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Review article

Noise-induced hearing loss (NIHL) and sound control standards for stone crushers

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Since globally industrial developments have utilized production machines, exposure to noise (any sound that may be hazardous to hearing) in workplace is inevitable. The same is true for Stone crushers manufacturer which is an important industrial sector in the Thailand. Therefore, the obvious measurement and criteria for sound control should be used in order to assess employee noise exposure, to prepare an effective noise reduction programmed and to protect the stone crushers workers from noise-induced hearing loss (NIHL). Legally, although there are hearing conservation program with periodic evaluations, health education about hearing mechanism and wearing personal protective equipment must be focused.

Keywords: Hearing loss, stone crushers, loud noise.

Thailand has developed modern technology to keep pace with the world. Knowledge is applied in both agriculture and industry. The industrial sector is one of the important mechanisms to lead Thailand into development and increasing competitiveness. Resulting in continuous industrial development, there are more machines used in the production process. Loud noise is a threat to the machines which the consequences are causing hearing loss. At present, there is a danger of noise exposure and legislation to control noise and reduce subsequent losses.

Data from the World Health Organization found that the number of patients with hearing loss from loud noise exposure are around 120 million people in 1995 and increased to 360 million people worldwide in 2012 ^(1, 2) which accounted for 5.3% of the world population. Majority of noise-induced hearing loss (NIHL) patients are males and work in the developing countries. Hearing loss from noise in adults caused by touching the loud noise from the occupation (more than 4 million DALYS). Exposure to loud noise that causes hearing loss is not only caused by occupation

but also from the environment. ⁽¹⁾ In addition, noised induced sufferers often do not realize that their hearing is being damaged.

As for the data patients with hearing impairment from loud noise from the medical and health data warehousing system, the Ministry of Public Health^(3, 4) found that 42,946 patients who were diagnosed with hearing loss (ICD 10, H90.3 - H90.5) in 2017 accounted for a sick rate per hundred thousand people equal to 71.3%.

The stone crusher is a large industrial plant that processed the stone. These rocks were obtained from the explosion of mountains and then processed. The stone crusher is a factory type 3 according to the factory act in 1992. Information from the Department of Primary Industries and Mines shows that there are 430 stone crushers distributed throughout all parts of Thailand with several stone sources registered as 325 concessions. Even though among the six-region division system used in Thailand, the northern region has the most rock sources whereas the Saraburi province in central region has the most stone crusher (61 stone crushers).

Information from the Ministry of Industry show that the demand for limestone minerals for the construction industry has increased every year. The consequences of the needs of users and the industrial expansion, it also increases environmental and health problems. One of the major problems is the impact of

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the noise from the operation of the stone crusher such as vibration, explosion, drilling, digging and the sound from the machine and various devices including the noise from the car that carried the stone. Continuous exposure to noises is not only annoying and giving tinnitus but also causes negative effects on health and quality of life^(5, 6) such as sleep disturbance and hormonal systems in the body⁽⁷⁾; increasing in the risk of cardiovascular diseases⁽⁸⁾ and hypertension.⁽⁹⁾ Brief exposure to high levels of noise causes a temporary loss of hearing however, if the exposure is repeated, the hearing loss can become permanent. So far, Noise induced hearing loss is incurable.

Continuous exposure to loud sounds does not cause clear symptoms in the early stages. Lack of awareness of the consequences and careless in appropriate protection may lead to subsequent losses.

From the information mentioned above it was found that patients with occupational NIHL have increasing trend every year. There are many stone crushing plants spread in every region of Thailand. The production of stone crusher in large industrial factories causing loud noise in the workplace. Hearing loss from loud noise caused by working in a stone crushing plant is the objective of this research review and should be used in the development of appropriate occupational health care guidelines.

Noise-Induced Hearing Loss among stone crusher workers

Sensorineural hearing loss caused by the pathology in the inner ear which has been deformed or peeled from the vibration of the sound. Exposure to loud sounds for a long period of time. It does not cause sudden hearing loss. The first phase of the loud touch will cause temporary hearing disorders called temporary threshold shift (TTS) which hearing loss occurs many hours after that, the hearing will gradually return to normal. If exposed to loud noise accumulated continuously this causes permanent hearing loss (PTS). The auditory nerve begins to deteriorate, causing hearing loss to both ears. In the first phase, will start at a high frequency and in the long term, the auditory nerve will begin to deteriorate at a lower frequency until hearing loss is found at all levels.⁽¹²⁾ If the loud noise still continues, the ear will eventually turn deaf. Sensorineural hearing loss is caused by loud noises, usually by hearing a loud noise that exceeds 85 dB (A) especially in construction, agriculture and industry.

Operations in the stone crusher are divided into 2 types of loud noises:

1. Work with impact sound causing the maximum loudness of noise such as rocking, loader work, ten-

Working process in the stone crusher^(10, 11)

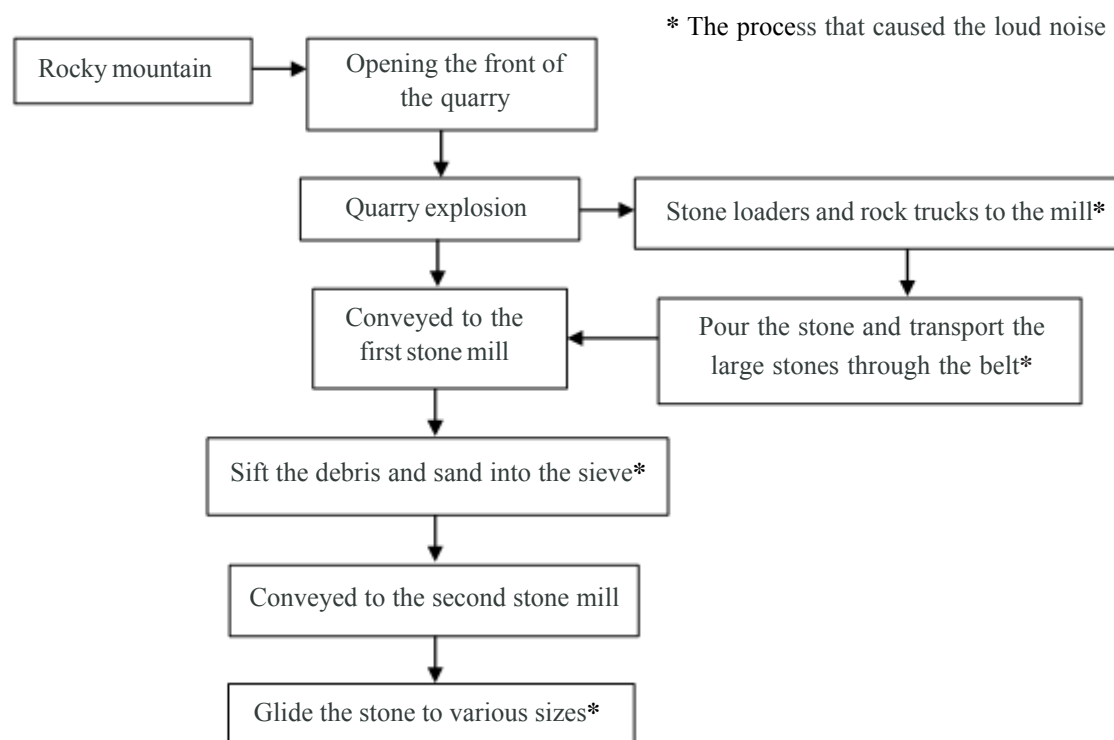


Figure 1. Working processes in the stone crusher.

wheeled truck driving, maintenance job. There is a peak level between 134.9 - 139.54 dB (A) which does not exceed the standards prescribed by the ministerial regulations they must not exceed 140 dB (A).

2. Work with continuous sound such as grinding work, machine-controlled works. The average measured over 85 dB (A) which the standard value of sound accumulated over 8 hours of work.

Diagnosis for occupational hearing loss (OHL)

Bureau of Occupational and Environmental Diseases have rules diagnosis for reporting occupational hearing loss as follows: ⁽¹³⁾

1. There are signs and symptoms of hearing loss;
2. Have work history and the duration of work that is exposed to loud noise;
3. Hearing test results look like a letter V with a notch at 4,000 Hz, compared to the sound at frequency 2,000 Hz and 8,000 Hz which is usual for both ears.

Evaluation of impacts from noise in a stone crusher

In Thailand, there is a sound environmental impact assessment. ⁽¹⁴⁾ For example, an environmental inspection reported a stone mill plant in Krabi (Dec 2013). Use Integrated sound Level Meter Type2 (General Type) for sound measurement from

all 6 stone crushers by conducting continuous measurements 24 hours a day. It was found that the average noise level was in the standard. The Pollution Control Department requires that the average noise level is 24 hours, not more than 70 dB (A) and the maximum noise level is 115 dB (A). It shows that mining activities do not affect the noise of the community. The level of sound in some stone crusher during the day (8AM-5PM) with some loud noise because of the grinding of stone which may affect the health of workers. Therefore, they should have protective equipment and be monitored the occurrence of deafness from loud noise regularly.

The noise level standard in the stone crusher

The demand for the construction industry is increasing. Loud noise from the operation of the stone crusher such as vibration, explosion, drilling, digging the sound from the machine has caused significant problems. People in the area will be more affected than those far away from the sound. At present, there is a push to control the noise in the environment or in the workplace. The measurement criteria and general noise levels in the stone crusher as shown in the Table 1- 3.

Table 1. The standard for controlling noise levels from quarrying in Thailand. ⁽¹⁶⁾

Noise level standards	Sound level measurement
The maximum noise level is not more than 115 dB(A).	Maximum sound level measurement Use the sound level meter to measure the level as the SPL value. (Sound Pressure Level) while blasting.
The average noise level is 8 hours. Not more than 75 dB (A)	Average sound level measurement 8 hours with milling and grinding.
The average noise level 24 hours. Not more than 70 dB (A)	Continuously check the sound level for 24 hours.

Table 2. The standard for controlling noise levels from quarrying in USA. ⁽¹⁷⁾

Industrial noise		Neighborhood noise	
Time	Noise exposure limits	Time	Noise exposure limits
07.00 - 21.00 hrs.	60 dB (A) Leq	07.00 - 18.00 hrs.	60 dB (A) Leq
21.00 - 07.00 hrs.	55 dB (A) Leq	18.00 - 21.00 hrs.	55 dB (A) Leq
21.00 - 07.00 hrs.	50 dB (A) Leq	21.00 - 07.00 hrs.	50 dB (A) Leq
A total character adjustment of +5 dB (A) should be applied to the measured value where the noise has a definite continuous note such as a whine or hiss.			

Table 3. In the United States Standard danger due to loud contact depending on the time that the sound is exposed to as follows:⁽¹⁷⁾

Time to reach 100% noise dose	Exposure level per NIOSH REL	Exposure level per OSHA PEL
16 hours	82 dBA	82 dBA
8 hours	85 dBA	85 dBA
4 hours	88 dBA	88 dBA
2 hours	91 dBA	91 dBA
1 hour	94 dBA	94 dBA

Noise measurement standards of mining activities: ^(15, 16)

1. Measurement of the maximum sound level using the sound level meter to measure the noise level in the area where the people live;
2. Measure the average noise level 24 hours, using the sound level meter to measure the sound level continuously for 24 hours;
3. Setting the microphone of the sound level meter at the outdoor area to be set at least 1.20 meters from the floor in a radius of 3.50 meters, horizontally around the microphone not have a wall or anything else that has the property of reflecting obstacles;
4. Setting the microphone of the sound level meter at the indoor area to be set at least 1.20 meters from the floor. In a radius of 1.00 meters horizontally around the microphone must be at least 1.50 meters away from the window or the opening of the building.

The situation and the impact of the noise exposure in the stone crusher

A study of loud noise in stone crusher in Ghana⁽¹⁸⁾ found that the prevalence of hearing loss in the group of stone crushing workers rather than in the control group with statistical significance, accounted for 21.5%, 2.8%, respectively. By finding that the ear nerve deteriorates in the left ear more than the right ear. From education 9 stone crushing plants in Taiwan,⁽²⁰⁾ it was found that more than half of the workers with personal sound measuring instruments had a sound level measured over 85 dB (A) and hearing measurement results (hearing thresholds) with an average that is greater than the normal level of 25 dB (A) both at high and low frequencies.

Thailand has a study of a stone crusher.⁽¹⁰⁾ It was found that the prevalence of dementia was 30.0%, which was close to researches on stone mills in other

countries. Assessment of knowledge about noise impact on hearing loss of workers found that most workers have the knowledge about the health effects of exposure to noises from the environment,^(18,19) but only some workers use protective equipment due to hot weather and uncomfortable feeling when wearing protective equipment while operating. Factors that affect hearing loss^(19,20) are the period of sound volume, age range, type of mining, duration of exposure. However, this study has limitations. There is no hearing level measurement as the basic value before starting work.

Stone crusher operations affecting the noise that not only affects workers in the stone mill but also including people living around the area. Some research in Bangladesh which deals with the effects of noise on the surrounding area. Sound volume level inversely proportional to the distance from the stone crusher. There are surveys from the surrounding residents. The noise from the machinery and the operation of the stone crusher causing annoyance, Headache and affect sleep. Workers in the stone crusher are concerned about side effects from exposure to loud noise less than normal people.^(18,21,22) There is a noise map to evaluate the surrounding effects.^(23,24) In the study, it was found that the noise-free distance was 57.3 hectares (573,000 square meters) by the distance, depending on the system and production process of each location.

Therefore, establishments should maintain the volume of noise in each area to be lower than the threshold of the specified area. It is recommended that there should be a barrier around the stone mill. To reduce broadcasting to neighboring areas by designing to reduce noise and determine the intensity of the area from the distance to the location of the stone crusher.

Assessment of return to work in the case of hearing loss from loud noise of stone crusher

Working in a stone crusher cannot avoid a loud noise. In addition, working in the area and the same job requires teamwork. They need to communicate with each other by remote communication such as telephone, radio, etc. Therefore, listening and communication skills are very important. The job can proceed according to the specified procedure such as telephone, radio, etc., to facilitate and proceed according to the specified procedure.

In Thailand, there is no criterion for assessing the proper hearing performance. In case of hearing loss from loud noise of stone crushing. Workers will be considered before returning to work from the occupational medicine doctor and otolaryngologist. In some countries, studies have shown that the ability to communicate in quarries and stone crushing complicated more than can hear only but still need understanding communication content.^(17, 25, 26) The development of the machine used to evaluate the ability communication of patients with hearing loss is Articulation Index (Developed by French⁽²⁷⁾ and Steinberg and modified by Kryter KD.⁽²⁸⁾). The scores are from 0 - 1. If the value is less than 0.4, there is difficulty in communicating by speaking and understanding.

Later, Speech Intelligibility Index was further developed by the American National Standards Institute (ANSI). The Speech Intelligibility Index Standard (SII) defines a method for computing a physical measure that is highly correlated with the intelligibility of speech. There is an acceptable point at 0.5 which means understanding words 50% comparable to understanding words and communication in normal people. The calculated value is only the ability to understand communication capabilities and cannot tell whether the work is safe or not. However, there must be an assessment of suitability and work ability in each position.

Measures to control the noise in the stone crusher industry in Thailand

According to studies on the exposure to excessive noise causing hearing loss in stone crusher workers in Thailand.⁽¹⁰⁾ There is usually an exceeded the standard level of noise that has been average throughout the working each day. Some workers have loss of hearing from working in a loud noise but there are some employees who work in the same manner with normal hearing. Even though normal hearing but

workers should wear protective equipment when working in the place that noise exceeds the standard. Most workers do not wear protective equipment. Therefore, they should be getting some information to the importance of using the device correctly and appropriately. Arranging hearing conservation if found to have employees who have been confirmed to have hearing loss due to loud contact as required by law to reach measures to control the volume to the standard criteria.

Rules and prevention measures to control and reduce the effects of hearing loss from noises⁽²⁴⁾ suggested by relevant agencies and experts, consisting of 3 main measures:

1. Engineering controls: design of machines with quiet sound and regular maintenance of machinery.
2. Administration controls: Reducing the time of contact with the loud noise of workers by working rotations and arranged time of exposure to loud noises.
3. Personal hearing protection: Using sound protection equipments, providing knowledge on health and safety education for the workers.

Conclusion

From the above research, stone crushers have some activities that cause loud noises. The loud noise while operating is inevitable and causing hearing loss. Depending on the position and the time that exposed the loudness and personal factors. It is difficult to modify the location and machinery to control and reduce the noise but can reduce violence and loss by taking measures and suggestion. In addition, the project should continue to support the hearing conservation program and evaluated periodically. There are inspections of work measures that Hearing Loud Noises. Determining the area, distance between communities and stone crushers to minimize impact from loud noise. Providing knowledge about how to wear devices to prevent employees from being affected by loud noise and should be surveillance of the effects and hearing loss.

Conflict of interest

The authors, hereby, declare no conflict of interest.

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