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Bullet Recovery in Shooting Ranges

Marine Container Concept

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Abstract

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The purpose of this thesis was to study a bullet trap developed by Espoon Ampumaratayhdistys (AMRY) and its bullet capture efficiency. The project focused on the marine container concept, which is built using a marine container. Environmental problems and requirements are constantly increasing, making it essential to develop new systems in shooting ranges to capture bullets containing hazardous substances.

Bullets are mostly made of materials harmful to the environment and living organisms, such as lead, antimony and arsenic. Also in Finland, the backstop in shooting ranges is commonly built using soil, and the bullets remaining in the soil pose a risk of polluting the soil, surface waters and ground waters.

The research was conducted in spring 2016 at Lahnus outdoor shooting range, in collaboration with AMRY's staff and biathlon team Tuusulan Voimaveikot (TV-V). Two different target devices were used in the experiment; cardboard flats and biathlon flats.

Results from the bullet recovery relative to the amount shot were excellent. More bullets were recovered (91.0–91.7 %), as expected, while shooting to the cardboard flats, but also biathlon flat recovery percentages were good (87.1–87.8 %).

When comparing this system to the other bullet traps on the market, the marine container concept provides a functional system as a whole, which can be used in all outdoor shooting ranges. While being a mobile unit, it can also be used outside shooting ranges, making it a potential solution to for example biathlon courses, where building a backstop using soil is not feasible.

Keywords	bullet trap, shooting range, hazardous waste

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Tämän insinöörityön tarkoitus oli tutkia Espoon Ampumaratayhdistys Ry:n (AMRY) ulkoampumaradoille kehittämää luotiloukkua ja sen talteenottotehokkuutta. Työssä keskityttiin merikonttiratkaisuun, jossa luotiloukku rakennetaan merikonttia käyttäen. Ympäristöongelmien ja -vaatimusten kasvaessa on oleellista, että ampumaradoille kehitetään järjestelmiä haitallisia aineita sisältävien luotien talteenottoa varten.

Luodit sisältävät ympäristölle sekä eläville organismeille haitallisia aineita, kuten lyijyä, antimonia ja arseenia. Suomessakin yleisesti käytettyyn maa-aineksesta rakennettuun taustavalliin jäävät luodit ovat riski, sillä ajan kuluessa luotien sisältävät aineet liukenevat ja pilaavat maaperää, pinta- sekä pohjavesiä.

Tutkimus toteutettiin keväällä 2016 Lahnuksen ulkoampumaradalla yhteistyössä AMRY:n henkilökunnan sekä ampumahiihtojoukkue Tuusulan Voimaveikkojen (TV-V) kanssa. Tutkimuksessa käytettiin kahta eri maalitaululaitetta; pahvitauluja ja ampumahiihtotaululaitetta.

Tulokset luotien talteenottoprosentteina suhteessa ammuttuun määrään olivat erinoimaiset. Luoteja saatiin odotettavasti talteen enemmän (91.0–91.7 %) ammuttaessa pahvitauluihin, mutta myös ampumahiihtotaululaitteiden osalta tulos oli hyvä (87.1–87.8 %).

Vertailtaessa muihin markkinoilla oleviin luotiloukkujärjestelmiin, merikonttiratkaisu tarjoaa toimivan kokonaisuuden, jota voidaan hyödyntää kaikilla ulkoampumaradoilla. Siirreltävyytensä ansiosta myös ampumaratojen ulkopuolella, tehden ratkaisun käytön mahdolliseksi esimerkiksi ampumahiihtoradoilla, joissa maasta rakennettu taustavalli ei ole mahdollinen.

Avainsanat	luotiloukku, ampumarata, ongelmajäte

Contents

1 Introduction

Shooting in Finland has a long history and an extensive inheritance. After the end of the World War II, shooting began to engage in a more competitive way, and the popularity of shooting ranges started to increase. Gradually, safety and environmental impacts were considered, and the design of the shooting ranges began to improve.

Suomen Ampumaurheiluliitto (SAL) is the largest Finnish shooting sport association with 310 member clubs. The clubs have a total of more than 34 000 members, of which ca. 15 000 are active. The purpose of SAL is to promote and develop the shooting sport in Finland, as well as to influence and participate in international shooting sports. The mission of the association is to promote and develop secure, supervised shooting range sports activities. In addition to SAL, there are reservist and hunting associations. The largest are Reserviläisurheiluliitto Ry, Suomen Metsästäjäliitto and Suomen Riistakeskus with thousands of active members practicing all kinds of shooting. [1]

There are hundreds of shooting ranges in Finland, whose activity is feared to cause damage to the environment and human health. Estimated number of shooting ranges in operation in Finland varies from 600 to 1000. Most of the shooting ranges are maintained by different hunting associations, and the largest single operator is the military. Shooting ranges most significant problem through the ages have been noise pollution and the contamination of soil. These environmental impacts can be controlled with proper planning of shooting ranges, remediation and recovery of contaminants. The future goal is that shooting is done in shooting centers, which do not disturb the surrounding residential areas or wildlife. Externalities are more easily and better managed in shooting ranges that are centralized and operating according to BAT-principle. [2, 3]

This research was done in collaboration with *Espoon Ampumaratayhdistys* (AMRY). The association's purpose is to promote all kinds of shooting in the city of Espoo. To achieve this purpose, the association has built an outdoor shooting range in Lahnus where the experiments were conducted. [6]

The association organizes firearms training and competition opportunities as well as education related to shooting. Shooting test prescribed by law can also be carried out in the Lahnus track. [6]

The marine container concept was mainly developed, constructed and tested in Lahnus shooting range by AMRY. Once properly tested, the project will be public and available for use to everyone.

The thesis consists of a literature review on the environmental impacts of shooting, a short introduction to the marine container concept and other bullet collection systems and experimental evaluation of the marine container concept's lead recovery efficiency.

2 Environmental Impacts of Shooting

2.1 Overview on the Environmental Impacts of Shooting

The most significant environmental impacts associated with the shooting sports are shooting noise and emission of harmful substances released by shooting. In particular, heavy metals can pollute the soil and ground water in the shooting range's proximity. The shooting noise travels far, and it can interfere with people and animals living in the surrounding areas. In competitions and other events where a considerable amount of audience gather around the range, the impact on the environment caused by humans may increase significantly. [2]

In addition to the environmental impacts caused by the actual shooting performance, activities related to shooting functions, as well as construction and maintenance of shooting ranges, result in both direct and indirect effects. Table 1 illustrates the direct environmental impacts of the different functions. Indirect effects are caused by transport, manufacture of arms and bullets, production of the shooting range structures, as well as heat and electricity production. [2]

Table 1. The direct environmental impacts of the shooting ranges [2: p.18].

	Direct consequences
Shooting performance	Noise, propellant combustion gases and lead dust to the air, heavy metal accumulation in the soil, possible contamination of ground water
Shooting activity related functions	Oily cleaning waste from the management of arms, caps, empty cartridge boxes, used cardboard targets
Construction and maintenance of shooting ranges	The destruction of a natural area, materials, energy and other resource consumption, waste from construction, emission to the air

2.2 Shooting Range's Contaminants

Shooting range activity loads the environment mainly due to harmful metals that shot pellets and bullets contain. The most significant contaminants in the most commonly used bullets in Finland are lead, copper, antimony and zinc. Shot pellets' main contaminants are lead and antimony. In addition, the powder and their additives used in cartridges, such as nitro-glycerine, may be harmful to the environment. [3]

Rifle and pistol cartridges consist of four components, illustrated in Figure 1: the cartridge case, the bullet, the propellant and the primer. The cartridge case forms the body of the cartridge, which is attached to the primer and the bullet. The most used raw material for the case is brass with 72% copper and 28% zinc. The jacket, which refers to a coating on the bullet, partly protects the lead from coming into contact with the surrounding soil. Currently, the jacket is made of a mixture of copper (90-95%) and zinc (5-10%). The core of the bullet is composed mainly of lead (97-99%) and small amounts of antimony (1-3%). Of the total mass, a bullet is about 89% lead and 9% of copper. Antimony and zinc take approximately 1% of the total mass. Even after the wars, bullets with a nickel jacket were used. The use of these ended in the 1950s. Thus, old shooting ranges may have nickel contaminants from bullets. [3, 10, 12]

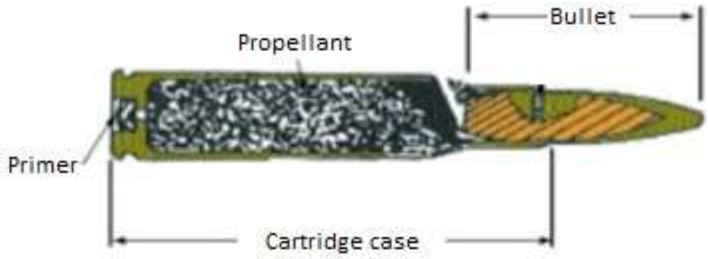

Figure 1. Components of a rifle and pistol bullet. [12]

Lead used in bullets and shot pellets is not pure, but largely comes from melted lead batteries containing many impurities. Pure lead corrodes very slowly. For example, lead used in ancient and medieval structures is mostly non-corroded. Other substances intentionally added to lead, such as antimony, increase the solubility of lead. [3]

Shooting range operations, excluding noise, will not result in direct or short-term impacts on the environment. The introduction of harmful substances into the environment is typically slow. When bullets and shot pellets ended up in the backstop come in contact with the environment (air, water and land), they are exposed to physical and chemical reactions. As a result, these metals may eventually dissolve in rain and melting water, precipitate in the varying conditions of soil's layers as different minerals and to bind in small particles in the soil. Metals may travel with rainwater to surface waters or get absorbed by soil to deeper layers and even end up in ground water. Environmental conditions, such as soil type, pH, permeability and rainfall significantly effect on how quickly and to what extent the erosion of bullets and shot pellets, and the resulting migration of contaminants released to the environment, occurs. In neutral and dry environment, such as sandy soil, erosion is typically very slow. On the other hand, in well permeable sand and gravel soil, transport of soluble contaminants, as the result of erosion, can be rapid and retention weak. A secondary mineral layer, formed on the surface of bullets and shot pellets, mainly composed of oxides and hydroxides, contributes to slow down the erosion and dissolution of the metals. However, in acidic or moist soil conditions, erosion occurs quicker, and the secondary mineral layer dissolves easily. The hummus and the micro-organisms in the soil, as well as plants, accelerate the erosion of metals, but on the other hand they are also capable of binding metals dissolved in the soil. Also, the clay minerals' and fine matters' permanent negative surface charge and ion exchange capacity allows binding of dissolved metals and thus slows down their migration. Soil conditions' effects on leaching of different metals are illustrated in Table 2. [3, 13]

Table 2. The effect of soil's properties on the dissolution of heavy metals. [3; p.26]

When the property increases	Lead (Pb) dissolution		Copper (Cu) dissolution		Antimony (Sb) dissolution	
	Increases	Decreases	Increases	Decreases	Increases	Decreases
Moisture	X		X		X	
Temperature	X		X		X	
Clay Content		X		X	X	
Hummus Content		X		X		X
pH		X*		X	X	

*With lead, the effect of pH-value is not unequivocal. The solubility increases with decreasing pH, but also strongly alkaline conditions cause increase in solubility of lead.

Particularly problematic in terms of environment are the locations where shot pellets and bullets come into direct and prolonged contact with water. Such a situation may arise in for example marshes, shooting in waters or in areas where the ground water level is close to the ground. [3]

2.2.1 Lead

Lead causes toxic effects on organisms and plants already at very low concentrations (e.g. decrease in reproduction and growth). Field mapping of an area contaminated by lead have shown how the contamination reduces species and their distribution. The contamination also reduces the soils growth conditions by affecting to the decomposition process through organisms. Lead accumulates in the food chain. Lead is particularly toxic for children. Exposure to lead can cause damage to the central nervous system, kidneys, blood-forming organs and to the bones. [14]

2.2.2 Antimony

Antimony is a semi-metal, which can easily migrate in the soil and end up in ground water. Some of the antimony compounds are highly toxic to aquatic organisms. Antimony has not been shown to be a necessary trace element for humans, animals or plants. Health effects of antimony are dependent on, among other things, antimony compound, manner of exposure and amount. Some of the antimony compounds may cause, for example, lung cancer. [2]

2.2.3 Arsenic

Arsenic is a common semi-metal in nature, mostly occurring with sulphide minerals. Arsenic normally binds to soil oxides, organic matter and clay minerals. Arsenic can easily migrate into ground water in coarse-grained soil. Naturally high levels of arsenic are common in ground water areas where arsenic is abundant in bedrock. Arsenic is carcinogenic and genotoxic. In addition, it is highly toxic to soil and aquatic organisms. [15]

2.2.4 Copper

In the soil, copper is present in sulphite and silicate minerals. As a result of human activity, copper in the soils is usually more mobile than the natural form. Soil acidity, low levels of organic matter and lack of copper binding materials add to its mobility. In small doses, copper is an essential trance element to humans, animals and plants. However, at higher concentrations, copper is toxic to aquatic organisms and can cause a number of health problems to humans and animals. [16, 17]

2.2.5 Zinc

Zinc occurs mainly as bound to sulphide and silicate minerals crystal lattice in soil and bedrock. Zinc ended up in the environment as a result of human activity is generally more soluble than the naturally occurring form. In the soil, zinc can form a variety of complex inorganic and organic compounds, many of which are soluble and readily mobile. Under acidic conditions, the solubility of zinc increases. Organic matter, clay minerals and iron and aluminium oxide precipitates bind zinc in the soil. Zinc is an essential trace element for plants, organisms and humans, but some of the compounds are harmful to health and the environment. Some of the compounds are also highly toxic to aquatic organisms. [18]

2.2.6 Nickel

Nickel is a silvery-white, hard, malleable and ductile heavy metal, which is highly resistant to corrosion. Nickel is commonly found in many different minerals, usually sulphide ores, of which the most significant being pentlandite. Human needs small amounts of nickel. At high concentrations, however, nickel is harmful to living organisms. Its harmfulness to human health depends on its form of presence. Nickel and its compounds can cause lung and nasal cancer and allergic disorders. Vaporous nickel is fatal even in small doses. [7, 19]

2.3 Formation Mechanisms and Accumulation of Soil Pollutants in Shooting Ranges

Fine lead dust is generated to the foreground of the firing point. The pressure from the combustion of gunpowder releases the lead styphnate in the primer of the cartridge. The combustion of gunpowder releases carbon dioxide, carbon monoxide, nitrogen oxides, hydrocarbons, and to a limited extent, antimony and arsenic. Shooting event also releases gunpowder and other propellants, such as nitro-glycerine. In addition, fine copper and zinc dust is generated to the foreground, derived from the bullet jacket rubbing against the barrel of the gun. [2]

The contaminants in the foreground of the shooting spot are fine and therefore more easily transported than the bullets in the target area. Metal dust, gunpowder and propellant residues can be carried by rainwater and melt water, and small amounts of contaminants may end up in the surface water or groundwater. [2]

Bullets mainly accumulate behind the target equipment to the backstop, bullet traps or other bullet collection structures. A small part of the bullets, due to missed shots or ricochets, end up in the area between the target and the shooting spot, other parts of the backstop or even outside the shooting range, if the backstop is not sufficiently high or wide. Shooting types where the targets are metal, such as biathlon, the bullet crushes to the target and fine metal fragments spread to the track surface layer around the target. Metal dust is generated and accumulated to the surface layer around the target device also with the use of certain metallic bullet traps. Figure 2 represents a simplified accumulation of contaminants to the structures of a shooting range.

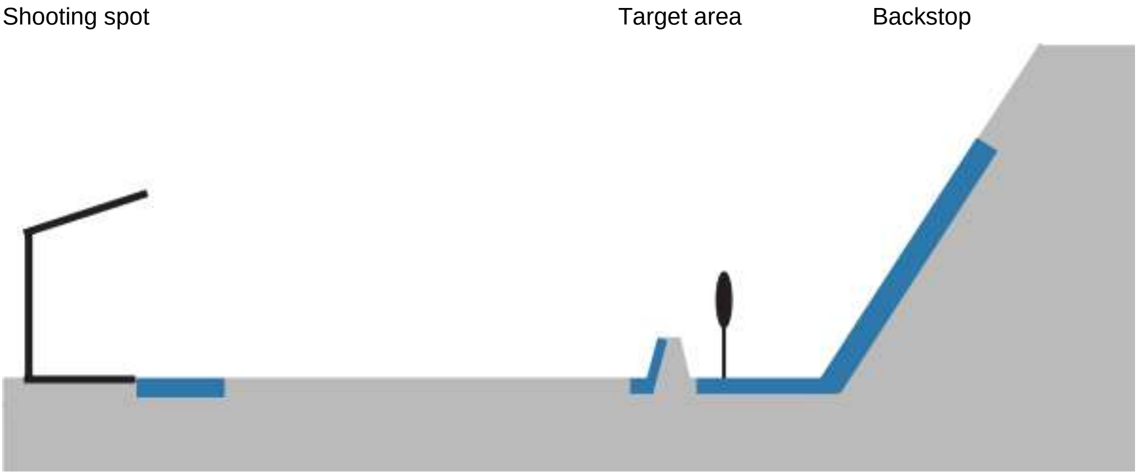

Figure 2. A simplified representation of the accumulation of contaminants to the shooting range structures (blue colour). [3; p.28]

2.4 Migration of Contaminants to Ground Water

Pollutants may travel from the structures of shooting ranges to ground water with rain or melt water absorbed by soil. Migration of the contaminants in the soil is influenced by the characteristics of both the soil and the pollutant. For ground water, most harmful substances are lead and antimony. Lead’s mobility in soil is usually relatively weak, but for example acidic and damp conditions, short distance between ground and ground water level, and large amount of lead in the soil contribute to the migration to the ground water. The solubility and mobility of antimony are often considerably larger than leads, but the concentrations and total amounts in the soil are smaller. [2, 20]

2.5 Migration of Contaminants to Surface Water

The contaminants in the shooting ranges usually migrate from the soil to the surface waters with runoff in a soluble form or as bound to particles. Contaminants may migrate to surface waters also as ground water discharging in surface waters, mostly in soluble form. Contaminants migrating from shooting ranges are mainly metals, of which the most significant in terms of concentration levels, are lead and copper. [2, 20]

3 Bullet Trap Comparisons

3.1 Marine Container

The goal of this concept, illustrated in Figure 3, is to develop a reliable, secure and cost-effective solution for the recovery of bullets. Using BAT-principle, this solution could be taken freely into use in all shooting ranges nationwide.

The marine container provides a robust and durable body for the collection system. In the front wall, there is an opening to the container to the direction where the bullets enter the system. Different targets/target devices are placed in the centre of the container. In the back wall there are steel plates working as a backstop, and between the backstop and the targets, there are thin rubber curtains to prevent any ricocheting caused by the bullets crushing into the backstop. Figure 4 shows a cross-section of the concept, where the arrow shows the direction of the incoming bullets.

Figure 3. Marine container concept.

The marine container concept significantly improves the level of environmental protection in outdoor shooting ranges. It reduces the need for new constructions, as the same container can contain a number of different target devices and collection systems. It may be the only cost-effective way to collect bullets in small-scale shooting ranges in the future, particularly in challenging ground water areas and thus preserves the local shooting facility network in its current form. Bullet scrap recovery and re-utilization improves significantly. The system also further increases the safety of the shooting ranges by also capturing possible missed shots inside the container. It may also reduce the need of other structures, for example the backstop. As a whole, this solution allows a secure storage for the target hardware against weather conditions and vandalism.

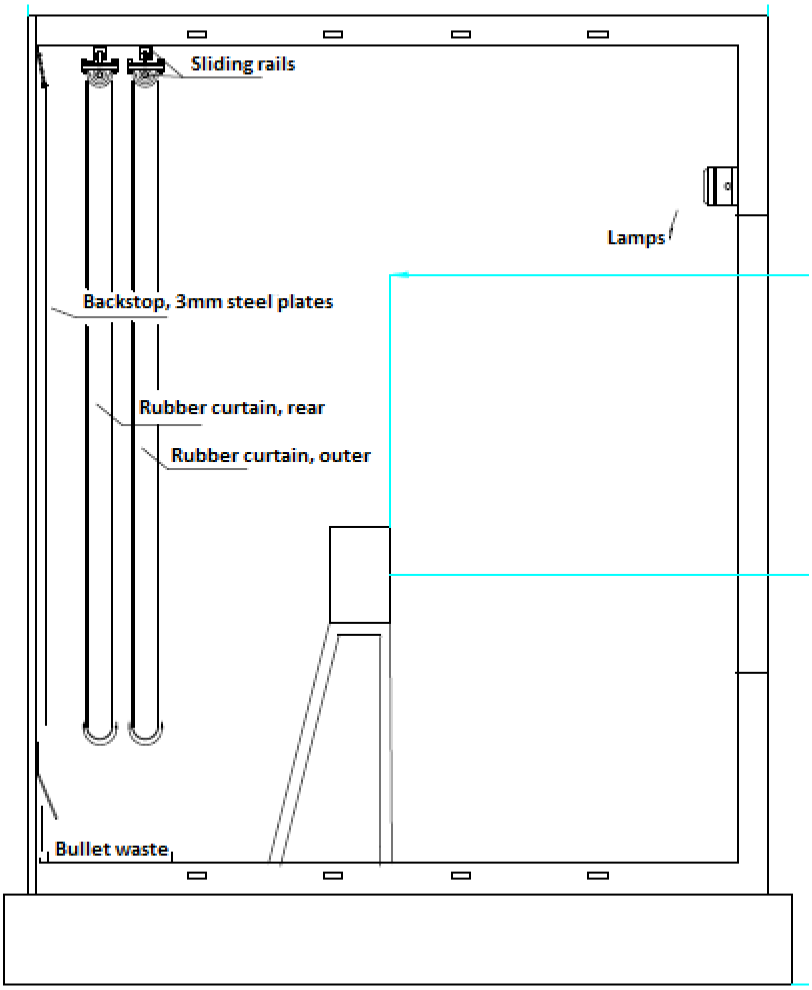

Figure 4. Marine container concept schema.

3.2 Granulated Rubber Bullet Trap

Granulated rubber bullet trap, illustrated in Figure 5, utilizes granulate rubber material to stop incoming bullets. The bullet impacts the soft media and is captured mostly intact, minimizing airborne lead dust, preventing back splatter and ricocheting, and minimizing impact noise. This solution provides cleaner and safer environment for shooting ranges and maximizes recovery and recycling of bullets. [5, 21]

Figure 5. Granulated rubber bullet trap. [21]

The granulated rubber bullet trap can accept all known pistol, shotgun, rifle and high-powered ammunition types, excluding incendiary, or tracer, rounds. [5]

3.3 Pit and Plate Trap

Pit and plate trap utilizes a steel plate which redirects bullets into a bed of sand. The steel plate causes bullets to smash into small fragments on impact before they are scattered on the sand below, shown in Figure 6. Bullet traps of this type require relatively much maintenance. The steel plate must be replaced frequently because of wear. Lead shrapnel must also be removed from the sand or the sand has to be changed from time to time, which causes costs. Benefits of pit and plate include lower initial cost and simple installation. [8]

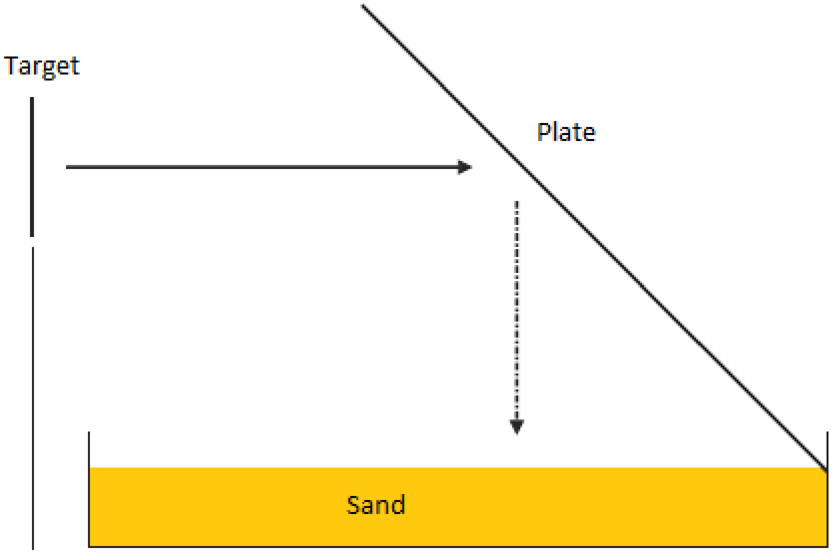

Figure 6. Pit and plate trap.

3.4 Venetian Blind Trap

Venetian Blind trap, shown in Figure 7, consists of a series of angled steel plates, which are at an angle of ca. 35 degrees downward. Bullets are redirected by the steel plates to horizontal chambers. Problems with this type of trap are mainly the emergence of bullet ricochets and the formation of lead dust. Benefits include durability of steel plates, no sand or other granules and a small floor space requirement. [8]

Figure 7. Venetian blind type of bullet trap. [8]

3.5 Escalator Trap

In the escalator bullet trap the bullets hit a steel plate which is set to about a 30 degree angle. An overview of the trap is illustrated in Figure 8. The steel plate leads the fragmented bullets to an open collection vessel. Some manufacturers recommend oiling the steel plate in order to reduce fragmentation. The benefits of this system include durability of steel and no sand or rubber granules needed. Weaknesses consist of bullet fragmentation, no close-range shooting and poor lead storage and collection. [8]

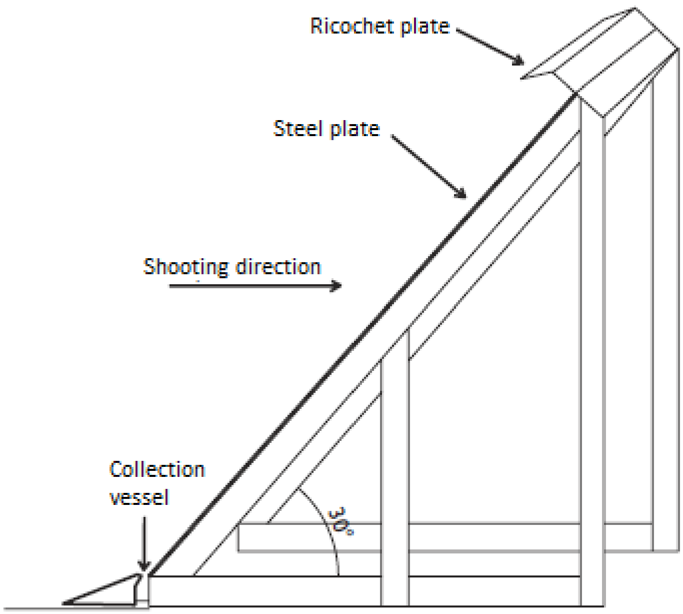

Figure 8. Escalator trap.

3.6 Snail Trap

Snail Trap (trademark) is a steel bullet trap consisting of two inclined steel ramps, which guide the bullet to a circular deceleration chamber, seen in Figure 9. The bullet revolves in the chamber until it falls into a collection vessel. The collected bullets are mainly intact and thus prevent lead dust from spreading into the air. The maintenance of this system is quite simple and it is mainly based on monitoring the condition of the chamber, emptying the collection vessels and oiling any moving parts. The metal parts in the deceleration chamber have to be replaced over time due to wear. [9]

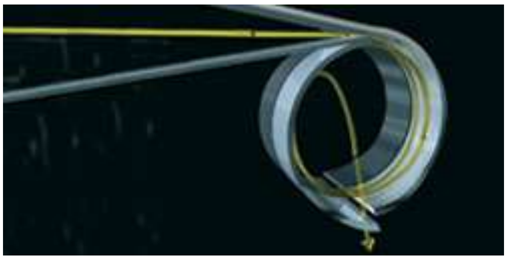

Figure 9. Snail Trap type of bullet trap. [22]

4 Bullet Trap Waste Treatment

All bullet collection systems require frequent emptying and cleaning of bullets/fragments accumulated in the structures. Lead is considered a hazardous waste, and should be treated accordingly. While handling dusty lead waste, proper protective equipment should be used. This includes wearing gloves and a dust mask.

Lead compounds or materials contaminated with lead must be stored in a safe and secure manner. They should be in leak proof containers to prevent release into the environment. Depending on the material, the packaging should be designed to prevent contact with rain water or it should be stored indoors.

Bullet waste disposal can be done by shipping it to the nearest sorting station with a hazardous waste container or to a metal recycling company.

5 Measuring the Effectiveness of the Marine Container Concept

5.1 Practical Experimental Arrangements

The experiment on measuring the efficiency of lead recovery relative to the amount shot was conducted using a .22 LR rifle. The experiment was divided into two main parts; cardboard flat and biathlon flat. Cardboard flat had a higher expectancy in salvage per cent because of its wooden backing, letting the bullets go through and ending up to the backstop of the container; therefore the experiment was divided into two parts with 1000 shots each. Biathlon flat were expected to cause more ricocheting due to metal framing, leading to a higher risk of fragments ricocheting out of the container, and therefore smaller salvage, thus the experiment was divided into four 500 shot parts. The shooting was done from a range of 50 meters in every experiment.

The bullet manufacturer gives a mass of 40 grains (2.592 grams) for a bullet. To make sure, one hundred bullets were separated and weighed at Metropolia's lab using *Precisa XB 3200C* precision scale, giving an average mass of 2.598 grams for one bullet. This was used as a reference for the total mass shot in each container.

5.2 Cardboard/Plywood Flat Experiment

The practical experiments were conducted March 3rd 2016 and May 19th 2016. We had one *J.G. Anschütz GmbH* .22 LR rifle in use and a total of three persons shooting. The weather was cloudy with -2 ^{o}C temperature, 0-1 m/s wind and ca. 20 cm of snow covering the ground in the first day, and sunny with 12 ^{o}C temperature and 0-2 m/s of wind on the second day. Cartridges used in the experiment were CCI's Standard Velocity Long Rifle bullets seen in Figure 10.

Figure 10. Bullets used in the experiments. [11]

The experiment began by carefully vacuuming the container, using *Kärcher MV 4* industrial vacuum, as well as possible within a reasonable timeframe. It ended up taking approximately one hour to reach a sufficient result. The targets were cardboard flats placed on unused plywood backgrounds, represented in Figure 11.

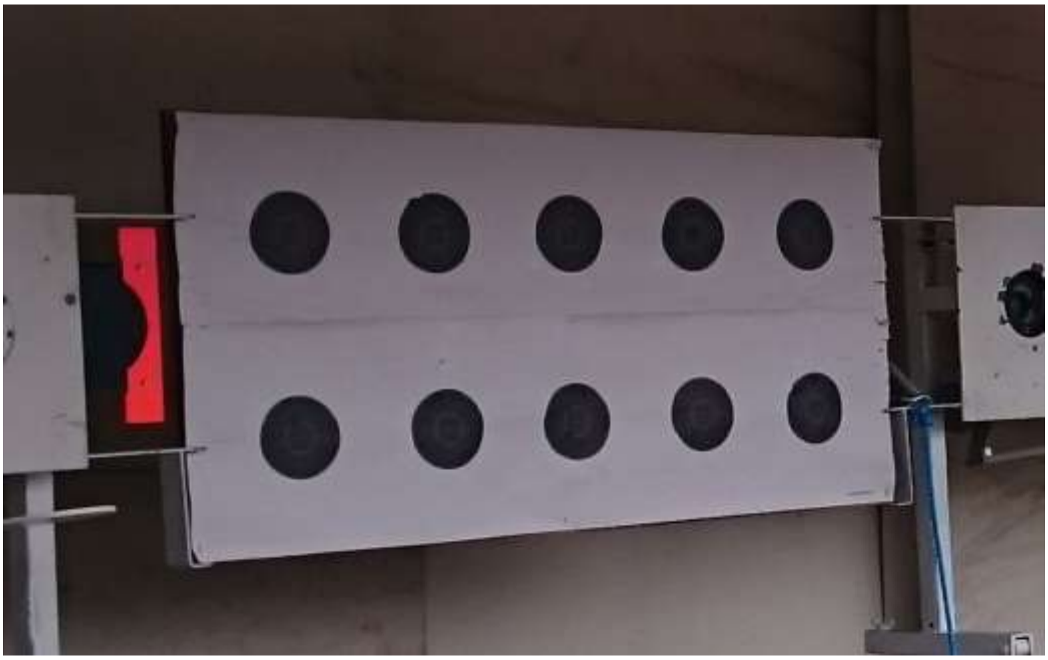

Figure 11. Cardboard targets mounted on plywood.

The shooting was done to the same container each time with 1000 shots each. There were no signs of significant ricocheting outside the container, as it would have been clearly visible due to the snow cover.

After the shooting the container was again vacuumed using the same industrial vacuum, but the dust bag was replaced with a new and clean one. The goal was to vacuum the container as similarly as possible as the first time. It took again approximately one hour, and the dust bag was taken to Metropolia Myyrmäki campus' laboratory for further investigation.

The material gained from the container was mainly a mixture of lead and plywood fragment illustrated in Figure 12. In order to weigh the lead mass, the plywood had to be separated from the material. This was done using a water bath, using the idea of wood having a lower density and hence rising to the surface of the water. However, after applying water to the vessel, it was quickly discovered that only a small part of the plywood stayed on the surface. Whether it was the plywood hydrating rapidly or that it was already moist, we had to come up with an alternative way of separation. In the end, a sufficient result was gained by first washing the material in flowing water and then creating an upstream in a cylinder.

Figure 12. Lead and plywood fragment vacuumed from the container.

After separation phase the lead shrapnel was dried in an oven in 130 ^{o}C for 9 hours, resulting in a lead mass seen in Figure 13. Finally, any visible unwanted material was separated by hand. The remaining lead shrapnel was weighed using *Denver Instrument Company TL-2101* precision scale. Results gained from the weighing can be seen in Table 3.

Table 3. Results of cardboard flat experiment.

	# of shots	Off weight (g)	Outcome (g)	Salvage (%)
1	1000	2598	2363.0	91.0
2	1000	2598	2381.6	91.7

The salvage percentages were lower than expected, as the hypothesis was to gain a result close to 100 %. Losses could have taken place in the shooting event, when small particles are released due to friction in the barrel, shrapnel ricocheting out of the container, possible missed shots, vacuuming and separation of the unwanted material. It is possible that the vacuuming of the container should have been done more carefully and making sure there were not any shrapnel left in the cracks and corners at the bottom of the container. Also, while washing the material, small amounts of fine lead particles could have been lost with the flowing water or as bound to the plywood shrapnel.

Figure 13. Separated and dried lead shrapnel.

5.3 Biathlon Flat Experiment

Biathlon flat practical experiment was conducted April 15th 2016 and May 13th 2016. On April the shooting was done by Tuusulan Voimaveikot (TV-V) biathlon team consisting of 10 personnel. The weather was cloudy with +5 ^{o}C and 0-1 m/s wind. On May the shooting was again done by TV-V biathlon team, this time consisting of six personnel. The weather was sunny with +12 ^{o}C and 0-3 m/s wind.

The containers were vacuumed using the same principle as in the previous experiment. This time, sufficient results were gained faster, as there were not as much plywood shrapnel mixed with the lead. The material was again taken to Metropolia Myyrmäki campus’ laboratory for further investigation.

Table 4. Results of biathlon flat experiment.

	# of shots	Off weight (g)	Outcome (g)	Salvage (%)
1	500	1299	1132.0	87.1
2	500	1299	1138.6	87.7
3	500	1299	1140.2	87.8
4	500	1299	1137.5	87.6

Although there were less of these so-called excess materials in the lead mass as in the previous experiments, the challenge was generated this time by the much smaller, almost powdery, size of the lead shrapnel. Any kind of flushing seemed to take more and more lead dust with it.

The results of the recovery in percentages were ultimately 87.1, 87.7, 87.8 and 87.6. The results seem a little dull and I believe that the actual percentages may be slightly higher. The materials were weighed in different stages of the investigation, and it was noticed that there were some losses even before the separation phase. The initial total mass shot in each container was 1299 grams, and the contents of the dust bags before separation weighed at 1109.6, 1116.9, 1115.2 and 1111.9 grams. A new, clean dust bag weighed at 63.1 grams, and the emptied dust bags weighed 124.3, 115.4, 116.8 and 120.1 grams, respectively, meaning that 61.2, 52.3, 53.7 and 57.0 grams, respectively, of fine lead dust were left inside the dust bags. These were added to the final results of the separated and dried material, giving the outcome represented in Table 4.

6 Conclusion

This research was done in collaboration with Espoon Ampumaratayhdistys (AMRY) and Metropolia UAS. The purpose of the research was to find out the bullet recovery efficiency of a bullet collection system used outdoors to protect the environment from harmful heavy metals.

The marine container concept uses a marine container modified for bullet collection purposes, giving a weatherproof, safe and durable solution to the bullet collector selection. Compared to other commercial systems, the marine container is a compact bullet trap, allowing it to be transported as a whole to the place where it is needed, making it a practical solution to for example biathlon championships. It can also reduce the need of other structures, for example backstop, which may not be possible to build in various locations.

The practical experiments conducted to see how efficient the concept is to recover bullets shot in to the system showed excellent results, giving the recovery percentages relative to amount shot up to 92 % with cardboard targets and 88 % with biathlon targets. This, with the mobility and robustness, makes it a very feasible option as a bullet collection system.

Further research could be done to determine, for example, lead emissions in front of the shooting place, proportion and the reason of bullets/shrapnel ricocheting out of the container, optimization of the bullet collection structures in the container and more accurate collection/separation of materials.

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