound dose of 28,800 Pasques (60 sec/min x 60 min/hr x 2,000 hrs x 0.004 Pasques for 70 dB sound level = 28,800 Pasques).

Now according to the OSHA guideline of 90 dB sound level, the same 2,000 hours per year would yield Pasques (Pasques for 90 dB sound level = 2,880,000 Pasques. What this means is that instead of having 2,000 hours per year of safe sound exposure time when using the EPA guidelines of 70 dB average sound level, just increasing the sound level to 90 dB average sound level, you'd dramatically shrink the OSHA safe exposure time from 2,000 hours to only 20 hours! (60 sec/min x 60 min/hr x 20 hrs x 0.4 = 28,800 Pasques)

That's how dramatic the safe exposure time changes between the OSHA and EPA scales.

Now let's assume on your time off you like to go to noisy venues such as nightclubs, discothèques, hockey games, NASCAR races, skeet shooting, etc. where the average sound level is 100 dB. Let's also assume you do this for an average of just 2 hours each week. How does this compare with working 2,000 hours per year in a 70 dB time-weighted average sound environment?

Hang on to your hats. Just exposing your ears for sounds at 100 dB every Saturday for just 2 hours yields a whopping 1,497,600 Pasques per year (60 seconds/min x 60 min/hr x 2 hr/week x 52 weeks/yr x 4 Pasques = 1,497,600). At this level, you would have used up your **safe** annual noise exposure of 126,227 Pasques 11.8 times over.

Now let's look at a real-life example. Many Canadians and Americans love hockey. Unfortunately, the sound levels in hockey arenas often greatly exceed safe sound levels.

Just how bad is it? The sound levels observed during the 2006 Stanley Cup playoffs between the Edmonton Oilers and the Carolina Hurricanes played in Edmonton, Alberta are a real eye-opener.

During each 3-hour game, noise levels almost **never** fell into the safe zone (sound levels below 80 dB). In fact, the **average** sound levels for 3 of those games in the best of seven series were 104, 101 and 103 dB respectively. That's loud!

In just these three games, using the EPA scale of 70 dB safe time weighted average of 8,835,934 Pasques for a 70 year lifetime or 126,227 Pasques per year as our base, just attending these three games, you'd have used up 2.3% of your lifetime safe sound exposure time or 1.6 years by just attending 3 hockey games in your whole life.

Here is how I arrived at that figure. The 3 games at an average of 100 dB time-weighted average per game works out to 60 sec/min x 60 min/hr x 3 hrs x 3 games x 4 Pasques at 100 dB = 129,600 Pasques. Add to this the goals at 120 dB time-weighted average and assuming 6 goals per game and 10 seconds per goal. This works out to 6 goals/game x 10 sec/goal x 3 games x 400 pasques at 120 dB = 72,000 Pasques. Thus, the grand total would be 202,600 Pasques. This is the equivalent of 1.6 years off your 70-year safe lifetime sound exposure limit.)

Not only that, but at that level, without ear protectors, you risk damage to your ears in just under 1 second for every goal scored. And that was for just 3 Saturdays in the year. Now you know why so many people have hearing losses and ringing in their ears and often loudness hyperacusis?

Drag racing is also exciting, but did you know that a nitro-powered dragster at full throttle puts out 120 dB. Those that care about their hearing come to such events wearing both foam ear plugs and sound-deadening earmuffs over them. The rest probably feel the results of their day at the races—permanent damage to their ears.

Therefore, if you are a hockey fan (or other sports or music enthusiast for that matter), as a minimum, wear the little foam ear protectors you can get at any drugstore or on-line (Fig. 3). They typically have a sound-reduction rating of 25 to 35 dB. Wearing these ear protectors will typically bring the noise level down to around 80 dB or less where minimal hearing damage may occur. And

Fig. 3. Foam ear protectors with a noise protection factor of 31 dB.

if you need further ear protection, wear the ear-muff style ear protectors over the foam ones. As a general rule, you should wear ear protectors when around noise louder than 80 dB or so for extended periods.

You can get a package of 100 pairs of these foam ear plugs for less than 8 cents a pair. That is certainly much cheaper than shelling out $4,000.00 every 3 to 5 years for the hearing aids you will eventually need if you don't look after your ears now!

Air Bags

It's good to be prepared when you are going to be around loud sounds, but sometimes loud sounds occur unexpectedly and blindside you and cost you more of your precious hearing. This happened to Lisa. She explained:

"Last week I was involved in what should have been a minor car accident. I wasn't paying attention and 'gently' hit the car in front of me stopped for a light.

What happened next was terrifying. The inside of the car seemed to explode in a deafening roar. I had an unimaginable pain in both ears and considerable bleeding from my ear canals. I also had a very loud ringing sound in my ears and was virtually deaf.

I was taken to the hospital where it was quickly determined that my eardrums had ruptured. I was referred to an ENT who said my ears should heal in 2-3 weeks. He said I had suffered inner ear damage that would affect my high-frequency hearing. He concluded by saying I would need to face life hearing impaired and may need to look at hearing aids."

She continued, "I have always protected my hearing and never would have thought about going to loud concerts or auto races without effective noise protection. I'm only 22 and I can barely hear conversation in a quiet room. With background noise, I am almost deaf."

Lisa is not alone. Many other people have also experienced hearing loss when air bags deploy. In fact, the results of researcher Richard Price's studies indicate that a whopping 17% of the people exposed to deployed air bags will experience **permanent** hearing loss. That's a **lot** of people, almost 1 in every 5 people exposed to air bags going off!

Loud Noise Damages Hair Cells

You may have wondered, as did one hard-of-hearing person, who asked me: “Is the noise damage threshold the same for me as it is for a person with normal hearing? In other words, do I just add my decibel loss (by frequency) to the noise damage threshold for normal ears? For example, if sustained noise at 90 dB is bad for a person with normal hearing, since I have a 60 dB hearing loss does my noise damage threshold begin 60 dB higher, in my case at 150 dB?”

This is an excellent question. It sounds so plausible on the surface–hard-of-hearing people should be able to stand far more noise than people with normal hearing because of their underlying hearing losses.

There are a couple of things wrong with this reasoning. First, as you now know, the math is wrong because, as you have learned, decibels are logarithmic units, so when adding 60 dB to 90 dB the answer is not 150 dB, but is still just 90 dB.

Second, the answer to the question, “Compared to people with normal hearing, can we hard-of-hearing people stand louder sounds without damaging our ears?” is, “It depends on the kind of hearing loss we have.

It is true if you have a conductive hearing loss because the loud sound never reaches your inner ears at its original volume. This is because damage you already have in your middle ears reduces the volume of the loud sound before it is passed to your inner ears. Essentially, it is much the same as if you were wearing ear protectors with a protection rating of about 30 dB. So, in this case, you could stand sound 30 dB louder than people with normal hearingbefore it would cause noise damage to your ears.

However, the answer is certainly not true for the vast majority of hard-of-hearing people since we have sensorineural hearing losses.

Here is why. Think about this logically. The mechanism of damage is the same whether we have normal hearing or have a sensorineural hearing loss. Excessively loud sounds generate free radicals that can damage or destroy the minute hairs (stereocilia) on the tops of the hair cells, and zap and kill the hair cells themselves. Furthermore, excessive noise can break the synapses on the underlying support cells in the spiral ganglion. If your body cannot repair these broken synapses in a reasonable length of time up to 3 months, both the hair cell and the supporting cell die thus preventing any sound signal being sent to our brains. As a result, you end up with a hearing loss at the frequency of sound to which those hair cells were sensitive.

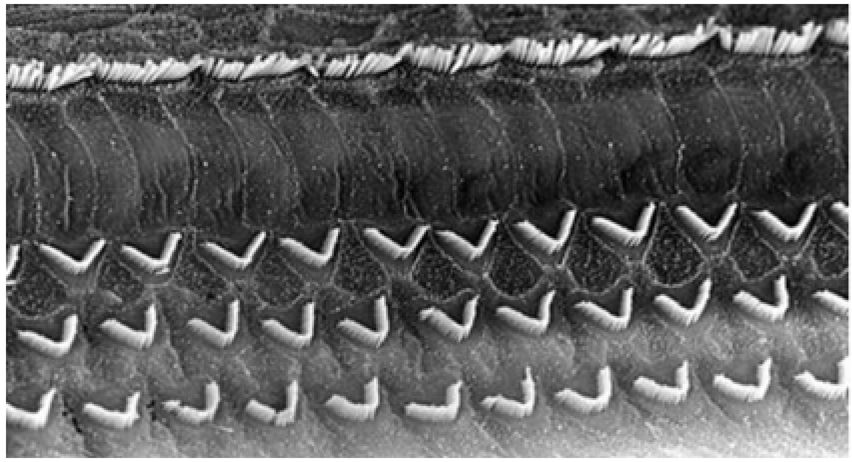
Fig. 4. Healthy cochlea showing 4 rows of hair cells. (Kaneb, (a) p. 1).

You'll understand it better when you can see actual photomicrographs of what normal hair cells look like and what noise damage does to them.

Fig. 4 shows a photomicrograph of a small section of a healthy cochlea showing the single row of inner hair cells at the top, and the three rows of outer hair cells at the bottom. Actually, what you are seeing are the stereocilia bundles (the "hairs") on the tops of the hair cells. Notice how regular and neat these 4 rows of hair cells are.

Fig. 5 shows a photomicrograph of a close up of just a single healthy hair cell showing its tiny bundle of stereocilia neatly perched on top of it. Each of these "hairs" is a single stereocilium (plural stereocilia), not cilium/cilia as many erroneously call them. (Cilia are different structures and are not found in the inner ear.)

Each stereocilium has a fine filamentous tip-link that ties it to the next stereocilium. So ultimately all the stereocilia are tied together. At the apex of each bundle of stereocilia is a special "boss" stereocilium called the kinocilium. When a sound wave in the cochlea causes all the stereocilia in a hair cell bundle to move towards the kinocilium, they all are working together to open a spring-loaded ion-gate to let sound signal ions pass through to the auditory nerve that passes the sound to the auditory processing areas in your brain.

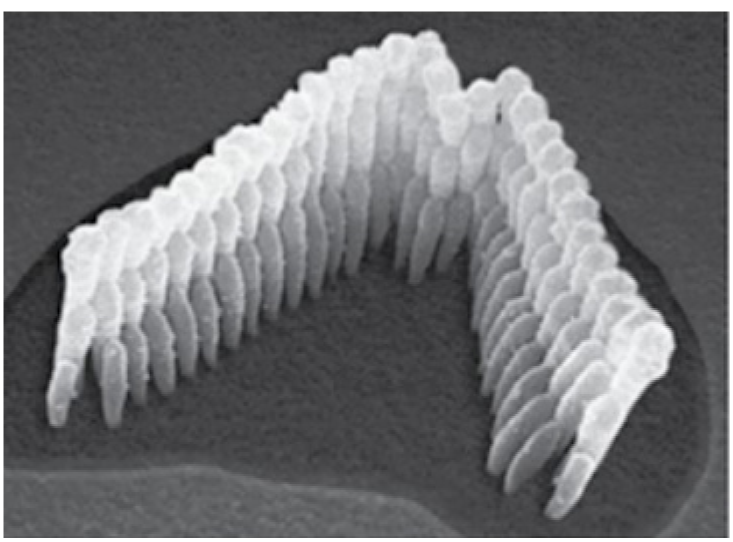
Fig. 5. Healthy stereocilia bundle. (What Is Noise-Induced Hearing Loss?).

Now, here's what exposing your ears to loud

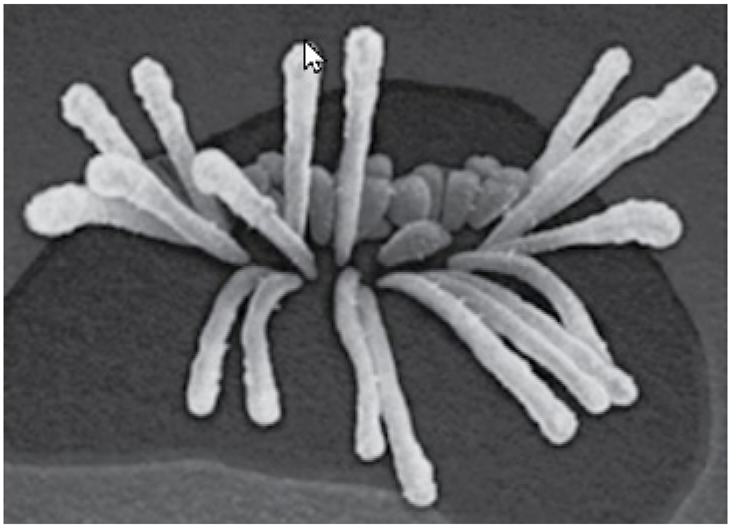

Fig. 6. Noise-damaged stereocilia bundle.(What Is Noise-Induced Hearing Loss?).

sounds does. Fig. 6 is a photomicrograph of a hair cell damaged by noise. Notice that many of the stereocilia are missing or broken, and those that remain are flopped over as the tip links are broken. Thus, these stereocilia bundles can no longer function properly if at all.

At first, if we have normal hearing, the few destroyed hair cells would not produce noticeable hearing loss. But as you continue to expose your ears to loud sounds, more and more damage occurs.

Fig. 7 is a photomicrograph showing progressive noise damage. Notice that more than half of the hair cells in the 3 rows of outer hair cells (bottom half of picture) are missing, and those that remain are flopping all over the place. Also notice the row of inner hair cells (at the top) only has a few missing, but the stereocilia are flopping around with broken tip-links.

Repeated exposures to loud noise can damage hair cells and their stereocilia bundles to the point that they can't recover and they die. When this occurs, the underlying support cell in the spiral ganglion that is connected to the auditory nerve dies also.

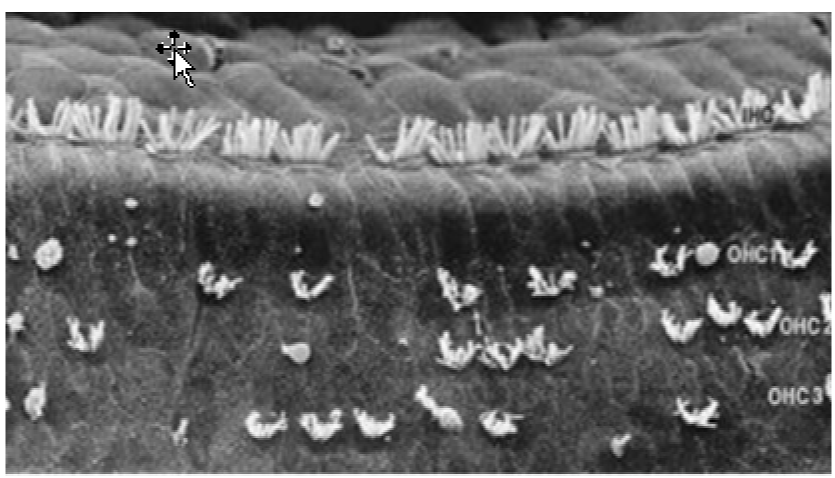

Fig.7. Section of cochlea showing noise-damaged hair cells. (Kaneb (b) p. 1.)

As these photomicrographs show, it is normal for a greater percentage of the 3 rows of outer hair cells to be destroyed first before the single row of inner hair cells.

Fig. 8 is a photomicrograph showing a section of the cochlea riddled

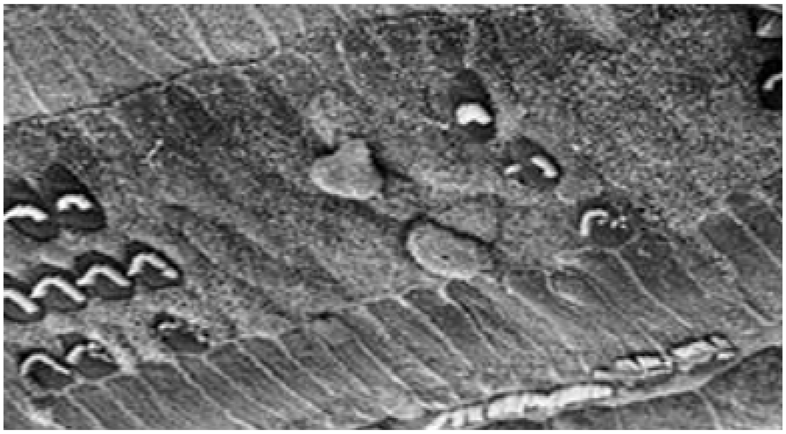

Fig.8. Section of cochlea showing almost all hair cells are either damaged or missing. (Hearing Protection. p. 1.)

with gaps where the hair cells have died. Notice the few hair cells in the inner row of at the top right and that very few of the 3 rows of outer hair cells that still remain. When enough hair cells are destroyed, not many sound signals get sent to our brains and we notice this as a severe hearing loss. Also, notice all the gaps where there are no hair cells at all now. This is what severe noise damage looks like.

To further answer the previous question about whether normal and hard-of-hearing ears suffer the same loss, the actual damage to our inner ears is basically the same whether we have normal hearing or already have a profound hearing loss. However, if we have a severe or profound hearing loss, we may not seem to lose much more hearing from being exposed to loud sounds. This is not because we have a higher tolerance for loud sounds, but because we do not have many hair cells left to be destroyed!

Here is another surprising fact regarding whether hard-of-hearing people can tolerate louder sounds than can people with normal hearing. Often, we cannot even stand sounds as loud as people with normal hearing people can—just the opposite of what you'd expect. Why? Many of us with severe or worse hearing losses usually have loudness hyperacusis as well. As a result, our tolerance for loud sounds is actually **less** than it is for those with normal hearing. For example, a sound of 110 dB, while very loud to a person with normal hearing can actually cause us severe pain because we now perceive this level of sound as much too loud to stand!

Loud Noise, Loudness Hyperacusis and Hearing Loss

Loud sounds can damage/kill the hair cells in your inner ears resulting in hearing loss as you now know.

However, sometimes you are blindsided when a sound level you have been exposed to in the past without any obvious side effects such as going to loud concerts suddenly turns on you. A young lady explained:

"About a week ago, I went to hear a band I like. It was a small venue, but I was in the back of the crowd. When they paused between sets, I immediately noticed that my hearing felt dull. When I got out my ears were ringing.

I have been to ever-so-many rock concerts back in college and even saw this very band a couple of years ago. I've never once had problems like this. I am so panicked right now."

Unfortunately, many young people think they are invincible. And this thinking extends to their ears. It never dawns on them that by repeatedly exposing their ears to loud music eventually they will have to "pay the piper" with a lifetime of hearing loss as this young lady now realizes.

The truth is that when you abuse your ears by going to loud music events without adequate ear protection, your ears suffer damage. Sometimes they let you know right away—muffled hearing and tinnitus—and other times the damage is insidious—no obvious signs of damage. For example, one day, like the young lady above did, you go to a concert no louder than previous ones you've gone to and much to your shock as one young teacher explained, "Now all sounds hurt my ears—my car stereo, the TV news and children's voices! I teach elementary school, so I can't really stay out of cacophonous rooms entirely. Even my own 'teacher' voice bothers me now."

This supersensitivity to sound blindsides you. You find that the normal sounds you used to hear are now too loud—much too loud, to shrill and strident, so loud they hurt.

This condition goes by the fancy name of loudness hyperacusis. Loudness hyperacusis may not show up immediately after the loud sound but often develops about 2 weeks later. The nasty thing is it takes time for hyperacusis to go away—think weeks or months or years. During this time, you need to protect your ears from loud sounds while your ears slowly recover.

Think of the analogy of a bruise. You get hit and a bruise forms. It hurts. Now, if someone hits you on the bruise before it is healed up, it just makes matters worse and the bruise will take even longer to heal. If you keep on hitting the bruise, it will never heal.

The same holds true with your ears. Every time you assault your ears with loud sounds you are "hitting the bruise" so to speak and it will just prolong the hyperacusis, and likely make it worse. In addition, you'll experience ever-increasing hearing loss.

How Do I Determine a Safe Level for Listening to Music Devices?

One person asked, "How concerned should we be about listening to cell phones, iPods and other personal music players? What should we define as "too much or too loud?"

There are different opinions as to what levels of sounds are safe and for how long. This has resulted in several different "safe" loudness tables. However, the United States Environmental Protection Agency (EPA) is probably closest to the truth when it says that keeping the sound level at or below an average of 70 dB per day (24 hours) will prevent any measurable (or minimal) hearing loss over a lifetime.

Therefore, it is wise to keep your sound exposure to an average of 70 dB or less if you want to preserve your hearing until you die. And if you preserve your hearing, it's almost certain you won't get tinnitus or loudness hyperacusis from noise exposure either.

As a general rule, when listening to typical music devices such as iPods, cell phones and various bluetooth streaming devices, if you keep the volume below 50% of the maximum volume your device produces, you can likely listen to music safely as much as you want.

However, an even better rule of thumb when listening to music, or anything for that matter, is to set the volume to roughly the same volume at which you typically converse, or to a level you would comfortably listen to a recorded class or lecture. You don't need loud volume to enjoy music!

Some iPods and other streaming devices can produce sounds up to 117 dB–but how many people do you see wearing them for only 1.5 seconds? (Refer back to Table 8.) Yet that is the daily safe time-weighted average according to the EPA guidelines.

Since we all have ears that have different sound sensitivities, it is not simple to nail down a safe standard that works for everyone in all situations. Therefore, to be safe, aim to protect your ears more, rather than seeing how close to the unsafe level you can go.

Some Sneaky Things That Can Team Up with Noise to Blindside You and Cause Even Worse Hearing Loss

So far, we have looked at safe and unsafe sound levels and how you can balance sound levels with exposure times to help protect your hearing and how noise impacts your cumulative lifetime sound exposure. Now let's look at a subject that I've never heard anyone speak on. This is about some insidious factors that you probably never have thought about that team up with noise to steal more of your hearing than noise alone would.

Additive vs. Synergistic Effects

Before we do this, we need to understand the difference in results depending on how these agents combine with noise. The results can be either additive or synergistic.

Normally the results are additive. This is where you simply add the noise effect and the effect of the other ear-damaging agent together to get the total hearing loss.

For example, if you were exposed to an ototoxic drug that caused you to lose 20 dB of hearing and at the same time you were exposed to noise that caused you to also lose 20 dB of hearing the total effect would be 20 dB + 20 dB which equals 23 dB of hearing loss as we saw earlier. This is the **additive** effect—the total is **equal to** the **sum** of its parts.

Now, let's say we had the same situation mentioned above but, in this case, your resulting hearing loss was 33 dB instead of the expected 23 dB. This loss would be 10 **times** worse than expected, not just twice as bad. This extra loss above the expected additive effect is called the synergistic effect—where the result is **greater** than the sum of the individual parts.

Conceptually think of it this way. To get the **additive** effect, you **add** the two separate effects together. However, you "**multiply**" the two effects together to get the **synergistic** effect. It is this synergistic effect that can blindside you because you didn't expect all this extra hearing loss.

Drugs

Now, let's look at some of these agents that can synergistically blindside you. Studies are now revealing there is often a sinister partnership between ototoxic drugs and noise. In a review of some studies, researchers observed that the incidence of sensorineural hearing loss was higher than expected in those people who were exposed to both noise and certain ototoxic agents such as antibiotics.

Note: This synergistic effect can also occur when taking two or more ototoxic drugs without any noise being present.

The aminoglycoside class of antibiotics can exacerbate the damaging effects of noise exposure on your hearing. This means that if you are taking any of these antibiotics (Gentamicin, Neomycin, Kanamycin, etc.) and are exposed to loud noise at the same time, the effects on your hearing may be considerably worse than either one by itself (the synergistic effect).

For example, exposing your ears to loud noise while you are taking Gentamicin can make the ototoxic effects worse than if you are not around loud noise when taking this drug. A number of studies of people taking Kanamycin plus being exposed to noise at the same time have revealed both additive and synergistic effects.[4]

In addition to the aminoglycoside antibiotics, the platinum anti-cancer drugs such as Cisplatin can act together with noise to cause even greater damage to your hearing. This is also true of some over-the-counter drugs. Studies have shown that taking higher doses of salicylates such as Aspirin in the presence of noise causes a greater temporary hearing loss. Furthermore, it takes longer for hearing to return to normal if you took Aspirin in the presence of noise than it does if you took Aspirin without the noise component.[5]

When Chloramphenicol, a microbial antibiotic, is taken alone, it typically is not very ototoxic. However, in the presence of noise, the synergistic effect of this drug and noise shoots the risk way up![6]

Watch the Noise for a Long Time

Here's a nasty effect of some ototoxic drugs when they team up with noise that you'd probably never suspect. This is the length of time your ears are susceptible to noise damage after taking certain ototoxic drugs.

When you are warned not to take certain drugs at the same time as you are exposed to noise, you might think this is referring to just the days you are actually taking the drug therapy. Surprise! Not true! You may have to avoid noise for much, much longer.

When you take aminoglycoside antibiotics or platinum anti-cancer drugs, such as Cisplatin, they are quickly transported to your inner ears. The problem is that, once there, they persist in your inner-ear fluids, not just for a few days, but it can be for several weeks to several months, and up to a year!

During this time, your ears are still very susceptible to the synergistic

4 Bauman, 2024. p. 176.
5 Bauman, 2024. p. 176.
6 Bauman, 2024. p. 176.

effects of loud noise.[7] This means that if you have taken an Aminoglycoside antibiotic or Cisplatin and are now finished with this drug therapy, your ears are still in danger of even more hearing loss if you expose them to loud noise any time in the next few months or more, depending on how sensitive your body is to these drugs. Heed this warning if you want to protect your ears from additional hearing loss!

Here is something else you should know, as I don't think many audiologists are aware of this. If you are getting new hearing aids and have been taking one of the ototoxic agents that are synergistic with noise, instruct your audiologist to set the gain and maximum power output on your aids as low as feasible in order to protect your ears during this critical time when your ears are still very sensitive to the effects of noise. It is more important at this time to protect your hearing at this time that it is to hit the target for properly setting your hearing aids. If you already wear hearing aids, keep the volume down during this time while your ears are healing.[8]

Caffeine Prevents Full Hearing Loss Recovery

Not only do some drugs have a synergistic effect when combined with noise, but a surprising discovery by researchers also revealed another nefarious trait of some drugs. Caffeine is a good example. If you have exposed your ears to loud sounds that has resulted in a temporary threshold shift (temporary hearing loss) taking caffeine at this time can prevent your hearing from returning to normal. This means that it can turn a temporary threshold shift into a permanent hearing loss.

For example, let's say you were out for a good time at your favorite night-club. Due to the loud music being played, by the end of the evening you notice everything sounds muffled. This has happened to you in the past and you are not worried. You head for home and bed to sleep it off and let your ears recover.

The next morning you down a strong cup (or two) of coffee to combat your hangover and get you going again. This is a typical scenario for thousands of people. But without realizing it, your cup of joe may have permanently cost you some of your precious hearing.

Researchers have also discovered that while your ears are recovering from your temporary threshold shift, caffeine can stop hearing recovery in its tracks and turn what would have been a temporary hearing loss into a permanent one.[9]

7 Bauman, 2024. p. 179
8 Bauman, 2024. p. 180.
9 Bauman, 2024. p. 176.

Remember that caffeine is found not only in coffee, but also in tea, soft drinks, chocolate and a number of drugs.

Smoking/Nicotine

Smoking while taking certain drugs can also have a synergistic effect on your hearing. For example, a man asked me: "While it is common knowledge that smoking is harmful to the lungs, I have been told that smoking may damage hearing as well. Is this true?"

I told him that this information was correct. There are a number of things to consider when discussing smoking and hearing loss. Here are three of them.

First, when you inhale smoke, you inhale nicotine. Nicotine is an ototoxic substance and has been associated with such unwanted ototoxic side effects as hearing loss, tinnitus, dizziness and vertigo.

Second, smoking constricts your blood vessels, not only in your lungs but also the tiny blood vessels in your inner ears. This restricted blood flow deprives your ears of the vital oxygen your ears need to work properly. This lack of oxygen makes the hair cells "sick" (to use a fancy medical term) and thus temporarily reduces your hearing.

Third, and this is not well known but smoking in the presence of louder noise makes your ears even more susceptible to hearing loss than exposing your ears to either smoking or louder noise separately. Thus, if you smoke and are around loud sounds, the resulting hearing loss will be more severe than it would have been had you not smoked.

Here's some proof. Researchers published the results of a study on workers in one manufacturing plant showing just how severely noise combined with smoking can affect hearing loss. Here are the shocking results. Workers who were exposed to noise above 85 dB **and** who smoked had an incidence of significant hearing loss 442% greater than those who worked in the same noisy environment but didn't smoke.

The researchers next compared the incidence of the workers who had hearing loss greater than 25 dB at 4,000 Hz in their better ear. Non-smokers had an incidence of hearing loss of 18.4%, but that figure sky-rocketed to 63.6% in smokers.[10] Thus, no matter how you slice it, smoking is not good for your ears (or the rest of your body either).

10 Bauman, 2007. p. 1.

Chemicals and Heavy Metals

Something that had puzzled researchers for some time was the question, "Why could some people working in noisy places not seem to suffer any hearing loss, while others working in quieter places ended up with significant hearing losses and other ear damage? What factor was increasing their risk of ototoxic damage? They know now. Being exposed to ototoxic agents and noise at the same time can make all the difference. One main avenue of this exposure that you may not think of is air pollution.

Two of the more common ototoxic hazards that occur in many work environments are exposure to noise and to volatile organic solvents at the same time. Researchers have discovered that taking an ototoxic drug, or being exposed to a volatile ototoxic industrial solvent, might not cause noticeable damage to your ears if you are in a relatively quiet place. However, if you get the same exposure to the chemical, and at the same time are exposed to loud noise for any length of time (say at work in a factory), the result could be significant ear damage. In fact, the combination of noise and drugs/chemicals can increase your risk of hearing damage many times over!

For example, in a 20-year study of hearing sensitivity in 319 employees, a remarkably large proportion (23%) of the workers in the chemical sector showed pronounced hearing loss as compared with employees in non-chemical environments (5-8%). These results were found in spite of the fact that the noise levels in the chemical sector (80-90 dB) were less than those in other divisions (95-100 dB).[11]

In another study, workers were grouped into one of four groups—those exposed to both noise and Toluene, those exposed to Toluene alone, those exposed to noise alone, and those not exposed to either Toluene or noise (the control group). The hearing loss of those exposed to noise alone was 4 times greater than the control group; the hearing loss of those exposed to **Toluene** alone was 5 times greater; and the hearing loss of those exposed to both noise and Toluene was 11 times greater![12]

In a study of Brazilian workers, those exposed to both noise and Toluene had a 53% incidence of hearing loss. In contrast, those exposed to noise alone had a 26% incidence rate while the control group had an incidence rate of only 8%. When these results were adjusted for age, they showed that noise exposure increased the risk of hearing loss by 4.6 times. When the noise was combined with exposure to **Toluene**, the risk jumped to a whopping 27.5 times![13]

11 Bauman, 2024. p. 173.
12 Bauman, 2024. pp. 174-175.
13 Bauman, 2024. p. 175.

The high-risk chemicals (as a group) that cause this synergistic effect seem to be the volatile organic solvents that are used in a lot of cleaners (among other uses). Some of these organic solvents include Carbon disulfide, Dinitrobenzene, Styrene, Trichloroethylene, Toluene and Xylene.

Household cleaners that may contain volatile organic solvents such as Xylene or Toluene include paint thinners, adhesives, and some degreasers. These chemicals are often found in products like nail polish removers, glues, and certain cleaning agents. If the cleaners you use have a stronger, pungent smell, they probably contain volatile organic solvents.

In addition, some other chemicals with this characteristic include **Arsenic**, Butyl alcohol, Butyl nitrite, Carbon monoxide**,** Heptane, Hexane, Lead, Manganese, Mercury and Trimethyltin.

In one study almost half of the workers exposed to synthetic varnishes and noise were found to have permanent hearing losses ranging from 10 dB to 60 dB. These varnishes contained organic solvents such as Benzene, Butyl acetate, Styrene, Toluene and Xylene**.**[14]

In a 1989 study of 258 workers in a viscose rayon factory, the incidence of hearing loss increased with the duration of exposure to noise and Carbon disulfide from 47% in the group exposed for up to 2 years as compared to 71% having hearing loss in the group exposed for 3 years or longer. Not only did the incidence of hearing loss increase with time, but also so did the severity of the resulting hearing losses.[15]

One study of shipyard workers found that workers exposed to a combination of high metal concentrations (including Lead, Cadmium and Arsenic) and solvents (including Toluene and Xylene) combined with high levels of noise increased their odds of developing significantly-reduced hearing by nearly 2.5 times when compared to workers who were not exposed to noise levels greater than 85 dB.[16]

One very interesting thing that has come out of animal studies is that the order of exposure seems to determine how bad the resulting hearing loss will be. If the noise exposure comes **before** the drug/chemical exposure, the effect is **additive** at best. However, if the noise exposure comes **after** exposure to the drug/chemical, the effect is **synergistic**.[17]

Here's another interesting fact. Not only can hearing loss be worse in the

14 Bauman, 2024. p. 177.
15 Bauman, 2024. p. 178.
16 Bauman, 2024. p. 178.
17 Bauman, 2024. p. 175.

presence of both noise and chemicals, but so can be your ability to understand speech. By comparing pure tone audiometry results to speech audiometry results, researchers determined that the chemical solvents not only caused hearing loss in the cochlea but also damaged the auditory circuits in the brain so that speech was not processed as clearly as before. This gives rise to lower-than-expected word recognition (discrimination) scores.[18]

In Conclusion

Be aware that the supposedly "safe levels" of noise exposure keep dropping, and for good reason. For example, when the pollutants in factories and mills are kept at the "safe" OSHA level **and** the noise is kept at the "safe" OSHA level, researchers were surprised to find that hearing loss was **still** occurring.

Therefore, even though you may be in an environment where exposure to ototoxic chemicals is kept in what is generally considered the "safe" range for those chemicals, and at the same time, you may also be in an environment where the noise level is kept below the level considered at risk for noise, you may think that your ears are thus safe. However, you may still be damaging your ears.

Obviously, the government needs to set even more stringent noise standards. And until they do that, if you value your precious hearing, take the most conservative noise standard (the EPA one) and then determine to stay below its recommended exposure limits.

Finally, let me share this bit of wisdom with you. Protecting your hearing is similar to driving safely on a narrow, backcountry mountain road with a 1,000-foot cliff on one side. In such situations, the safe rule of thumb is "stay as far away from the edge of the cliff as possible". Do the same with louder sounds and you'll enjoy maximal hearing for the rest of your life. And that makes it all worth it.

18 Bauman, 2024. p. 174.

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Good Books on Hearing Loss

Integrity First Books in the series:

Everything You Wanted to Know About Your Hearing Loss But Were Afraid to Ask

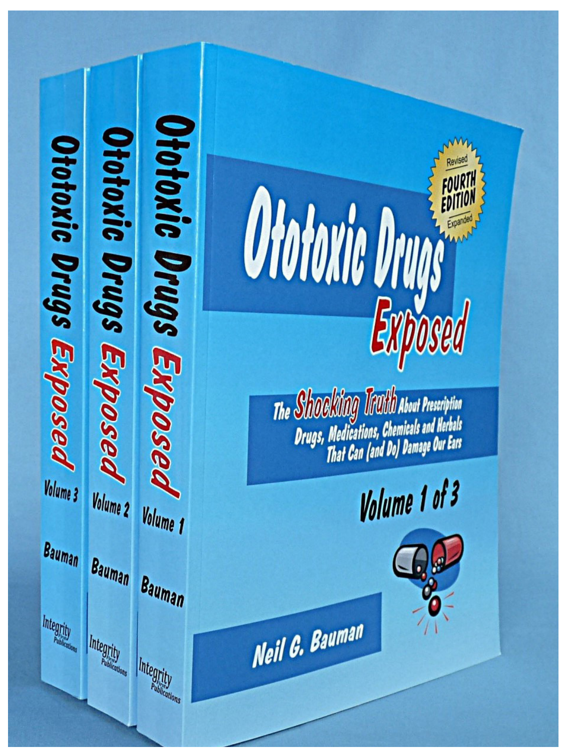
(Because You Knew You Wouldn't Hear the Answers Anyway!)

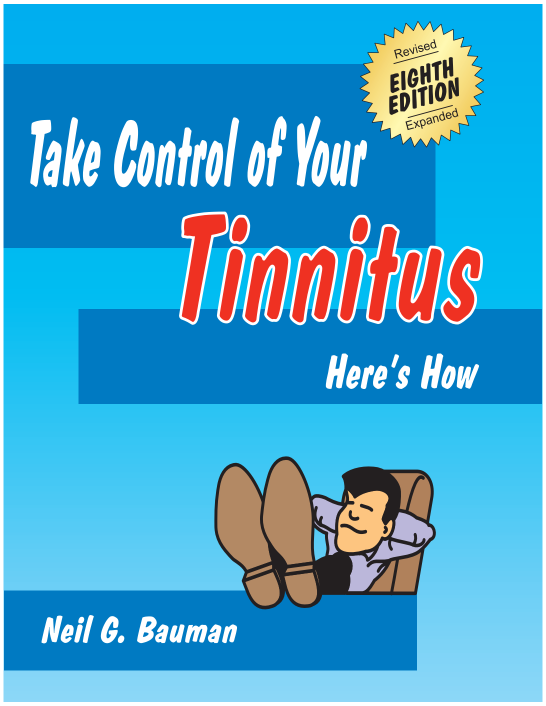
by Neil G. Bauman, Ph.D.

If you have enjoyed this comprehensive article and would like to learn more about hearing loss and how you can successfully live with it, you may be interested in some helpful books by Dr. Neil. Each book is packed with the things you need to know in order to thrive in spite of your various hearing loss issues. The direct link to the following books is at https://hearinglosshelp.com/product-category/publications/.

Ototoxic Drugs Exposed—The Shocking Truth About Prescription Drugs, Medications, Chemicals and Herbals That Can (and Do) Damage Our Ears
(3-volume set $79.95; eBook $59.95)

This book, now in its fourth edition, reveals the shocking truth that many prescription drugs can and often do damage our ears. Some drugs slowly and insidiously rob you of your hearing, cause your ears to ring or destroy your balance. Other drugs can destroy your ears in one fell swoop, leaving you with profound, permanent hearing loss and bringing traumatic change into your life. Learn how to protect your ears from the ravages of ototoxic drugs and chemicals. This book-set includes comprehensive listings of the specific ototoxic effects for each of the 1,604 drugs, 64 herbals and 144 chemicals in this 3-volume set. (1,662 pages in total.)



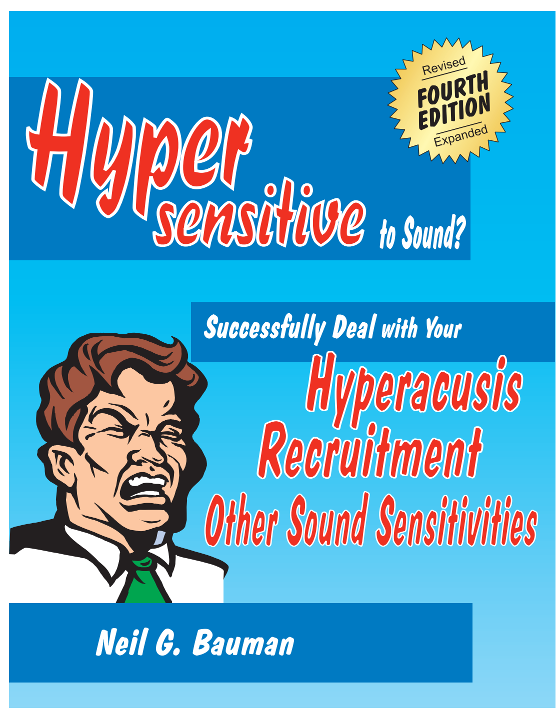


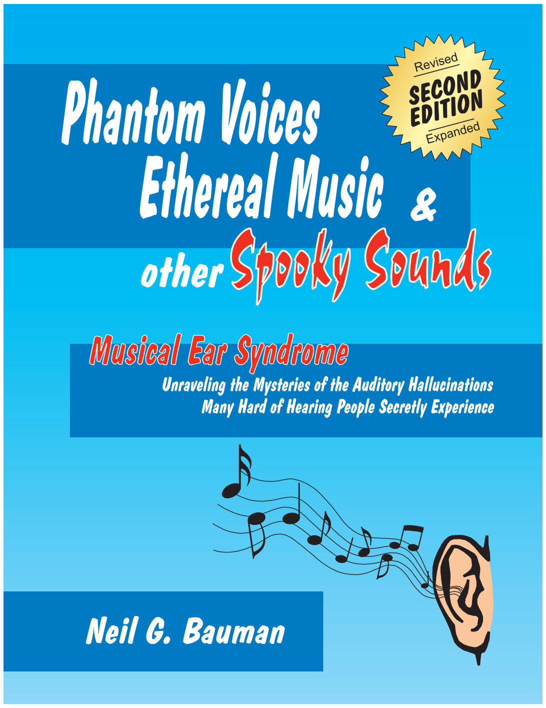
Take Control of Your Tinnitus—Here's How
($39.95; eBook $29.95)

If your ears ring, buzz, chirp, hiss, click or roar, you know just how annoying tinnitus can be. The good news is that you do not have to put up with this racket for the rest of your life. You can take control of your tinnitus. Recent studies show that a lot of what we thought we knew about tinnitus is not true at all. Exciting new research reveals a number of things that you can do to eliminate or greatly reduce the severity of your tinnitus so that it no longer bothers you. This totally-revised, up-to-date and expanded 8th edition contains the very latest in tinnitus research and treatment. In this book you will learn what tinnitus is, what causes tinnitus and things you can do to take control of your tinnitus. (684 pages)

Hypersensitive to Sound? Successfully Deal with Your Hyperacusis, Recruitment & Other Sound Sensitivities ($39.95; eBook $29.95)

If some (or all) normal sounds seem so loud they "blow the top of your head off", or make you wince or jump, or cause you headaches or ear pain, or affect your balance, or result in fear or annoyance of sounds so you feel you have to avoid these sounds, this book is for you! The good news is that you don't have to avoid noise or lock yourself away in a sound-proof room. This book teaches you to how to successfully deal with your hyperacusis and various other sound hypersensitivities. (544 pages)



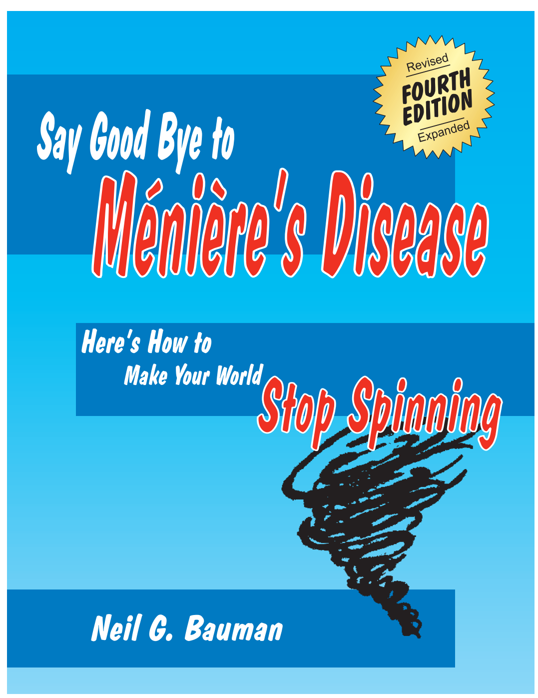


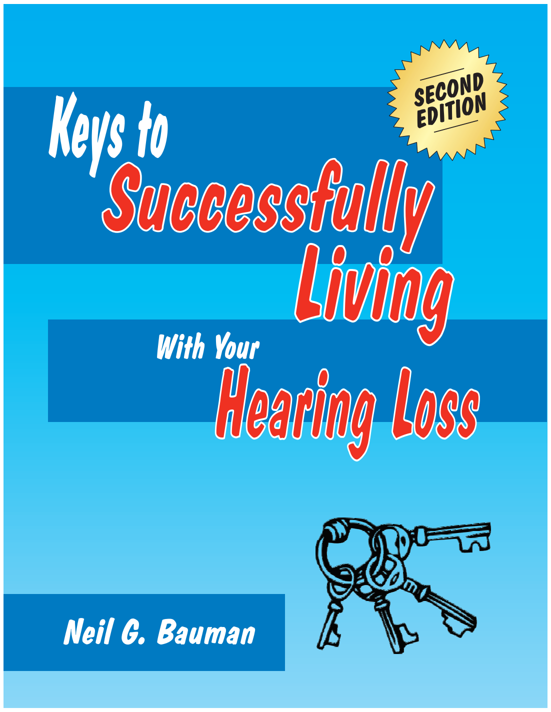
Phantom Voices, Ethereal Music & Other Spooky Sounds ($22.49; eBook $16.99)

When you realize you are hearing phantom sounds, you immediately think that something has gone dreadfully wrong "upstairs"—that you are going crazy. Because of this, few people openly talk about the strange phantom voices, music, singing and other spooky sounds they hear. This book, the first of its kind in the world, lifts the veil on "Musical Ear syndrome" and reveals numerous first-hand accounts of the many strange phantom sounds people experience. Not only that, it explains what causes these phantom sounds, and more importantly, what you can do to eliminate them, or at least, bring them under control. (178 pages)

Say Good Bye to Ménière's Disease—Here's How to Make Your World Stop Spinning ($21.95; eBook $16.49)

Ménière's disease is one of the more baffling and incapacitating conditions a person can experience. If you suffer from your world spinning, have a fluctuating hearing loss, tinnitus and a feeling of fullness in your ears, this book is for you. It details what Ménière's disease is like; explains the recent breakthrough into the underlying cause of Ménière's; and shows you how, at last, you can be free from the ravages of this debilitating condition. Each page is packed with practical information to help you successfully conquer your Meniere's disease. Join the hundreds and hundreds of people whose worlds have now stopped spinning (128 pages).



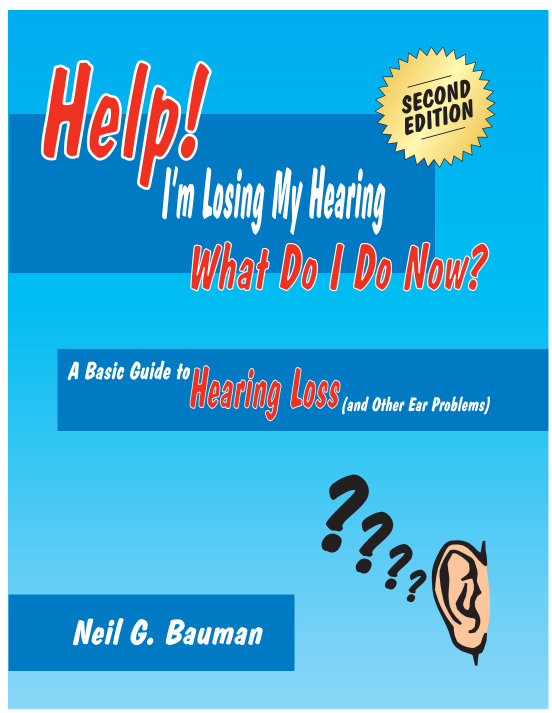


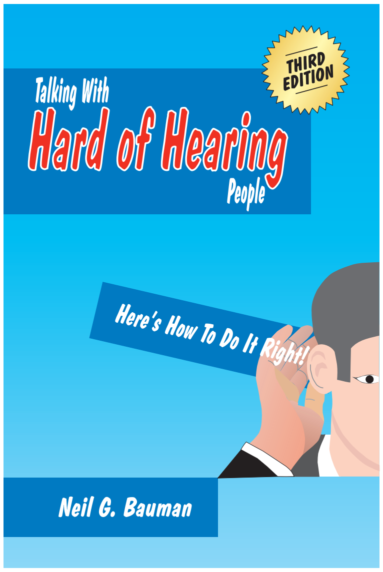
Keys to Successfully Living with Your Hearing Loss ($19.97; eBook $15.49)

Do you know: a) the critical missing element to successfully living with your hearing loss? b) that the No. 1 coping strategy hard of hearing people instinctively use is wrong, wrong, wrong? c) what the single most effective hearing loss coping strategy is? d) how you can turn your hearing aids into awesome hearing devices? This book addresses the surprising answers to these and other critical questions. Applying them to your life will put you well on the road to successfully living with your hearing loss. (84 pages)

Help! I'm Losing My Hearing—What Do I Do Now? ($18.95; eBook $14.49)

Losing your hearing can flip your world upside down and leave your mind in a turmoil. You may be full of fears, wondering how you will be able to live the rest of your life as a hard of hearing person. You don't know where to turn. You lament, "What do I do now?" Set your mind at rest. This easy to read book, written by a fellow hard of hearing person, is packed with the information and resources you need to successfully deal with your hearing loss and other ear conditions. (116 pages)



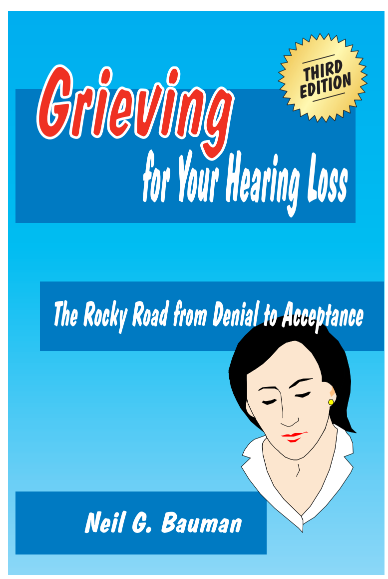


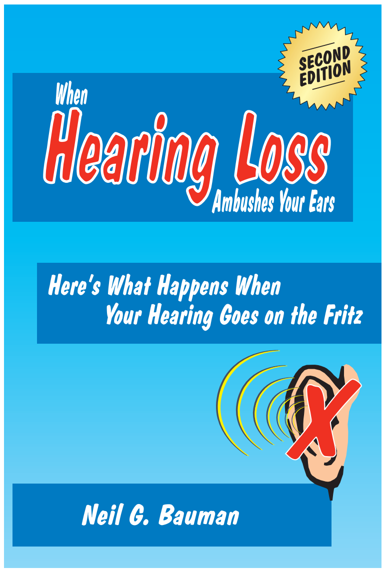
Talking with Hard of Hearing People—Here's How to Do It Right! ($9.95; eBook $7.95)

Talking is important to all of us. When communication breaks down, we all suffer. For hard of hearing people this happens all the time. This book is for you—whether you are hearing or hard of hearing! It explains how to communicate with hard of hearing people in one-to-one situations, in groups and meetings, in emergency situations, and in hospitals and nursing homes. When you use the principles given in this book, good things will happen and you will finally be able to have a comfortable chat with a hard of hearing person. (38 pages)

Grieving for Your Hearing Loss—The Rocky Road from Denial to Acceptance ($12.95; eBook $9.95)

When you lose your hearing you need to grieve. This is not optional—but critical to your continued mental and physical health. This book leads you through the process of dealing with the grief and pain you experience as a result of your hearing loss. It explains what you are going through each step of the way. It gives you hope when you are in the depths of despair and depression. It shows you how you can lead a happy vibrant life again in spite of your hearing loss. This book has helped many. (56 pages)



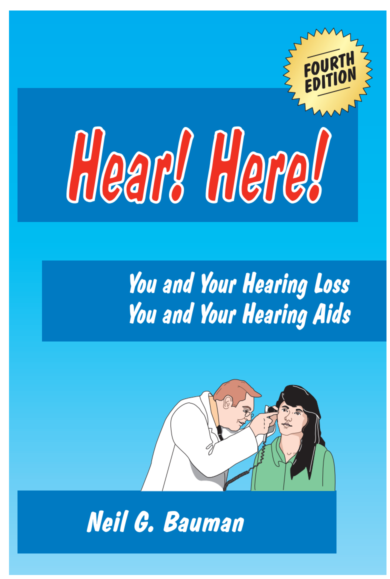


When Hearing Loss Ambushes Your Ears—Here's What Happens When Your Hearing Goes on the Fritz ($14.95; eBook $11.95)

Hearing loss often blind-sides you. As a result, your first step should be to learn as much as you can about your hearing loss; then you will be able to cope better. This most interesting book explains how your ears work, the causes of hearing loss, what you can expect to hear with different levels of hearing loss and why you often can't understand what you hear. Lots of audiograms and charts help make things clear. You will also discover a lot of fascinating things about how loud noises damage your ears. (88 pages)

Here! Here! You and Your Hearing Loss/You and Your Hearing Aids ($12.95; eBook $10.95)

Part I of this book contains a series of my newspaper articles on hearing loss such as, "Hear Today. Gone Tomorrow?" "Hearing Loss Is Sneaky!" "The Wages of Din Is Deaf!" "When Your Ears Ring…" "Get In My Face Before You Speak!" "How's That Again?" "Being Hard of Hearing Is Hard" "I'm Deaf, Not Daft!" Part II contains articles on hearing aids such as, "You Better Watch Out…" "Before Buying Your First Hearing Aid…" "Please Don't Lock Me Away in Your Drawer" "Good-bye World of Silence!" "Becoming Friends with Your Hearing Aids" "Two's Better Than One!". (56 pages)



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