Contents

Annex A: Manufacture and uses

A.1 Uses

Detailed information on use is available in Section 1.4 of the main report.

A.2 Manufacture of lead gunshot and bullets

Detailed information on manufacture is available in Section 1.4 of the main report.

A.3 Possible risk management measures

ECHA (2021a) detailed the potential RMMs for recovery of lead during the service life and as part of remediation at the end of life of a sport shooting range as follows:

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Guidance for RMMs to be applied at shooting ranges

US EPA published a guidance for best management practices for lead at outdoor shooting ranges (US EPA, 2005).

In the German shooting range guidelines (German BMI, 2012) and its update (German BMI, 2013), which is legally binding, detailed technical guidance are provided on establishment, approval and operation of shooting ranges (in German language).

The Finnish Ministry of the Environment published a document on best available techniques (BAT) for the management of the environmental impact of shooting ranges (Kajander and Parri, 2014).

The Environmental Protection Authority Victoria, Australia, published a guidance for managing contamination at shooting ranges (Victorian EPA, 2019) as well.

This list is not intended to be exhaustive.'

End of reproduced ECHA text

These references provide a number of recommendations which are summarised below.

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RMMs to recover lead gunshot

Lead shot recovery from natural soil and agricultural land requires removal of the impacted soil horizon and is not feasible in forests. Therefore, specific means are required to be able to recover lead shot effective and periodically.

Measures may include vertical barriers such as walls and/or nets and horizontal barriers such as coverage of the natural soil.

Vertical barriers

Most frequently used vertical barriers are walls. Figure A.1 presents a scheme for walls at trap and skeet ranges.

Figure A.1 Scheme for walls for trap and skeet ranges (Bavarian StMLU, 2003)

Nets are also used as a vertical barrier. An example is presented in Figure A.2. Net systems are available to effectively capture and collect lead shot (Bavarian LFU, 2014).

Vertical barriers have the benefit to reduce the shot fall zone (Figure A.3) and to concentrate the lead shot to assist lead recovery (Victorian EPA, 2019).

Figure A.2 Example for a vertical barrier in a clay shooting range (Herrmann, 2013)

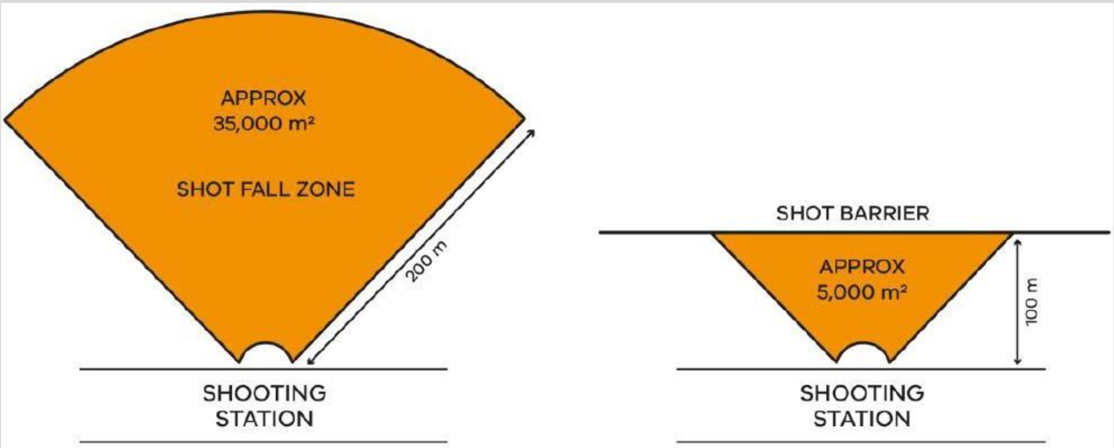

Figure A.3 Reduction in the shot fall zone by using a barrier at a trap station (Victorian EPA, 2019)

Horizontal barriers

To properly recover lead shot, horizontal barriers might also be required.

Figure A.4 presents an example of a horizontal barrier. Drawback of a horizontal barrier without a vertical barrier is the vast surface of land that is required and the spreading of lead shot. Furthermore, it would need to be ensured that no lead shot would land outside the range boundaries

Figure A.4 Example of a horizontal barrier (Bavarian LFU, 2014)

In Figure A.5 a combination of a vertical and horizontal barrier is presented.

Figure A.5 Example of a range with a horizontal and a vertical barrier (Bavarian StMLU, 2003)

Horizontal barriers could consist of materials such as membranes, plastic, specific geotextiles or asphalt (Bavarian LFU, 2014; Kajander and Parri, 2014).

For ranges with lead contaminated soil, an impermeable barrier to cover the soil is likely to be ineffective, as percolation can still occur, and the soil chemistry may be adversely affected by the development of anaerobic soil conditions. Therefore, for existing ranges, before the installation of an impermeable barrier is carried out, removal of the contaminated soil is likely to be needed.

Range layout to optimize lead recovery

Overlapping shot fall areas may improve the efficiency of lead recovery (Victorian EPA, 2019).

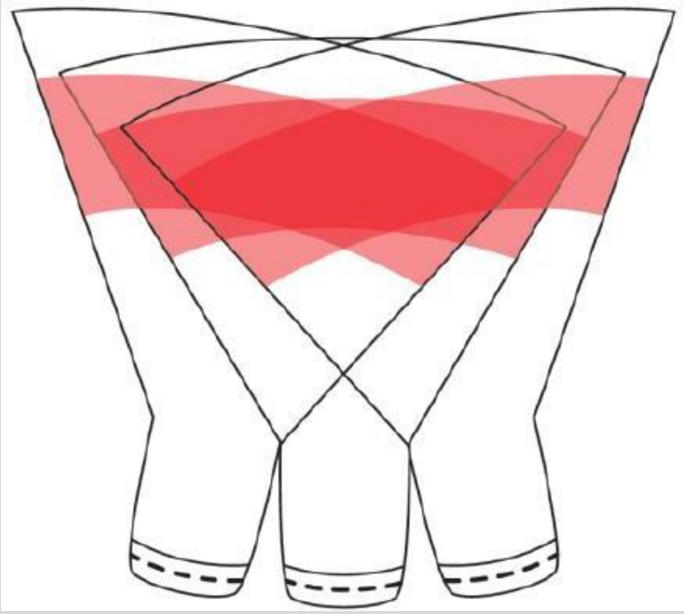

Figure A.6 Using overlap to reduce shot fall area at trap field (Victorian EPA, 2019)

Such measures can be applied to trap and skeet ranges but may not be suitable for all shooting range layouts such as in “sporting” shotgun disciplines.

With regards to lead shot recovery, the following specific information was submitted by several stakeholders:

- For shotgun ranges that do not have structures for the collection of lead shot in place, recovering and recycling is more difficult; if it would be done in a shooting range that is in operation, the investments needed in the required infrastructure would be significant. Therefore, the recovering is done at the shooting range only when the operation ceases or in the case the pollutant risk level is assessed to be too high (Finnish Shooting Sport Federation).
- 40 % of recovery rate was achieved by manually collecting lead shot by individuals who have contracts with shooting ranges for recycling (Cyprus Shooting Sport Federation).
- Almost 100 % recovery is achieved for trap/skeet shotgun ranges, in case shot net systems and appropriately prepared deposition areas on earth walls and in the flat are used (German Shooting Sport and Archery Federation).
- FITASC suggested that lead recovery may be mandatory at the time of closure for shooting ranges that are shutting down and recommended the

use of techniques to stabilise lead to reduce its potential to migrate.

RMMs to recover lead bullets

Bullets are either trapped in a bullet trap or a berm.

Bullet traps

Bullet traps are a very effective means to allow controlled containment, easy and frequent collection and recycling of the lead bullets (see Figure A.7) and therefore minimising the releases to the environment.

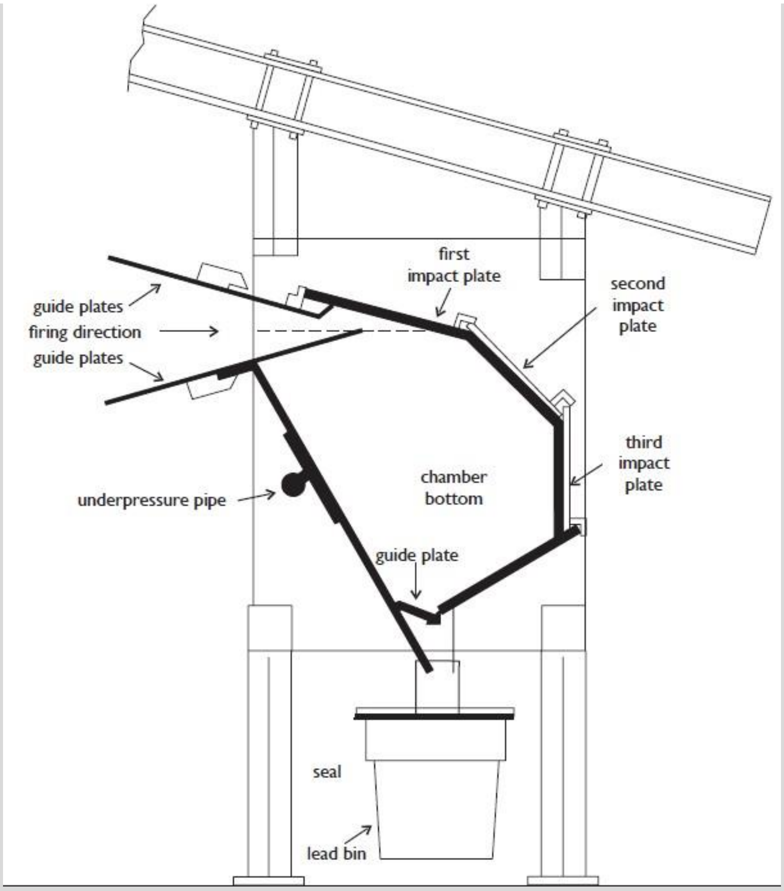

Figure A.7 Example of a total containment bullet trap (Kajander and Parri, 2014)

In the CSR (2020) bullet containment in the shooting range is required: at least one or a combination of bullet traps, sand traps or steel trap. According to the German shooting range guidelines (German BMI, 2012) and its update (German BMI, 2013), the following definition of bullet trap systems are provided (translated to English):

Bullet trap systems are self-contained assemblies which, as technical equipment or installations in shooting ranges, safely dissipate the bullet energy of impacting bullets. They must be designed and constructed in such a way that:

- the absorption or rejection or conduction of impacting projectiles, of whatever type, takes place reliably and safely
- enable the projectile material to be disposed of and separated from the catch material as far as possible
- safe firing (no dangerous rebound of projectiles and fragments) is ensured for the shooters when shooting at close range
- the removal of bullet trapping material is as simple and safe as possible.

The design and materials used in bullet trap systems must be adapted to the intended use of the respective type of ammunition and weapon and to the shooting technique.

In terms of safety, the bullet trap systems must be coordinated as a self-contained unit with the other structures of the internal safety of a firing range, and in the case of open firing ranges, also with external safety.

The bullet trap systems are classified according to their shooting sport or other intended purpose and the respective energy (E0) of the projectiles.

Examples for the construction of different bullet traps are provided in the German shooting range guidelines (German BMI, 2012), the Finnish BAT (Kajander and Parri, 2014) and in the thesis from Kärki (2016).

Figure A.8 Example of a prototype of biathlon target equipment and bullet traps installed in a shipping container (Kajander and Parri, 2014)

Figure A.9 Example for field-target trap (German BMI, 2012)

Kärki (2016) found bullet recovery relative to the amount shot of 91.0 to 91.7 % for shooting to cardboard flats and 87.1 to 87.8 % for biathlon.

With regards to lead bullet recovery, the following information has been submitted to

ECHA:

- 100 % recovery and recycling: in bullet trap systems (for rifles, pistols and airgun weapons) which are emptied regularly in compliance with the relevant occupational health and safety regulations (German Shooting Sport and Archery Federation);
- 95 to 100 % lead recovered (Royal Netherlands Shooting Sport Association);
- Average of 65 % lead recovery and recycling is achieved, depending on the type of range including impact berms/backstop (Swedish shooting sport federation).

In a survey among Member States and stakeholders, lead recovery rates for biathlon close to 100 % were reported in case bullet traps were used. The use of berms resulted in much lower recovery rates. Therefore, the Dossier Submitter considers that by using bullet traps a lead recovery rate of >90 % is achievable.

Data on the incidence of ranges in the EU that recover > 90 % lead bullet is not available.

For rifle and pistol ranges lead recovery by using bullet traps is one of the options among the required risk management measures described in the CSR but there is no evidence that this is a frequently used risk management measure in all EU countries. Soil berms seem to be a commonly used containment (safety) measure based on the available evidence.

Based on information available to the Dossier Submitter it is assumed that at about 70 % of rimfire, centerfire and pistol/revolver ranges lead bullets and fragments are removed from backstop berms. This might suggest that in about 30 % of ranges bullet traps are used to recover lead bullets.

Recovery reduces lead burden on the soil. However, depending on the discipline and method of recovery, fragments may remain in the soil even after recovery. Therefore, at the end of service life of a permanent range, a remediation plan is required as indicated in the CSR (2020).

Berm with roof

Berms are frequently used as a safety related RMM and to trap bullets. However, according to the CSR (2020) bullet containment (see above) is compulsory.

In backstop berms the bullets are trapped in soil. Contamination hotspots are the target area and the berm (see Figure A.10).

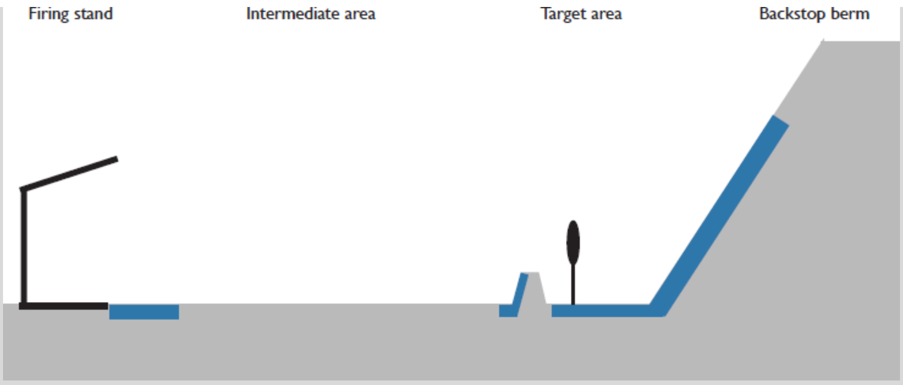

Figure A.10 Contamination hotspot areas at a rifle or pistol range (Kajander and Parri, 2014)

For outdoor rifle and pistol ranges, impact backstops and target areas may be covered with a roof or other permanent cover to prevent rainwater from contacting berms. However, the roof must be carefully designed to avoid safety issues with ricochets, etc. (US EPA, 2005). Furthermore, if a roof keeps a berm too dry, it could crack and erode. This can increase the risk of contamination spreading through wind as dust.

Using a berm made with sand (instead of earthen ones) could slow down lead weathering, but it may increase lead leachability in the long term (Victorian EPA, 2019).

Removal of lead from earthen backstops usually requires soil removal. Continued use of the backstop without removing the lead may result in increased ricochet of bullets and fragments. In addition, the backstop may lose its slope integrity because of “impact pockets” that develop (US EPA, 2005).

In the Finnish report on Best Available Techniques (BAT) for the management of environmental impact of shooting ranges (Kajander and Parri, 2014) three techniques are described for backstop berm renovation:

- Regular removal of the soil in the impact areas containing the most bullet scrap. The removal interval depends on the number of shots and is recommended every three to five years. It is particularly effective at new ranges when used regularly, allowing the removal of the most significant part of the bullets. At old ranges, some of the load is often deeper in the backstop berm and not affected by the technique. This technique is considered suitable for pistol and rifle ranges where the bullets accumulate in the impact areas. However, it is often expensive on the long term.

- Screening of the impact areas. The soil in the impact areas containing the most bullet scrap is removed regularly. The screening interval depends on the number of shots, recommended 3 to 5 years. The bullets are screened out of the soil that can then be returned to the structure or disposed of as waste. The bullets can be recycled. Fine-grained metal remains in the berm and disturbing the soil may increase the solubility of the metals. The spread of dust with metal content must be controlled. This technique is considered of limited suitability for pistol and rifle ranges where the bullets accumulate in the impact areas. At old ranges, there is the risk of the metal particles attached to the soil become mobile. Most usable at new ranges at sites where the reduction of load is considered to be a sufficient measure.

- Removal of bullet scrap and soil in their entirety. The contaminated soil containing bullet scrap is removed and transported away from the area. Removal in this manner, requires quite extensive earthmoving work. The soil and bullet scrap can be separated by screening. The mass replacement work causes some dust generation and the contamination of clean soil brought to the site. This risk management method is considered effective in principle, but an expensive solution that has poor eco-efficiency.

According to the German shooting range guidelines (German BMI, 2012) and its update (German BMI, 2013), natural hills or walls shall not be used as bullet trap. A berm covered with appropriate material or a wall may be required in addition to the bullet trap for safety reasons as for example for biathlon or for silhouette shooting.

Considering the negative aspects of berms to trap bullets and the availability of highly efficient bullet traps to prevent environmental exposure, the Dossier Submitter concludes that a berm is less effective compared to bullet traps.

RMM to reduce the mobilisation of lead

Spent lead bullets and shot are most often deposited directly on and into soil during shooting. When lead is exposed to air and water, it may oxidize and form one of several compounds. The specific compounds created, and their rate of migration, are greatly influenced by soil characteristics, such as pH and soil types. Knowing the soil characteristics of an existing range site is a key component to developing an effective lead management plan (US EPA, 2005).

Lead shot will remain on the surface between removal intervals with the risk of corrosion and mobilisation of lead to run-off water. There are several measures to reduce mobilisation of lead described in the literature.

Lime amendment

The main purpose of liming spreading is to adjust soil pH. Lime spreading should occur around earthen backstops, sand traps, trap and skeet shortfall zones, sporting clays courses and any other areas where the bullets/shots or lead fragments/dust accumulate. Spreading lime over the shot fall zone should raise the pH of the very topsoil layer to a pH closer to ideal levels and reduce the migration potential of lead, pH should be checked annually and multiple samples around the site should be taken.

Phosphate amendment

The main purpose of phosphate spreading is to bind the lead particles to form pyromorphite[1]. Phosphate spreading should be repeated frequently during the range's lifetime (even on a year basis). Based on information from Scheckel et al. (2013) and US EPA (2015) the following has to be noted:

- not suitable for all concentration ranges of Pb;
- long-term stability of pyromorphite and environmental conditions that could cause it to break down and release soluble Pb into soil not fully clear;
- pH level of soil may influence the chemical form of Pb in soil, with certain forms of Pb not easily reacting with phosphate to form pyromorphite;
- if applied in excess amendments may run off the application area and contaminate ground or surface water;
- uncertainties on the effects on the mobility of important Pb co-contaminants (e.g., As): possible enhanced mobility;
- unclear long term effects on soil quality for agricultural purposes.

Ferrous chemical amendments

The use of ferrous chemical amendments is also reported in the literature, in the form of industrial by-products, as potential stabilisers of metal contaminants (Berti and Cunningham, 1997; Aboulroos et al, 2006; Bertocchi et al, 2006; Kumpiene et al, 2007; Spuller et al, 2007). Such by-products include fly ash, beringite, bauxite and birnessite, which contain not only iron, but also aluminium and manganese oxides, have been shown to be effective in stabilising lead and other metals through different

[1] Pyromorphite is several orders of magnitude less soluble than most common Pb minerals in soils, suggesting that transformation of soil Pb to pyromorphite would reduce the bioavailability and therefore toxicity of Pb. Soluble Pb can be immobilized in pure systems as pyromorphite by adding sources of P, still doubts remain about the effectiveness of this approach in natural soil systems. Possibilities of inadequate immobilization, or dissolution of pyromorphite after P-amendments have been reported (Karna et al, 2018).

mechanisms to varying degrees, depending on their chemical composition (Sanderson et al, 2012).

Okkenhaug (2013) reports that metallic iron adsorbs heavy metals when oxidised and creates binding sites in the form of iron oxyhydroxides. The process is known to be pH dependent (e.g. iron oxyhydroxides adsorbed lead only when lime was added) and pH did not decrease. In the soil many reactions are occurring simultaneously, with other metals and organic matter in competition for binding sites available with organic matter.

Ultimately the effectiveness of each of these amendments is modified by soil properties, such as pH, texture, clay content, organic matter, as well as naturally occurring iron and manganese oxides (Dayton et al, 2006).

The use of ferrous chemical amendment is further discussed in Annex B (B.4.2.1).

Vegetation

Vegetative ground covers can impact the mobility of lead and lead compounds. Vegetation absorbs rainwater, thereby reducing the time that the lead is in contact with water.

Vegetation also slows down surface water runoff, preventing the lead from migrating off- site. However, recovery activities usually require vegetation to be removed before or during recovery. Furthermore, vegetation that attracts birds and other wildlife should be avoided to prevent potential ingestion of lead by wildlife (US EPA, 2005).

Excessively wooded areas (such as those often used for sporting clay ranges) inhibit lead recovery by making the soils inaccessible to some large, lead-removal machinery (US EPA, 2005).

New shooting ranges should be designed with few plants as possible to improve lead recovery and to reduce the attractivity for birds and other wildlife (US EPA, 2005).

Surface cover

Removable surface covers may be used at outdoor trap and skeet ranges. In this case, impermeable materials (e.g., plastic liners) are placed over the shot fall zone during non- use periods. This provides the range with two benefits during periods of rainfall: (1) the shotfall zone is protected from erosion; and (2) the spent lead shot is contained in the shotfall zone and does not come in contact with rainwater (US EPA, 2005).

Surface water (runoff) control

There are two factors that influence the amount of lead transported offsite by surface water runoff: the amount of lead fragments left on the range and the velocity of the runoff. Runoff control may be of greatest concern when a range is located in an area of heavy annual rainfall because of an increased risk of lead migration due to heavy rainfall events.

Examples of runoff controls include (US EPA, 2005):

- filter beds to collect and filter surface water
- containment traps and detention ponds to settle out lead particles during heavy rainfall
- dams and dikes to reduce the velocity of surface water runoff
- ground contouring to prevent lead from being transported off site.

For shotgun and other ranges, synthetic liners (e.g., asphalt, Astroturf™, rubber, other synthetic liners) can also be used beneath the shotfall zone to effectively prevent rainwater or runoff from filtering through lead and lead contaminated soil. Synthetic liners will generate increased runoff, which must be managed (US EPA, 2005).

These runoff controls are especially important at ranges at which the lead accumulation areas are located up-gradient of a surface water body or an adjacent property. Since lead particles are heavier than most other suspended particles, slowing the velocity of surface water runoff can reduce the amount of lead transported in runoff.

Use of a roof to cover the back-stop berm is an option at rifle and pistol ranges to reduce runoff (CSR, 2020).

After the end of life of a range without remediation, it is unlikely that maintenance will be made to control run off, with increased risks for nearby surface water and other receptors.

Groundwater control

Measurement of ground or leaching water is specifically relevant for older shooting ranges with heavy soil contamination that are located in water sensitive areas or with specific soil conditions; if leaching water or groundwater measurements show levels above the national threshold, remediation of the soil is required. Figure A.11 provides an example of a system to measure leaching water at a shooting range.

Figure A.11 Example for measurement of seepage water in a shooting range (Schleswig- Holstein LANU, 2005)

RMMs for remediation

Remediation of contaminated soil may be required at the end of life of a sport shooting range using lead ammunition, for example in case a risk to groundwater (which it is likely to materialise during the end of life phase rather than during the service life phase) is identified. Remediation is expected to be needed in case the site is intended to be used after the end of life for agricultural uses or other recreational uses. Remediation is the most expensive RMM measure and may cost up to several millions of euros depending on the site.

Remediation is expected to be needed in ranges located in a water sensitive area and operating for several years or even decades with accumulation of lead shot or lead bullets in the soil. However, in sensitive areas, such as wetlands, remediation may not be technically feasible.'

Summary of effectiveness of environmental RMMs

ECHA (2021a) undertook a comprehensive assessment of the effectiveness of RMMs:

'Considering the available literature (including guidance) on shooting ranges, the identified RMM are summarised in terms of environmental effectiveness (at qualitative level) in the following Table A.1. Appropriate RMMs should be implemented based on expert advice, considering the location of the range and the site specific characteristics.

It must be noted that in many instances, RMM (as surface water runoff control) applied during service life may need to be continued at the end of service life unless remediation is performed.

Table A.1 Environmental effectiveness of different types of RMM applied in shooting ranges

	Measure	Effectiveness	Comment
Lead recovery	Wall and/or nets and/or soil coverage to recover shot	Effective	To achieve a high percentage of recovery, several measures might need to be in place
	Bullet trap	Very effective	Regular lead recovery: easy, cheap
	Backstop berm (with or without a cover) to trap bullets	Not effective	Often considered as a “safety” measure, specifically when no cover is present. No regular lead recovery possible; mechanical disturbance of the berm may increase soil contamination
Reduction of lead mobilisation	Lime amendment	Measures may contribute in some sites to reduce lead mobilisation but are not proved to be effective in natural soil in the long term to prevent lead migration	Adjustment of pH to reduce migration potential of lead
	Phosphate amendment		Immobilisation of lead in natural soil systems may not be successful; it may have a negative impact on the environment (eutrophication).
	Vegetation		Vegetation reduces mobilisation of lead but needs to be removed before

	Measure	Effectiveness	Comment
Surface water (runoff) control	Such as: Filter beds Containment traps and detention ponds Dams and dikes Ground	Effective	Especially in clay target ranges where lead recovery is performed once a year or less, expert advice is required on the most appropriate measure(s) required to control and clean surface (runoff) water
Groundwater control	Measurements of leaching water or groundwater	Effective	Especially relevant for older shooting ranges with heavy soil contamination and located in water sensitive areas or with specific soil conditions (easily leaching to groundwater); if leaching water or groundwater measurements show levels above the national threshold, remediation of the soil is required
Remediation	Remediation	Effective	Remediation is very expensive.

It should be noted that shooting ranges (at which lead shot or bullets are used), even if all required environmental RMMs are implemented, should not be located in sensitive areas. These include wetlands, areas adjacent to surface waters, biosphere reserves, landscape, nature conservation, medicinal spring and drinking water protection areas, areas of rare or valuable soils and areas where soils have pH values less than 4 or greater than 9'

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A.4 Regulatory background

At the time of dossier drafting, ECHA's proposed restriction on "Placing on the market and use of lead in projectiles (for firearms and airguns), and in fishing sinkers and lures for outdoor activities" is at the opinion development stage. The Agency has used information from a published ECHA report to inform this dossier (2021a). However, this dossier does not include fishing sinkers and lures.

This dossier also uses data from a previous EU restriction on lead shot over wetlands (entry 63 of Annex XVII of EU REACH (2017)). The information for the EU restriction was gathered when the UK was a member of the EU (although it did not come into force until after the UK had left). As the UK already has legislation to protect wetland birds from the impacts of lead shot, the main focus of this dossier is on risks to the terrestrial environment and humans via food.

Lead is a widely regulated substance, for example in occupational settings, in sectors such as cosmetics and petrol, and under environmental pollution legislation. Although such legislation has been summarised in ECHA (2017), this information has not been included in this dossier as it is not directly relevant.

A.4.1 Existing legislation relating to lead ammunition

This section summarises the current legal framework which influences the marketing and use of lead ammunition for firearms and airguns. This is with respect to GB only, as under the terms of the Northern Ireland Protocol NI will continue to apply EU REACH and adopt EU REACH restrictions, including a restriction of lead shot over wetlands when it comes into effect after 15 February 2023.

A.4.1.1 Firearms and shooting clubs

In GB the possession by the general public of firearms, shotguns and ammunition is subject to strict control measures under the Firearms Act 1968 (as amended). Individuals must obtain a firearms certificate or a shotgun certificate from their local police force to own and use firearms. There are strict conditions imposed on the certificate holder to store their firearms safely and securely, and local police forces can impose additional conditions over and above the statutory ones. There are some other provisions which fall outside of the Firearms Act relating to the shooting of birds and animals, whereby shooting is allowed or prohibited under certain circumstances. Further information (and details of related legislation) is contained within Chapters 13 and 14 of the Home Office guidance (2021).

Police forces are also required to keep a register of firearms dealers, which are defined in the Firearms Act as a person or a corporate body who, by way of trade or business: manufactures, sells, transfers, repairs, tests or proves firearms or ammunition to which Section 1 of this Act applies, or shotguns; or sells or transfers air weapons. Firearm dealers are provided with a certificate of registration, listing all the premises within which the dealer operates, the categories of firearms and/or ammunition the dealer may trade in and, any conditions placed on the dealer by the local police force.

Additionally, Section 15 of the Firearms (Amendment) Act 1988 permits members of Home Office approved rifle and muzzle loading pistol clubs, school and cadet corps to have in their possession firearms and ammunition when engaged as members of the club, without holding a firearms certificate themselves. Shooting ranges themselves are not specifically covered by the Firearms Act and are no longer regulated by the Ministry of Defence (except at their own ranges). However, they must have the correct liability insurance to enable shooting to take place.

The Firearms Act does not specify what material must be used for ammunition. The Act and associated legislation are accompanied by a detailed guidance document. The guidance explains the relationship between firearms; weight of ammunition or shot; and feet per pounds of power. However, the guidance does not cover all situations where firearms are used and there is still potential for individuals to use firearms, in certain circumstances, without a certificate.

While certificates place specific requirements on the holder regarding the possession and use of the firearms they are permitted to hold, firearms legislation was put in place to control the possession and use of firearms and to protect members of the public. Furthermore, while these certificates cover possession and use of most firearms and shotguns in most circumstances, there are situations and types of firearms which fall out of scope. Therefore, firearms and shotgun certificates would not prevent, nor be able to enforce against, lead ammunition being used and consequentially affecting the environment.

The Gun Barrel Proof Act 1868 (as amended) contains specific reference to the gravity of lead and its relationship to the weight of bullets. This Act does cover the sale and supply of ammunition but mainly focuses on the "proving" of the barrels of the guns themselves and to ensure that they have been notified to proof houses established by this Act. However, as the scope of the proposed restriction also includes exemptions, different types of lead ammunition (not just bullets) and aims to regulate for environmental purposes, these requirements could be out of scope of the Act. Given the age of this legislation, it may require some updating to take account of newer technologies and concerns.

A.4.1.2 Hunting regulations

The Environmental Protection (Restriction on Use of Lead Shot) (England) Regulations 1999 (as amended: The Environmental Protection (Restriction on Use of Lead Shot) (England) (Amendment) Regulations 2002 and The Environmental Protection (Restriction on Use of Lead Shot) (England) (Amendment) Regulations

2003) specify that lead shot cannot be used in England for shooting any species of bird on or over any area below the high-water mark of ordinary spring tides; any species of bird on or over a list of specified Sites of Special Scientific Interest (some of which are inland); Eurasian Coot, Common Moorhen, Golden Plover, Common Snipe or any species of duck, goose or swan, anywhere. An identical restriction exists in Wales under equivalent legislation, The Environmental Protection (Restriction on Use of Lead Shot) (Wales) Regulations 2002. The scope of the equivalent Scottish legislation is slightly different: lead shot cannot be used for shooting any species of bird over wetlands (including the foreshore, streams, rivers, ponds, marshes, wet fields and moorlands with visible standing water), The Environmental Protection (Restriction on Use of Lead Shot) (Scotland) (No.2) Regulations 2004.

The Deer Act 1991 does not specify the material of the ammunition to be used for deer hunting. However, it does state the diameter of the shot and the weight/type of bullets.

The British Association for Shooting and Conservation (basc.org.uk) has issued guidance about permissible methods of killing or taking wildlife under the Wildlife and Countryside Act 1981 (as amended) (Quarry species & shooting seasons). It provides advice about illegal equipment, such as any shotgun where the barrel has an internal diameter at the muzzle of more than 1¾ inches. The use of this (or any other) guidance is not legally enforceable.

The use of lead is referenced within the Hunting Act 2004, which applies to England and Wales. Requirements concerning the weight of bullets may have an indirect relationship to lead.

A.4.1.3 Control of wildlife

The Department for Environment, Food and Rural Affairs (Defra), Natural England, NatureScot and Natural Resources Wales issue licences for individuals and companies to remove wildlife under specific conditions. This is mainly used for removing protected wildlife from an area or property where there is a risk of serious damage or health (Wildlife licences: when you need to apply - GOV.UK (www.gov.uk)).

However, the licences primarily consider conservation, air and public safety issues, and do not cover other activities such as hunting in general.

A.4.1.4 Hunting Birds

The Department for Environment, Food and Rural Affairs (Defra), Natural England, NatureScot and Natural Resources Wales issue licences for individuals and companies to remove wildlife under specific conditions. These are mainly used to remove protected wildlife from an area or property where there are health concerns or a risk of serious damage (Wildlife licences: when you need to apply - GOV.UK (www.gov.uk)). However, the licences primarily consider conservation, air and public safety issues, and do not cover other activities such as hunting in general.

A.4.1.5 Human health regulations

The Control of Lead Regulations 2002 set out the requirements for controlling human exposure to lead from work activities. Since these regulations are for occupational settings, they are not relevant for the concerns covered by this restriction proposal (environmental exposure and human exposure via food).

Although existing food regulations (European Commission Regulation (EC) No. 1881/2006 [as retained in GB law] “setting the maximum level of certain contaminants on foodstuffs”) prohibit the sale of specific food commodities containing lead above maximum specified levels (*0.10 and 0.50 mg/kg wet weight respectively in the case of Pb for meat (muscle) and offal of cows, sheep, pigs and poultry respectively*), they do not extend to game meat. and this value is only from lead present not from lead shot which is the case with game. The Food Standards Agency (FSA) provides advice to consumers of lead shot game (Lead-shot game | Food Standards Agency).

The Food Standards Agency (FSA) advises consumers to minimise their consumption of game meat obtained using lead shot (Lead-shot game | Food Standards Agency).

Annex B: Information on hazard, exposure/emissions and risk

B.1 Identity of the substance(s) and physical and chemical properties

B.1.1 Name and other identifiers of the substance(s)

This report concerns the use of zero-valent 'elemental' lead massive (particle diameter ≥ 1 mm) or lead alloys used as gunshot and bullets and describes the risks resulting from these uses to both human health and the environment.

Generally lead massive is used for lead shot, projectiles and bullets though lead alloys can also be used. The alloys used in gunshot (lead >90%) typically contain variable proportions of antimony (up to approximately 6 %) and arsenic (up to approximately 1.5 %) to produce specific properties in the lead shot, such as hardness and roundness (ECHA, 2017).

Table B.1 Identification of lead

EC number	231-100-4
EC name	Lead
CAS number	7439-92-1
Molecular formula	Pb
Molecular weight	207.2

B.1.2 Composition of the substance(s)

The Agency has used the same definition of lead and its alloys as ECHA (2017) to ensure consistency.

B.1.2.1 Lead metal massive (high purity grades)

This description is detailed here:

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'Degree of purity: 99.9 % (wet/weight (w/w))

Table B.2 Constituents

Constituent	**Typical concentration**	**Concentration range**	**Remarks**
Lead EC no: 231-100-4	99.9 % (w/w)	≥99.8 - ≤99.999 % (w/w)	

Table B.3 Impurities

Impurity	**Typical concentration**	**Concentration range**	**Remarks**
Different metal impurities not affecting the classification of the substance		≥0.0001 - ≤0.2 %	Metal impurities in the range <0.2% (w/w): e.g. Sb, Sn, Cu, Al, Zn, Fe, Cr, Se, Mg, Mn, Na, Ba, Sr, In, Ga, Te, Ag, Bi, Au, Ca, Pt; metal impurities in the range <0.1% (w/w): Ni, Co, Tl; metal impurities in the range <0.025% (w/w): As, Cd, Hg.

B.1.2.2. Lead metal massive (general grades)

Degree of purity: 95.0 % (w/w)

Table B.4 Constituents

Constituent	Typical concentration	Concentration range	Remarks
Lead EC no: 231-100-4	95.0 % (w/w)	≥80.0 - ≤99.99 % (w/w)	

Table B.5 Impurities

Impurity	Typical concentration	Concentration range	Remarks
Antimony EC no.: 231-146-5		≥0.0–≤15.0% (w/w)	
Tin EC no.: 231-141-8		≥0.0–≤15.0% (w/w)	
Sulphur EC no.: 231-722-6		≥0.0–≤10.0% (w/w)	only in elemental form
Oxygen EC no.: 231-956-9		≥0.0–≤10.0% (w/w)	only in elemental form
Copper EC no.: 231-159-6		≥0.0–≤10.0% (w/w)	
Nickel EC no.: 231-111-4		≥0.0–≤1.0% (w/w)	

Aluminium EC no.: 231-072-3		≥0.0–≤10.0% (w/w)	
Zinc EC no.: 231-175-3		≥0.0–≤10.0% (w/w)	
Iron EC no.: 231-096-4		≥0.0–≤10.0% (w/w)	
Selenium EC no.: 231-957-4		0.0–≤5.0% (w/w)	
Cobalt EC no.: 231-158-0		≥0.0–≤1.0% (w/w)	
Chromium EC no.: 231-157-5		≥0.0–≤10.0% (w/w)	
Magnesium EC no.: 231-104-6		≥0.0–≤10.0% (w/w)	
Manganese EC no.: 231-105-1		≥0.0–≤10.0% (w/w	
Sodium EC no.: 231-132-9		≥0.0–≤10.0% (w/w)	
Barium EC no.: 231-149-1		≥0.0–≤10.0% (w/w)	

Strontium EC no.: 231-133-4		≥0.0–≤10.0% (w/w)	
Indium EC no.: 231-180-0		≥0.0–≤10.0% (w/w)	
Gallium EC no.: 231-163-8		≥0.0–≤10.0% (w/w)	
Tellurium EC no.: 236-813-4		≥0.0–≤10.0% (w/w)	
Calcium EC no.: 231-179-5		≥0.0–≤10.0% (w/w)	
Silicon EC no.: 231-130-8		≥0.0–≤10.0% (w/w)	
Potassium EC no.: 231-119-8		≥0.0–≤10.0% (w/w)	
bismuth EC no.: 231-177-4		≥0.0–≤2.0% (w/w)	
Different metal impurities not affecting classification of substance		≥0.0–≤0.25% (w/w)	Metal impurities in the range <0.25% (w/w): e.g. Pt, Ag, Au; metal impurities in the

			range <0.1% (w/w): Tl; metal impurities in the range <0.025% (w/w): As, Cd, Hg.

B.1.2.3. Lead metal massive (with arsenic)

Degree of purity: 95.0 % (w/w)

Table B.6 Constituents

Constituent	**Typical concentration**	**Concentration range**	**Remarks**
Lead EC no: 231-100-4	95.0 % (w/w)	≥80.0 - ≤100.0 % (w/w)	

Table B.7 Impurities

Impurity	**Typical concentration**	**Concentration range**	**Remarks**
antimony EC no.: 231-146-5		≥0.0–≤15.0% (w/w)	
tin EC no.: 231-141-8		≥0.0–≤15.0% (w/w)	

sulphur EC no.: 231-722-6		≥0.0–≤10.0% (w/w)	only in elemental form
oxygen EC no.: 231-956-9		≥0.0–≤10.0% (w/w)	only in elemental form
copper EC no.: 231-159-6		≥0.0–≤10.0% (w/w)	
iron EC no.: 231-096-4		≥0.0–≤10.0% (w/w)	
selenium EC no.: 231-957-4		0.0–≤5.0% (w/w)	
cobalt EC no.: 231-158-0		≥0.0–≤1.0% (w/w)	
chromium EC no.: 231-157-5		≥0.0–≤10.0% (w/w)	
magnesium EC no.: 231-104-6		≥0.0–≤10.0% (w/w)	
Manganese EC no.: 231-105-1		≥0.0–≤10.0% (w/w	
sodium EC no.: 231-132-9		≥0.0–≤10.0% (w/w)	

barium EC no.: 231-149-1		≥0.0–≤10.0% (w/w)’	

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B.1.3 Physicochemical properties

The physicochemical properties are summarised in Section 1.3.2.

B.2. Manufacture and uses

Manufacture and use are summarised in Annex A.

B.3 Classification and labelling

Classification and labelling is summarised in Section 1.3.4.

B.4 Environmental fate properties

The environmental fate properties are summarised in Section 1.5.1.

B.5 Human health hazard assessment

The health effects of lead have been summarised in several reviews and restriction reports, including by the EFSA CONTAM Panel (EFSA, 2010), the Joint FAO/WHO Expert Committee on Food Additives (J.E.C.F.A., 2011), Public Health England (PHE, 2017), the UK Committee on Toxicity (C.O.T., 2013) and ECHA (2021b, 2018, 2017, 2016, 2014, 2011).

The human health hazard assessment below is reproduced from ECHA’s Annex XV restriction proposal for lead in ammunition and fishing tackle, which was published on ECHA's website in March 2021 (ECHA, 2021b). Where it is considered relevant to the present assessment, information provided in ECHA's restriction report and the associated annex is replicated. Any reference to health effects from exposure via fishing tackle have been removed, as fishing tackle is not within the scope of the current assessment.

ECHA human health hazard assessment

Reproduced ECHA text

B.5.1 Toxicokinetics (absorption, metabolism, distribution and elimination)

Absorption

Oral ingestion and inhalation are the most significant routes of lead exposure, whereas dermal absorption is considered as minimal (LDAI, 2008). However, even though absorption directly through the skin is considered negligible, lead can become systemically available through hand-to-mouth behaviour. This route of exposure is possible for both children and adults that come into contact with lead containing articles, both at home and occupationally (Klein and Weilandics, 1996).

According to the information in the Chemical Safety Report of the EU REACH Registration (CSR, 2020), inhalation absorption is 100 %, whereas oral absorption from food is 10 % in adults and 50 % in children. ATSDR (2007) reported similar rates for inhalation absorption with 95 % and for gastrointestinal absorption with 3 to 10 % for adults and 40 to 50 % for children. It is noted that the uptake estimates are only applicable to relatively low exposure levels yielding PbB levels up to 150 µg/L.

The efficiency of oral lead uptake varies depending on e.g. particle size and shape (surface area), amount of time particles spent in the gastrointestinal tract, concurrent food intake and the iron- and calcium status of the individual. Small lead-containing particles have a higher surface-to-volume ratio and will undergo more rapid dissolution upon ingestion.

Whereas 200 µm particles exhibit gastrointestinal uptake efficiency approximately one order of magnitude lower than for soluble compounds, a decrease in particle size to 6 µm (equivalent to the size of a particle that might be inhaled and subsequently translocated to the gastrointestinal tract) will increase uptake five-fold and largely mitigate potential impacts of speciation upon relative bioavailability (Barltrop and Meek, 1979). Case reports (mainly for children) prove that even one larger piece of lead ingested orally can create sufficient systemic exposure to produce clinical lead intoxication or even death. Precise prediction of the bioavailability that will result from ingestion of an individual lead fragments is thus a complex function of particle size, dissolution rates and residence time in the gastrointestinal tract. As a worst-case assumption, it can be assumed that the bioavailability of metallic lead is equivalent to that of soluble lead compounds such as e.g. lead acetate (LDAI, 2008).

In a recent Swedish study (Swedish NFA, 2014b), the percentage of lead released in stomach-like environment (0.1 M hydrochloric acid) was measured in relation to exposure duration and rocking of the sample. At the start, 8 mg of metallic lead in the form of metal shavings was placed in 40 ml of hydrochloric acid for up to 120 hours either stationary without rocking (Stillastående), slight rocking (Vaggning) or heavy rocking (Ökad vaggning).

After half an hour, samples with a rocking motion have a higher percentage of lead than stagnant samples. After 1 hour, 1-2 percent of lead was released in the rocked samples while less than 0.5 % of lead dissolved from stationary samples. The difference between stationary samples and rocked samples increased over time. If the speed in the rocking movement is increased, lead is released faster. After two days, the rocking movement stopped, and all samples were left stationary during the rest of the trial. Consequently, starting from 51 hours all four samples show the same release rate.

In the "increased rocking" experiment, no sub-samples were taken after 20 hours. The solutions were provided instead, standing still and after three months no visible traces of lead particles could be found in any of the test tubes. This experiment demonstrates that in a stomach-like environment relevant amounts of lead (up to 35 %) can be dissolved. For the in-vivo situation, it should be noted though that not all lead in solution may be absorbed due to the usual presence of food in the stomach that might reduce the absorption.

Metabolism

The lead ion is not metabolised or bio-transformed in the body, though it does form complexes with a variety of proteins and non-protein ligands. It is primarily absorbed, distributed and then the non-accumulated lead is excreted (WHO, 2003).

Distribution

Once it is absorbed, inorganic lead appears to be distributed to both soft tissues (blood, liver, kidney, etc.) and mineralising systems (bones, teeth) in a similar manner regardless of the route of absorption. The distribution of lead seems to be similar in children and adults, but in adults a larger fraction of lead is stored in skeletal tissue. More than 90 % of the total amount of accumulated lead in adults ends up in bone and tooth, while in children, 75 % is accumulated in bones. The distribution of lead in the body is initially dependent on the rate of delivery by the bloodstream to the various organs and tissues. A subsequent redistribution may occur based on the relative affinity of particular tissues for the element and its toxicodynamics (ATSDR, 2020).

Lead concentration is also related to calcium status; stored lead can therefore be released from bone tissue into the blood stream in situations where a person suffers from calcium deficiency or osteoporosis (LDAI, 2008).

It should be noted that lead is easily transferred to the foetus via the placenta during pregnancy. The foetal/maternal blood lead concentration ratio is approximately 0.9 (Carbone et al., 1998). As explained by Bradbury and Deane (1993) the blood-cerebral barrier is permeable to lead ions and the most sensitive end-point is connected to neurotoxicity and developmental effects.

Elimination

Elimination takes place mostly via urine (>75 %), and 15 to 20 % is excreted via bile and faeces (TNO, 2005). The half-life of lead in the human body differs across tissues. Blood lead and lead in soft tissue is considered the most labile with a half-life of approximately 40 days, while bone lead is very stable with a half-life of several decades (ATSDR, 2020). In chronically exposed infants and children, lead is progressively accumulated in the body and is mainly stored in skeletal tissue. Lead is eliminated from bone very slowly; the half-life can be 10 to 20 years or more. In this way, lead can lead to an internal exposure long after the external exposure has ended, by redistribution between different tissue pools (LDAI, 2008).

B 5.2 Acute toxicity

Very limited data are available on the acute toxicity of lead and its compounds for humans and it is difficult to accurately establish the dosimetry for physiological effects caused by the inhalation or ingestion of lead and its inorganic compounds after the administration of a single dose. Most data for acute toxicity actually describe the effects of ingestion or inhalation of lead compounds over a period of weeks or years – exposure time-frames that are more accurately regarded as being sub-acute to chronic in duration. Confusion is also caused by traditional definitions in the medical literature which refer to acute and chronic lead intoxication (poisoning) syndromes, both of which are actually the result of sub-chronic or chronic exposure events over extended time frames (CSR, 2020).

Symptoms of lead intoxication may include abdominal pain, constipation, headaches, irritability, memory problems, infertility and tingling in the hands and feet. It causes almost 10 % of intellectual disability of otherwise unknown cause and can result in behavioural problems. Some of the effects are permanent. In severe cases anaemia, seizure, coma or death may occur (CDC, 2018, WHO, 2019).

Acute inhalation of metal fumes including lead (Graeme and Pollack Jr, 1998), copper (Nemery, 1990) and especially zinc oxide (Cooper, 2008) may cause so-called metal fume fever. Metal fume fever is a poorly understood influenza-like or malaria-like reaction.

Reported symptoms are the abrupt onset of fever, shaking chills, malaise, excessive salivation, thirst, nausea, myalgia, headache, cough and respiratory distress. The pathogenesis is poorly understood; allergic and immunologic mechanisms are most often postulated. Tolerance to metal fumes develops and symptoms appear only after exposure to metal fumes following a period of abstinence. Metal fume fever will not occur on subsequent successive days of fume exposure.

B 5.3 Irritation

Not relevant for this report.

B 5.4 Corrosivity

Not relevant for this report.

B 5.5 Sensitisation

Not relevant for this report.

B 5.6 Repeated dosed toxicity

Signs of chronic lead poisoning include among others: sleepiness, irritation, headache, pains and others (LDAI, 2008). Blood lead level (PbB) is often the best reflection of the prevailing lead exposure status of the individual (Danish EPA, 2014). EFSA (2010) concluded, based on available human data, that the most critical effects in relation to small increases in PbB levels were developmental neurotoxicity in children aged 7 and younger and effects on blood pressure and chronic kidney disease in adults. The specific effects of lead (haematological effects, effects on blood pressure and cardiovascular effects, kidney effects, neurotoxicity and developmental effects, hyperactivity or attention deficit disorder, and neurological effects of post-natal exposure in children) are summarised in Annex B to the Background Document to the Opinion on the Annex XV dossier proposing restrictions on lead in shot (ECHA, 2018c).

In a recent toxicological profile for lead, ATSDR (2007) summarised the available information on health effects of lead and concluded that for the most studied endpoints (neurological, renal, cardiovascular, hematological, immunological, reproductive, and developmental), effects occur at the lowest PbB levels studied, which are ≤ 50 µg/L.

Haematological effects

Effects of lead on blood can be detected at low levels of exposure but are not considered to be adverse (ECHA, 2018d). As exposure rises, greater impact on haematological parameters can be expected. At PbB levels < 100 µg/L an inhibition of enzymes such as ALAD is observed; ALAD is involved in the synthesis of haeme (LDAI, 2008). These enzymatic effects are not considered adverse but are sometimes used as biomarkers of lead exposure. At higher levels of lead exposure, the cumulative impacts of lead upon multiple enzymes in the haeme biosynthetic pathway begin to impact the rate of haeme and haemoglobin production (EFSA, 2010). As PbB levels increases, further decreases in blood haemoglobin and loss of erythrocytes due to a lead-induced increased membrane fragility results in the development of anaemia (NAS 2013 as cited in (ATSDR, 2007)). Decreased haemoglobin production can be observed at PbB levels ≥ 400 µg/L in children. Impacts on haemoglobin production are sufficient to cause anaemia are associated with PbB levels ≥ 700 µg/L.

Effect on blood pressure and cardiovascular effects

Exposure to lead has been associated with a variety of adverse effects on the cardiovascular system in animals and humans. The most studied dose-response relationship is on the effect of lead exposure on blood pressure; more frequently reported for systolic than for diastolic blood pressure. Based on detailed analyses of five human studies, EFSA (2010) concluded that a PbB level of 36 µg Pb/L was associated with a 1 % increase in systolic blood pressure. Based on modelling this PbB level was converted to a daily lead exposure of 1.50 µg Pb/kg bw per day.

In a recent study Barry et al. (2019) investigated 211 adult men occupationally exposed to lead with the median age of 61.9 years (range 36.9-85.3 years). Median (IQR) bone, maximum past blood and current blood leads were 13.8 (9.4 – 19.5) µg lead per bone mineral gram, 290 (140 – 380) µg/L and 25 (15 – 44) µg/L, respectively. Bone lead was associated with increased continuous systolic blood pressure, driven by the top two bone lead quartiles.

According to industry data in the REACH registration dossier, reviews and meta-analyses of the current literature on the blood lead/blood pressure relationship indicate that there is at best a weak positive association between blood lead and blood pressure in the general population and occupational studies with average PbB levels below 450 µg/L. However, it can be hypothesised that a modest increase in blood pressure would increase the overall incidence of cardiovascular disease in a large population of individuals. This consideration of “societal risk” as opposed to “individual risk” merits careful examination. As indicated in the REACH Registration, given that recent studies find a lack of impact of environmental exposures upon blood pressure, a dose-response function that would serve as the basis for any health-based limit linked to blood pressure cannot be derived. The lack of dose dependent impacts indicates that lead impacts upon blood pressure are not a health endpoint suitable for quantitative risk assessment.

However, in a recent population-based cohort study including 14 289 adults, Lanphear et al. (2018) reported that low-level environmental lead exposure is a risk factor for cardiovascular disease mortality in the USA. The geometric mean concentration of lead in blood was 27.1 µg/L (geometric SE 13.1). 3 632 (20 %) participants had a concentration of lead in blood of at least 50 µg/L. During median follow-up of 19.3 years (IQR 17.6 – 21.0), 4 422 people died, 1801 (38 %) from cardiovascular disease and 988 (22 %) from ischaemic heart disease. An increase in the concentration of lead in blood from 10 µg/L to 67 µg/L, which represents the tenth to 90th percentiles, was associated with all-cause mortality (hazard ratio 1.37, 95 % CI 1.17 – 1.60), cardiovascular disease mortality (1.70, 1.30 – 2.22), and ischaemic heart disease mortality (2.08, 1.52 – 2.85). The population attributable fraction of the concentration of lead in blood for all-cause mortality was 18.0 % (95 % CI 10.9 – 26.1), which is equivalent to 412 000 deaths annually. Respective fractions were 28.7 % (15.5 – 39.5) for cardiovascular disease mortality and 37.4 % (23.4 – 48.6) for ischaemic heart disease mortality, which correspond to 256 000 deaths a year from cardiovascular disease and 185 000 deaths a year from ischaemic heart disease. Landrigan (2018) drew the conclusion from this analysis that lead has a much greater effect on cardiovascular mortality than previously recognised. Lanphear and colleagues' calculation that lead accounts for more than 400 000 deaths annually in the USA represents a tenfold increase over the number of deaths currently ascribed to lead. The authors argue that previous estimates have produced lower numbers because those analyses assumed that lead has no effect on mortality at amounts of lead in blood below 50 µg/L and, thus, did not consider the effects of lower exposures. Landrigan (2018) also concluded that these findings have substantial implications for global assessments of cardiovascular disease mortality.

Kidney effects

Exposure to lead has been associated with functional renal deficits including changes in proteinuria, glomerular filtration rates or creatinine levels and clearance. EFSA (2010) concluded a PbB level of 15 µg Pb/L to be associated with a 10 % increase of chronic kidney disease (CKD) in the population measured as reduction in the glomerular filtration rate (GFR) to values below 60 mL/min. Based on modelling this PbB level was converted to a daily lead exposure of 0.63 µg Pb/kg bw/day.

In the REACH Registration dossier of lead compounds (CSR, 2020), relevant studies (e.g. (Roels et al., 1994, Weaver et al., 2003)) were reviewed. The registrant concluded that blood lead levels at or below 600 µg/L appear to guard against the onset of lead nephropathy. A NOAEL of 600 µg/L was therefore adopted for renal effects and provided the basis for the DNEL proposed in the registration dossier. However, EFSA's CONTAM Panel concluded that there is no evidence for a threshold for renal effects in adults.

In ATSDR (2020), the most recent studies on effects of lead on kidney are summarised. Several large cross-sectional studies have examined associations between PbB and GFR in adults. Three large studies relied on data collected as part of the US NHANES survey. The Muntner et al. (2003) study, which included 4813 hypertensive subjects and 10938 normotensive subjects, found an association between increasing PbB levels and decreasing GFR in the hypertensive group. Navas-Acien et al. (2009) included 14788 adult subjects and reported decreased GFR (< 60 mL/minute/1.73 m2) among participants in the highest PbB quartile (mean > 24 µg/L). Spector et al. (2011) included 3941 adults. In the age group ≥ 60 years, the estimate for the decline in GFR was 4.5 mL/minute/1.73 m2 per doubling of PbB. The mean PbB level in this group was 22 µg/L.

In a recent study Barry et al. (2019) investigated 211 adult men occupationally exposed to lead with the median age of 61.9 years (range 36.9-85.3 years). Median (IQR) bone, maximum past blood and current blood leads were 13.8 (9.4 – 19.5) µg lead per bone mineral gram, 290 (140 – 380) µg/L and 25 (15 – 44) µg/L, respectively. Bone lead was not associated with a reduction in GFR.

Harari et al. (2018) performed a prospective population-based cohort study with 4341 individuals enrolled into the Malmö Diet and Cancer Study - Cardiovascular Cohort between 1991 and 1994 and for which blood lead level measurement were performed at that time (referred to as ’baseline’). 2567 individuals were followed up (2007 – 2012) for changes in GFR. Blood lead levels were presented in quartiles. Proportion of men, proportion of individuals with low education, alcohol consumption, waist circumference, hypertension and proportion of current smokers were all higher in the highest quartile (Q4; median 46 µg/L; range 33 – 258 µg/L) compared to the three lower quartiles (Q1 - Q3). Mean GFR at baseline and follow-up were 76 and 70 mL/min/1.73 m2, respectively. At both time points GFR was slightly lower in the group with the highest blood lead level. At baseline, linear regression analyses adjusted for age, sex, smoking, alcohol intake, diabetes mellitus, waist circumference, eGFR at baseline, and education level showed a statistically significant inverse association between lead levels (in quartiles) and eGFRs.

Barry and Steenland (2019) investigated the mortality in a cohort of 58368 male lead- exposed workers that was followed for a median of 19 years and experienced 6527 deaths. Average maximum blood lead was 259 µg/L and mean year of first blood lead test was 1997. Findings suggested associations with chronic renal disease, although the trend was not statistically significant.

Several smaller cross-sectional studies have also found associations between increasing PbB level and decreasing GFR in adult populations in which mean or median PbB levels were <100 µg/L (see references in ATSDR (2020)).

Collectively, these studies indicate that lead exposure is associated with decreasing GFR, and effects on GFR are evident in populations with PbB levels <100 µg/L.

People with on- going renal disease or hypertension may be more vulnerable to the effects of lead.

Estimates of the decline in GFR associated with increasing PbB levels vary across studies, with some studies indicating declines of 3 to 6 mL/minute/1.73 m2 at PbB levels <100 µg/L (Pollack et al., 2015, Spector et al., 2011, Yu et al., 2004). However, the estimates may be inflated by reverse causality for associations between deceasing GFR and increasing lead body burden.

Neurotoxicity and developmental effects

According to the CLH report submitted by KEMI (2012), the nervous system is the main target organ for lead toxicity. The developing foetus and young children are most vulnerable to lead induced neurotoxicity as the nervous system is still under development. The immaturity of the blood-brain barrier may also contribute to the vulnerability, as well as the lack of high-affinity lead binding proteins in the brain that trap lead ions in adults (Lindahl et al., 1999). Young children often exhibit hand-to-mouth behaviour and also absorb a larger percentage of orally ingested lead than adults, thus leading to a greater systemic exposure (EFSA, 2010).

Several epidemiological studies have been conducted examining the impacts of prenatal lead exposure on birth outcome and neurobehavioral development in children. Negative effects of perinatal lead exposure on neurobehavioral performance have been demonstrated both in experimental animals as well as in human prospective studies. Similarly, studies have demonstrated that postnatal exposure to lead may severely impact scholarly achievements.

JECFA (2010) and Lanphear et al. (2005) concluded that negative impact on IQ is the most sensitive endpoint for lead exposure and that no safe blood lead level has yet been established. Lanphear et al. (2005) examined data from 1333 children who participated in seven international population-based longitudinal cohort studies. EFSA (2010) concluded a PbB level of 12 µg Pb/L to be associated with a 1 % reduction on the IQ scale in children. Based on modelling this blood lead level was converted to a daily lead exposure of 0.5 µg Pb/kg bw/day.

Budtz-Jørgensen et al. (2013) published benchmark dose (BMD) calculations underlying the EFSA opinion. BMD results were quite robust to modelling assumptions with the best fitting models yielding lower confidence limits (BMDLs) of about 1.0 to 10 µg/L PbB for the dose leading to a loss of one IQ point. This range is confirmed by Rocha and Trujillo (2019) whose review of effects of low-level lead exposure on behaviour and cognition suggests that PbB levels below 30 µg/L may produce diminished cognitive function and maladaptive behaviour in humans and animal models.

B 5.7 Mutagenicity

Not relevant for this report.

B 5.8 Carcinogenicity

Not relevant for this report.

B 5.9 Toxicity for reproduction

ECHA assessment from the annex to the restriction proposal (ECHA, 2021a)**.**

As presented in Section B.3, lead massive is classified under CLP in category 1A (H360DF) for reproductive toxicity.

The CLH report on lead (KEMI, 2012) highlights that strong evidence by studies in both humans and experimental animals have demonstrated negative impacts on male fertility (e.g. semen quality). Furthermore, lead also causes neurodevelopmental effects. Pre- and perinatal lead exposure is toxic to the developing nervous system and IQ is one of the major parameters found to be negatively affected. The report concluded that lead clearly fulfils these criteria for reproductive toxicity and should therefore be classified as reprotoxic category 1A under CLP.

ECHA's Risk Assessment Committee, following the assessment of the KEMI CLH report (KEMI, 2012), has adopted a scientific opinion (ECHA, 2013) concluding that all physical forms of metallic lead should be classified as Repr. 1A; H360DF (Repr. Cat 1) (may damage fertility; may damage the unborn child) similar to the classification that applies for "lead and lead compounds").

The Background Document to the Opinion on the Annex XV dossier proposing restrictions on lead and its compounds in articles intended for consumer use (ECHA, 2018b), provided a good review of both animal and human studies on the reproductive toxicity of lead. An overview of these studies is given in the Appendix X of the restriction document on the Restriction on the use of lead shots over wetlands (ECHA, 2018a).

B 5.10 Other effects

B 5.11 Derivation of DNEL(s)/DMEL(s)

The EFSA CONTAM panel (EFSA, 2010) calculated BMDL values for the key effects of lead following chronic exposure. The following summaries are reproduced from ECHA (2021b).

Benchmark doses calculated by EFSA

The EFSA CONTAM Panel (EFSA, 2010) concluded that there is no evidence for a threshold for critical lead-induced effects and used the BMD approach to derive reference points for risk characterisation, where the BMD is defined as that PbB level or tibia bone lead concentration, respectively, which is associated with a pre-specified change in the outcome (i.e. loss in IQ, increase in blood pressure, or increase in the incidence of CKD), denoted the benchmark response (BMR). The lower one-sided 95% confidence bound of the BMD, denoted BMDL, was taken as the reference point.

IQ loss in children

The EFSA CONTAM Panel (EFSA, 2010) used the complete individual data from the seven studies analysed by Lanphear et al. (2005) to determine the 95th percentile lower confidence limit on the benchmark dose (BMD) of 1% extra risk (corresponding to 1 IQ point) as a reference point for the risk characterisation of lead when assessing the risk of intellectual deficits in children measured by the Full Scale IQ score. The CONTAM Panel considered several model equations to model this relationship. The logarithmic and piecewise linear models resulted in acceptable and similar fits. The mathematical properties of the logarithmic model and the marked uncertainty associated with the relationship at PbB levels <100 µg/L were such that the CONTAM Panel concluded that the piecewise linear model, using the segment fit to the lower PbB levels, provided a reliable estimate of the $BMDL_{01}$ of 12 µg Pb/L.

Chronic kidney disease in adults

The EFSA CONTAM Panel (EFSA, 2010) selected as benchmark response (BMR) for chronic kidney disease (CKD) a 10% change in the prevalence of chronic kidney disease (CKD), defined as a GFR below 60 mL/1.73 m^2 body surface/min. A 10% response was selected for the BMR as such a change was within the range of observable values and could have significant consequences for human health on a population basis.

The populations in whom the $BMDL_{10}$ values were derived, consisted of a large number of individuals from NHANES (n=15 000), which are representative of the US general population that accounted for a substantial proportion of inter-individual variation in toxicokinetics. The prevalence of kidney disease was compared with concurrent PbB levels. The EFSA CONTAM Panel noted that this effect would depend on lead exposure over a prolonged interval of time, during which such exposure was declining appreciably. Hence, the $BMDL_{10}$ intake value for this endpoint is likely to be numerically lower than necessary to protect against lead-induced CKD.

The EFSA CONTAM Panel fitted the quantal dose-response models recommended by EFSA to the incidence data […]. When fitting these data, separately from cadmium, using a BMR of 10% as recommended by the Scientific Committee of EFSA (2009) and an acceptability criterion of $p > 0.01$ for the model fit, a $BMDL_{10}$ of 15 µg/L was obtained. The highest PbB quartile of > 24 µg/L (median PbB level of 32 µg/L) was associated with an Odds Ratio (95 % CI) of 1.56 (1.17 - 2.08) adjusted inter alia for cadmium.

Cardiovascular effects in adults

The EFSA CONTAM Panel (EFSA, 2010) considered a 1% increase of systemic blood pressure (SBP) annually or on average in the whole population a public health issue, since this would result in an increased risk of cardiovascular morbidity and coronary heart disease (CHD) mortality in a population. Assuming an average SBP of 120 mmHg and a benchmark response level of 1%, the dose associated with an increase of SBP by 1.2 mmHg corresponds to a BMD_{01}. BMD_{01} and $BMDL_{01}$ values were derived based on the slope estimates from five selected studies on blood and tibia bone lead concentration.

Longitudinal data allowed the calculation of a BMD_{01} for the mean annual increase of SBP by 1% in an individual, whereas cross-sectional data allowed only the calculation of the BMD_{01} on a population-based increase of the means. The CONTAM Panel determined four $BMDL_{01}$ values for SBP ranging from 15 to 71 µg/L (longitudinal 27 and 71 µg/L, cross-sectional studies 15 and 21 µg/L). Given the strong overlap of the study results and the absence of any obvious design deficiencies in the studies, the CONTAM Panel proposed a mean $BMDL_{01}$ for SBP of 36 µg/L from the four studies and a $BMDL_{01}$ = 8 µg/g for tibia bone lead concentrations. A summary of the BMDL values defined by EFSA is given in Table B.8.

Table B.8 Toxicological reference values for lead toxicity by EFSA (2010)

Endpoint	Population	BMDL (µg/L)	Slope factor (**β**■)	Definition

Developmental neurotoxicity	children	12	8.33E-2	$BMDL_{01}$: 1 % change in full scale IQ score, i.e. a decrease in IQ by 1 point on the full scale IQ score
Kidney toxicity/ nephrotoxicity	adults	15	6.66E-2	$BMDL_{10}$: 10 % change in the prevalence of chronic kidney disease (CKD), defined as a GFR below 60 mL/1.73 m^2 body surface
Cardiovascular effects	adults	36	2.77E-2	$BMDL_{01}$: 1 % change in systolic blood pressure (SBP), corresponding to an increase of 1.2 mmHg from the baseline value of 120 mmHg in a normotensive adult

Since the EFSA CONTAM Panel (EFSA, 2010) concluded that there is no evidence for a threshold for critical lead-induced effects, the following BMDL values are considered as toxicological reference values for long-term oral exposure of the general population:

- $BMDL_{01}$ of 12 µg/L for developmental neurotoxicity in children (decrease in IQ by 1 point on the full scale IQ);
- $BMDL_{10}$ of 15 µg/L for 10 % increase in the prevalence of chronic kidney disease (CKD) in adults;
- Toxicological reference values for lead toxicity by EFSA (2010) $BMDL_{01}$ of 36 µg/L for 1 % increase in systolic blood pressure (SBP) in adults, corresponding to an increase of 1.2 mmHg from the baseline value of 120 mmHg in a normotensive adult.

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B.6 Human health hazard assessment of physicochemical properties

B 6.1 Explosivity

Not relevant for this report.

B 6.2 Flammability

Not relevant for this report.

B 6.3 Oxidising potential

Not relevant for this report.

B.7 Environmental hazard assessment

The environmental hazard information is summarised in Section 1.5.2.

B.8 PBT and vPvB assessment

Lead is a metal, so the PBT/vPvB criteria are not applicable.

B.9 Exposure assessment

B.9.1 Environmental exposure

The environmental exposure is described in Section 1.4.

B.9.2. Human health exposure

The principal risk to human health to be addressed in this report is that from the consumption of game animals and birds killed with lead ammunition.

B.9.2.1 Indirect exposure of humans via the environment

Lead in game meat

The following summary is reproduced from the Annex to ECHA (2017)**.**

Lead shot can 'fragment' after hitting quarry animals resulting in smaller particles of lead being distributed within the tissues of an animal. Some of these fragments may reside in tissues a considerable distance from the primary wound and remain there after butchery and food preparation (Green and Pain, 2015).

According to the available evidence, it is not possible for consumers to successfully remove all embedded fragments of lead from the wound channels of shotgun-shot game. Tiny lead particles would go unnoticed by consumers[2].

Pain et al., 2010 examined wild shot in gamebirds[3] obtained in the UK to determine the potential hazard to human health from exposure to fragments of shot in the tissues. The study found small fragments on X-rays in 76% of the 121 gamebirds examined. Most fragments were less than about a tenth of a shot in size. The fragments were sometimes clustered around bone, but sometimes appeared to be scattered throughout the bird.

The authors noted that small fragments cannot be effectively removed both because they are too small to be detected by the human eye, and because their removal would require discarding a large proportion of the gamebird carcass. Usually when a gamebird is killed several shot have penetrated it and the lead fragments and high tissue lead concentrations remain even when those shot pass in and out of a bird, as sometimes happens.

Proportions of samples exceeding 100, 1 000 and 10 000 ppb by wet weight (chosen as thresholds), were calculated. The thresholds 100, 1 000 and 10 000 ppb by wet weight (w/w), are equivalent to 0.1, 1.0 and 10 mg/kg or ppm. 100 ppb wet weight is the EU (1881/2006) ML (maximum level) permitted in bovine animals, sheep, pigs and poultry (excluding offal). No level has been set for game.

Pain et al., 2010 found that a high proportion of samples had lead concentrations exceeding 100 ppb ww (0.1 mg kg ww). The percentage of mallards exceeding 100 ppb ww was: 39.9%[4].

Another important parameter when consider the bioavailability of lead present in game meat for consumers, is cooking. Cooking methods seem to affect the bioavailability of lead in game meat. Mateo et al., (2007) reported that cooking small game meat under acidic conditions (i.e. using vinegar) increases the final lead concentration in meat as well as its bioavailability. Lead particles in game meat can

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[2] In the UK, the Food Standards Agency, referring to sale of small game, in a risk assessment (FSA 2012), stated that "Regarding sale of small game, colleagues from the FSA Operations Group have indicated that the lead pellets are very small and it would be impractical to ensure they are removed during the dressing procedure: trying to remove them would be very time consuming (would eat into the processor's profit margins) and would cause damage to the birds which would likely make them unsellable."

[3] Wild-shot pheasant (*Phasianus colchicus*), red-legged partridge (*Alectoris rufa*), woodpigeon (*Columba palumbus*), red grouse (*Lagopus lagopus*), woodcock (*Scolopax rusticola*) and mallard (*Anas platyrhynchos*).

[4] Adjusted value (approximates what would have been expected if the measurements of concentration in the whole meal derived from each bird had been available).

dissolve while cooking, producing soluble lead salts that contaminate parts of the meat. These salts have greater bioavailability and may pose an increased risk compared to metallic lead particles (Mateo et al., 2007).

Green and Pain (2015) reported that, in general, the bioavailability of dietary lead derived from ammunition (the proportion of the ingested amount which is absorbed and enters the blood) can be expected to be lower than that of lead in the general diet[5]. This is thought to be because some of the ingested ammunition lead may remain as metallic fragments after cooking and digestion. However, despite this, game meat may remain a significant source of lead in the diets of those that consume it regularly.

Table B.9 Percentages of samples of game and chicken that exceeded each of the three threshold values of lead concentration (0.1; 1.0; 10 mg/kg wet weight) (Pain et al., 2010)

Species	Cooking method	N	Percentage of game meat samples exceeding		
			0.1 mg/kg	1.0 mg/kg	10 mg/kg
Chicken	Acid	14	0	0	0
	Non-acid	42	2.4	0	0
Red grouse	Acid	10	50	0	0
	Non-acid	10	40	20	0
Partridge	Acid	13	61.5	7.7	2.1
	Non-acid	13	69.2	23.1	3.8
	Fresh	57	56.1	21.3	5.7
Pheasant	Acid	13	38.5	0	0
	Non-acid	10	60	10	1.6
	Fresh	58	46.6	17.9	2.4
Wood-pigeon	Acid	11	27.2	9.1	0.1
	Non-acid	10	20	0	0
Woodcock	Acid	8	87.5	25	5.4

[5] While the absolute bioavailability of ammunition-derived lead may be lower than that of lead in the general diet, the minimum plausible value of absolute bioavailability is nonetheless substantial and capable of causing elevation of blood lead concentrations.

	Non-acid	8	37.5	12.5	0.3
Mallard	Acid	8	25	0	0
	Non-acid	8	37.5	25	0.3

ECHA (2021b) provided additional information on the impact of lead ammunition on game meat, as follows.

Felsmann et al. (2016) investigated the effect of lead bullets on game meat. The projectile that penetrates the animal body generates a temporary cavity and this phenomenon is accompanied by a change in the pressure within the funnel of a wound and in the adjacent tissues. A cavity is formed behind the projectile and may persist even after the projectile has left the target. Its size is difficult to predict and the momentary shape of the frontal part of a projectile seems to have a major impact on its formation and size (Felsmann et al., 2012). Due to the temporary cavity phenomenon, especially pressure fluctuations in adjacent tissues, it may be assumed that this phenomenon is responsible for lead transfer deep into the tissues that surround the path of a wound.

The highly variable results of studies on the content of lead at the same distance from the path of a wound in individual animals are unsurprising due to this physical phenomena (Dobrowolska and Melosik, 2008). The increased lead levels in animals where projectiles were hitting bones, as reported by other authors, seem to confirm the hypothesised lead transfer from projectiles to animal tissues. After hitting the bone, a projectile may be fragmented, the core may be exposed, and secondary projectiles may be generated.

Detached fragments most often move at a different velocity than the projectile core, contaminating a larger area of tissues (Knott et al., 2010). These fragments increase the surface of lead elements that come in contact with the surrounding tissues. Detached projectile fragments and comminute bone become secondary projectiles that generate a temporary cavity and, although an individual “secondary” temporary cavity may coalesce, it always expands the area of contaminated tissues (Felsmann et al., 2016).

The Norwegian Scientific Committee on Food Safety (Norwegian VKM, 2013) reviewed the data on the impact of different ammunition types on the lead concentration in game meat and found that expanding lead-containing bullets produce a cloud of lead particles in the meat around the wound channel. Fragment sizes varied between < 1mm and up to 10 mm. Disruptively-expanding bullets may retain down to 10 % (fragmenting type) or 20-80 % (semi-fragmenting type) of their original weight. Expanding bullets may retain 60-100 % of their original weight, and some bonded types appear to be considerably more stable than unbonded types although great variations exist. Disruptively-expanding, expanding unbonded and some expanding bonded lead-containing bullets produced on average 200 radiographically visible fragments per bullet (range of averages 90 - 370), and up to 800 fragments per bullet were detected for individual bullet types. Very small fragments presumably remain undetected. Other types of bonded expanding lead-containing bullets produced fewer than 10 fragments per bullet. Non-lead disruptively-expanding bullets produced on average 6 to 23 fragments, while non-lead expanding-nose bullets produced 0 to 2 fragments. Lead fragments from disruptively-expanding, unbonded and some bonded expanding lead-containing bullets were found by radiography in various species (roe deer, red deer, wild board, sheep, chamois) with an average radius of 15 cm around the wound channel. The maximal penetration length of visible fragments was on average 29 cm. In a study on sheep, fragments from more stable types of expanding lead-containing bonded bullets were found at distances less than 5 cm. This is comparable to fragments from non- lead disruptively expanding bullets and non-lead expanding-nose bullets measured in the same study. Corresponding studies on moose have not been found. An available study indicates that lead concentrations above 0.1 mg/kg can be found at 25 cm distance from the wound channel in red deer and wild boar shot with various unknown types of lead ammunition (Norwegian VKM, 2013).

Broadway et al. (2020) investigated fragmentation in deer shot with three different types of low velocity lead ammunition (rifled slugs, sabot slugs and modern muzzle-loading bullets). All radiographed deer had evidence of fragmentation, with a geometric mean of 13.1 (95 % CI = 10.3, 16.8) fragments per deer. Most fragments (89 %) were <5 mm from wound channels, and no fragment travelled beyond 205 mm from a wound channel. Fragments were often retained within the muscle tissue of deer with a geometric mean rate of 0.55 (95% CI = 0.48, 0.65). Muzzleloader bullet fragments were larger than those generated by rifled and sabot slugs, and sabot slug fragments had the shortest dispersal from wound channels. Shoulder-shot placement and bone contact for all ammunition resulted in a significantly larger number of fragments. Shoulder-shots also generated more small fragments and higher fragment retention in muscle tissue. The author concluded that, compared to high-velocity rifle bullets, significantly fewer lead fragments are made available to humans and wildlife that consume game shot with low-velocity ammunition types.

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Further details on lead fragments and levels in European game-meat species are presented in the annex to ECHA (2021a).

In a survey of lead dietary exposure in the European population, EFSA (2012) reported that the highest individual lead level of all sampled foodstuffs was found in game meat. Contamination from lead ammunition resulted in some game-meat samples being excluded from the analysis as they were regarded as 'extreme outliers.'

Knott et al. (2010) estimated that, for deer (Cervus elaphus [red deer] and Capreolus capreolus [roe deer]) studied in the UK and shot with lead bullets, the average total weight of metal fragments, which were likely to be mostly lead, was 1.2 g per carcass and 0.2 g per viscera.

In a recent survey of 180 pheasants sold for human consumption in GB during the 2020/2021 shooting season, 99% of the birds from which shotgun pellets were recovered had been killed with lead shot (Green et al., 2021). Publicly-available but not peer-reviewed information provided to the Agency indicated that a proportion of game purchased from supermarkets during 2021 contained lead levels over 0.1 mg/kg ww.

Table B.10 Number of pheasants obtained during the 2020/2021 shooting season and the principal element of the shotgun pellet. One pellet was analysed per bird, *except for one bird from a Waitrose supermarket – one iron-based and one of three lead-based pellets were analysed (Green et al., 2021)

	Number of birds with a pellet composed principally of this element					
Source	Lead	Tungsten	Bismuth	Iron	Copper	Total birds
Southern England	49	0	0	0	0	49
Central England	28	0	0	0	0	28
Northern England	24	0	0	0	0	24
Scotland	35	0	0	1	0	36
Wales	10	0	0	0	0	10
Waitrose	33	0	0	1	0	33*
Total	179	0	0	2	0	180

In the UK, hunters can qualify through approved bodies to obtain qualifications in large and small game handling. Hunters who supply game to an approved game-meat handling establishment (AGHE) must hold such qualifications. The training to gain accreditation covers all areas of hygiene and handling of game meat, including the minimisation of contamination with ammunition. Upon delivery to the AGHE, the trained person must sign a declaration informing that the food is safe and fit to enter the human food chain. An FSA veterinary officer will subsequently inspect all game meat at the AGHE before and during the processing procedure. Additionally, the

FSA has published a Wild Game Handling Guide, which outlines the legal requirements to assure the safety of wild game supplied for human consumption[6], and a photographic guidance on best practice in handling game meat. The British Association for Shooting and Conservation (BASC) has published advice about game handling in relation to lead contamination.

Despite these measures, the use of a high-resolution computerised tomography scanner has demonstrated the location of small lead fragments in pheasant carcasses in the UK far from the nearest large shot (D. Pain, personal communication). This is consistent with the findings of Trinogga *et al*. (2019), who assessed the fragmentation patterns of lead-based and lead-free hunting-rifle bullets in wild ungulates shot in Germany; they found that both the number of bullet fragments and the maximal distance between fragments and the wound channel increased when lead-based bullets were used.

Game-meat consumption in the UK

In relation to game-meat consumption, ECHA (2021b) noted the following.

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Green and Pain (2019) reviewed the published information on game meat consumption in the EU. The authors conclude that the main consumers of game are hunters and their families and associates, and that a few percent of the general population in most EU Member States may be frequent (a few times per month) or high-level (once per week or more) consumers of game meat. Gerofke et al. (2018) concluded that for the average consumer of game meat in Germany the additional uptake of lead only makes a minor contribution to the average alimentary lead exposure. However, for high-frequency consumers (mainly members of hunter households) the uptake of lead from ammunition fragments may be several times higher than the average alimentary lead exposure.

While other parts of the general population do consume game meat, the focus of this restriction proposal is on game meat consumption of hunters and their families. Game meat consumption of hunter families has been estimated to be 50 g meat/day (Haldimann et al., 2002), up to 91 meals/year or 50 g/day (Gerofke et al., (2018)), more than one game meat meal per week, resulting in 50 g/day for adults and 25 g/day for children (ANSES, 2018) and 23 g/day on average with P95 of 97 g/day (AESAN, 2012).

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[6] Retained Regulations 852/2004 and 853/2004 (England and Wales) and Regulations 852/2004 and 853/2004 (Northern Ireland)

Information on game-bird consumption in the UK was published by Taylor et al. (2014). The study authors analysed the game-bird consumption of 2126 participants (aged 1.5 to > 65 years), comprising data from the sample population (National Diet and Nutrition Survey (NDNS) 2008 – 2010), women of childbearing age (15 – 45 years old) and children ≤ 6 years old. Fifty-eight (2.7 %) of the participants reported eating game birds. The consumption of game birds by women of childbearing age and children ≤ 6 years old was relatively low and intakes were small (see

Table B.11).

Table B.11 Portion size and proportion of total bird meat intake in 58/2126 persons of the general population in the UK consuming game birds (Taylor et al., 2014)

Age (years)	N	Game bird consumption (g/day) Mean ± SD; range	Game bird meat as proportion of total meat intake for game bird consumers Mean ± SD; range
≤ 6	3	6.8± 9.7; 1.3-23.2	0.08±0.11; 0.01-0.26
6-18	15	22.3±21.9; 3.75-92.9	0.19±0.19; 0.06-0.76
19-64	34	17.8±13.4; 2.0-46.9	0.18±0.16; 0.02-0.54
> 64	6	30.1±31.1; 1.8-79.0	0.28±0.29; 0.00-0.76

The Food Standards Agency in Scotland (FSAS) published a research report in 2012 that included a survey of 200 'high level' consumers of game meat in Scotland. Half the respondents (51%) ate lead-shot game at least once a week during the main shooting season, whilst 21% ate lead-shot game at least once a week out of the main shooting season. Most interviewees (80%) removed obvious lead pellets before cooking and discarded severely damaged meat. The authors estimated that these participants consumed an average of 47.4 g daily (equivalent to 331.5 g weekly, or 17.2 kg per year) based on the National Diet and Nutrition Survey (NDNS) data. The game meat consumption by the general UK population was estimated to be 11.7 g per day on average (FSAS, 2012).

Additional estimates of UK game consumption were provided by Green and Pain (2015). Data on lead concentrations in UK gamebirds (as reported in (Pain et al., 2010) were combined with UK National Diet Survey data and surveys of the numbers of high-level consumers of game meat and their levels of consumption. From this, Green and Pain estimated that at least tens of thousands of people from the shooting community were high-level consumers of wild-shot game, meaning that they were expected to have intakes of ammunition-derived dietary lead that would result in effects exceeding the EFSA (2010) benchmark response (BMR) levels. These high-level consumers were possibly consuming game meat at least once per week, averaged over a year. It was estimated that somewhere in the region of 4000 – 48 000 children in the UK were at a potential risk of incurring a one point or more reduction in IQ as a result of exposure to ammunition-derived lead. The numbers of adults potentially at risk of health effects was thought to be smaller, although the sparsity of the data did not allow firm conclusions.

The same authors used UK NDNS data to estimate that 2.52% of the UK population (95% CL 2.02 - 3.01%) consumed gamebird meat in a typical four-day period (Green and Pain, 2015). From a survey conducted by BASC and Countryside Alliance in 2014, it was estimated that 9000 (midpoint of the range 5500 – 12 500) children under the age of 8 and about 44 500 adults (range 27 000 – 62 000) from the UK shooting community consumed at least one game meal per week (all types of game), averaged over the year (cited in (Green and Pain, 2019; LAG, 2015). These estimated 53 500 adults and children represented 0.084% of the UK population. The percentage of high-level consumers of game in the UK would therefore seem to lie between 0.084 – 2.52% of the population.

Blood lead levels in consumers of game meat

ECHA (2021b) noted that there is very little information on the impact of game-meat consumption on BLL in the families of hunters, as replicated below.

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Very limited data is available on how frequent game meat consumption affects PbB levels in hunter families. When reviewing the published studies that measured PbB levels in game meat consumers, the following has to be considered:

- Men usually have higher PbB levels compared to females;
- Shooting /hunting has a significant contribution to the PbB level;
- Professional or leisure activities may contribute to PbB levels;
- The available studies investigating PbB levels in hunter and/or members of hunter families usually do not separate the data with respect to sex or shooting/hunting activities. Therefore, it is difficult to draw conclusions on PbB levels.

All reviewed data can be found in Annex B [of the ECHA restriction report].

Hunt et al. (2009) fed lead fragment-containing venison to four pigs to test bioavailability; four controls received venison without fragments from the same deer. The total amount of lead fed to each pig was unknown, but quantitative analysis of similar packages from other deer in the study showed 0.2 to 168 mg (median 4.2 mg) of lead. Mean blood lead concentrations in pigs peaked at 22.9 µg/L (maximum 38 µg/L) two days following ingestion of fragment-containing venison, significantly higher than the 6.3 µg/L averaged by the controls. The results indicate that after a single feeding of median 4.2 mg lead per pig, the PbB level increase was 17 µg/L. After 7 days the PbB levels returned to the baseline values.

The available data indicate that subsistence hunters living in the circumpolar region show the highest increases in PbB levels. For example, Bjerregaard et al. (2004) reported that sea bird consumption of one to three times per week resulted in an increase of the mean PbB level of more than 30 µg/L, for daily consumption even more than 90 µg/L. However, the data for males and females were not separated and the lead contribution from hunting was not considered. In males with even higher sea bird consumption, PbB level increases were 59 µg/L (5 - 15 bird equivalents per month), 67 µg/L (15 - 30 bird equivalents per week) and >113 µg/L (> 30 bird equivalents per week) (Johansen et al., 2006). Again, the lead contribution from the hunters in this group was not considered separately. Tsuji et al. (2008) separated the data for male and females and reported a clear different in the PbB levels of males and females. Compared to females in an urban area, PbB levels were 6 and 15 µg/L higher in native females. For males, PbB levels were 47 and 53 µg/L higher compared to the controls. Most probably a relevant fraction of the PbB level increase might be due to hunting activities. However, it was not reported how many of the circumpolar residents were hunters.

Males and females from hunter families (n = 115) consuming game meat, mainly moose meat, hunted with lead bullets in Sweden (Swedish NFA, 2014a, Swedish NFA, 2014c) had 5.3 µg/L higher PbB levels compared to the control group. For non-hunting women (n = 35) of hunter families the consumption of game meat resulted in PbB levels about 30 % higher (ca. 3.5 µg/L).

In a more recent publication on hunter families in Sweden, PbB level increase was 3.3 µg/L and 5.6 µg/L for females (n = 16) and males (n = 14), respectively, for moose meat consumption two to three times per week (Wennberg et al., 2017, Swedish NFA, 2014a). Hunting activities were not reported.

No increase in the PbB level was observed in non-hunting family members (possibly 10 females) that consumed game meat hunted with shots or bullets (Fustinoni et al., 2017). However, persons consuming game meat prior to testing were excluded.

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No further UK-specific data has been identified.

Additional sources of indirect exposure to humans via the environment

Additional sources of indirect exposure to humans might result from environmental contamination with lead from hunting with lead shot or uses of lead for sport shooting. ECHA's (2021b) summary of the available information on lead contamination of milk and dairy products, root and leaf crops and drinking water from hunting and shooting activities is reproduced below.

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Milk and dairy products

The risk of grazing ruminants being exposed to lead shot could be more prevalent than anticipated since clay pigeon shooting and the shooting of game birds is an increasingly popular rural business and can result in the contamination of land used for pasture, fodder or silage (Payne et al., 2013).

Lead poisoning of cattle is regularly reported in the US and the UK, arising from various sources: lead-containing paint, batteries as well as spent ammunition. Several studies report exposure of ruminant animals to ammunition derived lead, principally via the consumption of silage (Bjørn et al., 1982, Frape and Pringle, 1984, Howard and Braum, 1980, Payne et al., 2013, Rice et al., 1987).

Payne et al. (2013) present two cases of lead-shot ingestion and subsequent lead poisoning reported in cattle in which quantities of lead shot were retrieved from the reticulum or abomasum. The author postulates that lead shot deposited beyond the perimeter of the shooting zone falls on to grassland or arable fields. In these environments the lead shot becomes trapped in vegetation where it can be consumed by grazing ruminants. In addition, trapped lead shot can be incorporated in silage where the acidic environment of the silage making process can result in the formation of lead compounds that are more readily absorbed then metallic lead.

In contrast, Johnsen and Aaneby (2019) reported that sheep grazing at a shooting range used by the Norwegian Armed Forces were at little or no risk of acute or chronic lead poisoning. These data would suggest that sheep have lower sensitivity to lead poisoning than cattle, although the authors noted that the sheep had reduced soil ingestion rates compared to background information.

Root and leaf crops

Concentrations of lead in the soil of a shooting range can be very high. In the sector including backstop berm, target stand and a band of land about 5 to 10 meters wide around the berm, lead concentrations normally exceed 1 000 mg lead/kg. More than 20 000 mg/kg soil of bullets or their fragments can be found in this area. In the immediate surroundings of the backstop berm lead concentrations often fluctuates between 200 and 1 000 mg lead/kg (Dinake et al., 2019). In agricultural soils close

(10 m) to a trap shooting range, total lead concentrations were reported to range from 573 to 694 mg/kg (Chrastný et al., 2010).

A direct correlation between lead in soil and lead in plants has been reported (Bennett et al., 2007). In the biomass of spring barley (Hordeum vulgare L.) grown on shooting ranges, lead concentrations were 138 mg/mg in roots, 16 mg/kg in leaves, 4.2 mg/kg in stems and 2.4 mg/kg in spikes (Chrastný et al., 2010). Regulation 1881/2006 limits lead in cereals to 0.2 mg lead/kg food for human consumption.

Drinking water (via surface water or groundwater)

The concentration of lead in surface (run-off) water at US shooting ranges has been reported from 8 µg/L to 694 µg/L (Ma et al., 2002). In Finnish shooting ranges (Kajander and Parri, 2014), total lead concentration was > 50 µg/L in more than 60% of the samples.

Lead concentrations greater than 1 000 µg/L have been reported in groundwater affected by US shooting ranges (typically old shooting ranges located in sensitive areas), exceeding the threshold for lead in drinking water by more than 100-times (Soeder and Miller, 2003). In a shooting range in Germany (Mainbullau) with use of lead shots for more than 40 years, lead concentrations for leaching water was determined in five different locations with 44.5, 1 460, 198, 64.4, and 12.9 µg/L. The action levels for phase 1 (25 µg/L) requiring supervision was exceeded by 4/5 measurements and action levels for phase 2 (100 µg/L) requiring remediation, was exceeded by 2/5 measurements (Bavarian WWA Aschaffenburg, 2019). According to investigations in Finnish shooting ranges, lead concentrations clearly elevated from the background level are uncommon. In 5 of 24 samples the total lead concentrations in groundwater was > 10 µg/L, whereas the concentration of soluble lead was below 10 µg/L in 13 samples analysed (Kajander and Parri, 2014).

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The impact of these exposure pathways on human health is not investigated in the current report, but measures to restrict the use of lead ammunition would be expected to also reduce this source of secondary human exposure through reduced environmental contamination.

B.9.2.2 Direct exposure to humans

Direct exposure to humans from hunting and shooting activities can occur via the oral and inhalation routes, for example via hand-to-mouth exposures after handling lead or via inhalation of fumes or particles after firing fire-arms or melting of lead for home-casting of ammunition. Information provided to the Agency indicates that only a small proportion of shooters are likely to cast their own projectiles, but that home-loading of ammunition occurs more frequently. This involves shooters purchasing lead projectiles to load into cartridges themselves, which may result in hand-to-mouth exposure after handling lead. The LAG (2015) concluded that there is insufficient information on home-loading of lead ammunition in the UK to quantify the risks from this route of exposure.

Whilst these exposure pathways are not in scope of the present report, measures to restrict the use of lead ammunition might also reduce human exposure through these routes.

B.10 Risk characterisation

B.10.1. Environment

This section is available in Section 1.5 of the main report.

B.10.2. Human health

As outlined in section B.5., chronic exposure to lead is associated with non-threshold effects in children and adults. The potency of these effects has been determined by BMDL values, as derived for example by EFSA (2010) and Budtz-Jørgensen *et al*. (2013), primarily from the same dataset.

In EU restrictions of lead under REACH, different approaches to the risk characterisation have been taken depending upon the exposure scenarios and available information. In its proposal to restrict the use of lead in shot over wetlands, ECHA (2017) applied a qualitative approach to the risk assessment, noting that there was no data on the consumption of wildfowl relative to other game in the EU. Furthermore, ECHA noted that any reduction in dietary lead exposure resulting from the proposed restriction would contribute to a reduction in the health risks posed by lead.

In its characterisation of the risks from consumption of game-meat hunted with lead ammunition (ECHA, 2021b), ECHA applied a semi-quantitative approach. To support the restriction proposal, EFSA provided recent data on the consumption of game meat killed with lead shots and bullets in the EU (only data as presented in the restriction report is publicly available). This did not include UK data. The LAG noted that duck represented >50% of the sample set and questioned if the dataset took account of the proportions of ducks and geese in game consumed, since regulations require that they be shot with non-lead ammunition (LAG, personal communication). ECHA considered the 95th percentile of chronic consumption of game-meat to be a good proxy for high-frequency consumers such as hunter households, from which the daily intake of lead from meat was calculated. ECHA then used data from EFSA on the mean lower bound concentration of lead in game meat in the calculation of BLL resulting from daily lead intake via game meat. In doing so, the dietary intake values in µg/kg bw that correspond to the EFSA BMDL values (EFSA, 2010) were adapted to the bioavailability of metallic lead (10% for adults, 50% for children). The resultant relationships were:

- For developmental neurotoxicity in children aged ≤ 7 (1-point reduction on IQ scale)

12 µg Pb/L blood ≙ 1 µg/kg bw/d

- For the increase of prevalence of CKD in adults (10% increase in prevalence)

2.4 µg Pb/L blood ≙ 1 µg/kg bw/d

- For the increase in systolic blood pressure in adults (1% change)

2.4 µg Pb/L blood ≙ 1 µg/kg bw/d

The calculated mean values for daily intake, incremental BLLs and health impact indicated that the mean consumption of game hunted with lead shot resulted in a low impact (medium IQ losses of 0.24 and 0.41 points) for infants and toddlers, whereas the use of lead bullets had a higher impact (mean IQ loss of 4.1 and 5.9 points) for infants and toddlers. For adults, the calculated mean increase in prevalence of CKD was 0.9 and 6.3% for the use of shot and bullets, respectively, whilst the mean increase in systolic blood pressure was 0.05 and 0.31 mmHg for shot and bullets, respectively. ECHA concluded high risks were associated with this exposure route, primarily because of its relevant impact on the non-threshold effect of developmental neurotoxicity.

The RAC opinion on this approach was not available at the time the current report was written. The EFSA data was not publicly available other than where presented in the restriction report; besides which, it is not necessarily representative of consumption of game meat in the UK. As acknowledged by ECHA, this data and the risk characterisation were associated with several uncertainties: only limited information was available on the consumption of game by children; some of the 95th percentiles were calculated from information on fewer than 60 subjects, and so might not be statistically robust; use of the mean lead concentrations in game rather than the median was conservative, because the data was highly skewed, with median values being orders of magnitude lower than mean values; the calculations did not include lead exposure *in utero*.

Given the lack of information on consumption of game meat by children; very limited information on how game-meat consumption affects BLL in hunter families; uncertainty about the proportion of ammunition-derived lead that is absorbed or how much BLLs are increased per unit of dietary lead ingested; and the lack of reliable measurements of BLL in children of hunter families, a qualitative approach will be taken to the present risk characterisation. In line with the ALARP (as low as reasonably practicable) principle for the control of non-threshold substances, exposure to lead should be reduced as far as possible.

Annex C: Alternatives

C.1. Alternatives

This Annex holds generic information on alternative substances to lead in ammunition (shot and bullet) that are already on the market taken from Appendices C and D of ECHA (2021a). This information has been combined into a single section here, but not edited by the Agency. Information related to the potential alternatives to lead for use in fishing have not been reproduced here, and the human health risks discussed have been limited to those via consumption of game-meat hunted with alternative ammunition. Section C.1.7 summarises additional information regarding the cost of lead alternatives in the UK and accuracy implications of the replacement of lead ammunition with lead-free alternatives that was provided in the responses to the UK call for evidence and in additional data sources identified by the Agency.

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C.1.1 Identification of potential alternative substances and techniques fulfilling the function

C.1.1.1 Alternative shot substances

C.1.1.1.1 Hunting

C.1.1.1.1.1. Lead coated

Coated lead shot has been put in in the market in various forms, plating of shot has been done with nickel or with copper. The main idea behind plating is that that it overcomes the deforming of lead pellets by providing an extra hard layer around shot. Coating is performed by placing lead shot in a bath of an ionic solution and the plating material.

The application of the copper coating to the lead pellets protects the charge in its passage through the barrel to eliminate deformed pellets and ensure that pellets retain their perfect roundness. Today, the wide array of chokes and improvements in forcing cones employed in modern ‘over-under’ shotguns, with many users adopting full choke to increase pattern density to kill high birds, has meant that the shot charge and the pattern it throws is critical. This is where copper-coated shot plays a vital role. With less shot deformed there are more pellets in the pattern, ensuring clean kills of high birds

C.1.1.1.1.2. Non-lead alternatives

Alternatives for shot have been widely assed in the restriction proposal for lead in shot over wetlands. The main alternatives for lead in shot are based on the use of different metals with bismuth, tungsten and steel as the most commonly used materials.

In recent years, several companies have created non-toxic shot from bismuth, tungsten, or other elements or alloys with a density similar to or greater than lead, and with a shot softness that results in ballistic properties that are comparable to lead. These shells provide more consistent patterns than steel shot and provide greater range than steel shot. They are also generally safe to use in older shotguns with barrels and chokes not rated for use with steel shot e.g. bismuth and tungsten-polymer (although not tungsten- iron) shot. All non-lead shot other than steel is far more expensive than lead, which has reduced its acceptance by hunters.

Bismuth and its alloys

The ballistics or performance is generally good, provided the shot size is increased to allow for density lower than lead. Bismuth is suitable in all guns. Bismuth can be used as a drop in alternative to lead without concerns over compatibility with guns.

Bismuth is alloyed with 3–6 % tin to reduce the frangibility of the bismuth when used as shot. Shot made from bismuth-tin alloy is fully approved in the US as non-toxic (Thomas, 2019).

Copper and its alloys

The technical suitability of copper shot is discussed in the approval of this type of shot by the US Fish and Wildlife Service[7] the shot is described as

Corrosion-inhibited copper shot (CIC shot) consists of commercially pure copper that has been surface-treated with benzotriazole (BTA) to obtain insoluble, hydrophobic films of BTA-copper complexes (CDA 2009). These films are very stable; are highly protective against copper corrosion in both salt water and fresh water; and are used extensively to protect copper, even in potable water systems. Other high-volume applications include deicers for aircraft and dishwasher detergent additives, effluents of which may be directly introduced into municipal sewer systems, indicative of the exceptionally low environmental impact of BTA.

The idea behind using copper shot is similar to the copper coating (discussed above) to overcome the softness and deformation of lead by using a harder material that will

[7] https://www.federalregister.gov/documents/2017/08/15/2017-17175/migratory-bird-hunting-approval-of-corrosion-inhibited-copper-shot-as-nontoxic-for-waterfowl-hunting

provide more pellets in the shot pattern to take high birds. This shot type is usually considered to a be an alternative for the upper part of the market.

Steel (soft iron)

Steel was one of the first widely used lead alternatives that the ammunition industry turned to. But steel is one hundred times harder than lead, with only two-thirds its density, resulting rather different ballistic properties when compared to lead.

Therefore, rather than steel, “soft iron” is used for shots, which is manufactured by annealing iron containing approximately 1 % or less carbon (Thomas, 2019).

Steel shot does have the potential to cause some choke expansion ("bulging") particularly with heavy loads in older, traditional lightweight guns. Care is also needed when shooting steel shot as it can ricochet more than lead. However, an unsafe shot with steel would also be an unsafe shot with lead. As a result of its hardness, steel shot has traditionally been contained in robust plastic wads (BASC)[81]

Steel shot may be coated with a thin layer of copper or zinc to inhibit rusting which is permitted under US regulations (US FWS, 1997).

Tin

The low-density (7.31 g/cm3 vs. 11.3 g/cm3 for lead) does not predispose it for use as gunshot (Thomas, 2019).

Tungsten and its alloys

The density of tungsten shot is favourable for good ballistics and performance, so the percentage of tungsten in shot material is important. It is suitable for use in appropriately proved guns and widely available.

Tungsten can be made into shot either as a mixture of powdered metal mixed with a high-density polymer (95 %W + 5 % polymer), or as a composite mixed (sintered or alloyed) with other metals (Thomas, 2019).

For the use of tungsten matrix shot, the British Association for Shooting and Conservation (BASC)[8] recommends the following: Tungsten varieties come in many forms. It tends to be as dense or denser than lead so you may not need to change theshot size or you might even reduce the size of the load.

Powdered bronze can be sintered with tungsten powder to make a hard, high-density tungsten-bronze gunshot (Thomas, 2019).

[8] https://basc.org.uk/lead/guide-to-using-non-lead-shot.

Zinc and its alloys

Zinc is used most often as an alloying metal (Thomas, 2019).

C.1.1.1.2. Sports Shooting

The evidence provided in the call for evidence concerning the use of alternative shot inclay target shooting is less clear than for hunting.

ISSF and FITASC rules requires the use of lead shot with a gauge not greater than 12 mm (usually 12 mm is used). Shotguns must be smooth bored. They are invariably 12-gauge, single-triggered and over-under type — one barrel is placed above the other.

They fire cartridges loaded with lead pellets: the weight of the pellet load must not exceed 24.5 grams per cartridge; the diameter of each pellet must not exceed 2.6 millimetres. Guns and cartridges are subject to official checks during the shooting programme.

Based on the demand from hunters and sports shooters, soft iron shots have also beendeveloped for competition purposes (Figure C.1).

Rottweil Competition Line shotgun cartridges: since soft iron shot requires more volume for the same weight, the cup of the Steel Trap is correspondingly higher than that of the Special Trap. (© ROTTWEIL)

Figure C.1 Rottweil Competition Line shotgun cartridges with lead shots (left) and soft iron shots (right)

C.1.1.2. Alternative substances for bullets

C.1.1.2.1. Hunting

Lead as well as non-lead bullets used for hunting might either be monolithic, semi-jacketed or jacketed with other metals to facilitate the gliding of the bullets through the barrel. Further, non-lead bullets may contain traces of lead.

C.1.1.2.1.1. Lead, coated

Lead bullets are usually semi-jacketed bullets which consist of a hard lead alloy core and a jacket partly surrounding this core. The percentage of further metals (mainly antimony, arsenic and zinc) determines the degree of hardness of the alloy. The semi- jacket of most bullets consists of tombac, a copper-zinc alloy with a copper content of >80 %. Tombac additionally always contains arsenic which determines the hardness of the material. In addition, there are semi-jacketed lead containing bullets with a semi- jacket consisting of steel for hunting (Gerofke et al., 2018).

C.1.1.2.1.2. Non-lead alternatives

Based on an analysis of the information submitted in the call for evidence it is clear that for most larger game a wide variety of non-lead bullets already exist, the challenges in substitution are within the smaller calibres that are used for hunting smaller game and pests.

The main non-lead alternatives on the market are bullets made of copper or a copper alloy. Copper bullets expand rapidly, providing the hydrostatic shock necessary for quick kills. Unlike lead bullets, copper bullets don't break apart and release dusts that lead- based bullets do. Non-lead bullets are able to travel farther through the target, thus increasing stopping power because the bullet can more easily penetrate tissue and bone. In addition, non-lead bullets usually pass completely through the animal, leaving an exit wound. This may offer a benefit for hunters, as the resulting increased blood loss may leave a better trail for hunters should quarry escape after the initial shot.

Most of the non-lead bullets developed to replace lead are made from pure copper or copper-zinc alloy (brass), with or without other metal jacket coatings (Paulsen et al. 2015; Thomas et al. 2016).

Pure copper

Non-lead monolithic bullets consist of almost pure copper (density 8.96 g/cm3) or 100%-electrolyte copper. Such monolithic bullets are used as bullets for as slugs fired from shotguns.

Brass

Copper can also be alloyed with approximately 5 % (less than 40 %) zinc **brass** to make similar non-lead bullets (Thomas, 2019). Monolithic bullets made from brass, an alloy from copper and zinc with a percentage of zinc of less than 40 %.

Brass is also used for ammunition cartridges.

Bronze

Bronze is an alloy of approximately 90 % copper and 10 % tin which is potentially suitable for the use of bullets. However, metal hardness may be problematic (Thomas, 2019).

Tombac

Tombac or Tombak is a copper-zinc (brass) alloy with a higher zinc content (5 to 20 %). In tombac there is additionally always arsenic present which determines the hardness of the material. The semi-jacket of most bullets consists of tombac (Gerofke et al., 2018).

Polymers

There are different application of polymers. Polymers can for example be used as polymer shell to encase the lead projectile, as nose of the bullet or as a major component of the bullet.

Polymer coated bullets are hard cast bullets with a tough polymer shell which encases the lead projectile. They are similar in concept to copper plated bullets, except the plating is made out of polymer instead of copper or copper alloy.

Polymer-tipped bullets are a type of hollow-point bullet tipped with a polymer nose cone. Most tips are made of polyoxymethylene, although some manufacturers have used polyester urethane-methylenebis(phenylisocyanate) copolymers

In metal-polymer composites the polymer is a major component of the bullet. Such bullets are generally lighter and have higher velocities than pure metal bullets of the same dimensions. They permit unusual designs that are difficult with conventional casting or lathing. For example, a polycase bullet could consist of powdered copper and a nylon-like polymer matrix. Another example is a tungsten/polymer composite comprising of tungsten powder, another metal powder having a high packing density, and organic binder have high density, good processability and good malleability.

Advantages of polymer coated bullets are less friction between the bullet and the bore, less smoke, less debris left in the barrel, no toxic off-gassing and can be used for indoor shooting where lead bullets are restricted.

Tin

Due to the low-density of tin (7.31 g/cm3 vs. 11.3 g/cm3 for lead) it does not predispose it to use as bullets; however, it could be used as an alloying material (Thomas, 2019).

Tungsten

Tungsten can be used at any %W, when used as a densifier with other approved material (Thomas, 2019).

C.1.1.2.2. Sports shooting

The general feedback in the call for evidence was that here are no viable alternatives for the bullet calibres used in sports shooting.

The bullet calibres used (air and firearms) are .22LR, .30-.38 and 0.177 Air. These are the basic calibres used in many of the ISSF and IBU events, which are de facto standard as well for all sports shooting activities leading to these events.

The ISSF 10m Air Rifle target has a white central dot which is the 10 ring, with a radius 0.25mm. The surrounding 9 ring has a 2.75mm radius.

Very limited quantities of 0.22LR ammunition loaded with copper projectiles are available. Independent testing with this copper ammunition shows the enclosing circle diameters for only 5 shots at 45.7m (50 yards) to on average 35.6mm. This would not be considered acceptable for even entry level target shooting.

C.1.1.3 Risk reduction, technical and economic feasibility and availability of alternatives

C.1.1.3.1. Assessment of alternatives

The risks, availability, technical and economic feasibility of the list of potential alternative substances to lead have been reviewed.

C.1.1.3.2. Availability of alternatives

Table C.1 Price and availability of the alternative substances

Substance	Source	Critical supply?
Lead	Recycled lead essentially	Not critical. Recyclable
Bismuth	China (84 %)	Critical Raw Material. Limited abundance.
Brass	-	Not critical. Recyclable
Bronze	-	Not critical. Recyclable
Copper	Chile (29 %) Peru (12 %)	Not critical. Numerous competing uses.
High density polymer	-	Not critical.
Iron		Not critical. Numerous competing uses.
Stainless steel	China (44 %) Europe (4 %)	Not critical. Recyclable
Tin	China and Indonesia	Not critical. Relatively abundant
Tungsten	China (85 %) Russia (50 %) Portugal (17 %) Spain (15 %) Austria (8 %)	Relatively abundant; included within EU Critical Raw Materials;
Zinc	China (39 %), Australia (11 %) Peru (10 %)	Not critical. Relatively abundant

Source: https://www.lme.com/, https://www.metalary.com/, http://www.experience-zamak.fr/indice-zamak/, https://worldsteelprices.com/european-steel-prices/ consulted on 24 August, (Wood E & IS GmbH, 2020

C.1.2. Human health risks from consumption of game-meat hunted with alternative ammunition

C.1.2.1. Lead, coated

Most lead bullets used for hunting are usually semi-jacketed. Therefore, it can be assumed that the lead concentration measured in game meat results from hunting with semi-jacketed lead bullets. Therefore, the coating of the lead bullet does not prevent contamination of the game meat with lead.

C.1.2.2. Non-lead alternatives

Bismuth

Bismuth did not show a health hazard in a sub-chronic toxicity study in rats even when a water soluble salt was administered. Consequently, no human health risk is expected for the consumption of meat from game hunted with bismuth.

Copper and zinc

Reliable data on the metal concentration in game meat following the use of alternative shots or bullets are only available for game bagged with copper and zinc bullets.

Paulsen et al. (2015) simulated the release of different metals from non-lead rifle bullet fragments in game meat during storage and ingestion. The release of copper and zinc from meat posed no toxic risk post-ingestion by humans, but the authors advised that the aluminium, nickel, and lead content of bullets be kept deliberately low.

Irschik et al. (2013) indicated that the release of copper from shot game would not contribute much released metal to humans, concluding that the recommended daily would not be exceeded, especially if bullet fragments around the entry site were removed. However, solid copper bullets do not fragment to the same extent as bonded and unbonded lead-core bullets [(Hunt et al., 2009), (Irschik et al., 2013), (Stokke et al., 2017)].

Schlichting et al. (2017) examined the contamination of copper and zinc in game meat from roe deer, wild boar and red deer hunted either with lead bullets (surrounded by a tombac jacket with a high copper and zinc content) or non-lead ammunition (bullets).

Within the scope of the study, samples of 1254 roe deer, 854 wild boar and 90 red deer from different regions within Germany with known lead-contamination of the soil were examined. For each animal killed, the hunters had to fill in a sample data sheet in which detailed information on the animals (species, age and gender) and how they had been shot (including bullet material, i.e. lead vs non-lead), bullet type used, information on the entry and exit of the bullet, shooting distance and if a bone was hit were recorded. The hunted game was brought to game traders who had also been specifically trained for this project and who collected the samples according to uniform standards. Three samples were taken from each animal after completion of the regular process of skinning and cleaning the carcass according to hygiene standards for game meat. The samples were taken from marketable meat of the saddle and haunch and from the area close to the wound channel, which had been widely cut out. The sample amount was 100 g for each of the three subsamples. The samples were analysed by accredited laboratories.

For red deer, no difference was observed in copper and zinc content when using lead or non-lead ammunition. It should be kept in mind though that the sample size was significantly lower than that for the other two species. The outcome of this study shows that the usage of both lead-based ammunition and alternative non-lead ammunition results in the entry of copper (see Table C.2) and zinc (see **Error! Reference source not found.**) into the edible parts of the game. However, the levels of copper and zinc in game meat measured in this study are in the range found in previous studies of game (see

Table C.4). The content of copper and zinc in game meat is also comparable to those regularly detected in meat and its products from livestock (pig, cattle, sheep); copper compounds are used as a feed additive in the fattening of pigs and poultry. The consumption of game meat contributes to copper and zinc intake. If the mean or median values are considered then the intake of copper is between 0.2 and 0.5 mg and the intake of zinc is between 5.2 and 7.5 mg per day for average consumption. According to the authors a health risk for the consumer due to an average consumption of game meat with the reported content of copper or zinc is unlikely. The authors consider that since the general population on average eats more meat and/or products of farm animals, the intake of copper through the consumption of these products is much higher than it is through the consumption of hunted game meat, irrespective of whether lead or non-lead ammunition was used for hunting. This only applies, of course, if game meat hygiene measures have been properly applied, i.e. the meat close to the wound channel has been widely cut out and areas with hematomas have also been widely removed.

Table C.2 Copper content in hunted roe deer, wild boar and red deer (mg/kg) Schlichting et al. (2017)

Sample	Bullet	N	Copper concentration in game meat (mg/kg)				P
			Mean[a]	Median	95th[b]	Maximum	
Roe deer, haunch	Lead	745	1.614	1.564	2.196	6.451	0.359
	Non-lead	509	1.695	1.577	2.702	9.048	
Roe deer, saddle	Lead	745	1.810	1.759	2.769	4.034	0.576
	Non-lead	509	2.017	1.730	3.672	37.537	
Roe deer, around wound channel	Lead	745	1.464	1.400	2.063	3.946	<0.0001
	Non-lead	509	1.635	1.500	2.444	9.701	
Wild boar, haunch	Lead	514	1.437	1.375	2.136	4.300	0.432
	Non-lead	340	1.456	1.368	2.363	8.050	
Wild boar, saddle	Lead	514	1.506	1.200	1.986	110.000	0.005
	Non-lead	340	1.404	1.270	2.420	5.238	
Wild boar, around wound channel	Lead	514	1.426	1.322	2.286	9.616	0.005
	Non-lead	340	1.627	1.419	2.728	18.886	
Red deer, haunch	Lead	64	1.891	1.857	2.648	2.969	0.954
	Non-lead	26	1.896	1.874	2.478	2.902	
Red deer, saddle	Lead	64	1.794	1.746	2.462	4.787	0.789
	Non-lead	26	1.759	1.760	2.280	2.390	
Red deer, around wound channel	Lead	64	1.701	1.743	2.165	2.553	0.712
	Non-lead	26	1.755	1.650	2.363	2.721	

[a] Arithmetical mean

[b] 95th percentile

Table C.3 Zinc content in hunted roe deer, wild boar and red deer (mg/kg) Schlichting et al. (2017)

Sample	Bullet	N	Zinc concentration in game meat (mg/kg)				P
			Mean[a]	Median	95th[b]	Maximum	
Roe deer, haunch	Lead	745	30.574	31.660	44.640	65.000	0.089
	Non-lead	509	31.946	32.000	48.000	64.000	
Roe deer, saddle	Lead	745	28.842	31.324	50.000	63.000	0.006
	Non-lead	509	31.348	31.770	55.800	131.584	
Roe deer, around wound channel	Lead	745	30.532	29.719	48.000	72.296	<0.0001
	Non-lead	509	33.649	32.870	53.624	138.000	
Wild boar, haunch	Lead	514	31.700	32.029	45.700	56.000	0.397
	Non-lead	340	31.358	31.000	49.407	70.073	
Wild boar, saddle	Lead	514	28.266	29.000	45.000	98.521	0.049
	Non-lead	340	27.646	25.975	52.168	95.202	
Wild boar, around wound channel	Lead	514	30.406	28.410	52.000	88.232	0.027
	Non-lead	340	32.360	30.919	55.955	78.036	
Red deer, haunch	Lead	64	33.965	35.216	43.225	52.642	0.302
	Non-lead	26	35.850	36.373	52.410	57.510	
Red deer, saddle	Lead	64	35.371	37.486	53.010	58.990	0.689
	Non-lead	26	35.134	31.569	63.580	74.640	
Red deer, around wound channel	Lead	64	32.992	31.450	48.030	70.457	0.715
	Non-lead	26	34.110	32.575	48.417	67.933	

[a] Arithmetical mean

b 95th percentile

Table C.4 European studies on copper and zinc content in game meat (mg/kg wet mass). Data according to Ertl et al. (2016), complemented by additional references by Schlichting et al. (2017)

Species	Reference[1]	Country	Copper				Zinc			
			n	mean	median	max	n	mean	median	max
Roedeer	Dannenberger et al., 2013	Germany	118	2.8		4.2	118	23.5		39.3
	Falandysz, 1994	Poland	145	1.8		8.1	145	30		60
		Poland	84	1.7		6.0	84	36		56
	García et al., 2011	Spain					75	1.56		8.0
Wildboar	Amici et al., 2012	Italy	75	12.20	11.80	25.17	57	53.21	53.14	80.10
	Bilandzic et al.,2012	Croatia	31	3.12	1.68	15.3				
	Dannenberger et al., 2013	Germany	85	1.7		2.3	85	24.0		31.9
	Falandysz, 1994	Poland	149	1.7		5.8	149	32		93
		Poland	118	1.5		5.7	118	37		72
	Gasparik et al.,2012	Slovakia	120	1.61			120	13.48		
	Roslewska et al., 2016	Poland	8	6.15		6.8	8	61.28		80.60
		Poland	8	7.5		9.2	8	68.21		106.1
	Sager, 2005	Austria	14	1.17	1.19	1.48	14	37.3	34.4	60.6
	Strmiskova and Strmiska, 1992	Slovakia	10	1.3			10	41.0		

Reddeer	Falandysz, 1994	Poland	82	3.3		6.4	82	39		64
	Jarzynska and Falandysz, 2011	Poland	20	3.63	3.3	7.26	20	49.5	46.2	95.7
	Gasparik et al.,2004	Slovakia	22	2.49		5.34	22	54.76		109.12
	Lazarus et al.,2008	Croatia	48	3.48	3.02		48	43.4	43.8	67.4
	Sager, 2005	Austria	21	1.56	1.62	2.25	21	48.5	53.2	63.8

Notes: [1] references according to Ertl et al., 2016 and Schlichting et al., 2017

The maximum residue level (MRL) for copper permitted in food of animal origin from pigs, cattle, sheep, goats, horses, poultry and other farm animals is 5 mg/kg (fresh weight) according to regulation (EC) No 149/2008 and the amending regulation (EC) No 396/2005. For wild game meat (i.e. the meat after removal of trimmable fat) the permitted residue level so far has been 0.01 mg/kg, which corresponds with the lower level of detection. This is because since spring 2013 “game meat” has been listed under “other terrestrial animal products” in Annex I to regulation (EC) No 212/2013 and the amending regulation (EC) No 396/2005 and no residue value has been derived based on natural content up to now. In order to account for the natural background levels of copper in game meat (as a result of environmental uptake mainly through feeding), Germany in its role as “evaluating member state” proposed a residue level for copper in game meat of 4 mg/kg. EFSA found that the contribution of the proposed MRL to total consumer exposure to copper was negligible. It amounts up to 0.7 % of the Acceptable Daily Intake (ADI) of an adult (Schlichting et al., 2017).

Iron/steel

The main constituent of steel, iron, has a lower oral toxicity compared to lead, copper or zinc. Therefore, a potential health risk from the consumption of meat from game hunted with steel ammunition is not expected to be higher than that for zinc or copper in case appropriate meat hygiene is applied.

Tungsten showed adverse effects on kidneys in a sub-chronic toxicity study in rats when a water-soluble salt was administered. Due to missing information on tungsten concentrations in game meat, no conclusion on human health risk can be drawn.

C.1.3. Environmental risks related to alternatives

Major potential environmental risks related to the use of shots, bullets or fishing tackle made of alternative substances are aquatic toxicity and the toxicity of wildlife feeding on wounded or dead birds in which it was embedded or in the viscera of game left in the field.

C.1.3.1 Aquatic toxicity

C.1.3.1.1. Lead, coated

A galvanic tin-coated lead core prototype shot was shown not to leach tin in aquatic environment (Fäth et al., 2018).

C.1.3.1.2. Non-lead alternatives

The leaching behaviour of metals and their toxicity to Daphnia magna (EC50 value for 48 h immobilisation) of commonly available gunshot pellets was investigated under standardised medium for daphnids (Fäth et al., 2018) and under different water conditions (geology/redox conditions) (Fäth and Göttlein, 2019). The result of those studies are summarised in the following Table C.5 and addressed in the text below under the respective heading. The conditions of the experimental aquatic environments are also outlined in Figure C.2. The grey shading represents those values that exceeded the EC50 for Daphnia magna according to Khangarot and Ray (1989). Spring water originating from siliceous bedrock showed the highest concentrations of nearly all leached metals (Pb, Zn, Ni, Cu) under aerobic conditions. The authors concluded that according to the conducted leaching tests, Cu- and Zn-based as well as Zn-coated gunshot should be avoided by reason of the high risks they pose to the aquatic environment.

Table C.5 Metal concentrations (in µmol/L) for different shot types during short- and long-term exposure leaching tests as provided by (Fäth and Göttlein, 2019) including data from (Fäth et al., 2018)

Shot type (main component)	**Leached element**	**Metal concentration (µmol/L), mean±standard error**				
		ADaM	Siliceous (pH 6.5) aerobic	Calcareous (pH 7.6) aerobic	Siliceous (pH 6.5) anaerobic	Calcareous (pH 7.6) anaerobic
Short term period (1 day; 8 days)						
PL (Pb)	Pb	**1.81±0.26**	**1.77±0.36**	0.32±0.15	<LOQ	<LOQ[a]
	Sn	<LOD[b]	<LOQ	**0.39±0.06**	<LOQ	**0.31±0.08**
Blind Side (Fe)	Zn	**13.39±3.35**	**11.82±3.91**	2.47±0.26	0.21±0.01	<LOD
Hubertus (Zn)	Zn	**33.79±4.56**	**29.99±9.02**	3.96±0.81	1.33±0.19	<LOQ
Silver (Pb)	Ni	0.59±0.08	**0.68±0.09**	0.55±0.06	**1.56±0.47**	**0.65±0.10**
Sweet Copper (Cu)	Cu	**1.91±0.51**	**3.53±1.06**	**2.63±1.12**	0.14±0.01	<LOQ
Ultimate (W)	Sn	<LOD	<LOD	<LOD	0.89±0.29	0.89±0.44
Long-term period (15 days; 22 days)						
PL (Pb)	Pb	0.60±0.25	**4.30±1.12**	0.20±0.09	<LOQ	<LOQa
	Sb	<LOQ	<LOQ	**0.75±0.05**	<LOQ	0.59±0.05
Blind Side (Fe)	Cr	<LOQ	<LOQ	<LOQ	0.10±0.01	<LOQ
	Zn	**34.70±0.92**	24.82±1.29	3.78±0.16	0.49±0.11	<LOD[b]
Hubertus (Zn)	Zn	30.48±1.79	**55.71±3.75**	4.83±0.15	0.69±0.10	<LOQ
Silver (Pb)	Ni	**1.34±0.19**	0.52±0.02	0.31±0.04	**1.20±0.23**	<LOQ

Sweet Copper (Cu)	Cu	4.11±0.37	**5.92±0.27**	**6.35±0.10**	<LOQ	<LOQ
Ultimate (W)	Sn	<LOQ	<LOD	<LOD	**1.23±0.07**	0.65±0.08

ADaM: standardized medium termed "Aachener Daphnien Medium; LOQ: Limit of quantification; LOD: limit of detection; bold values indicate homogeneous subsets with the significant highest concentrations among the tested environments determined by ANOVA. Grey shading represents those values that exceeded the EC50 for Daphnia magna according to (Khangarot and Ray, 1989)

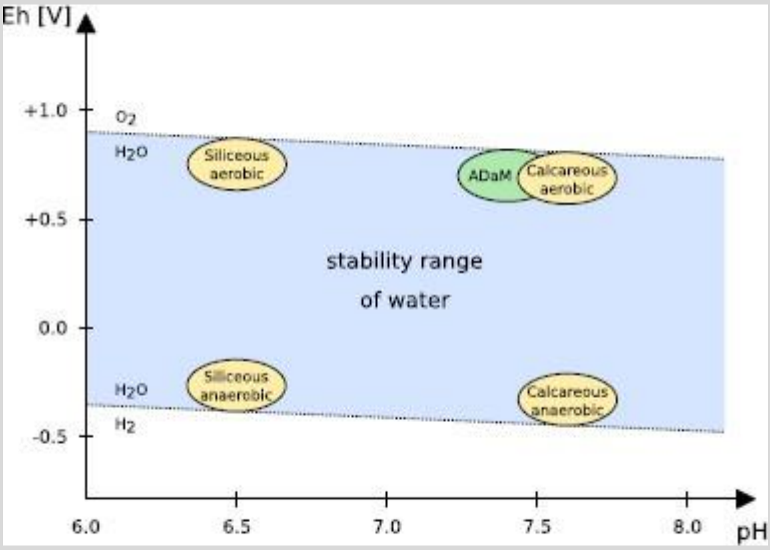


Figure C.2 Schematic placement of the four investigated environments (yellow) as well as the ADaM solution (green) used by Fäth et al. (2018) in the stability range of water defined by the redox potential and the pH value at 298.15 K and 105 Pa in an Eh/pH chart (Fäth and Göttlein, 2019)

Bismuth

Bismuth does not have any harmonised or self-classification.

When testing the leaching rate for a commercial bismuth shot (Eley Bismuth Alphamax) no detectable leaching rate of bismuth or other metals (tin, nickel, iron, lead) was identified (see also Table C.5) and consequently also no impact on immobilisation of Daphnia magna (Fäth et al., 2018).

Brass

For brass chemical fate studies demonstrated that the brass dissociated to its ionic components of copper and zinc quickly at pH 2.0. At pH 5.0 and 6.5, the dissociation occurred too slowly to account for the observed toxicity. The data suggested that the toxicity is due to filtration by the daphnids and subsequent ingestion. EC50 determinations for the brass particles are nearly identical with published EC50 values for copper salts (Johnson et al., 1986).

Pb (or Bi) is present in brasses as small “islands” of metal, whereas Cu and Zn are mixed in a solid solution. With time, Zn in the brasses was preferentially lost relative to Cu. Pb releases from the brass faucets in 6 hour stagnation runs increased rather than decreased with time. This behaviour is inconsistent with formation of passivating scale layers, but is consistent with progressive dezincification producing a porous surface layer through which Pb can diffuse more rapidly, or from which Pb particulates can be detached more readily with time (Maynard et al., 2008).

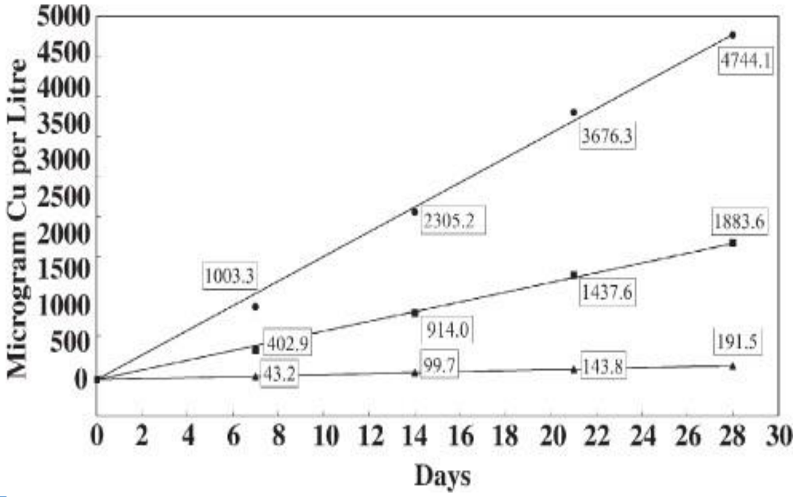
Copper

Copper massive does not have a harmonised classification for aquatic toxicity, whereas copper granulated has a harmonised classification for Aquatic Chronic 2 which shall apply from 1 March 2022. Copper powder and copper flakes are self-classified in the registration dossier for Aquatic Acute 1 and Aquatic Chronic 1.

The continental threshold for copper was reported to be 1.1 µg/L (Peters et al., 2019).

When testing the leaching rate of a commercial copper shot (FOB Sweet Copper) high leaching rates were demonstrated with 0.79, 3.03, 4.22 and 4.0 µmol/L after 1, 8, 18 and 22 days, respectively. The authors identified the EC50 value for 48 h immobilisation of Daphnia magna with 1.46 µmol Cu/L (Fäth et al., 2018). Even higher concentrations leached under siliceous and calcareous aerobic conditions as demonstrated that pose a risk to aquatic organisms (Fäth and Göttlein, 2019).

Thomas et al. (2007) measured the release of copper from pure copper shots, sintered tungsten-bronze shots and glass beads in a buffered, moderately hard, synthetic water of pH 5.5, 6.6, and 7.8 over a 28-day period. The dissolution of copper from the copper shot was affected significantly by the pH of the water and the



duration of dissolution (see

Figure C.3). The resulting Expected Environmental Concentrations (EECs) were not presented in the publication.

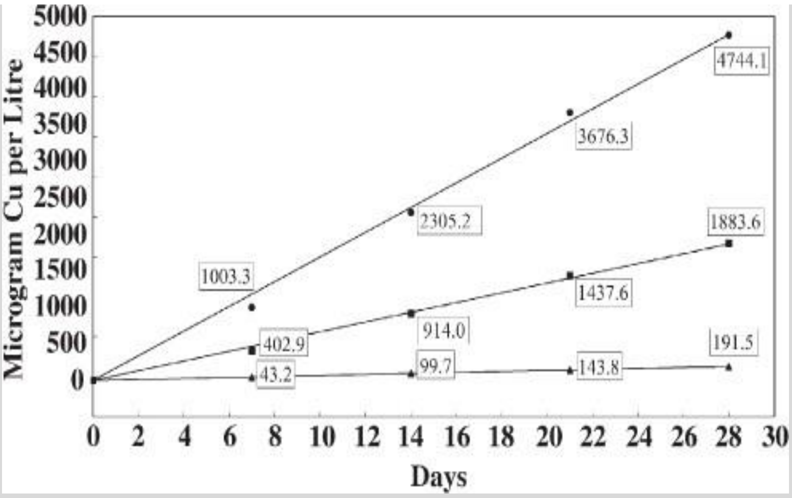


Figure C.3 Dissolution of copper from copper shot in moderately hard water at 15°C under three different pH levels during a 28-day period. Regression equation for pH 5.6 (●), y=169.67x (R2=0.9965). Regression equation for pH 6.6 (▪), y=67.038x (R2=0.9974). Regression equation for pH 7.9 (▴), y=6.8573x (R2=0.9981). Values accompanying each datum point are untransformed means (Thomas et al., 2007).

Nickel

Nickel powder, but not nickel metal, has a harmonised classification for Aquatic Chronic 3.

Metal bioavailability and toxicity to aquatic organisms is dependent on the physico-chemical composition of the surrounding medium. No information could be retrieved on the leaching of nickel from metal to aquatic environment.

Steel

The median iron concentration in rivers has been reported to be 0.7 mg/L. In anaerobic groundwater where iron is in the form of iron(II), concentrations will usually be 0.5– 10 mg/L, but concentrations up to 50 mg/L can sometimes be found. Concentrations of iron in drinking-water are normally less than 0.3 mg/L but may be higher in countries where various iron salts are used as coagulating agents in water-treatment plants and where cast iron, steel, and galvanized iron pipes are used for water distribution (WHO, 2003).

Elemental iron or iron powder does not have any harmonised or self-classification.

Iron is an abundant element in the earth’s crust and can be an environmental pollutant in waters near coal and hard rock mines. In the US the current water quality criterion is
1.0 mg/L. Based on more recent investigations the authors are proposing to reduce it to

0.49 mg/L (Cadmus et al., 2018).

When testing the leaching rate of two commercial steel shots (Rottweil Steel Game, Winchester Blind Side) the leaching of iron itself was not reported (Fäth and Göttlein, 2019).

The available data do not indicate a risk of iron for the aquatic environment.

Tin

Tin does not have a harmonised classification and is not self-classified for any endpoint.

In the registration dossier the following is concluded “Aquatic ecotoxicity data on tin is available for algae, invertebrates and fish. The test data on studies that are that based truly soluble tin indicate no adverse effects are expected at the range of concentrations of tin permitted by its very low solubility. The solubility of tin is very low due to its tendency to precipitate out of solution. The potential adverse effects of the precipitate were also studied in a chronic chironomid sediment and respiration inhibition tests and no significant adverse effects were seen. Therefore, an environmental classification is not proposed.”

When testing the leaching rate of a commercial tungsten shot (Ultimate) no leaching of tungsten was observed (see also Table C.5). However, leaching of **tin** occurred under anaerobic conditions; for the long-term period under siliceous conditions the leaching tin reached concentrations that pose a risk to aquatic organisms (Fäth and Göttlein, 2019).

The available data indicate no aquatic toxicity of tin in shots under aerobic conditions; the reported risk of aquatic toxicity of tin under anaerobic condition (Fäth and Göttlein, 2019) would require further investigations.

Tungsten (W)

Tungsten is not classified for environmental hazards.

In the registration dossier the following is summarised: “No definitive results were available from tests performed with tungsten metal. Therefore, the most reliable studies identified for sodium tungstate were used in for read-across in the PNEC derivations.

This approach is considered to be appropriate since sodium tungstate has been shown to undergo more dissolution in water solutions mimicking natural water conditions than tungsten metal. Hence, sodium tungstate is likely to be more bioavailable than tungsten metal and adequately protective for estimating potential toxicity. Furthermore, neither tungsten metal or sodium tungstate are classified for aquatic toxicity and their PBT profile is the same”

When testing the leaching rate of a commercial tungsten shot (Ultimate) no leaching of tungsten (see also Table C.5) was observed (Fäth and Göttlein, 2019).

Thomas et al. (2007) measured the release of copper from pure copper shots, sintered tungsten-bronze shots and glass beads in a buffered, moderately hard, synthetic water of pH 5.5, 6.6, and 7.8 over a 28-day period. The dissolution of copper from the control copper shot affected significantly by the pH of the water and the duration of dissolution (see Figure C. 4). The rate of copper release from tungsten bronze shot was 30 to 50 times lower than that from the copper shot, depending on pH. The observed expected environmental concentration of copper released from tungsten–bronze shot after 28 days was 0.02 µg/L at pH 7.8, and 0.4 µg/L at pH 5.6, using a loading and exposure scenario specific in a U.S. Fish and Wildlife Service protocol. Ratio Quotient values derived from the highest EEC observed in this study (0.4 µg/L), and the copper toxic effect levels for all aquatic species listed in the U.S. Environmental Protection Agency ambient water quality criteria database, were all far less than the criterion value (0.1 µg/L).

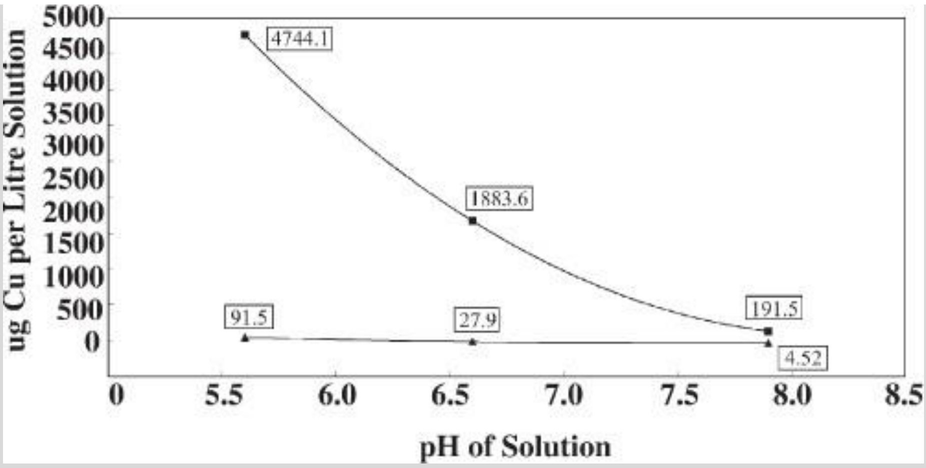


Figure C. 4 The effect of pH on the dissolution rate of copper from copper shot and tungsten– bronze shot when immersed in a moderately hard water at 15 °C for 28 days. Values accompanying each datum point are the untransformed means from day 28. Regression equation for copper shot (▪), $y=677.79x^2-11130x+45814$ ($R^2=1.0$). Regression equation for tungsten– bronze shot (▴), $y=19.69x^2-303.53x+1173.8$ ($R^2=1.0$) (Thomas et al., 2007).

In the call for evidence (CfE #1034), VLIZ mentioned recent studies which highlight movement and detection of tungsten in soil and drinking water sources (Emond et al., 2015, Inouye et al., 2006, Tuna et al., 2012, Wasel and Freeman, 2018). Movement and detectability of a substance are usual behaviour and would not be a problem in case of a non-toxic substance such as tungsten. VLIZ mentioned also that Inouye et al. (2006) even ‘showed that the sub-lethal toxicity of tungsten appears to be higher than that of lead’. The authors of this study tested a soluble tungsten salt and a soluble lead salt.

Since tungsten metal is insoluble, such a statement is not correct for tungsten metal. Based on the available data there are no indications for aquatic toxicity, or other environmental hazard of tungsten used in shots, and fishing tackle.

Zinc

Zinc powder - but not zinc massive - has a harmonised classification for Aquatic Acute 1 and Aquatic Chronic 1.

In the registration dossier, zinc massive is not self-classified for aquatic toxicity. It is noted that the potential ecotoxicity of metals in massive form is determined by their capacity to release ions in aqueous media. This capacity was assessed in transformation/dissolution (T/D) testing at pH 6, at which release of zinc ions from metal was found to be maximal. It was noted that the diameter of a zinc metal sphere of 1 mg should be ≤ 0.082 mm, in order to reach the reference value for acute aquatic effects.

This particle size is much smaller than the default particle size distinguishing massive metal from powder/dust (1mm). The critical diameter of a spherical metal particle, resulting in sufficient surface loading to reach the reference value for chronic aquatic effects at 1mg/l loading of the substance was set at 2.1 mm. Accordingly, the critical diameters of a sphere, resulting in reaching the reference value for chronic aquatic effect at mass loading criteria of 0.1mg/l and 0.01mg/l are determined to be 0.21 mm and 0.021 mm, respectively.

When investigating the leaching behaviour of metals from alternative shots in different environmental conditions, high leaching of zinc (up to 55.7 µmol/L; see also Table C.5) has been observed that pose a risk to aquatic organisms under aerobic conditions (Fäth and Göttlein, 2019).

Based on the experimental results (Fäth and Göttlein, 2019), aquatic toxicity of zinc leaching from zinc containing shots containing under certain environmental conditions has to be assumed.

C.1.3.2. Toxicity to wildlife

C.1.3.2.1. Lead, coated

Attempts to cover lead shot to prevent lead toxicity with a protective coating of non-toxic metals or other materials to prevent the degradation and uptake of lead while in the gizzard/stomach of birds have all failed (USFWS, 1986), (Scheuhammer and Norris,1995), (Friend et al., 2009), Thomas (2019). The coatings (if used for shot or fishing tackle) will wear off or will be dissolved in the highly acidic environment of the avian gizzard and stomach, exposing lead core to the digestive actions of the gut.

Different species of birds have different stomach pH. For example, the pH of a duck stomach ranges from 2.0 - 2.5, whilst that of an eagle is closer to 1.0 (USFWS, 1986). Due to the highly acidic environment of the raptors and scavengers stomach, jacketed lead bullets (fragments) can be equally expected to wear off or be dissolved in the birds stomach.

In addition to the toxicity for wildlife, comment CfE #1034 is also highlighting the issue of secondary microplastics creation from the abrasion of the polymer-based coating.

C.1.3.2.2. Non-lead alternatives

In the USA 11 distinct shot types have been given approval for hunting fowl (US FWS, 1997) (see also Table C.3-2) [in ECHA Annex] largely based on experimental data with game-farmed ducks. Alternative shots are either made of steel, bismuth or tungsten.

Bismuth and its alloys

Shot made from bismuth-tin alloy is also fully approved as non-toxic (Thomas, 2019). Sanderson et al. (1997) demonstrated that ingested bismuth-tin shot or implanting bismuth-tin alloy into the breast muscle of ducks did not have any toxic impact on the birds and did not affect their reproduction.

Brass

Zinc can be alloyed with copper to make brass, which lowers the mobility of zinc in solution. Brass might also contain lead as an impurity or additive to limit copper corrosion. Therefore, brass exhibits less potential toxicity than zinc and lead alone to animals which might ingest them (Thomas, 2019).

Copper

Franson et al. (2012) reported that American kestrels (Falco sparverius) that were dosed experimentally with copper shot exhibited no signs of toxicity.

Feeding of shots made from copper to 24 mallards resulted in 4 % mortality which was below the mortality of control birds fed plastic (20 %) (Irby et al., 1967).

Feeding of 6 copper or **brass** shots to 10 ducks did not results in relevant body weight loss during a 4 week retention period (Krone et al., 2009b).

Iron/Steel

Feeding of shots made from pure iron, zinc-coated iron, or molybdenum-coated iron to 23 or 24 mallards resulted in mortality of some animals (12 % for iron, 4 % for zinc- coated iron) was below the mortality of control birds fed plastic (20 %) (Irby et al., 1967).

Twenty mallards (Anas platyrhynchos) of both sexes were dosed by oral gavage with steel shot. All pellets were fired from a shotgun into an absorbent material, retrieved, and weighed prior to introduction into the ducks. Birds were fed whole kernel corn and grit and observed for signs of toxicity for 30 days following dosing. Steel shot pellets lost 57 % of their mass in the birds' gizzards. No mortality was observed, mean bird weight change was not different, and there were no significant morphologic or histopathologic abnormalities of the liver and kidney (Brewer et al., 2003).

Steel shot may be coated with a thin layer of copper or zinc to inhibit rusting and is permitted under US regulations (US FWS, 1997). The level of uptake of copper and zinc from the dissolution of these metals in the gut of birds from such a thin layer would be defined as non-toxic under the US FWS (1997) regulations (Thomas, 2019).

Tin

After force-feeding of pure tin shots, mallards did not show a significant body weight loss and did not die within 30 days (Grandy IV et al., 1968).

Tungsten

Twenty mallards (Anas platyrhynchos) of both sexes were dosed by oral gavage with No. 4 Heavi-Shoty (H-S), a commercially available shot that contains a mixture of tungsten (W), nickel (Ni), and iron (Fe). All pellets were fired from a shotgun into an absorbent material, retrieved, and weighed prior to introduction into the ducks. Birds were fed whole kernel corn and grit and observed for signs of toxicity for 30 days following dosing. Hevi- Shot pellets lost an average of 6.2 % of their mass in the birds' gizzards. No mortality was observed and mean bird weight change was not different. There were no significant morphologic or histopathologic abnormalities of the liver and kidney.
Results indicated that mallards dosed orally with eight No. 4 H-S pellets were not adversely affected over a 30-day period, and that H-S provides another environmentally safe nontoxic shot for use in fowl hunting (Brewer et al., 2003).

Failure to distinguish between elemental tungsten and tungsten alloys has caused confusion, especially about their relative toxicity in shotgun ammunition. Controlled experiments indicate that the carcinogenicity of embedded tungsten–nickel–cobalt alloys derives from their nickel and cobalt content, and not the tungsten. The carcinogenicity of metallic nickel and cobalt implants in animal tissues is well-established. Studies in which pure tungsten metal is embedded in animal and human tissues indicate that there is no toxicity or carcinogenicity developed locally or systemically. The exposed tungsten corrodes slowly in the tissue fluids and is excreted from the body. Chronic studies in which pure tungsten-based shot are placed, continuously, in the foregut of ducks over 150 days indicate that there are no adverse physiological effects, nor disruption of ducks' reproduction and development of their progeny (Thomas, 2016).

When shot made of bismuth-tin alloy was implanted into mice intra-peritoneally for extended periods of time no toxic effects were reported (Pamphlett et al. 2000; Stoltenberg et al. 2003). Although mobilization of bismuth from the shot occurred over months, no detrimental effects on weight gain, movements, and appetite were observed.

Zinc

Because of the demonstrated acute toxicity of ingested **zinc** shot to birds, fishing weights and gunshot should never be made of this pure metal (Thomas, 2019).

For example, ingested zinc shot has been demonstrated to be acutely toxic to mallards (Levengood et al., 1999), (Levengood et al., 2000), (Grandy IV et al., 1968).

Feeding of 6 zinc shots to 10 ducks did not results in mortality but in 80 % body weight loss during a 4 week retention period (Krone et al., 2009b).

C.1.4. Summary of risk reduction potential of the alternative substances

C.1.4.1 Lead, coated or jacketed

The use of jacketed lead bullets is significantly reducing lead exposure of the shooter orhunter. However, coating of lead bullets does not prevent lead contamination of game meat bagged with jacketed lead bullets.

The use of coated leaded shots or lead fishing tackle is expected to reduce lead exposurefrom handling via the hand-to-mouth route.
Attempts to cover lead shot to prevent lead toxicity with a protective coating of non-toxic metals or other materials to prevent the degradation and uptake of lead while in the gizzard/stomach of birds have all failed (USFWS, 1986), (Scheuhammer and Norris,1995), (Friend et al., 2009), Thomas (2019). The coatings (if used for shot or fishing tackle[9]) will wear off or will be dissolved in the highly acidic environment of theavian gizzard and stomach, exposing lead core to the digestive actions of the gut.

Different species of birds have different stomach pH. For example, the pH of a duck stomach ranges from 2.0 - 2.5, whilst that of an eagle is closer to 1.0 (USFWS, 1986). Due to the highly acidic environment of the raptors and scavengers stomach, jacketed lead bullets (fragments) can be equally expected to wear off or be dissolved in the birds stomach.

C.1.4.2. Non-lead alternatives

The dossier submitter considers that potential human health risks related with the use ofalternative shot substances are mainly a consequence of inhalation of

[9] Whether the shot is picked up from a marsh or ground, or from the bodies of wounded or dead birds in whichit may be embedded, is not relevant for the overall toxicity.

fumes/dusts from shooting, home-casting and the consumption of game bagged with such alternative substances.

Potential environmental risks are mainly related to aquatic toxicity of the used shot material and toxicity to wildlife picking up the shots from a marsh or ground, or from thebodies of wounded or dead birds in which it was embedded.

The dossier submitter considers that – in contrast to shots – aquatic toxicity of alternative bullets is less relevant because bullets might either remain in the carcass ofthe bagged animal or in the soil.

However, the risk of spent alternative bullets and their fragments being ingested by scavengers from discarded gut piles, non-retrieved killed or wounded animals has to be assessed.

C.1.4.3 Summary table of risk reduction potential

Table C.6 Toxicity of the alternative substances compared to lead

Alternative material	Human health Game meat (game meat)	Aquatic toxicity	Wild life toxicity (ingestion)
Lead	**Yes**	Depending on Pb release from shots: Pb metal not classified; Pb powder Aquatic Acute/Chronic 1	**Yes**
Alternative shots for hunting			
Lead, coated	**Yes**	Depending onrelease of andrisk of coating material and release of Pb over time	**Yes**

Bismuth-tin (3-6 %) alloy	No	No: Bi notclassified	No
Brass (copper-zinc alloy)	No	Depending on Cu, Zn (and Pb)release from shots	
Bronze (copper-tin alloy)	No		
Copper (Cu)	No (based on data generated with Cu bullets)	Depending on Cu release from shots: Cu metal not classified; Cu granulated Aqua Chronic 2; Cu powder self-class. Aqua Acute/Chronic 1	No
Nickel (Ni) (alloying metal)	**>4 µg/kg**	Depending on Ni release from shots: Ni metal notclassified; Ni powder Aquatic Chronic3; Ni release fromshots	**Yes**
Steel (soft iron >99 % Fe)	No oral	No: Fe notclassified	No
Tin (Sn)	No hazard identified	No: Sn notclassified, Sn release fromW shots under anaerobic conditions	

Tungsten (W)		No: W not classified; no Wrelease from shots	No
Tungsten -bronze		No: Cu release 30-50-times lower than from Cu shots	
Zinc (Zn)		Depending on Zn release from shots: Zn metal notclassified Zn powder Aquatic Acute/Chronic 1	**Yes**
Alternative bullets for hunting			
Lead, coated	**Yes (based on Pb data)**	n/a	**YES**
Copper, pure	No (based on data)	n/a	No
Brass (copper-zinc <40 %)	No (assumed based on Cu andZn data)	n/a	
Bronze (copper-tin 10 %)		n/a	
Tombac (copper-zinc up to 20 %)	No	n/a	
Tungsten (oftenused as alloyingmetal)	>0.48 mg/kg bw(DNEL oral)	n/a	

Zinc	No (based on data)	n/a	**YES**

C.1.5. Availability, technical and economic feasibility of alternatives

C.1.5.1. Lead in gunshot

C.1.5.1.1. Function of lead in shot

The focus of this restriction proposal are shotgun cartridges that are loaded with spherical lead 'shots'. The spherical shots are propelled during the use of the cartridge to reach a target. The spherical shots should penetrate (and may pass through) the target, causing the death or wounding of the target, where it is an animal.

Lead has historically been used as gunshot in cartridges (TemaNord, 1995) because of its:

- softness and lubricating features (resulting in low abrasion of the shotgun barrel);
- low melting point (making it easily transformed into shot);
- high density (yielding high momentum after firing).
- relatively low price and high abundance (resulting in low cost of cartridges)

Based on these properties, lead is often considered to be an ideal material for use in ammunition. Other materials often have somewhat different ballistic behaviour to lead but this does not necessarily result in a conclusion that they are technically or economically inferior to lead gunshot. The technical and economic feasibility of the use of alternative to lead in gunshot is outlined in the sections below.

C.1.5.1.2. Suitability of lead-free shot

Non-lead shot cartridges are widely available in Member States with existing regulations on the use of lead gunshot. The call for evidence organised by ECHA to support the development of this restriction proposal confirmed that alternatives (e.g. steel, tungsten or bismuth) are already commonly used in wetlands.

In the EU, Denmark has been a testing ground for the introduction and evaluation of alternative gunshot, following the initial regulation for hunting in wetlands in 1985 and the total phase out of lead shot in 1996. Many products have been designed specifically for the Danish market and users (Kanstrup, 2006). There is no indication that a lack of suitable alternative shot types, shot sizes, or other potential drawbacks of the shift from lead to non-lead shot in Denmark has changed the cost of hunting, the number of hunters, or their harvest (Kanstrup, 2015).

Although the risks from the dispersal of lead gunshot in the environment have been known since the late 1800s, the first alternative gunshot materials were only marketed in North America in the 1970s. The availability of alternatives to lead gunshot has increased steadily since this time, corresponding with the introduction of bans on the use of lead gunshot in countries within and outside the EU. Steel gunshot (soft iron) is by far the most used alternative to lead gunshot.

In response to Danish and US regulatory requirements, additional metals were introduced in the early 1990s as alternative to lead shot: specifically, bismuth and tungsten. Originally, bismuth was used in shot in an almost pure form; more recently it has been alloyed with tin (6 %) to reduce the tendency of pellets to fragment. Tungsten shot is often based on metal powder embedded in a plastic polymer (Tungsten Matrix) and has ballistic properties very similar to lead shot (Scheuhammer, 1995).

In the US, the environmental safety of alternatives to lead shot is evaluated before they can be placed on the market. Table C.7 gives an overview of the currently allowed shot types in the US. Following extensive testing on captive waterfowl in the US and Canada, zinc gunshot considered to be toxic, and it is not permitted to be placed on the market in either country (Scheuhammer 1995; Putz, 2012).

Table C.7 Approved 'non-toxic' shot in the US (USFWS).

Alternative	Composition
Bismuth-tin	97 % bismuth, and 3 tin%
Iron (steel)	iron and carbon
Iron-tungsten	any proportion of tungsten, and ≥1 iron
Iron-tungsten-nickel	≥1 % iron, any proportion of tungsten, and up to 40 % nickel
Copper-clad iron	84 to 56.59 % iron core, with copper cladding up to 44.1 % of the shot mass
Tungsten-bronze	51.1 % tungsten, 44.4 %copper, 3.9 % tin, and 0.6 % iron, or 60

	% tungsten, 35.1 % copper, 3.9 % tin, and 1 % iron
Tungsten-iron-copper-nickel	40–76 % tungsten, 10–37 % iron, 9–16 % copper, and 5–7 % nickel
Tungsten-matrix	95.9 % tungsten, 4.1 % polymer
Tungsten-polymer	95.5 % tungsten, 4.5 % Nylon 6 or 11
Tungsten-tin-iron	any proportion of tungsten and tin, and ≥1 iron
Tungsten-tin-bismuth	any proportion of tungsten, tin, and bismuth
Tungsten-tin-iron-nickel	65 % tungsten, 21.8 % tin, 10.4 % iron, and 2.8 % nickel
Tungsten-iron-polymer	41.5–95.2 % tungsten, 1.5–52.0 % iron, and 3.5–8.0 % fluoropolymer

Steel

This alternative is widely available, but due to its comparatively greater hardness (relative to lead) it requires use in compatible guns. The Dossier Submitter considers that 100 % of new guns currently on the market are compatible with steel gunshot and that a maximum of 15 % of existing (old) guns. This issue is further discussed in the Suitability of guns section.

Steel gunshot is widely seen to provide equivalent performance to lead or other materials, (Scheuhammer, 1995; Pierce, 2014) without major concerns caused by ricochet (DEVA, 2013). However, some adaptation to the different ballistic properties of steel may be required by hunters to achieve equivalent performance e.g. typically used shot size would need to be increased to account for the lower density of steel.

According to the proofing rules of the '**Permanent International Commission** for the Proof of small arms' (CIP)[10], which sets standards for firearms and ammunition in the EU, "standard" steel gunshot cartridges are suitable for use in the majority of standard 'nitro-proved' shotguns[11]. "High performance" steel cartridges, which generate greater pressures when fired, are only to be used in 'steel shot' proved guns. The difference between standard steel and high-performance steel is further explained in the Suitability of guns section.

Steel shot is the most commonly used alternative due to its price, which is in the same range or even below that of lead shot, making it the cheapest of the known alternatives (ignoring the cost of any gun modification such as modifying choke, barrel change etc).

Bismuth

The ballistics or performance is generally good, provided the shot size is increased to allow for density lower than lead. Bismuth is suitable in all guns. Bismuth can be used as a drop in alternative to lead without concerns over compatibility with guns. Bismuth shot is available in most gauges and with a wide variety of loadings. The shot is available for home loading, including for large-bore guns. Bismuth is an alternative that can be used in all guns and is often used in forests where owners limit the possibilities to use steel[12]

Tungsten

The density of tungsten shot is favourable for good ballistics and performance, so the percentage of tungsten in shot material is important. It is suitable for use in appropriately proved guns and widely available. Tungsten-based shots have been approved as nontoxic by the US Fish and Wildlife Service. However, it is relatively more expensive than lead and steel gunshot, which has restricted its use as an alternative.

The term 'suitability' refers to whether the alternative can be used to the same effect. In the context of hunting this means that alternatives can be used with the same

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[10] The Commission internationale permanente pour l'épreuve des armes à feu portatives ("Permanent International Commission for the Proof of Small Arms" – commonly abbreviated as C.I.P.) is an international organisation which sets standards for safety testing of firearms. (The word portatives ("portable") in the name refers to the fact the C.I.P. tests small arms almost exclusively; it is ordinarily omitted from the English translation of the name.) As of 2015, its members are the national governments of 14 countries, of which 11 are European Union member states. The C.I.P. safeguards that all firearms and ammunition sold to civilian purchasers in member states are safe for the users.
[11] Standard steel not suitable in certain specific 'standard proofed' shotguns, such as Damascus barrelled shotguns.
[12] Personal communication, Finnish hunting association.

level of performance in killing game in the fastest and least painful way possible.

The suitability of alternatives for lead shot has already been established in the ECHA dossier on the use of lead in/over wetlands (ECHA, 2018b), and have been evaluated by ECHA's Committees for Risk assessment (RAC) and Socio-Economic Analysis (SEAC)[13]. The conclusion of SEAC on alternative ammunition was that steel gunshot has a comparable performance once shooters have adjusted to its ballistic properties, e.g. in terms of patterning. For hunting larger fowl, high performance steel gunshot may have to be used, which requires the use of a shotgun that has been proofed accordingly.

The main difference between hunting in and over wetlands and hunting outside of wetlands (upland game shooting/hunting) is in the species involved. Whereas wetland species are mainly birds such a duck and geese. The species hunted outside of wetlands with shot are pheasants and grouse but also small mammals such as rabbit, hare but even roedeer.

Table C.8 A list of nontoxic shot cartridges available for hunting upland game species of birds and mammals (Thomas, 2009).

species	steel shot in gauges 10,12,16, 20	bismuth tin shot in gauges 10,12,16,20, 29, .410	tungsten based shot e.g. tungsten- matrix, tungsten- iron or Hevi Shot. IN gauges 12,16,20
Geese species	+	+	+
Large-bodied ducks	+	+	+
Small-bodied ducks *	+	+	+
Ring-necked pheasant *Phasianus colchicus*	+	+	+
Partridge species	+	+	+

[13] https://echa.europa.eu/documents/10162/07e05943-ee0a-20e1-2946-9c656499c8f8

Wood Pigeon *Columba palumbus*	+	+	+
Woodcock *Scolopax rusticola*	+	+	+
Snipe *Gallinago gallinago*	+	+	+
Red Grouse *Lagopus lagopus scotica*	+	+	+
Ptarmigan *Lagopus muta*	+	+	+
Golden plover *Pluvialis apricaria*	+	+	+
Rabbit *Oryctolagus cuniculus*	+	+	+
European hare *Lepus europaeus*	+	+	+
Mountain hare *Lepus tímidos*	+	+	+

Notes: A + indicates that the type of nontoxic shot is appropriate for that species

Several field studies examine the suitability of non-toxic shot for hunting purposes. Comparative studies on the efficiency of lead versus non-lead shot are abundant in the literature. Nicklaus (1976) reported no difference in crippling loss when using lead or steel. Cochrane (1976) reported that the best lead shot shells available outperformed the best steel shot shells in that they produced fewer cripples at “normal” shooting ranges. Hartmann (1982) concluded that steel shot is suitable for water bird hunting within normal shooting distances (max. 35 m). Kanstrup (1987) reported no difference in the “killing impact” of lead and steel shot in Eider Duck (Somateria mollissima) hunting. Morehouse (1992) reported a slight increase in fowl crippling loss rates in the US during the early steel shot phase-in over the period 1986-1989, but also that crippling loss for both ducks and geese declined in 1991 towards levels observed during the early 1980s. Strandgaard (1993) concluding that steel shot is just as effective as lead shot when used to kill roe deer and is a valid alternative.

In a more recent study, Gundersen et al. (2006) find that an appropriate combination of shot type and size resulted lead and non-lead ammunition with similar “killing impact”. Likewise, a large-scale European study on the effectiveness of steel gunshot ammunition in hunting fowl (Mondain-Monval et al., 2015) indicates performance levels of steel gunshot very similar to lead shot. The study also suggests that hunter behaviour and judgement, the abundance of birds and strong wind conditions are significant determinants of a hunter’s ability to bag birds.

In a recent, large-scale comparative study of the effectiveness of steel and lead shot in shooting mourning doves (Zenaida macroura) (Pierce et al., 2014), hunters using lead shot (cal. 12, with 32 g of US #71/2 shot) and steel shot (cal. 12, with 28 g of US#6 and US#7 shot) produced the same results in terms of birds killed per shot, wounded per shot, wounded per hit, and bagged per shot. Hunters in this double-blind study wounded 14 % of targeted birds with lead shot, and 15.5 % and 13.9 % with #7 and #6 steel shot, respectively. Hunters missed birds at a rate of 65 % with lead shot, and 60.5

% and 63.6 % with #7 and #6 steel shot, respectively. Pierce et al. (2014) conclude that “[shot] pattern density becomes the primary factor influencing ammunition performance”, and that this factor is controlled by the shooter.

Comments from the call for evidence (Gun Trade Association, British Sports shooting Council) highlighted that Non-lead shotgun ammunition has been found to perform effectively in the field. However, CIP recognizes that in order to achieve equivalent lethality to lead in ‘standard’ hunting ammunition loaded with steel shot, current limits on momentum for ‘standard’ loads would have to be increased.

C.1.5.1.3. Suitability of guns

Standard steel can be used

The suitability of steel for using in gunshots has already been widely discussed in the dossier on wetlands, and indeed many of the findings on (shot) gun suitability are applicable to the use of steel shot outside of wetlands as well.

Proofing of guns is accompanied by proof marks that are stamped into the metal of the gun barrel (typically in the parts underneath the chamber). In a European context the most reliable system of proof marking is that used by the CIP. The CIP system uses a “Standard Mark”, a “Superior Mark” and a “Steel Mark”. These terms apply to the performance (pressure) of the cartridges that can be used in a gun. A general observation is that the marking can be interpreted equally for lead shot and alternative shot types, including steel, bismuth and tungsten (matrix types).

Standard or superior/magnum-proved guns can fire ‘standard’ steel and other alternative shot cartridges. To fire ‘high performance’ steel cartridges, the gun is recommended (by the CIP) to be subject to the “Steel Shot” proof, which is a more rigorous test of the gun’s ability to handle the pressures and shot hardness of steel/steel-like shot cartridges. A gun successfully passing “Steel Shot” proof will be stamped with a Fleur de Lys on its barrel, see Figure C.5 right).

Figure C.5 Proof marks used by CIP.

Practical guidance for hunters on how to be sure that steel shot can be used in the shotgun they currently own can be found on the websites of the BASC (UK) and the website of the Victoria Game Authority (AUS):

On the use of steel shot in guns the BASC notes the following[14]:

For steel-like shot the CIP imposes limits on velocity, momentum (weight of load x velocity), and pellet size. For pellets BB and larger it also limits choke, to maximum half choke.

Currently the regulations cover 10 bore, 12 bore, 16 bore and 20 bore guns/ cartridges. There are two types of steel shot cartridges: Standard and High

[14] https://basc.org.uk/wp-content/plugins/download-monitor/download.php?id=722

Performance.

- Standard steel shot cartridges, meeting defined limits of cartridge size, and shot velocity and momentum, can be fired through standard and magnum-proved guns.
- High Performance steel cartridges, with their own, higher, size, velocity and momentum limits, are to be fired only through guns which have passed special steel shot proof.

Some hard tungsten-based shot types are now treated as steel, and are to be used accordingly.

Most tungsten-based shot types, though, including ITM, TMX, Hevi-shot II (but not Hevi- shot I) and others, are made to a similar softness to lead and are treated by CIP as lead.

This is stated again on the website of the Victorian game authority[15]

It does not mean that an existing gun, without this proof stamp, is inherently unsafe to use steel loads which generate lower chamber pressures, comparable to existing lead shot loads. If in doubt about your gun – see a competent gunsmith.

Practical guidance is also available for hunters in Germany[16],[17],[18], France[19][20], Austria (Putz, 2012) and France (Baron, 2001) and is all of a similar nature, explaining to hunter which sort of cartridges can be used in guns with different proof marks (Summarised in Table C.9).

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15 http://www.gma.vic.gov.au/education/fact-sheets/non-toxic-shot/steel-shot-standards-pressures-and- proofing
16 http://www.flintenschuetze.de/cms/front_content.php?idcat=119
17 http://www.jagd-bayern.de/fileadmin/_BJV/Jagd_In_Bayern/jib_2006_07/JiB_7_06_Alternativ_Schrote.pdf

18 https://www.beschussamt-ulm.de/beschussamt/Interne_Dokumente/Dokumente/VF_504_M_Info-Verwendung-Bleifreie-Schrote.pdf?m=1488869144
19 http://www.fdc54.com/fichiers/munitions_sans_plomb.pdf
20 http://www.syndicatdelachasse.com/actu04/dec/acier.pdf

Table C.9 Operating pressure, cartridge size and proofing[21]

cartridge type	cartridge size	max operational pressure (bar)	max velocity (2.5 m after muzzle) m/s	max impulse (NS)	max shot size	gun proofing
standard	12/65 – 12/70	760	400	12	3.25	normal
high performance	12/70	1050	430	15	no limit	steel proof
high performance	12/76 and above	1050	430		no limit	steel proof

This advice is in line with the CIP specification on the use of steel shot. It must be noted that if any of the limits for the standard proof are exceeded, then the cartridges must be treated as high performance cartridges and can only be used from a steel proofed gun (with fleur de lys).

Using steel gunshot cartridges therefore becomes a matter of carefully selecting cartridges based on the specification of the shotgun that a hunter owns. The CIP specification for standard and high-performance steel cartridges, and the BASC's explanation of these specifications, clearly outline the types of steel gunshot cartridges that can be used in different shotguns[22]. Not complying with these rules can result in 'ring bulging', overload and increased wear and tear in guns.

Wear of the gun barrel derives primarily from the friction of the shot load passing through the barrel. The load consists of two elements: The load of shot pellets (in normal cal. 12 loads 30-34 gram) and the wad that provide a seal that prevents gas from blowing through the shot rather than propelling it. Originally, wads were made from felt or paper, but more recently, plastic has become the most used material. At

[21] http://www.chircuprodimpex.ro/produse/alice-non-toxice-de-vanatoare/cip-regulations-on-steel-shot-ammunition.pdf

the same time the wad has been developed not only to provide a seal between the powder and shot but also to prevent direct contact between the gunshot pellets (the load) and the inner wall of the barrel, which is achieved by constructing the wad like a cup that contains the load.

This applies for most shot types, including also many lead shot cartridges. For soft materials like lead, the primary reason for preventing contact between shot and barrel is to minimise deformation of shot and thereby optimising the pattern of the shot cloud.

For hard materials like steel the reason to use a plastic wad is mainly to prevent the hard pellets damaging the barrels of softer and not hardened steel qualities. Due to the use of modern plastic wads the use of hard pellets does not impose an increased risk of wear in the barrel bore. The only point along the barrel where some wear might arise is when hard shot passes through the choke (the narrowed portion at the mouth of the gun barrel).

The chokes used in shotguns produced by different manufactures are not produced in consistent, uniform manner. Concerns relating to the use of steel gunshot pertain to abruptly developed, as opposed to progressively-developed, chokes[23].

It is possible that large hard shot (larger than US #4 steel, 3.5 mm diameter) passing through an abruptly developed, tightly-choked barrel, could cause a small ring bulge to appear around the choke conus, simply because the hard shot do not deform when passing through the constriction. This does not occur if the barrels are more openly choked, such as “modified” or “improved cylinder”. This is the essence of the concerns about wear from hard non lead shot types, such as steel. Ring bulges are also known to occur in shotgun barrels when large lead shot pellets are fired through tight chokes. A gun barrel with a ring bulge can continue to fire any shot type. It is a cosmetic change, and not related to safety or the risk of exploding barrels (Thomas et al. 2015). This might however decrease the value of the gun.

In addition, wear of gun is also caused by the physical impact released by the recoil from heavy loads, which may cause stress to the gun lock and stock Recoil is a function of, powder type, load weight and velocity and, in principle, independent of shot material.

However, as non-lead shot is normally accelerated to a higher velocity there is a

[23] In firearms, a choke is a tapered constriction of a shotgun barrel's bore at the muzzle end. Chokes are almost always used with modern hunting and target shotguns, to improve performance. Its purpose is to shape the spread of the shot in order to gain better range and accuracy. Chokes are implemented as either screw-in chokes, selected for particular applications, or as fixed, permanent chokes, integral to the shotgun barrel.

general tendency that alternative gunshot may cause a more pronounced recoil, though lighter loads and improved powder composition can compensate for this. Danish gunsmiths have experienced that guns more regularly need maintenance and lock repair when firing large numbers of rounds of high velocity (>420 m/s) cartridges with steel shot.

This applies only to standard guns that are not constructed to deal with heavy recoil[24], but would equally apply to heavy load lead shot cartridges.

The Victoria game authority mentions that the effect of steel shot on the barrels of a selection of 10 English and European manufactured firearms was undertaken by the Royal Military College of Sciences in the UK in 1996 (Report no longer publicly available). The types of firearms used included a Browning U/O, Beretta U/O, Miroku U/O, Purdy SxS, Holland and Holland SxS. All guns used were full choke models, some with integral chokes and some with screw in chokes. After over 9 000 standard steel shot cartridges had been fired through the ten different guns, no measurable damage had occurred to any of the guns. The standard cartridges used recorded muzzle velocities in the range of 377 m/s to 392m/s with shot weights between 24 and 32 grams. These were regarded as being light for game loads. Three of the guns were then tested with cartridges loaded to produce much higher muzzle velocities (438m/s, 28 gram) and in each case deformation of the chokes resulted after approximately 50 cartridges were fired.

Coburn (1991) reported, from the Winchester perspective, that ring bulging has not been a significant issue over the twenty or so years since steel shot was introduced, although it has occurred, usually in full choked barrels, either as integral chokes or screw-in chokes. Where this has been known to occur, the actual deformation was in the range of three to five one-thousandths of an inch (0.003 to 0.005 inch), which is barely discernible to the naked eye. In the early days for some screw-in chokes, the threading expanded, and chokes were difficult to remove. However, today, manufacturers have overcome this problem through redesign.

The third impact factor is temperature, i.e. the heating of the shotgun barrel and lock after firing multiple rounds of ammunition over a short period of time. This is only discussed briefly here but is known particularly from the hunting of game species occurring in large numbers, for instance during driven shoots or excessive pigeon and dove hunting.

Heating derives from the burning of the powder, the pressure and the friction of the shot and wad against the barrel wall. There is very little information about the affect of different shot types and cartridge constructions on temperate. Temperature and

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[24] Nystrøm & Krabbe, gun and ammunition retailer.

heating per se is not a significant concern, apart from certain gun types, e.g. semi-automatics where excessive heating may cause increased wear on sliding mechanisms due to reduced effectiveness of greasing. However, in the context of water bird hunting in a Europe context the number and frequency of shots taken is regarded, broadly, to be limited, and the concern of heating of guns seems to be of very low importance. There is no indication that non-lead ammunition should impose a greater impact than leaded ammunition in this regard.

Possibilities for non-steel proofed guns

The advice offered by manufacturers to customers asking if their gun are suitable for use with steel gunshot have been compiled from a selection of manufacturers' websites (Table C.10)

Table C.10 Advice from shotgun manufacturers on the use of steel shot in shotguns (non-exhaustive list).

Manufacturer	Advice given (direct quotes from websites)
Remington	We do not recommend the use of steel shot through any barrel manufactured before 1963 or through any barrel having a fixed Full choke. Anything larger would not perform well out of a fixed full choke and could open up your muzzle over time. If you have barrels manufactured after 1963, with fixed Modified or Improved Cylinder chokes, you may shoot up to size #2 steel shot. The use of steel shot larger than size #2 is only recommended in modern barrels with the Rem Choke system. If you have the Rem Choke system, you may shoot any size steel through the Improved Cylinder and Modified choke tubes. The Full choke tube must state "For Steel or Lead" to be capable of handling steel shot. Source: https://support.remington.com/General_Information/Can_I_use_steel_shot_i n_my_shotgun_barrel%3F

Winchester	Generally speaking, any shotgun designed for smokeless powder is able to withstand the pressures generated by today's steel shot loads, within the appropriate chambering. As steel shot does not compress like lead, we do not suggest using steel shot through firearms with a full-choke. We do not suggest the use of steel shot in the Winchester Model 59 with a fibre glass barrel. Source: http://www.winchester.com/learning-center/faqs/firearms-guns/Pages/Firearms-and-Guns-Question02.aspx
Browning	1. WILL ACCEPT ALL CURRENT FACTORY STEEL SHOT LOADS: All Browning shotguns with the Standard Invector, Invector-Plus or DS choke tube systems, However, we do not recommend the use of Invector full or extra full chokes with steel shot. They pattern too tightly, and sometimes result in a "blown" pattern. 2. WILL ACCEPT ALL CURRENT FACTORY STEEL SHOT LOADS EXCEPT THOSE WITH T, F, BB AND BBB SIZE SHOT: The B-2000 and B-80 shotguns with conventional chokes (Non-Invector) 3. DO NO USE ANY STEEL SHOT LOADS: The Belgian-made A-5, Superposed, Leige, and other Belgian Over/Under models, Double Automatic, American-made A-5 and all other models not listed in category 1 or 2. Note: Belgian Auto-5 barrels are interchangeable with the new Invector barrels which are made in Japan. With this new Invector barrel installed on the Belgian-made Auto-5 receiver, steel shot loads can be used. Source: http://www.browning.com/support/frequently-asked-questions/can-i-shoot- steel-shot-in-my-browning-shotgun.html
Beretta	The manual (available at :

	http://stevespages.com/pdf/beretta_shotguns.pdf[25]) explains how to change the choke so as to be able to safely use steel shot in Beretta shot guns
Bernelli	The manual (available at : http://www.benelliusa.com/sites/default/files/originals/product-manuals/ethos_2013.pdf) explains how to change the choke so as to be able to safely use of steel shot in Bernelli shot guns

[25] The original manual can be purchased at: http://estore.beretta.com/en-eu/beretta-overandunders/side-by- sides-owner-manual-ita-fr-eng-/

The conclusion of this assessment is that if a gun has no steel proof mark then this does not mean that it cannot be used with steel shot on the condition that the right cartridges are used. The shotgun can still be used if attention is payed to selecting the right cartridge type that is compatible with shotgun that is used, especially chamber length, and pressure of the cartridge (Putz, 2012).

As explained by the BASC and the Victorian game Authority, the actual risk depends on the selection of cartridges and ensuring that cartridges are used that match with the proof level of the shotgun.

Putz (2012) argues on the basis of an analysis of the characteristics of the non-lead cartridges provided by one German manufacturer (Rottweil) that hunting ducks and fowl can still continue with steel cartridges of which the maximum diameter of the pellet is not bigger than 3.25 mm. In line with the guidance given, as well as the findings of Ronholt (1991) that steel shot exhibited somewhat different ballistic properties compared with lead. However, it could be used effectively within normal hunting ranges and Hartmann (1982), concluding that steel shot are suitable for water bird hunting within normal shooting distances (max. 35 m).

For those hunting geese, hare, foxes bigger shot sizes are needed and consequently, following CIP rules, steel proofed guns would be required (Putz, 2012).However, this is subject to debate as many hunters use ‘magnum proof’ shotguns which are capable of withstanding higher pressures than those generated with standard lead shot. Hence, with suitable cartridges adaptations can be made.

However, the considerations surrounding the proofing of guns may leave a concern that many modern guns may be proofed only to a standard level and owners therefore may hesitate to use them with the most available non lead ammunition, i.e. steel shot in the range of standard and high performance types. This concern is more related to the question of availability of non-lead ammunition suited for their gun, particularly on the local scale. To evaluate this quantitatively the distribution of different gun types among European hunters is needed. Unfortunately, no such statistics are generally available, neither of the types and constructions of guns owned by hunters, nor of the distribution of guns used in different types of hunting, including hunting in wetlands.

In a recent announcement to voluntarily phase out the use of lead shot in the UK, the Gun trade association issued guidance on the of us steel shot[26] which reinforces the conclusion made in the wetlands dossier on the possibilities to use steel shot.

This guidance states that all tough steel shot lacks the density of lead and is almost

[26] https://www.gwct.org.uk/media/1094678/GTA_factsheet_shootingnonlead_ver102.pdf

as hard as the barrels, the manufacturers have got around those issues. First, steel shot cartridges use cup wads to prevent the shot from touching the barrel walls. These have traditionally been made from hard plastics but now environmentally friendly fibre or water-soluble cups available. Secondly, to make up for the lower density, size and velocity can be changed.

For live quarry shooting the advice is to choose a size two larger than your old lead size e.g. If you were shooting size 6 lead shot, you should choose 4s in steel.

'Standard steel' cartridges have been designed by manufacturers in association with proof authorities[27] that can be fired through any nitro-proved gun[28]. They must have a cup wad to protect the barrel; they have a maximum shot size of 4; and they have to conform to the normal pressure limits of nitro proved guns.

Trials in 1991[29] using standard steel cartridges with light loads (24 grams) demonstrated that even light walled game guns of contemporary manufacture with ¾ chokes showed no damage after firing 1000 rounds.

Standard steel loads can be fired safely through light walled guns but there is a risk that in some circumstances a slight bulging at the choke neck can occur. The likelihood of such bulging is increased by heavy loads, large diameter shot and steep, tight chokes.

Old guns may be more vulnerable. The British Proof Authority recommend less than half choke (0.5mm). Such a bulge would not be an immediate safety issue but would inevitably have an impact on its proof status and value. Having a gunsmith widen the chokes would reduce this risk. Further trials to quantify this risk are planned.

Increased velocity can also be achieved by changing the propellant and generating more pressure. Such cartridges are known as 'high performance' steel. They should only be fired in guns proved for steel. This is indicated by a 'fleur-de-lis' mark on the gun and the words STEEL SHOT.

The gun trade association provides further guidance on what to pay attention to in the use of steel shot, in terms of safety and gun compatibility.

<u>Need to replace guns</u>

There are very few data available on the number of 'old guns' in the EU that may need to be replaced as a result of the proposed restriction. This is because in many Member States shotguns are not registered, especially old guns. Therefore,

[27] Rules of Proof 2006. http://www.gunproof.com/Proof_Memoranda/RULESOFP.PDF
[28] Steel shot should not be fired through Damascus steel barrels.
[29] The Assessment of the Tolerance of Shotgun Chokes to Steel Shot – An Initial Study, Allsop, RMCS, May 1991.

estimations of the share of old non-suitable guns among hunters could be very biased. It is not known to what extent old guns are used in the field.

Some guns may not be suitable for use with certain types of non-lead shot types, particularly hard shots such as steel. Hence, some hunters may choose to replace their shotgun, and a regulation of lead shot ammunition on the European level would impose an extra cost to such hunters.

Shotguns may be purchased either as new guns or second-hand. The cost of a gun is not linked to its utility but mostly to other features, e.g. brand, stock quality and cosmetics (engraving and other decorations). Furthermore, the prices vary between countries.

However, judged from a sample of online stores in five different EU Member States, prices for shotguns suited for the use of non-lead shot, including high performance steel shot cartridges, range from approximately €500 (for instance a Frankonia Magnum 12/76, over/under, in Slovenia at €490, second-hand) to several thousand Euros. Typical prices for a suitable new or well-maintained second-hand gun are approximately €1 000 Euros (for instance a new Beretta A300 Outlander 12/76, semi-automatic in Finland at

€890, or a new Bok FAIR Premier, over/under, in Poland at €1,000). To many hunters such a cost may not be regarded as negligible. However, as the typical service life of a shotgun is likely to exceed 15 years it is likely to be affordable given the average annual hunting budget of a European hunter, which is estimated to be €2 400 (Kenward et al., 2009).

Hunters who are in doubt of the suitability their gun(s) can get advice from a gunsmith, or submit a gun for 'proof testing' (also termed 'pressure testing' or 'proofing'. A typical price for a pressure test is around 70 Euros. The price level for a modification of the choke, if recommended, is also around 70 Euros per barrel[30].

Guns that can fire standard lead shot cartridges safely can also fire standard non-lead shot cartridges safely, if they are the same length, and of an equivalent load weight (Thomas et al. 2015). Thus lead-like shot types like tungsten matrix shot or bismuth-tin can be used confidently in any standard-proofed European gun with any choke constriction.

Also, standard steel gunshot cartridges can be used in any modern gun (most guns built after 1961) typically used to fire lead gunshot cartridges.

As to the use of 'robust guns', be that side-by-side, over-and-under, semi-automatic or pump-action guns, designed and proofed for high performance cartridges with

[30] Mr. Thorkild Voigt, Korsholm Skjern. http://www.korsholm.dk/

lead or non-lead shot, there seems to be no limitations in the use of non-lead shot, and steel shot cartridges of either standard or high performance quality is regarded to be the most suited for water bird hunting depending on quarry size, hunting conditions, shooting distances.

Waterbird hunting in Europe is generally performed with robust guns. This is driven by two main factors: 1. That waterbird hunting due to the size of quarry and rather rough environment calls for robust equipment, and 2. That many European countries already have established regulations prohibiting the use of lead gunshot, hence this has motivated hunters to already adopt non-lead hunting, which in terms of waterbird hunting is generally regarded to be using with steel gunshot cartridges.

Some hunters may, for different reasons, need to have their gun(s) proofed, modified or, eventually replaced. Based on the Dossier submitter's analysis the cost of such actions is rather limited compared to the general budget of average European hunters.

Thus, the gun making industry has pro-actively responded in addressing the present and future needs, as major gun manufacturers export a large proportion of their guns to countries that already have non-lead shot regulations in place (e.g., the US and Canada), their guns are already now able to firing standard and high performance non- lead shot.

In conclusion, many guns manufactured after 1961 can fire standard steel shot. Guns manufactured before this date would need to be proofed (if not already done) at a one- off cost of 70 euro and a modification cost of 70 euro for a new choke. All guns manufactured after 1954 will be stamped with the relevant proofing mark. Furthermore, for guns not proofed for steel, using standard cartridges remains a viable option for fowl hunting.

Face recognises this on their website[31] where they explain that shotguns can be categorised as follows:

- Suitable: Shotguns capable for use with non-lead shot without testing/modification;
- Limited suitability: Shotguns capable for use with a limited range of non-lead shot cartridges without testing/modification (e.g. standard pressure, limited range of shot sizes);
- Unsuitable: Shotguns that are currently unsuitable for steel shot, which require

[31] https://www.face.eu/2020/12/what-does-the-new-regulation-on-banning-lead-shot-over-wetlands-mean- for-europes-hunters/

modification (e.g. to choke or chamber), or replacement and/or testing to ensure they support the pressures of alternatives.

However exact figures on the share of guns falling in limited suitability of unsuitable are not known.

Comments from the call for evidence on gun replacement.

In the call for evidence the Gun trade association (UK) and the Finnish hunting association had submitted information on the number guns. Other organisations had submitted comments that indicated that indeed there may be issues with older guns, but these comments were not supported by evidence on the extent of the issue. As such the dossier submitter decided to use the most factual evidence to see if there was a need to change any of the assumptions used in the proposal on lead in shot over wetlands.

The Gun trade association argued that, based on figures of the 1 375 556 licenced shotguns in England & Wales (estimated 1.5 million in the UK), 491 564 (estimated 540 000 in the UK) are traditional ‘side-by-side’ shotguns. It is further estimated that of these, approximately 60 % (324 000) are older shotguns with 2.5 inch (65mm) chambers which are not suited to currently produced steel shot cartridges. Taking this example and knowing that this estimate were made as well in the light of total phase out of the use of lead in the UK, it can be argued that 324 000 / 1 375 556 shotgun are not suitable for standard steel, equivalent to about 21 %.

Furthermore, shotgun barrels that are heavily choked may not be suitable for use with steel shot. The modification or replacement cost of shotguns for those shooters required to use steel shot instead of lead shot could thus be considerable.

Barrels comprise three regions: the chamber, the barrel bore, and the terminal choke. The only point along the barrel where some risk might arise is when the steel shot passes through the choke. However, the shooting of steel shot smaller than #4 does not cause concern when fired through tight chokes.

If a gun is particularly old, has thin walls, or Damascus barrels, it should be checked by a gunsmith, but experience from Denmark, where lead has been banned for 25 years and most shooters use steel, suggests that the risks are very minimal.

CIP approval exists for ‘standard’ steel shot cartridges in calibre 12 (70mm chamber length only) and also for calibres 10, 16 and 20. No CIP approval currently exists for ‘standard’ steel shot cartridges in calibres 28 and .410. While the large majority of the shotguns used in the UK are in calibre 12 (1,185,978 shotguns in England & Wales), around 14 % are in calibres 28 and .410, for which no standard steel shot approval currently exists (15,092 shotguns in calibre 28 and 171,288 shotguns in calibre .410).

Adding these figures together would imply that around 15-20% % of shotguns would not be suitable for the use with steel. An internet[32] search however would suggest that the

.410 and calibre exists in a lead-free versions, thus it can be anticipated that with regulation in place, demand would increase and consequently availability would increase.

Another issue that is problematic is the number of steel-proofed shotguns. In Finland, there are only 50 000-80 000 hunters with a steel-proofed shotgun (The number is based on data obtained from the Finnish Customs since 1996). In Finland this is anticipated to change with the wetland's restriction entering into force.

In the dossier on wetlands it was estimated that 21 % of all hunters will already be impacted by that restriction. Face reports there is a wide variety of non-lead shot available for 10, 12, and 20 gauge, but few options for 16, 28 bore and .410. which would imply that most hunters can obtain lead free shot without needing to change guns.

For the size 16[33], 28 and .410[34] bismuth cartridges are available and can be used.

All in all, the Dossier submitter argues that given the above information, in the best case no shotguns will need to be replaced and most adaptation will already follow from the wetland's restriction. In the worst case, 15% of the guns will not be able to handle steel shot, the dossier submitter assumes that 15 % of guns owners will move to bismuth solutions but will not replace guns en masse.

C.1.5.1.4. Animal welfare

One of the key concerns in using non-lead shot relates to the potential for an increase in "crippling loss" of birds. This term refers to birds that have been shot, but are un- retrieved, either because they have not been killed outright (wounded birds), or because they have been killed but the carcass cannot be found (Thomas et al., 2015).

The crippling loss for some birds has been reported to be in the range of 10-50 % (Haas, 1977; Nieman et al., 1987). In this case the crippling loss describes the number of wounded birds that survive with pellets in the body (so-called "pellet carriers") plus the number of deadly wounded but non-retrieved birds over the

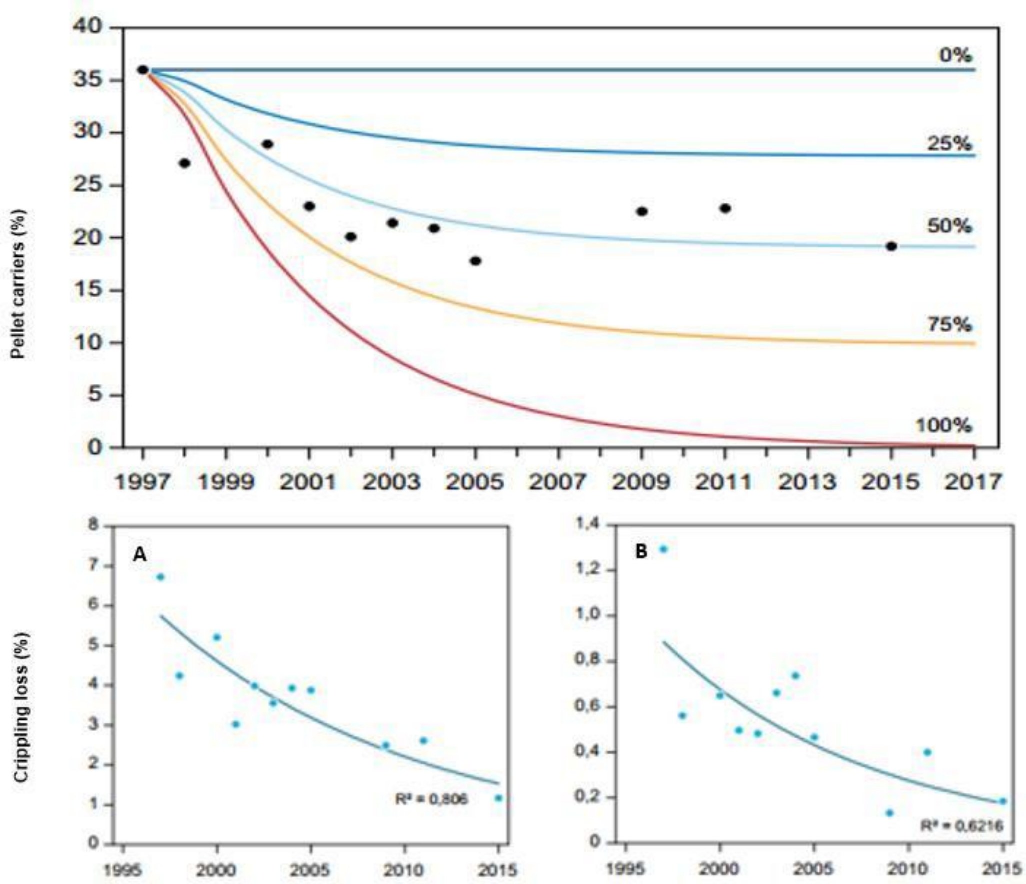
[32] https://www.munitionsexpress.com/shotgun-ammo/lead-free/410-bore/ or
[33] See https://www.eleyhawkltd.com/products/game-cartridges/vip-bismuth
[34] https://www.riocartridges.com/en/rio_ammunition/products/hunting_loads

number of all birds hunted.

This range is independent of the shot types used. Noer et al. (1996) found in Denmark in a population of Pink-footed Goose (Anser brachyrynchus) a prevalence rate of 36 % of lead shot carriers, and for eider suck (Somateria mollissima) a prevalence rate of 34 %. For both species accurate data on population dynamics were available. Based on annual survival rates and the frequency of shot carriers it was estimated that per bagged bird, another bird was wounded (and survived). Moreover, there was an unknown number of mortally wounded but non-retrieved birds. Hence, the estimated crippling loss was well beyond 50 %. Notably, most of the examined birds had been wounded before the Danish ban on lead shot in wetlands (in 1993), and the carried shot was mostly lead shot.

Cartridge consumption per bagged bird varies considerably depending on the skill of the shooter, the shooting distance, the quarry size and many other factors. Haas (1977) found that dove hunters fired an average of 8.6 (lead) shots per bagged bird. Noer et al. (1996) found between 1.5 and 10.50 shots per bagged bird among 14 duck hunters, with an average of 3.3 (steel) shots. These large numbers of shot fired without creating a kill represent a risk not only for missing the target, but for wounding it. Noer et al. (2001) also found a clear correlation between cartridge consumption and the prevailing crippling loss ratio. Here, an ideal situation would be a 1:1 ratio – one bagged bird per shot. Whilst this is not achievable in practical terms, the setting of goals for reducing cartridge consumption has proven to be an effective tool to control crippling. As a result of a Danish campaign (in 1997) a code of maximum three shot per bagged bird was established. In addition, the shooting distance was found to be crucial for both cartridge consumption and wounding risk. Hence, the recommended shooting distances in the same set of hunting codes were reduced accordingly.

The latest evaluation of the impact of the campaign is presented by Holm et al. (2015). The results are summarised in Figure C.6. The top panel shows the development in frequency of pellet carriers from 1997 to 2015 for pink-footed goose. The bottom panels show for old (A) and young specimens (B), the corresponding development in crippling loss (i.e. % wounded birds / % bagged birds), based on the frequency of pellet carriers and data on the total annual bag.



Notes: Top: The frequency (%) of old (>1 year) with embedded pellets. The curves show the predicted development, if the level of wounding was un-changed (0 %) or declined with, resp. 25 %, 50 %, 75 % and 100 %. The dots show the actual trend. Bottom: Crippling loss (% wounded / % bagged birds). A: Old birds (>1 year); B: Young birds (1 year)

Figure C.6 Development of wounding of pink-footed goose in Denmark over the period 1997-2015. After Holm et al. (2015).

Holm et al. (2015) detect a clear and significant reduction in wounding rates over time. The authors attribute this to better organisation and planning of hunting, combined with a better education of hunters. shows the harvest of pink-footed geese in Denmark and Norway since 1990 (Madsen et al. 2015).

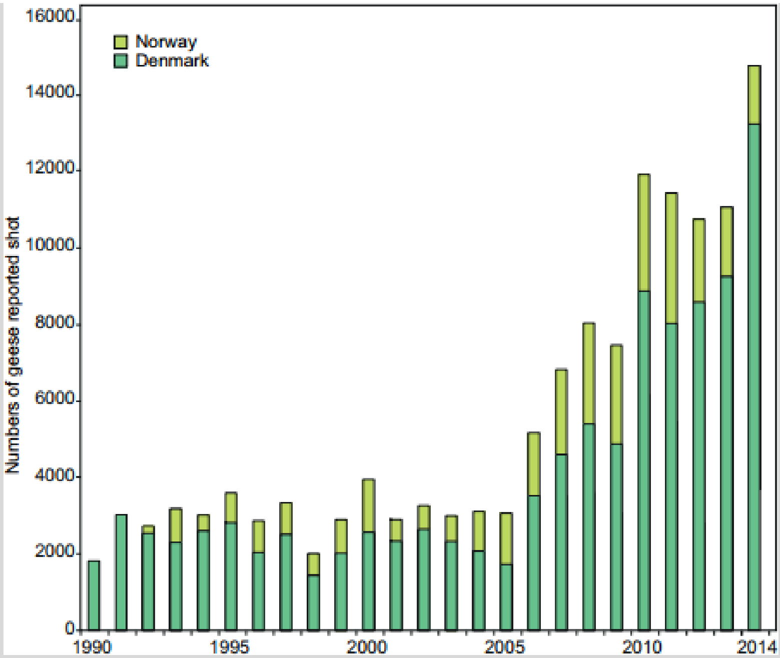


Figure C.7 Harvest of pink-footed geese in Denmark and Norway from 1990-2014. After Madsen et al. (2015).

Comments in the call for evidence from the Finnish Hunters' Association conducted a field test to test for non-lead shotgun cartridges and their penetrating in ballistic gelatin. On the basis of the test, it can be said that the most efficient High Performance -steel cartridges already outperform the average lead cartridges. On the other hand, Standard Steel -cartridges for older shotguns are significantly weaker in penetration and are at high risk of increasing the number of clipped animals if used in the same way as lead, highlighting the need to adapt hunting techniques to the shot material that is used.

Evidence that was submitted in the call for evidence from the USA where Non-toxic alternatives to lead shot are being used efficiently and are effective, as demonstrated by low crippling rates in the USA where use of lead shot in wetlands was banned 30 years ago. United States Fish and Wildlife Services Waterfowl Harvest Survey data show that crippling rates for both ducks and geese were slightly higher in the phase-in period of five years (1987 - 1991) immediately after the ban on lead shot was introduced.

However, after the phase-in period (1992 – 2001) crippling rates of both ducks and geese were much lower than when lead shot was the predominant ammunition used (1952 – 1986) and showed a long-term continuing decline during the period reported. Average post-phase-in crippling rates with non-toxic shot (predominantly steel) were 18 % lower than pre-ban crippling rates (predominantly lead) for ducks and 15 % lower for geese. The small short-lived increase in crippling during the phase-in period probably occurred while hunters switched from lead to steel and got used to the differences in ballistics between ammunition types. Once they had done so, the period with non-toxic ammunition was associated with less crippling.

C.1.5.1.5. Ricochet

All types of shot can ricochet (i.e. deflect) from a hard surface such as water, rocks, or the surface of tree trunks if they hit the surface at an acute angle. Shot made from soft lead, tungsten and bismuth-tin may flatten and even break up on direct contact with rocks. However, steel shot will bounce off hard surfaces, and is not so prone to deformation or fracture, but whether this difference is sufficient to increase the likelihood of injury is not supported by the available evidence.

Ricochet can, roughly, be divided into two components: 1. Ricochet angles and 2. Energy of ricocheting shot. DEVA[35] studies show that ricochet angles do not differ significantly between different types of shot (DEVA, 2013). The same studies show that some types of lead-free shot have greater ricochet energy due to mass stability and that steel and other hard shot has a higher tendency to direct rebound from hard surfaces.

This last element was mentioned particularly by the UK Lead Ammunition Group (LAG, 2015). This was evidenced as the result of pattern testing early steel shot loads at a special pattern testing facility at Holland & Holland's shooting grounds in North London. The Group concluded that in such circumstances precautions need to be taken when firing steel shot at a resilient pattern plate, as steel will rebound to a greater extent than lead. However, for all practical purposes when shooting in the field the group concluded: "An unsafe shot with steel is an unsafe shot with lead".

Under the practical circumstances of hunting the risk of ricochet depends on the physical environment, i.e. the risk of hitting rocky surfaces and obstructions like bush and trees. Water bird hunting in wetlands has a high prevalence of shots in open space with "the sky as background", hence with a low risk of hitting obstructions. Birds (e.g. wounded birds) may be shot/dispatched at the water. Shot of any type will ricochet from water surfaces given that the hitting angle is small (< 5o), but with no difference between shot types.

Danish experience

Ricochet was a central part of the Danish debate during the transition from lead to non- lead gunshot in the 1990s. Many actors were concerned that particularly steel

[35] http://www.deva-institut.de/home.php

shot, which was then the only available alternative, would create an increase in ricochet accidents. For this reason, various measures were introduced. Codes of safe hunting were adapted, including that recommended safety angles were increased from 25o to 40o, and hunters were recommended to wear safety glasses when hunting in groups. In addition, a safety campaign was launched under the motto “better red than dead” – meaning that hunters were recommended to wear red caps or hat ribbons to be visible to fellow hunters. The campaign was inspired by the switch from lead to non-lead shot.

Today, two decades later, there is no evidence, that the change from lead to non-lead shot has caused any change in risk of injury. Research from DEVA (DEVA, 2013) concluded that ricochet from lead and steel is comparable. Furthermore, the Danish Hunting Insurance[36] company registers reports on shooting accidents including accidents caused by ricocheting gunshot. However, the records from period after the phase-out of lead shot do not indicate any increase in frequency of such accidents. This may be a product of the precautionary steps that were taken in the 1990s, and also that hunters have used lead-like gunshot (bismuth-tin) particularly for forest hunting where the risk of ricochets (e.g. from tree trunks) is larger than in open habitats. Furthermore, hunters are educated to take safety angles into consideration. This is a mandatory part of education and testing of hunters in Denmark and has been so since 1967.

Since 1985 the use of lead shot for training and competition shooting (clay pigeon) has gradually been phased out in Denmark. Today, lead shot is allowed on a few specially approved shooting grounds. Steel shot has become the only realistic alternative and was from the beginning foreseen to generate an increased risk of accidents caused by shot ricocheting from clay pigeons’ installations, ground (running target), etc. However, after 20 years and millions of rounds later there has been no detectable change in accidents caused by ricocheting shot[37]. So, this initial concern proved groundless. Shooters are recommended to wear safety glasses (in some disciplines this is mandatory). This precaution is mainly introduced to prevent eye injuries from clay pigeon splinters, but will in addition protect against shot – either direct or ricocheting shot. This applies equally to steel and lead shot.

Based on research and experiences there is no indication that a change from lead shot for hunting to other types including steel shot would cause any increased danger due to ricocheting shot.

The Finnish hunting association had submitted information in the call for evidence that particularly steel and some tungsten-based shot, can ricochet more and are

[36] http://www.danskjagtforsikring.dk/

[37] Danish Wing Shooting Association, personal communication

more likely to bounce-back. Hunters and their dogs can be at greater risk when shooting around hard surfaces and water.

Danish experiences from hunting accidents do not indicate an increased risk of ricochet caused by non-lead shot, including steel shot. Neither do Danish experiences from clay pigeon shooting indicate a higher danger/risk of ricochets with use of non-lead shot (steel) than with lead shot. In general, there is no evidence from shooting in countries where steel shot has been used for many years of an increase in reported accidents or insurance claims.

A study from DEVA (DEVA, 2013) demonstrated that ricochet occurs both in steel and in lead shot, a conclusion also reached by the Game and wildlife conservation[38]

C.1.5.1.6. Impact of forest industry

A concern often raised within the context of substitution lead with steel is the possible damage steel shot in timber on sawmills.

There is no documented evidence of any problem with the use of steel ammunition in forestry in the Nordic countries (Denmark in particular). Concern that steel shot might damage standing timber was raised when lead was to be prohibited in the 1990s in Denmark, and the forestry authorities had recommended against the use of steel. There is still concern among some woodland owners. Experience from Scandinavian countries suggests however that it has not been a significant problem; except possibly in woodlands managed for veneer timber, though even in this instance it has not been a major issue in practice

The items was original discussed in a study from the Nordic council, reference was made to a study of the Danish institute of forest technology which carried out a series of shooting test to establish penetration capacity of steel shot in in various species of wood, Norwegian spruce, oak and old and young beech. The shots were fired at distances of 20 and 30 metres. The test showed a maximum penetration of 7.5 mm and no significant difference in depth of penetration for lead shot and steel shot. The density of shot in raw material was analysed. On average, one shot for each 29 cm3 of beech was found.

This would mean that at normal shooting distances that the shot would remain in the bark of the trees (which in most case for timber production is removed).

Shot embedded in the xylem (most notably the outer bark) system of a tree will remain the same distance to the centre of the tree as the tree grows. It is assumed

[38] https://www.gwct.org.uk/media/1094670/Moving-away-from-lead-shot-QA.PDF

that steel shot will corrode over time, more quickly in species heavy in tannin. The corrosion will cause the wood the discolour and will this reduce it quality. Discoloration will also often occur simply because of the access the oxygen provided by the penetration of a shot.

The last cause is seen to be common for both steel and lead shot.

In an online publication[39] on timber quality control, UPM (one of Finland's larger forestry companies) states that timber is systematically scanned for foreign objects an iron contamination from a size of eight millimetres must be detected in a reliable and trouble- free manner.

Many sawmills these days are equipped with metal detectors[40] for reason other than just steel shot. Advertisements for metal detectors suitable for the timber industry are numerous, ranging from handheld devices to full blown automatic sorting system that disregard timber with a large metal objects, select them out and put this timber to other uses.

During the Public consultation on the wetlands proposal, concerns were raised on the impact of steel shot on machineries used in the forestry industry. Evidence received in the SEAC consultation however (based on experiences in DK and FI), suggested that there is no impact on forestry industry to be expected at the EU level. ECHA followed up on this aspect with the Finnish forestry authorities, who investigated the issue with their clients who reported that hard shot (such as steel) poses no problem in their machinery. Consequently, the Finnish Forest Authorities will lift the existing ban on the use of steel shot in Finnish forests in autumn 2018[41].

ECHA learned[42] from Metsahallitus that they have asked all their clients to see what the problem is, all the sawmill companies replied that here is no problem and that hard shot (such as steel) can be used. There has been no feedback from private landowners that the trees have been damaged by the shots. In a reaction to this and to prepare for a future without lead shot Metsahallitus lifted the ban.

C.1.5.1.7. Availability of lead-free shot

From the wetland dossier the Dossier Submitter had learned that availability of steel

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[39] https://d-nb.info/102516010X/34
[40] https://sahateollisuuskirja.fi/en/sahatavaran-valmistus/sahatavaran-laadutusjarjestelmat-konenakosovellukset/
[41] https://www.eraluvat.fi/ajankohtaista/ajankohtaiset-aiheet/uutiset/korvaavien-haulien-kielto-poistuu
[42] Personal communication, Antti Otsamo

gunshot in Europe. This was done through an online search of the product catalogues of ammunition manufacturers that are members of AFEMS[43] as well as other companies. Ten manufactures were identified in the following countries: Italy (2), UK (2), Spain (1), Sweden (1), Germany (1), Poland (1), Czech Republic (1), and Greece (1). All of these companies have a line of non-lead shotgun hunting cartridges. All have a steel gunshot production line with a rather varied selection of calibres and loads. Bismuth shot cartridges are also produced by two manufacturers, copper by two, and zinc by one. The manufacturers have agencies in most European countries, hence their products, including non-lead ammunition, are available or can easily become available in any Member State, once the demand is there. In addition, several North American manufacturers produce and export non-lead ammunition to Europe. These companies have a long tradition for production of non-lead hunting cartridges. One (Kent) has specialised in this type (i.e. steel shot) and is directly affiliated with a British company (Gamebore). It has, at present, a significant share in the Danish market of shot cartridges.

Kanstrup and Thomas (Kanstrup and Thomas, 2019) identified 22 European manufactures of non-lead shot cartridges distributed among the following 7 Member States: Italy (6), , France (4), Spain (4), Sweden (1), Germany (1), Poland (1), and Czech Rep. (1). All companies had a steel shot line, some with a wide selection of gauges and loads. Bismuth shot cartridges were produced by two, copper by two, and zinc by one company (Table 1). In addition, six North American and four UK manufacturers produced non-lead cartridges. One (Kent Cartridge) had specialized in this type of non-lead cartridge and was directly affiliated with a British company (Gamebore). The 28 manufacturers, including the six North American companies, had agencies in most European countries; hence, their products, including non-lead ammunition, were available, or could easily become available in any region or country, subject to demand. The result of this survey are in Table C.11.

[43] http://www.afems.org/

Table C.11 Availability of lead free shot.

Country	Regulation of lead shot for hunting[a]	Number of non-lead cartridge manufacturers identified	Number of non-lead cartridge brands identified	Non-lead shot types available
Austria	x		1	S
Belgium	x		1	S, B
Bulgaria	x		1	S
Czech Rep.	x	1	1	S
Croatia	x		0	–
Denmark	xx		16	S, B, T
Estonia	x		1	S
Finland	x		8	S, B, C
France	x	4	3	S
Germany	x	1	4	S, B
Greece	–		2	S
Hungary	x		1	S
Iceland	–		1	S
Ireland	–		0	–
Italy	x	6	1	S
Latvia	x		2	S
Lithuania	x		2	S

Luxemburg	x		2	S
Malta	x		1	S
Norway	x		2	S, B
Poland	–	1	0	–
Portugal	x		1	S, B, T
Romania	–		0	–
Slovakia	x		0	–
Slovenia	x		0	–
Spain	x	4	0	–
Sweden	x	1	1	S, B
The Netherlands	xx		4	S

1. [a]No regulation, x = ban of lead shot in wetlands/waterbird hunting, xx = total ban of lead shot

2. S steel shot, B bismuth shot, T tungsten shot, C copper shot, –none

Alternative shot is expected to be readily available. Many European manufacturers of lead gunshot have production lines of steel gunshot and other non-lead alternatives. There are also non-EU manufacturers selling different types of non-lead ammunition on the EU market. Some local retailers might currently not hold stocks of non-lead gunshot though or have limited quantities on stock.

ECHA organised a call for evidence (from 4 October 2019 to 21 December 2019, to test to what extent the SEAC conclusion on the use of lead shot in wetlands are applicable to the use of lead shot outside of wetlands. In this call for evidence comments on this issue were received from:

- British association of Shooting and Conservation (BASC)
- British sports shooting council (BSSC)
- Norges Jeger- og Fiskerforbund (NJFF)

- Federation for Hunting and Conservation - Malta (FKNK)
- Finnish hunting association
- Finnish ministry of Agriculture.

In their submission to the call for evidence the British Association for Shooting and Conservation (BASC) reported the result of a study by (Ellis, 2019) on availability of lead free shot. (Ellis, 2019) finds that there is a general trend for a greater variety of non- lead brands available for the popular shotgun gauges and chambers.

These comments covered the availability of lead-free shot, the following issues were raised

- A research of five major European ammunition manufacturers indicates that while lead-shot alternative products for 12-gauge is available for all five, only two manufacturers produce 16 and 20 gauge lead-shot alternatives. None seems to produce non-lead shot cartridges for the 28 or 36 gauge (.410 calibre) firearms. The 36 gauge (.410 calibre) has increasingly become popular, especially in the Mediterranean basin, with more and more firearms being made available by the trade in this calibre.
- CIP approval exists for ‘standard’ steel shot cartridges in calibre 12 (70mm chamber length only) and also for calibres 10, 16 and 20. No CIP approval currently exists for ‘standard’ steel shot cartridges in calibres 28 and .410. While the large majority of the shotguns used in the UK are in calibre 12 (1,185,978 shotguns in England & Wales), around 14 % are in calibres 28 and .410, for which no standard steel shot approval currently exists (15,092 shotguns in calibre 28 and 171,288 shotguns in calibre .410).

Non-lead shotgun cartridges are available in most Member States from retail shops with online service. However, the screening showed that the product range of non-lead ammunition is significantly restricted compared to lead shot brands. This is supported by research undertaken by the UK Lead Ammunition Group (2015) who concluded that “the available variety of non-lead shotgun and rifle ammunition is more restricted than currently available for lead, so optimum loads may not yet exist for all circumstances”.

This may very well be the situation in other EU Member States with no or partial bans on the use of lead gunshot. Stocks of non-lead ammunition held in local retail shops may be very limited in quantity, specification and brand. Hence, a small-scale local purchaser may not initially be able to buy the most appropriate cartridge for their shotgun or hunting purpose. However, this should not be considered to mean that an appropriate cartridge is not available.

The availability of non-lead ammunition is first and foremost limited by the demand at the national, regional, and local level (Thomas, 2013). Manufacturers provide non-lead ammunition and their products are available, or can easily become available in any Member State, regionally and locally, once the demand is there. Another example of this, is in Italy where a partial ban has been put in place Recent industry information suggests that the market share of alternatives for lead was estimated to be up to 50 %[44]

In Denmark, ammunition dealers at retail level will offer a very broad selection of non- lead cartridge types. One example is Korsholm[45], who offer 15 different brands of non- lead shot cartridges (mostly steel) in different calibres each with a selection of 3-5 different shot sizes. In contracts, our screening identified that no non-lead gunshot was available online in Poland where a restriction on the use of lead gunshot has yet to be introduced. This is despite the fact that Polish company FAM produces steel gunshot hunting cartridges.

The impact of demand on the availability of non-lead gunshot was discussed in by UK LAG (2015). It was concluded that, based on the development of non–toxic markets in Denmark, the Netherlands and in North-America that “the variety and performance of non-lead ammunition will, if demand exists, improve to meet demand”. Also, Thomas (2014) finds that manufacturers in Europe make and distribute cartridges according to hunter demands, which, in turn, is driven by regulations.

As already highlighted in the section on gun replacement, in the shot sizes mentioned, alternatives are available in bismuth and can be used without the need to change guns.

ECHA conducted market study of its own to investigated the availability of non-lead shot in various member states, the results (see Table C.12) highlight that lead free shot is widely available throughout the EU.

[44] Personal Communication AFEMS 2017.
[45] http://www.korsholm.dk/dk/jagt-produkter/ammunition/halgpatroner.html?m-layered=1

Table C.12 Result of market study: availability of lead shot.

Gauge	Number of brands found				
	Lead	**Steel**	**Copper**	**Bismuth**	**Tungsten**
12/70	13	17	2	2	10
	Remington Express Extra Long Range Hornady Varmint Express Baschieri & Pellagri Baby Magnum Baschieri & Pellagri MG2 Mythos HV Baschieri & Pellagri F2-4 Trap Baschieri & Pellagri F2 Long Range MB Dispersante Sellier & Bellot Buck Shot Forest Favorit Forest Crowbuster Forest Ammo Blitz hunting shotshell, HV RWS Game Edition pigeon Sellier & Bellot	Remington Nitro Steel Rottweil Steel Game Sellier & Bellot SB Steel Shot FIOCHI FSteel SAGA Heavy Steel Sellier & Bellot Jagd Steel RWS Game Edition Ente Sellier & Bellot B+P 3 Valle Steel HV Sellier & Bellot Eco-Game Steel Tunet Steel Shot Line Armusa Steel Sellier & Bellot Steel Shot WINCHESTER ZZ Canard Steel Winchester X2	Rottweil Copper Unlimited B&P 4 Dual Shock	LEY VIP Bismut h Gamebore	Gyttorp Silver Saga Maximum Tungsten AmmoX Premium Baschieri & Pellagri MG2 Tungsten TUNET SPHERO TUNGSTEN UnA-Tungsten Clever Mirage Tungshot KENT Impact tungsten Fob Sphero Tungsten MARY-ARM XTREM Tungsten

	Long Range RWS Game Edition Crow	Steel Mirage T4 Waterfowl Steel Shot Remington Steel shot Winchester Buckshot			
16/70	5	2	-	2	-
	Sellier & Bellot Red/Black Sellier & Bellot Vega plastic BRENNEKE Camou Brenneke classic WINCHESTER Super Speed 2nd Generation	Rottweil Steel Mirage Soft Steel T3	-	LEY VIP Bismuth Rio Bismut h	-
20/70	6	2	1	3	2
	WINCHESTER Super Speed 2. Generation B&P Mythos Valle Semi-magnum Mirage T3 Rottweil Exact Rottweil Waidmannsheil RC Italy SIPE T3	Fiocchi Steel Shot 20 Rottweil Steel Game	FOB Sweet Copper	Eley Bismuth Eley Field Special Bismuth Gamebore Bismuth	Kent Impact Tungsten Matrix B&P MG2 Tungsten Cal.20

C.1.5.1.8. Economic Feasibility of alternatives

Alternative ammunition used to be more expensive than lead. However, recent data on the market price of gunshot cartridges indicate that on average there may be no significant difference in price between lead and steel gunshot. Moreover, the long-term economic impact on shooters due to different prices of alternative shot is difficult to reliably predict because several factors affect the retail price of gunshot including raw material price, production processes, market demand for different cartridge gauges and taxes, e.g. VAT, in different Member States.

(Kanstrup and Thomas, 2019) conducted an internet study to evaluate the prices of lead shot and non-toxic shot in various European countries, Tungsten shot was by far the most expensive type of non-lead shot. Steel shot cartridges are available at much lower prices, approximately the same as equivalent, high-quality lead shot cartridges, which correspond with the findings of (Thomas, 2014), (Kanstrup and Thomas, 2019)see Table C.13

Table C.13 Average prices of shot types in retail sale identified in the Internet search in 29 European countries (Thomas, 2014), (Kanstrup and Thomas, 2019).

Type	N[a]	Price in Euro/25 pcs	
		Average	Range[b]
Steel	36	11.9	7.50–25.25
Bismuth	8	57.81	42.25–60.00
Tungsten	2	85	79.25–90.00
Copper	3	37.28	21.50–41.25
Lead	25	10.45	6.50–18.25

Within the framework of ECHA's call for evidence, many commenters stated that the prices of steel shot where prohibitive of regulating the use of lead further, outside of wetlands. Some commenters however had submitted actual quantitative evidence and data.

One of such commenters, the British Association for Shooting and Conservation had submitted a market study on the availability and process of steel shot and other alternative to steel shot. This study covered both the use of shot as well as rifle ammunition.

Comments from the call for evidence (BSSC, gun trade association) reported that a total of 730 shotgun cartridge brands were found for sale on the websites of the 15 largest ammunition retailers in the UK. Of these, 87 % were lead cartridges at an average cost of £0.32/cartridge. The remaining 13 % of cartridge brands were predominantly steel (10 %) at an average cost of £0.38, followed by bismuth (3 %, £1.30/cartridge) and tungsten (0.2 %, £2.53/cartridge). 76 % of the non-lead shotgun cartridges were for 12 bore shotguns, and 15 % for 20 bore. There were four non-lead cartridges available for 28 bore, two each for 10 bore and 16 bore and only one for .410.

Wholesale and retail prices of cartridges will basically depend on production prices, but will also—and to a very high degree—be influenced by volume, transport cost and other basic vectors. Particularly, the profits generated along the value chain from production to retail, taxes, VAT etc. influence the retail prices to be paid by the hunters. To exemplify this, the price per cartridge for ELEY VIP Bismuth calibre 12/70 (shot size 3.2 mm) was

€1.4 on the webpage of a UK-based supplier[46], but €2.7 at a Danish store[47]. This illustrates that the retail price of two identical cartridges may differ by a factor of two depending on market factors.

There is significant variation in price per cartridge even within a single gauge and chamber combination for a single shot type. This is due to variation in the intended use and specification of the load. For example, sporting loads tend to be cheaper than high performance goose loads whether the shot material is steel or lead.

[46] http://www.sportingsupplies.co.uk/contents/en-uk/d194.html
[47] http://www.iversen-import.dk/bismuth-forrest-vip-32-gr-skovpatron-405-m-sek.html

Table C.14[48] The average for lead and steel cartridges for all of the gauge and chamber length combinations found for sale on Guntrader. (Ellis, 2019)

Gauge	Chamber length (mm)	Steel price per cartridge €	
		Average lead	Average steel
.410	50	0.35	-
.410	65	0.42	2.19
.410	70	-	0.55
.410	76	0.49	1.46
10	89	2.15	1.06
12	65	0.43	0.21
12	70	0.43	0.53
12	76	0.81	0.80
12	89	1.34	0.88
16	65	0.16	0.26
16	70	0.58	0.69
20	65	0.42	0.36
20	70	0.45	0.47
20	76	0.85	0.68
28	65	0.4	2.19
28	70	0.51	0.87

Note: Range is not given where only a single brand was found. The cheapest choice for each combination is given in bold

[48] *Prices converted to euro with conversion rate of 1:1.13 (pound to euro)*

In the dossier concerning wetlands this was already highlighted by the dossier submitter, in which was found that the retail prices of lead and various non-lead shot cartridges based on the information from different European countries reported in Table E.5. Lead shot cartridge prices vary from €0.29-0.65 (mean = €0.45), while steel shot cartridges vary between €0.23-0.99 (mean = €0.46). Bismuth (and tungsten cartridges) are significantly more costly with prices between approximately €1.7-2.5 per cartridge (with a central price estimate of €2.0), see also Table C.15. These prices are taken forward in the impact assessment.

Table C.15 Comparative prices for of lead and non-lead shotgun cartridges in the EU in cal. 12 (32 gram load).

Shot material	Summary statistic	Price (€)
Lead (n=48)	Mean	0.45
	Min	0.29
	Max	0.65
	Median	0.47
Steel (n=23)	Mean	0.46
	Min	0.23
	Max	0.99
	Median	0.38
Bismuth (n=3)	Mean	1.96
	Min	1.68
	Max	2.50
	Median	1.71

These data support the general finding that prices of lead and steel shot are currently comparable while bismuth (and tungsten), which are produced, sold and used in lower volumes, are likely to remain more expensive than lead (even though the price of bismuth shot may reduce slightly).

C.1.5.2. Lead in bullets

C.1.5.2.1. Function of lead in bullets

Rifle ammunition cartridges contain a single projectile (bullet). The mass of the bullet is described in grains in the US but in grams in the EU. – there are 437.5 grains in an ounce, one grain is approximately 0.06 gr.

"Calibre" is the measure of a bullet's diameter; the higher the calibre, the bigger the bullet and, when used for hunting – it generally follows that the larger the bullet the larger the game it can be used to hunt. The calibre of the ammunition must match the calibre of the rifle/gun being used (the calibre is usually stamped on the barrel or receiver of the rifle). For example, .22 calibre 55-60 grain bullets can be used in a .22 calibre rifle (a 55 grain bullet has a mass of 3.6 g), a 150 grain bullet has a mass of 9.7 g, and a 220 grain bullet has a mass of 14.3 g. Bullets of different size (grains) are selected based on the species being hunted e.g. a 150 grain bullet can be used to hunt white-tailed deer, a 220 grain bullet to hunt bear.

Calibre can also refer to the complete set of dimensions (length, calibre, etc) of a bullet. As such the word bullet in that case refers to a specific type of bullet.

(Stroud and Hunt, 2009) reviewed basic bullet materials available to bullet manufacturers, which include lead alloys, lead with external copper wash, lead core with copper jacket, pure copper, and bismuth. Lead and bismuth are highly frangible, whereas pure copper bullets tend to remain intact after impact. Bullet fragmentation increases the degree of lead contamination in tissue.

Modern bullet design, velocity, composition, and bone impact are significant factors in the character and distribution of lead particles in carcasses, gut piles, and wound tissue left in the field by hunters. Prior to the 1900s, bullets were made entirely of lead. Their velocity was relatively slow (<2,000 feet per second), and their tendency to fragment was accordingly lower than that of modern ammunition. Development of smokeless powder in the 1890s increased bullet speeds above 2,000 feet (610 m) per second, causing lead bullets to melt in the barrels and produce fouling which reduced accuracy. Copper jacketed lead-core bullets were therefore developed, which permitted velocities that may exceed 3,000 or even 4,000 ft/sec in modern firearms. Standard hunting bullets now typically travel at 2,600 to 3,100 ft/sec, speeds highly conducive to fragmentation.

On modern hunting ammunition, Norma states[49]:

Expanding bullets are the most common hunting bullets in the world. The principle behind expanding bullets are in the name, it is a projectile that expands predictably upon impact to reach a diameter size that is larger than the original bullet. This controlled deformation results in greater hydrostatic shock at the target which is the effect which gives the bullet a certain level of stopping power and as the diameter increases it also creates more displacement and greater cavities. All of these characteristics is something that is desirable to most hunters, who don't just need to hit a target but also to have a certain effect on the target. Expansion of the bullet can be achieved by many different construction and design variants; it is therefore best to think of expanding bullets as an effect description rather than a certain construction

Figure C.8 A soft-nose constructed bullet going through different stages of expansion

The same guide on expanding bullet state that the following designs are used (see Table C.16)

[49] https://www.norma-ammunition.com/en-gb/norma-academy/dedicated-components/bullets/the-basics-of- expanding-bullets

Table C.16 designs for expanding bullets.

Design	description
Lead-lock	A lead-lock is a mechanism to control and reduce expansion. The bullet is appended at the base so that the core and mantle stay together and the mushrooming stops. This is especially important at short distances where bullet energy and velocities are high, and the projectile can risk complete deformation and therefore unstable behaviour at the target.
Monolothical body	This is a design principle found in expanding copper bullets. As copper is more firm than traditional lead bullets, an expanding copper bullet has a different set of challenges in the design phase. By working with the body shape and copper composition, just the right balance between softness, which equals mushrooming expansion, and hardness, which equals a projectile that won't just melt away, is achieved.
Forward bullet jacket	By reducing the thickness of the forward jacket, the bullet becomes less resistant at impact and therefore will deform. A thick forward jacket will mean the bullet will be more likely to maintain its shape upon impact without deforming, behaving more like a piercing projectile rather than expanding. A well-constructed forward jacket will deform without crumbling
Bonding technology	Bonding technology ties the core of the bullet to the outer mantle, which means that when the bullet makes impact with a target and starts expanding, the bullet is more likely to stay in one piece. Even when the bullet is mushrooming very aggressively, the core will not separate from the mantle which means you get high residual weights despite having a very high degree of expansion.

All of the designs described inevitably lead to the opening op of a lead core (except for monolithical bullets) and consequent exposure and fragmentation of the lead core during flight and upon impact.

One of the advantages of monolithical non-lead bullets is that they do not fragment like lead bullets (see Figure C.9)

Fragmentation in modern centrefire lead rifle bullets is a direct result of their design to be a controlled-expansion projectile. They are specifically designed so that the frontal portion of the bullet consistently and reliably expands to almost twice their original diameter.

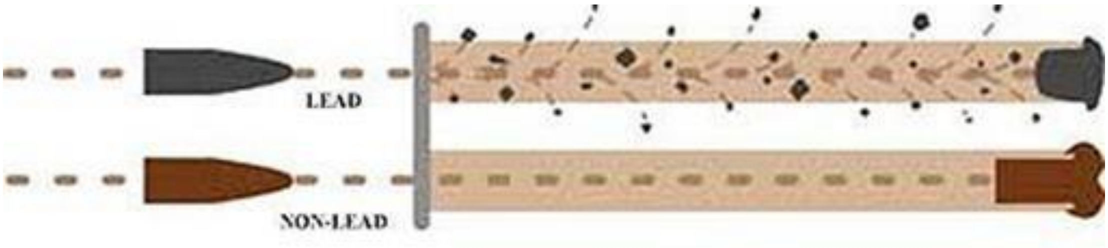


Figure C.9 Bullet Fragmentation: Lead vs 100 % copper or gilding metal construction (typically 90 % copper) Source: IWS

This design ensures a quick and humane kill:

1. It delivers a hydrostatic shock wave that travels out from the bullet's path and into the animal's body that has received the bullet, causing significant damage to internal organs and bones.
2. It ensures that when the bullet passes through the body, the increased diameter and sharp edges of the expanded bullet causes more internal physical damage to the animal.

However, one other consequence of a rapidly expanding lead bullet traveling at high velocities is that some of the soft metal itself erodes away from the frontal section of the bullet as it strikes and travels through the animal. The fragmenting characteristic of lead bullets is cause for concern for wildlife and humans who eat any portion of an animal shot with this type of bullet. While efforts have been made to retain the expanding characteristic of lead bullets but eliminate the fragmenting aspect (e.g. special bonding of the jacket to the bullet core), none have been entirely successful in this regard. IWS also notes that lead rim fire ammunition (e.g. .22 calibre bullets) which can be used to hunt smaller game animals, also fragment extensively despite travelling at lower velocities. (Hunt and Strout, 2009) X-rayed rifled-killed deer hunted with lead bullets and found all contained lead fragments, with 74 % containing >100 lead fragments.

These lead fragments were then shown to be bioavailable and could result in elevated blood lead levels following human consumption of the contaminated meat.

C.1.5.2.2. Suitability of non-lead or non-toxic rifle ammunition

Non-lead ammunition has the advantage that it fragments less (Figure C.9), the bullets are of monolithical design and retain their weight upon impact with a target.

The Institute of Wildlife Studies (IWS)[50] states that non-lead bullets are extremely effective and notes that bullets made from 100 % copper were initially developed by Barnes Bullets in the mid 1980's as a premium bullet for big-game hunting in Africa.

They were found to have excellent performance properties including extremely consistent and rapid expansion, combined with excellent weight retention and associated deep penetration. In addition, they gained a reputation as being very accurate.

Continued advancements have resulted in more manufacturers producing numerous calibres and bullet weights using either 100 % copper or gilding metal construction (typically 90 % copper). Non-lead bullets are available in factory loaded ammunition from all major manufacturers including Federal, Hornady, Winchester, and Remington, as well as for reloaders.

IWS has shown that non-lead bullets compare very favourably with lead bullets in terms of ballistics. In this test two popular non-lead bullets (100 % copper and copper-zinc alloy containing 90 % copper) and one lead bullet used for hunting were fired into the same block of standard ballistic gelatin to compare expansion, penetration, and hydrostatic shock. The two non-lead (copper) bullets compared very favourably to the lead bullet in terms of performance

In a technical note to support the transition to lead free bullets, (Kanstrup and Haugaard, 2020a) notes that a change from lead to copper will change the projectile's weight / volume ratio. In general, the shift from lead to other materials (Such as copper) will imply a shift to material with a lower density. This has several consequences:

1. to preserve the volume, a change from lead to copper will result in a weight reduction. To maintain the weight, the volume will increase. Within a given calibre (projectile diameter) to maintain the weight, constant volume is achieved only by increasing the length of the projectile.
2. the project length must be increased by a factor corresponding to the ratio between the density of the lead-containing and lead-free projectile. Increasing project length affects the projectile's passage of the rifle barrel, as this increases contact and thus i.e. greater friction. This can increase the pressure during firing.
3. In addition, the increase in the rifle range is adapted to a specific project

[50] The US-based Institute of Wildlife Studies (IWS) is a non-profit group of hunters and wildlife biologists that is dedicated to promoting hunting and wildlife conservation through the use of non-lead ammunition.[103] This group provides extensive information on the advantages and disadvantages of lead and non-lead hunting ammunition.

weight and thus length, in a given calibre. Changes in project length can cause that the projectile is not stabilized properly, thereby affecting the external ballistics and the projectile becomes inaccurate.

4. In some calibres, increased projectile weight may have the consequence that the total cartridge length becomes too large and that the cartridge cannot be placed in the magazine of the weapon or in its chamber. Rounding of the projectile tip can be done so that it becomes more round-nosed, but this affects its ballistic properties.

The contact surface between the projectile and the rifle barrel can also be reduced by the projectile is provided with a number (1-3) of radial cuttings which also counteracts material deposits in the rifle barrel. This too causes a weight loss that can only be offset by changing length and shape.

Non-lead monolithic bullets (e.g. 100 % copper hunting bullets) are longer than lead core bullets of the same weight. Longer bullets may react differently, depending on the twist rate the gun barrel.

Because of increasing project length, manufacturers of lead-free projectiles in the individual calibres reduced the projectile weight and, in some cases, changed their shape. Reduced weight gives - all other things being equal - less energy at all shooting distances. This can in principle be compensated for by increasing the speed by adjusting gunpowder type and quantity. However, the speed has great importance for the stabilization of the projectile in the rifle barrel and thus for the precision and change of combustion and speed also have safety (pressure) and wear aspects. Copper bullets tend to perform better when they are faster, which provides additional energy to expand the projectile. This is usually achieved by using a lighter projectile (for example a 130-grain copper bullet instead of 150 grain lead bullet).

The smaller the calibre, the more pronounced the effects described above are. As volume and weight of a projectile (a cylinder) is related to the square of the calibre (diameter), maintaining a given ball weight will result in an increase in length, which is relatively larger for small calibres than for large ones (Figure C.10).

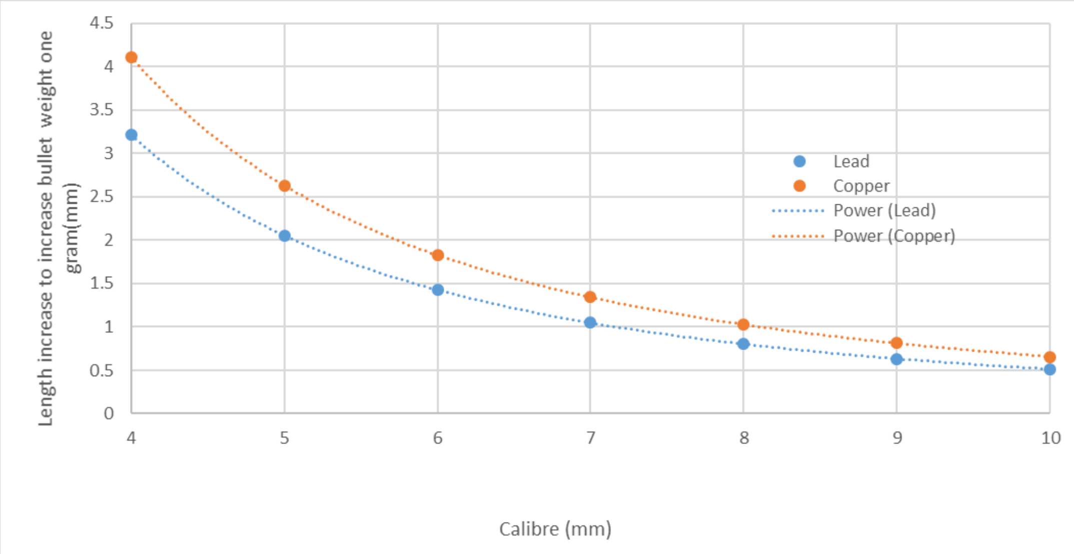


Figure C.10 The need to increase the length of the projectile to achieve a gram weight increase as a function of calibre for resp. lead and copper projectiles.

It is recommended to choose a lighter non-lead option to result in a similar length and performance to the lead bullets that the hunter is familiar with.

The overall result has been shown to be that lead-free projectiles in most calibres produced in a lighter version bullet weight and thus basically also energy compared to the equivalent lead projectiles.

This has been of limited importance for the larger calibres as these are already available with spherical weights and impact energy lying significantly above the legal requirements for rifle hunting in e.g. Denmark. But for some of the smaller calibres this implies that the shift from lead ammunition to unleaded ammunition, that the legal requirements for bullet weight and / or energy cannot be complied with.

Hunting legislations where the use of non-lead ammunition is allowed recognise this and permit non-lead bullets of lower weight

Kanstrup (Kanstrup and Haugaard, 2020a) notes further that in combination with a limited supply the energy requirements of the Danish hunting legislation can all be met with lead free alternatives for the highest classes of game.

Comments from the call for evidence (Gun Trade Association, BSSC) highlighted that the limited availability of non-lead rifle bullets poses potential risks to animal welfare because currently gun shops tend to stock like-for-like copper bullets and so it is not possible to buy lighter/faster non-lead bullets.

The effectiveness and lethality of non-lead rifle bullets made of copper or gilding metal have been demonstrated by field shooting on UK species of deer (Knott et al. 2009) and on German species of deer and wild boar (Sus scrofa) by Spicher (2008).

These results have been supported by the experimental shooting of euthanised sheep and wild white- tailed deer by Grund et al. (2010) at distances of 80-175 m. Further evidence of the effectiveness of non-lead rifle bullets is provided by detailed, controlled, ballistic experiments of Trinogga et al. (2013) and Gremse et al. (2014). Both studies concluded that non-lead bullets were as effective as lead-core counterparts in expanding, creating destructive wound channels, and retaining their initial mass after penetration. It is possible that some tiny copper bullet fragments could be ingested by scavengers (e.g. golden eagles and humans. However, Franson et al. (2013) reported that American kestrels Falco sparverius experimentally-dosed with copper pellets did not exhibit any signs of toxicity.' (Thomas, 2015)

From the available studies, it appears that two main factors determine the technical feasibility of alternatives; bullets are compared usually in calibre size (i.e. does the bullet fit in the gun), and on hunting efficiency (will the bullet not cause unnecessary harm to the animal). The suitability of non-lead bullets in hunting is discussed by Kanstrup (Kanstrup et al., 2016), who found that non-lead and lead-core rifle bullets were equally effective in producing rapid, one shot, kills of red deer and roe deer in Europe and concludes that for hunting purposes there is no consistent and significant difference between lead containing and non-lead bullet for hunting roe and red deer under normal circumstances. These results are like the results in other studies mentioned by Kanstrup (Spicher, 2008; Knutt et al., 2012; Gremse and Rieger, 2012). Further studies by Gremse (Gremse, 2014a) and (Gremse, 2014b) indicate that abandoning of lead as a bullet material for hunting bullets is possible.

A more recent study (Martin et al., 2017) is more definitive. It sets the length of the escape lead and lead compounds distance as an indicator for adequate bullet effectiveness for human killings of game animals in hunting. Based on 2 059 shooting records (Martin et al., 2017) concluded that there is no indication that non-lead ammunition results in longer escape distances of dear or wild boar. The length of the escape factor depends more on other factors such as shot placement, shooting distance, hunting method or the age of the animals. Caudell (Caudell et al., 2012) conclude that for most typical hunting equipment, the level of performance is good enough with standard alternative ammunition but there might be certain scenarios (outside of typical hunting) where higher performance non-lead bullets are desired. These scenarios include most notably professional wildlife management where the penetration and consecutive continued flight of the bullet after hitting the animal may pose additional risks (e.g. wildlife management at airports).

Although some doubts have also been raised, ((Hoffmann, 2013) or and (Bahr, 2013) have for instance noted longer flight distances for shot animals. The more recent studies rebuke these findings by pointing put that the comparison made in the study of Hoffman and that from Bahr compared lead free and lead containing bullets in different calibres which rendered the test non-conclusive.

From the available studies it appears that the suitability of centrefire ammunition from 5.56 mm and up (smallest calibre tested: .222 and .223 which is equivalent to 5.56) is well established. This would imply that, based on the hunting legislation in e.g. Netherlands and Italy that set the minimum calibre at 5.6 mm centrefire. that for hunting species of roe deer and heavier game species, suitable alternatives exist.

For small game bullets, these bullets have only been recently introduced (they were restricted in California only as per mid-2019) and the Dossier Submitter has not found substantive testing of these calibres in literature. The most popular calibre in the small rimfire cartridges (.22LR) has been tested by both (Hampton et al., 2020) and by (McTee et al., 2017), the test were performed on the same brand an model (CCI .22 LR), there where McTee tested the bullet positively, Hamilton expressed doubts but also recognised the limitations of the test. Other products in the same calibres (RWS and Norma) have not been found by the Dossier Submitter, although one grey literature test found the Norma lead free .22LR performing[51] well. Other grey literature test in Denmark[52], showed that some combinations of .22LR and guns demonstrated high accuracy whereas other combinations did not.

An overview of the tests to which references are made in the text above describing the main outcomes as well as the calibres used is described in Table C.17.

[51] https://midwestoutdoors.com/greatoutdoors/norma-ammunition-22-long-rifle-performance- review/
[52] https://www.projektkort.dk/wp-content/uploads/2017/03/22lr-Ammo-Comparison-Test-within-AccurateShooter.com_.pdf

Summary of relevant field studies

Table C.17 overview of tests of lead and non-lead bullets.

Source	Year	Cartridges used	Game	Conclusion
OBS praxis test	2014	Barnes TSX 5,4 g .270 Win. Kupfer Deformation BlaserCDC 9,4 g 7mm BlaserMag. Kupfer Deformation RWS Evolution Green8,8 g .300 Win. Mag..30- 06.308 Win.Zinn Teilzerleger IBEX6,3 g 6.5x576.5x57 RKupfer Teilzerleger IBEX7,8 g .270 Win. Kupfer Teilzerleger Jaguar Classic 3,1 g 5,6x50R Kupfer Teilzerleger Jaguar Classic 4,7 g .243Win.6x62 FreresKupfer Teilzerleger NORMA Kalahari 7,8 g .270 Win Kupfer	Roe deer, red deer, chamois, wild boar, mouflon, marmots	Non-lead bullets are available to hunt in an animal-welfare-friendly manner, to enable a possible search and to achieve high venison quality. There is no such thing as the perfect non- lead bullet! (as with leaded bullets). Rather, everyone has to find the right ammunition for their weapon and the respective game species. Deformation bullets with stable mass are preferred where possible, as they do not leave any splinters in the game

		Teilzerleger NORMAKalahari 8,1 g 7mm Rem.Mag. Kupfer Teilzerleger		
(Grund et al., 2010)	2009			
(Knott et al., 2009)	2009	Norma, 130 grain (n=34) Barnes Federal Vital Shok, 130 grain (n=59), Nosler BT, 95 grain (n=17); Norma, 130 grain (n=3) Barnes Federal TSX (n=32, Calibres: .270 /.243 . 308 . 270	red deer and roe deer Capreolus capreolus sika deer Cervus nippon	When all shots were combined across sites, the mean accuracy score was 1.04 for lead bullets and 1.04 for copper bullets, while the mean outcome score was 1.22 for lead bullets and 1.38 for copper bullets. However, when ‘heart and lung’ shots at the southern English site were excluded (as these are not the normal practice at the site), the mean outcome score across sites improved to 1.22 for copper bullets and 1.13 for lead bullets (Fig. 2). Mean accuracy was not affected by excluding these shots. The mean comparison score was 1.05, indicating a high degree of satisfaction with the copper bullets’ performance compared to that of traditional lead bullets. Discussion: The results of this

				trial suggest that there is no difference in the accuracy of copper and lead bullets. Furthermore, it suggests that differences in killing power between the two are small, especially when normal practice is followed. Using newly available copper bullets designed to expand to a greater degree than the bullets used in our trial may further erode this difference. These conclusions should be treated as indicative rather than definitive. The number of stalkers involved was small and some desirable aspects of experimental design, such as blinding of the stalkers to the type of ammunition, were not practical.
(Caudell et al., 2012)	2012			
(Trinogga et al., 2013)	2013	Barnes XLC or TSX Non-lead deforming bullet 5 Lapua Naturalis Non-lead deforming bullet 5	34 carcasses — 15 wild boar (Sus scrofa), 13 roe deer (Capreolus capreolus), four chamois	Bullet material did not exert a significant influence on wound dimensions under real life hunting conditions, this study clearly demonstrates the equality of non-lead bullets to conventional hunting bullets in terms of killing effectiveness. Non-lead hunting rifle bullets thus meet the welfare requirements of killing wildlife without

		RWS Bionic Yellow Non-lead partially fragmenting bullet 4 Moeller KJG Non-lead partially fragmenting bullet 2 Reichenberg HDBoH Non-lead partially fragmenting bullet 5 Norma Vulkan Bullet with one or two lead-core(s) 1 RWS Evolution Bullet with one or two lead-core(s) 5 RWS UNI classic Bullet with one or two lead- core(s) 2 Semi-jacketed Bullet with one or two lead-core(s)	(Rupicapra rupicapra), one red deer (Cervus elaphus) and one fallow deer (Cervus dama	superfluous pain as good as do conventional bullets. The present study evaluated real life hunting conditions, accepting that not all details of the actual shots can be known with certainty. Our results show that in those situations that hunters judge as appropriate for shooting, non-lead hunting rifle bullets function as well as conventional bullets

(Hoffmann, 2013)	2013	Schützen mit 9,3x62 und Magnum-Patronen nutzen verstärkt bleifreie Munition, Jäger mit Waffen in den Kalibern 7x64 oder 7x65R eher Bleimunitio		
(Bahr, 2013)	2013			
(Hackländer et al., 2015)	2015			226 protocols on hunting events by professional hunters covering 55 variables on hunter, rifle, ammunition, shot conditions, hit point, behavior of game (roe deer, red deer, sika deer, fallow deer, chamois, mouflon, wild boar and marmot) and game meat evaluation. The protocols compile the use of 15 expandable bullet types in 14 calibers. Apart from three established lead bullet types, 12 non-lead bullet types were used. The statistical analysis with the help of regression trees revealed that the bullet material (lead vs. non-lead) did not affect killing efficacy, blood trails, or evaluation of game meat quality. Instead, other factors such as hit point, exit wound size, caliber etc. were important. These results are in line with various studies and underline the general option to switch from lead to non-lead rifle

				ammunition.
(Kanstrup et al., 2016)	2016	Accubond 7 WSM Barnes TSX 270 Barnes TSX **223** Barnes TSX 30-06 Barnes TSX 308 Barnes TTSX 308 Barnes TTSX 6,5x55 Barnes TXS 30-06 Barnes TXS 6,5x55 Barnes X **222** Barnes X 270 Barnes X-tsx 270 Hornady 222 Hornady 30-06 Hornady GMX 30-06 Kobber 30-06	657 hoofed animals, most red deer (Cervus elaphus) and roe deer (Capreolus capreolus)	The efficiency of copper versus lead bullets was tested using flight distance after being hit as the primary response parameter. For red deer, we were not able to show any statistical significant difference between performance of non-lead and lead bullet. For roe deer, we found a small, statistically significant, relation between flight distances and shooting distance for roe deer struck with non-lead bullets but not with lead bullets. However, this difference was not of such magnitude as to have any practical significance under hunting conditions. We conclude that in terms of lethality and animal welfare, non-lead ammunition within the tested range of bullet calibres can be recommended as an effective alternative to lead-core bullets.

		Lapua 222 Lapua Mega 30-06 Lapua Mega 308 Lapua Mega 6,5x55 Lapua Naturalis 30-06 Lapua Naturalis 308 Lapua Naturalis 6,5x55 Naturalis 30-06 Norma Oryx 6,5x55 Nosler 7 RM Nosler Accubond 7 RM Nosler Bal Tip 270 Nosler Partition 6,5x55 Nosler E-tip 6,5x55 RWS Evolution 7 RM RWS Evolution Green 7 RM RWS Kegles 30-06 Teilmantel spitz**223** Unknown **222** unknown 308 Vulcan 7 RM		
(McCann et al., 2016)	2016	Rifle calibre .308	983 elk (Cervus	Among 921 elk removals evaluated, mean shot distance was 182 meters, and the median and mode of distance travelled were

			elaphus)	46 m and 0 m, respectively. Multivariate analyses revealed that shots to the head and neck were most effective, followed by those striking the shoulder and chest. Heavier bullets should be used whenever practical. Mean group size for non-lead ammunition fi red through NPS fi rearms was 50 mm at 91 m, with minimum and maximum group sizes of 18.8 and 98.6 mm, respectively. We found that non-lead ammunition provided the necessary precision for accurate shot placement in spot and stalk hunting conditions and that these bullets typically accomplished instantaneous or near-instantaneous incapacitation of elk whenever vital areas of the body were impacted. We conclude that non-lead bullets are effective for wildlife management and hunting scenarios.
(Martin et al., 2017)	2017	Hornady GMX non-lead; gilding metal; plastic tip Sako Hammerhead single lead core with tombac jacket; non-bonded RWS H-Mantel double lead cores	1,254 roe deer (Capreolus capreolus) and 854 wild boar (Sus	escape distances of roe deer and wild boar were compared in order to analyse whether lead or non- lead ammunition showed a significantly different killing efficiency. There was no difference based on bullet material between the percentage of the two wildlife

		with tombac jacket; copper tip; non-bonded RWS ID Classic double lead cores with nickel - plated steel jacket Hornady Interlock single lead core with tombac jacket; non-bonded Möller KJG non-lead; copper; plastic tip RWS KS single lead core with tombac jacket; non-bonded Lapua MEGA single lead core with tombac jacket; non-bonded Lapua Naturalis LR non-lead; copper; plastic tip Norma Oryx single lead core with tombac jacket; bonded Nosler Partition double lead cores with tombac jacket; non-bonded Wiinchester Silvertip single lead core with tombac jacket; aluminium tip; non bonded Brenneke TAG non-lead; copper; coated; aluminum tip	scrofa) from different regions within Germany	species that had no or only a very short escape distance (<10 m). Moreover, neither was there any significant difference in the average length of the escape distance (10 m or more) between animals shot using lead ammunition and those shot with non-lead bullets. Our research does not suggest that non-lead ammunition leads to an unreliable killing effect

		Brenneke TIG double lead cores with nickel - plated steel jacket Brenneke TIG Nature non-lead; double tin cores with nickel - plated steel jacket Generic TM single lead core with tombac jacket; non-bonded Brenneke TOG single lead core with copper-nickel-plated tombac jacket; bonded Barnes TSX non-lead; copper Barnes TTSX non-lead; copper; plastic tip Brenneke TUG double lead cores with nickel - plated steel jacket Brenneke TUG Nature non-lead; double tin cores with nickel - plated steel jacket Brenneke Uni Classic double lead cores with nickel - plated steel jacket Norma Vulkan single lead core with tombac jacket; non-bonded Sellier & Bellot XRG non-lead copper;		

		aluminum tip		
(McTee et al., 2017)	2017	.17 HMR (Hornady Magnum Rimfire), .22 LR (long rifle), and **.223** Rem (Remington) rifles with expanding and nonexpanding lead and nonlead bullets	Columbian ground squirrel	All types of lead bullets left lead in at least one- third of the Columbian ground squirrels. Unexpectedly, estimated concentrations of lead in carcasses did not differ between expanding and nonexpanding bullets within the .17 HMR and .22 LR calibres, partially because of the high variability in fragmentation. The greatest estimated concentrations of lead were in Columbian ground squirrels shot with expanding ammunition in .17 HMR and .223 Rem, which had an average of 23.6 mg and 91.2 mg Pb/carcass, respectively. Nonlead bullets incapacitated similar to lead bullets. Our results indicate that nonlead bullets eliminate the risk of additional lead exposure to scavengers while maintaining the lethality of lead bullets.
(Hampton et al., 2020)		lead-based expanding Winchester® Power-Point 40- grain (gr) hollow-point ammunition (Winchester Australia Ltd., Moolap, VIC, Australia), as per Hampton et al. (2016), and		The only commercially available lead-free .22 LR ammunition available for shooting European rabbits in Australia at the time of our study produced lower precision, poorer

		2) lead-free CCI® Copper 21-gr hollow-point ammunition (CCI Ammunition, Lewiston, ID, USA; Fig. 1a). The lead- free bullets were of sintered copper construction, meaning they were made from compressed powdered metal (Caudell et al. 2012). The lead-free bullets were advertised by the manufacturer as being for small game (CCI Ammunition).		animal welfare outcomes, poorer terminal ballistics, and were more expensive than commonly used lead-based ammunition We do not suggest that results of our study are indicative of all lead-free ammunition performance. The specific lead-free product we tested could be an anomaly. Our study had several limitations, including small sample size, shooting at a single species, using a single rifle, using a single type of lead-based and lead-free ammunition, and observing a single shooter. McTee et al. (2017) demonstrated that different lead-based .22 LR bullets have vastly different abilities to instantly incapacitate. Had we used a lead-based bullet with poor terminal ballistics, the conclusions of our study may have been different.
(Stokke et al., 2019)	2019			We found no appreciable difference in killing efficiency between copper and lead-based bullets in our study, which was based on data collected by hunters under normal hunting conditions in Fennoscandia. We evaluated the efficiency of copper versus lead-based ammunition in relation to a quantifiable

				animal welfare standard. We did not detect any significant difference between reported animal flight distances between copper and lead-based ammunition relative to our standardized predicted animal flight distances based on body mass. Copper ammunition exhibited a larger, more reliable and stable expansion compared to lead-based ammunition. This characteristic seems to offset the advantage lead-based ammunition has in terms of killing efficiency due to fragmentation effects
GUNLEX	2019	Hornady Superformance International (monolithic copper alloy bullet with plastic tip) Hornady Custom International (monolithic copper alloy bullet with uncovered expansion tip) Sellier&Bellot XRG (monolithic copper alloy bullet with aluminium tip) Sellier&Bellot TXRG (monolithic copper alloy bullet with plastic tip) Sako Racehead HPBT (lead core / full metal	Target shooting	According to testing shooter, these values of disperse are sufficient for hunting purposes and for short-to-medium distance sports shooting where precision is not critical (for example, disciplines like dynamic rifle or shooting metal silhouettes). It is insufficient for any precision-based shooting disciplines.

		jacketed bullet) (control group)		
GUNLEX	2019	COPPER-22 ammunition with bullet weighing 1,05 g	Target shooting	According to testing shooter, this disperse is insufficient not only for target shooting, but (considering additional disperse caused by average shooter and firearm) even for recreational shooting or small game hunting.

C.1.5.2.3. Impact on guns

Every copper-jacketed bullet fired from a barrel leaves some copper residue (fouling) on the rifling of the barrel. It builds up with every bullet fired and, if not removed, may interfere with bullet placement accuracy and pressure. This applies also to non-lead bullets, and some shooters report greater copper fouling with these bullets than with similar lead-core bullets, thus requiring more frequent barrel cleaning.

Copper fouling is already recognized by different makers of non-lead bullets who have created shallow rings in the mid-posterior section of the bullet into which copper is displaced during its contact with the rifling. In this way, copper build-up is theoretically reduced. This is a feature of the non-lead bullets made by Barnes Bullets, Hornady, RWS, Cutting Edge Bullets, and others. The last-named company actually reduces the length of the bullet's region that engages the rifling, both to increase velocity and to reduce the amount of copper fouling in barrels. The nature of the material used to make the non-lead bullet may vary among companies. Thus, “pure copper”, “annealed copper”, “gilding metal”, and “brass” are listed as choice materials to enhance ballistic performance. Annealing copper softens the metal made hard by shaping in die-made (swaged) bullets. Perhaps the greater extent of fouling (if real) can be attributed to the different metal types used. By way of comparison, the composition of non-lead bullets should be compared to the material used for jackets of lead-core bullets, for which metal fouling affecting accuracy does not appear to be a concern. In theory, the pure copper surface of non-lead bullets and that of copper-jacketed lead-core bullets should leave the same amount of fouling in a given barrel. The same consideration applies to bullets made from copper-zinc alloys (gilding metals).

Repeated firing with non-lead bullets during range practice can be expected to produce copper residue in the barrel bore, and it is customary to remove it after such practice. Under typical European hunting conditions in which a hunter uses a sighted-in rifle with a cleaned bore, many cartridges are not expected to be fired during a day's hunt, so the issue of extensive barrel fouling and reduced accuracy may not arise. This may be a simple issue of raising awareness and instructing hunters in proper gun maintenance. In the German field studies (Gremse and Rieger 2012), the average bag per person per year was between 3.2 and 11.2 animals. Regular gun care during the hunting seasons and a thorough cleaning twice a year have become the norm during these 6-year-field trials with over 1300 participants. These practices have shown themselves suited to ensure rifle accuracy.

The California impact assessment assumes that 10 % of the guns (or gun-owners) need to replace guns due to the gun's age, and their dependency on rare calibres for which it is likely that alternatives will not be developed. Discussions with industry[53] on this subject indeed suggest that there is little need to replace guns but that for some calibres, alternatives are not yet readily available (or never will be) and hunters may need to purchase new guns.

Guidance on the website of the German hunting association states that: (translated from German:

Only with pure copper bullets does it have to be cleaned more frequently than before. After about 40 to 60 shots have been fired, barrel cleaning with chemical barrel cleaners (e.g. Robla Solo, Hoppes Benchrest or the ammonia-free Bore-Blitz or M-Pro 7) is recommended.

The biggest danger for the barrel, however, is the powder smoke that reacts with the air and can attack the barrel steel. It is therefore advisable to neutralize the powder smoke with an oil or CLP after every shooting or after strong temperature changes (condensation) and to wipe the barrel so dry that the point of impact is prevented by the so-called oil shot. In principle, every weapon should be thoroughly cleaned at the end of the hunting season.

The sighting should always be carried out on the shooting range in compliance with the minimum precision requirement (scatter circle at 100 m not larger than 4 cm to 5 cm). Especially after thorough chemical cleaning, it can take a few shots when moving until enough of the bullet material has spread in the barrel to ensure consistent precision and point of impact.

C.1.5.2.4. Ricochet

In 2008 reservations arose as to the allegedly unpredictable behaviour of ricocheting non-lead bullets. A study by Kneubuehl ((Kneubuehl, 2011) did not confirm these findings. On the same issue the lead ammunition group (Lead Ammuntion Group, 2015) concludes[54]:

In other circumstances of deflection as opposed to rebound, such as is more normal in the field, heightened risk is restricted to the vicinity of the strike as kinetic energy is lost on impact though perhaps to a greater extent with lead than steel. For all practical purposes, an unsafe shot with steel shot is an unsafe shot with lead. There is no evidence from shooting in countries, where steel shot has been in use for many

[53] Personal communication with Nammo Lapua Oy

[54] http://www.leadammunitiongroup.org.uk/reports/LEAD AMMUNTION GROUP 2015. Lead Ammunition, Wildlife and Human Health.

years, of an increase of reported accidents. Bill Harriman, BASC's Director of Firearms, reviewed the risk in 2010 and his report "Ricochet characteristics of rifle bullets" concluded:

- Any bullet of any type or construction will ricochet if the circumstances are correct.
- Ricochets from high velocity rifle bullets are rare.
- Copper alloy rifle bullets do not appear to be any more likely to ricochet than conventional jacketed bullets.
- Ricochets are only likely to be dangerous in the immediate vicinity of the impact

i.e. in a situation that would be an inherently unsafe shot.

- Ricochets are not an issue if a shot is taken with the target animal in front of a safe backstop.

Further studies have been published in Germany by the Federal Ministry for Food and Agriculture in a project on "Deflection of projectiles in hunting ammunition 2009 –2011". The project concluded that there are no significant differences evident in deflection characteristics between ammunition using bullets containing lead, and without it respectively (Heider 2014).

C.1.5.2.5 Situations where replacement poses challenges

Further to that, ECHA received information in the call for evidence on situations where the use of non-lead ammunition would pose further difficulties due to specific shooting or hunting conditions, these are summarised in

Table C.18.

These comments are a compilation of comments submitted by

- The Finnish hunting association (grouse hunting, difficulty to replace .22lr in general)
- The Finnish ministry of agriculture (seal and grouse hunting, difficulty to replace .22lr in general, full metal jacket use)
- British sports shooting council (difficulty to replace .22lr in general)
- Classic Old Western Society of Finland ry (difficulty to replace .22lr in general)
- The Gun Trade Association (difficulty to replace .22lr in general))
- Several Individuals (difficulty to replace .22lr in general))

Table C.18 comments from CfE on hunting situations where lead substitution would pose problems.

Type of hunting	Calibres	what blocks
hunting game birds shotgun distances <35 metres rifle distance 40-300 metres	222Rem, 223 Rem, 243 Win, 6,5x55, 7,62x39, 308 win, 7,62x53R, 30-06	• The shooting range is often long (150-250 m) and the target small. • Full metal jacket bullets (copper shell + lead core) pass through the bird intact, which leave no lead fragments in the target and per consequence do not pose a human health risk, or a risk to scavengers or raptors,
Practice shooting		• Shooting practice is carried out with cheaper full metal jacket bullets (could be hundreds of bullets/year) and just test accuracy of actual hunting bullets (expanding lead or copper) compared to training bullets. • bullets can be recovered from the shooting range with bullet catchers and those do not lead to lead dust (the copper shell contains lead). • Army and police buy their training bullets (FMJ) also from same market and same production lines affecting cartridge availability for military if civilians and voluntary national defence personnel cannot buy FMJ cartridges from home market or EU –market. 70-90 % of cartridges are used by civilians.
Game target competitions		
Racoon, mink and badger hunting in caves	22LR	There is no alternative to a 22LR rifle because of the bullet design of the cartridge, .22LR is used for willow grouse short distances less than 50 meters. 22LR is used in pistols to kill raccoon dogs, minks and badgers in caves. Raccoon dog is included on EU list of Invasive Alien Species of Union Concern.

Seal hunting		• Seal hunting (grey seal and ringed seal) requires the use WMAX –bullets for safety reasons. Impact causes dramatic fragmentation of the core and jacket. It is very dangerous to shoot full metal jacket or full copper bullet, ricochet on water could carry the bullet far away • The accuracy that is required is high, as good as shooting game birds (shooting range 100-200 metres, shoot seals to the head (very small target). If full copper bullet hits any other part of animal than then the animal is lost as it dives. Exploding bullet is safer to humans because it explodes also in water impact kill instantly upon hit. • Bullet to the seals head do not damage the meat. Typical calibres for seal hunting are 243, 308, 30-06. Seal hunting is traditional hunting in Finland for meat, oil and fur but seals are hunted also because they cause damage to fisheries.
Roe deer can be hunted with shot as well, e.g. in Sweden for roe-deer hunting shotguns are allowed only between 1 October and 31 January[55]		

Note: controlled hunting is allowed for grey seals in Denmark, Estonia, Finland and Sweden, ringed seals in Finland and Sweden, and harbour seals in Denmark and Sweden, see http://stateofthebalticsea.helcom.fi/pressures-and-their-status/species-removal-by- fishing-and-hunting/

C.1.5.2.6. Alternatives and forest fires

In some of the comments (AFEMS) it was highlighted that that alternatives to lead could play a role in faster ignition of forest fire, ECHA examined the source of this claim (Finney et al., 2013) and found that:

As with all fire behaviour and ignition research, moisture content of the organic material will be an important factor in ignition. Peat moisture contents of 3-5 %, air temperatures of 34-49 °C (98-120 °F), and relative humidity of 7 to 16 % were necessary to reliably observe ignitions in the experiments. Peat moisture contents above this (perhaps 8 %) did not produce ignitions. Field conditions matching the

[55] *https://jagareforbundet.se/jakt/hunting-in-sweden/permitted-firearms-and-ammunition/*

experimental range would imply summer-time temperatures, as well as solar heating of the ground surface and organic matter to produce a drier and warmer microclimate where bullet fragments are deposited.

Is highly unlikely that when the European hunting season opens these conditions will be met regularly.

C.1.5.2.7. Product availability of non-lead rifle ammunition

For all but the smallest calibre bullets (those used for varmint hunting and hunting smaller animals), non-lead ammunition is widely available. Currently available alternatives are either made completely of non-lead materials, such as copper; or designed such that a lead interior is “jacketed” by copper and theoretically protected from exposure upon impact. Other designs have been proposed and it is expected that the increase in demand will result in greater options of non-lead ammunition. Non-lead bullets generally have equivalent, if not superior, performance when compared to their lead counterparts. Copper bullets were originally designed for the “premium” market not because of concerns over lead poisoning but rather for their enhanced ballistic capabilities.

(Epps, 2014) stresses that it is important to recognize that equally effective non-lead options do not yet exist for all types of firearms used in hunting, including one of the most common cartridges used in the United States: the rimfire .22, used for small game hunting. While non-lead .22 ammunition using bullets made of tin is available, many shooters report that it does not function well (or at all) in some common types of .22 firearms, especially semi-automatic firearms that require pressure from heavier bullets to self-load. Other firearms for which non-lead options are very limited or unavailable include: 1) traditional muzzleloading firearms (designs dating to before circa 1865, loaded with loose black powder and a separate bullet rather than a self-contained cartridge), 2) firearms from the black powder cartridge era (designed before circa 1900) which are widely used in the highly popular “Cowboy Action” shooting competitions and by many hunters, especially in states where use is permitted in primitive weapons deer seasons, and 3) some modern hunting rifles chambered for less common cartridges.

The analysis of Thomas (Thomas, 2012) suggests that alternatives for the most popular cartridges are available on both the EU and US market. The 37 leading ammunition manufacturers produce a wide range of 35 non-lead bullet calibres that in theory cover a wide variety of hunting types. An analysis for the European market is made by Thomas (Thomas et al., 2016) in which the authors conclude that product availability (i.e. that which is made) of non-lead rifle ammunition in a wide range of calibres is large in Europe and is suited for all European hunting situations. At least 13 major European companies make non-lead bullets for traditional, rare, and novel rifle calibres. Local retail availability is now a function of consumer demand, which relates, directly, to legal requirements for use.

Thomas et al. (2016) found the efficacy of non-lead bullets equal to that of traditional lead-core bullets. Comments submitted in the call for evidence would suggest that there are in general good alternatives for hunting big game (roe deer*, white-tail deer, sika deer, wild boar, brown bear and moose, elk) at shooting distances 50-100 meters, with the use of calibres like 243 Win, 6,5x55, 7,62x39, 308 win, 7,62x53R, 30-06.

Information from FACE[56] would suggest that for certain calibres there is a problem securing non-lead ammunition for .22LR (a very popular round for pest control) and the

.243 WIN (a popular multipurpose deer/fox). A non-lead .243 round that was heavy enough to be legal for large deer would have to be longer than current barrels are able to stabilise, so there would need to be a shift to larger calibres or many hunters would need new barrels. There are several other calibres below .6mm where alternatives are poorly available including air rifles and pistols used for target shooting. Indeed, these calibres in lead containing form (or similar calibres) are scheduled to be phased out with a longer transition period under the Californian regulation regarding the use of lead ammunition for hunting (Duncan, 2014) . Since the introduction of the Californian regulation, alternatives in that same calibre have been developed (Winchester .22).

Both rifle bullets and .22 calibre rimfire bullets are currently marketed with non-lead alternatives. Non-lead ammunition in .22 rimfire was made available only after California required the use of “nontoxic” .22 ammunition in the range of California condors. Prior to that time, expert testimony was presented to the California Fish and Game Commission claiming that non-lead .22 calibre rimfire was impossible to produce. However, commercially available non-lead .22 calibre ammunition was available four months after the Commission decision to ban lead .22 ammunition (Miller, 2012).

The .22 calibre rimfire cartridge is, by far, the most popular ammunition made and used in North America. It is used for everything from target shooting and competition to the control of nuisance wildlife and hunting. Tradition .22 cartridges have a pure lead bullet that fragments very easily, leaving behind many toxic shards. New, alloy and pure copper bullets, coated with a lubricating polymer, are now available. While the weight of the bullets is less than traditional lead projectiles, the new non-lead .22 cartridges produce extremely high velocity, increasing accuracy and efficacy on

[56] Personal communication from David Scallan, FACE.

impact.

Thomas (Thomas et al., 2016) presents a list of lead free ammunition that is available in Europe wherein data is presented on lead free bullet availability from the principal 13 European rifle ammunition makers that have already developed their own brands.

Thomas argues that is this is in response to the ongoing demand for and evaluation of non-lead rifle ammunition in Germany (Gremse and Rieger, 2014), and possibly, for export into the growing North American market.

Thomas (Thomas et al., 2016) concludes that the major companies, Blaser, Brenneke, Fiocchi, Geco, Lapua, Norma, Rottweil, RWS, Sako, Sellier & Bellot, Sax, Sauvestre, Schnetz, and Hornady International, list calibres suitable for hunting every European game species and for every commonly used rifle and conclude from this that the product availability (i.e. that which is manufactured, as opposed to what is commonly available at the retail level) of non-lead rifle ammunition is not a limiting factor in Europe in the further growth in the use of non-lead bullets.

Comments submitted in the call for evince (from BASC) showed that out of 94 manufacturers, 58 produced at least one non-lead ammunition brand. In total almost 1,500 brands of non-lead ammunition were found, with roughly 60 % from America and the remaining from Europe, particularly France and Germany.

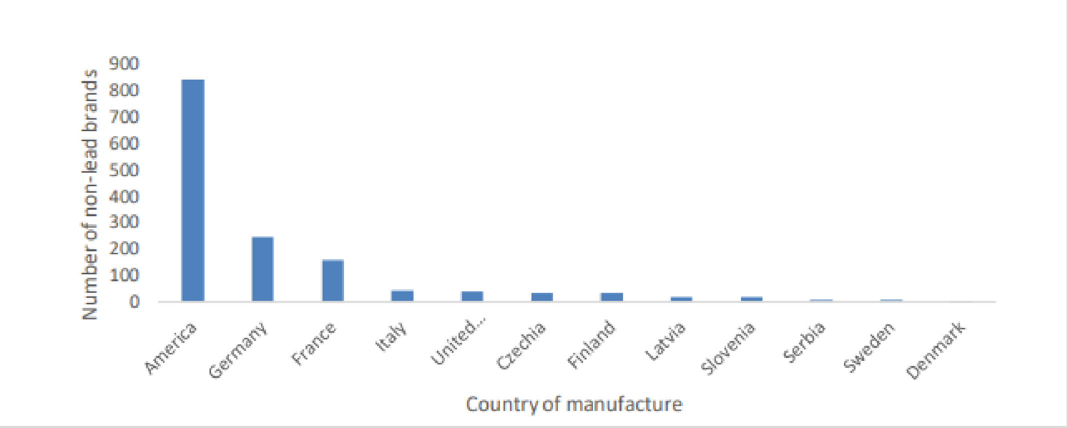
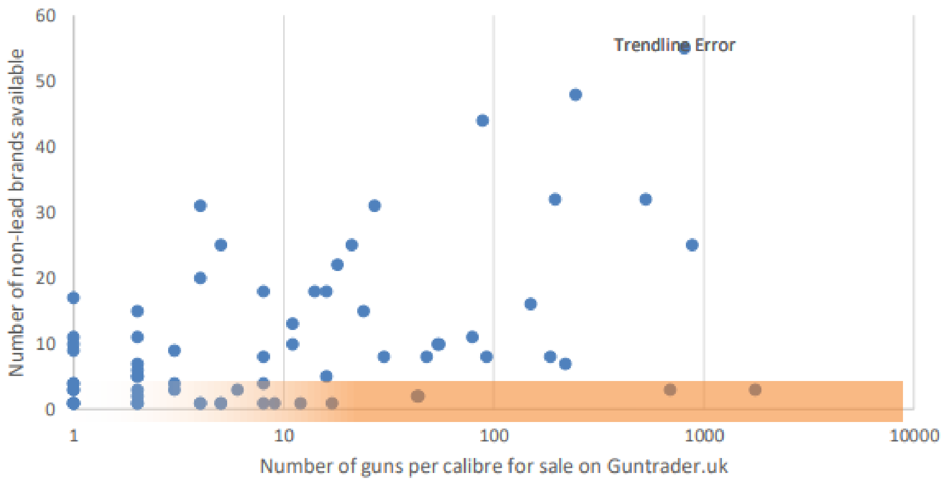


Figure C.11 The number of non-lead brands produced per country (Ellis, 2019)

Generally speaking, the more popular a calibre is, the greater the available choice of ammunition. However, there are important exceptions to this as shown by the orange



box in

Figure C.12, which represents those calibres where there is at least one gun for sale on Guntrader.uk, but there are fewer than 5 non-lead alternatives available (sometimes none).

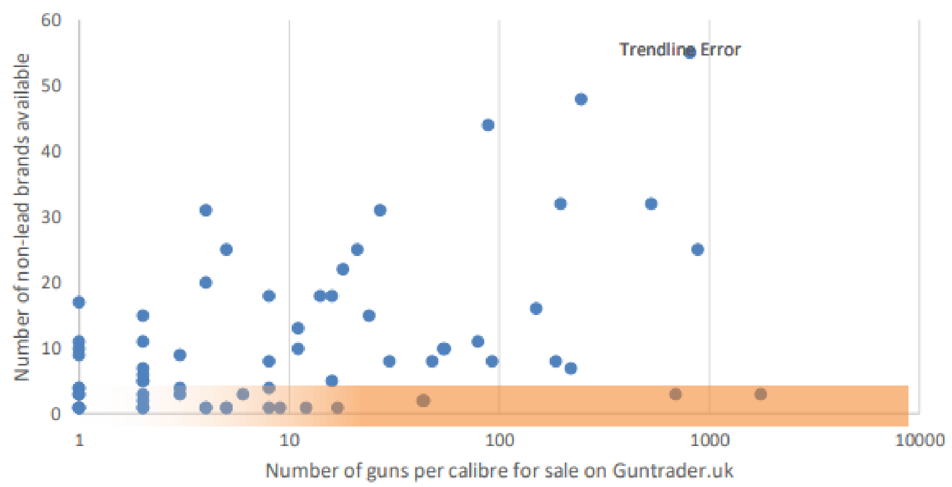


Figure C.12 The relationship between the number of guns for sale on Guntrader.uk and the number of non-lead ammunition brands for that calibre. The number of guns axis is log transformed to aid presentation. The orange box highlights those calibres were there are few non- lead alternatives available

Amongst the top ten most commonly sold calibres there is generally a good selection of non-lead brands available (Table C.19). However, for the rimfire calibres there are only three options each, with limited availability also for .22-250Rem and 6.5x55SE.

Table C.19 The number of non-lead ammunition brands available for the ten

most commonly advertised rifle calibres on Guntrader.uk.

Calibre	Number of guns for sale on GunTrader	Number of non-lead brands available
.22 LR	1763	3
.243 Win	877	25
.308 Win	810	55
.17 HMR	690	3
.223 Rem	528	32
.30-06 Springfield	245	48
.22-250 Rem	218	7
.270 Win	196	32
6.5 x 55 SE	185	8
6.5 Creedmoor	150	16

The most commonly sold calibres with poor choices of non-lead ammunition are shown in Table C.20. These are the calibres that would be most affected by a phase-out of lead ammunition.

Table C.20 The ten most common calibres for sale on Guntrader.uk with five or fewer non-lead brands available.

Calibre	Number of guns for sale on GunTrader	Number of non-lead brands available
.22 LR	1763	3
.17 HMR	690	3
.204 Ruger	44	2
.22 WMR	43	2
7.62 x 54 R	17	1
.260 Rem	16	5
.22 Hornet	12	1
6.5 x 47 Lapua	9	1
.17 Hornet	8	1
.45 Colt	8	4

ECHA carried out an independent investigation into the availability of non-lead alternatives for some of the common calibre types used in the European Union (Table C.21). Of all the examined calibres only two - .222 REM and 17 HMR – were found to have fewer than five non-lead alternative brands available, whereas the remaining calibres had non-lead alternatives available in excess of five, or sometimes even ten, different brands. Some of the non-lead brands were available for most of the calibre types. Of these KJG-SR (Sax Munitions GmbH), Evolution Green (RWS), ZERO (GECO), TUG Nature+ (Brenneke), Naturalis (Lapua), Ecostrike (Norma), HIT (RWS), and GMX (Hornady) were some of the most encountered brands. Much akin to their lead-based counterparts, non-lead alternatives are available in a multitude of grains for hunters to choose from, depending on their specific hunting needs and preferences.

Table C.21 results of ECHA market Study: availability.

Calibre	Available grains	Lead		Non-lead alternatives		Recommended for
		Manufacturer	Brand	Manufacturer	Brand	
9.3 x 62	155 (1) 184 (2) 196 (3) 220 (4) 225 (5) 232 (6) 250 (7) 255 (8) 258 (9) 285 (10) 286 (11) 291 (12) 293 (13)	RWS	Cineshot (3)	Sax Munitions GmbH	KJG-SR (1)	Large and medium sized game (e.g. wild boar, moose, red deer, bear)
		RWS	DK (5)	RWS	Evolution Green (2)	
		Geco	Softpoint (8)	GECO	ZERO (2)	
		RWS	Speed Tip Pro (9)	Brenneke	TUG nature + (4)	
		Remington	PSP (10)	Brenneke	TAG (5)	
		Lapua	Mega (10)	Norma	Ecostrike (6)	
		Winchester	Power Point (11)	Lapua	Naturalis (7;10)	
		Hornady	InterLock ® SP-RP (11)	Hornady	GMX (7)	
		RWS	Evolution (12)	RWS	Hit (7)	
		RWS	UNI CLASSIC (13)	RWS	HIT Short Rifle (7)	
.30-06	124 (1)	Winchester	Ballistic silvertip	Sax	KJG-SR (1)	Light to Medium game

Spr.	136 (2) 147 (3) 150 (4) 155 (5) 165 (6) 168 (7) 170 (8) 180 (9) 184 (10) 185 (11)		(7)			(e.g. wild boar, wild goat, deer, moose).
		Winchester	Ballistic silvertip (9)	RWS	Evolution Green (2)	
		Hornady	Interlock SP (9)	Geco	Zero (2)	
		RWS	Uni Classic (10)	Brenneke	TUG nature + (3)	
		RWS	Evolution (10)	Hornady	GMX (4)	
		Lapua	Mega (11)	Norma	Ecostrike (4)	
		Brenneke	Basic (11)	Brenneke	TAG (5)	
		RWS	SPEED TIP PRO (6)	Hornady	GMX (6)	
				RWS	Hit (6)	
				RWS	HIT Short Rifle (6)	
				Lapua	Naturalis (8)	
				Barnes	TTSX Euroline (4;7;9)	
				Nosler	E-Tip (4;7;9)	
.308 Win.	124 (1) 136 (2) 147 (3)	RWS	Cineshot (3)	Sax	KJG-SR (1)	Medium to heavy game (e.g. antelope, deer, pronghorn, elk,
		Remington	Core-Lokt PSP (4)	RWS	Evolution Green (2)	

	150 (4) 155 (5) 165 (6) 170 (7) 180 (8) 184 (9) 185 (10)	RWS	Speed Tip pro (6)	GECO	ZERO (2)	moose and bear)
		Geco	Express (6)	Brenneke	TUG nature + (3)	
		Geco	Softpoint (7)	Norma	Ecostrike (4)	
		RWS	Uni Classic (8)	RWS	HIT Short Rifle (4)	
		RWS	HMK (8)	Brenneke	TAG (5)	
		RWS	Evolution (9)	RWS	Hit (6)	
		RWS	Speed Tip (9)	Lapua	Naturalis (7)	
		Winchester	Power Point Subsonic (10)	Barnes	TTSX Euroline (4)[57]	
		Lapua	Mega (10)	Hornady	GMX (4;6)	
		Brenneke	Basic (10)			
8x57	127 (1) 139 (2) 150 (3) 160 (4) 170 (5)	Federal	Power-shok (5)	SAX	KJG-SR (1)	Medium to large- sized game (e.g. moose, chamois, badger, red deer, wild
		GECO	Softpoint (8)	RWS	Evolution Green (2)	
		RWS	Cineshot (9)	GECO	Zero (2)	

[57] Also available in 130 and 168 grains.

	175 (6) 180 (7) 185 (8) 187 (9) 195 (10) 198 (11) 201 (12)	RWS	JS HMK (9)	Brenneke	TUG nature + (3)	boar, bear
		WINCHESTER	JRS (10)	Barnes	TTSX Euroline (4)	
		RWS	JS Classic (11)	RWS	HIT (4)	
		RWS	JS Evolution (12)	RWS	HIT Short Rifle (4)	
				Norma	Ecostrike (4)	
				Brenneke	TAG (6)	
				Hornady	GMX (7)	
				Lapua	Naturalis (7)	
7x64	104 (1) 127 (2) 128 (3) 139 (4) 140 (5) 145 (6) 150 (7) 159 (8) 160 (9) 162 (10) 165 (11) 178 (12)	RWS	Cineshot (4)	Sax	KJG-SR (1)	Medium to heavy game (Best for wild boar, red deer and similar)
		Brenneke	Teilmantel ™ (6)	Geco	Zero (2)	
		RWS	Speed Tip (7)	Brenneke	TUG nature + (3)	
		RWS	Speed Tip PRO (7)	Hornady	GMX (5)	
		RWS	Evolution (8)	Barnes	TTSX (5)	
		RWS	ID Classic (10;12)	RWS	Hit (5)	
		RWS	KS (10)	RWS	Evolution Green (9)	

		Geco	Softpoint (11)			
.300 Win.Mag	124 (1) 136 (2) 147 (3) 150 (4) 155 (5) 165 (6) 170 (7) 180 (8) 184 (9)	RWS	Cineshot (3)	Sax	KJG-SR (1;4)	Medium to heavy game (**Especially** recommended for: red deer, wild boar, moose, bear).
		RWS	SPEED TIP (4)	RWS	Evolution Green (2)	
		Federal	Power Shok (4)	GECO	ZERO (2)	
		RWS	KS (6)	Brenneke	TUG nature + (3)	
		Geco	Express (6)	Brenneke	TAG (5)	
		GECO	Teilmantel (7)	Hornady	GMX (6)	
		Geco	Plus (7)	RWS	Hit (6)	
		RWS	Uni Classic (8)	RWS	HIT Short Rifle (6)	
		Federal	Power Shok (8)			
		RWS	Evolution (9)			
.243 Win	58 (1) 75 (2) 76 (3) 77 (4) 80 (5)	Winchester	SUPER X SOFT POINT (5)	Hornady	Superformance® (1;2;5)	For small and varmint-sized game (Alternative for medium sized game, such as deer)
		RWS	WIN TMS	Norma	Tipstrike Varmint (3)	
		Winchester	SUPREME	Sax	KJG-HSR (4)	

	90 (6) 95 (7) 96 (8) 100 (9) 105 (10)		BALLISTIC SILVERTIP (7)			
		Winchester	WSSM (9)	Barnes	Vor-TX (5)	
		Lapua	SoftPoint (9)	Nosler	E-Tip (6)	
		Federal	Power Shok (9)	Lapua	Naturalis (6)	
		Geco	Teilmantel (10)	Brenneke	Win TOG (8)	
				Norma	Tipstrike Oryx (9)	
6.5x55	92 (1) 93 (2) 106 (3) 120 (4) 123 (5) 130 (6) 140 (7) 156 (8)	RWS	Target Elite Plus (6)	SAX	KJG-SR (1)	Mostly recommended for deer-sized or smaller game.
		GECO	Softpoint (8)	RWS	EVOLUTION GREEN (2;3)	
		RWS	Evolution (8)	Lapua	Scenar (4;5;7)	
				Lapua	Naturalis (7)	
				Hornady	SST Superformance (7)	
				RWS	Doppelkern (7)	
17 HMR	239 (1) 247 (2)	Norma	V-Max (3)	Hornady	NTX (1)	Varmint and small-game
		Winchester	V-MAX (3)	CCI	TNT Green (2)	

	262 (3) 309 (4)	Federal	V-Shok TNT HP (3)			hunting.
		Winchester	JHP (4)			
		Hornady	XTP (4)			
		Hornady	V-Max (4)			
.222 REM	40 (1) 50 (2) 55 (3)	Norma	V-Max (1)	Lapua	Naturalis (2)	Small to medium game hunting such as roe deer, small antelopes, fox, and birds.
		Sako	Gamehead (2;3)	Sako	Powerhead II (2)	
		Sako	Range FMJ (2)			
		Sako	Speedhead			
		Hornady	V-Max (2)			
		Lapua	FMJ (3)			
		Norma	Jackmatch (3)			

C.1.5.2.8. Economic feasibility of non-lead rifle ammunition

A comparison of prices for lead-core and non-lead rifle ammunition was presented in(Thomas, 2013)). That study compared the retail prices of nine commonly used calibres (from .223 to .416) of assembled rifle ammunition in different weights, types, and brands available across the USA. It found that prices for the two types of ammunition were generally comparable, and where the non-lead products cost more, the relatively small increase was not enough to deny purchase and use. The same result applies to bulk lead and non- lead compounds, purchase of bullets for ammunition hand- loaders: lead-core and non-lead bullets cost about the same at the retail level. An economy of scale effect is likely to lower the price of non-lead ammunition further, as more hunters adopt this ammunition. A regulated use of non-lead rifle ammunition in hunting would increase an economy of scale effect across the most widely used bullet calibres. Kanstrup (Kanstrup et al., 2016) concluded that non-lead rifle ammunition is largely available in all normal calibres (particularly 6.5×55, 308 Win. and 30–06) in Danish hunting stores at prices comparable to equivalent lead products. The lowest range of availability was found in the small calibres (<6 mm). In Germany,(Gremse and Rieger, 2014)) found non-lead rifle ammunition in adequate supply across the range of hunting calibres typically used, with ammunition for small calibres (≤6 mm) being offered mostly by specialty manufacturers. Pricing comparisons in Germany mirror the conclusions of (Thomas, 2013)

Figure C.13 shows that as the number of non-lead brands for each calibre increases, the price drops rapidly. This is especially true where there are fewer than 5 brands for a given calibre. Once there are more than 5 brands available the price falls more slowly and stabilises at around £2.50 per cartridge.

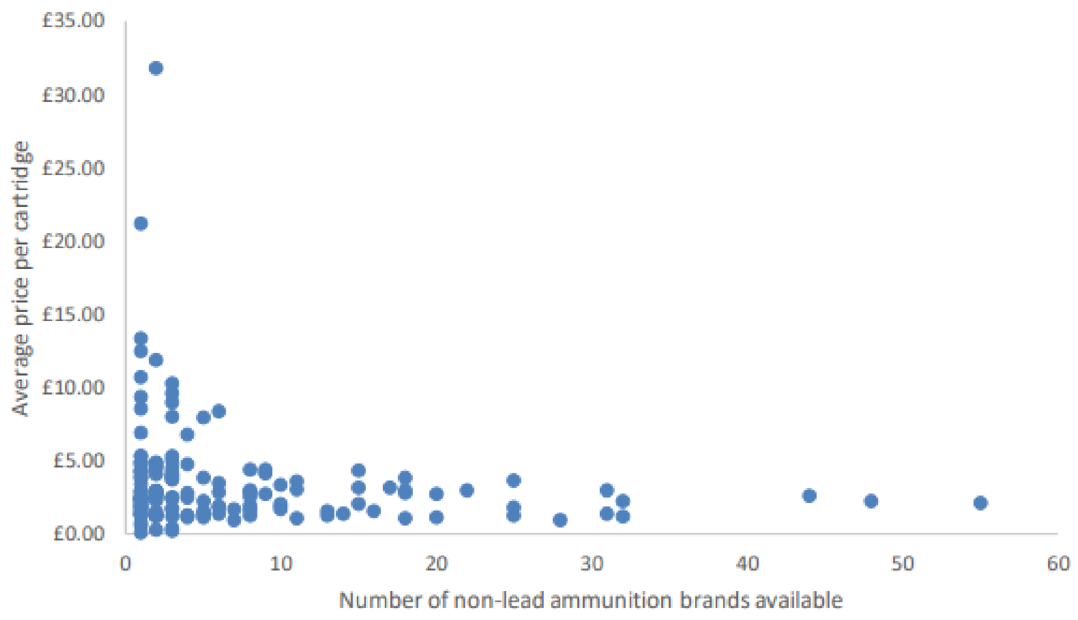


Figure C.13 The impact of availability of non-lead ammunition per calibre on average prices (Ellis, 2019)

An average cost of £2.50 per cartridge seems high for relatively common calibres such as .308 Win. However, this is an average that includes speciality ammunition, as well as normal hunting ammunition. Table C.22 shows that the average cost per cartridge for lead and non-lead cartridges is broadly similar for the ten most sold rifle calibres.

Table C.22 The average cost (and range) for the ten most commonly sold calibres on Guntrader. The cheapest option for each calibre is given in bold (Ellis, 2019)

Calibre	Lead price per cartridge		Non-Lead price per cartridge	
	Average		Average	
.17 HMR	0.59 €		0.43 €	
.22-250 Rem	2.43 €		1.93 €	
.223 Rem	1.53 €		1.40 €	
.22LR	0.22 €		0.26 €	
.243 Win	2.67 €		2.08 €	
.270 Win	2.99 €		2.54 €	
.30-06 Spring	3.02 €		2.53 €	
.308 Win	2.90 €		2.37 €	
6.5mm Creedmoor	2.60 €		1.79 €	
6.5x55SE	2.73 €		3.21 €	

ECHA undertook a market analysis of its own to validate some of the comments submitted in the call for evidence as well as to validate arguments brought forward to support and or object to substitution. The independent market analysis centred on assessing the market availability and pricing of non-lead alternatives for some of the most popular calibre sizes in the European Union. To this end, ECHA surveyed more than 120 online retail stores located in the EU. In the course of performing online searches, ECHA collected information on prices for both lead-based ammunition and non-lead alternatives. Table C.23 displays minimum, average and maximum prices for lead-based ammunition and non-lead alternatives. The non-lead alternatives are further broken down in the following five categories on the basis of the material relied upon in the manufacture of the bullet:

- Copper
- Copper and zinc (brass)
- Copper with steel casing
- Copper and nickel alloy
- Tin

Furthermore, for each calibre size the total number of surveyed online stores and countries is indicated. On the whole, the greater the popularity of the calibre size, the higher the number of online stores and countries in which these ammunitions are sold. For instance, two of the most popular centrefire rifle calibres used for hunting big game-.308 WIN and .300 WIN MAG – were encountered in 70 and 75 online stores respectively, each representing 20 countries.

Table C.23 results of ECHA market study: price difference between lead and non-lead.

Calibre	Online stores		Countries	Price for lead €			Price for non-lead																
							Non-lead (all) €			Copper €			Copper and zinc (Brass) €			Copper with steel casing €			Copper and nickel alloy €			Tin €	
	40		19	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AV
9.3 x 62				38	73	114	50	92	129	50	90	126	68	94	122	88	100	105	-	-	-	72	92
.30-06 Spr.	47		17	30	60	80	30	65	89	50	67	88	54	62	65	30	52	75	60	74	89	39	65
.308 Win.	70		20	30	57	80	40	72	133	52	74	133	54	62	69	70	74	81	-	-	-	40	66
8x57	58		17	30	64	103	51	78	102	58	76	102	66	75	88	70	85	101	70	81	89	51	70

7x64	56		17	32	63	101	32	71	100	58	79	100	52	65	84	-	-	-	-	-	-	32	70
.300 Win.Mag	75		20	27	74	121	57	86	111	77	96	111	58	68	89	81	93	102	-	-	-	57	86
.243 Win	28		16	26	47	63	30	57	80	42	55	80	55	58	61	-	-	-	-	-	-	30	54
6.5x55	18		10	28	51	75	60	86	109	60	77	86	-	-	-	-	-	-	-	-	-	86	95
17 HMR	10		3	19	27	35	21	86	35	21	27	35	-	-	-	-	-	-	-	-	-	-	-
.222 REM	4		2	16	33	45	42	50	59	42	50	59	-	-	-	-	-	-	-	-	-	-	-

For all the calibre sizes, with the unique exception of 17 HMR, average price of the non- lead alternatives lumped together was found to be higher compared with their lead- based counterparts (Table C.23). In few instances, namely for .222 REM and 6.5x55, the average price of non-lead alternatives was more than 50 % higher in comparison with the corresponding lead-based ammunition. In most cases, the average price difference was less than 25 %, and in some it went down as low as 7 % (e.g. .30-06 Spr.).

However, lumping all the non-lead alternatives together, without accounting for the specific material used, provides a potentially skewed and misleading view of the magnitude and nature of the price differences. Given the versatility of the materials used in the manufacture of rifle cartridges and the great variance in the material costs, it is reasonable to suggest that ‘non-lead alternatives’ should be differentiated on the basis of the specific material used. Furthermore, it has been observed that the more popular the calibre is, the more brands are usually available in non-lead versions, which in turn drives down the prices. For this very reason, the price differences between lead-based cartridges and non-lead alternatives for popular calibre sizes is significantly less accentuated than between those for less popular calibres (e.g. 6.5x55).

Table C.24 illustrates price differences between lead-based ammunition and non-lead alternatives, whilst also providing a breakdown of the latter in terms of material used, which provides a more nuanced view of the price-level differences. For instance, for .30- 06 Spr., the average price of all the non-lead alternatives lumped together irrespective of the material differences was 7 % higher than that of the lead-based version. However, the material-specific focus enables us to better unravel the pricing intricacies. The average price of non-lead alternative to .30-06 Spr., based purely on brass would be only 3 % higher than the price of the same calibre bullet based on lead, whereas the average price of an alternative containing copper with steel casing would cost 13 % less. Similarly, for another popular calibre size - .300 Win.Mag – the average price of all the analysed non-lead alternatives was about 16 % higher than that of the lead-based versions, however, the material-specific focus provides a more detailed and informative picture, namely that a brass-based alternative would cost on average 8 % less than the lead-based ammunition of the same calibre. Therefore, it is important that the price differences are viewed in the context of the material-specific breakdown.

Table C.24 price differences with break down on material uses.

Calibre	***AVG price of lead ammo per 1 case (€)***	***% difference with lead***					
		Non-lead ammo	*Copper*	*Brass*	*Copper with steel casing*	*Copper and nickel alloy*	*Tin*
9.3 x 62	*73*	*26 %*	*23 %*	*29 %*	*37 %*	*-*	*26 %*
.30-06 Spr.	*60*	*7 %*	*12 %*	*3 %*	*-13 %*	*23 %*	*8 %*
.308 Win.	*57*	*21 %*	*30 %*	*9 %*	*30 %*	*-*	*16 %*
8x57	*64*	*21 %*	*19 %*	*17 %*	*33 %*	*27 %*	*9 %*
7x64	*63*	*13 %*	*25 %*	*3 %*	*-*	*-*	*11 %*
.300 Win.Mag	*74*	*16 %*	*30 %*	*-8 %*	*26 %*	*-*	*16 %*
.243 Win	*47*	*18 %*	*17 %*	*23 %*	*-*	*-*	*15 %*
6.5x55	*51*	*69 %*	*51 %*	*-*	*-*	*-*	*86 %*
17 HMR	*27*	*0 %*	*0 %*	*-*	*-*	*-*	*-*
.222 REM	*33*	*52 %*	*52 %*	*-*	*-*	*-*	*-*

C.1.5.2.9. Other factors that may influence substitution

Besides prices and product availability, other factors could influence substitution from lead in bullets. These are described in this section.

Adaptation of hunting laws

All though not extensively analysed throughout this dossier, hunting laws in several EU Member States define minimum weight and momentum bullets must have in order to achieve efficient and humane taking of game.

Transition away from lead to non-lead bullets would imply to allow lighter bullets to be used. The need for these changes is recognized in publications like (Kanstrup and Haugaard, 2020b) that strongly suggest, that for the tested types of ammunition in caliber 6,5x55 SE the use of bullet mass and minimum impact energy values as currently specified under § 14 NFS 2002:18 are excluding lead ammunition from use in hunting for all game (Klass 1). Despite that commercially available non-lead bullets and ammunition that have shown closely similar terminal ballistic performance, in standardized, repeatable, terminal ballistic testing are equally fit for the same use.

In view of the results presented (Table C.17) for the German studies this strongly suggests equal field performance for the known quantity leaded constructions and the tested lead free alternatives. A change in legislation reflecting the state of knowledge in science that bases projectile and ammunition selection on measured terminal ballistic performance should generally be considered. This approach would likewise aid decision- making processes in regard of reducing lead introduction in game meat.

Recently the Finnish government hunting laws have been adapted in order to accommodate better the use of non-lead ammunition[58][59]:

The is likely to be a factor of influence in setting the transition period.

C.1.5.3. Lead in other hunting ammunition

C.1.5.3.1. Air rifles

Lead is used as the pellet material due to its combination of properties (density, plasticity, low melting temperature) meaning that it grips the rifling and deforms into the barrel dimensions and has enough weight for continued momentum. There is no other material that has the same range of properties plasticity and low melting temperature.

Non-lead pellets are commercially available in low quantities and are generally made of tin-zinc alloys. The market share is extremely small as the ballistic performance is not sufficient for target shooting.

Common pellet calibres: .177, .22, .25

As one of the most accurate calibres from long distances, the .177 calibre pellet is by far the most popular on the market today. As the smallest pellet of the available

[58] https://www.finlex.fi/en/laki/kaannokset/1993/en19930666_20140412.pdf
[59] https://valtioneuvosto.fi/paatokset/paatos?decisionId=0900908f806821d5 https://riista.fi/mmm-lyijyttomiin-luoteihin-siirtymista-helpotetaan/

calibres, the .177 can be fired at the highest velocities means greater accuracy from longer distances. The .22 calibre pellet is larger in weight and size compared to .177 calibre pellets. .25 calibre is the largest of the common calibres.

When used for hunting, lead pellets are used for pest control. As vermin are not considered “game”, there is no risk to humans from ingesting lead fragments in game meat

Lead-free airgun pellets are usually made from zinc alloy. Though harder than lead, this

material is still malleable and shouldn’t cause any harm to the barrel of your air rifle.

Unlike for hunting bullets, there are no known studies or peer reviewed comparative test comparing the performance of lead and non- lead (often tin) based air rifle pellets

Product reviews on hunting for a, online purchasing fora would suggest that the accuracy of air rifles for hobby shooting (which would cover a fair share of their use) is adequate. However these tests and or reviews are not conclusive enough to come to a firm decision on product suitability.

C.1.5.3.2. Muzzle loaders

In the call for evidence comments were submitted from

- MLAIC - Muzzle Loaders Associations International Federation
- Historical Breechloading Smallarms Association
- The British Shooting Sports Council
- Association of Manufacturers of Hunting and Sport Weapons and Ammunition (JSM)
- British Association for Shooting and Conservation
- Deutscher Schützenbund e.V.
- Classic Old Western Society of Finland ry
- ANPAM - Associazione Nazionale di Produttori di Armi e Munizioni civili e sportive
- Svenska Pistolskytteförbundet
- The Gun Trade Association

- The Finnish Shooting Sport Federation
- Federation of European Societies of Arms Collectors (FESAC).

Many of these firearms are muzzle loading, or early breech loading, which can only be loaded with pure lead balls or bullets. The principle, dating to the 1840s, depends on the bullet expanding in the barrel, to engage the rifling. Only pure lead can achieve this.

Many of the later rifles have a rifling twist that is designed for lead-filled, jacketed bullets, of a certain density range. They will not be accurate when firing bullets under this density range. There are consequently no practical alternatives to pure lead, or jacketed lead, for use in these vintage firearms

These types of guns can only support lead, as there was no other type of ammunition available when they were designed. Many muzzle loading and black powder rifles depend on the expansion of soft lead ammunition during shooting for accuracy. More abrasive metals would cause excessive wear to the barrels and a dangerous loss of accuracy, which could result in bullets flying wide of the bullet catcher.

The abrasive nature of steel shot quickly destroys the barrels of these modern guns, so they are designed for easy barrel replacement, which eliminates the cost of replacing the entire shotgun. This is obviously not the case with antique and vintage shotguns, which have a far higher value than some modern shotguns, due to their rarity. Their continued existence is due to the care with which they are looked after by their owners, who wish to preserve them for future generations, as they are part of our national heritage. This care includes the use of suitable ammunition, which is traditionally lead.

Due to the expense of black powder shotgun cartridges, few people hunt with them, using them mostly for specific, historic clay target competitions.

C.1.6. Alternatives

C.1.6.1. Function of lead

ISSF[60] and FITASC[61] rules requires the use of lead shot with a gauge not greater than 12 mm, usually 12 mm is used. Shotguns must be smooth bored. They are

[60] https://www.issf-sports.org/getfile.aspx?mod=docf&pane=1&inst=462&file=1.%20ISSF%20Shotgun%20Rules_2020.pdf
[61] https://www.fitasc.com/upload/images/reglements/20191001_Rglts_CS_01012020_ENG.pdf

invariably 12-gauge, single-triggered and over-under type — one barrel is placed above the other. They fire cartridges loaded with lead pellets: the weight of the pellet load must not exceed 24,5 grams per cartridge; the diameter of each pellet must not exceed 2,6 millimetres. Guns and cartridges are subject to official checks during the shooting program.

The ammunition that is used must ‘Pellets must be made of lead, lead alloy or of any other ISSF approved material’ but most commenters in the call for evidence indicated that in practice lead is most frequently used.

According to BIS Research[62] (Research, 2012) the most popular calibre for sports shooting is gauge 12 , followed by gauge 20,28 and 16 (see Figure C.14)

[62] Research. (2018). Market size of the global sports gun market for shotguns in 2017, by calibre type. Statista. Statista Inc.. Accessed: December 02, 2020. https://www.statista.com/statistics/994613/market-size-global-sports-gun-market-shotguns- caliber/

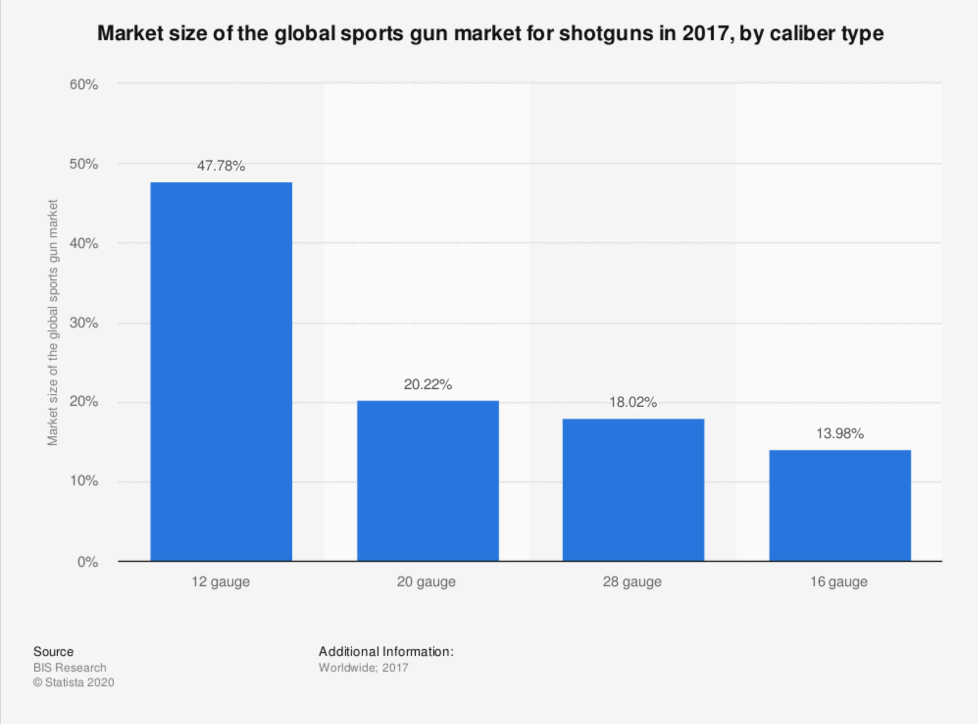


Figure C.14 market size of global sports gun market.

Shooting sports that use shotguns (e.g. trap and skeet, sporting clays) discharge lead projectiles over a diffuse area and a single cartridge may contain up to 36 g47 of lead, but a 32 g load is the most common. In addition, large numbers of cartridges are used hence creating high lead shot densities in the impact area. The nature of trap and skeet shooting causes spent shot to land in a wide but predictable impact area. Sporting clays shooting typically takes place over 40-100 ha of land, and the continually changing layout of the course means that loadings of shot occur over a much wider area than for trap and skeet. Rifle and pistol shooting sports generally fire projectiles into backstops. Hence, these sports have lead accumulations in a more restricted area. Where projectiles are fired into earthen backstops lead may be readily removed from the backstops and recycled (Darling and Thomas, 2003).48

Typically for skeet/trap shooting a full box of 25 rounds is typically used (typically using 32 g lead per shot with 12 gauge ammunition). One round of trap or skeet shooting (25 shots) will add therefore add 800 g of lead per shooter to the impact area. A session of sporting clay shooting uses 50 or 100 rounds and typically 12 gauge ammunition is used (containing 32 g of lead per shot). A typical round of sporting clays (100 shots) will release 3.2 kg of lead per shooter to the impact area (Darling and Thomas, 2003).

Darling and Thomas (2003) noted that rifle/pistol target shooting sports that fire solid bullets into earthen backstops, while still presenting a potential environmental lead hazard, were less of a concern than shotgun sports (trap/skeet/sporting clays) due to the greater amount of lead per cartridge and the more diffuse fallout from discharged shot.

C.1.6.2. Suitability of non-toxic shot

The shot type and gauge that is required in sports shooting events (12 mm) is a load for which commenters in the public consultation had indicated that many alternatives exist (at least for hunting purposes).

The suitability of alternatives has been discussed by Thomas who highlights that the ISSF rules prescribe the use of lead or other approves shot and that shot made from steel is not approved by the ISSF. In reaction to this (Thomas add source) argues that steel would be as suitable alternative because

1. volume of cartridges fired by competitors,
2. the parity with prices for lead cartridges,
3. the suitability of steel shot to be used in trap and skeet events,
4. and the ease of substitution for lead shot in conventional 12 and 20 gauge shotgun cartridges

According to ((Thomas and Guitart, 2013)) Olympic skeet and trap shooting regulations do not stipulate which gauge of shotgun can be used, only the shot load. Consequently, 12 gauge guns dominate the events because of the higher number of shot that can be fired at each target compared to those fired from 20 gauge guns. This facilitates the use of 12 gauge cartridges for Olympic shooting events. ((Thomas and Guitart, 2013)).

Thomas presents a number of factory loads that are widely available and that could be considered as alternative for lead shot in shooting.

Table C.25 Characteristics of steel shot shotgun cartridges for clay target shooting made by major international cartridge companies in 12 and 20 gauge (ga). Velocity of shot is given as feet per second (fps), and meters per second (mps). All cartridges are 70 mm.

Company and cartridge gauge	Shot mass (oz and g)	Shot size (English) and diameter (mm)	Muzzle velocity (fps and mps)
Kent Gamebore			
12 ga	1 oz 28.4 g	#7 (2.4 mm)	1290 fps: 393 mps
12 ga	7/8 oz 24.8 g	#7 (2.4 mm)	1350 fps: 451 mps
20 ga	7/8 oz 24.8 g	#7 (2.4 mm)	1215 fps: 370 mps
Federal			
12 ga	1 oz 28.4 g	#6,7 (2.6, 2.4 mm)	1375 fps: 419 mps
12 ga	11/8 oz 31.9 g	#7 (2.4 mm)	1145 fps: 349 mps
20 ga	¾ oz 21.5 g	#7 (2.4 mm)	1210 fps: 369 mps
Winchester			
12 ga	1 oz 28.4 g	#7 (2.4 mm)	1325 fps: 404 mps
20 ga	¾ oz 21.5 g	#7 (2.4 mm)	1325 fps: 404 mps
Remington			
12 ga	1 oz 28.4 g	#7 (2.4 mm)	1325 fps: 404 mps
20 ga	¾ oz 21.5 g	#7 (2.4 mm)	1325 fps: 404 mps
Rio Cartridges			
12 ga	1 oz 28.4 g	#7 (2.4 mm)	1325 fps: 404 mps
20 ga	7/8 oz 24.8 g	#7 (2.4 mm)	1325 fps: 404 mps

According to Thomas, the loads presented in table closely fit the ISSF requirements:

1. Given the lower density of steel shot versus lead shot, it is necessary to use steel shot of a larger diameter than the lead equivalent, coupled with an increase in shot velocity, to achieve the same ballistic efficiency and effective range. Thus a shot diameter of 2.6 mm might be advisable for Olympic trap shooting, in which targets may be broken at a longer distance than in skeet shooting. The ISSF regulations would, already, allow pellets of this diameter to be used (ISSF 2012)
2. The maximum allowable velocity of steel shot cartridges, as set by the International Proof Commission is 425 m/s (Government of Victoria 2011). A velocity of 390 m/s (for example) would equate with the same velocity of many lead shot cartridges, and still enable steel shot cartridges to perform well at the distances that trap and skeet targets are usually hit.

According to Thomas, the possibilities to substitute lead exist but would require approval of the ISSF and other federation to allow the use of non-lead shot.

In the call for evidence comments were submitted from the following organisations:

- International sports shooting federation (ISSF)
- Fédération Internationale de Tir aux Armes Sportives de Chasse (FITASC) And various other shooting clubs and individual sports shooting clubs

Among the points most frequently brought forward are the following:

C.1.6.2.1 Ricochet in sports shooting ranges

The issue of ricochet and increase risk thereof when using steel shot has been widely discussed. Many of the commenters highlighted the risk of increased ricochet at shooting ranges due to the use of steel shot.

The Dutch shooting federation[63] highlighted that in the use of steel shot at shooting ranges they had no encountered any accidents related to ricochet of steel shot since the introduction of the general ban on the use of lead at shooting garages; objects on which steel shot could ricochet had been covered with wood.

C.1.6.2.2. Noise

In response to follow up questions, the FITASC submitted an extensive study on the

[63] Personal communication Sander Duivenhof

possibilities to substitute lead with steel in sports shooting. This submission contained a comparative study in the levels of noise generated by both lead and steel and argued that using steel shot would require guns to generate higher pressure which would be associated with higher noise levels. These levels would be of such a degree they are no longer compliant with regulatory limits (the study quotes the French regulatory framework for noise).

In a number of EU countries, clay shooting ranges are subject to an authorisation procedure prior to their installation, during which the potential for noise and soil and pollution are investigated.

The essence of these regulation when it comes to noise is to limit the level of noise to avoid neighbourhood disturbances.

In their submission, FITASC argues that the use of steel shot would lead to more noise, this is based on a acoustics study that using steel sheet is associated with an increase of

11.5 % in pressure generated in the same gun, shooting similar loads. This increased pressure would is caused by the higher powder charge used for steel projectiles and cause an increase in noise during the detonation phase.

Such an increase in pressure would at 100 m distance cause an increase in noise of around + 6 to +9 db using steel. Measurements were performed using the NF s 31-160(20129)[64] and NF EN ISO 17201-1[65](December 2018) standards.

Taking into account the comparative noise levels measure at the same point of 83 db and (lead) and 92 db (steel) an increase of 6 db gives an increase in sound pressure of pf (0.796-0.282) 180 % and would constitute a breach of peace.

The submission does not argues to what extend this breach of peace is achieved by all shooting ranges and its representativeness is therefore not known.

The Finnish Bat on management of shooting ranges says on noise that

The possibilities for noise prevention at a shooting range depend on what the starting situation is like. If one starts implementing noise control measures from a situation where the shooting range does not have firing enclosures, noise berms or any other structures intended for noise abatement, one can achieve clear noise abatement results with enclosures and berms to the sides and the rear, for instance,

[64] French national standard uses in **Arrêté du 5 décembre 2006 relatif aux modalités de mesurage des bruits de voisinage (See : https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000463330&dateTexte=20180803)**

[65] Acoustics — Noise from shooting ranges, see https://www.iso.org/standard/66940.html

from 5 to as much as 15 dB. However, if the starting situation is that the range already has relatively good enclosures, side berms and possibly other noise control measures implemented as well, it may be difficult to achieve an additional noise abatement of just 5 dB at the site

And highlight that noise management is first and foremost a matter of location, it recommends using noise zones to avoid noise disturbance. The BAT states that, according to estimates, 285,000 people live (in Finland) the noise areas of public highways, and 500,000...600,000 in the noise areas of city streets. In total, around

1 000 000 people are estimated to be exposed to noise exceeding the guideline values (Saarinen A 2013). The number of people exposed to shooting range noise is less than 1% of this.

The dossier submitter recognises that noise may be an issue but also highlights that without contextual information (population living around shooting ranges) this point is difficult to assess further.

C.1.6.2.3. Impact on guns

According to Thomas, there would be no impact on the guns from the use of steel shot cartridges for sports shooting.

Thomas argues that damage to the choke of barrels could occur and that this is a possibility with heavy magnum steel cartridge loads with large diameter shot (>3.6 mm) fired through barrels with abrupt large choke constrictions (i.e., full and extra full choke).

However, Tomas argues that such cartridges designed for long distance fowl hunting would never be admissible for Olympic events. Both the shot loads and the shot size of cartridges suited for Olympic shooting would permit ready passage of steel shot through any choke constriction. Skeet shooting uses the smallest barrel choke constriction of any event, so this concern does not exist. Trap shooting requires choke constrictions, and small steel shot of diameter 2.5–2.6 mm can be used in existing guns designed for lead shot cartridges. Modern competitive trap shotguns are designed with removable choke tubes of different choke constrictions, allowing competitors to select the choke constriction that gives them the optimal shot pattern at the distance they usually break clay targets. Coated steel shot, unlike lead shot, can also be retrieved easily from the fallout zones of shooting ranges using portable magnetic machinery, and be recycled, or possibly re-used.

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C.1.7 Other information on alternatives

Additional information regarding the cost of lead alternatives in the UK and accuracy implications of the replacement of lead ammunition with lead-free alternatives was provided in the responses to the call for evidence and in additional data sources identified by the Agency.

C.1.7.1 Accuracy

C.1.7.1.1 Target Shooting

The International Shooting Sport Federation (ISSF) supplied information in response to the call for evidence which highlights the requirement of a high level of accuracy particularly for international athletes competing at a high level and states that only lead bullets are capable of this. In addition, the existing law limits the muzzle energy with airguns to a maximum of 7.5 Joules and it is stated that it isn't understood whether modified or new airguns capable of firing lead-free rounds can stay within this limit.

In July 2020, Fédération Internationale de Tir aux Armes Sportives de Chasse (FITASC) published a comparative analysis between the ballistic trajectory characteristics of lead and steel pellets (Audibert, 2020), the findings of which are summarised in Table C.26.

Table C.26 Comparison of parameters in order to obtain the same reach with a steel pellet

Pellet material	**Mass (g)**	**Reach (m)**	**Ejection velocity (m/s)**	**Energy at ejection (kg-equiv)**	**Recoil at ejection (kg-equiv)**	**Flight duration (ms)**	**Impact velocity (m/s)**	**Impact energy (mj)**
Lead	0.082	107.77	400.0	6572	3.35	685	79.4	259
Steel	0.056	107.77	645.7	11617	3.67	723	59.0	97
Variation Steel vs Lead			+61.4 %	+76.8 %	+9.5 %	+5.6 %	-25.7 %	-62.6 %

Tests were undertaken comparing the ballistic behaviour of steel and lead pellets in lateral wind speeds of 0km/h and 30km/h. The analysis concludes that when shot under the same conditions, the reach of a steel pellet is significantly shorter, reaches a highest altitude significantly lower and loses energy significantly faster than that of a lead pellet. Furthermore, the steel pellet was more significantly affected by wind than lead.

In an addendum (dated May 2021) by FITASC and ISSF/ESC calculations were provided for steel pellets intended as a replacement for trap shooting with diameters ranging from 2.4 mm to 3.0 mm and muzzle velocities ranging from 390 m/s to 600 m/s and the resulting energies (in joules) for these pellets at ranges of 30 m, 40 m and 50 m.

The conclusion drawn is that a replacement of lead with steel alternatives would result in a decrease of performance of 34%, 41% and 47% at 30m, 40m and 50m respectively. There are two specific shooting conditions where the steel pellet performs approximately (falls within a +/- 5% range) as the lead pellet, namely where the pellet has a diameter of 2.9mm with a muzzle velocity of 425m/s or a diameter of 3.0mm with a muzzle velocity of 425m/s.

For skeet shooting, a similar set of calculations were produced for diameters from 2.4 mm to 3.0 mm and muzzle velocities ranging from 390 m/s and 600 m/s at 30m. These results show a decrease in performance in 49 of the 56 shooting conditions, with 7 shooting conditions being comparable to lead.

Within this document a study by Audibert (2021) relating to shot cartridges used in sport shotguns is referenced. The behaviour of 4 types of ammunition shot from a gun both horizontally and at a 40° upwards angle were calculated in a simulation. The conditions were set at projectiles being fired from a height of 1.5 m and a velocity of 400 m/s. This concluded that the reach of steel pellets is 17 % less and the energy is almost half than that of lead.

In response to the call for evidence, a paper was provided detailing tests conducted by the National Small-bore Rifle Association (NSRA) examining the accuracy of 5 different .22 rim fire rounds (2 lead and 3 lead-free). This was conducted at the Eley limited test range in Birmingham where an Anschutz Match 54 action rifle (considered by the NSRA to be representative of a popular, reasonably accurate rifle) was fixed to a test rig and 40 rounds of each type of ammunition was fired at a distance of 50m in groups of 10 shots which is the standard testing regime used. The results are outlined in Table C.27.

Table C.27 A summary of results from the test conducted by the NSRA examining the accuracy of .22 rim fire lead and non-lead rounds fired at 50m

Material	Type	Group (40 shots) mm	Expected Decimal Score	Integer Score
Lead	Eley Club	27.1	617.36	393
	Eley Tenex	18.9	633.64	400
Non-lead	CCI Copper	48.9	579.13	368
	RWS Green	70.7	534.55	316
	Norma Eco Speed	76.2	532.24	314

Comparing the results from this test with the standard of scores in competitions the NSRA concluded that the accuracy of the lead-free rounds were lower than that of the lead rounds.

At the NSRA Aldersley Range at Wolverhampton tests were conducted on the accuracy of lead and non-lead airgun pellets. A fixed test rig was used to fire two rifles, an Anschutz 9007 and Air Arms S400 each at a distance of 10 m and 25 yards respectively.

Table C.28 Results for the test of accuracy of lead and non-lead rounds fired from an Anschutz 9007 air rifle at a distance of 10m

Material	Type	Group (10 shots) mm
Lead	H and N Finale Match Light	4.95
Non-lead	RWS Hyper Match	9.12
	RWS Hyper Dome	11.00
	H and N Field Target Trophy Green	8.75

Table C.29 Results for the test of accuracy of lead and non-lead rounds fired from an Air Arms S400 air rifle at a distance of 25 yards

Material	Type	Group (10 shots) at 25 yards (mm)	Group (10 shots) factored to 20 yards (mm)
Lead	JSB Exact	13.2	10.6
Non-lead	RWS Hyper Match	44.7	35.8
	RWS Hyper Dome	73.4	58.7
	H and N Field Target Trophy Green	38.2	30.6

The NSRA noted that the difference in accuracy between the lead and lead-free .22 rimfire ammunition was again noticed when using air rifles for both field target and hunter field target but at a greater significance and that the issues become more apparent when the test was conducted at a greater distance from the target.

As a result the NRSA have concerns that the inaccuracy of lead-free ammunition and its ballistic inefficiency would turn competitive shooting into a matter of chance rather than skill, both for small-bore and air rifle shooting disciplines.

C.1.7.1.2 Hunting

Kanstrup (2018) reported that studies have shown that shooting efficacy is more related to the experience of a hunter and the distance which the shoot takes place rather than the material of the cartridge and that cartridge performance was shown to be largely independent of the shot material itself.

Kanstrup also states that the quality of non-lead shot types were initially of low quality but the efficiency of these have improved. Additionally, this report refers to studies by Hartmann (1982), Kanstrup (1987), Strandgaard (1993), Mondain-Monval *et al*. (2015) and Pierce *et al*. (2014) which concluded that there was no difference in the efficacy of lead and steel shot. Steel and other alternatives can be used as effectively as lead shot for water bird hunting (Thomas et al., 2014).

Factors such as shot sizes, shooting distances, and cartridge quality (i.e. sufficient energy and conformity of components) play a more important role than the material the shot is made of. In addition whilst shooters may need to adapt to using different ammunition, the success of the shot is as a result of the ability of the shooter rather than the ammunition used.

Regarding the need to modify existing firearms due to the risk of damage caused by steel, Kanstrup (2018) reports that at the time of writing, most experts regard modifications unnecessary.

C.1.7.2 Cost

Thomas (2014) contains a breakdown of prices for lead shot alternatives from a UK on-line retailer (Table C.30).

Table C.30 Comparative prices for lead and non-toxic shotgun cartridges in 12 gauge (as taken from a major cartridge selling website). Prices are those advertised in November, 2014).

Shot type	Manufacturer	Price per box of 25	Price per case of 250
Steel shot	3 different UK makers	£7.10-7.75	£64-69
Bismuth-tin shot	Eleyhawk	£36.25	£323
Hevi-Shot	Loaded in the UK	£56	£497.50
Tungsten Matrix	Gamebore	£70	£626.25
Lead shot (across 4 UK makers):			
Lead	Gamebore	£6.80-6.95	£60.50-£62.00
Lead	Eley	£6.95-7.05	£62.00-63.00
Lead	Hull	£9.25-£9.50	£81.25-83.00
Lead	Lyavale	£8.15-9.70	£72.75-86.75

In response to the call for evidence, a paper was provided by the National Small-bore Rifle Association (NSRA) with information on the cost of lead-free alternatives (Table C.31, Table C.32).

Table C.31 Cost of .22LR cartridges

Ammunition Type		**Cost (per box of 50 rounds)**
Lead Rounds	Eley Club	£5.25
	Eley Tenex	£11.75
Lead Free Rounds	CCI Copper (copper-polymer compostition)	£11.95
	RWS Green HV (copper plated zinc)	£10.50
	Norma Eco Speed (copper plated zinc)	£8.07

Table C.32 Cost of .177 Pellets

Ammunition Type		**Cost**	**Cost (factored to 500)**
Lead Rounds	H and H Finale Match Light	£10.00 per 500	£10.00
	JSB Exact	£11.00 per 500	£11.00
Lead Free Rounds	RWS Hypermatch (tin)	£8.99 per 250	£17.98
	RWS Hyperdome (tin)	£7.49 per 200	£18.73
	H and N Field Target Trophy	£11.99 per 300	£19.98

The NRSA reports that the cost of lead-free airgun pellets is considerably higher than their lead counterparts. This has even more impact than for .22LR since airgun shooting represents the easy access end of target shooting sport; the ranges are easier to build and access, and there is no requirement for a firearms certificate.

On the topic of cost, the paper concludes that there are concerns that if lead ammunition were no longer available for use it would mean that clubs would have to revisit the construction of their ranges in order to ensure compliance as specifications for ranges established in documents including the Military JSP 403 and its civilian equivalent "The Design Construction and Maintenance of Target Shooting Ranges" are based on the use of lead ammunition. The majority of clubs are run by volunteers and operate on an at cost basis, so significant costs incurred by clubs would be carried by the membership. This would affect accessibility to the sport from a financial perspective which will impact people from a wide socio-economic backgrounds as the sport attracts schools, uniformed groups (scouts, guides, cadets etc.) and youth organisations.

The Historical Breechloading Smallarms Association (HBSA) provided a response which stated that whilst bismuth shot may be used in some shotguns it is extremely expensive and not practical for competition shooting.

The value of firearms unfit for modification required to use steel shot has been estimated by The British Shooting Sports Council (BSSC) and are broken down in Table C.33.

Table C.33 Estimated value of firearms within the UK unsuited for using lead-free ammunition

Type of firearm	**Estimated cost**
Shotguns	£940,777,440
Cartridge rifles	£302,400,000
Muzzle loading rifles	£20,000,000
Airguns	£2,450,000,000
Total	£3,713,177,440

The addendum May 2021 document supplied by FITASC states that tungsten and bismuth appear to be best substitutes and that tin can be used to increase hardness but has a high cost compared to bismuth. ISSF states that the use of steel shot for Olympic and non-Olympic shooting activities would require a complete redesign of trajectories and a complete reorganization of shooting ranges thus representing an unbearable cost for many shooting ranges.

Kanstrup (2018) reported that during the transition period in Denmark after the early introduction of steel shot in 1981, the price was a significant concern however steel shot is now cheaper than lead shot equivalents for sport shooting and are available for the same price for hunting, whereas other non-lead types, like bismuth and tungsten shot, cost significantly more.

Schulz *et al*. (2021) reported that when gauging attitudes about the use of lead and non-lead ammunition, hunters who used lead ammunition agreed more strongly with the statements that 'non-lead damages firearms', 'non-lead was not accurate' and 'lead is more effective in killing deer' than non-lead users.

Non-lead users agreed more strongly than those unlikely to use alternatives that 'non-lead was ballistically superior', 'compatible with modern firearms' and that there is 'minimal complexity using non-lead'. Non-lead users also agreed more than lead users that alternatives cost too much and are difficult to find in stores.

Kanstrup and Thomas (2020) stated that the product range of lead free ammunition in countries where there are partial regulations is restricted compared to lead shot brands. This is not limited by production but rather by demand at national, regional and local levels

Some alternative types, including bismuth and tungsten based, gunshot are significantly more expensive than lead shot cartridges. In terms of the overall budget of hunters however, the cost of ammunition is proportionally low.

The most common alternative shot (steel) is expected to become significantly cheaper than traditional lead shot following the manufacturing patents ending in 2019 since the production costs will lower substantially.

In Canada non-lead gunshot are required for waterfowl hunting or hunting on wetlands but lead is still allowed in gunshot for upland game hunting, Thomas (2019) reports that every species of provincially or territorially regulated game that is currently hunted with lead shot can be effectively hunted with any of the three major types of non-lead shot cartridges, namely steel, bismuth tin-alloy and tungsten-based. Whilst steel shot cartridges may cost slightly more than equivalent high quality lead cartridges and those containing bismuth-tin shot or that are tungsten-based are significantly more expensive, Thomas (2019) claims that in the event of a that a transition to non-lead is required, most hunters of upland game will continue to use steel shot cartridges as they are the cheapest and most readily available alternative to lead cartridges and there is no great economic barrier to making this transition.

Widemo (2021) conducted a survey gauging the habits of shooters in Sweden during the phasing out of lead shot. Responses to the survey showed that of those who practiced using a shotgun, 41.5 % used steel, 57.4 % used lead and only 0.5 % had used bismuth or tungsten.

Cromie *et al.* (2019) reported that whilst ammunition manufacturers supply non-toxic ammunition ranges, lead ammunition remains a product with demand and therefore industry will continue to produce it due to profit. Initiatives including a non-toxic ammunition scheme or ammunition swap in the USA and the African-Eurasian Migratory Waterbird Agreement (AEWA) Non-toxic Shot Workshop held in Romania have shown to be successful in removing practical obstacles in the transition to lead-free alternatives and distrust in their performance.

Annex D Impact assessment

Uncontrolled risks to the environment and human health arising from the use of lead ammunition have been identified for all the use scenarios. Possible REACH related risk management options other than restriction are detailed in Table D. 1. None of these would be effective in reducing the risk to either human health or wildlife. Instead, a number of different risk management options are considered for each use in the following Sections.

Table D. 1 Other risk management options

Risk management option	Could support the preferred risk management option?	Description of the option
REACH authorisation	No	Lead is classified as Repr. Cat 1a, and as such is identified as a SVHC, so it could be included on the Candidate List and prioritised for Annex XIV inclusion. However this would cover all the uses of lead massive and not just the use in ammunition. It would also not apply to imported articles, so is therefore not an appropriate option to reduce the identified risks.

Risk management option	**Could support the preferred risk management option?**	**Description of the option**
REACH Restriction onsubstances and mixtures for consumer uses classified as reproductive toxicants cat. 1A or 1B and listed in appendices 5 and 6 (Restriction entry 30)	No	As described below by ECHA (2021a) lead ammunition is out of scope of this restriction. ‘Lead and its compounds are classified as reprotox. 1A in the CLP Regulation and are listed in appendix 5 to entry 30. Nevertheless, Reprotox. substances that are present in articles are not within the scope of the restriction imposed by entries 30. Therefore this restriction entry cannot apply to lead ammunition.’

Risk management option	**Could support the preferred risk management option?**	**Description of the option**
REACH Restriction onlead in articles – Article 69(4) (Restriction entry 63)	No	As described below by ECHA (2021a) lead ammunition is out of scope of this restriction. ‘According to the restriction Entry 63 - paragraph 7: lead and its compounds ‘shall not be placed on the market or used in articles supplied to the general public, if the concentration of lead (expressed as metal) in those articles or accessible parts thereof is equal to or greater than 0,05 % by weight, and those articles or accessible parts thereof may, during normal or reasonably foreseeable conditions of use, be placed in the mouth by children.’ The associated guideline clarifies in Table 2c the list of articles which are considered out of scope of the restriction due to non-mouthability / non- reachability under normal or reasonably foreseeable conditions of use. It includes "ammunition is typically out of the reach of children in normal or reasonably foreseeable conditions of use”.’

D.1 Lead in hunting

Please see the main report for details

D.2 Outdoor sports shooting with shot cartridge ammunition

Please see the main report for details

D.3 Outdoor sports shooting with lead-based bullets

Please see the main report for details

D.4 Impact assessment

D.4.1. Approach to impact assessment

There are various uses of lead in ammunition which involve different sectors and different stakeholders in the value chain. Exposure and releases to the environment vary also depending on the type of use. Because of different technical functions needed for each use, the readiness, availability and costs of suitable alternativesvary also among the uses. For the purpose of this impact assessment, the uses are therefore grouped into two overarching sectors: hunting and sports shooting.

Because of the differences in the identified uses of lead, different restriction conditions are proposed, and use-specific impacts are expected from the restriction. This is particularly true for the risk reduction capability, the costs, benefits and other socio-economic impacts of the proposed restriction. In order to recognise these specificities, separate impact assessments (incl. risk reduction capability (effectiveness), costs, socio-economic aspects and proportionality) are carried out for the different sectors of use concerned by the proposed restriction, i.e. for the use of lead in hunting, sports shooting and fishing.

The geographical scope of the impact assessment is GB.

- Regarding the timeline for the impact assessment, 2022 was assumed to be the first full year of entry into force of the proposed restriction, and a 20-year period was assumed as horizon of the impact assessment.
- Some of the text in this analysis is based on ECHA. Where ECHA use EU data and evidence, this has been replaced by UK data if available. When UK data has not been available, this analysis uses data produced by ECHA and adjusted for the UK population as a proportion of the EU (~13%). This has then been adjusted for GB population (97% of UK).
- The appraisal period used is 20 years and the discount rate is the Green Book recommended 3.5%. ECHA analysis uses a 4% discount rate, so where ECHA costs are used, they have been adjusted.
- Price year: the different sources of costs and benefits are in different price years (include the detail here). The have all been adjusted to 2021 prices using HMT GDP deflators.

D.4.2 Costs

D.4.2.1 Substitution costs methodology

The ECHA report calculates the substitution cost induced by the current restriction proposal as comprised of a stock cost (for testing existing guns and prematurely replacing non-standard proofed shotguns) and a flow cost (related to the incremental cost from switching over to non- lead gunshot). In order to make these two cost components commensurable one needsto i) bring forward the replacement of non-standard proofed guns, and ii) convert the stock cost into a constant annuity, which can then be compared to the incremental costfrom using steel and bismuth shot. Both steps are explained below (following Sydsæter et al., 2005), the actual results of the substitution are presented in the next section.

This section covers the ECHA methodology for calculating substitution costs. The method used in the impact assessment for GB is based on this but adapted for the different circumstances.

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D.4.2.1.1 Forwarding the replacement of shotguns

As explained in the main report, the central case scenario and the worst case scenario both presume that a certain number of non-standard proofed shotguns would need to beprematurely be replaced. Under the worst-case scenario it is assumed that these guns would not have been replaced over the 50 years following the entering into force of the restriction; under the central case scenario it is assumed that 95 % of the shotguns thatwould need to be prematurely replaced, would have been replaced (in equal annual proportions) over the 20 years following the entering into force of the restriction, whereas 5 % would not have replaced over the 50 years following the entering into forceof the restriction.

It is useful to introduce the following notation for modelling the forwarding of the investment into new shotguns. Let:

- N denote the total number of non-standard proofed shotguns to be replaced;
- $n = N/(T - \delta)$ be the constant annual fraction of shotguns to be replaced over the relevant period T (taking into account a transitional period to comply of δ years);
- P be the average retail price of a new shotgun; and
- r denote the social discount rate.

Then, the present cost (PC) of forwarding the purchase of those shotguns that would nothave been replaced otherwise can be modelled as:

$$PC(not\ replaced\ otherwise) = N * P * (e^{-r\delta} - e^{-rT}),$$

whilst the PC of forwarding the purchase of those shotguns that would have been replaced (in equal annual proportions, i.e. entailing a constant stream of replacement cost) over the next 20 years can be modelled as:

$$PC(replaced\ otherwise) = \int^{T} n * P * e^{-rt}dt = n * P * (\ e^{-r\delta} - e^{-rT})/r.$$ I

n the calculations presented in Table XXX of the main report a transitional period of δ = 3years and a social discount rate of 4 % (in accordance with the SEA guidance on restrictions) are assumed.

D.4.2.1.2 Annuitisation of the stock cost

The obtained PC of replacing the stock of non-standard proofed shotguns needs to be converted into a constant annuity to make it commensurable with the annual flow cost (i.e. the incremental cost of using alternative shot ammunition). This can be achieved by annuitising the estimates as derived above using the standard formula:

$$PC = A\frac{1-(1+r)^{-T}}{r} \leftrightarrow A = PC\frac{r}{1-(1+r)^{-T}}.$$

This results in a constant annuity A, which, when paid each year over the next T yearsand assuming a constant social discount rate r, corresponds to the PC.

D.4.2.1.3 Private vs cost of the restriction

There is obviously a difference between the private cost of the restriction to be borne by the individual hunter and the social cost of the restriction. The private cost as calculated in Section XX of the main report contains the VAT, which is a simple transfer from hunters to governments and should therefore be disregarded when calculating the social cost. One may turn to a stylised micro-economic model to think about the welfareimpacts of the restriction.

It is important to think about the net impact in terms of the elements that it would entail. The restriction is made to address an externality, namely the lead poisoning of waterbirds, the internalisation of which is denoted by ΔE; it will impose a consumer surplus loss ΔCS as hunters will have to pay more for each cartridge they consume; it willentail a producer surplus change ΔPS (possibly a gain), as producers will sell steel and other non-lead cartridges instead of lead cartridges on which they may earn more (at least that is what the evidence reported in Annex B?? suggests). The total welfare impactis simply the sum over the three elements: $\Delta W = \Delta E + \Delta PS + \Delta CS$; notably, these elements will have different signs.

As a convention, the social cost will be defined as $\Delta PS + \Delta CS$, while the social benefit equals the externality addressed by the regulation. To better understand the social cost, consider a simple world with one buyer (i.e. the hunters) and one seller (i.e. the gun industry) and abstract form any taxes. Let the indirect utility function of the buyer before(denoted by v_0) and after (denoted by v_1) the regulation be given by:

$v_0 = y - p_L q$ and $v_1 = y - p_S q$,

where y denotes disposable income; p_L and p_S are the per unit prices (excl. VAT) of leadand steel shot, respectively; q is the number of cartridges consumed per year (assumedto be unaffected by the restriction for the quantification of impacts on hunters). The impact of the regulation on the buyer can thus be summarised as:

$\Delta v = v_1 - v_0 = -(p_S - p_L) = -q\Delta p$,

i.e. the buyer suffers a consumer surplus loss that equals the aggregated price differential he is facing due to the restriction.

Next, consider the seller's profit function before (denoted by Π_0) and after (denoted by

Π_1) the regulation enters into force:

$\Pi_0 = p_L q - c_L q - f_L$ and $\Pi_1 = p_S q - c_S q - f_S$,

where c_L and c_S are the per unit production costs for lead and steel shot, respectively; f_L and f_S are costs unrelated to the production (incl. shipping, stocking, selling, etc.). The impact of the regulation on the seller can be summarised as:

$\Delta\Pi = \Pi_1 - \Pi_0 = (p_S q - c_S q - f_S) - (p_L q - c_L q - \ ) = q(\pi_S - \pi_L) - \Delta f = q\Delta\pi - \Delta f$,

where $\pi_S = p_S - c_S$ and $\pi_L = p_L - c_L$ are the per unit profits made from selling steel and leadshot, respectively. The sign of the producer surplus change $\Delta\Pi$ depends on both the change in the per unit profit $\Delta\pi$ and the change in other costs Δf.

One may now conclude on the net social cost of the restriction in this model economy:

$\Delta CS + \Delta PS = \Delta v + \Delta\Pi = -(\Delta p - \Delta\pi) - \Delta f = -q\Delta c - \Delta f$,

which just equals the extra resource cost (in terms of material, energy, and labour) implied by the restriction.

D.4.3 Cost calculations

D.4.3.1 Hunting

Gunshot

Best - low impact

Under this scenario it is assumed that with the Ramsar definition and the wording of therestriction in its current form, many hunters in countries with more than 20 % of the area covered in wetlands will already adapt to this restriction and start using steel shot.This would imply that in countries like Finland, Ireland, Lithuania, Latvia, Estonia, Sweden, due to the abundance of wetlands in these countries as well as the inclusion ofa 100 meter buffer zone, hunters will opt to use steel more frequently than in other countries.

The remaining impact is as per the worst-case scenario for the wetland dossier: the scenario assumes that hunting on waterfowl and fowl (primarily in peatlands) is assumedto comprise 10.0% and 53.4%, respectively, of all hunting activities. Impacts are expected to occur in all Member States except those which have a full ban in place (BE, HR, DK, NL).

In sum it is assumed that about 40 % of all hunters are already impacted by the wetlandor by existing legislation covering the use of lead in terrestrial areas. 60 % of hunters are impacted by this restriction.

Middle - middle impact

The middle scenarios assumed that the wideness of the wetlands restriction will impact most hunters and a significant number of terrestrial hunters are already impacted by thewetland restriction. However, the additional impacts expected for member states with more than 20 % of their territory covered by wetlands would not occur, it is assumed that here are still areas where hunters would be able to use lead.

The remaining impact is as per the worst-case scenario for the wetland dossier: the scenario assumes that hunting on waterfowl and fowl (primarily in peatlands) is assumedto comprise 10.0% and 53.4%, respectively, of all hunting activities. Impacts are expected to occur in all Member States except those which have a full ban in place (BE, HR, DK, NL).

In sum, this scenario assumed that 35 % of all hunters are already impacted by the wetland’s restriction or existing legislation and that 65 % of the hunters will be impactedby this restriction. This scenario is expected to be the most realistic

Worst – high impact

The worst scenario assumes that the impact of the wetland restriction is as follows:

Hunting on waterfowl and fowl (primarily in peatlands) is assumed to comprise 8.0% and 53.4%, respectively, of all hunting activities. Impacts are expected to occur in Member States (IE, GR, PL, RO) that do not have any measure on lead gunshot in place, in Member States (DE, LV, EE, LI) in which >10% of wetlands are peatlands and where current bans are area-based and have a narrow geographical scope as well as in Member States (BG, HU, IT, ES, PT, LU, MT, FI and parts of the UK) in which >10% of wetlands are peatlands and where there is a ban of lead shotgun to hunt on waterfowl species (but does not exclude fowl hunting with lead shot). The restriction would result in costs to around 252 000 waterfowl hunters and around 1.24m fowl hunters in those Member States. The percentage of hunters that would yet be covered by the wetland scenario is thought to be around 30 %, so 70 % of the hunters outside of wetland not being impacted by the wetland's restriction just yet.

Table D. 2 Main assumptions used in impact assessment of shot

Scenario	**Best case**	**Central**	**Worst case**
one-off costs			
Number of hunters impacted by proposal Total hunters = 5 862 770	Assuming that practically a full ban will be in place in countries with more than 20 % of wetland surface (SE, LV, EE, LI, IE, SI and FI) Minor impact expected in Member states with a wide restriction on use in wetlands	Countries wide ban on wetlands hunting prior to EU wide restriction, broad definition of wetland will lead to most water bird hunting impacted (10 %) as well as 53 % of all terrestrial shooting	Smallest possible implementation of wetland ban, number wetland hunters impacted
	3 585 780 (61.2 % of all hunters)	3 801 458 (64.8 % of all hunters)	4 132 522 (70.5 % of all hunters)
Average purchase price of a new shotgun[l]	€750	€1 000	€1 500
Counterfactual replacement of existing shotguns that are not standard proofed.	No need to replace shot guns	95 % of shotguns to be replaced over the next 20 years; 5 % of shotguns not to be replaced within the next 50 years.	No shotguns would be replaced within the next 50 years

Percent of gun owners that re-proof	0 %	5 %	5 %
Cost of proofing test per barrel	€70		
Shotguns prematurely replaced[k]	0 %	5 %	10 %
Amortisation period (years)[h]	10 years	20 years	50 years
Operational costs			
Number of lead cartridges consumedin EU-27 g	663 million		
Retail price of lead shot	€0.45 per cartridge	€0.45 per cartridge	€0.465per cartridge
Retail price of alternative shot	(100 % of the price for a lead shot);Bismuth/Tungsten: not relevant €0.45	(102 % of the price for a lead shot); Bismuth/Tungsten: €2 per cartridge (400 % of the price for a lead shot) € 0. 46	Steel: €0.61 per cartridge (104 % of theprice for a lead shot); Bismuth/Tungsten: €3 per cartridge (430 % of the price for a lead shot) € 0.47

Percentage steel	100 %	85 %	85 %
Percentage Bismuth/Tungsten	0 %	15 %	15 %
Emission reduction (t)			
	12 796	13 756	14 954

Notes: a – based on Amec (2013); b - Hirschfeld and Heyd (2005); c - Based on market assumptions for steel cartridges – Source, BASC/Niels Kanstrup; g – based on Amec (2013); h – to be consistent with assumptions on the 'lifetime' of shotgun used in the scenario; i – Sweden also excluded as they have a ban on the use of lead gunshot for hunting birds; j - Source: Waarde van de jacht, tijd en geld besteed door jagers aan maatschappelijke diensten, CLM Onderzoek en Advies 2014; k – 25 % based on personal communication from stakeholders (BASC & John Swift), 10 % based on the fact that the average hunter own 2.6 shotguns (25/2.6 is 10 (rounded) (Amec, 2013) l source: Amec 2013

Bullets

Table D. 3 Main assumptions used in impact assessment for bullets

Scenario	**Best case**	**Central**	**Worst case**
one-off costs			
Share of hunting performed withlead free bullets	15 % I.e. 15% of all game captured in the EU iscurrently taken with lead free ammunition The share in the low scenario sis based onstakeholder feedback suggesting the share of non-lead use can be as high as 20% in Finland (Stokke et al) or even 20% in Germany (Gremse, personal communication).The dossier submitter lowered this to 15% to be on the conservative side.	10 % I.e. 10% of all game captured in the EU iscurrently taken with lead free ammunition The share in the low scenario sis based onstakeholder feedback, AFEMS suggested that the share of use would not be higher than 10%	5 % I.e. 5% of all game captured in the EU iscurrently taken with lead free ammunition. The share in the low scenario is based onstakeholder feedback

Average purchase price of a new rifle	Not relevant for larger calibres, existing non-lead bullets can be used without adaptation For small calibres adaptation is foreseen for the barrel (Caudell et al., 2012)	Not relevant for larger calibres, existing non-lead bullets can be used without adaptation For small calibres adaptation is foreseen for the entire gun (Caudell et al., 2012)	Not relevant for larger calibres, existing non-lead bullets can be used without adaptation For small calibres adaptation is foreseen for the entire gun (Caudell et al., 2012)
Counterfactual replacement of existing rifles that are not standard proofed.	95 % of rifles to be replaced over the next 10 years; 0 % of rifles not to be replaced within the next 10 years.	90 % of rifles to be replaced over the next 20 years; 5 % of rifles not to be replaced within the next 20 years.	95 % rifles to be replaced over the next 20 years; 5 % of rifles not to be replaced within the next 50 years.
Number of hunters that prematurely replace their gun	403 628 (small calibre only)	605 442 (small calibre only)	1 210 884 (small calibre only)
Amortisation period (years)[h]	10 years	20 years	50 years
Operational costs			
Prices were taken as averages per group of cartridges that were suitable for a specific group of animals, prices without VAT			
Price différence vis-à-vis lead shot.	Small calibres: € 2.36 Large calibres: € 0.65	Small calibres: €2.68 Large calibres: € 1.74	Small calibres: € 2.68 Large calibres: € 1.75
Bag or large game per hunter	4 (Reimoser and Reimoser, 2016)	4 (Reimoser and Reimoser, 2016)	4 (Reimoser and Reimoser, 2016)

Bag of small game per hunter With small game defined as per the hunting statistics in section on baseline (small animals, all animals smaller then roe deer)	15 (lower bound of average bag estimate by (Gremse and Rieger 2012) to be 11.2 which is rounded off to 15)	10 Mid of the range of rounded of low-high values	5 (average bag estimate by (Gremse and Rieger 2012) to be 3.2 which is rounded off to 5)
Impact per hunter (large game)	= average bag per hunter (4) times average price) = 4* €0.65 = €2.6	= average bag per hunter (4) times average price) = 4* €1.75 = €7	= average bag per hunter (4) times average price) = 4* €1.75 = € 7
Impact per hunter (small game)	= average bag per hunter (5) times average price) = 5 * €2.36 = € 12	average bag per hunter (10) times average price) = 10* €2.68 = €27	average bag per hunter (15) times average price) = 15* € 2.68 = €40.2

D.4.3.2 Sport shooting

Table D. 4 Calculation of cost associated with ban on shot for sports shooting

Parameter	Data		
Volume of lead used per year	Tons		
Weight per cartridge	Based on FITASC contribution: 60 % of shooters use 28 gram cartridge, 40% of shooters use 24 gramcartridge. 60 % 28 gram and 40% 40 gram = 26.4 gram per cartridge onaverage		
Number of cartridges	XXX / 26.4 gram per cartridge = 1 326 million cartridges		
Price per cartridge	€0.42		
Price difference	Min	Middle	Max
	1 % higher price for steel		5 % higher price for steel

	€0.0042	€0.0084	€0.021
Compliance costs	Nr of cartridges * price difference		
	€5.6 m	€11.1 m	€27.8 m
Number of sports shootersin the EU	2.5 million (based on FITASC information)		
Costs for premature replacement	10 % replaces gun prematurely = € 11.3 m for forwarding cost of gunreplacement		
Cost per year after the transition period	€16.9 m		€39 m
Cost over 20-year period (NPV, 4%)	€187 m	€249 m	€435 m
Parameter			**Data**
Cost effectiveness per yearafter the transition period	0.48 €/kg		1.12 €/kg
Cost effectiveness over 20years	€249 m (central case), (NPV, 4%, 20 years) / 15 * 35 000 tonnes = 0.48 €/kg		

Table D. 5 Calculation of cost associated with ban on shot for sports shooting with a derogation for international athletes

Parameter	Data		
	Min	Mid	Max
Volume of lead used per year	14 840	19 160	23 480
Weight per cartridge	Based on FITASC contribution: 60 % of shooters use 28 gram cartridge, 40% of shooters use 24gram cartridge. 60 % 28 gram and 40% 40 gram = 26.4 gram per cartridge onaverage		
Number of cartridges	562 m	725 m	889 m
Price per cartridge	€0.42		
Price difference	Min	Middle	Max
	1 % higher price for steel	2 % higher price for steel	5 % higher price for steel
	€0.0042	€0.0084	€0.021
Compliance costs	Nr of cartridges * price difference		
	€2.36 m	€6.09 m	€18.67 m
Number of sports shooters in the EU	2.5 million (based on FITASC information)		
Costs for premature replacement	10 % replaces gun prematurely = € 11.3 m for forwarding cost of gun replacement		

Parameter	***Data***		
Cost per year after the transition period	€13.7 m	€17.4 m	€30m
Cost over 20-year period (NPV,4%)	€151 m	€193 m	€333 m
Cost effectiveness per year after the transition period	0.92 €/kg	0.91 €/kg	1.27 €/kg
Cost effectiveness over 20 years	€249 m (central case), (NPV, 4%, 20 years) / 262 500 tonnes = 0.74 €/kg		

D.4.3.3.1.Costs of Risk Management Measures

Table D.11 gives an overview on the information that was gathered and combined to obtain an order of magnitude estimate regarding the baseline costs and the investment costs needed per site to achieve a minimum recovery rate of > 90 % in comparison to the costs of using steel. In addition, costs for maintenance and final clean up at the end of service life are provided.

Table D. 6 Overview of investment costs for different site to achieve a recovery rate of > 90 %

Scenario	Baseline costs[1]	Costs for RMMs required o achieve recovery > 90%	Costs for the use of alternative(s)[2]
A: Any area or range using steel shot	No lead used; no costs in relation to lead	Not applicable	Only steel used
B: Temporary areas; no ENV RMMs; 5 000 – 10 000 rounds per year	No lead recovery assumed; Areas often not remediated	Not achievable in practice for atemporary range	€2 000 – 4 000 per range (40 years)
C: Permanent ranges;no ENV RMM; 5 000 – 10 000 rounds per years	< 50 % lead recovery; Costs to recover lead from soil (40 years): >> €1 million	Costs for RMMs, maintenanceand end-of life cleaning: €2 million (20 years) €4 million (40 years)	€2 000 – 4 000 per range (40 years)
D: Permanent ranges; some ENV RMM available (e.g., berm) 10 000 -100 000 rounds per years	>50 - < 90% lead recovery; Costs to recover lead from soil (40 year): ca. €0.9 million	Costs for RMMs, maintenanceand end-of life cleaning: €0.4 million (20 years); €0.6 million (40 years)	€26 000 per range (40 years)
E: Permanent range; ENV RMMs available torecover > 90 % lead 100 000 – 350 000 rounds per year	> 90 % lead recovery Costs for maintenance and end-of life cleaning: €389 000	No additional costs	€90 400 per range (40 years)

Notes: [1] costs for the environmental impact not quantified; [2] in case of substituting lead gunshotwith steel gunshot, additional clean up costs might arise, this is considered as advancing the cost of existing end-of life clean-up

In order to provide more insight into those costs involved at being able to recover lead (at different lead recovery rates), the cost per type of range can be combined with informationon the rate of recovery of lead that is theoretically possible into a Marginal Abatement Cost(MAC) curve. Policy-makers use MAC-curves in order to demonstrate how much abatementan economy can afford and the area of focus, with respect to policies, to achieve the emission reductions.

Combining the various cost information with key information on example case with claimedrecovery rates gives some insight in what lead recovery can be achieved at which costs.

However, only few shooting ranges have reported the amount of lead shot that is kept at the shooting range in combination with the RMM that are installed in order to achieve that.

The marginal abatement cost curve is displayed in Figure D.1 where (A)-(D) denote the risk management measures described in Table D.11.

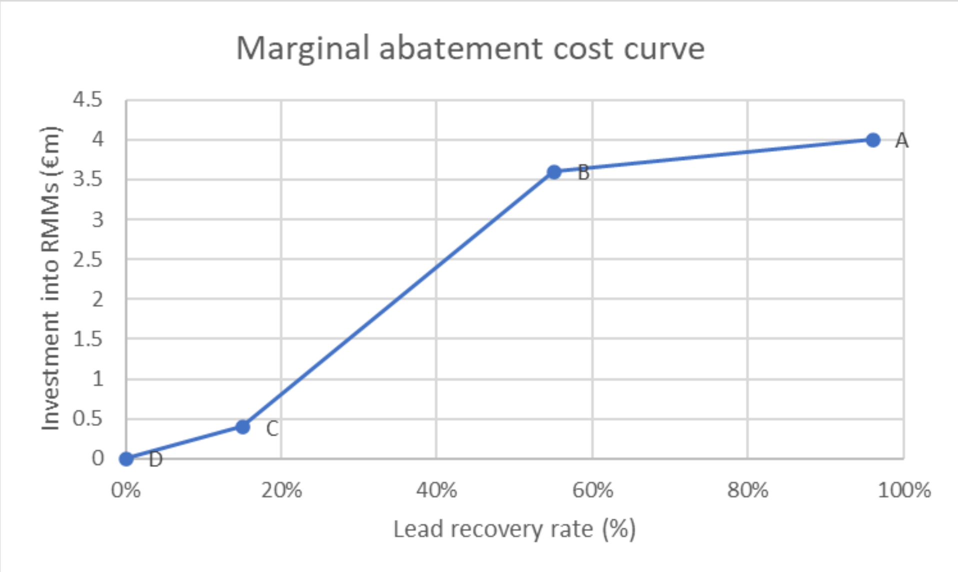

Figure D. 1 Marginal abatement cost curve for shooting ranges

Extrapolating the cost to an EU wide scale can be achieved by multiplying the costs in Table D.11 with the number of ranges per category in Europe. The precise number of ranges in the EU that fall into which category is unknown but is assumed to be 4 000 to 5 000. The Dossier Submitter has suggested a random distribution of these ranges to define an order ofmagnitude estimation. This can only give an order of magnitude estimate as the specific requirement per range can vary as per the environment of the range and its specific surroundings and thus investment need in infrastructure to meet a 90 % shot capture rate (ad theoretical recovery rate) may be bespoke for each and every site.

Table D. 7 Estimation of number of ranges in the EU

Scenario	Number of sites impacted by the need to install further RMMs		
	Low	middle	High
Temporary area	5 %; 200 – 250	5 %; 200 - 250	5 %; 200 – 250
Permanent range, no RMM	30 %; 1 200 – 1 500	45 %; 1 800 – 2 250	60 %; 2 400 – 3 000
Permanent range someRMM (<90% recovery)	60 %; 2 400 – 3 000	40 %; 1 600 - 2 000	20 %; 800 - 1 000
Permanent range RMM(>90% recovery)	5 %; 200 – 250	10 %; 400 – 500	15 %; 600 – 750
Total	4 000 – 5 000	4 000 - 5 000	4 000 - 5 000

Combining the information above, the estimated cost of implementing RMMs across all affected sites in the EU27-2020 can be obtained; which is estimated at €6.2bn - 11bn. The purpose of this estimate is not to give an exact estimationof all cost but rather to obtain an order of magnitude estimation that can be refined furtherwith information coming from the consultation.

The value that was deducted would amount to an annualised vale of €456 million to €798 million (over a 20-year period, discounted at 4 %) resulting in a cost-effectiveness value of

17.1 €/kg compared to a cost-effectiveness value for lead shot in hunting of 6€/kg,demonstrating that substitution might be less costly to comply with.

Assuming:

- a transition period of 5 years after which cost will be incurred, the cost (NP,4%, 20 years) will be €8 527 m (range: €6 210- €10 845 m),

- an emission reduction of 498 750 tonnes (RO4, section 2.6.1.2)gives a cost effectiveness estimate of 17.9 €/kg.

Those costs are calculated for the assumption that all sited will be equipped with RMMs toachieve lead recovery of high effectiveness (> 90%).

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D.5 Benefits

The benefits of the proposed restriction are the avoided costs from the use of lead ammunition. The two main categories of cost are the costs associated with impacts to the environment and wildlife and the costs to human health as a result of exposure to lead.

D.5.1 Costs to the environment and wildlife

D.5.1.1 Replacement costs

ECHA assessment

The ECHA report the impact on birds by the opportunity costs of not being able to shoot the birds. The opportunity cost is then approximated by the replacement cost or stocking cost incurred to raise a bird of the same species. It is possible to value the premature death of an individual game bird by the opportunity cost of not being able to shoot it. This opportunity cost can be approximated by the stocking cost incurred to raise one bird of the same species. Stocking costs for 17 game bird speciesfor which lead gunshot ingestion represents a risk have been gathered by the Dossier Submitter through a market survey made in the EU 27-2020.

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Table D. 8 Economic value of 17 captive-bred bird's species (per bird) that should be released annually in the EU to replace wild birds died due to the ingestion of lead gunshot.

Scientific name	Common name	Low price (€) per bird in the EU -2020	Medium price (€)per bird in the EU -2020	High price (€) per bird in the EU -2020
Alectoris barbara	Barbary Partridge	20	37	50
Alectoris chukar	Chukar	18	36	50

Alectoris graeca	Rock Partridge	15	25	40
Alectoris rufa	Red-legged Partridge	10	20	35
Bonasa bonasia	Hazel Grouse[178]	34	34	34
Coturnix coturnix	Common Quail	1	3	10
Lagopus lagopus	Willow Grouse	13	13	13
Lagopus muta	Rock Ptarmigan	13	37	63
Lyrurus tetrix	Black Grouse	135	268	445
Perdix perdix	Grey Partridge	8	20	47
Phasianus colchicus	Common Pheasant	3	18	50
Columba livia	Rock Dove	4	17	30
Columba oenas	Stock Dove	2	3	5
Columba palumbus	Common Woodpigeon	18	36	75
Streptopelia decaocto	Eurasian Collared-dove	2	5	7
Streptopelia turtur	European Turtle-dove	14	14	85
Scolopax rusticola	Eurasian Woodcock[179]	25	25	30

In addition to the cost of buying captive-bred birds for release, the Dossier Submitter calculated how many captive-bred birds would have to be released to compensate for the loss due to the ingestion of lead shot taking into account the higher mortality rate ofcaptive birds in the months following release into the wild. Andreotti et al. (2018) reported for captive-bred waterbirds a natural mortality of 72.7 %, when released into the wild. The Dossier Submitter is not aware of specific mortality rates for all terrestrial species and therefore assumed that the upper bound of mortality rate of captive birds inthe months following the release into the wild could be similar to that of waterbirds.

However, information provided by different sources on pheasants seems to support thisassumption for this species. Madden et al. (2018) report that natural mortality (excluding shooting) of reared pheasants from release to the start of shooting season inFebruary runs at 61 %; an Italian regional authority reports that “the release of farmed game should be limited to the hunting period, in order to minimize natural mortality, which can reach an incidence of 80 % in the first 20 days after release”

For all captive-bred terrestrial species at risk of lead poisoning the same post-releasemortality into the wild was assumed. In Table D.14, the Dossier Submitter built two restocking scenarios to calculate how many captive-bred birds would have to be releasedinto the wild in order to balance population losses through lead poisoning.

Table D. 9 Replacement scenarios to calculate how many captive-bred birds would have to be released into the wild to compensate for the loss due to the ingestion of lead shot for 17 game birds species

	Lower bound restocking cost assuming 1:1 replacement (€) SCENARIO A			**Upper bound restocking cost assuming 1:7 replacement (€) SCENARIO B**		
	Low price	Central price	High price	Low price	Central price	High price
Barbary Partridge	2 750	10 278	27 500	19 250	71 947	192 500
Chukar	57 063	230 366	634 035	399 442	1 612 562	4 438 245
Rock Partridge	5 703	18 916	60 837	39 924	132 415	425 858
Red-legged Partridge	591 386	2 345 832	8 279 408	4 139 704	16 420 826	57 955 857

Hazel Grouse	250 714	501 428	1 002 855	1 754 997	3 509 993	7 019 986
Common Quail	9 658	65 404	386 321	67 606	457 829	2 704 246
Willow Grouse	38 218	76 436	152 873	267 527	535 055	1 070 109
Rock Ptarmigan	21 975	126 016	429 209	153 828	882 110	3 004 461
Black Grouse	932 433	3 695 197	12 294 300	6 527 030	25 866 378	86 060 099
Grey Partridge	67 614	338 566	1 588 921	473 296	2 369 959	11 122 450
Common Pheasant	63 519	782 186	4 234 623	444 635	5 475 303	29 642 361
Rock Dove	698 868	5 840 540	20 966 042	4 892 077	40 883 783	146 762 297
Stock Dove	7 993	25 577	79 928	55 950	179 039	559 498
Common Woodpigeon	3 139 812	12 495 819	52 330 208	21 978 687	87470735	366 311 453
Eurasian Collared-dove	187 172	868 480	2 620 413	1 310 207	6079359	18 342 892
European Turtle-dove	349 183	698 366	8 480 153	2 444 279	4888559	59 361 068
Eurasian Woodcock	254 891	509 783	1 223 479	1 784 240	3568479	8 564 350
Total (rounded)	**6 700 000**	**28 600 000**	**114 800 000**	**46 800 000**	**200 400 000**	**803 500 000**

The Dossier Submitter assumes that the aggregate opportunity cost for restocking approximately 1 200 000 terrestrial birds (related to EU 26) from these 17 species that are currently lost per year due to lead poisoning is close to the average value between scenario A and scenario B presented in Table D.14 and amounts to approximately €114million per year. This captures only part of the birdspecies that are vulnerable to lead poisoning from different sources of lead (in ammunition and fishing tackle) in the EU.

However, it does assume that all birds lost due to lead poisoning would actually be restocked. This assumption is supported by abundant evidence that restocking of birds for hunting purposes is a common practice in many EU Member States. For example, Madden et al. (2018) report that each year approximately 25-50 million pheasants are released in the UK.

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D.6.1.2 Treatment Cost

An alternative to replacing wildfowl lost to lead poisoning would be to find and treat all poisoned birds. For wildfowl, treatment costs would be approximately €1,000 a bird for a minimum level of treatment. Treating the 1 million wildfowl estimated to die in Europe each year would therefore cost about €1billion a year and with the additional 3 million wildfowl that suffer sublethal effects would cost €4 billion a year.

However, finding, catching and treating all such birds is not a practical proposition even were financial resources available as it would only be possible to find a small proportion of poisoned birds in a condition that would allow for their treatment prior to death. Assuming 1% of the estimated 1 million wildfowl dying every winter in Europe could be treated, this equates to avoided costs of €10 million per year. These figures are substantial underestimates as the costs of finding sick birds are likely to be greater than treatment costs and these have not been included.

D.6.1.3 Cost of services lost

Pain and Dickie (2019) summarise the literature on services that wild birds provide a to society, such as

(i) Birdwatching: In the UK alone, six million people were reported to enjoy birdwatching every couple of weeks (Kellaway 2009). People benefit physically and mentally from walking in greenspaces of high natural value and from exposure to birds and other nature (e.g. Barton et al. 2009; Cox et al. 2017, 2018), and many industries benefit economically from birdwatching including optics (binoculars, telescopes and cameras), publishing, bird food, tourism and associated industries. While it is difficult to quantify the economic impact on human health and wellbeing of the reduction in quality of the natural environment caused by the avoidable loss of birds due to lead poisoning, other economic values are more readily quantified. Specific birdwatching opportunities and general interest in birds also generate revenue. Examples are goosewatching in Scotland, estimated at £1.5 million a year more than 20 years ago (Rayment et al.1998). There are many conservation organisations across Europe members of which have an interest in birds. While it is not easy to use these figures to ascribe a value to the loss of birds to lead poisoning, it highlights some of the value that people place upon birds.

(ii) Hunting for sport or food: Game species of wetland and terrestrial birds provide leisure hunting opportunities and harvest opportunities for meat or for feathers. In the 2017/18 season, about 38% of pheasants and red-legged partridges released in the UK were shot and the average income per bird shot was c. £36. Therefore, income lost in the UK as a result of lead-poisoning deaths of an estimated 232 402 pheasants and partridges would be an estimated £3.18 million.

(iii) Environmental and human health: Wild birds support environmental health in variety of ways, a clear example being that of scavenging raptors, which remove potentially biohazardous material from our environment (summarised by Birdlife International 2018). Vultures, as scavengers, are particularly vulnerable to the ingestion of lead from ammunition in the carcasses of dead large game animals, and losing their services comes at a cost. As an example, following an outbreak of bovine spongiform encephalopathy (BSE) in 2001 and the detection of Creutzfeldt–Jakob disease in humans, sanitary legislation (Regulation EC 1774/2002) was passed in the EU requiring that domestic animal carcasses be collected from farms and transformed for use for industrial purposes or destroyed in authorised plants. This reduced the food supply for the vultures that had traditionally relied in part on the flesh of domestic livestock for their food, consequently providing an important environmental health service. Morales-Reyes et al. (2015) estimated that in Spain (which holds 90% of European vultures—BirdLife International 2015), carcass collection and transport to processing plants resulted in additional emissions of 77 344 metric tons of CO_2 eq. to the atmosphere per year, plus payments by farmers and regional/national administrations ca. $50 million (€44 million) to insurance companies for livestock carcass removal and processing in 2012.

(iv) Other Services :Many species help with the dispersal of plants and lower organisms supporting ecosystem functioning. Waterbirds alone provide a range of key services via their roles in many aquatic ecosystems (Green and Elmberg 2014). These include as predators (including of 'pest' species), herbivores and vectors of seeds, invertebrates and nutrients. Many species can be effective sentinels of potential disease outbreaks and bioindicators of ecological conditions. While we have not attempted to estimate the value of the services lost as a result of lead poisoning.

Willingness to Pay

A WTP study in Scotland found that on average, people were willing to pay an estimated £10.99 (in 2017 prices) per household per year for avoided losses of 10% in all goose species (Hanley et al.2001). In the absence of better valuation evidence, the Scottish value could be extrapolated to the number of UK households in 2017.

D.6.1.4 Environmental impacts (costs of clean up)

The costs of removing lead from the environment would be extremely difficult to calculate. Pain and Dickie quote some values but they would be very difficult to apply here.

D.6.2 Costs to human health

D.6.2.1 Costs of estimated reduction in IQ in children

Several estimates exist of the number of children under eight years old in the UK at risk of incurring a one point or more reduction in IQ as a result of their current levels of exposure to ammunition-derived dietary lead from game. Green and Pain (2015) estimated this to be thousands of children in the UK (calculated to be in the range 4 000—48 000) at risk from lead exposure via gamebird meat alone. An unpublished British Association for Shooting and Conservation/Countryside Alliance (BASC/CA) game meat consumption survey estimated that 9 000 (midpoint of 5 500—12 500) children from the shooting community consume at least one game meal per week averaged over the year (reported in LAG 2014).

The implication of this exposure to lead (to the BMD) has been estimated as a 1 point or more decrease in IQ in children (EFSA 2010), which can have a significant cost to Society. In the UK, with 800 000 hunters, one survey estimated that 27 000–62 000 adults eat game more than once a week and 5500–12 500 children eight years old or younger eat game once a week (cited in LAG 2014). In the EU, although they use different methods, two different studies have valued a reduction in 1 point in IQ (per child) based upon reviews of the literature, at around €8 000 and €10 000 (ECHA 2011; Bierkens et al. 2012).

Using this range of values (€3 882—10 000), the consumption of lead-shot game by children within the EU today may be linked to a potential loss in IQ estimated to be worth €322 million to €830 million. This is a cost to the cohort of children 8 years old or younger.

This assessment uses the value of Euro 10,000 per IQ point lost and a population of 10,000 children.

D. 6.2.2 Other health costs

EFSA (2010) considered that the possibility of adverse effects on chronic kidney disease and systolic blood pressure could not be excluded in adults with high levels of wild game consumption.

Annex E: Stakeholder information

E.1. Stakeholder mapping and engagement

Before launching a call for evidence for the restriction proposal, HSE and EA undertook stakeholder mapping to identify agriculture, countryside, industry, sports and trade associations, gun and ammunition manufacturers, trade unions, training providers, NGOs and OGDs that could be affected by the restriction proposal on lead in ammunition. HSE directly notified these stakeholders when the call for evidence opened. HSE also directly notified more than 60,000 subscribers to its REACH e-bulletin service when the call for evidence launched. Information about the call for evidence was also cascaded via social media.

E.2. Call for evidence

The call for evidence was published on HSE's consultation hub website to gather information from relevant stakeholders on lead used in ammunition. Information was sought on risks to the environment and human health from the use of lead in ammunition (projectiles) in all habitats in GB (i.e. England, Scotland and Wales).

The call for evidence opened on 23 August 2021 and closed on 22 October 2021. In total, 92 respondents provided information to the call for evidence. 5 confidential attachments and 31 non-confidential attachments were also provided by respondents. Respondents included companies, industry or trade associations, NGOs and individuals. The comments were taken into account in the development of the report. Where possible, HSE and/or EA also contacted respondents to clarify their comments.[66]

[66] Respondents were able to indicate if they were content to be contacted by HSE or EA on the basis of the information they provided.

Appendix E.1. Call for evidence questions

Questions for the call for evidence for the lead shot / ammunition restriction proposal

We are gathering information and evidence to support the development of a technical dossier (report) on risks to the environment and human health of the use of lead in ammunition (projectiles) in all habitats in Great Britain (GB; England, Scotland, Wales). Military and non-civilian use of ammunition is excluded.

Please support your contribution with references and reliable data (facts and figures).

Section 1. Personal information

This information will be used by HSE/EA and we may contact you about your comment and to request additional information. Any information given will be held for the duration of this project.

First name:

Last name:

E-mail:

Country of Residence:

I am content to be contacted by HSE or EA on the basis of the information I provide Y/N

Section II. Organisation

I am submitting information*

As an individual ☐

On behalf of an organisation / institution ☐

Type of organisation / institution: [drop-down list – Company, National authority, Regional or local authority, Academic institution, National NGO, International NGO, Industry or trade association, National institution, International organisation, Trade union, Other contributor]

Country where the organisation or institution is legally established: [drop-down list of countries]

*Select one of the following options [*Note: the type and country of your organisation / institution will always be disclosed]:*

☐I agree to the disclosure of the name of my organisation / institution to the public

☐I want to keep the name of my organisation / institution confidential

Name of organisation / institution:

Section III. Non-confidential comments

Besides the specific information requests below, we are seeking information on any additional issues not covered by the European Chemicals Agency (ECHA) restriction proposal, for example GB-based manufacturers or any type of shooting that only takes place in GB.

General comments

* ☐ I understand that it is my responsibility not to include confidential information in any responses given in this call for evidence (e.g. company names, email addresses, phone numbers and signatures etc.)

Please note: HSE will not be liable for any damages incurred by making non-confidential responses publicly available.

Specific information requests

The scope of the assessment is the use of lead ammunition in environmental habitats. Outdoor shooting ranges are therefore included in the assessment, but indoor shooting ranges are not. Applying the same definition of sport shooting as the European Chemicals Agency (ECHA) (*Shooting at any inanimate (non-living) target with a gun. Includes practice, or other shooting, performed in preparation for 'hunting.' Examples of relevant types of targets are 'clay pigeons', paper targets, biathlon targets, silhouettes etc.*), we would like to gather GB-specific information on outdoor shooting ranges.

Section 1 - Shooting ranges

Number of sites and quantity of ammunition used

Please provide information on the areas below:

i. As accurately as possible, what is the number of outdoor shooting (static target) ranges that meet the above definition?

ii. As accurately as possible, what is the number of outdoor trap and/or skeet ranges that meet the above definition?

iii. As accurately as possible, what is the number of sites that have both static target and outdoor trap and/or skeet on the same site?

iv. As accurately as possible, what is the quantity of lead ammunition used on these sites? (please split by lead shot and other projectiles, if possible)

v. As accurately as possible, what is the number of outdoor ranges (temporary or permanent) that have agricultural uses within the site boundary?

Measures to limit releases to the environment at outdoor shooting ranges

To allow us to understand risk management measures that are in place at outdoor shooting ranges, please provide information on the areas below:

i. What industry standards or guidance are you aware of/currently use for the reduction or minimisation of lead releases from shooting activities (for example, recovery of bullets or shot)

ii. What measures are currently in place at GB outdoor shooting ranges to reduce or minimise environmental releases of lead to collect a minimum of 90% lead ammunition?

iii. As close as possible, please give the numbers of outdoor shooting ranges that apply such measures (e.g. bullet traps and alternatives) and include your estimate of the % recovered for each one.

Measures to limit releases to the environment at outdoor trap and/or skeet ranges (clay pigeon)

To allow us to understand the releases at outdoor trap and/or skeet ranges please provide information on the areas below. (Please clarify how the estimates of the number of ranges and stands were derived and provide supporting evidence, where possible):

i. As close as possible, what number **and** proportion of trap and/or skeet **ranges** have measures currently in place that are suitable to collect a minimum of 90% lead shot?

ii. As close as possible, how many **individual** trap and/or skeet stands are usually available at ranges that have measures in place that are suitable to collect a minimum of 90% lead shot?

iii. Information on the types of measures that are currently used to reach this 90% recovery rate (please provide details from example cases)

iv. Information on the costs of such measures that are currently used to reach this 90% recovery rate (please provide details from example cases)

v. What measures are currently required for containment of lead gunshot? (Please include information on the type and cost of such measures and, where possible, the relation to number of stands covered.)

vi. What measures are currently required for the monitoring and, where necessary, treatment of surface (run-off) water? (Please include information on the type and cost of such measures and, where possible, the relation to number of stands covered.)

Remediation of shooting ranges/areas

We are interested in how lead shot and ammunition are removed from historical ranges.

Please provide information below on the following:

i. Information on the remediation of shooting ranges that are no longer in operation. (For example, what measures were taken for remediation of former shooting ranges to ensure clean-up of the sites was effective?)

ii. As close as possible, what is the number of operational sites that have a remediation plan in place, currently?

Section 2 - Hunting

Area of land and quantity of ammunition used

Applying the same definition of hunting as ECHA (pursuing and killing live animals/birds using a gun), we would like to gather GB-specific information on the area of land on which hunting takes place and the quantity of ammunition used to hunt.

Please provide information below for the following:

i. Please provide information on the area of land in GB **actively** used for live animal/bird hunting, if possible split by organised hunts and pest / population control (please place an x if the area is used for hunting or pest/population control).

Area of land used for live animal/bird hunting	Hunting	Pest/Population Control	Both

ii. The quantity of lead ammunition used for hunting in GB

	Quantity of lead ammunition used for hunting in GB
Small calibre, animal/bird hunting	
Small calibre, pest/population control	
Large calibre, animal/bird hunting	
Large calibre, pest/population control	
Other	

Consumption of lead-shot game

We are interested in receiving information on the consumption of lead-shot game in GB.

Please note: game includes pheasant, partridge, black grouse, red grouse, ptarmigan, brown hare, deer, duck, goose, wood pigeon, woodcock, snipe, rabbit, golden plover. Game meat refers to meat from these species. Lead-shot game means game that has been shot for food with ammunition made of lead.

Please provide information on the following:

i. What is the amount of game meat consumed in GB (by region, if available)?

Please note: an approximation of the weekly/yearly consumption in grams and/or the frequency of meals can be provided per person or proportion of the population, as well as the specific species consumed. If possible, please quantify the proportion of game that originates from GB and the proportion that is imported for consumption in GB (with its country of origin). We are especially interested in unpublished but evidence-based information.

ii. If available, please give the frequency and quantity of consumption of game meat in specific groups such as infants, small children, women of childbearing age or high consumers (such as hunters and their families) in the table below.

Category	**Frequency (daily/weekly/monthly – please specify)**	**Quantity (weight in grams)**
Infants		
Small children		
Women of childbearing age		
High consumers		
Other specific group		

<u>Lead in game meat</u>

i. What, if any, standards/inspections are in place to avoid and limit the amount of lead shot in game meat?

ii. Please provide data on lead in game meat that is shot and consumed in GB (for example, concentrations of lead in different types of game meat, the proportion of game (with species) that contain lead pellets or fragments and the size range/visibility of lead fragments).

<u>Section 3 - Manufacture and supply of lead shot and ammunition</u>

<u>Sources of shot and ammunition</u>

Please provide information below on where suppliers source lead shot and ammunition. If possible, please split all answers to the questions below by lead shot and ammunition.

Is the ammunition manufactured in GB or imported?

- Manufactured in GB (please split by the quantity of shot cartridges and quantity of ammunition)
- Imported (please split by the quantity of shot cartridges and quantity of ammunition)

ii. As accurately as possible, what are the total sales in GB (in tonnes)?

Home casting of lead cartridges

Please provide information on the extent of home casting of cartridges in GB.

i. As accurately as possible what number of cartridges are made by home casting?

ii. What is the estimated quantity of lead used when making home-cast cartridges?

iii. Please provide an estimate below of the number of people (by region) who home-cast cartridges:

Region	**Estimated number of people who home-cast cartridges**
England	
Scotland	
Wales	

Section 4 - Substitution of lead in ammunition

Availability of alternatives

Please provide information on the following aspects of alternatives to lead ammunition for use in hunting and shooting ranges:

i. What, if any, existing or emerging alternatives are you currently aware of? (Please specify below)

ii. Briefly, how would you describe the existing market share of comparable products that do not contain lead in GB?

iii. Technical and economic feasibility of potential alternatives, including information on product performance, price differences between lead-containing products and alternatives, the number of affected products, expected costs and timelines for full-scale production of alternatives, etc.

iv. How do you view availability of alternatives to lead ammunition currently?

- Very good availability
- Good availability
- Neutral
- Poor availability
- Very poor availability
- Don't know/unsure

Why do you think this?

v. What do you think availability of alternatives will be in the future? (Please give details on why you think this.)

vi. Are there any potential impacts that you could see stemming from the use of alternatives?

- Yes
- No
- Don't know

[If yes] Please briefly specify below:

vii. What non-lead rifle cartridges are already used; where would substitution be problematic or costly?

Impact of voluntary agreement

Shooting and rural organisations have proposed to end the use of lead in ammunition within five years (by February 2025). We would like to understand the impact of this voluntary initiative so far.

i. Please provide any evidence of a reduction in the use of lead ammunition since the voluntary agreement came into place in February 2020.

ii. Has the sale of lead shot/ammunition been impacted since the voluntary agreement in February 2020?

- Yes

- No

[if yes] Please provide details of how

iii. To the best of your knowledge, what steps have been taken to phase out lead ammunition?

iv. To the best of your knowledge, what are the plans for further reduction in use?

Section 5 - Impacts

Impacts of lead ammunition on wildlife in GB

i. Please provide information on the frequency and extent of lead poisoning observed in terrestrial wildlife (including predatory and scavenging species) in GB.

ii. Please also provide unpublished monitoring information on lead shot and ammunition in soil, water and biota in GB.

Impacts of a possible restriction on businesses, hunters and shooters

Please provide information on the costs and benefits of a possible restriction to affected actors (including producers of alternatives); these actors could include manufacturers (e.g., ammunition, shotgun, rifle, air-rifle), professionals (e.g., pest controllers), the general public, including hunters

a. Please provide data on key economic parameters, for example profit-loss, turnover, number of people employed, current share of products containing lead, etc.

Thank you for your contribution. Please leave any further comments below:

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