A Review on Noise Mitigation Methods on Shooting Ranges

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ABSTRACT

One of the most significant environmental impacts of training on shooting ranges is weapon noise. All types of weapons are generating noise, which has negative impact on environment as well as human health. In order to reduce noise from shooting ranges using weapons different methods has been studied. This paper presents different technologies to mitigate the noise from both light and heavy weapons. Different examples of noise attenuation using mobile shooting tunnels, noise suppressors, absorption materials covering the bullet trap screens, noise screens, sound mufflers, foam covering explosives and mobile shooting tunnels are discussed.

1.0 INTRODUCTION

Blast noise from artillery, demolition, and explosives ordnance disposal (EOD) can cause major environmental noise problems if an Army installation's space limitations require that these activities be conducted near populated areas. At some installations, annoyance and damage complaints have restricted blast noise-producing training to day-time/favourable weather operations. If the noise produced by such activities could be reduced at the source, then such operations would not have to be curtailed.

2.0 NOISE EMISSIONS

Noise emissions of large calibre weapons can be divided into the propellant blast, the sonic boom from supersonic projectiles (projectile noise) and noise from target impact (impact/explosion noise).

2.1 Blast noise

The blast from the barrel (muzzle blast) is created by the explosive combustion of the charge of a projectile that is fired. The rapidly expanding gases from the explosion cause an acoustic blast to emerge from the barrel. The blast signature can be described as a point source with strong directivity. The sound level of the muzzle blast is typically strongest in the direction of fire, and decreases as the off-axis angle increases.

2.2 Projectile noise

Projectile noise is created when the projectile travels faster than the speed of sound (sonic boom). The projectile noise forms a cone whose vertex is centered on the moving projectile at any time and whose sides are tangent to the muzzle blast front. The sound radiation direction strongly correlates to the local speed of the projectile relative to the local sound speed. The areas affected by projectile noise are very limited and normally there are no residential areas within the region. Therefore, the projectile noise is often not considered when dealing with environmental noise assessment from training and shooting areas. An exception is Denmark, where this sometimes is a big problem for the residents near by the training area.

2.3 Impact/explosion noise

Detonation noise occurs when the projectile has a detonating charge and explodes on impact. This also applies to detonations that occur during EOD (disposal) and Engineer (demolitions) activities. The noise signature can be described as an omnidirectional sound source that emits equal amounts of sound in all directions in a spherical pattern.

3.0 FACTORS AFFECTING OUTDOOR SOUND PROPAGATION

In order to understand how the noise mitigation methods work there are a number of factors affecting outdoor sound propagation that will be briefly listed here.

- The distance between the source and receiver determines the amount of loss from wavefront spreading (or divergence), which decreases the peak sound pressure as 1/R, where R is the propagation distance.

- Attenuation by air absorption increases with distance, and is a larger effect at higher frequencies.

- The ground has two different effects, the interference between the direct and reflected sound and the effect of ground impedance. Reflections from the ground surface interfere with the direct sound path in a way that varies, depending on the geometry, frequency, and ground impedance. Acoustical ground impedance itself also varies according to the nature of the ground surface. Highly porous surfaces will have higher sound energy loss because more incident sound energy will enter the pores and be dissipated by viscous and thermal losses.

- The water is considered as an acoustically hard surface. When sound propagates over a hard surface, such as water, very little sound is absorbed. Unlike sound propagation over land (where the pressure wave decays relatively quickly), without ground or vegetation to absorb the sound, gunfire propagates very efficiently across the face of the water (White et al., 1993).

- Meteorological conditions can have a large influence, especially at longer distances. These include wind and temperature gradients that can bend sound propagation towards or away from the ground surface, enhancing propagation along the surface in downward refracting directions. Thus, meteorological conditions may cause an asymmetry in the aerial distribution of sound levels, and also a time variability as atmospheric conditions change.

- Turbulent scattering tends to affect higher frequencies more than lower frequencies, and introduces an instantaneous fluctuation in the received sound levels. It also tends to blur or fill in the sharp shadow zones that would be otherwise expected from interference or meteorology.

- Obstructions along the propagation path, such as topography or sound barriers, can influence the sound levels by scattering, absorption, and diffraction.

4.0 NOISE MITIGATION METHODS

4.1 Mobile shooting tunnels for small arms

The noise attenuation using mobile shooting tunnels is studied in order to minimize the muzzle noise in the shooting ranges, where other conventional mitigation methods are not sufficient. Two different mobile shooting tunnels are tested (with circular and square cross-sectional area). In the test three different calibres have been used in the measurements: 5.56 mm, 7.62 mm and 8.6 mm. The noise level at a distance of 1000 m from the firing line has been estimated using the calculation program NoMeS. The measurements show that the shooting tunnel with square cross-sectional area has an amplification effect in all directions except at a direction of 90°, where it has an attenuation effect up to 0.7 dB. Furthermore, the shooting tunnel with circular cross-sectional area has an attenuation effect in all directions except at a direction of 180°, where it has an amplification effect up to 0.4 dB. The highest attenuation effect can be obtained at a direction of 90°, in which the attenuation is up to 15.8 dB, whereas the attenuation effect is only 1.6 dB in the direction of shooting (Alfred, 2014).

Figure 1: The mobile shooting tunnels with circular (left) and square (right) cross-sectional area.

4.2 Noise suppressors for small arms

The sound suppression can be used on rifles and pistols and can remove the need for special sound containment measures on a range. Suppressors control only muzzle blast. Suppressors cannot affect the ballistic downrange sound from a supersonic bullet. Management of this source of shooting sound may still need berms or other constructions.

One study found the muzzle blast of a 7.62 mm rifle could be reduced by 15-20 dB(A) using a suppresser with a 50 mm cross section, 185 mm length, and 710 g weight (Buchta, 1985).

Figure 2: A typical sound suppresser for a small caliber weapon.

4.3 Sound mufflers for small arms

Muffled firing line is a firing line that has one or more design features installed at it, to reduce or re-direct sound waves, thereby reducing the impulsive noise levels heard off range.

Figure 3: Sound mufflers for a small caliber weapon.

4.4 Noise barriers for small arms

A noise-shielding structure that is interposed between source and observer does not achieve a total acoustical shadow because some sound energy is diffracted around the edges of the structure into the shadow zone. The amount of sound energy diffracted into the shadow zone depends on the frequency of the sound and the size of the structure; lower frequency means more sound energy is diffracted around a barrier of given size and thus less noise reduction is realized. Noise-shielding structures such as partial enclosures and barriers have potential utility in reducing small arms noise because the acoustic energy from this source is concentrated at higher frequencies so that barriers are larger in terms of wavelength, and thus better noise shielding is achieved. One suggested technique for reducing noise in the region to the rear of the range is to partially enclose the firing line in an open-front shed.

Another suggested method of reducing noise disturbance caused by small arms ranges is by building noise barriers similar to those used along highways to reduce traffic noise. These "interlane" barriers would be located between the firing lanes of a rifle range. This arrangement allows a barrier to be located close to a gun, and enables significant noise reduction to be achieved from barriers of relatively modest size and cost as compared with a barrier located at the boundary of the rifle range. An interlanc barrier can provide effective noise shielding for locations to the side of the range but not to locations directly uprange or downrange.

4.5 Absorption materials covering the bullet trap screens

The reflection of the forward muzzle noise from the bullet trap screen can be crucial for the noise in the direction opposite to the direction of the shooting, especially in the situations where the backward muzzle noise is screened by a noise barrier or a shooting house. The purpose of this study is to determine the absorption coefficient of three new absorption materials (Metal Membrane, Fibber Membrane and Cellular Membrane) and combinations of them, which used to cover the bullet trap screen in order to minimize the reflected muzzle noise from the screen. Three different calibres have been used in the measurements: 5.56 mm, 7.62 mm and 8.6 mm. The measurements show that Fibber Membrane has the best absorption of the three materials. Cellular Membrane has the lowest absorption, and a combination of Fibber and Cellular Membrane has the best absorption at high frequencies. The perforated metal plate, which is placed on the outer frame of the panel in front of the Fibber Membrane, increases the absorption at any frequency. Furthermore, the measurements show that there is no significant difference in the absorption coefficient, whether the absorption material is mounted directly on the bullet trap screen or there is an air gap between the absorption material and bullet trap screen. The installation of an additional layer of absorbent material provides better absorption at high frequencies (Alfred, 2014).

4.6 Quieting the large calibre guns

In 1969 US Army developed a silencer for 105 mm howitzer (M102). The silencer was 20 feet long and 5 feet in diameter. This was one of the earliest works on silencing a heavy weapon. In 1983 a new silencer was developed with 20 feet long and 7.5 feet in diameter. This silencer achieved 15-20 dB noise reduction (AEHA, 1985).

The German Army developed a super gigantic silencer for 155 mm cannon (turreted self-propelled howitzer M109) in order to suppress loud noises coming from artillery test firing at a range in Germany after many complaints from residents close to the range. The length of barrel that is encompassed by the silencer sleeve has gas vents drilled into it that allows the propellant gas to escape. This results in some of the energy from the fired rounds being lost as it exits the barrel at less than the speed of sound, reducing reverberations and preventing a deafening sonic boom.

Figure 4: A silencer developed by the German Army to suppress the noise from 155 mm howitzer cannon.

The silencers for heavy guns require a massive weight, which is considered as a limitation.

Noise reduction from firing large calibres can only be used at test firing ranges with fixed positions, as these kinds of silencers cannot be moved because of their weight.

Other noise mitigation methods can be:

- Use of 500 Ib bombs instead of 2000 Ib bombs.
- Use of inert artillery training rounds instead of high explosive rounds.
- Use of point-detonating (PD) or super-quick PD (SQPD) fuzes on artillery rounds, which detonate the rounds at ground level, instead of Variable Time fuzes, which detonate the rounds in the air above the target.

4.7 Noise screens for heavy weapons

Noise attenuation using noise screens has only a minor effect and the screens need to be placed close to the noisy activities or neighbours.

At smaller activities with fixed positions, noise screens can be a solution to achieve noise reduction. The effect of a noise screen can be up to 15 dB. Noise screens have been used, for example, to reduce noise from anti-tank weapons firing positions.

Pits or berms are used around explosive training or demolition sites mainly for safety reasons. Berms or pit walls can also have some effect on noise attenuation. These structures can reduce noise with smaller explosions but are usually negligible when the mass of explosive charges are 5-10 kg or larger.

Figure 5: An example of a safety berm at a demolition area that has also noise screening properties (EPHW, 2019).

4.8 Noise attenuation using foam

Use of aqueous foam for quieting unconfined explosives was investigated back in 1981 (Raspet, 1981). The study concluded the following:

- Both high- and low-expansion ratio[1] foams can be used to reduce the blast noise of Army explosive charges. For unconfined explosions (like explosives), blast noise can be reduced by up to 14 dB; if the explosion is confined (like artillery), the foam's effectiveness is increased by about 3 to 6 dB.

- Aqueous foam can be used to reduce the blast noise levels of shaped charges and artillery.

The Danish Defence had tested the possibility to reduce the noise with the foam used in fire-fighting equipment by covering explosives with that foam. This method is especially useful with smaller explosions/blast less than 2 kg TNT (or equivalent). A noise reduction up to approximately 10 dB can be

[1] Expansion ratio is the ratio of foam volume to liquid volume.

achieved if the thickness of the covering layer of foam is approximately 1 m. At explosions/blast between 2 and 10 kg TNT (or equivalent), the noise reduction is reduced to 3-4 dB (Sweco, 2016).

4.9 Increasing the distance

The simplest way to reduce the noise exposure is to increase the distance between source and receiver. Since most heavy weapons and explosions are dominated by low frequencies, the air absorption will be minimal. Therefore, the noise exposure will be reduced approximately 6 dB for every doubling of distance from a point source. E.g. If the distance to nearest neighbor is 500 m, a 12 dB noise reduction can be achieved by increasing the distance to 2 km. On actively used training areas, this option to increase the distance to neighbors is often already fully utilized or very restricted.

4.10 Taking advantage of ground Impedance

When sound propagates over a freshly plowed field or loose snow, it is attenuated much faster than when it propagates over a lake or an expanse of flat concrete.

When laying out small arms ranges, it is preferable to locate ranges where soldiers fire from a prone position closer to the community and ranges where the gun is fired at a higher position (e.g., pistol or sniper range) farther from the community.

Ground impedance is particularly useful with rifles because rifles tend to generate most of the sound at 500 Hz and ground is particularly good at attenuating at 500 Hz.

4.11 Use of vegetation

Forests are more effective in reducing high frequency sound than low frequency sound. Forest is much more effective in reducing the annoyance of things like small arms than the annoyance of heavy weapons, because the spectrum of heavy weapons usually contains more low frequency sound than from the small arms. The low frequency sound waves from heavy weapons propagate over much longer distances than the sound waves of higher frequency.

The effect of a forest on propagation of blast noise generated by large guns and explosions is currently not well understood. Theoretically, the forest might affect noise propagation in several different ways, including scattering and absorption by trunks, branches, and leaves; by absorption by the porous ground conditions caused by detritus in the forest; and by the effects of the forest on microclime values of wind and temperature. No definitive experimental data could be found regarding whether low-frequency (30 to 80 Hertz) blast noise from military activities will be scattered or absorbed by forest vegetation, and contradicting anecdotal evidence exists. Although the ground surface impedance within a forest is known to be absorptive at higher frequencies, there is a lack of measured data at low frequencies.

A study made by US Army Corps of Engineers showed that forests do indeed provide some noise mitigation benefit. This can be as much as 4 dB unweighted peak, if the propagation path is partially forested. To realize the greatest noise mitigation benefit, the source must be located in the open field and the receiver in the forest. However, when examining experimental frequency spectra, it is unclear if there is a greater benefit caused by the forest for low frequencies, or if the peak level reduction is mainly due to significant reductions in higher frequencies. Because the simulations only accounted for changes in the density of the trees, the results from the comparison between full forest and those with one-half as many trees showed changes only above 200 Hz. Lower frequencies were largely governed by atmospheric effects, which are expected to change as a function of tree number density and corresponding canopy density (Swearingen, 2005).

4.12 Optimization of meteorological conditions

Weather conditions have a major influence on sound propagation. This is especially the case at large distances, which often is applicable at training areas. For example, at sound propagation over a 2 km distance, noise exposure can vary more than 30 dB between up- and downwind. During windy conditions, the sound from the range may be hardly audible in upwind locations. Sound levels are typically higher downwind than upwind from the source. Therefore it is better to locate a range downwind from a noise-sensitive area than upwind. Under clear skies and calm winds, sound propagation can be at its greatest. A layer of snow or low clouds can cause reflect/redirect sound and therefore increase its perceived level.

Weather conditions are a more important variable than the size of the weapon when calculating the noise at the neighbouring area. For example although the 15 Ibs of high explosive (HE) in a 155 mm howitzer round will, on average, make more noise than the 5 Ibs of HE in the 105 mm round; a 105 mm howitzer round under worst case weather conditions will sound louder than a 155 mm round during ordinary conditions.

In order to reduce noise exposure the activities can be completed mainly on days where weather conditions are least favourable for sound propagation, or activity locations can be adjusted to the actual weather conditions.

Especially at inversion, i.e. increasing temperature at increasing height over terrain, the noise exposure at certain areas can be considerably louder than normal due to focusing of the noise. Activities which involve heavy weapons and explosives should therefore be avoided at inversion. Inversion often occurs in the period after sunrise.

While changes in daily weather conditions can usually not be taken into account when planning training, it is possible to plan training taking into consideration typical seasonal weather phenomena. For example in spring and autumn mornings after cold nights, an inversion layer often exists in the morning hours and can cause noise from training to focus in residential areas where noise is not usually very loud. Scheduling noisy activities on midday and afternoon hours during these seasons could be an effective noise management procedure.

4.13 Use of barrier, berm or natural terrain

Barriers are most effective against higher frequency sounds. Barriers must be located in the line-of-sight between the source and the receiver.

Barrier effectiveness increases with height, width, and proximity to either the source or the receiver.

If there are gaps in a barrier, the potential benefits of acoustical shielding will be substantially reduced.

The effects of all barriers are lessened by atmospheric sound scattering and by the effects of noise “spilling” around the edges of the barrier.

Low frequency sounds require higher barriers than high frequency sound, as the calibre of a gun tube increases, the acoustic spectrum of the propellant blast shifts toward lower frequencies and the efficiency of a typical barrier decreases.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Most favorable and effective noise mitigation methods usually used for environmental noise, such as reducing noise emissions, are not applicable to training with heavy weapons. For reducing the effects of noise from heavy weapons training, several noise mitigation or management methods are needed simultaneously.

The following noise mitigation or management methods are recommended:

- Use of mobile shooting tunnels to attenuate the noise when shooting with small arms. These shooting tunnels can obtain attenuation up to 15.8 dB in some directions.
- Use of sound suppressers and sound mufflers to attenuate the muzzle noise when shooting with small arms.
- Use of noise screens or barriers at smaller activities with fixed positions can be a solution to achieve noise reduction when shooting with small arms and heavy weapons.
- Berms or pit walls can reduce noise with smaller explosions but are usually negligible when the mass of explosive charges are 5-10 kg or larger.
- Use of the foam to reduce the blast noise levels of explosives and artillery. This method needs more investigation.
- Increasing the distance between source (weapon) and receiver (neighbour).
- Avoid having bodies of water between military training area and the community.
- Forests are effective in reducing noise when shooting inside the forest.
- Completing the activities on days where weather conditions are least favorable for sound propagation. While changes in daily weather conditions can usually not be taken into account when planning training, it is possible to plan training taking into consideration typical seasonal weather phenomena.

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