# Hearing Loss Prevention and Noise Control

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**ABSTRACT**
*Work-related hearing loss is a leading occupational disability to workers in construction, agriculture, and other industries. Most workers suffer as a result of acoustic trauma (onetime exposure to loud sound) and through daily exposures to moderately loud sound over an extended period of time. Some of the symptoms of hearing loss include problems with understanding words, particularly with background noise or in a crowd and asking others to speak louder or repeat words/sentences. A workplace can help conserve hearing and reduce noise by conducting initial and annual hearing tests, incorporating administrative and engineering controls, providing personal hearing devices to workers, and educating workers about hearing conservation. Implications for the teaching of noise-inducted hearing loss as an environmental health topic are discussed.*
***Umwelt und Gesundheit Online, 2008; 1, 22-29.***

*"Young people live in a loud and noisy world. In this age of the escalating use of personal stereo systems, hands-free cell phones, and portable movie/game systems, youth worldwide are exposed to harmful levels of noise every day."*

James F. Battey, Jr., MD., PhD
Director, National Institute for Deafness and Communications Disorders, USA, February 2006

## Introduction to the Problem

Noise-induced hearing loss is the number one occupational disability. It is generally *painless*. It is *progressive* over time. It is *permanent*. It is preventable!!!

Work-related hearing loss continues to be a critical workplace safety and health issue. The National Institute for Occupational Safety and Health (NIOSH) (2008) and the occupational safety and health community named hearing loss one of the 21 priority areas for research in this century. Noise-induced hearing loss is 100% preventable but once acquired, hearing loss is permanent and irreversible. Therefore, prevention measures must be taken by employers and workers to ensure the protection of workers' hearing.

Approximately 30 million workers are exposed to hazardous noise on the job and an additional nine million are at risk for hearing loss from other agents such as solvents and metals (NIOSH, 2008). Noise-induced hearing loss is one of the most common occupational disease and the second most self-reported occupational illness or injury. Industry specific studies reveal:

- 44% of carpenters and 48% of plumbers reported that they had a perceived hearing loss.
- 49% of male, metal/nonmetal miners will have a hearing impairment by age 50 (vs. 9% of the general population) rising to 70% by age 60 (NIOSH, 2008).

Whereas any worker can be at risk for noise-induced hearing loss in the workplace, workers in many industries have higher exposures to dangerous levels of noise. Industries with high numbers of exposed workers include: agriculture; mining; construction; manufacturing and utilities; transportation; and military.

## Sound, Noise, and Hearing Loss

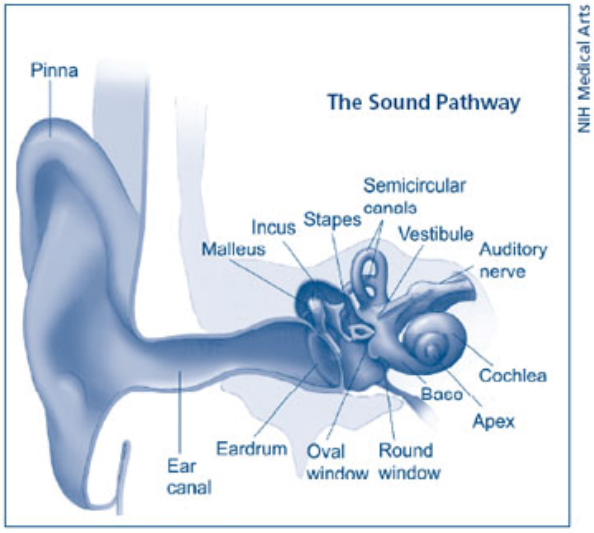
*Sound*. Sound is the outcome of vibrations or waves that move through the air or water. These vibrations or waves are caused by molecules bumping into each other. The faster a wave vibrates, the higher the sound; slower waves produce low sound. Our voice produces sound because of vocal cords in our throat that vibrate when air is forced through them.

*How do we hear?* The ear is divided into three parts (Figure 1). These parts include:

- The outer ear or pinna, funnels sound waves into the ear canal, which will lead to the eardrum. The eardrum is a membrane that stretches across the entrance to the middle ear.
- The middle ear has three tiny bones, the hammer, the anvil, and the stirrup. This is where waves become amplified.
- Inside the inner ear is a coiled tube called the cochlea. It is filled with fluid, special "hair cells," and nerve endings. It signals the brain, which lets you know what sound you heard. You will also find the semicircular canals which help control

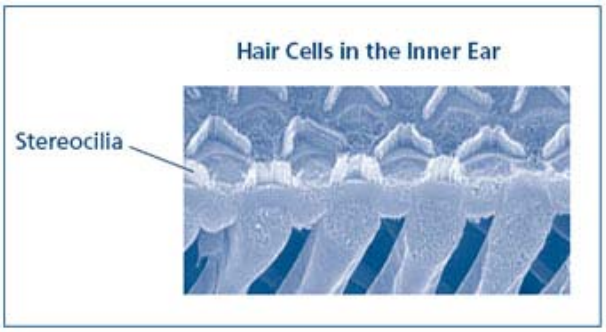
balance. The hair cells are damaged when a person is exposed to too much noise (Figure 2).

Figure 1. The Outer, Middle, and Inner Ear.




(Source: NIH Medical Atlas, 2007.)

Figure 2. Hair Cells in the Inner Ear




(Source: NIH Medical Atlas, 2007)

*Sensory Hearing Loss*. Sensory hearing loss is caused by damage to the tiny hair cells in the cochlea. It is permanent. Most common causes are aging and loud noises. Hearing loss due to loud noises is preventable.

*What is noise and how is it characterized?* Simply stated noise is any unwanted sound. There are many different ways to characterize noise, but the best way is by frequency (perceived as pitch), intensity (perceived as loudness), nature (steady-state vs. impulse/impact), and duration (length of time exposed). A combination of these characteristics, when taken to high levels, leads to hearing loss.

*Noise Induced Hearing Loss*. Every day, one experiences sound in the environment, such as the sounds from television and radio, household appliances, and traffic. Normally, one hears these sounds at safe levels that do not affect hearing. However, when one is exposed to harmful noise—sounds that are too loud or loud sounds that last a long time—sensitive structures in the inner ear can be damaged, causing noise-induced hearing loss (NIHL). These structures, called hair cells, are small sensory cells in the inner ear that convert sound energy into electrical signals that travel to the brain. Once damaged, these hair cells cannot regenerate.

Scientists once believed that the pure force of vibrations from loud sounds caused the damage to hair cells. However, other studies show that exposure to harmful noise triggers the formation of molecules inside the ear that can damage or kill hair cells.

Initially, exposure to noise causes a loss of sensitivity to high frequency (high pitch) sound. Continued exposure to noise can result in damage to mid frequency region as well. One can experience progressive high frequency hearing loss and not be aware of it until it becomes severe (doesn't affect loudness perception).

*How can hearing loss happen?* One main way of getting hearing loss is through some type of acoustic trauma, where one has a onetime exposure to loud sound. The other primary way of getting hearing lost is through daily exposures to moderately loud sounds over a long period of time.

*Noise and its Effect on Hearing*. High levels of noise damage hearing. Both the amount of noise and the length of time one is exposed to it determine its ability to damage hearing. Noise levels are measured in decibels (dB). The higher the decibel level, the louder the noise. Sounds above 80dB are considered potentially hazardous. Hearing loss due to loud noises is common in children, adolescents, and adults.

*How do we know that something is too loud?* If one has to raise one's voice to be heard by someone standing within about 1 yard or 1 meter (approximately an arm's length), then the level is most likely above the hazardous noise level. Secondly, one can measure loudness objectively with proper noise level dosimeter equipment.

## Signs and Symptoms of Hearing Loss

Signs and symptoms of hearing loss may include:

- Muffled quality of speech and other sounds.
- Difficulty understanding words, especially against background noise or in a crowd of people.
- Asking others to speak more slowly, clearly and loudly.
- Needing to turn up the volume of the television or radio.
- Withdrawal from conversations.

- Avoidance of some social settings (Mayo Clinic, 2008)

Tinnitus is a ringing, swishing, or other type of noise that seems to originate in the ear or head. In many cases it is not a serious problem, but rather a nuisance that eventually resolves. It is not a single disease, but a symptom of an underlying condition. Nearly 36 million Americans suffer from this disorder. In almost all cases, only the patient can hear the noise (Cunba, 2008).

Tinnitus can arise in any of the four sections of the ear: the outer ear, the middle ear, the inner ear, and the brain. Some tinnitus or head noise is normal. If one goes into a sound proof booth and normal outside noise is diminished, one becomes aware of these normal sounds. One is usually not aware of these normal body sounds, because outside noise masks them. Anything, such as wax or a foreign body in the external ear, that blocks these background sounds, will cause one to be more aware of head sounds. Fluid, infection, or disease of the middle ear bones or ear drum (tympanic membrane) also can cause tinnitus (Cunba, 2008).

One of the most common causes of tinnitus is damage to the microscopic endings of the hearing nerve in the inner ear. Advancing age is generally accompanied by a certain amount of hearing nerve impairment, and consequently tinnitus. Today, loud noise exposure is a very common cause of tinnitus, and it often damages hearing as well. Unfortunately, many people are unconcerned about the harmful effects of excessively loud noise, firearms, and high intensity music. Some medications (e.g., aspirin) and other diseases of the inner ear (Meniere's syndrome) can cause tinnitus. Tinnitus can, in rare situations, be a symptom of such serious problems as an aneurysm or a brain tumor (acoustic tumor) (Cunba, 2008). Hearing loss and tinnitus may be experienced in one or both ears, and may happen all the time, or only occasionally throughout a lifetime.

*Who is affected by noise-induced hearing loss?*

More than 28 million people in the United States have some degree of hearing loss, including children, adolescents, young adults, and older people. Over 5 million, 6-19 year olds have hearing loss directly related to noise exposure.

*What sounds cause noise-induced hearing loss?*

NIHL can be caused by a one-time exposure to an intense "impulse" sound, such as an explosion, or by continuous exposure to loud sounds over an extended period of time, such as noise generated in a woodworking shop.

The loudness of sound is measured in units called decibels. For example, the humming of a refrigerator is 40 decibels, normal conversation is approximately 60dB, and city traffic noise can be 85dB. Sources of noise that can cause NIHL include motorcycles, firecrackers, and small firearms, all emitting sounds from 120dB to 150dB. Long or repeated exposure to sounds at or above 85dB can cause hearing loss. The louder the sound, the shorter the time period before NIHL can occur. Sounds of less than 75 dB, even after long exposure, are unlikely to cause hearing loss (NIOSH, 2008).

Although being aware of decibel levels is an important factor in protecting one's hearing, distance from the source of the sound and duration of exposure to the sound are equally important. A good rule of thumb is to avoid noises that are "too loud" and "too close" or that last "too long."

## Noise Levels and Time to Hearing Loss

Some steady-state noise examples include:

- rustling leaves 20dB
- empty theater 20dB
- private office 40dB
- near home dishwasher 60dB
- conversation 60dB
- automobile 70dB
- busy department store 70dB
- alarm clock 80dB
- new garbage disposal 80dB
- screaming child 90dB
- pneumatic drill 100dB
- edge of highway 100dB
- helicopter 110dB
- near pile-driver 120dB
- military jet takeoff 130dB
- live rock concert 130dB

Listening to music on earphones at volume level 5, the sound reaches a level of 100dB, loud enough to cause permanent damage after just 15 minutes per day! More Examples of things that cause too much noise include target shooting, hunting, woodworking, shop tools, video games and arcades, movie theaters, snowmobiling, power boating, hair dryers, blenders, vacuum cleaners, garbage disposals, gas-powered lawn mowers and string trimmers, leaf blowers, musical concerts, and sports events.

Impulse noise examples in the military include:

- M16, blanks w/suppressor 147dB
- Vulcan XM197 20mm 159dB
- Shotgun 12 gauge 160dB
- Machine Gun 60 cal 165dB
- Launcher, M20-A 35" Rocket 171dB
- TOW Missile 180dB

Loss of hearing sensitivity due to hazardous noise exposures from either steady state noise or impulse noise occurs even before one can measure the change.

### Permanent threshold shift (PTS) vs. temporary threshold shift (TTS)

Exposure to harmful sounds causes damage to the hair cells as well as the auditory, or hearing, nerve (Figure 2). Impulse sound can result in immediate hearing loss that may be permanent. This kind of hearing loss may be accompanied by tinnitus—a ringing, buzzing, or roaring in the ears or head—which may subside over time. Hearing loss and tinnitus may be experienced in one or both ears, and tinnitus may continue constantly or occasionally throughout a lifetime.

Continuous exposure to loud noise also can damage the structure of hair cells, resulting in hearing loss and tinnitus, although the process occurs more gradually than for impulse noise. Exposure to impulse and continuous noise may cause only a temporary hearing loss. If a person regains hearing, the temporary hearing loss is called a temporary threshold shift. The temporary threshold shift largely disappears 16 to 48 hours after exposure to loud noise. One can prevent NIHL from both impulse and continuous noise by regularly using hearing protectors such as ear plugs or ear muffs (NIDCD, 2008).

*What about the person who can't hear within normal hearing range?*

A normal listener can hear:

- Footsteps at 10 meters.
- Voices at 100 meters.
- Noisy door closing at 1000 meters.

A person with hearing loss can hear:

- Footsteps at < 1 meter
- Voices at 32 meters
- Noisy door closing at 46 meters

One can see from the above information that the person with a hearing loss is at a big disadvantage in regards to being to hear normal sound that those with good hearing can pick up. If one is exposed to hazardous noise levels unprotected…it's not a matter of *whether* one will develop hearing loss but *when* one will develop hearing loss…the odds are rarely defeated.

### Ways of Preventing and Reducing Noise Problems and Conserving Hearing

The best way to conserve hearing and reduce noise in any environment is by having a four-part hearing loss program. The four components include exposure source/dose measurement and tracking, engineering noise controls, worker empowerment and education, and communication in noise and use of personal protection equipment (PPE).

*Annual Hearing Testing*. It is important that all adults (and in many cases children too) get a baseline hearing test to determine their current hearing abilities. An annual test provides feedback before one's hearing becomes a problem, not five years later when it definitely is a problem. If one works in a noisy area, he or she should consider getting a hearing test every year or so to see whether there is a change in hearing acuity.

*Administrative Controls*. One good way to limit exposure time to noise is by implementing shift work schedules. Engineering controls usually are the best approach to dealing with noise problems. Engineering controls are defined as any modification or replacement of equipment, or related physical change at the noise source or along the transmission path (with the exception of hearing protectors) that reduces the noise level at the employee's ear. Typical engineering controls involve:

- Reducing noise at the source;
- Interrupting the noise path;
- Reducing reverberation; and
- Reducing structure-borne vibration.

Common ways of implementing such controls include:

- Installing a muffler;
- Erecting acoustical enclosures and barriers;
- Installing sound absorbing material;
- Installing vibration mounts; and
- Providing proper lubrication.

Hearing Protection. The only thing standing between a person and a potential permanent hearing loss is hearing protection. People state many reasons (perhaps more aptly classified as "excuses") as to why they cannot wear hearing protection including:

- "My ears will become infected"
- "They hurt my ears"
- "I can't hear to do my job"
- "I can't hear sounds needed to hunt, etc."
- "Thinking short-term instead of long-term"

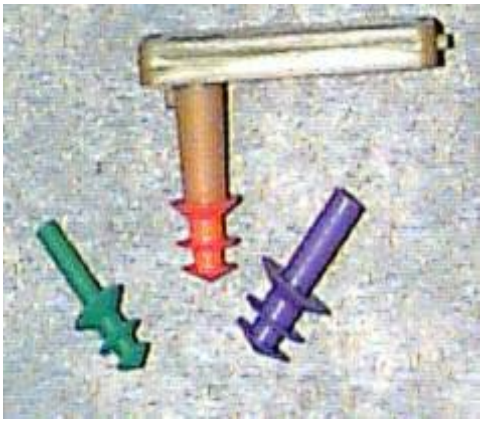
Hearing protection includes ear plugs and ear muffs to reduce the intensity or loudness of sound. Ear plugs (Figures 3 and 4) are placed into the ear canal so that they totally block it. They come in various pre-made shapes and sizes, or are custom-made by taking an impression of the ear (Table 1). Ear plugs can reduce noise 15dB-30dB depending on make and fit (ASHA, 2008).

**Table 1. Types of Ear Plugs and Ear Muffs**

| Type of ear plug or ear muff | Noise Reduction Rating | Sizes |
|---|---|---|
| Single Flange (Figure 3) | 23dB | White – extra small<br>Green – small<br>Orange – medium<br>Blue - large<br>Red – extra large |
| Triple Flange (Figure 4) | 26dB | Green - small<br>Orange - medium<br>Blue - large |
| Hand Formed | 29dB | |
| Circum-aural noise ear muffs (Figure 5) | 23dB | |

**Figure 3. Singe Flange Ear Plugs**

**Figure 4. Triple Flange Ear Plugs**



Characteristics of a good pre-formed ear plug fit include:

- Voices sound muffled
- "Vacuum" effect
- Comfortable
- Single flange tab facing toward back of ear
- Largest flange of triple flange is flush against ear canal opening

Ear muffs fit completely over both ears (Figure 5). Again, they must fit tightly so that sound is blocked from entering the ears. Like ear plugs, ear muffs can reduce noise 15dB-30dB depending on make and fit. Ear muffs fit completely over both ears. (ASHA, 2008). One should replace ear cushions when they are cracked or worn. Certain types of ear muffs allow placement of the headband on top of the head, behind the head, or under the chin.

**Figure 5. Noise-reducing Ear Muffs**

Ear plugs and ear muffs can be used together to achieve even greater sound reduction. All hearing protection devices have a Noise Reduction Rating

(NRR). Field testing suggests that the actual NRR is approximately half of what is listed on the package. Keep all hearing protective devices clean with mild soap and water and dry before using. Replace when material hardens/cracks or does not clean. Check for cracks on earphone seals, heads, and tension and replace as needed.

## Summary

Hearing loss occurs when protective procedures are not undertaken. Noise-induced hearing loss is 100% preventable. Auditory health starts with work or home.

## Implications for the Teaching of Environmental Health

Throughout life one is surrounded by sounds in the environment. The ability to hear plays an essential part in everyday existence. Students should develop an understanding of the role technology plays in personal and social decisions. To meet these goals one needs to integrate aspects of responsible behavior toward hearing health into the middle school science curriculum along with concepts of the science of sound. If time and resources are available, teachers can extend this topic in several interesting ways. A lesson on measurement of sound can be added as enrichment. Using a sound-level meter, students can create a visual representation of different levels of sounds. This activity allows them to associate what they are hearing with the specific decibel reading.

Noise-induced hearing loss is not new – it has been with around since people started firing guns and working with loud machinery. When humans of any age are repeatedly exposed to hazardous sound levels without using adequate hearing protection, the common result is noise-induced hearing loss. Consequences of noise-induced hearing loss include communication difficulties, lower academic performance, reduced productivity, social isolation, depression, and tinnitus (ringing, buzzing or hissing in the ears or head). Unlike many other causes of hearing loss, nearly all cases of noise-induced hearing loss can be prevented if people are taught to take a few simple precautions.

Children are often exposed to excessive levels of sound: loud music, real or toy firearms, power tools, fireworks, loud toys, snowmobiles or other loud engines such as jet skis or motorcycles. The effects of excessive noise exposure continue to accumulate over one's lifetime.

Teaching children to protect themselves from NIHL isn't a new idea, either. For more than 30 years, numerous experts have recommended teaching hearing loss prevention practices to children in schools (see the article "Why Aren't Hearing Conservation Practices Taught in Schools?" for a list of quotes and references dating back to 1974: http://www.healthyhearing.com/library/article_content.asp?article_id=151.

In 1990, the National Institutes of Health (NIH) held a conference on "Noise and Hearing Loss." This panel of experts made the following recommendation in their Consensus Statement:

> "In addition to existing hearing conservation programs, a comprehensive program of education regarding the causes and prevention of NIHL should be developed and disseminated, with specific attention directed toward educating school-age children."

In 1997, the World Health Organization held the conference "Prevention of Noise-Induced Hearing Loss" in Geneva, Switzerland. Recommendations from this conference included the following: "There is a great need for creating more public awareness of the harmful effects of noise on hearing and the prevention of NIHL. It is recommended that this matter should be included in school and all health educational programmes."

In 2000, the U.S. Department of Health and Human Services published *Healthy People 2010*, "a statement of national health objectives designed to identify the most significant preventable threats to health and to establish national goals to reduce these threats." The authors of *Healthy People 2010* state the following about hearing: "Prevention of noise-induced hearing loss is necessary for people both on and off the job . . . Public education can promote hearing health and behavior to reduce noise-induced hearing loss, which is a fully preventable condition." *Healthy People 2010* objectives include the following:

- Increase the use of appropriate ear protection devices, equipment, and practices.
- Reduce noise-induced hearing loss in children and adolescents aged 17 years and under.
- Reduce adult hearing loss in the hearing loss in the noise-exposed public.

In spite of recommendations made by experts over the last three decades, basic hearing loss prevention information that could prevent countless cases of NIHL remains conspicuously absent from most school curricula. Why? Here are some of the reasons for this omission:

- Lack of public awareness about how excessive sound exposure damages hearing and the consequences of hearing loss. In general, people tend to take hearing for granted until their own hearing loss becomes so severe that it interferes with communication. Because most teachers, school administrators, and parents are not aware of the problem, hearing conservation and the preventability of NIHL are given a low priority if they are considered at all.
- Students are routinely bombarded with a plethora of health education messages including admonishments about smoking, drugs, alcohol, sex, and personal safety. Compared to the potential life-and-death consequences related to these topics, NIHL might not seem like such a big deal. School curricula are already so packed with required elements that many teachers and administrators would hesitate to add yet another public health campaign.
- Lack of effective dissemination of existing hearing loss prevention programs. Although some organizations have attempted to market their curricula and materials nationally, the total percentage of schools that ever purchased or used them is minuscule.
- Lack of perpetuation of hearing loss prevention education. A relatively small number of teachers, audiologists, nurses, or trained volunteers present hearing conservation curricula in selected classrooms across the country. However, if the person who implemented the program retires, moves, or stops making such efforts for other reasons, hearing conservation education in those schools usually diminishes or ceases completely.
- Lack of a mandate. According to the Occupational Safety and Health Administration's Occupational Noise Exposure Standard and Hearing Conservation Amendment (published in the Federal Register on March 8, 1983), if workers are exposed to excessive sound levels, "the employer shall administer a continuing, effective hearing conservation program."(29 CFR Part 1910.95c1) Even though children are often exposed to excessive sound levels, there are *no* policies requiring hearing loss prevention practices to be taught in our nation's classrooms.

*What can be done to address these problems?*

- Raise public awareness about hearing, how hearing can be damaged by excessive sound exposure, the consequences and permanent nature of hearing loss, and how and why NIHL can and should be prevented. Parents should be encouraged to implement hearing loss prevention practices at home and communicate the importance of these precautions to children.
- Inform teachers and school administrators about existing hearing loss prevention programs, curricula, and materials that can be used in classrooms.
- Persuade teachers to integrate hearing loss prevention messages into existing lesson plans on hearing, sound, music, science, math, and health.
- Qualified volunteers or health professionals such as school nurses, audiologists or speech pathologists could present hearing loss prevention curricula as "guest speakers" in classrooms. Teachers who observe the presentations should be encouraged to integrate hearing loss prevention messages into appropriate lesson plans on a regular basis.
- Seek a mandate from state and local school boards, state or federal legislatures and health agencies to implement and perpetuate hearing loss prevention instruction to each new 4th, 7th, and 10th grade class of students in all of the nation's schools on a continuing basis.

Effective prevention of noise-induced hearing loss, as with other environmental health risks, should begin prior to one's exposure to the hazard. The *Healthy Youth!* website of the Division of Adolescent and School Health of the U.S. Centers for Disease Control and Prevention (2008) states: "Establishing healthy behaviors during childhood is easier and more effective than trying to change unhealthy behaviors during adulthood. Schools have a critical role to play in promoting the health and safety of young people and helping them establish lifelong healthy behavior patterns because: Each school day is an opportunity to teach behaviors to America's 54 million students; America's 121,000 schools provide many opportunities for students to practice healthy behaviors."

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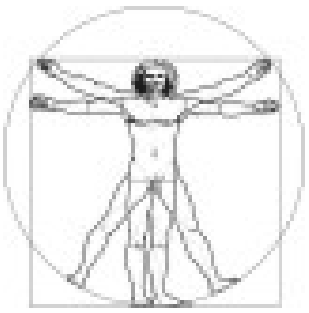

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