Annex 15 Restriction Report

Proposal for a restriction

Substance name(s): Lead

IUPAC names(s): Lead

EC NUMBER(S): 231-100-4

CAS NUMBER(S): 7439-92-1

AGENCY for UK REACH:

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PROPOSAL FOR A RESTRICTION

Definitions used in the proposal

This report covers the use of lead projectiles as used in shotguns, firearms and airguns, all of which are defined as defined in the Firearms Act 1968.

The definitions of some of the common terms in this report are given below. They are consistent with those in the ECHA annex 15 restriction proposal for lead in ammunition and fishing weights (ECHA, 2021a).

Waterfowl	Typically species from the avian family Anatidae, i.e. ducks, geese and swans. These birds are adapted for surface water swimming (i.e. having webbed feet and oily feathers). However, a broader interpretation to include other waterbirds (e.g. Common Snipe) that are hunted is not uncommon. Hunted waterfowl and waterbirds can be referred to as game waterfowl.
Wildfowl	Principally associated with the hunting of *waterfowl*, although can refer to any hunted (game) bird, such as waders, grouse, pheasants, or partridges.
Waterbird	Used in the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA) to refer to birds that are ecologically dependent on wetlands for at least part of their annual cycle. This definition includes many species of divers, grebes, pelicans, cormorants, herons, storks, rails, ibises, spoonbills, flamingos, ducks, swans, geese, cranes, waders, gulls, terns and auks.
Raptors (predatory or scavenging)	Predatory birds (birds of prey) that have keen vision, powerful talons with claws and strong curved beaks, including owls. These birds can also scavenge carrion, either occasionally or as their main food source. Generally considered to exclude storks, gulls, skuas and penguins, even though these birds are also predators.
Scavenging birds (non-raptor)	Other bird species that typically scavenge carrion, e.g. vultures, corvids, gulls.
Projectile(s)	Object(s) expelled from the barrel of a gun. Examples of relevant types of projectiles are bullets, gunshot, shotgun ‘slugs’, air gun pellets and BBs.

Primer	A chemical compound that ignites the propellant (e.g. gunpowder) when struck by a firing pin. Primer may be placed either in the rim of the case (rimfire) or in the centre of the base of the case (centrefire).
[Gun] Barrel	A barrel is the metal tube that the projectile travels through as a result of pressure from burning gunpowder, compressed air, or other like means. The barrel also guides the projectile in the intended direction.
Hunting	Pursuing and killing live quarry using a gun.
Sports shooting	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.
Wildfowling	The hunting of wildfowl, particularly ducks, geese and waders.
Small game	Quarry species that are relatively small. For example: ducks, pheasants, partridges, hares, squirrels, rabbits, foxes, etc.
Large game	Quarry species that are relatively large. For example: deer, wild boar, etc.

Executive Summary

On 29th April 2021, the Health and Safety Executive (HSE), as the Agency for UK REACH, received a request under Article 69(1) of UK REACH from the Secretary of State for Environment, Food & Rural Affairs, with the agreement of the Scottish Government and the Welsh Government, to prepare an Annex 15 restriction dossier assessing the risks from lead ammunition on the basis '*that the use of lead in ammunition raises concerns related to both human health and the environment. The harm of lead ammunition to wildfowl is of particular concern – poisoning from ingesting lead ammunition causes long-term suffering and slow painful deaths for animals. The health of humans, particularly children, may also be adversely affected from eating meat killed using lead ammunition*.' Military, police and non-civilian uses are excluded from the scope of this request, as are indoor uses (such as at indoor firing ranges) and lead-containing propellants.

The hazards and potential risks posed by lead to both people and the environment are generally well understood, and legally binding risk management measures are already in place in the UK to reduce some of these risks from the use of lead in ammunition. In particular, each of the devolved administrations has already enacted a ban on the use of lead shot over wetlands in response to the African-Eurasian Waterbird Agreement. These bans were introduced between 1999 and 2004 with the aim of protecting waterbirds from the impact of lead poisoning, but each varies slightly in the definitions used and its application.

The potential remaining risks from the use of lead ammunition have been considered previously in England. In 2010 the Lead Ammunition Group (LAG) was set up by the Department for Environment, Food & Rural Affairs (Defra) and the Food Standards Agency (FSA) to evaluate the published scientific evidence of the impact in England of lead ammunition on human health, wildlife and the environment generally and on livestock and to propose possible mitigation for the risks identified. The group members included key stakeholders and experts from the gun and ammunition trade, game dealers, landowners, animal welfare and conservation organisations, human health and environmental health and sports shooting organisations. In its 2015 report, the LAG concluded that an eventual phase-out of lead ammunition would be the only effective way to address the risks to wildlife and human health.

The potential risks from lead in ammunition are also being considered under REACH in the European Union (EU). An EU REACH restriction of the use of lead shot in wetlands comes into force on 15th February 2023. Under the Northern Ireland Protocol EU REACH continues to regulate the Northern Ireland market and so any EU restriction will apply in Northern Ireland. This report therefore focusses on Great Britain (GB). The EU is also currently considering a restriction on the use of lead ammunition in all habitats.

Throughout this report the Agency[1] has extensively referenced the work done by LAG and by the European Chemicals Agency (ECHA) on EU REACH restrictions. Since the UK was a member of the EU when the technical documents to support the EU wetlands restriction proposal were drafted, the EU dossier includes data from the UK (and therefore GB). Data which LAG and/or ECHA assessed to be reliable are considered to be of a sufficient standard for inclusion in this report without duplicative detailed review and analysis by the Agency.

The Agency has identified several different uses of lead ammunition for the purposes of this restriction proposal, based on technical function and operational conditions. These uses are the same as those defined by ECHA (2021a).

Sector of use	**Use number (#)**	**Use title**	**Use overview**
Hunting	1	Hunting with shot shell ammunition	Lead used as a projectile, either by itself or in quantity (i.e. gunshot) where the technical function is to provide mass for energy transfer to a target. Projectiles can be of various sizes and shapes depending on the desired ballistic properties. They can be used by consumers or
	2a	Hunting with bullets -small calibre, including airguns	
	2b	Hunting with bullets -large calibre	
Sports shooting	3	Outdoor sports shooting with shot shell ammunition	
	4	Outdoor sports shooting with bullets	

[1] Under Article 2B of UK REACH the Agency obtained the advice of EA as part of preparing this dossier and this advice has been used by HSE (as the Agency for UK REACH) in the assessment of risk to the environment from lead in ammunition and the exposure via the environment. The EA's advice has also been used by HSE in the assessment of the impact and options for restriction. When providing this advice to the Agency, the EA collaborated with the environmental regulators in Wales and Scotland

Sector of use	Use number (#)	Use title	Use overview
	5	Outdoor shooting with air rifle/pistol	professionals. The ballistic properties vary depending on whether ammunition is for hunting or sports shooting as well as the size and type quarry and the type of gun used. Projectiles can sometimes be coated with another metal (termed ‘jacketed’).
Shooting with historical weapons	6	Other outdoor shooting activities including muzzle-loaders, historical re-enactment, etc.	

Hazard and risk

Environment

Lead is a non-essential, toxic element. The range of possible adverse effects of lead exposure have been investigated in experimental laboratory studies and evidence of the effects of lead on wildlife is available from pathology reports and observational studies. As well as causing mortality, lead exposure can result in sub-lethal effects on behaviour, development and reproduction. In addition to the lethal and sub-lethal effects that can be measured, there are also likely to be welfare impacts that are less easy to determine.

Toxicity resulting from metallic lead ingestion is generically termed ‘lead poisoning’. The principal routes of lead poisoning by lead ammunition are:

1. Primary ingestion (primary poisoning): the direct ingestion of lead projectiles or fragments of projectiles through normal feeding or foraging from the environment (for example, mistaking lead particles for grit, which is used to aid break up of food or for minerals); and

2. Secondary ingestion (secondary poisoning): the indirect ingestion of lead through feeding on food contaminated with lead (for example, lead particles in prey/carrion, lead contaminated tissues or plants).

The environmental receptor of main concern for both primary and secondary poisoning is birds. Primary ingestion is of particular concern for bird species with muscular gizzards that ingest lead shot, mistaking it for grit. The lead particles are ground down in the gizzard, enhancing its dissolution and then uptake within the intestine. Secondary poisoning is particularly important for bird species that consume prey or carrion left in the environment that contain lead shot or lead bullet fragments within them.

Mortality in birds has been observed in experimental studies after ingestion of a single lead shot pellet. It is also reasonable to assume that sub-lethal and welfare effects can occur at exposure concentrations lower than those at which mortality occurs. Impacts are likely to depend on the amount of lead ingested (either directly or via secondary poisoning) in relation to the body size of the bird, with different species also having differing sensitivities depending on their physiology.

A fully quantitative risk assessment for the various uses of lead in ammunition has not been attempted for the purposes of this report, because the implicit assumption is that there is no safe threshold of lead exposure for wildlife. As the source of the lead does not alter the impact, the various uses are considered together in a single environmental risk assessment. When possible, a semi-quantitative estimate of risk has been made, but where this was not appropriate risks are assessed qualitatively.

There is strong evidence from both GB and international studies that there is direct ingestion of lead shot by terrestrial and wetland birds. An assessment of the available evidence results in an estimate of 16,100 to 804,000 terrestrial wild birds in the breeding population being at high risk of lead poisoning in the UK. The figures are higher when terrestrial game birds bred and released for the purposes of hunting are included, with a minimum estimate of 47,100 game birds at risk of lead poisoning in the UK. Wetland birds that feed on terrestrial areas are also considered to be at risk but an estimate of numbers at risk has not been made.

There is also strong evidence from both GB and international studies that secondary exposure of predatory/scavenging birds is a key exposure pathway for lead ammunition and is likely to result in deaths. The number of predatory/scavenging birds at risk has not been estimated, but the potential exposure pathway is clear and even if only a small proportion of the population ingests lead via secondary poisoning, large numbers of individual birds may be adversely affected.

There is no empirical evidence to suggest that adverse effects on individual terrestrial birds from different species are having an effect at the population level in GB. However, the studies that would be necessary to establish this have not been carried out, and it is unknown how much mortality due to lead can be compensated for before population level effects are observed.

Risks have also been identified for other taxonomic groups. There is some evidence that animals may ingest lead shot whilst grazing. This is considered a relevant exposure pathway for livestock (and likely wild animals) that feed in areas with high lead shot use (e.g. on a shooting range). Concentrations of lead in vegetation grown in areas of high lead ammunition use are also reported to exceed thresholds set for lead in forage and feed, indicating that there may be a risk of secondary poisoning of livestock via this route. Measured concentrations of lead in soil in areas of high lead ammunition use are reported to be above the Predicted No-Effect Concentration (PNEC) for soil, indicating risks to soil organisms at these sites.

Human health

Chronic exposure to lead is associated with a wide range of health effects in humans. These effects include toxicity to the blood system, nervous system, kidneys, cardiovascular system and reproductive systems (male and female fertility, adverse effects on development following exposure during pregnancy). The critical effect in the developing foetus and young children is developmental neurotoxicity; even at low levels of lead exposure, cognitive development and intelligence quotient (IQ) are reduced. Elevation of systolic blood pressure and kidney toxicity are the most sensitive effects in adults. It is generally accepted that none of these effects has a threshold. The most relevant human health impact of the proposed restriction is that on developmental toxicity (neurotoxicity) in the most vulnerable population to the adverse effects of lead, i.e. young children, including those exposed *in utero*.

The primary human health risk addressed in this report is that to consumers of game meat that has been shot with lead ammunition (i.e. wild game). The highest consumers of game meat are hunters and their families. Estimates of high-level consumers of game (at least one portion ≥ 100g of game meat per week) in the UK range between 0.084 – 2.52% of the population (adults and children). Further estimates have indicated that 4,000 – 48,000 children in the UK are at a potential risk of incurring a one point or more reduction in IQ from exposure to ammunition-derived lead.

Meat hygiene measures and stewardship schemes are in place to minimise the amount of metal in meat sold for human consumption in the UK and the removal of obvious ammunition fragments by hunters and their families / friends appears to be reasonably widespread. Nevertheless, meat can still contain small fragments of metal that cannot be easily detected and that might be far from the shot site. The FSA therefore advises that the consumption of game meat be minimised, particularly in vulnerable populations such as toddlers, children, pregnant women and women trying to conceive.

As lead is a non-threshold neurotoxic substance, risks to humans from the consumption of game shot with lead ammunition cannot be excluded and exposure to lead should be reduced as far as possible.

Conclusion on risk

The identified risks for each use are described in the table below. The Agency considers that for all identified uses there is a risk to the environment that is not adequately controlled. In addition, there is a risk to human health from consumption of game shot with lead ammunition that is not adequately controlled.

For the environment, the greatest risk (in terms of tonnage used, geographic scale and size of impact) is from the use of lead shot. Hunting with lead shot has the highest estimated annual release, and there are no identified risk management measures that could be implemented to reduce the environmental emissions or to entirely remove the risk to human health. Sports shooting with lead shot uses a lower tonnage than hunting, but as lead shot is emitted to the environment and remains on the surface of the ground there is a risk of primary poisoning to birds and livestock unless it is immediately collected. There are also risks to soil and to livestock via secondary poisoning if lead shot remains uncollected over longer periods of time.

The tonnages of lead used as bullets are lower than the tonnages used as shot, and bullets do not pose a risk of primary poisoning. Hunting with bullets has a lower annual tonnage than sports shooting, but there are no identified risk management measures that could be implemented to reduce the environmental emissions or to entirely remove the risk to human health. For sports shooting it may be possible to mitigate against the identified risks to soil and livestock by the implementation of appropriate risk management measures at shooting ranges.

In the absence of specific information on the use of air rifles/pistols/guns for sports shooting and historic weapons in GB the Agency considers that the risk profile is likely to be similar to that for the use of bullets for sports shooting. It may therefore be possible to mitigate against the identified risks to soil and livestock by the implementation of appropriate risk management measures for these uses.

Sector of use	**Use #**	**Use title**	**Main risks identified**	**Estimated release to the environment (tonnes per year)**
Hunting	1	Hunting with shot shell ammunition	Primary and secondary poisoning of wildlife (birds) Humans via consumption of game meat	6,357
	2a	Hunting with bullets - small calibre, including airguns	Secondary poisoning of wildlife (birds) Humans via consumption of game meat	14.5

Sector of use	Use #	Use title	Main risks identified	Estimated release to the environment (tonnes per year)
	2b	Hunting with bullets - large calibre	Secondary poisoning of wildlife (birds) Humans via consumption of game meat	
Sports shooting	3	Outdoor sports shooting with shot shell ammunition	Primary and secondary poisoning of wildlife (birds) Secondary poisoning of livestock (ruminants) via silage grown on shooting ranges/ areas used as agricultural land Ingestion of contaminated soil or vegetation by livestock (ruminants) on shooting ranges/ areas used as agricultural land Risks to soil compartment	1,680
	4	Outdoor sports shooting with bullets	Ingestion of contaminated soil or vegetation by livestock (ruminants) on shooting ranges/areas used as agricultural land Risks to soil compartment	28.8 - 72
	5	Outdoor shooting with airrifle/pistol		No data
Shooting with historical weapons	6	Other outdoor shooting activities including muzzle-loaders, historical re-enactment, etc.		No data

Justification for consistent action across GB

Some legally binding risk management measures are already in place at a devolved administration level to mitigate the risks from the use of lead shot over wetlands. The wetland restrictions across GB vary between the administrations and do not uniformly apply to all wetland habitats or protect wetland birds that feed in terrestrial habitats (such as grazing swans, geese and ducks) from ingestion. There is also evidence from monitoring studies that compliance with the current restrictions on the use of lead shot over wetlands is low.

The main justifications for a GB-wide restriction are therefore:

- to ensure a harmonised high level of protection of the environment and human health to address the identified risks which are common to all the devolved administrations
- to increase compliance with the existing bans on some uses of lead shot to meet our commitments under the African-Eurasian Waterbird Agreement (AEWA, 1999)
- to ensure free movement of goods within GB
- to ensure a level playing field for everyone engaged in sports shooting within GB.

Risk management options

In order to propose a restriction under Article 69(1) of UK REACH, the Agency must demonstrate that there is risk that is not adequately controlled and that the proposed restriction is the most appropriate measure to manage that risk. The appropriateness of the proposed restriction is assessed on these criteria:

- Effectiveness: the restriction must be targeted to the effects or exposures that cause the risks identified, capable of reducing these risks to an acceptable level within a reasonable period of time, and proportional to the risk.
- Practicality: the restriction must be implementable, enforceable and manageable.
- Monitorability: it must be possible to monitor the result of the implementation of the proposed restriction.

For each identified use, the Agency has considered a number of risk management options that could be implemented. These options included regulatory measures under UK REACH as well as other options, such as voluntary agreements. Each option has been considered for effectiveness, practicality and monitorability. In addition, potential linkages or interactions between different risk management options have been considered.

As a result of this analysis, the Agency is proposing a restriction:

- On the sale and use of lead shot

An unacceptable risk has been identified for both hunting with lead shot (environment and human health) and sports shooting (environment). There are no realistic ways to limit the amount of lead entering the environment or to eliminate the risk to humans from ingestion of lead when lead shot is used for hunting. When used for sports shooting, lead shot can remain on the surface of the ground where there is a risk of primary poisoning to birds and livestock unless it is immediately collected – this is not considered practical. Risk management measures may be available to manage the risks to soil and to livestock via secondary poisoning, but these are of secondary concern compared to the risk to birds. The most effective risk management option is therefore a complete ban on the sale and use of lead shot.

Lead shot is banned for use over wetlands within the UK, so alternatives are already available on the GB market, especially steel shot. Some shooters have already made the transition to these, and a number of UK shooting and rural organisations have voluntarily committed to using alternatives to lead shot for the hunting of live quarry by 2025, whilst some supermarkets have also committed to only selling game meat from animals killed using non-lead ammunition. Lead shot is not used for indoor shooting, so a ban on sale would not have knock-on consequences for low risk uses. It would also be readily enforceable as there would be no legal use for lead shot. A ban on the sale and use of lead shot is therefore considered practical.

This option would also be monitorable. Compliance with the existing lead shot bans over wetlands is thought to be low, so a total ban on the sale and use of lead shot would tackle this issue.

The Agency is aware that the use of lead shot is required for national and international competitions in some outdoor sports shooting disciplines. Therefore, an optional derogation could be considered, involving a licensing system to allow the relevant athletes to continue training, and suppliers to continue sales to these authorised athletes. This derogation would also include a licensing system for the shooting ranges where this training takes place to ensure that lead collection systems are in place to minimise the risks to the environment from this activity. This optional derogation requires further consideration to ensure it is practical and proportionate, noting that it would not be fully effective at removing all the environmental risks identified.

- On the use of lead bullets for hunting

An unacceptable risk has been identified for hunting with lead bullets (for both the environment and human health). There are no realistic ways to limit the amount of lead entering the environment from this use or to eliminate the risk to humans from ingestion of lead when lead bullets are used for hunting. The most effective risk management option is therefore a ban on the use of lead bullets for hunting. Other options (such as mandatory product labelling, training for hunters and potentially a buy-back scheme) could provide useful supplementary options to support the restriction.

There are already viable alternatives for large calibre bullets and the ammunition industry is developing small calibre (including for airguns) non-lead bullets. There is a move to lead-free ammunition, with the in-progress EU restriction also proposing a ban on lead bullets for hunting. It is therefore likely that more alternatives will be developed and brought to market over time, and that prices for non-lead bullets would eventually decrease. A ban on the use of all lead bullets for hunting is therefore considered practical, as long as transition periods are appropriate to take account of the development of alternatives.

Lead bullets would still be available to purchase for other uses (e.g. indoor sports shooting). This would limit the enforceability of this restriction as lead bullets could still be sold and used for other uses outside the restriction. Compliance could be monitored by checks at organised hunts or by sampling game carcasses to check that they do not contain lead bullets or bullet fragments.

- On the use of lead bullets for sports shooting with a derogation for shooting at licensed ranges with appropriate environmental protection measures

An unacceptable risk has been identified for sports shooting with lead bullets (for the environment). Due to the risks identified and the range of risk mitigation measures available, the Agency considers that implementation of specified risk management measures at shooting ranges would be sufficient to minimise the risk. These measures are already recommended in the EU REACH registration dossier for metallic lead to ensure safe use, and the Agency anticipates that they will also be included in the full UK REACH registration dossier when it is submitted in due course. It is most effective to ban this use, with a derogation for those shooting ranges that can apply the required measures.

Sports shooting ranges would need to demonstrate that the necessary operational conditions and risk management measures are in place to ensure a minimum of 90 % recovery of deposited lead (e.g. using appropriate lead collection systems). The land should not be used for agricultural purposes either. To ensure this option is practical and monitorable, it is proposed that shooting ranges are licensed for outdoor use of lead bullets, as checks can be made that the site operators have the appropriate risk management measures in place as required by their licence.

This option also means that lead bullets would still be available to purchase for other uses (e.g. indoor shooting).

The Agency currently considers that any risks from the use of lead ammunition for air weapons for sports shooting and for historic weapons can be managed in the same way, subject to additional information provided during the consultation stage.

- Mandatory labelling of the packaging of lead projectiles regarding the hazards and risks of lead.

As an additional supporting measure, manufacturers could be required to include information on the packaging regarding the hazards and transition periods for lead ammunition, and suppliers would be required to display this information at the point of sale. This would inform users about the negative consequences of using lead ammunition (like the warning labels on cigarette packets). This could be effective at raising awareness of both the risks of lead and the timelines for transition to alternatives.

Transition periods

A transition period for the sale and use of lead shot cartridges of 18 months is proposed. If the optional derogation for use of lead shot in sports shooting is agreed, a transition period of 5 years is proposed for the ban on the sale and use of lead shot to give shooting ranges time to install the recovery systems required and for a licensing scheme to be developed and implemented. This extended transition period would apply to all uses of lead shot as it would not be practical for suppliers to sell only for sports shooting in the absence of appropriate vetting processes. Nevertheless, existing voluntary commitments by a number of UK shooting and rural organisations to use alternatives to lead shot by 2025 for the hunting of live quarry could still significantly reduce the risks arising from hunting during this period.

A transition period of 18 months is proposed for the ban on the use of large calibre lead bullets for hunting, due to the availability of substitutes. However, a transitional period of 5 years is proposed for the ban on the use of small calibre (including airguns) lead bullets for hunting, to allow additional time for the development and testing of alternatives.

A transition period of 18 months is proposed for the ban on the use of large calibre lead bullets for sports shooting, due to the availability of substitutes and the expectation that shooting ranges may already have risk management measures in place sufficient to meet the proposed derogation or that these can be readily installed. A transitional period of 5 years is proposed for the ban on the use of small calibre (including airguns) lead bullets for sports shooting, to allow additional time for the development and testing of alternatives.

Transitional periods between 6 months and 5 years are proposed for the mandatory labelling requirements, depending on the final derogations, to raise awareness of both the risks of lead and the timelines for transition to alternatives.

The preferred risk management options and potential derogations described above are included in the consultation stage, to gather additional information about whether they are likely to be effective and proportionate. The derogations would also include a requirement to report to the relevant authority on the use of lead ammunition and the effectiveness of the risk management measures in place. These options have been taken forward for the socioeconomic analysis.

Socioeconomic analysis (provisional)

This impact assessment has relied heavily on the ECHA analysis because of the lack of UK or GB information on several key metrics, for example number of users, number of shotguns used and the breakdown of releases between small and large calibre bullets. Where GB information was not available the Agency adjusted the ECHA numbers using a proportion of the population to apply them to GB.

The most comprehensive impact assessment has been done for hunting with lead shot and to a lesser extent with bullets. The numbers show that even with a very partial monetisation of the benefits from the restriction, the costs of the restriction are very close to the benefits.

For sports shooting, the cost-benefit assessment is much less robust, as our analysis does not include any quantified benefits. For shooting with lead shot, it seems that a ban would be cost-effective, while the optional derogation with RMMs would not be cost-effective. The costs of a derogation would include the cost of RMMs. These have not been assessed for GB, but the analysis done by ECHA concludes that the costs of RMMs are much higher than the costs of a complete ban. If the derogation under strict conditions for lead shot would be implemented instead of a ban, then the total cost of the restriction for sports shooting would depend on the extent that the derogation is taken up by actors who wish to continue to use lead and take the necessary risk management measures to achieve > 90 % recovery. Given that such costs can be avoided by not taking up the derogation then the upper bound cost of this restriction option is bounded by the costs associated with the complete ban. For sports shooting with bullets, some costs have been calculated based on the ECHA analysis, but the lack of accurate information on lead releases by the different types of bullets makes it difficult to assess the cost-effectiveness of the proposed restriction.

Further evidence to improve the evidence on costs and benefits will be sought as part of the consultation stage, particularly in respect of unquantified costs and benefits, as well as on improving GB-specific estimates and data. Socioeconomic evidence will also be sought on the proposed optional derogations.

The Agency concludes that, based on information currently available, the proposed restriction is effective, practical, enforceable (in principle) and monitorable for each individual sector and use affected. The transition periods and possible derogations identified in the analysis of options have been used in the proposed legal text.

Costs and benefits of the proposed restrictions for the different uses

<table>
<tr><th>Use</th><th>Costs</th><th>Benefits</th></tr>
<tr><td>Hunting with shot</td><td>Total cost of the proposed restriction: £152 million (PV[2] over a 20-year period)</td><td rowspan="3">~ 86,000 tonnes of lead releases avoided over a 20-year period.

Reduce and prevent lead accumulation/availability in the habitats for species at risk of lead poisoning via primary and secondary routes.

Avoid the mortality of over 2 million birds over a 20-year period, due to direct ingestion of lead shot. Partial monetisation of this benefit gives a value of £114 million over 20 years.

Potential avoided environmental impacts (not monetized), such as impacts on wildlife other than birds exposed through the food chain.

Avoided exposure to lead for humans (via diet), quantified impact £93 million for IQ loss in children.

Reduction in chronic kidney disease valued at £38 million.
In terms of social welfare, the reduction of the adverse effects from the use of lead ammunition has multiple consequences, such as increased (long-term) opportunities for hunting and other leisure activities, e.g. birdwatching.

Total societal benefit: £230 million over a 20-year period.</td></tr>
<tr><td>Hunting with bullets

– small calibre</td><td>Total cost of the proposed restriction: £73 million (PV over a 20-year period)</td></tr>
<tr><td>Hunting with bullets

– large calibre</td><td>Total cost of the proposed restriction: £27 million (PV over a 20-year period</td></tr>
<tr><td>Outdoor sports shooting with shot</td><td>Total cost of the proposed restriction for a ban of lead in sports shooting: £25 million over a 20-year period. The costs of a derogation</td><td>~ 24,000 tonnes of lead releases avoided over a 20-year period

Reduce and prevent lead accumulation/availability in the habitats for species at risk of lead poisoning via primary and secondary routes.

Avoid the mortality of birds</td></tr>
</table>

[2]PV = Present Value

Use	Costs	Benefits
	would include the cost of RMMs. These have not been assessed for GB, but the analysis done by ECHA concludes that the costs of RMMs are much higher than the costs of a complete ban	Avoided environmental impacts (not monetized), such contamination of soil, uptake by vegetation and impacts on wildlife other than birds exposed through the food chain. Total societal benefit: unquantified.
Outdoor sports shooting with bullets	The costs for GB are very uncertain due to lack of data on releases but are estimated to be ~£14-£28m for small and ~£16m for large calibre bullets over a 20-year period	The number around emissions is very uncertain but a range of 390 to 970 tonnes of lead releases avoided over a 20-year period is assumed. Avoided environmental impacts (not monetized), such as contamination of soil and uptake by vegetation.

Proposed restriction entry

The text of the proposed entry in Annex 17 has been drafted to describe the intention of the Agency. The final legal wording (i.e. to update Annex XVII of REACH) is subject to change and would be decided by the Appropriate Authorities in due course.

Some elements of the proposal are presented in square brackets [….]. This is intended to indicate that either this element of the conditions of the restriction is (i) included on the basis of a preliminary conclusion that is subject to a review during the opinion-making phase (i.e. after further information gathering via the consultation stage) or (ii) that the element is part of an optional derogation that should be considered by the decision maker.

The elements in red italic font present an optional derogation: the four elements are proposed in conjunction with each other (i.e. as a set of measures) in order to achieve an optimum risk reduction potential of this option.

Designation of the substance	**Conditions of the restriction**
Lead and its compounds	1 . Shall not be placed on the market for use in a concentration equal or greater than 1 % w/w in gunshot
	2. Shall not be used, in a concentration equal or greater than 1 % w/w: a. in gunshot b. in any other projectiles not defined as gunshot
	3. By way of derogation: a) *[OPTIONAL CONDITIONAL DEROGATION (part 1/4): Paragraph 1 shall not apply to the placing on the market of lead gunshot for sports shooting if:* - *the supplier has a licence to place lead gunshot for sports shooting on the market]* b) *[OPTIONAL CONDITIONAL DEROGATION (part 2/4): Paragraph 2a shall not apply to the use of lead gunshot if:* - *the individual [athlete] has a licence to use lead gunshot for sports shooting; AND* - *the use takes place at a location that has a licence to use lead gunshot for sports shooting; AND*

	- *the following measures are in place at the licenced location:* • *Regular [at least once a year] lead shot recovery with [>90%] effectiveness (calculated based on mass balance of lead used versus lead recovered in previous years) to be achieved by appropriate means (such as walls and/or nets, and/or surface coverage); AND* • *Containment, monitoring and, where necessary, treatment of surface (run-off) water to ensure compliance with the environmental quality standard (EQS) for lead specified under the Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 and the Scotland River Basin District (Standards) Amendment Directions 2015; AND* • *A ban of any agricultural use within site boundary]"* c) Paragraph 2b shall not apply to the use of lead in projectiles not defined as a gunshot for sports shooting, if: - the use takes place at a location that has a licence to use lead projectiles not defined as a gunshot for sports shooting; AND - the following measures are in place at the licenced location: • Regular lead recovery with [>90%] effectiveness (calculated based on mass balance of lead used versus lead recovered) achieved by the means of bullet containment (i.e. bullet traps) AND • A ban of any agricultural use within site boundary
	4. Without prejudice to the application of other legal provisions on the classification, packaging and labelling of substances, mixtures, and articles: a) Suppliers of gunshot and projectiles not defined as a gunshot, containing lead in concentrations equal to or greater than 0.3 % w/w, shall ensure that,at the point of sale, in close proximity, the following information is clearly and visibly provided to consumers and professionals: - 'Contains lead'

	- 'Lead is very toxic to the environment and birds' - 'Lead may damage fertility or the unborn child' - 'The use of lead in [gunshot outside of wetlands for all uses/ projectiles for hunting - to be selected as appropriate] will be banned in GB from [EiF+TP as specified in paragraph 6]'. - 'Lead-free alternatives are available.' b) Suppliers of projectiles not defined as a gunshot containing lead in concentrations equal to or greater than 0.3 % w/w, shall ensure, before the placing on the market for use, that product packaging is clearly, visibly, and indelibly labelled with the information listed in paragraph 4a. In addition, projectiles not defined as a gunshot shall be labelled: - 'Not permitted for hunting'. If the packaging is too small, and the information listed in paragraph 4a cannot be provided on the packaging, this information can be provided in fold- out labels (leaflet) or on tie-on tags. *c) [OPTIONAL DEROGATION (part 3/4): Suppliers of gunshot containing lead in concentrations equal to or greater than 0.3 % w/w, shall ensure, before the placing on the market for use, that product packaging is clearly, visibly, and indelibly labelled with the information listed in paragraph 4a. In addition, individual cartridges shall be labelled:* *- 'Not permitted for hunting'.* *If the packaging is too small, and the information listed in paragraph 4a cannot be provided on the packaging, this information can be provided in fold-out labels (leaflet) or on tie-on tags.]*
	5. [OPTIONAL DEROGATION (part 4/4): The relevant enforcing authority shall supply a report on an annual basis to the Minister which includes: *- the number of licences granted to locations in GB under paragraph 3b and their location.* *- the number of licences granted to individuals in GB under*

	paragraph 3b. *- the quantity of lead gunshot used in GB under paragraph 3b.]*
	6. Entry into force of the restriction: a) paragraph 1 and 2a, shall apply [18 months OR 5 years (if optional derogation chosen)] from entry into force of the restriction b) paragraph 2b shall apply [18 months] from entry into force of the restriction for centrefire ammunition with a calibre greater than or equal to 5.6 mm c) paragraph 2b shall apply [5 years] from entry into force of the restriction for centrefire ammunition with a calibre less than 5.6 mm and any projectiles not defined as a gunshot of any calibre d) paragraph 4a shall apply 6 months from entry into force of the restriction. e) paragraph 4b shall apply [18 months] from entry into force of the restriction for centrefire ammunition with a calibre greater than or equal to 5.6 mm f) paragraph 4b shall apply [5 years] from entry into force of the restriction for centrefire ammunition with a calibre less than 5.6 mm and any projectiles not defined as a gunshot of any calibre *g) [paragraph 4c shall apply [5 years] from entry into force of the restriction.]*
	7. This restriction on lead in outdoor shooting shall not apply to the following applications: shooting in an indoor shooting range, police, security services, military applications and testing and development of materials and products for ballistic protection.
	8. For the purposes of this regulation: - ‘centrefire ammunition’ means ammunition where the primer is located in the centre of the case head or base; - ‘gunshot’ means pellets used [or intended for use in quantity] in a single charge or cartridge for shooting with a shotgun; - ‘hunting’ means pursuing and killing live quarry using a gun;

	- ‘projectile’: means an object intended to be expelled from a gun, irrespective of the means of propulsion; - ‘shotgun’ means a smooth-bore gun; - ‘sports shooting’ means shooting at any inanimate (non-living) targetwith a gun. It includes practice, or other shooting, performed in preparation for ‘hunting’.

1 Introduction

Lead has been used in ammunition for hunting and sports shooting for centuries. It is estimated that around 8,150 tonnes per year are deposited into the environment in GB, of which 6,400 tonnes per year are from hunting and 1,750 tonnes per year are from sports shooting (see Section 2.3).

In GB, each of the devolved administrations has already enacted a ban on the use of lead shot over wetlands in response to the African-Eurasian Waterbird Agreement (AEWA, 1999). These bans were introduced between 1999 and 2004 with the aim of protecting waterbirds from the impact of lead poisoning.

The English and Welsh regulations are similar and use of lead shot is prohibited:

- on or over any area below the high-water mark;
- on or over certain Sites of Special Scientific Interest;
- for the shooting of ducks, geese or swans of any species, coots or moorhens on or over both wetlands and terrestrial habitats.

In Scotland, the use of lead shot is prohibited on or over all wetland areas (but excluding peatlands with no visible water) but the ban does not extend to waterfowl outside of wetlands.

There is currently a ban on the use of lead shot in wetlands in Northern Ireland in response to the AEWA agreement. Under the Northern Ireland Protocol, EU REACH continues to regulate the access of chemicals to the Northern Ireland market. The EU restriction of the use of lead shot in wetlands comes into force on 15th February 2023 and will apply in Northern Ireland[3].

In 2010 the Lead Ammunition Group (LAG) was set up by the Department for Environment, Food and Rural Affairs (Defra) and the Food Standards Agency (FSA) to evaluate the published scientific evidence of the impact (in England only) of lead ammunition on human health, wildlife and the environment generally and on livestock and to propose possible mitigation for the risks identified. The group members included key stakeholders and experts from the gun and ammunition trade, game dealers, landowners, animal welfare and conservation organisations, human health and environmental health and sports shooting organisations. In its 2015 report (LAG, 2015a), the LAG concluded that an eventual phase-out of lead ammunition would be the only effective way to address the risks to wildlife and human health.

The Defra Secretary of State, with the agreement of the Scottish Government and

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[3] UK REACH entered into force on 31st December 2020 at the end of the transition period. It regulates the access of chemicals to the GB market. Under the Northern Ireland Protocol, EU REACH continues to regulate the access of chemicals to the Northern Ireland market.

the Welsh Government asked the Agency under Article 69(1) of UK REACH to prepare an Annex 15 restriction dossier for lead ammunition on the basis '*that the use of lead in ammunition raises concerns related to both human health and the environment. The harm of lead ammunition to wildfowl is of particular concern – poisoning from ingesting lead ammunition causes long-term suffering and slow painful deaths for animals. The health of humans, particularly children, may also be adversely affected from eating meat killed using lead ammunition*.'

1.1 Scope

1.1.1 Concerns to be addressed:

The Defra request relates to considering the risks posed by the use of lead in ammunition, and the potential need for further risk management measures beyond those already in place. Further clarification received from Defra confirmed that lead-containing propellants are not within scope. The focus of this Annex 15 report is on civilian use of ammunition only; police and military use are outside the scope defined by Defra.

LAG (2015a) and the subsequent update (LAG, 2018) identified concerns for both wildlife and human health from the use of lead in ammunition:

a) There is a risk to human health through consumption of game, with the highest levels of lead being in game birds, although the highest risk is to those that consume the highest quantities of game. Potential adverse effects on the health of high-level consumers include reduced intelligence and cognitive function of children, increased risk of spontaneous abortion in pregnant women and cardiovascular effects and chronic kidney disease in adults.

b) There is a present but low risk to human health from consumption of grazing livestock or foraging birds such as ducks and pheasants that have fed on land contaminated with lead ammunition.

c) There is a risk to wildlife either by direct ingestion of the ammunition or by scavenging contaminated carcasses.

d) There are likely subclinical effects on wildlife, with some impacts recorded in wildfowl and some other water birds.

e) There is the potential for exposure of wildlife to lead to impacts on population size.

Therefore, the scope of this Annex 15 report addresses both the risks to human health and wildlife from the placing on the market and use of lead ammunition for civilian outdoor activities.

Throughout this report the Agency has extensively referenced the work done by LAG but also that of ECHA on their wetlands restriction and proposed total lead ammunition (and fishing weights) restrictions (ECHA, 2017a, 2021a; LAG, 2015a, 2018). Since the UK was a member of the EU at the time that the wetlands restriction was proposed and the technical documents to support the proposal were drafted, the information in EU dossier includes data from the UK (and therefore GB). Data which have been assessed by ECHA and/or LAG as reliable are considered to be of a sufficient standard for inclusion without duplicative detailed review and analysis by the Agency. Data from GB have been used when available, with data for the UK, Europe or elsewhere used to add supporting information or to fill data gaps.

The Agency also held a call for evidence, the questions of which are in Annex E, to gather additional GB specific information. The information supplied has been used throughout this report and referenced to the organisation who supplied it. Information was received from a range of stakeholders, including organisations representing the shooting and animal welfare industries, academics and a number of individuals.

1.2 Substance identity and physico-chemical properties

1.2.1 Substance identification

This report concerns the use of zero-valent ‘elemental’ metallic lead or lead alloys used as projectiles. Generally metallic lead is used for projectiles, though lead alloys can also be used. The alloys used in gunshot (lead concentration >90 % by weight) typically contain variable proportions of antimony (up to approximately 6 % by weight) and arsenic (up to approximately 1.5 % by weight) to produce specific properties in the lead shot, such as hardness and roundness (ECHA, 2017a).

Table 1.1 Identification of lead

Identifier	
EC Number	231-100-4
EC name	Lead
CAS number	7439-92-1
Molecular formula	Pb
Molecular weight range	207.1978

Information on the composition of lead and its typical impurities are summarised in Annex B.1.2.

1.2.2 Physical chemical properties

The key physicochemical properties of lead that are relevant for this assessment are summarised in Table 1.2 based on information from the ECHA dissemination website (ECHA, 2021b).

Table 1.2 Physicochemical properties of lead

Property	Result
Physical state at 20 °C and 1013 hPa	Lead is available on the market as a solid in both powder and massive forms.
Melting point	326 °C at 1013 hPa (study result, EU A.1 method).
Relative density	11.45 (study result, EU A.3 method).
Vapour pressure	Lead metal is stated to have a vapour pressure of 133 Pa at a temperature of 1,000 °C. It has a negligible vapour pressure at 20 °C.
Water solubility	185 mg/L at 20 °C (study result, EU A.6 method). Water solubility varies with pH and solid form
n-Octanol-water partition coefficient	Not relevant for an inorganic substance.

1.2.3 Justification for grouping

Metallic lead and lead alloys have been considered together in this restriction report as they are used in both shot pellets and single projectiles and the hazards and impacts are very similar, as they both result in the emission of lead to the environment and may ultimately result in lead poisoning of environmental receptors (principally birds).

1.2.4 Classification and labelling

Lead powder (particle diameter <1 mm) and lead in massive form (particle diameter ≥ 1 mm) have a harmonised classification of Repr. 1A (H360FD) and Lact. (H362) in Annex VI of the EU Classification, Labelling and Packaging of substances and mixtures (CLP) Regulation (EC) No 1272/2008. The existing harmonised classification of lead powder (particle diameter <1 mm) was amended to add Aquatic Acute 1 (H400) and Aquatic Chronic 1 (H410) prior to the UK exiting the European Union. The amended classification has been added to the legally binding GB Mandatory Classification and Labelling (MCL) list of substance classifications and hazard labelling. Table 1.3 presents the resulting classifications as they appear in the GB MCL list.

Table 1.3 Classification and labelling as listed in the GB MCL list

Index No.	International Chemical Identification	EC / CAS No	Hazard class category	Hazard statement code(s)	Spec. Conc. Limits, M-factors, ATEs
082-013-00-1	Lead powder [particle diameter <1 mm	231-100-4 / 7439-92-1	Repr. 1A Lact. Aquatic Acute 1 [1] Aquatic Chronic 1 [1]	H360FD H362 H400 H410	Repr. 1A; H360D: C ≥ 0,03 % M = 1 M = 10
082-014-00-7	Lead massive [particle diameter ≥ 1 mm]	231-100-4 / 7439-92-1	Repr. 1A Lact.	H360FD H362	

Note: [1] shall apply from 1 March 2022 onwards

1.3 Manufacture and use

1.3.1 Uses of lead in ammunition

Lead is used in the manufacture of shot cartridges and other ammunition used by members of the public, law enforcement and the military.

Under UK REACH there are 13 grandfathered registrations and 1 new registration for metallic lead (as of 21st December 2021). Of the submitted dossiers, 8 include part A of the chemical safety report (CSR), which contains a summary of the risk management measures and declarations that risk management measures are implemented and communicated through the supply chain. These dossiers all state that Part B, which includes the information on hazard, fate, exposure and relevant risk management measures will be submitted by the Lead Registrant. A Lead Registrant has not yet been appointed for metallic lead under UK REACH, so this information has not yet been submitted. In the absence of this information the Agency has drawn from the ECHA restriction reports (2021a, 2021c) as the use of lead-based shot and ammunition is considered to be the same in GB as in the EU. An overview of uses and technical functions defined by ECHA (2021b) is used in this report (Table 1.4).

Table 1.4 Overview of uses and technical functions (as defined by ECHA 2021b)

<table>
<tr><th>Sector of use</th><th>Use #</th><th>Use title</th><th>Use overview - Brief description of the use of lead and its technical function</th></tr>
<tr><td rowspan="3">Hunting</td><td>1</td><td>Hunting with shot shell ammunition</td><td rowspan="7">Used as a projectile, either by itself or in quantity (i.e. gunshot) where the technical function is to provide mass for energy transfer to a target

Projectiles can be of various sizes and shapes depending on the desired ballistic properties. They can be used by consumers or professionals

The ballistic properties vary depending on whether ammunition is for hunting or sports shooting as well as the size and type quarry and the type of gun used. Projectiles can sometimes be coated with another metal (termed ‘jacketed’).</td></tr>
<tr><td>2a</td><td>Hunting with bullets -small calibre, including airguns</td></tr>
<tr><td>2b</td><td>Hunting with bullets -large calibre</td></tr>
<tr><td rowspan="3">Sports shooting</td><td>3</td><td>Outdoor sports shooting with shot shell ammunition</td></tr>
<tr><td>4</td><td>Outdoor sports shooting with bullets</td></tr>
<tr><td>5</td><td>Outdoor shooting with air rifle/pistol</td></tr>
<tr><td>Shooting with historical weapons</td><td>6</td><td>Other outdoor shooting activities including muzzle-loaders, historical re-enactment, etc.</td></tr>
</table>

In this report, each of the uses are assessed to determine whether they pose a risk to human health and/or the environment that is not adequately controlled. As each of the uses may have a different risk profile and differing potential for substitution with an alternative substance, the potential benefits and consequences of a restriction on marketing or use will also vary.

1.3.2 Manufacture of lead projectiles

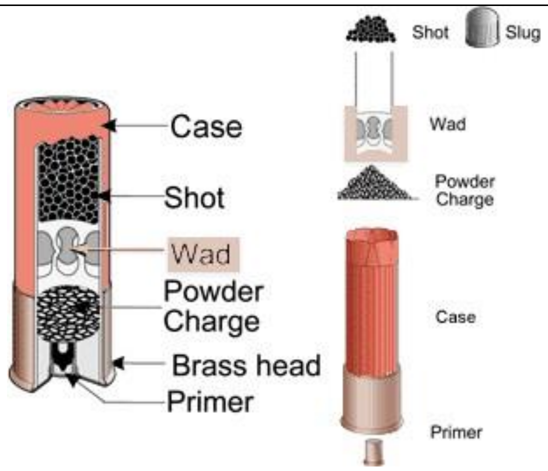
ECHA (2021c) provides an overview of the manufacturing processes which is summarised here. Further information can be found in ECHA (2021c).

There are several different types of projectiles as detailed below:

- Shot cartridges
- Solid lead bullet
- Jacketed bullet with lead core
- Shot shell ammunition
- Metallic ammunition
- Reloading ammunition

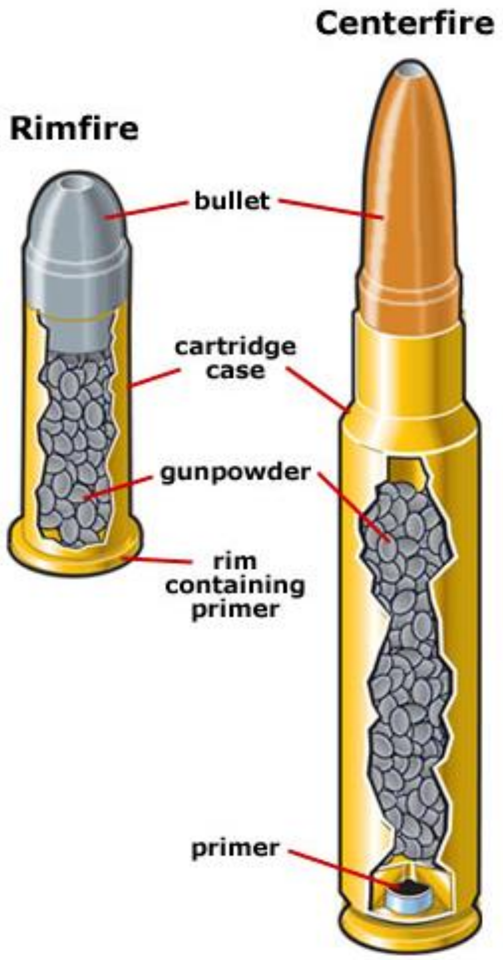
Lead shot is manufactured in two different ways, depending on the size of shot required. The Bliemeister method is used for smaller sized shot (between 2 and 2.4 mm in diameter). This involves dropping molten lead alloy through small holes into a hot liquid. It is then rolled down an incline to produce regular spheres. Larger shot sizes are manufactured using the wire process, where extruded lead wire is fed into dies and then tumbled and polished to produce the round shot. The resulting shot pellets are loaded into a cartridge assembly, which is summarised in Table *1.5* (based on ECHA 2021b):

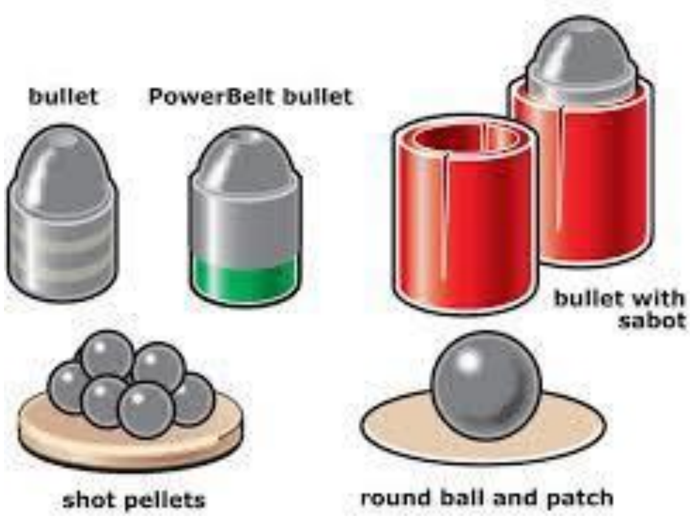
Table 1.5 Overview of components in a shot cartridge

Use	Description of a lead shot cartridge
Hunting and sports shooting with shot	 Source: http://theshotgunguide.blogspot.com/2013/06/the-anatomy-of-shotgun-ammo.html, accessed 5th January 2022

The manufacture of solid lead bullet components for centrefire cartridges, rimfire bullets, air rifle pellets, muzzle loader projectiles and shotgun slugs is done by the shaping of lead from ingots which is then punched into an appropriately shaped mould. A description of these types of ammunition is provided in Table *1.6* (based in part on (ECHA, 2021a):

Table 1.6 Overview of other types of lead ammunition

Use	Description of other types of lead ammunition
Hunting and sports shooting with bullets (centrefire and rimfire)	A centrefire round is a metallic cartridge whose primer is located at the centre of the base of its casing (i.e. "case head"). Unlike rimfire cartridges, the centrefire primer is typically a separate component seated into a recessed cavity (known as the primer pocket) in the case head and is replaceable by reloading. Rimfire ammunition is a type of metallic cartridge whose primer is located within a protruding rim at the base of its casing. When fired, the gun's firing pin will strike and crush the rim against the edge of the barrel breech, sparking the primer compound within the rim, and in turn ignite the propellant within the case.  Source: https://www.hunter-ed.com/california/studyGuide/Centerfire-and-Rimfire-Ammunition/20100501_66837/ accessed 2nd March 2022

Pest control and sports shooting with air rifles	A pellet is a low weight (6 g) non-spherical small calibre (.177) metal projectile of 4.5 to 5 mm diameter designed to be shot from an air gun (or pellet gun). Air gun pellets differ from bullets and shot used in firearms in terms of the pressures encountered; airguns operate at pressures as low as 50 atmospheres while firearms operate at thousands of atmospheres. Airguns generally use a slightly undersized projectile that is designed to obturate upon shooting so as to seal the bore and engage the rifling.  Source: https://www.shootinguk.co.uk/guns/ammunition/picking-perfect-airgun-pellets-80011 accessed 2nd March 2022
Muzzle loading guns	Muzzle loading firearms generally use round balls, cylindrical conical projectiles, and shot charges  Source https://www.hunter-ed.com/muzzleloader/studyGuide/Projectiles/222099_88839/ accessed 5th January 2022

Slugs (also known as “Brenneke”)	Slugs are projectiles for shot guns. The projectile is placed in a casing like that used in a shotgun cartridge.  Source: https://www.brenneke-ammunition.de/en/law-enforcement/atsr-anti-terror-slug/ accessed 2nd March 2022

ECHA (2021a) contains a comprehensive description of the different types of ammunition and is quoted in full below:

‘Lead gunshot is made in various sizes and placed on the market in cartridges of various load weights and gauges (cartridge diameter). Hunters and sports shooters select cartridges that fit in their guns and are suited to the type of shooting undertaken. On average a lead sports shooting cartridge contains about 24 g of lead gunshot (fixed by International Sports Shooting Federation (ISSF) rules) and a hunting cartridge contains between 30 and 34 g depending on the number of individual gunshot pellets (load) and their size. The latter two (load and size) specifications allow hunters to select a cartridge that is suitable for the intended quarry. For further information see Annex C.

Lead bullets are supplied to the market in various forms: either in ready-to-use cartridges or as separate components for ‘reloading’ by hunters. Hunters and shooters can choose between various calibres and bullet weights. Calibre size is positively related to the size of game being hunted or is (in sports shooting) set out by International Sports Shooting Federation such as the International Sports Shooting Federation of the International Biathlon Union. Hunters can furthermore choose the weights of the bullets, again bullet weight is positively related to game size. Lead bullets are not only used for (recreational) hunting but also in different forms of pest control or wildlife population management.

The ammunition value chain can be complex with various interactions by manufacturers, ammunition loaders and cartridge suppliers. Some manufacturers are global players and some other manufacturers supply only on a local scale, parts and components can be sold together by dedicated assemblers or be put on the market as such for reloading purposes.’

1.3.3 Use of lead in hunting

In GB there are a wide range of hunting pursuits, broken down as follows:

- Wildfowling
- Game and game keeping
- Pest and predator control, including pigeons, crows and rabbits
- Deer stalking and wild boar hunting

The choice of gun and ammunition used for each activity is defined by the prey being shot and the preference of the shooter. Hunting takes place in various forms, for example organised groups for deer stalking, driven game shoots or farmers shooting pests on their own land. The purpose of the projectile, whether shot or bullet, is to transfer sufficient energy to a target to result in a rapid kill (where unnecessary suffering is minimised) (ECHA, 2021a).

1.3.3.1 Risk management measures (RMM) for the environment during hunting

Hunting takes place over a diverse range of habitats, including woodlands and open grouse moors. As such, any ammunition that misses its target is unlikely to be recovered. The Agency has no information on the proportion of carcasses recovered following hunting and cannot draw any conclusions on the amount of lead in carcasses that are recovered or left in the environment. However, it is assumed that at least some carcasses are not retrieved and so lead is emitted to the environment via this route.

1.3.4 Use of lead in sports shooting

Sports use covers the shooting of both static targets and moving targets such as clay pigeon shooting.

Sports shooting in GB takes place either at formal permanent ranges or at temporary locations for training or competition. The sport of target shooting is a test of accuracy and speed of reaction and involves the use of air rifles, pistols, muzzle-loading rifles and pistols, and cartridge rifles (both rimfire and centrefire). Clay shooting, practical shotgun and practical rifle are also important branches of the target shooting disciplines. The rules for different disciplines are set by various international shooting organisations including the International Sports Shooting Federation (ISSF) and the Federation International des Armes de Chasse (FITASC). Most clay shooting is done through clubs with their own shooting grounds where there will be a series of traps or launchers which catapult clay targets into the air to simulate a variety of wild quarry species.

A wide range of ammunition is used, ranging from shot cartridges containing small pellets to air pellets to large calibre bullets.

1.3.4.1 Risk management measures (RMM) for the environment at shooting ranges in GB

In GB there is no statutory requirement for the design of ranges, although the National Rifle Association has published a series of guidance documents for range managers and range safety officers. This guidance does not refer to the protection of the environment. There is also published guidance from the Defence Safety Authority for only military ranges.

1.3.4.1.1 Call for evidence information

During the GB call for evidence (Annex E) a number of shooting organisations submitted extensive information collected from their members and the sites they operate. The British Sports Shooting Council estimated the number of sites in GB to be 400 outdoor shooting ranges and 280 registered clay pigeon shooting grounds of which 178 have trap and / or skeet, which are different types of clay pigeon shooting, on the same site.

The British Sports Shooting Council undertook a survey of their members asking for information on the collection and recovery of spent lead projectiles. A summary of the responses is provided below.

The largest shooting complex in GB is at the National Shooting Centre at Bisley in Surrey, owned by the National Rifle Association of the UK. This site has both rifle ranges, including a military range, and a clay pigeon shooting centre. The site estimates that approximately 5 million copper jacketed bullets are shot each year on their target ranges. These bullets are captured using either sand or rubber composite stop butts, which are screened to recover the bullets twice a year. The range recovers 25 - 30 tonnes of lead per year which, based on the average weight of a bullet being 7 g (ECHA, 2021c), gives a recovery rate of between 71 and 85 %. The clay pigeon target shooting centre has a fallout zone which is covered by rough grass, heather, scrub and trees. It is screened every 3-5 years by scraping off the top 5 cm of soil and spinning it to remove the lead shot. The last time this was done 340 tonnes of lead was removed for recovery.

Information was supplied by 2 other outdoor rifle ranges, one of which de-leads the range twice a year and recovers 300-800 kg of lead / copper each time. The material is retrieved by hand, heated and separated and sold for scrap. The other organisation has 2 ranges. The 100-yard (91-metre) range is de-leaded every 100,000 rounds. The 500-yard (457-metre) range is de-leaded when 20,000 rounds have been fired into each target bullet catcher. At the last de-leading the contractor removed 940 kg of material for re-processing. For both of these organisations the percentage recovered, and the method of bullet capture is unknown.

The United Kingdom Practical Shooting Association (UKPSA) has reported on lead recovery at four of its clubs. One of these clubs operates 2 airgun ranges, 3 fullbore rifle ranges and 4 shotgun ranges, using lead slugs on the airgun ranges, copper jacketed lead bullets on the rifle ranges and lead shot cartridges on the shotgun ranges. On this range approximately 750,000 rounds are fired per year, amounting to 3,500 kg of lead. Information was not provided to allow a break down on this total value by ammunition type.

The shot pellets are captured using rubber curtains, where the shot falls to the ground for recovery. The fullbore ranges have sand backstops, are situated beneath steel and concrete bullet catcher canopies and are de-leaded by a mechanical process every 200,000 rounds, with a recovery rate of 95%. The sand is kept dry so no water runoff takes place in this area. Of the other UKPSA sites that provided information, one has not attempted lead recovery and two do recover the lead, but no information on quantities is available.

The Preparatory Schools Rifle Association (PRSA) is an association of 30 school rifle clubs using air rifles, air pistols and .22 rimfire rifles for national competitions of which only 5 are outdoor ranges. All the clubs collect the bullets using metal deflector bullet traps and over 90% of lead pellets are recovered. Small sand traps are usually situated beneath the deflector plates to assist this process. Recovery is a relatively quick operation, taking only one day in most cases. Owing to range construction there is minimal, if any, water run-off.

The Clay Pigeon Shooting Association (CPSA) has 319 registered grounds, of which 17 offered responses to the call for evidence questionnaire. Lead containing shot cartridges are used on all these grounds, with approximately 12 million registered clay targets shot each year. If the Agency assumes that only one shot cartridge is fired for each clay target then this amounts to 360 tonnes of lead, based on an average of 28 g of lead per cartridge (ECHA, 2021c). Clay pigeon shooting sites in GB are very varied; some are located on open land, others are within woodlands and some of them are located in or close to agricultural land. They may be fixed location or mobile. Trap grounds are easier to recover lead from, owing to their topography. Sporting grounds, where shots are often fired within or into woodland, present much greater difficulty.

Two of the 17 respondents (11.8 %) recover lead and a further 3/17 (17.6 %) are considering recovery (so around 71 % of the respondents had no plans). There is no information about recovery for 312 (97.8%) of the total number of registered grounds covered by the CPSA. One of the individual respondents to the call for evidence said that they did not think that any of the clay pigeon sites would be able to recover a minimum of 90 % of the lead shot as proposed by ECHA (2021a).

1.3.4.1.2 Summary from call for evidence

Based on the information submitted during the call for evidence, recovery of lead ammunition on outdoor shooting ranges is higher than at clay pigeon sites. There are varying amounts of active recovery at a small number of sites the Agency received information from. At Bisley, a significant amount of lead recovery is undertaken but the proportion of the total used is unknown as the total amount of lead shot has not been given. Except for the Preparatory Schools Rifle Association ranges, which have confirmed achieving 90 % recovery, the Agency does not know the actual recovery rate at other ranges. It is also unknown how representative the sites that provided the information summarised above are of the other outdoor shooting ranges and clay pigeon grounds in the UK.

Several respondents to the call for evidence stated that while they were not aware of any sites with remediation plans and no closed sites that had or will undergo remediation, the regular maintenance of bullet collection systems is done to ensure they continue to operate correctly. The cost of the contractor can partially be offset by the price given for the lead recovered, in some cases up to 80 %.

1.3.4.2 Risk management measures (RMM) from the EU Chemical Safety Report

The Agency has not seen the EU Chemical Safety Report (CSR) for the use of lead in shot and ammunition submitted by the Lead Consortium to ECHA in 2020 as part of their REACH registration obligations as it was submitted after the end of the transition period. In their report ECHA (2021c) reviewed the CSR and stated that it contains several required RMM for the use of lead ammunition in sports shooting, indicating that an unacceptable risk is identified by the Registrants without these. Below is an excerpt from the ECHA restriction (ECHA, 2021c).

> ‘Exposure Scenarios (ES) for these various uses of lead in ammunition are described, including an ES for the professional and consumer (non-military) use of lead ammunition, (service life). In this ES, the use of lead ammunition in sports

shooting is covered, in relation to outdoor pistol/rifle shooting and clay target shooting (incl. sporting clays or simulated game hunting). The RMM identified in the CSR as “required” to prevent releases during service life at different types of shooting ranges are the following:

- Measures to prevent rivers from crossing the lead deposition area
- Bullet containment in the shooting range: at least one or a combination of bullet traps, sand traps or steel traps
- Overhanging roof over the lead impact zone to prevent runoff
- Control of water runoff
- Lead shot deposition must be within the boundaries of the shooting range
- Remediation plan upon closure

Specifically, the identified RMM are supposed to be applied according to Table . No information is provided in the CSR in relation to the expected specific effectiveness of each of the measures.’

Table 1-5 RMM to prevent releases during service life in a typical outdoor pistol/rifle range and (sporting) clay target range, as indicated in the EU REACH registration CSR

RMM to prevent releases during service life	Outdoor pistol/ rifle range	Clay target range	Sporting clay target range (simulated game hunting)
Measures to prevent rivers from crossing the lead deposition area	required	required	required
Bullet containment in the shooting range: at least one or a combination of bullet traps, sand traps or steel trap	required		
Overhanging roof over the lead impact zone to prevent runoff	required		
Control of water runoff		required	required
Lead shot deposition must be within the boundaries of the	required	required	required

shooting range			
Remediation plan upon closure	required	required	required

Although these RMM are listed in the EU CSR as required to ensure safe use, the Agency does not know to what extent these have been implemented for all sports shooting ranges in GB (Section 1.3.4.1).

ECHA (2021c) undertook a detailed review of the potential RMM for sports shooting, which have been replicated in Annex A.3.

1.3.4.3 Conclusion on risk management measures for sports shooting

The Agency considers that based on the information provided during the call for evidence, and the information in Annex A.3, it is possible for static ranges to be able to implement shot and bullet control and recovery measures to meet a recovery rate of 90 %. Implementation for mobile ranges is more difficult, particularly given some of the terrain involved, and therefore shot and bullet capture is very unlikely.

1.4 Environmental assessment

1.4.1 Environmental fate

This review of the environmental fate properties of lead is based on detailed reviews by (ECHA, 2018a, 2018b). Those reviews included data from LDAI (2008), Danish EPA (2014), SAAMI (1996) and the EU REACH registration dossiers.

Lead is an element and so, by definition, cannot be degraded. Therefore, it is not relevant to assess degradation rate as is usually done for organic compounds. As such, this section considers the potential transformation of lead in water, its environmental distribution and bioaccumulation.

1.4.1.1 Transformation

Lead in its metallic form (Pb^0) can be transformed to its ionic forms in the environment; Pb (II) (Pb^{2+}) is the dominant form, as it is more stable than Pb (IV) (Pb^{4+}) (ECHA, 2021c). Environmental conditions affect lead speciation (ECHA, 2021c). The extent and rate of transformation has been assessed in standardised transformation/dissolution protocol (T/Dp) tests in accordance with OECD guidance, showing a decrease in transformation to ionic forms occurs with:

- higher pH: T/Dp tests carried out on fine lead powders (<75 µm diameter) at a loading of 100 mg/L for 24 hours resulted in concentrations of 3,211 µg/L at pH 6, 607 µg/L at pH 7 and 188 µg/L at pH 8 (ECHA, 2017a).

- larger particle size: a T/Dp test carried out on fine lead powder (<75 µm) at a loading of 100 mg/L at pH 6 produced a dissolved lead concentration of 3,211 µg/L at 24 hours. Assuming a linear kinetic model for dissolution, a 100-fold decrease in loading rate from 100 mg/L to 1 mg/L would decrease the concentration of the lead in solution 100 times from 3,211 µg/L to 32 µg/L. This is a conservative assumption; the concentration at 1 mg/L loading is likely to be >32 µg/L at 24 hours for fine lead powder (<75 µm). A T/Dp test carried out on larger lead particles (1 mm diameter) at a loading of 1 mg/L at pH 6 produced a dissolved lead concentration of 5.1 µg/L after 7 days (ECHA, 2018b).

Transformation rates of lead under normal environmental processes are slow, demonstrated by the results from the full T/Dp test (1 mg/L loading of 1 mm particles for 28 days at pH 6), where concentrations of lead were 5.1 µg/L at day 7 and 14.2 µg/L at day 28 (ECHA, 2018b).

Transformed lead ions can precipitate as hydroxides, sulphates, sulphides, carbonates and phosphates; these processes are directly controlled by pH, oxidation-reduction conditions and the concentrations of the anions (in turn, driven by, for example, dissolved organic carbon content) (ECHA, 2021c). Such processes vary across sites, meaning it is the site-specific conditions that determine lead solubility.

The half-life of lead (the time needed for half of the amount to be lost) in soil has been estimated to be between 740 and 5,900 years (Alloway *et al*., 1997). No half-life data are available for sediments, but as the metallic lead corrodes the lead compounds formed may associate with the sediment. Lead sulphide is likely to form in anaerobic sediment.

1.4.1.2 Environmental distribution

Lead is a natural constituent in all environmental compartments, including biota (ECHA, 2021c). Overall, the fate of spent lead ammunition in the environment largely depends on whether it remains exposed or becomes buried in sediments or soils (ECHA, 2021c).

Lead ammunition can accumulate on the soil surface of shooting areas. Projectiles may fragment on impact and/or lead may leach from projectiles due to weathering. The rate of corrosion of metallic lead is often controlled by the build-up of lead salts on the metal surface. Many of these salts have very low solubility in water, particularly lead sulphate and lead carbonate. Several studies have considered the effects of weathering on lead (for example, Anderberg *et al*., 1990; Linder, 2004; Scheinost, 2004). Based on these studies, the supplementary CSR for the use of lead ammunition developed for the EU REACH registration of lead (ILAE, 2010; cited within ECHA, 2021c) identified corrosion rates of 1 % per year as a worst-case estimate. Corrosion rates of 1 % per year (or less) demonstrate that large amounts of lead ammunition remain in the environment in solid form (approximately 99% or more per year), providing an ongoing exposure route via direct ingestion (see Section 1.4.4).

Small fragments of projectiles, smaller sizes of lead shot and the lead compounds that result from weathering are the most mobile (ECHA, 2021c). Where shooting areas are continuously disturbed and therefore soil is left bare, erosion during rainstorms and the associated surface water runoff can cause the transport of lead to adjacent water bodies (ECHA, 2021c).

The fate of lead within terrestrial and aquatic compartments is regulated by physico-chemical processes, including oxidation/reduction, precipitation/dissolution, adsorption/desorption and complexation/chelation (ECHA, 2021c). In the terrestrial environment, soil conditions (e.g. mineral content, organic matter content, pH, and redox conditions) affect both the speciation of lead and the sorption of lead species to the soil, as reviewed in detail by ECHA (2021c). In the aquatic environment, the partitioning of lead into the dissolved phase in surface waters is driven by pH, natural organic matter levels, the presence of anions (hydroxides, carbonates, sulphates and phosphates), and water velocity (i.e. mechanical disturbance). The parameters that control the fate of lead are highly variable between sites (dependent on the site hydrological and geological conditions) and, therefore, the mobility of lead in both the terrestrial and aquatic environments is site-specific (ECHA, 2021c).

In surface soils, where lead ammunition is commonly found, conditions are usually oxic (unless waterlogged), which leads to high sorption and relatively low mobility of lead (ECHA, 2021c). If the soil surface layer capacity of lead is reached, lead will migrate towards lower soil layers, again driven by site-specific soil properties.

Solid lead slowly dissolves in soft waters, whereas it generally does not dissolve in hard waters. In most surface and ground waters, dissolved lead tends to form complexes with anions, which precipitate out of the water column. Therefore, in general, a significant fraction of the lead present in surface waters can be expected to be present as (ECHA, 2021c):

1. colloidal particles;
2. larger undissolved complexes of lead carbonate, lead oxide or lead hydroxide; or

3. other lead compounds incorporated within/sorbed onto particulate matter.

Partition coefficients (log K_D) for lead between freshwater and suspended particulate matter in the UK are provided in Table 1.7 (ECHA, 2021c); these demonstrate strong adsorption to suspended particulate matter. In aquatic environments with low water velocities, the suspended matter with lead bound to it will become buried in bottom sediments, moving lead to the anoxic sediment layer where it can become strongly adsorbed onto sediment particles.

Table 1.7 K_D values reported for lead in freshwaters in the UK

Location	Log K_D (L/kg)	Remarks	Reference
Calder River	4.45 – 5.98	minimum–maximum	(Lofts and Tipping, 2000; cited within ECHA, 2021c)
Nidd River	4.69 – 6.25	minimum–maximum	
Swale River	4.58 – 6.20	minimum–maximum	
Trent River	4.61 – 6.06	minimum–maximum	
All rivers	5.41	observed mean	
All rivers	5.71	predicted mean	
Upland-influenced river water	4.6	modelled value	(Tipping *et al*., 1998; cited within ECHA, 2021c)
Low-salinity water	5.5	modelled value	

1.4.1.3 Potential effect of steel shot replacement

It is likely that steel shot would replace the use of lead shot at shooting ranges (see Annex C). ECHA (2021c) modelled how this may affect lead mobility in two soil types. Overall, ECHA (2021c) found that the metals which may dissolve from steel shot are unlikely to enhance the mobility of lead:

- Released iron may reduce the mobility of lead through the formation of iron (hydr)oxide precipitates, which have a high affinity for lead sorption.
- In theory, dissolved manganese or nickel ions from steel could increase the conductivity of soil porewaters and enhance the corrosion of lead shot. However, evidence from the literature indicates that the amount potentially

released from steel shot would not have a significant effect.

ECHA (2021c) also considered in detail how steel shot could promote soil acidification via the corrosion of iron and in turn potentially enhance the mobility of lead. They concluded that, assuming both oxidation and hydrolysis reactions of the different iron species occur, the corrosion of iron would not have acidifying effects and therefore enhanced mobility of lead is unlikely. In the unlikely event that the iron in the steel shot is oxidised before being fired (i.e. the shot is rusty), there may be some acid formation, but the buffering capacity of soils mean that this is not expected to significantly affect soil pH (and therefore changes in lead mobility are unlikely) (ECHA, 2021c). The Agency agrees with these conclusions.

1.4.1.4 Bioaccumulation

ECHA (2021c) reviewed the bioconcentration factors (BCFs) and bioaccumulation factors (BAFs) for lead from water to aquatic invertebrates and fish as summarised in LDAI (2008) and the EU REACH registration for lead. A focussed review on BAFs was provided because these are preferred over BCFs, due to their higher ecological relevance as they include all possible exposure routes: water, food and soil/sediment.

ECHA (2021) selected a concentration range of 0.18 to 15 µg/L lead to represent background levels. Within the 0.18 to 15 µg/L concentration range, reported BAFs range between (10–90th percentile) (ECHA, 2021c):

- 11 and 143 L/kg$_{ww}$ (median: 23 L/kg$_{ww}$) for fish;
- 18 and 3,850 L/kg$_{ww}$ (median: 675 L/kg$_{ww}$) for molluscs;
- 968 and 4,740 L/kg$_{ww}$ (median: 1,830 L/kg$_{ww}$) for insects;
- 1,583 and 11,260 L/kg$_{ww}$ (median: 3,440 L/kg$_{ww}$) for crustaceans.

For lead exposure of predators (birds and mammals) via the aquatic compartment, ECHA (2021c) calculated a ‘realistic mixed diet’ BAF of 1,553 L/kg (median; 90th percentile of 3,890 L/kg), which assumed that birds and mammals consume equal portions of crustaceans, molluscs, annelids, acarida, insects and fish.

For terrestrial bioaccumulation, in line with R.16 of the REACH Guidance (ECHA, 2016), ECHA (2021c) considered the soil–earthworm–earthworm-eating predator food chain, drawing on LDAI (2008). The BAF range for earthworms is 0.13 to 0.17 kg$_{dw}$/kg$_{ww}$ (10 to 90th percentile; median, 0.39 kg$_{dw}$/kg$_{ww}$).

1.4.2 Environmental hazard

Lead and lead compounds are hazardous; there are extensive data on the effects of both short- and long-term exposure for aquatic and terrestrial organisms, which have been collated in EU REACH registration dossiers (ECHA, 2021d) and LDAI (2008), among other reports. The toxicity of lead in the environment is generally dependent on its bioavailability; more bioavailable forms, for example dissolved ionic species, usually have relatively greater toxicity (ECHA, 2021c). Metallic lead can transform into soluble (and therefore bioavailable) species in the environment (See Section 1.4.1), the rate being faster for small particle sizes (diameter < 1 mm) than larger ones. In addition, small particles of lead metal or alloy (for example, arising from lead ammunition) can be ingested by animals (primarily birds) and thereby pose a hazard as they pass through the gut.

This section discusses the toxicity of lead in the aquatic and terrestrial compartments, and on the non-compartment specific effects of lead. As this restriction is mainly focussed on risks to birds, only a brief summary of key hazard endpoints is provided for aquatic and soil-dwelling organisms.

1.4.2.1 Aquatic compartment (including sediments)

The mandatory environmental hazard classification of lead in powder form (particle diameter < 1 mm) under UK classification, labelling and packaging legislation is Aquatic Acute 1 (H400), with an acute M-factor of 1, and Aquatic Chronic 1 (H410), with a chronic M-factor of 10. This is based on a 72-hour EC_{50} of 20.5 µg/L for *Pseudokirchneriella subcapitata* and a 30-day EC_{10} of 1.7 µg/L for *Lymnaea stagnalis* (growth). Further details are provided in ECHA (2018a).

A decision about the environmental hazard classification for metallic lead (particle diameter ≥ 1 mm) has not yet been taken. The EU is considering new data and the environmental classification has not been included in Annex VI to Regulation (EC) No. 1272/2008 as of December 2021. Metallic lead does not currently have a mandatory environmental hazard classification under UK law. Nevertheless, companies still have a responsibility to self-classify. The lead EU REACH Registrant considers that this form of lead does not require a classification for the environment (ECHA, 2021d).

Based on the aquatic toxicity data set, a freshwater Predicted No-Effect Concentration (PNEC) of 2.4 µg/L (as dissolved lead) is presented in the CSR (2020). The quality of the data set, its appropriateness for different abiotic conditions (such as hardness and pH) and derivation method have not been evaluated by the Agency for the purposes of this report. A sediment PNEC has not been considered either.

Under UK water quality legislation (such as the Water Framework Directive

(Standards and Classification) Directions (England and Wales) 2015), lead and its compounds have an Annual Average Environmental Quality Standard (AA-EQS) of 1.2 µg/L (as a bioavailable concentration) in inland surface waters (defined as rivers and lakes and related artificial or heavily modified water bodies). A slightly higher AA-EQS of 1.3 µg/L can be used for other surface waters. The EQS expressed as a Maximum Allowable Concentration (MAC-EQS) is 14 µg/L (as a dissolved concentration).

1.4.2.2 Terrestrial compartment

A generic PNEC for soil of 212 mg/kg dry soil (as lead) is presented in the CSR (2020), based on ecotoxicity data for soil-dwelling organisms. The quality of the data set, its appropriateness for different abiotic conditions (such as organic carbon content and pH) and derivation method have not been evaluated by the Agency for the purposes of this report.

1.4.2.3 Non-compartment specific effects

Acute or chronic toxicity resulting from metallic lead ingestion is generically termed ‘lead poisoning’. The principal routes of lead poisoning by lead ammunition are (ECHA, 2021a):

- Primary ingestion (primary poisoning): that is, the direct ingestion of lead metal through normal feeding or foraging from the environment (for example, mistaking lead particles for grit, which is used to aid break up of food or for minerals); and
- Secondary ingestion (secondary poisoning): that is, the indirect ingestion of lead through feeding of food contaminated with lead (for example, lead particles in prey/carrion, lead contaminated tissues or plants).

There has been extensive research on the effects of lead poisoning in birds (Section 0). There are limited studies on the effects of lead poisoning in mammals; predators and scavengers, like foxes, may be exposed through primary or secondary ingestion, but the information is insufficient to detail here. Data on toxicity to humans is reviewed in Section 1.5. There are some data available on ruminants (Section 1.4.2.3.2).

1.4.2.3.1 Birds

The hazard to birds posed by ingestion of lead metal depends on the ecology and physiology of the species (ECHA, 2021a). In particular, species with muscular gizzards are subject to primary poisoning because ingested lead is ground down in the gizzard, enhancing its dissolution and then uptake within the intestine (ECHA, 2021a). Secondary poisoning is particularly important for species that consume prey or carrion left in the environment that have lead within them. Literature describing lead ammunition as a source of lead poisoning has emerged since the 1930s, with recent reviews, as cited within ECHA (2021a), including: Rattner *et al.* (2008), Franson and Pain (2011), Delahay and Spray (2015), LAG (2015a), Golden *et al.* (2016), Plaza and Lambertucci (2019) and Grade *et al.* (2019).

Absorption

The main factors that affect the initial absorption of lead metal following ingestion are stomach characteristics, retention time in the gastrointestinal tract, diet and sex (ECHA, 2021a).

The stomach of birds comprises (ECHA, 2021a):

1. The proventriculus: here, gastric juices create an acidic environment. The pH varies but it can be strongly acidic; for example, ducks have a stomach pH of 2.0 to 2.5, and eagles have a stomach pH of 1.0 (ECHA, 2021a). In chickens (n = 20), pigeons (n = 15), pheasants (n = 11), turkeys (n = 4) and ducks (n = 10), the pH of the proventriculus was reported to be 4.4, 4.8, 5.7, 4.7, and 3.4, respectively (Farner, 1942).

2. The muscular gizzard: this grinds food into smaller pieces, often with the aid of grit. The pressures created vary, with species that feed on coarse objects (grain/plant material) more muscular and larger than those that predominantly feed on meat. For example, geese, ducks and chickens can create pressures up to 37, 24 and 17 kPa, respectively (ECHA, 2021a). The environment remains strongly acidic in the muscular gizzard; Farner (1942) reported pH levels of 2.6, 2.0, 2.1, 2.2 and 2.3 in the gizzard of chickens, pigeons, pheasants, turkeys and ducks.

These stomach characteristics (creation of smaller lead particles and a low pH) promote the dissolution and erosion of lead ammunition when ingested (see Section 1.4.1.1), leading to greater potential for its absorption in the gastrointestinal tract.

Once ingested, lead metal can be regurgitated or passed through the gastrointestinal tract. If not ejected from the body within the first 24 hours, most of the lead will be retained within the gastrointestinal tract for an extended period of time. Here, it is subject to erosion and dissolution in the stomach, and according to ECHA (2021a) will generally be completely eroded within 20 days. However, this might not always be the case. For example, a recent study, in which Pekin Ducks (*Anas platyrhynchos* forma *domestica*) were administered with six lead shot pellets by oral intubation, showed 45.3% mass loss of the pellets after 4 weeks (Krone *et al*., 2019); the Agency assumes that these pellets were retained within the gizzard and thereby provided an ongoing source of lead to the birds.

Bird species that have whole or part-grain diets are more likely to be subject to primary poisoning than those that do not because:

1. they are more likely to mistake lead shot and grit for grain and consume it; and

2. their gizzard is especially muscular, to enhance grinding capabilities.

Where birds have diets high in protein and calcium, these can reduce acidity within the stomach and therefore moderate the initial dissolution of lead within the gastrointestinal tract (ECHA, 2021c).

Sex affects the initial absorption of lead because of the role calcium plays in eggshell formation. Calcium used to form egg shells is sourced from both the diet and the medullary bones (which are effectively an internal calcium reservoir) (Kerschnitzki *et al*., 2014). Therefore, actively laying birds increase their intestinal absorption of calcium to both directly form egg shells and also replace the calcium that has been sourced from the medullary bones. Lead and calcium have similar chemical properties due to the stable 2+ oxidation state. They also have similar atomic radii and can act as substitutes for each other in some structures (e.g. bone). This means that greater absorption of calcium concurrently results in greater absorption of lead.

Distribution

Once absorbed, lead is transported around the body in the bloodstream (ECHA, 2021a). From the bloodstream, lead is rapidly deposited into soft tissues, with the highest concentrations generally found in the bone, then kidney and liver (ECHA, 2021a). In Pekin Ducks, Krone *et al.* (2019) demonstrated high levels of lead in the liver, kidney and pancreas, compared with the breast muscle and brain, 4 weeks following oral intubation with six lead shot pellets. Over the lifetime of a bird, lead accumulates in the bone in particular, although it can be mobilised (for example during egg laying, as described above). Muscle tissues generally have low lead concentrations (ECHA, 2021a).

Metabolism

In birds, calcium plays two important physiological roles, namely, providing structural strength to the skeleton and being integral to several biochemical reactions within the body. Due to the similarity of the biological behaviour of lead and calcium, lead competes with calcium ions and affects those biochemical processes that normally involve calcium (ECHA, 2021a). Lead also becomes deposited in the bone instead of calcium.

Elimination

Lead can be eliminated from birds in their faecal sacs. However, with continuous or repeated exposure, lead will be retained and concentrations within their bones will increase (ECHA, 2021a).

Lethal and sub-lethal effects

Toxicological studies have been conducted with captive birds, including wildfowl species (primarily), predators and scavengers (ECHA, 2021a). In general, birds have been dosed with lead ammunition and then blood lead concentrations, physiological parameters and other clinical signs have been monitored (ECHA, 2021a).

Lethal effects

Acute (short-term) and chronic (long-term) exposure to lead metal (i.e. lead ammunition) can both cause mortality in birds. Acute exposure generally occurs after a bird has ingested a large quantity of lead shot over a short period of time, although it can occur after ingesting just one shot; it causes mortality within 1 to 3 days, without the bird exhibiting obvious symptoms of lead poisoning (ECHA, 2017a). Chronic lethal poisoning occurs when a bird ingests 1 to 15 lead pellets (often 1 or 2) and develops a progressive illness that results in death after 20 days (on average) (ECHA, 2017a). In this case, birds initially exhibit almost fluorescent, green faecal diarrhoea, followed by increasing muscular weakness, which initially causes abnormal wing positioning, then progressive loss of the ability to walk or fly (ECHA, 2021c). Finally the emaciated birds seek refuge and become comatose before death (or are eaten by a predator) (ECHA, 2021c). Internally, birds subject to chronic lethal poisoning often have myocardial damage, liver atrophy, an enlarged gall bladder (due to build-up of thick, dark-green bile) and impaction of the oesophagus and stomach (ECHA, 2021c).

Lethal effects have been demonstrated in:

- Mourning Doves (*Zenaida macroura*): of 157 birds that were administered 2 to 24 lead pellets, 104 died (all 22 in the control group survived) within 21 days (Schulz *et al*., 2006; cited within ECHA, 2021c). In a separate study, mortality in doves (25 per treatment) exposed to 0, 1, 2 or 4 #8 lead shot was 0%, 24%, 60% and 52%, respectively (Buerger *et al*., 1986).

- Cowbirds (*Molothrus ater*): of 10 birds dosed with a single 7.5 mm lead shot and given a relatively natural diet, three died within one day. Of the survivors, all but one excreted the lead shot they had ingested within 24 hours. All of the dead birds retained their shot. The greatest erosion of lead was observed in birds that died (2.2 to 9.7%) (Vyas *et al*., 2001).

- Willow Ptarmigan (*Lagopus lagopus*): four groups of 9 birds were each administered 0, 1, 3 and 6 individual 2.5 mm lead shot, respectively. In both the 3-shot and 6-shot groups, 22% mortality was observed within 8 to 15 days. The amount of eroded lead among the birds that died was significantly different from the survivors, with a tendency towards increased lead residues in the liver with increased eroded lead (Gjerstad and Hanssen, 1984).

- Bald Eagles (*Haliaeetus leucocephalus*): four out of 5 birds dosed with lead shot (10 shot at a time, additional doses administered if previous shot regurgitated) died, after 10, 12, 20 and 125 days. The fifth bird became blind and was sacrificed after 133 days. Each bird had lost body weight at death (23, 17, 16, 23 and 20%, respectively). Individual responses were variable, but cardiovascular lesions (myocardial necrosis, fibrinoid necrosis) and renal lesions (nephrosis) were observed (Pattee *et al*., 1981).

- Mallard Ducks (*Anas platyrhynchos*): one shot comprising 0.073 g lead caused 35% mortality in 10 ducks, with higher doses (0.21 to 1.0 g) causing 80 to 100% mortality (Finley and Dieter, 1978). In another study, 0.2 g lead shot caused 90% mortality (n = 10) (Brewer *et al*., 2003).

In experimental studies, the time to death after ingestion of lead ammunition has been shown to vary between species and dosage; waterfowl generally die within 2 to 4 weeks, while some raptors can survive more than 15 weeks.

Sub-lethal effects

Sub-lethal effects associated with lead poisoning at levels that may not cause immediate mortality have been demonstrated following both short-term and long-term exposure. These have been summarised into the following categories:

- **Haematology**: lead causes severe anaemia (potentially leading to death), as a result of the accumulation of non-haeme iron and abnormal blood pigments in malformed erythrocytes (ECHA, 2017a). The abnormal surface membranes of the erythrocytes means they are unable to effectively transport oxygen, are short-lived and break down much more rapidly than normal erythrocytes; this leads to accumulation of haemosiderin in tissues, particularly the liver, causing hemosiderosis (ECHA, 2017a, 2021c)

  Lead causes inhibition of two enzymes involved in haemoglobin synthesis: delta-aminovulinic acid dehydratase (δ-ALAD) and haeme synthetase (ferrochelatose; responsible for combining ferrous iron and protoporphyrin IX, PPIX). In Domestic Pigeons (*Columba livia*), oral exposure to a single lead pellet caused an 80% decrease in plasma δ-ALAD activity compared to the controls (J. P. Holladay *et al*., 2012). Northern Bobwhite Quail (*Colinus virginianus*) dosed with single, spent, 50 mg shot exhibited δ-ALAD inhibition, which was particularly severe for females (92% inhibited 8 weeks after dosing) (S. D. Holladay et al., 2012). In Griffon Vultures (*Gyps fulvus*) and Eagle Owl (*Bubo bubo*) a 94% and 79% decrease in δ-ALAD activity was observed at blood lead concentrations of >30 µg/dL and >20 µg/dL, respectively (Espín et al., 2015). Inhibition of ferrochelatase causes the accumulation of PPIX in erythrocytes. Bald Eagles exposed to lead shot exhibited reduced haematocrit, haemoglobin and δ-ALAD activity as well as changes in serum biochemistry (ECHA, 2017a).

- **Cardiovascular system**: anaemia as described above can cause damage to the walls of blood vessels. This can result in atrophy of muscles in the heart and myocardial infarction (dead portions of heart muscle) (ECHA, 2017a, 2021c).

- **Kidney histopathology**: histologic sections of kidney tissue from lead poisoned mallards (*Anas platyrhynchos*) contained 'acid-fast intranuclear inclusion bodies' or 'renal inclusions' located in the nuclei of cells within the proximal convoluted tubule of the kidney. These cells are responsible for resorption of water, simple sugars and other essential nutrients. The functioning of these cells is compromised by the presence of renal inclusions, causing lead-poisoned animals to lose excessive water, amino acids, salts and simple sugars (Locke and Thomas, 1996; cited within ECHA, 2017a). Renal inclusions have been reported in several bird species when exposed to lead, including Mute Swans (*Cygnus olor*), Whooper Swans (*Cygnus cygnus*), and White-tailed Eagle (*Haliaeetus albicilla*) (Golden et al., 2016; cited within ECHA, 2017a).

- **Ocular effects**: Eid *et al.* (2016) described ocular lesions in a male Bald Eagle (*Haliaeetus leucocephalus*) in association with blood lead concentrations of 6.1 ppm (610 µg/dL). Pattee et al. (1981) dosed 5 Bald Eagles with lead shot (10 shot at a time, additional doses administered if previous shot regurgitated) and one bird became blind before being sacrificed after 133 days (the other 4 birds died before this point; see Section above).

- **Growth and body condition**: winter body condition in Whooper Swans (*Cygnus cygnus*) was significantly negatively correlated with blood lead concentrations when they were >44 µg/dL (these levels were found in 27/260 swans tested) (Newth et al., 2016).

- **Behaviour and learning**: Common Terns (*Sterna hirundo*) and Herring Gulls (*Larus argentatus*) exposed to lead (via injection of lead acetate at doses sufficient to produce lead concentrations in feathers equivalent to those found in wild birds) exhibited changes in locomotion, begging behaviour, individual recognition, balance, depth perception, and thermoregulation; further experiments in the wild showed the behavioural deficits were sufficient to affect growth and survival in the Herring Gulls (Burger and Gochfeld, 2000).

  Exposure to 1,000 µg lead/L in drinking water during development (0 to 100 days post-hatch) caused disruption in song learning ability, reduction in the volume of song nuclei and bills with less redness in male Zebra Finches (*Taenoiopygia guttata*), resulting in less attention from females (Goodchild et al., 2021).

- **Immune function**: A detailed review of the immunotoxic effects of lead on birds by Vallverdú-Coll *et al.* (2019) showed lead at blood levels >50 µg/dL in adults and >10 µg/dL in developing birds can cause immunosuppression and ultimately reduce resistance to infection. Lead affects B-lymphocytes and the humoral immune response; T-lymphocytes and the cell-mediated immune response; macrophage function; granulocyte cells and total leukocyte counts; and oxygen-independent forms of pathogen killing (e.g. lysozyme activity) (Vallverdú-Coll et al., 2019).

  A study into the seasonal variability of the effects of lead in Red-legged Partridges (*Alectoris rufa*) also portrayed a complex picture (Vallverdú-Coll et al., 2015b). It showed lead exposure reduced natural antibody levels in spring, while in autumn it reduced lysozyme levels but increased phagocytic activity. Exposure to lead increased the T-cell response to phytohemagglutinin (PHA) (indicative of cell-mediated immune responsiveness) in both seasons, but caused a decrease in the humoral immune response (T-independent) in autumn (Vallverdú-Coll et al., 2015b). In Mallard (*Anas platyrhynchos*) ducklings, positive correlations were found between blood lead concentrations and the humoral immune response, endogenous antioxidants and oxidative stress biomarkers, while negative correlations were observed between blood lead concentrations and the cellular immune response (Vallverdú-Coll et al., 2015a).

- **Reproduction and development**: lead can disrupt the blood-brain barrier in immature birds, reduce juvenile survival and affect reproductive success (including hatchability, growth and survivability) (ECHA, 2021c). For example:

- Mallard (*Anas platyrhynchos*) eggs collected from nests in close proximity to rice fields (where lead shot was still allowed and Mallards feed) produced ducklings with mean blood lead concentrations of 35.7 ± 13.4 ng/mL (n = 30), which demonstrates maternal transfer. Those ducklings with blood lead concentrations >180 ng/mL had reduced body mass and survival (they all died within one week of hatching) (Vallverdú-Coll et al., 2015a).

- Exposure of 15 female Red-legged Partridge (*Alectoris rufa*) to 3 shot pellets (330 mg lead) significantly decreased hatching rate (from 80% in the control group to 62%). In males (n = 15) 3 shot pellets appeared to reduce acrosome integrity (from 65.7 to 56.3%) and sperm motility (from 17.7 to 14.6%). However, exposure to 1 pellet (110 mg lead) resulted in significantly heavier chicks (12.28 to 12.51 g) and an apparent increase in sperm vigour (e.g. viability 72.4 to 78.5%; acrosome integrity 65.7 to 75.6%; and motility 17.7 to

20.1%) (Vallverdú-Coll et al., 2016), demonstrating a complexity of effects.

- Mourning Doves (*Zenaida macroura*) (n = 25) also exhibited a significant decrease in egg hatchability following exposure to single #8 lead shot, despite there being no differences in egg length, width or weight, productivity, fertility or squab weight (Buerger et al., 1986).

- **Susceptibility to lethal events**: the sub-lethal effects described above may directly affect the health of a bird, and may increase the potential for it to be subject to predation, hunting or death via collision (ECHA, 2021c).

  Table 1.8 summarises sub-clinical effects of lead in raptors, amended from Monclús *et al.* (2020). Although not all of these species are found in the GB, they are taxonomically related to species that do occur (with the exception of vultures, which are exclusively vagrants), and the review demonstrates a wide range sub-clinical effects. Studies in raptors where sub-clinical effects were not found are summarised in Table 1.9 (Monclús et al., 2020).

Table 1.8 Sub-clinical effects of lead in raptors (reproduced from Monclús et al., 2020).

Effects	Association with lead levels	Species	Year	Number of samples	Location	Reference
Biomarkers						
Oxidative stress (GPx, CAT, TBARS)	bl ≥15 µg/dL	Griffon Vulture	2014	66	Spain	(Espín et al., 2014a)
Oxidative stress (GPx, CAT, TBARS)	bl ≥2 µg/dL	Eurasian Eagle Owl	2014	141	Spain	(Espín et al., 2014b)
δ-ALAD inhibition	bl ≥10 µg/dL	Eurasian Eagle Owl	2011	218	Spain	(Gómez-Ramírez et al., 2011)
δ-ALAD inhibition	bl ≥5 µg/dL	Booted Eagle; Common Buzzard; Northern Goshawk	2004	27; 4; 3	Spain	(Martínez-López et al., 2004)
δ-ALAD inhibition	bl ≥5 µg/dL	Eurasian Eagle Owl	2014	139	Spain	(Espín et al., 2015)
δ-ALAD inhibition	bl ≥8 µg/dL	Griffon Vulture	2014	66	Spain	(Espín et al., 2015)
δ-ALAD inhibition	bl ≥30 µg/dL	Griffon Vulture; Eurasian Eagle Owl	2014	139; 66	Spain	(Espín et al., 2015)
No fledglings/breeding	Decrease with increase	Bonelli's Eagle	2018	57	Spain	(Gil-Sánchez et al.,

Effects	Association with lead levels	Species	Year	Number of samples	Location	Reference
attempt	lead f: 0.82 (±0.4) µg/g					2018)

Note: bl, blood; f, feathers; l, liver; e, eggs

Table 1.9 Studies where sub-clinical effects of lead in raptors were not found (reproduced from Monclús et al., 2020).

Effect studied	No association with lead levels	Species	Year	Number of samples	Location	Reference
DNA damage	bl: 3.88 (±4.3) µg/dL	Black Kite	2006	132	Spain	(Baos et al., 2006)
Chronic stress (corticosterone)	f <0.5 µg/g	Golden Eagle	2018	24	Switzerland	(Ganz et al., 2018)
Nestling mortality	l: 1.13 (±0.25)	Tengmalm's Owl	1996	13	Sweden	(Hornfeldt and Nyholm, 1996)
Fecundity	bl: ≥1.83 (±0.25) µg/dL	Booted Eagle	2017	8	Spain	(Gil-Jiménez et al., 2017)
Egg viability	e: 0.82 (±0.4) µg/g ww	Spanish Imperial Eagle	1988	10	Spain	(Gonzalez and Hiraldo, 1988)
Shell thickness	e: 0.037 µg/g ww	Marsh Harrier	1999	13	France	(Pain et al., 1999)

Note: bl, blood; f, feathers; l, liver; e, eggs

1.4.2.3.2 Ruminants

Absorption

When ingested, lead ammunition can often remain in the reticulum (forestomach), which is an alkaline environment; in this case, the metallic lead would remain inert and would not be absorbed. However, if the lead ammunition moves to the abomasum (gastric stomach), it can become more bioavailable (due to the acidity of the abomasum), leading to absorption (ECHA, 2021a). In line with this, lead absorption after oral ingestion has been shown to vary from 1% to 80%, depending on animal species, dose, form of lead, feed composition, nutritional status and age (ECHA, 2021a).

A further route of exposure to lead shot for ruminants is via contaminated feed (ECHA, 2021a). If, during a shooting event, lead ammunition becomes lodged in broad-leafed vegetation destined for silage, it can be incorporated into the feed during processing (ECHA, 2021a). This processing includes a fermentation process that can result in the production of lead salts. The lead metal incorporated into the feed and the lead salts are more easily passed through the gastrointestinal tract and more readily absorbed (ECHA, 2021a).

Distribution

Once absorbed, lead is transported around the body in the blood stream. In cattle and sheep, doses of 100 mg/kg body weight may cause lead blood concentrations of 200 to 400 µg/dL within 12 hours, then reduce to 0.1 µg/dL within 72 hours and then remain above controls for two months (ECHA, 2021a). Lead concentrates in the liver, kidney and, following long-term exposure, bone. It can also enter the brain. Lead can be excreted into milk (ECHA, 2021a).

Metabolism

Lead blood concentrations depend on absorption from the gastro-intestinal tract and mobilisation from bone. Lead is not metabolised (ECHA, 2021c).

Elimination

Lead is mainly eliminated unabsorbed via faeces. In ruminants, <2% of the ingested dose is excreted via the urine (ECHA, 2021a). Overall, elimination rates are very slow; the elimination half-life of lead in lactating ewes is approximately 250 days and it is 95 to 760 days in cattle (ECHA, 2021a).

Lethal and sub-lethal effects

Scheuhammer and Norris (1995; cited within ECHA, 2021c) identified three independent studies that demonstrated no effects or no increase in lead concentrations in cattle after exposure to lead ammunition:

- Allcroft (1951) did not observe evidence of lead poisoning in calves fed metallic lead. No details of this study are available to provide further information.
- Bjørn *et al.* (1982) found no elevation of blood lead concentrations in heifers that grazed in pastures where bird hunting was common. No details of this study are available to provide further information, but the level of exposure is unclear.
- Clausen *et al.* (1981) examined 415 cattle and found 230 of these had between 1 and 55 lead pellets (average 0.47 g lead) present in their reticulum. No correlation was found between the number of pellets in the reticulum and the lead content in the liver or the kidneys.

Scheuhammer and Norris (1995; cited within ECHA, 2021c) also found three studies that did demonstrate lead poisoning, including that of Rice *et al.* (1987; cited within ECHA, 2021c), who studied steers that were fed silage from a field used for clay target shooting (n = 14); one died, one exhibited clinical signs of lead poisoning and all showed sub-clinical poisoning in the form of inhibited δ-ALAD activity. ECHA (2021c) state the other two studies, Frape and Pringle (1984) and Howard and Braum (1980), also indicate dairy cattle fed grass or corn silage contaminated by lead shot can suffer from lead poisoning, but the Agency does not have access to these studies to provide further details.

Three further studies have demonstrated the lethal and/or sub-lethal effects of lead exposure to cattle:

- Cattle exposed to lead-contaminated feed in the Netherlands displayed blindness, muscle twitching and hyperirritability; two animals died from the lead poisoning and 40% of the affected cows had to be slaughtered (Wijbenga et al., 1992; cited within ECHA, 2021c). Only an abstract of this study is available, and it does not mention whether the feed was intentionally contaminated.
- An investigation into an incident where 5 out of 25 cattle (20%) died over a few days at a dairy farm situated near a shooting range, near Calcutta, India. This found that prior to death, the cattle exhibited abdominal pain, low temperature, salivation, bloody discharge from nostrils, convulsions, and coma. Samples of the soil, subsoil and grass taken from the sides of the shoot range had lead concentrations of 0.22 to 0.88 µg/g, 0.011 to 0.42 µg/g and 0.53 to 2.24 µg/g, respectively. Autopsies showed subcutaneous haemorrhage, blood and metal particles in the congested stomach and intestinal mucosa, easily detachable mucous membrane in the rumen, and

blood fluid in the peritoneal cavity, among others. Concentrations of lead were measured in the liver, kidney, spleen, stomach walls and intestines, at 5.0, 11.7, 3.5, 7.1, and 4.5 µg/g respectively (Ganguli and Chowhuri, 1953).

- In a study where calves (n = 5; 7 to 9 months old) were allowed to graze in an area that had been used as a shooting range over several years, one calf (25%) died from acute poisoning after 5 days. The other calves became ill 1 to 3 days later, and all but one of these (which was euthanized) died within hours of first exhibiting symptoms. Neurological disturbances, including maniacal movements, opisthotonos, drooling, rolling of the eyes, convulsions, licking, jaw champing, bruxism, bellowing and breaking through fences, were observed. Grass and soil lead concentrations were 29,550 and 3,900 mg/kg, respectively in a single sample of each (Braun et al., 1997).

  A review of lead poisoning in cattle and sheep (Payne et al., 2013; cited within ECHA, 2021a) reported the following observed effects:

- In animals that died of acute poisoning: congestion of the liver and pale kidneys, gastrointestinal haemorrhage, and visible oedema of the central nervous system;
- In animals with sub-acute poisoning: laminar cortical necrosis within the cerebrum and nephrosis; and
- In animals subject to chronic poisoning: loss of body condition, emaciation, muscle wastage and developmental abnormalities in foetuses.

1.4.2.4 Hazard conclusions

Numerous studies have convincingly demonstrated that exposure to lead shot can cause a range of toxic effects in wildlife, particularly birds. Ingestion of a single lead shot pellet is enough in some circumstances to kill an individual bird. A variety of sub-lethal effects can also arise in many unrelated species, such as reduced body condition, altered immune responses, effects on blood parameters and the cardiovascular system, altered kidney histopathology and ocular lesions which may lead to blindness. Effects that could be considered to be more directly relevant at a population level include those on behaviour and learning, and reproduction, growth and development (such as reduced egg hatchability and juvenile survival). Intoxicated birds may also be more susceptible to lethal events such as predation or collision.

Typically, in environmental risk assessments the calculation of a $PNEC_{oral}$ can be used to assess the risk of direct toxicity for predators (i.e. birds) due to exposure of the predator via its prey (i.e. characterising the soil–worm–bird food chain). The

PNEC is calculated based on toxicity data derived from standard test guideline studies, which expose test organisms via the diet and explore endpoints that are considered population relevant (ECHA, 2008). However, the available data summarised in this section do not adhere to standard test guidelines, due to the nature of lead shot. Its toxicity is dependent on pellet size and the toxicokinetics of the various bird species. Therefore, it is not possible to derive a PNEC for birds for use in this assessment where the key exposure route is the direct ingestion of lead or the secondary ingestion of lead particles in prey items.

ECHA (2021a) identified indicative thresholds that represent levels where adverse effects in birds are likely to occur based on previously published thresholds, as summarised in Table 1.10. It should be noted that sub-lethal effects have been found at lower blood lead concentrations than these. For example, Espin et al. (2014a) demonstrated that blood lead concentrations of >15 µg/dL can cause oxidative stress in Griffon Vultures (Gyps fulvus), while the threshold for sub-clinical poisoning defined in Table 1.10 is 20 to <50 µg/dL ww. ECHA (2021a) identified that these discrepancies may indicate a need for a review of the thresholds. The Agency notes that as more experimental studies examining additional sub-lethal endpoints become available these may indicate that a revision of the thresholds is required. However, the thresholds in Table 1.10 can still be used to provide an indicative interpretation of concentrations in lead measured in birds and other animals. In addition, as novel data would only lower the thresholds the current values can be used as a best-case estimate of the scale of potential effects.

The thresholds should not be considered equivalent to PNECs, although they can be used to interpret tissue concentrations in the management of wildlife on contaminated areas and compare lead concentrations in unexposed wild birds with those where clinical effects and mortality may occur (ECHA, 2021c). In live birds, the sequential analysis of blood lead concentrations within an individual can give a clear picture of exposure over time; that is, the concentrations of lead in the blood provide an indicator of recent (weeks to months) ingestion (ECHA, 2021c). The concentration of lead in the bone is generally considered indicative of lifetime (not recent) exposure (ECHA, 2021c).

Separately, Buekers *et al.* (2009) selected 19 experimental and 6 field toxicity studies from a pool of approximately 80 to consider the risk of lead to wildlife using a tissue residue approach. Studies were selected that (1) provided data of blood lead concentrations at all doses and where at least two doses above the control were applied, (2) were performed for >42 days, (3) demonstrated a clear dose-response relationship and had normal background exposure levels, and (4) (if field studies) reported lead related effects and lead blood concentration data. The authors derived critical blood lead concentrations that would protect mammals and birds from lead toxicity by identifying the HC_5 (5^{th} percentile of species' NOEC values; using growth, reproduction or haematology endpoints across 15 different species). The HC_5 was significantly lower, at 18 µg/dL, for mammals, compared to 71 µg/dL for birds.

Table 1.10 Indicative thresholds of lead exposure that represent levels where adverse effects in birds are likely to occur (adapted from ECHA, 2021a)

Lead poisoning endpoint	Blood lead concentration	Liver lead concentration	Bone lead concentration
Background (i.e. no history of lead exposure)	<20 µg/dL ww *or* <0.2 µg/g ww	<2 µg/g ww *or* <6 µg/g dw	<10 µg/g dw
Subclinical poisoning	20 to <50 µg/dL ww *or* 0.2 to <0.5 µg/g ww	2 to <6 µg/g ww *or* 6 to <20 µg/g dw	10 to 20 µg/g dw
Clinical poisoning	50 to 100 µg/dL ww *or* 0.5 to 1 µg/g ww	6 to 15 µg/g ww *or* 20 to <50 µg/g dw	>20 µg/g dw
Severe clinical poisoning	>100 µg/dL ww *or* >1 µg/g ww	>15 µg/g ww *or* >50 µg/g dw	-

1.4.3 Environmental exposure

A fully quantitative exposure assessment for the various uses of lead in ammunition has not been attempted for the purposes of this report, due to the wide range of locations and environments where shooting can occur. Instead, the Agency has considered the evidence about the key exposure pathways for each use in GB. The available information on the releases of lead ammunition to the environment, evidence of lead exposure in birds and other animals that can be linked to use of lead in ammunition, and information on concentrations of lead in water, soil and vegetation that can be linked to the use of lead in ammunition has also been reviewed.

1.4.3.1 Quantities of lead shot used in GB

In their response to the call for evidence, the Gun Traders Association estimated that 260 million shotgun cartridges per year were produced or imported as a 5-year average from 2015 to 2019 in GB. This estimate was from the 4 largest manufacturers and the 2 largest importers of lead shot cartridges. Information was not provided on the proportion of these exported. The estimated split provided by the Gun Traders Association is 70% for clay pigeon shooting (182 million) and 30% for game hunting (78 million). The Gun Traders Association was not able to provide data on the total amount of lead ammunition (including bullets) on the GB market within the timescale given for the call for evidence.

In their response to the call for evidence, the British Association of Shooting and Conservation (BASC) reported that 60 million shotgun cartridges are used for clay pigeon shooting on an annual basis (50 million of which are for practice and training) in GB. This figure is significantly lower than the estimate from the Gun Traders Association and is thought to be because the Gun Traders Association have provided information on sales and BASC have provided information on use. The BASC value is preferred for this assessment because it originates from an organisation that represents the end users. This number of cartridges is equivalent to 1,680 tonnes of lead per year, assuming 28 g of lead per cartridge, as commonly used for clay pigeon shooting (LAG, 2015a). A large proportion of the shot used in clay pigeon shooting is expected to remain in the environment as the number of sites that currently recover the lead is very small (Section 1.3.4.1).

Assuming that the market is stable, and that the amount produced replaces the amount actually used, this information implies that approximately 200 million shotgun cartridges are used for hunting each year (260 million produced each year minus 60 million for clay pigeon shooting).

In the 2012/13 hunting season 20 million game birds and 2.2 million other species (such as pigeons, corvids, squirrels and foxes, but excluding deer) were estimated to have been shot in the UK (PACEC, 2014), as presented in Table 1.11 and Table 1.12. These numbers were obtained from a survey of live quarry shooting providers undertaken on behalf of a number of shooting and countryside organisations, and updated a previous survey undertaken in 2004/5 (PACEC, 2006).

Table 1.11 Estimate of the number of game birds shot in 2012/13 (PACEC, 2014)

Quarry species	**Total UK**
Pheasant	13,000,000
Partridge	4,400,000
Grouse	700,000
Duck	1,000,000
Goose	110,000
Woodcock	160,000

Quarry species	Total UK
Snipe and other waders	110,000
Total game birds	20,000,000

Note: Individual figures have been rounded and therefore may not appear to sum exactly to the total.

Table 1.12 Estimates of the number of other species shot in 2012/13 by shooting sports participants (i.e. not as part of a job) (PACEC, 2014)

Quarry species	Total UK
Red deer	74,000
Other deer	110,000
Wood pigeon	1,100,000
Rabbit	520,000
Corvids	300,000
Grey squirrel	150,000
Fox	66,000
Hare	73,000
Total	2,393,000

These estimates are uncertain because the scaling up of survey data to account for the whole shooting community population required several assumptions to be made about the participants (e.g. in terms of the non-response rate for people with lesser involvement, membership by an individual of more than one partner organisation, etc.). The study authors considered that due to the complex nature of the grossing up technique, the margin of error of the total estimates was likely to be at least 10 %. All species estimates, therefore, are rounded to two significant figures.

From the data in Table 1.11 and Table 1.12, game birds (excluding ducks, geese and snipe and other waders) accounted for 89.2 % of the total number of quarry shot and the hunting of other pests (excluding deer) accounted for 10.8 %. Cartridges used for hunting are generally larger than the 28g used for clay pigeon shooting: 30 g is commonly used for pigeon shooting and 32 g is commonly used for pheasant hunting (LAG, 2015a). Assuming that the 2012/13 season was typical, and the number of rounds used for hunting is approximately the same regardless of quarry type, it can be estimated that 89.2 % of the 200 million cartridges contained 32 g of lead each (totalling 5,709 tonnes) and 10.8 % contained 30 g of lead each (totalling 648 tonnes). This gives a total estimate of approximately 6,357 tonnes of lead shot used in hunting each year.

Depending on the shot size, each cartridge contains between 100 and 600 lead pellets. When fired, these pellets spread out in a cone shape; the distribution of lead across the environment will depend on the layout of the shooting stations (ECHA, 2017a). Depending on factors such as range and marksmanship, only a small proportion of the pellets from a single shotgun cartridge are likely to hit the intended target, in the order of 1% or fewer (see for example (Cromie et al., 2010; Pain et al., 2010) for the number of pellets found in shot quarry). Most of the shot (99% or more) will therefore miss the intended target and be deposited in the environment. Animals that are shot but escape, or are shot but not retrieved, will also contain lead pellets that can then become available to other organisms either through predation or scavenging.

Therefore, it is clear that over 99% of the approximately 8,037 tonnes of lead shot released in GB from clay pigeon shooting and hunting each year will be left in the environment (i.e. about 8,000 tonnes per year).

1.4.3.2 Quantities of bullets used in GB

Deer stalking requires the use of centrefire bullets to provide enough power for a clean kill (The Deer Initiative, 2011). It is recommended that deer are shot in the chest (Deer Initiative, 2011). Smaller calibre bullets are used for other purposes (e.g. pest control).

In the absence of primary data on the amount of lead bullets used for deer stalking, an estimate can be made based on the number of deer shot. Using the same methodology as the LAG (2015a), who used data from the previous PACEC survey in 2006, it can be estimated that 184,000 deer are shot annually for sport not as part of a job (see Table 1.12), with another 297,600 deer shot annually as part of a job or by unpaid guns (16 per shoot provider and 18,600 providers of deer stalking) (PACEC, 2014). If only one bullet were used per deer shot and deer shooting was the only activity using bullets, this would equate to 481,600 bullets. At an average of 7 g of lead per projectile (ECHA, 2021c), this is 3.4 tonnes of lead a year. This would represent a minimum number of bullets and therefore amount of lead used. All of these calculations are based on a survey covering the whole UK.

The total number of rounds of .22 rimfire bullets purchased for all quarry/pest/target shooting each year was estimated as 4.5 million by LAG (2015a), which is equivalent to 10.8 tonnes of lead, based on an average of 2.4 g of lead per bullet (ECHA, 2021c). This is an additional source to the bullets used in deer stalking. However, there is significant uncertainty in this figure. For example, in their response to the call for evidence, the National Rifle Association estimated that 12 million rounds of rifle ammunition were fired annually by target shooters at outdoor ranges (excluding military and police use). It therefore appears that there may be between 28.8 and 72 tonnes (12,000,000 x 2.4 g and 12,000,000 x 7 g) of bullets used for outdoor target shooting, in addition to the 3.4 tonnes of bullets used for deer stalking and the 10.8 tonnes of .22 rimfire bullets. It cannot be excluded that lead bullets are used for other types of hunting as well.

The proportion of missed shots and number of shot animals that escape are unknown. The fate of all animals that are successfully killed is also unknown. It is possible that some might be left where they are shot (e.g. if they are killed as pests). A proportion are likely to be trophy killings (e.g. for antlers), and it is not known what happens to the carcass in these circumstances. Culling to reduce grazing pressure may occur, and the fate of the carcasses in this situation is also unknown. If the animal is taken away for human consumption, any bullets within the carcass are assumed to be removed during butchering, although it is possible that bullet fragments could remain. It is not known what happens to any discarded parts of a butchered carcass (e.g. the entrails) that may contain lead bullet fragments.

Due to this lack of basic information, it is not possible to reliably estimate the quantity of lead remaining in the environment as a result of hunting, pest control and outdoor target shooting with bullets, although it is expected to be significantly below 86.2 tonnes.

1.4.3.3 Lead ammunition densities in the environment

According to PACEC (2014) '*shooting providers influence the management of 14 million ha of land, around two thirds of the area of rural land in the UK. Specific habitat and wildlife management for shooting is carried out on 1.8 million ha of land in the UK. 46 % of this work (by area) is general management of heather moorland, and 27 % is coppicing or thinning woodland.*'

The density of lead shot in the environment differs depending on the source. A number of studies have focused on the density of lead found in the environment around areas of high shooting activity such as shooting ranges, clay pigeon sites, and intensively reared game bird shooting estates or regularly used blinds (ECHA, 2021c). Clay pigeon and sports shooting ranges typically have the densest concentration of spent shot as they are generally in fixed places and hold multiple shoots per year.

There is no up to date information on ammunition density in the UK, but LAG (2015a) summarises the limited historic data. At a clay pigeon shoot in Lancashire, a maximum of 257 shot/m^3 was found in the top 15 cm of soil, with decreasing density farther away from the shooting positions. The site had been operating for approximately 20 years. A study of shot density close to a clay pigeon shooting range at Lough Neagh, County Antrim showed the soil contained 2,400 shot/m^3 in the upper 5 cm of the shoreline in front of the range. Shot was also retrieved from the lake bed up to 60 m from the shore. Additional studies have taken place in the EU (LAG, 2015a, 2015b). For example, a study at two Dutch clay pigeon sites found shot densities of 400 and 2,195 shot/m^2 and an additional study reports four Danish shooting ranges located near shallow water which had shot densities ranging from 44 to 2,045 shot/m^2.

There are no GB data available for sports shooting ranges. ECHA (2021c) presents some information on ranges in the EU. The quantity was reported as 15 tonnes per range per year in Finland, and up to 44 tonnes per range per year in Cyprus (based on a stakeholder survey which reported that 220 tonnes had been used over 5 ranges each year).

The density of lead ammunition on shooting estates, open fields or moorlands has not been studied in detail, but there are a few studies from European shooting estates. For example, LAG (2015a) discusses a Spanish estate where Red-legged Partridges (*Alectoris rufa*) had been shot occasionally since the 1950s: the shooting density was 7.4 shot/m^2 in the top 1 cm of soil, in front of the shooting lines, which equated to 8.1 kg lead/hectare of number 7 shot. ECHA (2021c) describes the distribution of lead ammunition on shooting estates across the world and concludes that the distribution in European estates is likely to be similar to those in US fields managed for dove hunting:

> ‘On five public hunting areas managed for dove hunting in Missouri during 2005–2011, the average amount of lead ammunition deposited per year ranged between 2.5 and 8.9 kg ha^{-1} among areas. The estimated average number of no. 8 lead pellets (2.26 mm in diameter) ranged between 35 624 and 128 632 hectare (ha) per year among areas (Schulz et al. 2012). Shultz et al. (2006) reported that on 14 managed public hunting areas in Indiana, the mean density of lead shot post season was 27 515 pellets/ha; a 645 % increase from pre-season soil sampling estimates (Castrale, 1989). Using similar soil sampling protocols, posthunt shot densities in Missouri were 6 342 pellets/ha; a 1697 % increase from pre-season estimates (Schulz et al. 2002).’

Summary

In conclusion, the available evidence indicates that shooting occurs over a significant proportion of rural land in GB and therefore there is widespread deposition of lead shot and potentially bullets. This can result in a high density of lead in a range of different environments, including rivers / lakes, agricultural fields and moorland. It is also clear that the highest density of shot and bullets is found close to fixed shooting positions such as clay pigeon or target ranges.

1.4.4 Exposure pathways

The Lead Ammunition Group report to Defra (LAG, 2015a) identified five potential exposure pathways for lead from ammunition. These were:

a. Direct ingestion of spent lead ammunition (mainly shotgun pellets) from the environment (primary exposure).

b. Indirect ingestion by predators/scavengers of spent lead ammunition in the bodies of their prey (secondary exposure).

c. Movement of lead via plants into their consumers.

d. Movement of lead by ingestion of soil or soil organisms/invertebrates into their consumers.

e. Movement of lead from embedded shot/bullets into body tissues/organs.

LAG (2015a) concluded that there was evidence of both pathway ‘a’ (for many species of wildfowl, and some other waterbirds and game birds) and for pathway ‘b’ (raptors) from the UK and other parts of the world. Other wildlife may also be exposed via pathway ‘a’, although there is little published evidence of this in the UK. There was some evidence to support pathways ‘c’ and ‘d’, although this was generally not from the UK. Although there is evidence that lead ammunition can become embedded in shot animals that are not killed, there is uncertainty about whether this results in increased tissue concentrations that would support exposure pathway ‘e’.

The following sections of this report summarise the evidence reviewed by LAG (2015a) and supplementary evidence reported in Pain *et al*. (2019b), ECHA (2021a, 2021c) and a list of publications relevant to the risk assessment of lead from ammunition maintained by the LAG (http://www.leadammunitiongroup.org.uk/resources/). Although two separate environmental risk assessments were reported by LAG (2015a, 2015b) using different methodologies, the same exposure datasets were reviewed in both and a consensus conclusion on exposure pathways was reached. In all sections, GB studies are discussed first, followed by a brief summary of evidence from other countries.

1.4.4.1 Direct ingestion of spent lead ammunition (mainly shotgun pellets) from the environment (primary exposure)

The primary ingestion exposure pathway is particularly relevant for bird species that may mistake the lead shot deposited in the environment for food items or grit. Some bird species seek out and ingest grit sized particles that remain in their muscular gizzards to aid digestion. As well as breaking down food by grinding, the avian gizzard is generally highly acidic (Farner, 1942). Any lead shot that is ingested may be ground down in the gizzard, increasing its surface area which together with the acidic pH will enhance its dissolution and then uptake within the intestine.

1.4.4.1.1 Terrestrial birds

Butler (2005) examined 637 post-mortem records for Red-legged Partridge (*Alectoris rufa*) recorded by the Game Conservancy Trust's pathology unit from sites across the UK between 1955 and 1992. Of these, 1 (0.2 %) reported the presence of lead shot in the gizzard. LAG (2015b) note that this study relied on a sample of birds that had been found dead (so the sample may not be representative of the population) and historical reports conducted by different pathologists, who were not specifically investigating the presence of lead shot in the gizzard.

Butler (2005) also reports on the presence of lead shot in the gizzard of 144 shot Red-legged Partridge collected from 10 UK shooting estates in the 2001/02 shooting season. Of the birds examined 2 (1.4 %) had ingested lead shot.

Butler (2005) reported on the number of Common Pheasants (*Phasianus colchicus*) with lead shot found in their gizzards. The birds were collected from 1996 to 2002 from 32 game farms across 11 counties in the UK. A total of 437 birds were examined, with half shot during the shooting season and half shot on licence outside the shooting season. On average, 3 % had ingested pellets. Of these, 77 % had ingested a single pellet, 15 % two pellets and 8 % three pellets.

Potts (2005) examined post-mortem records for wild Grey Partridge (*Perdix perdix*) found dead in south-east England between 1963 and 1992. Of the 446 adult birds examined 20 (4.5 %) had lead shot in their gizzard. A further 29 chicks collected from the South Downs between 1968 and 1978 were examined, and of these 2 (6.9 %) had lead shot in their gizzard. LAG (2015b) notes similar weaknesses in this study as for Butler (2005). Potts (2005) also references a doctoral study that examined 77 Grey Partridge killed by raptors at 20 sites in England in which no birds were found to have lead shot in the gizzard.

Thomas, Scheuhammer and Bond (2009) investigated the lead content of shot Red Grouse (*Lagopus lagopus*) from two estates in Scotland (Glendye and Invermark) and one in Yorkshire, and attempted to identify the source of the lead exposure using isotope ratio analysis. The authors considered an elevated bone lead level to be >20 µg/g dw. Although 38 Red Grouse from the Yorkshire estate were considered to have elevated bone lead levels, the isotope ratio of these indicated exposure to galena (a naturally occurring mineral) was responsible for the majority of this. The Red Grouse collected from the two Scottish estates had elevated bone lead in 3 of 85 (3.5 %) and 6 of 111 (5.4 %) cases and the authors considered the isotope ratios found to be consistent with the ingestion of lead shot.

AHVLA (2012, 2010) report on thirteen incidents of lead poisoning in birds in the UK between October 2007 and December 2012. Of these, six (46%) are related to the ingestion of lead shot or airgun pellets by chickens, ducks and geese. In one incident, Payne *et al*. (2013) report that a flock of 2,000 free-range poultry was exposed to lead shot from nearby clay pigeon shooting. Post-mortems on a representative sample of the chickens found lead pellets in the gizzards. In a second incident, the source of lead poisoning of 400 ducks was found to have come from adjacent land that had been used for clay pigeon shooting for the previous 10 years (LAG, 2015b). In a third incident, between 3 to 5 % of 400 ducks reared for shooting 150 metres from a clay pigeon shoot suffered clinical disease and numerous lead pellets were found in the gizzards of the ducks (LAG, 2015b).

The UK evidence for ingestion of lead shot in terrestrial bird species or ducks exposed via the terrestrial environment is summarised in Table 1.13. Several studies have been identified that provide information on this potential exposure pathway, with five relating to game birds, one to domestic chickens and two to ducks. Although the studies are small in number, and use relatively small sample sizes, they demonstrate that some terrestrial birds do ingest lead shot and therefore are exposed via this route.

Table 1.13 Evidence of ingestion of lead shot in UK birds via the terrestrial environment

Species	**Number of birds**	**% overall ingestion (average)**	**% with elevated bone lead concentration (>20 µg/g dw)**	**Reference**
Common Pheasant (*Phasianus colchicus*)	437 (collected between 1996 and 2002)	3	NR	(Butler et al., 2005)
Red-legged Partridge (*Alectoris rufa*)	637 (collected between 1955 and 1992)	0.2	NR	(Butler, 2005)
	144 (2001/02 hunting season)	1.4	NR	(Butler, 2005)
Grey Partridge (Per*dix perdix*)	446 (collected between 1963 and 1992)	4.5	NR	(Potts, 2005)
	29 (collected between 1968 and 1978)	6.9	NR	(Potts, 2005)
	77	0	NR	(Watson, 2004) cited in (Potts, 2005)
Red Grouse (*Lagopus lagopus scoticus*)	111 (Glendye, 2003)	NR	5.4	(Thomas et al., 2009)
	85 (Invermark, 2003)	NR	3.5	(Thomas et al., 2009)

Species	Number of birds	% overall ingestion (average)	% with elevated bone lead concentration (>20 µg/g dw)	Reference
Chickens (*Gallus gallus domesticus*)	2000	NR	NR	(Payne et al., 2013) cited in (LAG, 2015)
Domesticated mallards (*Anas platyrhynchos*)	400	NR	NR	(LAG, 2015b)
Ducks (species not stated)	400	NR	NR	(LAG, 2015b)

NR: not reported.

LAG (2015b) and ECHA (2021a, 2021c) also review the evidence from outside the UK. Both documents conclude that there is evidence of lead shot ingestion from numerous different terrestrial bird families, with the prevalence of ingestion varying as a function of diet and grit preference and lead availability. The ingestion of lead shot has not been investigated in many species specifically. However, it is likely that the same exposure pathway can be assumed for species that have similar feeding habits.

Most seed-eating birds, and some birds that eat invertebrates, will eat grit (Best and Gionfriddo, 1994; Gionfriddo and Best, 1999). The size of the grit ingested will vary between species but, in general, smaller birds eat smaller grit although there is often a wide range in grit size. For example, several song bird species were found to have grit <0.2 – 3.4 mm (Vyas et al., 2000) and House Sparrows (*Passer domesticus*) to have grit 0.1 – 2.4 mm in size (Gionfriddo and Best, 1995). The typical shot sizes used for shooting range from 2 to 3.1 mm (Section 1.3.2), so are in this same size range.

Two studies were identified that have reported ingestion of lead shot by terrestrial bird species found in the UK, but for which UK data are not available. Romero *et al*. (2020) found evidence of lead shot ingestion in Rock Dove (*Columba livia*), Stock Dove (*Columba oenas*) and Common Woodpigeon (*Columba palumbus*) from Spain and Stamberov *et al*. (2018) found evidence in Quail (*Coturnix coturnix*) from Bulgaria. In addition, Tavernier *et al*. (2004) also report ingestion of lead shot by racing pigeons (*Columbia livia*) in Belgium.

LAG (2015b) also reviewed studies from outside the UK that attempt to identify the source of elevated lead concentrations in wild birds that may be due to primary ingestion either by using stable isotope analysis or calculating the association between spatial or temporal changes in exposure and measured tissue concentrations. Many of the studies focus on wetland birds, so are not reviewed here. Scheuhammer *et al*. (2003) analysed the lead content and isotope ratios of soil, earthworms and wing bones from the American Woodcock (*Scolopax minor*) in Canada. Total lead and lead isotope concentrations were positively correlated between soil and earthworms. However, despite earthworms being a major food source for this species, the Woodcock samples had different isotopic ratios, which were consistent with the ingestion of lead shot. Franson, Hansen and Schulz (2009) sampled 4,229 Mourning Doves (*Zenaida macroura*) from areas where lead shot was permitted for use and 655 from areas where it was banned in the United States of America (USA). Similar proportions of birds had evidence of ingested ammunition in both areas. Bone lead concentrations were found to be higher in those areas where lead could be used, but no difference was found in liver concentrations. The field studies reviewed (both terrestrial and wetland) are considered by LAG (2015b) to provide strong evidence that ingestion of lead shot by birds is the main cause of elevated tissue concentrations in areas where shooting occurs.

1.4.4.2 Wetland birds

GB has previously concluded that there is evidence of ingestion of lead shot by wetland birds, particularly those that ingest grit as part of their feeding ecology, and that this exposure leads to an unacceptable risk. Legislation was introduced to mitigate this risk in England in 1999, with similar legislation in Wales and Scotland following shortly after (see Annex A.4). The evidence for this exposure pathway has therefore not been re-examined here.

The wetland restrictions across GB vary between the administrations and do not uniformly apply to all wetland habitats or protect wetland birds that feed in terrestrial habitats (such as grazing swans, geese and ducks) from ingestion (as evidenced by the two studies on domesticated duck summarised in the previous section).

There is also evidence that compliance with the current restrictions on the use of lead over wetlands is low. Cromie *et al*. (2010) were commissioned by Defra to assess the compliance with the legislation in England by identifying the shot types used to kill ducks purchased from game suppliers in 2008/09 and 2009/10. Their study found that non-compliance with the Regulations was widespread, with 344 of 492 (70 %) of the ducks analysed having been killed with lead shot. An updated study (Cromie et al., 2015) estimates that breaches of the Regulations are still high, with the proportion of ducks killed illegally with lead shot increasing from 68 to 77 % over surveys carried out from 2001 to 2013. The variability between survey years was not statistically significant (Stroud et al., 2021). The results of this investigation suggest that shooting of wetland birds with lead shot is still widespread, even though it is illegal.

Therefore, this exposure pathway is still considered relevant for GB.

1.4.4.2.1 Other animals

The ingestion of lead shot by non-avian species has not been well investigated. However, some GB studies were identified that report on this exposure pathway.

Payne and Livesey (2010) reviewed 454 incidents of lead poisoning of cattle or sheep in the UK between 1998 and 2008. The ingestion of metallic lead (including lead shot from clay pigeon shooting, lead flashings and pipes, and unspecified sources) was found to be the source of the lead in 31 (6.8%) cases. No further information is given on the numbers of each source within the group 'metallic lead'.

Frape and Pringle (1984) reported that dairy cows ingested lead pellets and clay fragments in haylage that had been harvested from a field where clay pigeon shooting had occurred before harvest. Payne *et al*. (2013) report that cattle were exposed to lead via maize silage harvested from a field adjacent to a clay pigeon shoot. Payne *et al*. (2013) also report lead poisoning from cattle grazing directly from a field near a shoot.

There are a few further studies from outside GB. Braun *et al*. (1997) and Muntwyler (2010) report on the direct ingestion of lead shot and the effects (acute poisoning and mortality) on cows that were grazing on or adjacent to shooting ranges in Switzerland. In contrast, sheep grazing on shooting ranges are not thought to absorb as much lead as cows once ingested and no mortality has been reported (ECHA, 2021a). In a study on the potential for lead poisoning of sheep on Norwegian Armed Forces' shooting ranges, analysis of liver samples of grazing lambs showed no difference in lead concentrations with those of lambs grazing elsewhere (Johnsen et al., 2019).

Howard and Braum (1980), Rice *et al*. (1987), Bischoff *et al.* (2012) and Bischoff *et al*. (2014) report exposure of cattle to lead shot within silage harvested from areas contaminated with shot in the USA, and Vermun, Hill and Quinn (2002) report on a case in New Zealand. Rice *et al*. (1987) state that even when lead pellets were removed, samples of silage still contained a concentration of lead sufficient to cause toxicity, independent of ingestion of any lead gunshot pellets. This suggests that the process of producing the silage or the uptake of lead by plants growing in soils contaminated with metallic lead may be an exposure route, in addition to the direct ingestion of lead shot pellets. Silage is very acidic (pH< 4.8), which may increase the rate of lead solubilisation (see Section 1.4.1).

There is the potential for wild animals, such as deer, to consume shot whilst grazing. However, reports of this pathway are lacking.

1.4.4.2.2 Conclusion

There is strong evidence from both GB and international studies that direct ingestion of lead shot by terrestrial and wetland birds is a key exposure pathway for this assessment.

There is some evidence that other animals ingest lead shot whilst grazing. This is considered a relevant exposure pathway for livestock (and likely wild animals) that feed in areas with high lead shot use (e.g. on a shooting range). There is also a potential exposure pathway via silage harvested from areas contaminated with lead shot.

No evidence was found to evaluate the potential for animals to directly ingest lead bullets or bullet fragments. Although this remains a theoretical pathway, this is not considered further in this assessment.

1.4.4.3 Indirect ingestion by predators/scavengers of lead from lead ammunition in the bodies of their prey (secondary exposure)

There are three pathways by which indirect ingestion may occur. Firstly, the previous section demonstrated that lead shot can be directly ingested by birds. If these birds are preyed upon then the lead can move up the food chain. Secondly, evidence is available on the presence of lead shot in quarry animals that are not killed (Section 1.4.4.6). Quarry animals that are weakened, but not killed, are also thought to be at greater risk of predation. Thirdly, animals that are shot and killed but that are left unrecovered in the environment, or that are butchered in the field and have the viscera discarded, could also be eaten by predators/scavengers.

Pain *et al*. (2007) conducted radiographs of rabbits that had been shot with 0.22 calibre rifles. The analysis demonstrated many bullet fragments along the path of the bullet in 3 of the 4 rabbits, with between 1 and 10 objects per rabbit. The bullet fragments were distributed in the thorax and abdomen of two of the rabbits and one object was found in the forelimb of the third rabbit, indicating that the fragments can be widely spread.

Pain *et al*. (2010) analysed for the presence of lead shot and tissue lead levels in six wild-shot species of game birds. Birds were bought from supermarkets, butchers or directly from shoots across England, Scotland and Wales. A sample size of 16 to 26 birds was available for Pheasant (*Phasianus colchicus*), Red-legged Partridge (*Alectoris rufa*), Woodpigeon (*Columba palumbus*), Red Grouse (*Lagopus lagopus*), Woodcock (*Scolopax rusticola*) and Mallard (*Anas platyrhynchos*). Across all samples, 65 % contained lead shot or fragments of lead shot, with this ranging from 50 to 85 % between species. On average, each bird that contained shot had 2.2 embedded pellets, ranging from 1 to 18 for each individual bird. Radiographs identified that 76 % of birds contained radio-dense particles, ranging from 65 to 85 % by species. These were presumed to be metallic fragments of the shot, and were sometimes associated with the pellet wound channels. When both analyses were considered together, 87 % of birds contained visible whole shot or (presumed) fragments of shot. Of the birds not visibly containing shot, 60 % contained small radio-dense particles that were presumed to be fragments of lead shot.

Knott *et al*. (2010) conducted radiographs of ten Red Deer (*Cervus elaphus*) and two Roe Deer (*Capreolus capreolus*) that were shot by a single lead rifle bullet to the thorax. The ammunition used was 0.270 ammunition (Norma 130gr copper-jacket lead-core bullet). The deer were eviscerated before a radiograph was taken from each side of the carcass, and a third radiograph was taken of the viscera. The average number of fragments was 412 in the carcass and 180 in the viscera, equating to 1.48 g and 0.21 g of metal respectively. Metal fragments in the viscera were typically smaller than those in the carcass.

The Agency is aware of other relevant studies that are in the process of publication in the academic literature (for example, on the presence and distribution of lead shot in pheasants). It is expected that stakeholders will flag these papers during the consultation stage once they have been published.

LAG (2015b) summarises a large number of non-UK studies that report on the prevalence of embedded shot in bird (mainly wildfowl) species, as well as data on the concentration of lead in the flesh of game animals shot with lead ammunition (see also Section 1.5.2). Quarry species can survive carrying lead shot, and in some wildfowl species this can be as high as 20 to 30% of the population (Pain et al., 2014). The human health assessment in LAG (2015b) concluded that the available data indicated that mean lead concentrations in meat from animals shot with lead ammunition were often elevated compared to background levels, and that this was particularly the case for small game and meat from tissues where the ammunition had struck. Pain *et al*. (2019b) reported that additional studies post the LAG review have found the presence of lead fragments or elevated tissue concentrations in prey species. This adds to the evidence of lead contamination in these populations.

Nadjafzadeh, Hofer and Krone (2015) conducted feeding experiments by providing ungulate carcasses containing different size particles of iron to wild Ravens (*Corvus corax*), Buzzards (*Buteo buteo*) and White-tailed Eagles (*Haliaeetus albicilla*) and six captive White-tailed Eagles. As the diameter of the iron particles increased, so did the avoidance of the particles; nearly all particles with a diameter of 8.8 mm or more were not ingested. However, the particle sizes smaller than 8.8 mm, which were more similar to those of lead shot or bullet fragments, were more frequently ingested.

The available data on animals hunted using lead ammunition (both shot and bullets) clearly shows that lead fragments are dispersed in the carcass. Together with primary ingestion of lead shot exposure, there is an obvious potential for predators or scavenging wildlife to be exposed to lead in their diet.

1.4.4.3.1 Birds

Obligate scavengers that eat carrion only, such as vultures, do not live in the UK. Red Kite (*Milvus milvus*), Golden Eagle (*Aquila chrysaetos*), White-tailed Eagle (*Haliaeetus albicilla*), Common Buzzard (*Buteo buteo*), Raven (*Corvus corax*), Carrion Crow (*Corvus corone*), Hooded Crow (*Corvus cornix*) and Magpie (*Pica pica*) are facultative scavengers, and so are the bird species whose diet is most likely include carrion (including animals shot but not recovered) and discarded viscera from hunting. These same species, together with all raptors, could also feed upon live prey which contain lead ammunition. Prey animals that are debilitated by injury or lead intoxication may form a larger proportion of the diet than those that are not debilitated (ECHA, 2021c).

Pain, Sears and Newton (1995) reported on the liver lead concentrations of 424 raptors from 16 species that had been found dead and collected between 1981 and 1992 in the UK. The number of individual birds per species varied from 1 to 150. An arbitrary concentration of 6,000 µg/kg dw was used to identify samples that were considered to be above typical ‘background’ levels of exposure based on thresholds suggested by other authors. Median liver concentrations ranged from below the limits of detection to 2,170 µg/kg dw, with a maximum of 909,100 µg/kg dw in one Buzzard. The mean percentage of individuals exceeding the ‘background’ level was 4.7 %. However, although the authors considered that lead ammunition from food sources was likely to be the cause of the elevated lead concentrations, this study did not attempt to demonstrate this analytically.

Pain *et al*. (2007) analysed regurgitated food pellets from a Red Kite roost site in the Midlands to determine whether they contained lead shot. Radiographs showed that 29 of 264 (11 %) contained radio-dense material, not verified but presumed to be mainly shot or shot fragments. Sixteen pellets were dissected, six of which (37.5 %) contained 1 to 3 objects regarded as lead shot. The authors estimated that a minimum of 2 % of the total regurgitated food pellets contained shot. Pain *et al*.

(2007) conducted post-mortem analyses and liver and bone lead analysis on Red Kites that had been found dead across England. One of the 87 birds investigated (1.1 %) had a cause of death attributable to lead poisoning. However, 7 of 44 birds analysed (16 %) had liver lead concentrations above the 'background' (6,000 µg/kg dw) and 18 of 86 (21 %) had bone lead concentrations above 'background' (20,000 µg/kg dw). Lead isotope analysis suggested that the lead found in the regurgitated food pellets was the source of the elevated liver and bone concentrations, and did not match with that of other sources of lead (i.e. mining, petrol, coal).

Walker *et al*. (2012) carried our lead isotope analysis on liver samples from Red Kite carcasses submitted by members of the public in England and from Sparrowhawks (*Accipiter nisus*) from England, Wales and Scotland. For both species, the lead isotope analysis substantially overlapped with that of lead ammunition, marginally overlapped with that of coal, but was distinct from leaded petrol.

Molenaar *et al*. (2017) analysed the concentration of lead in Red Kites from England that were submitted for post-mortem analysis between 1989 and 2007. Six of the 44 birds (14 %) were determined to have liver lead levels greater than 15,000 µg/kg dw. In an additional 11 birds (13 %), reported mean bone lead values of 30,300 to 187,500 µg/kg dw were reported. One of these birds was found to have lead shot in the oral cavity.

The UK Predatory Bird Monitoring Scheme (PBMS) sampled 220 dead or dying Common Buzzards found in the wild between 2007 and 2018 (Taggart et al., 2020). These carcasses were obtained opportunistically following requests to members of the public, bird watchers and wildlife managers and the cause of death was not clear in many cases, so they may not fully represent the population at large. Samples were taken from both the liver and the femur and analysed for lead:

- The results of the liver analysis showed that the mean concentration of lead in 187 birds was 2,573 µg/kg dw (standard deviation: 7,516 µg/kg dw). Liver lead concentration was not related to the age of the bird, but varied markedly between years and increased substantially during the UK hunting season. The authors assumed that a liver lead concentration in excess of 6,000 µg/kg dw (around 2,000 µg/kg ww), derived by Pain *et al*. (1995) as having biological significance, was indicative of an abnormally high exposure to lead. Fifteen of the samples (8 %) exceeded this value.

- The results of the analysis of the femur from 125 birds showed that the mean concentration was 5,460 µg/kg dw (standard deviation: 10,669 µg/kg dw). Femur lead concentrations did not show a consistent pattern over time, but older birds had around double the levels of younger individuals. The authors assumed that a bone lead concentration in excess of 10,000 µg/kg dw, derived by Mateo *et al*. (2003) as having biological significance, was indicative of an abnormally high exposure to lead. Twelve of the samples (9.6 %) exceeded this value.

In order to identify whether the lead found in the buzzard samples was due to lead shot, samples of cartridges sold by the 5 largest manufacturers that represent 90 % of UK sales were obtained and the lead isotope ratios determined for each brand. These ratios were then compared to the ratios found in the liver samples, and a significant positive correlation found. The authors concluded that buzzard liver samples with higher lead concentrations more closely resembled the isotope ratios of lead shotgun pellets widely used in the UK than samples with lower lead concentrations. The stable isotope analysis indicated that 57 % of the lead detected in the sampled livers was derived from shotgun pellets, increasing to 89 % for the birds with lead concentration indicative of acute exposure. An uncertainty identified in the study was that ideally a larger sample of cartridges would have been analysed.

The Environment Agency (2021) summarises data on the concentrations of lead detected in the liver of Eurasian Sparrowhawks (*Accipiter nisus*) found dead in England between 2007 and 2014. These data were also generated as part of the UK PBMS. The concentrations of lead were not found to be significantly different over time and the range of lead concentrations in the 172 birds analysed was 35 to 16,800 µg/kg dw. No indication is provided of the possible source of the lead.

The levels of lead found in wild raptors and scavengers in the UK and the sources of this as suggested by the report authors are detailed in Table 1.14.

Table 1.14 Lead concentrations in wild UK birds of prey

Species	**Study timing**	**Lead concentration in tissues** mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	**Lead source**	**Reference**
Common Buzzard (*Buteo buteo*)	1981-1992	Liver: 1.34* (NA-909.1) n=56	Suggested ingestion of ammunition	(Pain et al., 1995)
	2007-2018	Liver: 2.573 (<0.011-85.4) n=187 Bone: 5.46 (0.146-110) n=125	Suggested ingestion of ammunition	(Taggart et al., 2020)
Eurasian Sparrowhawk (*Accipiter nisus*)	1981-1992	Liver: 0.55* (NA-12.33) n=150	NA	(Pain et al., 1995)
	NS	Liver: NA	Suggested ingestion of ammunition	(Walker et al., 2012)
	2007-2014	Liver: 0.69 (0.035-16.8) n=172	NA	(Environment Agency, 2021)
Goshawk (*Accipiter gentilis*)	1981-1992	Liver: 1.21* (NA- 4.63) n=6	NA	(Pain et al., 1995)

Species	**Study timing**	**Lead concentration in tissues** mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	**Lead source**	**Reference**
Golden Eagle (*Aquila chrysaetus*)	1981-1992	Liver: 0.34* (NA- 2.96) n=5	NA	(Pain et al., 1995)
Hen Harrier (*Circus cyaneus*)	1981-1992	Liver: 2.17* (NA- 5.71) n=7	NA	(Pain et al., 1995)
Hobby (*Falco subbuteo*)	1981-1992	Liver: <0.1* (NA- 12.33) n=7	NA	(Pain et al., 1995)
Kestrel (*Falco tinnunculus*)	1981-1992	Liver: 0.69* (NA- 10.32) n=32	NA	(Pain et al., 1995)
Little Owl (*Anthene noctua*)	1981-1992	Liver: 0.82* (NA- 14.15) n=27	NA	(Pain et al., 1995)
Long Eared Owl (*Asio otus*)	1981-1992	Liver: <0.1* (NA- 2.67) n=22	NA	(Pain et al., 1995)
Marsh Harrier (*Circus aeruginosus*)	1981-1992	Liver: <0.1* n=1	NA	(Pain et al., 1995)

Species	Study timing	Lead concentration in tissues mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	Lead source	Reference
Merlin (*Falco columbarius*)	1981-1992	Liver: <0.1* (NA- 14.93) n=63	NA	(Pain et al., 1995)
Montagu's Harrier (*Circus pygargus*)	1981-1992	Liver: 2.12* (NA- 2.9) n=2	NA	(Pain et al., 1995)
Peregrine Falcon (*Falco peregrinus*)	1981-1992	Liver: 0.48* (NA-22.03) n=26	Suggested ingestion of ammunition	(Pain et al., 1995)
Red Kite (*Milvus milvus*)	1981-1992	Liver: 1.52* (NA- 3.06) n=6	NA	(Pain et al., 1995)
	1995-2003	Blood: 24.07 (0.8-333.78) n=125; Bone: 18.28 (5-187.5) n=86; Liver: 6.26 (0.5-46.7) n=44	Lead shot in regurgitated pellets	(Pain et al., 2007)
	NS	Liver: NA	Suggested ingestion of ammunition	(Walker et al., 2012)

Species	**Study timing**	**Lead concentration in tissues** mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	**Lead source**	**Reference**
	1989-2007	Bone: NA (30.3-187.5) n=11; Liver: >15 n=6	1 bird with lead shot in the oral cavity	(Molenaar et al., 2017)
Sea Eagle (*Haliaetus albicilla*)	1981-1992	Liver: <0.1* n=1	NA	(Pain et al., 1995)
Short Eared Owl (*Asio flammeus*)	1981-1992	Liver: 1.61* (NA-7.25) n=15	NA	(Pain et al., 1995)

Monclus *et al*. (2020) report a systematic review and meta-analysis of all published data on lead in raptors (covering the period 1983 to 2019). The authors reviewed 114 studies, covering 39 raptor species across Europe. They found that the Common Buzzard, the Golden Eagle and the White-tailed Eagle had the highest lead concentrations in their tissues and that the highest levels were found during the hunting season. These are their final conclusions:

- '*scavengers, both obligate and facultative species, are more prone to lead contamination than non-scavengers including birds of prey and owls,*
- *lead contamination in raptors is still widely detected across Europe despite partial bans on the use of lead in ammunition and shot,*
- *there is a seasonal peak in blood lead concentrations related to hunting season in southern European countries,*
- *the levels of exposure in several species are generally relatively high and exceedance of subclinical threshold levels is widespread.*'

1.4.4.3.2 Other animals

Other scavenging animals that could be exposed to lead via this pathway in GB are Badgers (*Meles meles*), Red Fox (*Vulpes vulpes*), Pine Martens (*Martes martes*) and other mustelids. No GB data on secondary poisoning of these species or any other predatory or scavenging non-avian species have been identified. However, it is likely that they may be exposed to lead through the predation and consumption of contaminated prey and through contaminated gut piles, discarded meat or unrecovered game left in the environment by the hunters (Pain et al., 2019b).

There are very few studies from outside GB. ECHA (2021a) refers to one case of lead poisoning in Cougar (*Puma concolor*) that was attributed to lead shot and bullet ingestion (Burco et al., 2012), and two additional studies where ammunition was the suspected source of lead poisoning in Grizzly Bears (*Ursus arctos*) and European Brown Bear (*Ursus arctos*) (Lazarus et al., 2020; Rogers et al., 2012).

1.4.4.3.3 Conclusion

There is strong evidence from both GB and international studies that secondary exposure of predatory/scavenging birds is a key exposure pathway for this assessment. Secondary exposure will be considered for all use scenarios where primary ingestion has been identified as a key exposure pathway and for all scenarios which involve hunting of live quarry.

There is no GB evidence that other animals are exposed via this route. However, as prey items are known to contain lead arising from ammunition, this is still a potential exposure pathway.

1.4.4.4 Movement of spent lead ammunition via ingestion of soil, accumulation in soil organisms or vegetation

Lead in ammunition is emitted to the environment during use, unless it is collected (e.g. in animal carcasses retrieved during hunting and pest control, or in bullet traps for sports shooting). It may enter the environment as intact bullets or shot or be present as fragments or lead 'dust'. In areas which are repeatedly used for shooting (e.g. shooting ranges), both the number of lead particles and the soil lead concentrations would be expected to increase over time. Soil may be ingested by some animals, or the lead present could accumulate in soil-dwelling organisms that could then be eaten. Although metallic lead is expected to be relatively stable in the environment, it can transform to more soluble forms which may be mobile especially in acidic soils (such as those in heath/moorlands which may be used for game birds) (Section 1.4.1) and have the potential for uptake by plants.

Natural lead concentrations in uncontaminated European topsoil tend to range from 10 to 30 mg/kg soil [not stated whether dw or ww] (EFSA, 2010a). The British Geological Survey (BGS) has identified a Normal Background Concentration (NBC) of soil lead over 94 % of the area of England as 180 mg/kg dw (Ander et al., 2013). The NBC is defined as a typical level of lead that could be expected as a combination of both natural background and diffuse pollution inputs. Urban areas and areas with high lead content in the underlying rock have higher NBC values.

A number of GB studies have reported on the concentration of lead in soil from sites at which lead ammunition is used.

Mellor & McCartney (1994) measured soil lead concentrations at a clay pigeon shooting range in Bolton, which had been in use for 20 years. Samples were taken from near to the shooting stands and from a control site 300 m away. Samples were sieved with a 1.8 mm sieve, extracted with nitric acid and acetic acid extraction (to provide both total and plant available concentrations) and analysed by atomic absorption spectrophotometry. In samples taken from 80 to 140 m from the shooting stands the total soil lead concentrations ranged from 5,000 to 10,600 mg/kg and the plant available lead concentrations ranged from 1,000 to 4,100 mg/kg. The authors also counted the number of lead pellets in these samples and up to 257 pellets per sample were reported in a 10 cm core from the top 15 cm of soil.

Clements (1997) measured soil lead concentrations on a dairy farm in southern Worcestershire. Samples were collected from areas with a 10-year history of clay pigeon shooting and from control fields. Samples were not sieved and were extracted with nitric acid followed by flame atomic absorption analysis. In samples taken 100 to 175 m from the shooting stands the mean soil lead concentration was 3,038 mg/kg (maximum 8,172 mg/kg dw), compared to 72 mg/kg dw in the control samples.

Reid and Watson (2005) measured soil lead concentrations at a clay pigeon site in Norfolk that had been used since the 1960s. Samples were collected from the shooting area and control areas that were not used for shooting. Samples were not sieved and were extracted with nitric acid and acetic acid (to provide available and total lead concentrations) before analysis by inductively coupled plasma optical emission spectrometry. Mean total soil concentrations were 6,410 ± 2,250 mg/kg dw in samples from the shooting area and 296 ± 98 mg/kg dw in control samples. The available lead concentrations were reported to be 1,050 ± 240 mg/kg dw from the shooting area and 12 ± 9 mg/kg dw in the control area.

Sneddon *et al*. (2009) measured soil lead concentrations in samples from a Cheshire shooting ground that had been used for 200 years for game shooting and 20 years for intensive pheasant shooting. Samples were collected from a woodland copse used for shooting, a meadow used for shooting and a woodland and a grassland control site. Samples were sieved with a 2 mm sieve, before they were extracted with nitric acid and analysed by plasma-mass spectrometry. Mean total lead concentrations were 160 mg/kg dw in the woodland, compared to 60.2 mg/kg dw in the control site, and 68.3 mg/kg dw in the meadow compared to 43.9 mg/kg dw in the control site.

A small number of UK studies have investigated the potential for lead in soil that is attributed to the use of lead in ammunition to be accumulated by plants or soil-dwelling organisms.

LAG (2015b) cites an unpublished study by RPS Environmental Sciences Ltd (1989) which investigated lead concentrations in grass, cereals, potatoes, beans and heather at samples taken from long established UK clay shooting grounds. Lead concentrations in samples of potatoes and beans were not elevated compared to controls. Concentrations of lead in heather ranged from 8 to 35 mg/kg dw, compared to 8 to 18 mg/kg dw from control samples. Concentrations of lead in grass samples ranged from 18 to 95 mg/kg dw, compared to 4 to 9 mg/kg dw in control samples. Although highly variable, cereals had the highest recorded lead concentrations ranging from 9 to 160 mg/kg dw, compared to 5 to 10 mg/kg dw in control samples.

LAG (2015b) also cites a second unpublished study (RPS Clouston, 1991) that investigated lead concentrations in grasses (permanent and ley pasture) and heather from areas of intensive and informal game shooting. The intensive areas had been in operation from 15 to over 100 years and held 10 to 20 drives per stand per year. The informal game shooting areas had been in operation for 12 to 15 years, and held shoots on between 24 and 30 days per year. Lead concentrations ranged from 31 to 360 mg/kg in the grass samples and from 18 to 19 mg/kg in the heather samples. No results from control samples are reported in LAG (2015b).

Several of the studies that reported soil lead concentrations summarised above also reported on lead concentrations in vegetation collected from the same sites.

Mellor and McCartney (1994) measured lead concentration in oilseed rape collected from within the fall-out area of the clay pigeon shooting range. The results are reported as both parts per million (ppm) and mg/kg, with different values given for both (a factor of 20 different) without further explanation. Despite this, the results demonstrate that samples taken from the shooting range had elevated lead levels compared to the control in the roots (up to 470 ppm dw compared with 10 ppm), stem (62 ppm dw compared with 4 ppm) and seeds (148 ppm dw compared with below the limit of detection).

Clements (1997) analysed 50 unwashed rye grass samples from the fall-out area of a clay pigeon range on a dairy farm. Forty-nine of the samples had lead concentrations below the limit of detection, but a single sample had a lead concentration of 121.75 mg/kg dw.

Sneddon *et al*. (2009) reported concentrations up to 38.4 mg/kg dw in washed rye grass from the shooting field in their study, compared with 0.89 mg/kg dw in the control grassland.

Two GB studies were identified that investigated the uptake of lead from ammunition in terrestrial organisms.

Reid and Watson (2005) collected earthworms from the same sites as they collected soil samples. The worms collected from the clay pigeon shooting sites had concentrations of lead nearly 1,000 times higher than worms collected from a control site (mean 6.1 mg/g dw, compared to 0.0071 mg/g dw).

As well as reporting on lead concentrations in soil and vegetation samples, Sneddon *et al*. (2009) also analysed earthworms and their gut contents together with hair samples taken from Wood Mice (*Apodemus sylvaticus*) and Field Voles (*Microtus arvensis*) for lead content. The worm body lead content was not statistically significantly different to the control in the shooting field samples, but for the woodland samples the shooting area had significantly higher concentration than the control (111.79 mg/kg dw compared to 5.49 mg/kg dw, $p < 0.01$). For worm gut content, a statistically significantly higher lead concentration was found in the shooting field samples than the control (35.61 mg/kg dw compared to 16.41 mg/kg dw, $p < 0.01$). Although worm gut lead levels were highest from the woodland samples (298.86 mg/kg dw), no control data were reported to compare this to. The lead concentrations measured in rodent hair were variable and did not follow a consistent pattern, but the highest concentration was reported in a sample from the control area.

ECHA (2021c) also summarise reported soil lead concentrations from areas of lead ammunition use and uptake of lead by plants outside the UK. Dinake, Kelebemang and Sehube (2019) reviewed over 100 studies on the concentrations of lead in soils from shooting ranges published between 1983 and 2018. The highest reported concentration was 300,000 mg/kg dw in a berm from a shooting range in the Netherlands (Van Bon and Boersema, 1988). ECHA (2021c) notes that soil lead concentrations are likely to be highly variable within a shooting range due to the irregular distribution of the lead ammunition. Several studies have investigated the uptake of lead by plants grown on shooting ranges and shown concentrations above control samples in Pine trees (Turpeinen et al., 2000), Spring Barley (Chrastný et al., 2010), vegetation comprised of ~85% *Poaceae* grasses (Bennett et al., 2007) and in unspecified plants collected from berms (Dallinger, 2007).

1.4.4.4.1 Conclusion

GB data and evidence from other parts of the world clearly shows that soil lead concentrations in areas of intensive or repeated lead ammunition use will be above background levels. In GB, measured concentrations up to three orders of magnitude higher than natural background have been reported, whilst concentrations up to four orders of magnitude higher than natural background have been observed in other parts of the world. Several species of grasses and crops have also been reported to accumulate lead when grown on shooting ranges. Increased soil and vegetation lead concentrations will occur both during and after the service life of the site, unless a remediation plan is implemented. The lead in soil has the potential to be ingested directly by soil organisms or grazing animals or to be taken up and accumulated by plants, which may then be eaten. This exposure pathway is therefore relevant for those uses which result in high inputs of lead in ammunition to the same sites (e.g. shooting ranges or rural areas with regular shoots).

1.4.4.5 Movement of lead from spent lead ammunition to surface or ground waters

Lead compounds and lead powder can be relatively mobile in soil solution or runoff water. Therefore, where sites are contaminated by lead ammunition and are in close proximity to surface water, there is a risk for the transport of lead into the aquatic environment (see Section 1.4.1). Leaching has been demonstrated under aerobic conditions in *in vitro* leaching tests, but not under anaerobic conditions (ECHA, 2021c).

Information was submitted to the Agency during the call for evidence by a local council that had investigated two instances of drinking water contamination with lead that were suspected to be caused by the release of lead from spent ammunition. In the first case, bullets fired during soldier training on an acidic moorland were considered to be the cause of lead contamination of a private water supply serving thirteen dwellings. Lead concentrations up to 27.4 µg/L were reported. In the second case, lead shot from a clay pigeon shooting range on an acidic moorland site was considered to be the cause of lead contamination of a private water supply serving a commercial premises. Lead concentrations up to 27.7 µg/L were reported. In both cases, natural occurring lead deposits and lead sources from water distribution systems (i.e. pipework/storage tanks) were ruled out as the potential source. No information was provided on the duration that the sites were used or on the number of bullets/shot present, but spent bullets and cartridge shells were observed at both sites.

Neither LAG (2015b) nor ECHA (2021c) identified any published studies on the concentration of lead in surface waters or groundwaters in GB from sites at which lead ammunition is used, although some non-GB studies were reviewed. Concentrations of waterborne lead up to 2,900 µg/L have been observed in surface waters located near to land contaminated by lead ammunition (cited within ECHA, 2021c; US EPA, 1994). Lead concentrations in water leaching from a clay pigeon site that had been closed for 20 years were higher than those from an adjacent site that was in use for the previous 20 years in Finland (Selonen et al., 2012). Also in Finland, concentrations of lead in groundwater at one of three shooting ranges studied was above the drinking water standard (Sorvari, 2007).

1.4.4.5.1 Conclusion

There is the potential for contamination of surface waters and groundwaters in areas of intensive ammunition use (e.g. shooting ranges or rural areas with regular shoots). The scale of this exposure pathway will depend on the amounts of lead emitted to the environment, site conditions, proximity of surface water courses or groundwaters and time. Increased water lead concentrations may occur both during and after the service life of the site, unless a remediation plan is implemented. Aquatic organisms in surface waters may be exposed to the lead, or humans may be exposed via drinking water. As there is no evidence from GB that surface waters are contaminated with lead from the use in ammunition this pathway is not considered further in the environmental risk assessment as it is not considered a key pathway.

1.4.4.6 Movement of lead from embedded shot/bullets into body tissues/organs

No GB data to support this potential exposure pathway have been located.

LAG (2015b) and Pain, Mateo and Green (2019b) review the evidence for this potential pathway using data for both birds and other animals from other countries. Studies on 22 species of live wildfowl have shown that 20 to 30 % of individuals have lead shot embedded in their bodies (Pain et al., 2014). There is some evidence that embedded lead can be mobilised and result in higher blood lead concentrations in birds (e.g. Berny et al., 2017). Although some authors have linked embedded lead to reduced survival or condition, it is often difficult to identify toxicity arising from the embedded lead as the cause of these impacts, rather than the shooting injury, lead ingestion or a combination of factors.

1.4.4.6.1 Conclusion

The number of studies on this topic is small. They suggest that any effects on the organism from embedded lead are likely to be less important than those that are due to ingestion of lead from ammunition. Therefore, although this remains a theoretical exposure pathway which could lead to sub-lethal effects, this is not considered further in this assessment.

1.4.4.7 Overall conclusions

The evidence base for the potential exposure pathways for lead in ammunition were comprehensively reviewed by LAG (2015b). Further information has been summarised in Pain, Mateo and Green (2019b) and ECHA (2021c, 2021a).

For the purposes of this assessment, the following exposure pathways will be taken forward for consideration in the environmental risk assessment:

Table 1.15 Overview of key exposure pathways for the environment

Use	Use name	Exposure pathways
1	Hunting with lead shot	Primary and secondary poisoning of wildlife (birds)
2a	Hunting with bullets – small calibre	Secondary poisoning of wildlife (birds)
2b	Hunting with bullets – large calibre	

3	Outdoor sports shooting with shot shell ammunition	Primary and secondary poisoning of wildlife (birds) Ingestion of contaminated soil and vegetation by livestock and wildlife on shooting ranges/areas used as agricultural land Poisoning of livestock (ruminants) via silage grown on shooting ranges/areas used as agricultural land Soil contamination
4	Outdoor sports shooting with bullets	Ingestion of contaminated soil and vegetation by livestock and wildlife on shooting ranges/areas used as agricultural land Soil contamination
5	Outdoor shooting with air rifle	
6	Other outdoor shooting activities including muzzle-loaders, historical re-enactment, etc.	

1.4.5 Environmental risk assessment

A fully quantitative risk assessment for the various uses of lead in ammunition has not been attempted for the purposes of this report, because the implicit assumption is that there is no safe threshold of lead exposure for either wildlife or people. Instead, the Agency has considered the reported impacts on individuals and populations along with the evidence on hazard (Section 1.4.2) and exposure pathways (Section 1.4.4) to produce a description of the risk. As the source of the lead does not alter the impact, the various uses are considered together in a single environmental risk assessment. When possible a semi-quantitative estimate of risk has been made, but where this was not appropriate risks are assessed qualitatively.

The risk assessment endpoints considered are adverse effects on:

- individual animals, including lethal and sub-lethal effects; and
- the population.

1.4.5.1 Impacts on individual birds (mortality/sub-lethal) – primary and secondary exposure

Primary and secondary exposure of birds has been identified as a key exposure pathway (Section 1.4.4). In order to conclude on the potential risk it is necessary to determine the level of exposure that may result in adverse effects.

Lead is a non-essential, toxic element. The range of possible adverse effects of lead exposure have been investigated in experimental laboratory studies (Section 1.4.2). Evidence of the effects of lead on wildlife is also available from pathology reports and observational studies (e.g. (AHVLA, 2012; Pain et al., 2007; Potts, 2005). As well as causing mortality, lead exposure can result in sub-lethal effects on behaviour, development and reproduction. In addition to the lethal and sub-lethal effects that can be measured, there are also likely to be welfare impacts that are less easy to determine (LAG, 2015a, 2015b).

Mortality has been observed in experimental studies after ingestion of a single lead shot pellet (e.g. (Buerger et al., 1986; Finley and Dieter, 1978; Vyas et al., 2001). These studies used adult birds and it is likely that higher levels of mortality would have been observed if chicks or juveniles had been used (the dose being proportionally higher due to their lower body weight). It is also reasonable to assume that sub-lethal and welfare effects can occur at exposure concentrations lower than those at which mortality occurs. Impacts are likely to depend on the amount of lead ingested (either directly or via secondary poisoning) in relation to the body size of the bird, with different species also having differing sensitivities.

Some researchers have attempted to define concentrations of lead in liver, bone or blood that can act as thresholds to determine background concentrations, sub-clinical or clinical poisoning (Section 1.4.2). Again, the thresholds support the conclusion that there is no safe level of exposure of lead, as the only concentration range at which effects are not anticipated are background concentrations.

1.4.5.2 Primary exposure of birds

Several UK studies have reported on the proportion of terrestrial game bird samples that contained lead shot in their gizzards (Section 1.4.4.1). The proportions were 3 % in Common Pheasant (Butler et al., 2005), 0.2 to 1.4 % in Red-legged Partridge (Butler, 2005) and 0 to 4.5 % in Grey Partridge (Potts, 2005; Watson, 2004). A study of Grey Partridge chicks reported a higher proportion of 6.9 % (Potts, 2005).

These reported values are a spot estimate in time, from either a limited sample of shot birds or birds found dead. It is therefore important to consider their potential biases. Once ingested, the lead particles in the gizzard will be eroded over time until they become too small to be observed, or leave the gizzard completely. Lead pellets are estimated to remain in the gizzard for up to 20 days (LAG, 2015a), although some studies suggest a longer duration (Section 1.4.2), and therefore the reported values would underestimate the numbers of birds exposed annually. Studies using birds found dead may underestimate the number of birds with ingested lead, as lead poisoning debilitates birds and may make individuals more prone to predation or hiding when sick or dying (LAG, 2015b). Shot bird samples are likely to over-represent young birds, as these are more usually shot. Individuals that have ingested shot may have already been removed from the population if they have died due to lead poisoning and so be underestimated. However, Bellrose (1959) reports that mallards experimentally dosed with 1, 2 or 4 lead shot pellets were 1.5, 1.9 and 2.1 times more vulnerable to hunting, respectively, than control ducks, indicating that birds with ingested lead may be over-represented in samples of shot birds. There is therefore the possibility that the reported values may both underestimate or overestimate the proportion of birds with ingested lead shot, depending on the species involved and sample type. Studies that have collected fully representative samples of birds are not available, either from the UK or other countries.

A single study is available on the levels of mortality attributable to the ingestion of lead shot by a terrestrial game bird in the UK. Potts (2005) examined post-mortem records for wild Grey Partridge found dead in south-east England between 1947 and 1992. During 1947-1958 0.3 % (3/872) were considered to have died as a result of lead poisoning; however, the proportion was higher at 4 % (9/224) between 1963 and 1969 and 2.7 % (6/222) during 1970-1992. Over the whole time period 1.4 % were considered to have died as a direct result of lead poisoning (18/1,318). A third of birds with 1 to 3 gizzard pellets and all birds with 4 or more pellets were considered to have died as a result of lead poisoning, but sample sizes were small.

Two studies report modelled mortality rates. Pain *et al*. (2019a) used the data on ingestion rates of lead shot in Common Pheasant and Red-legged Partridge (Butler, 2005; Butler et al., 2005) to estimate mortality rates due to lead ingestion of 0.56 and 0.32 %, respectively, for the UK populations. Pain *et al*. (2019a) consider that this is likely an underestimation, as they do not include juveniles or account for sub-lethal poisoning; mortality is also estimated at half the rate of Mallards as an arbitrary figure. A study by Meyer *et al*. (2016) modelled the percentage mortality for Grey Partridge to be 4 % for deaths directly related to lead shot ingestion in continental Europe based on results from pathology reports.

Based on the data on the ingestion rates and mortality rates of terrestrial birds, and for the purposes of this assessment, the Agency has selected a range of values between 0.1 and 5 % to represent those terrestrial birds potentially exposed and at direct risk of death due to the primary ingestion of lead shot. A range has been selected as there is uncertainty in this number and the number of studies on which this is based is limited and does not cover all species potentially at risk. This range is considered to be a reasonable estimate based on the data available. ECHA (2021a) follow a similar approach and select a central value of 1 % (range 0.5 to 2 %) based on the mortality data alone.

A list of the terrestrial species at most risk of lead poisoning is provided as Table 1-29 in ECHA (2021a). This list is based on evidence of ingestion of lead shot by these species, extrapolation from species in the same taxonomic group based on similarity of feeding ecology and an assessment by the United Nations Environment Programme Convention on Migratory Species (UNEP/CMS) ad hoc Expert Group. The number of wild birds in the UK for each of these species has been taken from the data submitted to the European Environment Agency (EEA) under Article 12 of the Birds Directive for the period 2013 to 2018 (available at https://nature-art12.eionet.europa.eu/article12/report?period=3&country=UK, accessed 14/12/21). Data are reported as 'individuals', 'breeding pairs' or the 'number of calling males'. To provide an estimate of the total breeding population (Table 1.16), data reported as pairs or number of calling males was doubled (although this is an underestimate for data based on number of calling males).

Table 1.16 UK population of terrestrial bird species identified as being at high risk of lead poisoning due to primary ingestion

Latin name	Common name	Breeding population estimate
Alectoris rufa	Red-legged Partridge	145,494
Columba livia	Rock Dove (wild)	6,000
Columba livia	Rock Dove (feral)	920,930
Columba oenas	Stock Dove	643,560
Columba palumbus palumbus	Common Woodpigeon	10,310,120
Coturnix coturnix	Common Quail	748
Lagopus lagopus hibernica	Willow Grouse	404
Lagopus lagopus scotica	Red Grouse	529,530
Lagopus muta	Ptarmigan	17,000[a]
Lyrurus tetrix britannicus	Black Grouse	9,654
Perdix perdix	Grey Partridge	74,254

Phasianus colchicus	Common Pheasant	1,681,458
Scolopax rusticola	Eurasian Woodcock	114,216
Streptopelia decaocto	Eurasian Collared Dove	1,617,794
Streptopelia turtur	European Turtle Dove	7,176
Tetrao urogallus	Western Capercaillie	1,114
TOTAL breeding population		**16,079,452**
Numbers at risk assuming 0.1% exposed		**16,100**
Numbers at risk assuming 0.5% exposed		**80,400**
Numbers at risk assuming 1% exposed		**161,000**
Numbers at risk assuming 5% exposed		**804,000**

[a] The population estimate is provided as a minimum to maximum estimate of 2,000 to 15,000 breeding pairs. The mean value is used here.

Assuming between 0.1 and 5 % of these birds are exposed to lead shot via primary ingestion, this equates to between 16,100 and 804,000 individuals at risk of death. As these values relate to the breeding population, they do not include the immature population. In addition, the winter population of Woodcock increases substantially due to immigration, with an additional 1.4 million individuals estimated to be present (Woodward et al., 2020). Other ground foraging species (especially those with a granivorous diet such as larks, finches and buntings) may also be affected by lead exposure, but evidence is lacking. These figures may therefore underestimate the actual number of impacted birds that suffer and die because they consume lead shot pellets.

These figures do not include terrestrial game birds bred and released for the purposes of hunting. The numbers are very large. For example, it is estimated that between 8.1 and 13 million partridges and 39 and 57 million pheasants are released annually in the UK, with 85 % released in England (Madden and Sage, 2020). Although these birds are a commodity, rather than a wild population, the risks to them are the same as for wild birds, or potentially even greater as they are more likely to be located in areas used for shooting. Even if only a small proportion of the released population ingest lead shot then large numbers of birds may die from an avoidable cause. For example, if it is assumed that between 0.1 and 5 % of these two types of game bird are exposed to lead shot via primary ingestion, this equates to between 47,100 and 3,500,000 individuals at risk of death.

In addition to terrestrial birds, aquatic birds that feed outside of wetlands may also be exposed to lead shot. A list of the wetland species at most risk of lead poisoning due to exposure via the terrestrial environment is provided as Table 1-28 in ECHA (2021a). This list was produced using the same methodology as for the terrestrial birds. Table 1.17 reports the size of the UK population based on the data submitted to the EEA. Most of the data was for the number of over-wintering individuals. Some species were reported as breeding pairs, and in this case the numbers have been doubled.

Table 1.17 UK population of wetland bird species identified as being at high risk of lead poisoning due to primary ingestion via the terrestrial environment

Latin name	Common name	Estimate of number of individuals potentially affected
Anas acuta	Northern Pintail	20,062
Anas crecca	Common Teal	435,710
Anas platyrhynchos	Mallard	674,885
Anser albifrons albifrons	Greater White-fronted Goose	2,100
Anser albifrons flavirostris	Greater White-fronted Goose	10,942
Anser anser	Greylag Goose	91,000
Anser brachyrhynchus	Pink-footed Goose	510,000
Anser caerulescens	Snow Goose	8
Anser fabalis fabalis	Taiga Bean Goose	230
Anser fabalis rossicus	Tundra Bean Goose	300[b]
Branta bernicla bernicla	Dark-bellied Brent Goose	98,000

Branta bernicla hrota	Pale-bellied Brent Goose	5,000
Branta canadensis[a]	Canada Goose	109,048
Branta leucopsis	Barnacle Goose	100,745
Cygnus atratus[a]	Black Swan	38
Cygnus columbianus bewickii	Bewick's Swan	4,371
Cygnus cygnus	Whooper Swan	19,590
Cygnus olor	Mute Swan	13,912
Grus grus	Common Crane	56
TOTAL population		**2,095,997**

[a] Not listed by ECHA but has a similar feeding ecology to other swans.

[b] Not listed in data submitted to the European Environment Agency (EEA) under Article 12 of the Birds Directive, but included in Woodward *et al*. (2020)

As with terrestrial birds, these numbers may be an underestimate. For example, Woodward *et al*. (2020) report an additional 230,000 Greylag Geese, 75 Snow Geese, 32,000 Brent Geese, 165,000 Canada Geese and 52,500 Mute Swans overwintering in the UK.

An estimate has not been made of the potential exposure and risk to these wetland birds from the use of lead shot in terrestrial environments. It is not possible to use data on amounts of ingested lead shot to estimate this as it is not possible to distinguish uptake of lead shot from terrestrial environments from that used illegally over wetlands or present due to historic use. However, the potential exposure pathway is clear and even if only a small proportion of the population ingest lead shot then large numbers of birds may suffer and die because they consume lead shot pellets.

1.4.5.3 Secondary exposure

Several UK studies have reported on the concentrations of lead in the liver, bones or blood of wild scavenging or predatory birds that were found dead or dying and collected for analysis (Table 1.18). These concentrations can be compared to the thresholds provided in (Table 1.10) to provide an indication of the biological significance of the concentrations measured. A liver lead concentration in excess of 6 mg/kg dw (~2 mg/kg ww) is likely to have resulted from abnormally high exposure to lead and result in subclinical poisoning, and a concentration exceeding 20 mg/kg dw (~6 mg/kg ww) in liver is indicative of acute exposure and is likely to have caused mortality. For bone, a concentration in excess of 10 mg/kg dw is viewed as being elevated and likely to result in subclinical poisoning, and a concentration exceeding 20 mg/kg dw is compatible with lethal poisoning. For blood, lead concentrations greater than 20 µg/dL are indicative of subclinical poisoning and concentrations over 50 µg/dL are likely to have caused mortality.

Table 1.18 Comparison of lead concentrations in wild UK birds of prey to thresholds of biological significance

Species	Study timing	Lead concentration in tissues mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	Above subclinical toxic threshold	Above clinical threshold	Lead source	Reference
Common Buzzard (*Buteo buteo*)	1981-1992	Liver: 1.34* (NA-909.1) n=56	Liver: 5% (3/56)	Liver: 2% (1/56)	Suggested ingestion of ammunition	Pain et al., 1995
	2007-2018	Liver: 2.573 (<0.011-85.4) n=187 Bone: 5.46 (0.146-110) n=125	Liver: 8% (15/187) Bone: 9.6% (12/125)	Liver: 2.7% (5/187) Bone: 4% (5/125)	Suggested ingestion of ammunition	Taggart et al., 2020
Eurasian Sparrowhawk (*Accipiter nisus*)	1981-1992	Liver: 0.55* (NA-12.33) n=150	Liver: 0.7% (1/150)	Liver: 0%	NA	Pain et al., 1995
	2007-2014	Liver: 0.69 (0.035-16.8) n=172	Liver: 1.2% (2/172)	Liver: 0%	NA	Environment Agency, 2021

Species	**Study timing**	**Lead concentration in tissues** mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	**Above subclinical toxic threshold**	**Above clinical threshold**	**Lead source**	**Reference**
Goshawk (*Accipiter gentilis*)	1981-1992	Liver: 1.21* (NA- 4.63) n=6	Liver: 0%	Liver: 0%	NA	Pain et al., 1995
Golden Eagle (*Aquila chrysaetus*)	1981-1992	Liver: 0.34* (NA- 2.96) n=5	Liver: 0%	Liver: 0%	NA	Pain et al., 1995
Hen Harrier (*Circus cyaneus*)	1981-1992	Liver: 2.17* (NA- 5.71) n=7	Liver: 0%	Liver: 0%	NA	Pain et al., 1995
Hobby (*Falco subbuteo*)	1981-1992	Liver: <0.1* (NA- 12.33) n=7	Liver: 29% (2/7)	Liver: 0%	NA	Pain et al., 1995

Species	Study timing	**Lead concentration in tissues** mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	Above subclinical toxic threshold	Above clinical threshold	Lead source	Reference
Kestrel (*Falco tinnunculus*)	1981-1992	Liver: 0.69* (NA-10.32) n=32	Liver: 3% (1/32)	Liver: 0%	NA	Pain et al., 1995
Little Owl (*Anthene noctua*)	1981-1992	Liver: 0.82* (NA-14.15) n=27	Liver: 7% (2/27)	Liver: 0%	NA	Pain et al., 1995
Long-eared Owl (*Asio otus*)	1981-1992	Liver: <0.1* (NA- 2.67) n=22	Liver: 0%	Liver: 0%	NA	Pain et al., 1995
Marsh Harrier (*Circus aeruginosus*)	1981-1992	Liver: <0.1* n=1	Liver: 0%	Liver: 0%	NA	Pain et al., 1995
Merlin (*Falco columbarius*)	1981-1992	Liver: <0.1* (NA-14.93) n=63	Liver: 10% (6/63)	Liver: 0%	NA	Pain et al., 1995

Species	Study timing	Lead concentration in tissues mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	Above subclinical toxic threshold	Above clinical threshold	Lead source	Reference
Montagu's Harrier (*Circus pygargus*)	1981-1992	Liver: 2.12* (NA- 2.9) n=2	Liver: 0%	Liver: 0%	NA	Pain et al., 1995
Peregrine Falcon (*Falco peregrinus*)	1981-1992	Liver: 0.48* (NA-22.03) n=26	Liver: 15% (4/26)	Liver: 4% (1/26)	Suggested ingestion of ammunition	Pain et al., 1995
Red Kite (*Milvus milvus*)	1981-1992	Liver: 1.52* (NA- 3.06) n=6	Liver: 0%	Liver: 0%	NA	Pain et al., 1995

Species	Study timing	**Lead concentration in tissues** mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	Above subclinical toxic threshold	Above clinical threshold	Lead source	Reference
	1995-2003	Blood: 24.07 (0.8-333.78) n=125[a]; Bone: 18.28 (5-187.5) n=86; Liver: 6.26 (0.5-46.7) n=44	Blood: 36.8% (46/125) Bone: NS Liver: 16% (7/44)	Blood: 2.4% (3/125)[b] Bone: 21% (18/86) Liver: 14% (6/44)	Lead shot in regurgitated pellets	Pain et al., 2007
	1989-2007	Bone: NS (NA – 187.5) n=86; Liver: NS (NA – 46.7) n=44	NS	Bone: 13% (11/86) Liver: 14% (6/44)[c]	1 bird with lead shot in the oral cavity	Molenaar et al., 2017
White-tailed Eagle (*Haliaetus albicilla*)	1981-1992	Liver: <0.1* n=1	Liver: 0%	Liver: 0%	NA	Pain et al., 1995

Species	**Study timing**	**Lead concentration in tissues** mean (range); *=median. Blood µg/dL Bone and Liver µg/g dw	**Above subclinical toxic threshold**	**Above clinical threshold**	**Lead source**	**Reference**
Short-eared Owl (*Asio flammeus*)	1981-1992	Liver: 1.61* (NA-7.25) n=15	Liver: 7% (1/15)	Liver: 0%	NA	Pain et al., 1995

[a] Blood samples were from juvenile kites (5-12 weeks old) collected from the wild and held in captivity but fed on shot carcasses with attempts made to remove pieces of lead shot.

[b] Authors use a threshold of 20-100 µg/dL and 100-500 µg/dL, so this is an underestimate of those above the clinical threshold of 50 µg/dL.

[c] Authors use a slightly lower threshold of 15 µg/g dw, so this is worst case.

Based on GB data for liver, blood and bone concentrations, there is evidence to suggest that deaths of wild Common Buzzards, Peregrine Falcons and Red Kites are being caused by lead poisoning. In samples of birds found dead, the proportion with elevated lead concentrations that are associated with mortality was up to 4 % in Common Buzzards, 4 % in Peregrine Falcons and 21 % of Red Kites (although only 9 % of Red Kite deaths were attributed to lead poisoning in this study; Pain *et al.*, (2007)). Studies have linked the sources of the lead in liver and bone to lead from ammunition by the use of lead isotope analysis (Pain et al., 2007; Taggart et al., 2020; Walker et al., 2012). Birds have also been found with lead shot in their oral cavity (Molenaar et al., 2017) and lead shot has been found in regurgitated food pellets (Pain et al., 2007). Although other species have not been found to have such high lead concentrations in the carcasses submitted for study, the samples are unlikely to be fully representative for each species and so should not be taken to mean that higher lead concentrations are never present. Samples are biased to those dead birds found and then submitted for analysis, so the geographical location of the samples may not match with those areas of highest exposure, and are often small in number.

A larger proportion of the bird samples and a larger range of species were found to have levels of lead above background concentrations, in the range at which sub-clinical effects may be expected. There is no analytical or observational evidence to link these increase lead concentrations to lead in ammunition. However, the same exposure pathway is expected to exist.

A list of the species at most risk of lead poisoning due to secondary exposure is provided as Table 1-29 in ECHA (2021a). This list was produced using the same methodology as for the terrestrial and wetland birds. Table 1.19 reports the size of the UK population based on the data submitted to the EEA. When data were reported as a range of minimum to maximum population, a mean was calculated. Some species were reported as breeding pairs or breeding females, and in this case the numbers have been doubled. As these values relate to the breeding population, they do not include the immature population.

Table 1.19 UK population of bird species identified as being at high risk of lead poisoning due to secondary poisoning

Latin name	**Common name**	**Breeding population estimate**
Accipiter gentilis all others	Northern Goshawk	1,168
Accipiter nisus all others[a]	Eurasian Sparrowhawk	60,516
Aquila chrysaetos	Golden Eagle	1,020

Latin name	Common name	Breeding population estimate
Asio flammeus[a]	Short-eared Owl	2,800
Asio otus[a]	Long-eared Owl	7,800
Athene noctua[a]	Little Owl	7,226
Buteo buteo	Common Buzzard	150,510
Circus aeruginosus	Western Marsh Harrier	1,283
Circus cyaneus	Hen Harrier	1,090
Circus pygargus	Montagu's Harrier	16
Corvus corax	Common Raven	20,054
Corvus corone	Carrion Crow	2,622,918
Corvus frugilegus[b]	Rook	1,963,028
Corvus monedula[b]	Jackdaw	3,110,726
Falco columbarius[a]	Merlin	2,324
Falco peregrinus	Peregrine Falcon	3,462
Falco subbuteo[a]	Hobby	4,142
Falco tinnunculus[a]	Kestrel	62,384
Haliaeetus albicilla	White-tailed Eagle	216
Milvus milvus	Red Kite	8,776
Pica pica[bc]	Magpie	1,217,764
TOTAL breeding population		**9,249,223**

[a] Not listed in ECHA but listed in (Pain et al., 1995)

[b] Not listed in Table 1-29 in ECHA but listed in (ECHA, 2021a)

[c] Not listed in ECHA but listed in (LAG, 2015a)

Green *et al*. (2022a) attempted to determine the population level impact of lead exposure on European (including UK) raptor species and as part of this estimated the number of individual birds that may die as a result of lead poisoning. Exposure levels were based on measured concentrations of lead in liver samples collected from dead or dying wild birds reported in previously published studies, and impacts on the individual likely to cause or contribute to death were assumed when the concentration exceeded a threshold of 20 mg/kg dw (the same threshold used here). Of the 22 species for which there were data, 10 had measured concentrations above the threshold, ranging from 0.3 to 16.5 %. The additional annual mortality of each of the 10 species was calculated, assuming that the proportion of individuals with lead concentrations above the threshold was equal to the proportion of deaths attributable to lead poisoning, and the expected annual survival rate in the absence of lead poisoning was estimated using this figure and published annual survival rates based on observations. Green *et al*. (2022a) report that for the 10 species with measured liver lead concentrations above the threshold the modelled number of adult deaths attributable to lead poisoning ranged from 1 (Bearded Vulture) to 2,597 (Common Buzzard) across Europe. The total annual number of deaths for the 10 species was 5,498 birds across Europe. Although the source of the increased liver lead concentrations could not be identified conclusively, countries with higher hunting rates (in terms of number of hunters/area) were positively correlated with the prevalence of lead poisoning. The authors also note that those species that are known to regularly scavenge or prey on game animals, birds or waterfowl had a higher annual probability of death from lead poisoning than those with different feeding habits.

The available observational data indicate that a proportion of the deaths of scavengers and avian predators in the UK is likely to result from lead poisoning arising from the use of lead ammunition. Data to support the possible exposure pathways that are thought to exist in the UK are presented in Section 1.4.4. The data on the proportion of birds found dead with increased lead concentrations above those that would be expected from background exposure has not been used to estimate the number of scavenging or predatory birds affected, although a recent study (Green *et al*., 2022) has attempted to model this for European raptors so there may be potential for this. Despite this, the potential exposure pathway is clear and even if only a small proportion of the population ingest lead via secondary poisoning then large numbers of birds may be adversely affected.

In summary, it is not possible to conduct a quantitative risk assessment for the risks from the use of lead in ammunition to birds. However, based on the evidence of exposure via both primary and secondary ingestion, and even assuming only a small proportion of the bird populations are exposed, large numbers of terrestrial and wetland birds are expected to suffer from increased mortality and sub-lethal effects.

1.4.5.4 Impacts on bird populations – primary and secondary

Mortality and sub-lethal effects (for example reduced reproduction rates) can affect the overall population size of a species, if these effects cannot be compensated for by other factors. The point at which population level effects may occur will vary from species to species, and between locations and time, depending on what other stressors or compensatory factors are in place. An adverse effect on a population may be observed as a decline, or as a reduction in the rate of population increase and may result in changes in population distribution. Population level effects as a result of increased mortality of individuals are most likely to occur in species such as raptors that have lower natural annual mortality rates and lower annual reproductive rates (Pain et al., 2019b).

In GB, there is no empirical evidence to suggest that adverse effects on individual terrestrial birds from different species are having an effect at the population level. However, LAG (2015b) note that the studies that would be necessary to establish this have not been carried out in the UK, and it is unknown how much mortality due to lead can be compensated for before population level effects are observed. In addition, due to the long-term use of lead ammunition and lack of population data from before its use, it is not possible to estimate the size of the population in the absence of lead to determine if a reduction in size is occurring.

An attempt to estimate the additional mortality due to lead poisoning that could be compensated for by two theoretical raptor populations and allow a steady population size was made in LAG (2015b) following the Demographic Invariants Method (DIM) of Niel and Lebreton (2005). The DIM model allows an estimate to be made of the additional mortality, beyond that which would occur naturally, that can be adjusted for by density-dependent mechanisms. LAG (2015b) modelled a long-lived raptor with annual adult survival of 0.95 and a mean first age of breeding of 5 years, and a second shorter-lived raptor with an annual adult survival of 0.8 and a mean first age of breeding of 2 years. These values were selected to cover most UK species of raptor. For the long-lived raptor an additional annual mortality of 2.2 % per year could be compensated for. This value was 8.2 % for the short-lived raptor. When converted to the proportion of all adult deaths due to the modelled lead poisoning, this equated to around 30 % for both species. The proportions of scavenger or raptor samples with concentrations of lead above levels expected to result in clinical poisoning (Table 1.18) are all below 30 %, suggesting that population level effects in the UK would not be anticipated. However, the modelling approach is based on many assumptions and the measured data also has limitations.

Following an alternative method, Meyer *et al*. (2016) modelled populations of Grey Partridge in continental Europe, Common Buzzard in Germany and Red Kite in Wales to estimate how mortality due to poisoning (including lead) could alter the population sizes. Exposure estimates for each species were based on levels seen in observational studies and ranged from 4 to 16 % for lead shot ingestion. For Grey Partridges, the population size was reduced by 10 % due to lead shot alone. For Red Kites, the population growth rate was reduced from 6.5 % annual increase to 4 % due to lead shot. Effects on the population of Common Buzzard were much smaller, with a decrease of <1 % modelled for both lead shot and other poisons combined. Although the significance of this paper to the UK is unclear, it does demonstrate that different species are likely to respond differently based on levels of exposure, life history and resilience of the population.

Green *et al*. (2022a) attempted to determine the population level impact of lead exposure on European (including UK) raptor species (see details in Section 1.4.5.3). Additional annual mortality of 10 species was calculated, assuming that the proportion of individuals with lead concentrations above the threshold was equal to the proportion of deaths attributable to lead poisoning, and the expected annual survival rate in the absence of lead poisoning was estimated using this figure and published annual survival rates based on observations. These values together with demographic data for each species (e.g. age at first breeding) were used to model population size over time both with and without lead poisoning and the difference between these values was reported as the expected proportion by which the European population of each species may be reduced due to lead. Reductions in adult population size were modelled to be between 0.2 % (Eurasian Sparrowhawk) and 14.4 % (White-tailed Eagle). When compared to the population sizes modelled in the absence of lead exposure, the total reduction in population size across all 10 species was 2.2 % which equates to around 55,000 birds across Europe.

Niel and Lebreton (2005), Meyer *et al*. (2016) and Green *et al*. (2022a) focus on how increased mortality due to lead exposure may affect the population. However, sub-lethal effects can also alter the reproduction rate, and therefore result in changes to the population size. Indeed, Meyer *et al.* note that when additional effects on reproduction rate were also included in their model the predicted effects were slightly greater. It should therefore be remembered that adverse effects that may be population relevant are not restricted to mortality, so estimates based on mortality alone are a “best case” and are unlikely to be realistic.

The use of lead ammunition has been linked to population level effects in several raptor species from outside GB. The strongest evidence is for the California Condor, which would be predicted to have become extinct due to the mortality caused by lead from ammunition if it were not for the mitigation measures put in place to protect this species (references in LAG, 2015b and Pain *et al.*, 2019b). Modelling studies have also indicated that population level effects may be occurring in Bald Eagles in America (Hanley *et al*., 2022) and Steller’s Sea Eagles in Japan (Saito, 2009; Ueta and Masterov, 2000), both of which have ecological similarities to the White-tailed Eagle which is found in GB. For all three species, the studies have linked the lead associated mortalities of individual birds to a decline in population, rather than sub-lethal effects on reproduction rate.

An assessment of the population status of UK birds is made in the fifth review of the Birds of Conservation Concern (BOCC) (Stanbury *et al*., 2021). Species are assigned to either a red, amber or green list, based on an objective set of criteria. Green indicates that there is no significant concern for conservation, and amber and red indicate increasing levels of concern due to declines in number or range based on the available monitoring data. In addition to the BOCC listing, the International Union for the Conservation of Nature (IUCN) listing for each species is also presented. The IUCN listing is based on the risk of extinction of a species, rather than conservation status in a broader sense. The BOCC and IUCN listing for each of the terrestrial bird species considered at highest risk of primary and secondary lead poisoning are shown in Table 1.20.

Table 1.20 BOCC and IUCN listing for the terrestrial birds at most risk of primary and secondary poisoning from lead in ammunition

Latin name	Common name	BOCC listing	IUCN listing
Alectoris rufa	Red-legged Partridge	Not included	Not included
Columba livia	Rock Dove	Green	NT
Columba oenas	Stock Dove	Amber	LC
Columba palumbus palumbus	Common Wood Pigeon	Amber	LC
Coturnix coturnix	Common Quail	Amber	EN
Lagopus lagopus hibernica	Willow Grouse	Not included	Not included
Lagopus lagopus scotica	Red Grouse	Green	LC
Lagopus muta	Ptarmigan	Red	VU
Lyrurus tetrix britannicus	Black Grouse	Red	VU
Perdix perdix	Grey Partridge	Red	VU
Phasianus colchicus	Common Pheasant	Not included	Not included
Scolopax rusticola	Eurasian Woodcock	Red	VU

Latin name	Common name	BOCC listing	IUCN listing
Streptopelia decaocto	Eurasian Collared Dove	Green	NT
Streptopelia turtur	European Turtle Dove	Red	CR
Tetrao urogallus	Western Capercaillie	Red	EN
Accipiter gentilis	Northern Goshawk	Green	NT
Accipiter nisus	Eurasian Sparrowhawk	Amber	VU
Aquila chrysaetos	Golden Eagle	Green	NT
Asio flammeus	Short-eared Owl	Amber	EN
Asio otus	Long-eared Owl	Green	LC
Athene noctua	Little Owl	Not included	Not included
Buteo buteo	Common Buzzard	Green	LC
Circus aeruginosus	Western Marsh Harrier	Amber	LC
Circus cyaneus	Hen Harrier	Red	EN
Circus pygargus	Montagu’s Harrier	Red	CR
Corvus corax	Common Raven	Green	LC
Corvus corone	Carrion Crow	Green	LC
Corvus frugilegus	Rook	Amber	NT
Corvus monedula	Jackdaw	Green	LC
Falco columbarius	Merlin	Red	EN
Falco peregrinus	Peregrine Falcon	Green	LC
Falco subbuteo	Hobby	Green	NT
Falco tinnunculus	Kestrel	Amber	VU
Haliaeetus albicilla	White-tailed Eagle	Amber	EN
Milvus milvus	Red Kite	Green	LC

Latin name	Common name	BOCC listing	IUCN listing
Pica pica	Magpie	Green	LC

IUCN threat status categories: CR critically endangered, EN endangered, VU vulnerable, NT near threatened, LC least concern.

For those species at highest risk of primary ingestion, six species are red listed on the BOCC and a further three are amber listed. One species is critically endangered, two are endangered and four are vulnerable based on the IUCN listing.

For those species at highest risk of secondary poisoning, three species are red listed on the BOCC and a further six are amber listed. One species is critically endangered, four are endangered and two are vulnerable based on the IUCN listing.

The reasons for the status of the threatened species are varied, and this assessment does not attempt to link exposure to lead from ammunition as a specific cause for any of them. However, some populations of bird species that have feeding ecologies that increase the likelihood that they will be exposed to lead from ammunition, either via primary or secondary exposure, are already threatened.

Overall, there is no specific evidence to show that the size of GB bird populations is impacted due to exposure to lead from ammunition, although this may be due to a lack of investigation and difficulties in collecting the data needed to do so. It is precautionary to avoid additional pressures on already vulnerable populations (for example due to sub-lethal effects of lead) where possible. In addition, a large number of individual birds are at risk from suffering and increased mortality from an avoidable cause.

1.4.5.5 Risks related to soil

Increased soil lead concentrations due to the input of lead ammunition has been identified as a potential exposure pathway for areas that are regularly shot over or which have intensive use, i.e. shooting ranges (Uses #3, #4, #5 and #6) (Section 1.4.4). This exposure pathway is not considered relevant for the other uses included in this assessment.

A small number of GB studies have measured the concentrations of lead in soil samples collected from shooting ranges that had been in use for between 10 and 40 years. Three studies were from clay pigeon sites and reported concentrations of up to 10,600 mg/kg dw (Mellor and McCartney, 1994) and 8,172 mg/kg dw (Clements, 1997) and a mean concentration of 6,410 ± 2,250 mg/kg dw (Reid and

Watson, 2005). One study from a shooting ground used for game and intensive pheasant shooting reported mean concentrations of 160 mg/kg dw in a woodland copse used for shooting and 68.3 mg/kg dw in a meadow used for shooting (Sneddon et al., 2009).

There are no UK soil environmental quality thresholds for lead. A generic PNEC for soil of 212 mg/kg dw is presented in the EU REACH CSR (2020), based on ecotoxicity data for soil-dwelling organisms (Section 1.4.2.2). All three studies from GB clay pigeon sites report soil concentrations that are significantly greater than this PNEC. The single study from a game shooting ground did not exceed the PNEC, although how representative this study is of other sites is unknown. The Agency notes that even at a single shooting range, soil lead concentrations would be expected to be highly variable depending on the proximity to the target and the site conditions. Variability between sites would also be expected due to the length of service life, intensity of shooting at the site and type of shooting. The limited number of GB soil monitoring studies clearly demonstrate that soil lead concentrations can be elevated considerably above background at shooting ranges, and achieve concentrations that are a trigger for risk management action. A single study from a game shooting ground does not allow this risk to be ruled out for that use.

Dinake *et al*. (2019) reviewed over 100 studies on the concentrations of lead in soils from shooting ranges published between 1983 and 2018. Elevated concentrations of lead were found at shooting ranges globally, ranging from 11 to 300,000 mg/kg dw, with the highest concentrations found in berms. Dinake *et al*. (2019) note that in nearly all the studies they reviewed the lead concentrations were orders of magnitude greater than the available regulatory limits.

Repeated shooting at a site, without any risk management measures in place to capture or collect and remove the lead ammunition, will result in increasing soil lead concentrations over time. The Agency considers that the concentration of lead in soil at sites used for intensive or regular shooting for extended periods of time can reach levels that result in unacceptable risks to the environment. It may be possible to introduce risk management measures to mitigate against this risk, depending on the specific use. These are considered further in Section 1.3.4.

1.4.5.6 Impacts on livestock

Exposure of livestock (and potentially wildlife) has been identified as a potential exposure pathway for areas that are regularly shot over or which have intensive use, i.e. shooting ranges (Uses #3, #4, #5 and #6) (Section 1.4.4). Exposure may occur via the direct ingestion of lead ammunition, or via ingestion of soil, soil-dwelling organisms or vegetation that has increased lead content. In addition, a potential exposure pathway via ingestion of silage contaminated with lead shot (Use #3) has been identified (Section 1.4.4). These exposure pathways are not considered relevant for the other uses included in this assessment.

Payne and Livesey (2010) report on lead poisoning of livestock in the UK due to the direct ingestion of lead shot. Braun *et al*. (1997) and Muntwyler (2010) also report on direct ingestion of lead shot by cattle in two studies in Switzerland that resulted in acute poisoning and mortality. A report from New Zealand stated that around 20 of 100 cattle had died or been euthanised following exposure to lead shot that was embedded in fodder beet grown on a shooting range (Macnicol, 2014).

Cases of lead poisoning resulting in sub-lethal and lethal impacts on cattle have been reported in the UK (Frape and Pringle, 1984; Payne et al., 2013), New Zealand (Vermun et al., 2002) and in the USA (Bischoff et al., 2014, 2012; Howard and Braum, 1980; Rice et al., 1987) after ingestion of silage contaminated with lead shot. In all cases, the plant material used to make the silage had been harvested from areas used for sports shooting with lead shot.

The Agency considers that lead shot ingested whilst grazing or contained within silage can result in unacceptable risks to livestock. By extension, this could also affect mammalian wildlife.

Several GB studies have reported on the uptake of lead by plants growing in areas of intensive shooting. Grass samples were found to have concentrations up to 95 mg/kg dw (RPS Environmental Sciences Ltd, 1989), 360 mg/kg dw (RPS Clouston, 1991), 121.75 mg/kg dw (Clements, 1997) and 38.4 mg/kg dw (Sneddon et al., 2009). None of these studies attempted to model or measure the exposure of livestock ingesting these plants.

Some thresholds have been set for the acceptable concentrations of lead in forage and feed. Directive 2002/32/EC on undesirable substances in animal feed that has been retained in GB law sets a lead concentration of 30 mg/kg for forage (including hay, silage, fresh grass, etc.) with a moisture content of 12 % and 10 mg/kg in other feed materials with a moisture content of 12 %. These thresholds are equivalent to 34 mg/kg dw and 11.4 mg/kg dw, respectively. All four GB studies that reported on concentrations in grass have maximum lead concentrations above the forage threshold, with one study having a maximum concentration ten times higher (RPS Clouston, 1991).

The Agency considers that the concentration of lead in grass growing on sites used for intensive or regular shooting for extended periods of time can reach levels that result in unacceptable risks to livestock. By extension, this could also affect mammalian wildlife.

Although the geographic scale of this risk may be small, the potential impacts to the livestock (or wildlife) affected are likely to be severe. The Agency therefore considers that the use of agricultural land for sports shooting with lead ammunition (Uses #3, #4, #5 and #6) poses an unacceptable risk to the environment.

1.4.5.7 Summary of risks

The identified environmental risks are summarised in Table 1.21, and are considered to be possible in the absence of any risk management measures. Risk management measures to mitigate against the identified risk are further considered in Section 1.3.3, Section 1.3.4 and Annex A.

Table 1.21 Summary of the risks identified related to the use of lead ammunition for hunting and sports shooting.

Use	Use name	Birds	Ruminants	Soil
1	Hunting with lead shot	+	NA	NA
2a	Hunting with bullets – small calibre	+	NA	NA
2b	Hunting with bullets – large calibre	+	NA	NA
3	Outdoor sports shooting with shot shell ammunition	+	+	+
4	Outdoor sports shooting with bullets	NA	+	+
5	Outdoor shooting with air rifle	NA	+	+
6	Other outdoor shooting activities including muzzle-loaders, historical re-enactment, etc.	NA	+	+

NA: not applicable

1.5 Human health assessment

1.5.1 Human health hazards

Chronic exposure to lead is associated with a wide range of health effects, as summarised in Annex B.5 (extract from (ECHA, 2021c)) and by Public Health England (PHE, 2017). These effects include toxicity to the blood system, nervous system, kidneys, cardiovascular system, and reproductive systems (male and female fertility, adverse effects on development following exposure during pregnancy). The critical effect in the developing foetus and young children is developmental neurotoxicity; even at low levels of lead exposure, cognitive development and intelligence quotient (IQ) are reduced. Elevation of systolic blood pressure and nephrotoxicity are the most sensitive endpoints in adults.

The main routes of absorption of lead are via inhalation and ingestion. Dermal absorption is reported to be low (estimated to be ≤ 0.06% by PHE (2017) and ECHA, (2021c)). The absorption of lead depends on its physical and chemical state and is also influenced by various factors, including a person's age, physiological status, nutritional status and genetic characteristics (PHE, 2017). Inhalation exposure can result in up to 100% absorption, whereas absorption is normally up to 15% of orally ingested lead in adults and approximately 50% in children; however, absorption via the gastrointestinal tract can be up to 45% in adults under fasting conditions. Absorbed inorganic lead is mainly transported in blood and is distributed to soft tissues and organs (e.g. liver, kidneys) and mineralising systems (bones, teeth). PHE (2017) reported that, in adults, approximately 90% of the lead body burden is in bone, whilst in children this value is approximately 70%. These values were consistent with those reported by ECHA (2021c). Both PHE (2017) and ECHA, (2021c) reported that during periods of bone resorption or increased calcium demand (i.e. pregnancy, lactation, menopause and osteoporosis), lead can be released from the bones into the bloodstream; this can result in an increase in blood lead levels (BLLs) after the original exposure has ceased. Lead can also be passed from mother to infant *in utero* (placenta to foetus), with the concentration of lead in cord blood being up to 90% of the level in maternal blood. Lead transfers to breast milk, although maternal milk is estimated to be a minor source of exposure for infants (PHE, 2017).

1.5.1.1 Key effects of lead

Annex B.5. contains details of the hazards to human health of lead, as described in the ECHA assessment for the restriction report on lead in shot and fishing tackle (ECHA, 2021c). A summary of the main effects is presented below.

1.5.1.2 Neurotoxicity

The nervous system is the main target organ for lead toxicity and in the developing foetus. Young children are the most vulnerable population to lead-induced neurotoxicity. Consequently, the primary human health concern of lead is its effect on the nervous system in young children arising from exposure *in utero* and during early childhood. Even at low levels of exposure, there is evidence of cognitive impairment in children aged seven and younger. The Joint FAO/WHO Expert Committee on Food Additives (JECFA, 2011) concluded that the negative impact on IQ is the most sensitive end-point for neurodevelopmental effects, and that there was no indication of a threshold for this effect; this position was supported by EFSA (2010b), the UK Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (C.O.T., 2013) and in several RAC assessments of lead for both restriction and occupational exposure limits (see below).

JECFA (2011) and EFSA (2010b) modelled dose-response relationships for neurodevelopmental effects from the same analysis of IQ tests and four measures of BLLs amongst children followed from infancy (see Annex B.5). JECFA estimated that the chronic dietary exposure of a 20 kg child that corresponded to a 1 IQ-point decrease was 0.6 µg Pb/kg bw/day, with a 90% confidence interval of 0.2-7.2 µg Pb/kg bw/day. In its risk assessment, EFSA also used a 1% change in full-scale IQ score (a decrease in IQ by one point) as a point of departure, from which it derived a $BMDL_{01}$ of 12 µg Pb/L (which by modelling converted to an exposure of 0.5 µg Pb/kg bw/day).

Other neurotoxic effects have also been reported after lead exposure, as summarised by PHE (2017) and ECHA (2018c).

1.5.1.3 Kidney effects

Lead exposure in humans is associated with a dose-dependent increase in nephrotoxicity with increasing BLLs. At lower BLLs (< 20 µg/dL), decreased glomerular filtration rate (GFR) has been observed, whilst changes in enzymuria and proteinuria occur at levels above 30 µg/dL. Severe deficits in renal function and pathological changes occur at BLLs > 50 µg/dL. Those with on-going renal disease or hypertension may be more vulnerable to the effects of lead. EFSA (2010b) determined that that 15 µg Pb/L (converted to 0.63 µg Pb/kg bw/day) was associated with a 10 % increase of chronic kidney disease (CKD) in the population (measured as reduction in the GFR to values below 60 mL/min). EFSA also concluded that there was no threshold for these renal effects in adults.

1.5.1.4 Cardiovascular effects

Lead exposure has been associated with several adverse effects on the cardiovascular system in animals and humans. The most studied dose-response relationship relates to the effect of lead on blood pressure, in particular systolic blood pressure. EFSA (2010b) concluded that a PbB level of 36 µg Pb/L (which corresponds to 1.50 µg Pb/kg bw/day) is associated with a 1% increase in systolic blood pressure in normotensive adults; the dose-response relationship amounted to an increase in systolic blood pressure of approximately 1 mm Hg with each doubling of BLL, without an identifiable threshold (EFSA, (2010b); ATSDR, (2007)). EFSA's CONTAM panel (2010a) concluded that the change in blood pressure could have significant consequences on human health on a population basis.

JECFA (2011) also concluded that a threshold for cardiovascular effects in adults could not be established (the critical effect being increase in systolic blood pressure). The committee reported that a lead exposure level of 3.0 µg Pb/kg bw/day would cause a population increase in systolic blood pressure of approximately 2 mm Hg, an increase that was associated with moderate increases in the risk of ischaemic heart disease and cerebrovascular stroke. The committee considered this to be of concern, but less so than the neurodevelopmental effects in children.

ECHA (2021c) reported that information provided in the EU REACH registration, submitted in 2015, indicated that there was a weak association between BLL and blood pressure in the general population and in occupational studies where average BLL were below 45 µg Pb/dL. As the dossier highlighted a lack of dose-dependency between environmental lead exposure and blood pressure, ECHA considered it not to be a suitable health endpoint for quantitative risk assessment.

1.5.2 Human health exposure

The primary human health risk to be addressed in this report is that to consumers of game meat that has been shot with lead ammunition (i.e. wild game). The highest consumers of game-meat are hunters and their families.

1.5.2.1 Consumption of game meat

Game meat of relevance to this report is wild game that has been killed with lead ammunition. Farmed game animals are not killed with lead ammunition and so consumption of their meat does not contribute to this source of lead exposure.

A recent survey of pheasants sold for human consumption in GB during the 2020/2021 shooting season found that 99% of the birds from which shotgun pellets were recovered had been killed with lead (Green et al., 2021). Lead ammunition that hits an animal often fragments into small particles upon impact. For example, a survey identified that 76% of UK game birds contained fragments too small to be detected by the human eye and that, in some cases, were scattered throughout the bird (Pain et al., 2010). A high proportion of the meat samples had lead concentrations that exceeded 100 ppb w/w (0.1 mg/kg w/w, the maximum level permitted in bovines, sheep, pigs and poultry). For example, 56% and 47% of fresh meat samples from partridge and pheasant, respectively, exceeded 0.1 mg Pb/kg, 21% and 18% exceeded 1.0 mg Pb/kg, and 5.7 % and 2.4 % exceeded 10 mg Pb/kg. Other UK data indicates that metal fragments (most likely to be lead) are found in deer (Knott et al., 2010, p. 20), and the Veterinary Medicines Directorate National Surveillance Scheme (2004 – 2011 data; cited in FSAS, (2012) determined that half of the sampled pheasants and partridges and 17% of wild deer had an average lead concentration exceeding the EU maximum level for non-game meats.

Other UK data indicates that metal fragments (most likely to be lead) are found in deer (Knott *et al.*, 2010, p. 20), and the Veterinary Medicines Directorate National Surveillance Scheme (2004 – 2011 data; cited in FSAS, 2012) determined that half of the sampled pheasants and partridges and 17% of wild deer had an average lead concentration exceeding the EU maximum level for non-game meats.

Meat hygiene measures and stewardship schemes are in place to minimise the amount of metal in meat sold for human consumption in the UK; these include accreditation through approved bodies before hunters can supply game to an approved game-meat handling establishment (AGHE), veterinary-officer inspection and FSA guidance. Game handling to remove obvious ammunition fragments by hunters and their families / friends is reasonably widespread (LAG, 2015b) (LAG, 2015a) (FSAS, 2012).

Despite these measures, meat can still contain small fragments of metal that cannot be easily detected and might be far from the shot site ((Trinogga et al., 2019); D. Pain, personal communication). Investigating wild ungulates shot with hunting-rifle bullets, Trinogga *et al*. (2019) found that the use of lead-based bullets causes a broad contamination of the carcass and the viscera with bullet material.

The Food Standards Agency (FSA), referring to the sale of small game, stated in a risk assessment (2014) (FSA, 2012) 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 and would cause damage to the birds which would likely make them unsellable.'

Another consideration is the cooking method: roasting of whole birds is reported to be typical, which does not permit the removal of lead fragments before cooking (LAG, personal communication).

Some information on game consumption in the UK is available. In a survey by Taylor *et al*. (2014), 2.7% participants reported eating game birds. Consumption by women of childbearing age and children ≤ 6 years old was relatively low and intakes were low. Data collected from high-level consumers of game meat in Scotland indicated that 51% ate lead-shot game at least once during the main shooting season; average consumption as estimated by National Diet and Nutrition Survey data was cited to be 47.4 g daily (equivalent to 331.5 g weekly or 17.2 kg per year) (FSAS, 2012). Green and Pain (2015) estimated that somewhere in the region of 4,000 – 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. BASC and Countryside Alliance estimated in 2014 that 9,000 (midpoint of the range 5,500 – 12,500) children under the age of 8 from the UK shooting community consumed at least one game meal per week (all types of game, one portion assumed to be ≥ 100 g), averaged over the year (cited in (Green and Pain, 2019; LAG, 2015b)). The percentage of high-level consumers of game in the UK (adults and children) seems to lie between 0.084 – 2.52% of the population (Green and Pain, 2019).

The most common and accurate method of assessing lead exposure is by analysis of lead in whole blood. BLLs reflect recent lead exposures, whereas bone-lead measurements are an indicator of cumulative exposure (ATSDR, 2007). Data from Germany has recently been used to statistically derive reference values (95th percentile) for the general population of 4 µg/L for adult men, 3 µg/L for adult women and 3.5 µg/L for children (HBM4EU, 2019).

The data on BLL increments from game meat consumption only (excluding hunting and shooting activities) are very limited. The available data indicate a small increase in BLL of 3 to 5 µg/L in adults with consumption of moose meat two to three times a week. For groups relying on subsistence hunting, the blood lead contribution from game meat consumption seems to be higher; in one study the increment for females (assumed to be non-hunters) was 6 and 15 µg/L (Tsuji et al., 2008). No reliable BLL measurements in children from hunter families are available. No UK-specific information on the impact of game-meat consumption on BLL has been identified.

In a recent review, Green and Pain (2019a) summarised the available evidence as giving an indication of increased human BLLs in association with the consumption of game meat that contains ammunition-derived lead; however, the observations did not indicate what proportion of the ammunition-derived lead is absorbed or how much BLLs are increased per unit of dietary lead ingested. To address this, Green and Pain (2012) used observations from two studies of Greenland adults to correlate by linear regression modelling the mean daily intake of dietary lead from the meat of birds killed with lead shot to the mean concentration of BLL. Whilst there was a strong relationship between mean BLL and the estimated mean rate of intake of dietary lead from this source, the regression model indicated that the effect of ammunition-derived lead was 39% lower than that expected for lead from non-ammunition sources. Possible explanations were that a proportion of ingested ammunition lead might remain as metallic fragments after cooking and processing in the gastrointestinal tract; and that metallic lead, especially if in larger fragments, might not be totally dissolved or absorbed as readily as more soluble lead salts and complexes. However, the authors highlighted a potential bias that could have led to an under-estimation of lead bioavailability. Taking into account the higher bioavailability of lead in the ordinary diet of children compared with adults, Green and Pain (2012) used the same model to estimate a value of 0.306 for the absolute bioavailability to children of dietary lead derived from the cooked meat of wild birds.

1.5.2.2 Additional indirect exposures to humans

Other potential sources of indirect exposure pertinent to the scope of this report are drinking water and other food types. 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 secondary human exposure via the environment through reduced environmental contamination with lead.

1.5.2.3 Direct exposure to humans

Direct exposure to humans can occur by the oral and inhalation routes. For example, hand-to-mouth exposure might occur where hunters self-fill their own cartridges with lead gunshot, if the lead shot is handled without the use of adequate protective equipment and hygiene practices. Inhalation exposure can occur from melting of lead to home-cast ammunition. Other sources of inhalation exposure can be from lead particles, which form from some disintegration of the lead projectile and are ejected at high pressure from gun barrels. Such exposures are outside the scope of the present assessment and information on their impact is limited (ECHA, 2021a, 2021c); therefore, they have not been further assessed in this report. These oral and inhalation exposures make it difficult to isolate the impact of game-meat consumption on the BLL of hunters.

1.5.3 Risk characterisation

ECHA's Risk Assessment Committee (RAC), has previously assessed the human health effects of lead in several restriction proposals, including lead in jewellery (ECHA, 2011), lead in consumer articles (ECHA, 2014), lead in PVC (ECHA, 2018c), lead in gunshot over wetlands (ECHA, 2018c) and substances in tattoo inks and permanent make-up (ECHA, 2019). In these assessments RAC agreed there was no threshold for the neurotoxicological and other key effects of lead and that any exposure constitutes a risk. RAC supported a qualitative approach in some of these assessments (lead in PVC; lead in shot over wetlands; substances in tattoo inks and permanent make-up) in accordance with REACH Annex I 6.5, as DNELs could not be derived owing to the non-threshold nature of these effects. RAC did, however, apply a (semi-)quantitative approach to some of these assessments (lead in jewellery; lead in consumer articles) by the use of a maximum lead exposure level for children of 0.05 µg lead/kg bw/day; this was based on the $BMDL_{01}$ determined by EFSA (2010a), since EFSA considered that a margin of exposure of 10 or greater in relation to this BMDL would be sufficiently low to present no appreciable risk. Some commenters, however, have questioned the validity of this approach, since the question of acceptable risk or negligible effect levels for non-threshold substances is a matter of regulatory policy rather than science (Green and Pain, 2019; Wilson and Richardson, 2013).

In June 2020, RAC adopted an opinion on occupational exposure limits (OEL) for lead and its compounds in which it recommended an 8-hour time-weighted average OEL of 4 µg lead/m^3 (inhalable fraction) and a biological limit value of 150 µg/L blood for lead and its inorganic compounds (ECHA, 2020). RAC noted that neither of these values protected against the risk of developmental toxicity.

As lead is a non-threshold neurotoxic substance, a qualitative risk assessment is appropriate according to REACH Annex I (paragraph 6.5). Risks to humans from the consumption of game shot with lead ammunition cannot be excluded. 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.

1.6 Justification for a GB-wide restriction measure

The Agency has concluded that the use of lead ammunition presents a risk to both the environment (particularly birds) and human health (via secondary exposure through the consumption of lead-shot game) that is not adequately controlled and needs to be addressed.

1.6.1 Environmental hazard, exposure and risk

Lead is a non-essential, toxic element. The range of possible adverse effects of lead exposure have been investigated in experimental laboratory studies and evidence of the effects of lead on wildlife is available from pathology reports and observational studies. As well as causing mortality, lead exposure can result in sub-lethal effects on behaviour, development and reproduction. In addition to the lethal and sub-lethal effects that can be measured, there are also likely to be welfare impacts that are less easy to determine.

The available evidence indicates that shooting occurs over a significant proportion of rural land in GB and therefore there is widespread deposition of lead shot and bullets. The highest density of shot and bullets is found close to fixed shooting positions such as clay pigeon or target ranges.

There is strong evidence from both GB and international studies that there is direct ingestion of lead shot by terrestrial and wetland birds. An assessment of the available evidence results in an estimate of 16,100 to 804,000 terrestrial wild birds in the breeding population being at high risk of lead poisoning in the UK. These figures do not include terrestrial game birds bred and released for the purposes of hunting. Owing to the very large number of game birds bred and released annually the numbers at risk are higher than for wild birds, with a minimum estimate of 47,100 birds at risk in the UK. It is known that despite the existing ban on the use of lead shot over wetlands in GB that compliance with this is low and wetland birds that feed on terrestrial areas are also considered to be at risk.

There is also strong evidence from both GB and international studies that secondary exposure of predatory/scavenging birds is a key exposure pathway for lead ammunition. The available observational data indicate that a proportion of the deaths of scavengers and avian predators in GB is likely to result from lead poisoning arising from the use of lead ammunition. This number of birds at risk of lead poisoning has not been estimated, but the potential exposure pathway is clear and even if only a small proportion of the population ingest lead via secondary poisoning then large numbers of birds may be adversely affected.

Risks have also been identified for other taxonomic groups. There is some evidence that other animals may ingest lead shot whilst grazing. This is considered a relevant exposure pathway for livestock (and likely wild animals) that feed in areas with high lead shot use (e.g. on a shooting range). Concentrations of lead in vegetation grown in areas of high lead ammunition use (e.g. on a shooting range) are also reported to exceed thresholds set for lead in forage and feed, indicating that there may be a risk of secondary poisoning of livestock via this route. Measured concentrations of lead in soil in areas of high lead ammunition use (e.g. on a shooting range) are reported to be above the soil PNEC, indicating risks to soil organisms at these sites.

1.6.2 Human hazard, exposure and risk

Chronic exposure to lead is associated with a wide range of health effects in humans. These effects include toxicity to the blood system, nervous system, kidneys, cardiovascular system and reproductive systems (male and female fertility, adverse effects on development following exposure during pregnancy). The critical effect in the developing foetus and young children is developmental neurotoxicity; even at low levels of lead exposure, cognitive development and intelligence quotient

(IQ) are reduced. Elevation of systolic blood pressure and kidney toxicity are the most sensitive effects in adults. It is generally accepted that none of these effects has a threshold. The most relevant human health impact of the proposed restriction is that on developmental toxicity (neurotoxicity) in the most vulnerable population to the adverse effects of lead, i.e. young children, including those exposed *in utero*.

The primary human health risk addressed in this report is that to consumers of game meat that has been shot with lead ammunition (i.e. wild game). The highest consumers of game meat are hunters and their families. Estimates of high-level consumers of game (at least one portion ≥ 100g of game meat per week) in the UK range between 0.084 – 2.52% of the population (adults and children). Further estimates have indicated that 4,000 – 48,000 children in the UK are at a potential risk of incurring a one point or more reduction in IQ from exposure to ammunition-derived lead.

Meat hygiene measures and stewardship schemes are in place to minimise the amount of metal in meat sold for human consumption in the UK and the removal of obvious ammunition fragments by hunters and their families / friends appears to be reasonably widespread. Nevertheless, meat can still contain small fragments of metal that cannot be easily detected and that might be far from the shot site. The Food Standards Agency advises that the consumption of game meat be minimised, particularly in vulnerable populations such as toddlers, children, pregnant women and women trying to conceive.

As lead is a non-threshold neurotoxic substance, risks to humans from the consumption of game shot with lead ammunition cannot be excluded and exposure to lead should be reduced as far as possible.

1.6.3 Existing risk management

In GB, each of the devolved administrations has already enacted a ban on the use of lead shot over wetlands in response to the African-Eurasian Waterbird Agreement (AEWA, 1999). These bans were introduced between 1999 and 2004 with the aim of protecting waterbirds from the impact of lead poisoning.

The existing regulations in England and Wales are based on species and habitat. The use of lead shot is prohibited:

- on or over any area below the high-water mark;
- on or over certain Sites of Special Scientific Interest;
- for the shooting of ducks, geese or swans of any species, coots or moorhens on or over both wetlands and terrestrial habitats.

In Scotland, the use of lead shot is prohibited on or over all wetland areas (but excluding peatlands with no visible water, which are within scope of the EU restriction).

There is evidence that compliance with the current restrictions on the use of lead shot over wetlands is low. Two studies were undertaken which both estimated a non-compliance rate of approximately 70% (Cromie *et al*. (2010) and (2015)). Stroud (2021) suggested that the low compliance may '*relate to the restriction being only partial, in that they cover only the shooting of certain species (largely ducks and geese) and/or in certain places (listed wetlands and the foreshore)*'. A wider restriction where the sale and use of lead shot was banned would ensure that compliance over wetlands was also increased.

Several UK shooting organisations have signed up for a voluntary phase out of lead shot used for hunting live quarry.

1.6.4 Justification for consistent action across GB

Some legally binding risk management measures are already in place at a devolved administration level to mitigate the risks from the use of lead shot over wetlands. The wetland restrictions across GB vary between the administrations and do not uniformly apply to all wetland habitats or protect wetland birds that feed in terrestrial habitats (such as grazing swans, geese and ducks) from ingestion. There is also evidence that compliance with the current restrictions on the use of lead over wetlands is low.

The main justifications for a GB-wide restriction are therefore:

- to ensure a harmonised high level of protection of the environment and human health to address the identified risks which are common to all the devolved administrations
- to increase compliance with the existing bans on some uses of lead shot to meet our commitments under the African-Eurasian Waterbird Agreement (AEWA, 1999)
- to ensure free movement of goods within GB
- to ensure a level playing field for all engaged in sports shooting within GB.

2 Impact assessment

2.1 Introduction

Exposure to lead from ammunition poses risks to the environment (including wildlife) and human health. These risks are described in Sections 1.4.5 and 1.5. The proposed restriction focuses on two uses of lead ammunition: hunting and sports shooting. Within each of these uses there are two types of lead ammunition that are assessed: gunshot and bullets. This impact assessment therefore looks at a proposed restriction for each of these uses.

The Agency conducted a detailed analysis of a series of restriction options for each sector of use (i.e. hunting and sports shooting). The assessment is underpinned by information on uses, releases, availability of alternatives and socio-economic impacts. Each restriction option is also analysed against the criteria outlined in the Annex 15 to REACH for assessing the appropriateness of a REACH restriction: effectiveness, practicality (including enforceability) and monitorability. The detailed analysis of each restriction option per sector of use is available in Section 2.4.

Whenever relevant, the impact of a proposed transition period is also part of the restriction option analysis.

This impact assessment has been prepared by the Agency to assess the impact of a restriction on lead ammunition. It is based on the analysis produced by ECHA (2021a, 2021c) and it is adapted, where possible, to incorporate GB-specific information. The purpose of the socioeconomic analysis is to look at the socioeconomic impacts of the different options proposed for the restriction.

Where good quality and detailed information on cost elements was available, the Agency has undertaken a quantitative impact assessment of the restriction options proposed. Sensitivity analysis has been undertaken on key uncertainties. Where quantification of all the benefits of a restriction (e.g. valuation of specific environmental impacts) was not possible, a qualitative description of the benefits was done instead. For some restriction options information on potential impacts are presented and summarised, but no quantitative estimates of the cost and/or benefit of a potential restriction are provided because of the lack of information available, specifically on sports shooting. It is expected that the consultation on the restriction report will provide some of the missing evidence and validate some of the assumptions.

2.2 Approach to the impact assessment and assumptions

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 also vary depending on the type of use. Because of different technical functions needed for each use, the readiness, availability, and costs of suitable alternatives also vary among the uses. For the purpose of this impact assessment, the uses are therefore grouped into two overarching sectors: hunting and sports shooting.

A long list of restriction options has been developed for each use. The options are broadly similar but also use-specific. The impacts of each restriction are also variable both in terms of their effectiveness in reducing the risk but also in their costs, benefits and wider socio-economic impacts. The options are described in detail are in Section 2.4.

The following assumptions have been used:

- The geographical scope of the impact assessment is GB.
- Timeline: 2024 was assumed to be the first full year of entry into law, with a transition period of up to 5 years of the proposed restriction depending on the use. A 20-year period was assumed as horizon of the impact assessment and it is selected based on the expected time for the costs and benefits of the restriction to fully develop
- A conclusive quantification of the benefits expected from the restriction is not possible due to a lack of data regarding the environmental impacts. This makes it challenging to quantitatively demonstrate that the benefits of the proposed restriction outweigh its costs. A cost-effectiveness approach is used instead, considering releases of lead as a proxy for risk. Affordability of the costs of the restriction has also been considered. This has been complemented with a quantitative cost-benefit approach where possible. Where that was not possible, the benefits have been described qualitatively instead.
- This analysis is mostly based on the ECHA reports (ECHA (2021a, 2021c). Where ECHA use EU data and evidence, this has been replaced by UK/GB data if available. When UK specific 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%). Then it is adjusted for GB as a proportion (97%) of the UK population[4].

[4] The ability to apply scaling factors to account for differences between the EU and UK will depend on the extent to which the scaling factors are applicable across individuals and/or the populations being considered. Scaling factors are perhaps more likely to be applicable when seeking to account for differences in some socioeconomic factors compared to others. For example, in some cases it may be possible to assume that the benefits and costs of a restriction will vary in the same proportion across the EU/UK population scale. However, making such an assumption may be problematic depending on

- The appraisal period used is 20 years and the discount rate is the Green Book (2020) recommended 3.5 %, except for health impacts where the discount rate used is 1.5 %. The 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. The have all been adjusted to 2021 prices using HMT GDP deflators (2022).

- Prices have been converted from Euros to Pounds Sterling ("GBP") using the official exchange for the relevant price year[5].

2.3 Baseline

Baseline release estimates for all uses

The estimated annual consumption of lead shot in cartridges in hunting is 6,357 tonnes of lead per year that is dispersed across GB as described in Section 1.4.3. This is split into 5,709 tonnes per year in hunting game birds and 648 tonnes per year hunting smaller prey such as squirrels and pigeons. The estimate of the number of bullets used in GB is subject to several uncertainties, as described in Section 1.4.3. The quantity of bullets for deer stalking is estimated to be 481,600 per year, which is estimated to be equivalent to a total of 3.4 tonnes of lead per year. In addition the total number of rounds of .22 rimfire bullets purchased for all quarry/pest/target shooting each year was estimated as 4.5 million by LAG (2015a), which is equivalent to 10.8 tonnes of lead, based on an average of 2.4 g of lead per bullet (ECHA, 2021c). Section 2.4 provides further details.

Table 2.1 Baseline below provides an overview of the baseline across all the uses that have been assessed and the estimated releases over the 20 years of the appraisal period for GB. It is assumed that for all uses – except hunting with shot where voluntary commitments have been made – releases will be constant over the period.

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the nature of local differences in (for example) tastes/preferences, working/leisure practices, sociodemographic characteristics, etc. Further consideration of the need for and appropriateness of the scaling factors applied in the analysis will be considered during the consultation phase of the restriction.

[5] Exchange Rates UK - Compare Live Foreign Currency Exchange Rates www.exchangerates.org.uk

Table 2.1 Baseline

Use	Annual release (tonnes per year)	Release over 20 years (tonnes)
Lead in hunting (gunshot)	6,357	114,420
Lead in hunting (bullets – small and large calibre)	~ 14.5 tonnes (uncertain data)	290
Lead in sports shooting (gunshot)	1,680	33,600
Lead in sports shooting (bullets)	28.8– 72 tonnes	576 – 1,440
Total	**8,081 – 8,123.5**	**148,886-149,750**

For **gunshot** the baseline is a release of 6,357 tonnes per year and 114,420 tonnes in 20 years. Because of existing voluntary commitments, we assume this would result in a 10 % reduction in releases by 2025 (see below).

For **small and large calibre bullets** the baseline is a release of 14 tonnes per year, which results in an average release of about 290 tonnes in 20 years.

For **sports shooting with gunshot** the baseline is a release of 1,680 tonnes per year or 33,600 over 20 years.

For sports shooting with **small and large calibre bullets** the baseline is a range of releases between 29 – 72 tonnes per year, which results in an average release of about 1,000 tonnes in 20 years.

It is clear from Table *2.1* that the vast majority (around 75 %) of lead releases arise from hunting with gunshot. There is, however, a lot of uncertainty around the releases from sports shooting especially.

As discussed above separate assessments are carried out for the different uses and sectors that will be affected. As noted above, some UK stakeholder groups have already made voluntary commitments to phase out the use of lead gunshot in hunting by 2025. The baseline for this impact assessment is therefore that some reduction in the use of lead ammunition for hunting with shot will take place because of these voluntary commitments. Some recent research shows that the voluntary measures have had no significant impact so far. Green *et al*. (2022b) found that 99.5 % of the 215 pheasants from which shotgun pellets were recovered in 2021 had been killed using lead ammunition. These results are in contrast with those of recent surveys of attitudes and intentions of various groups of hunters, which indicate that a large proportion had already implemented, or intended to implement, the transition. The ECHA analysis assumes a reduction of 15% which seems very high given the current uptake in GB. Therefore, an assumption of 10% reduction by 2025 is made here.

For the other uses we assume that the baseline is a “Do nothing” option where no restriction on the use of lead in ammunition is imposed in GB. However, since the EU is likely to impose a restriction within the next year or so, we can assume that this will have an impact on the GB market as well in terms of encouraging and accelerating the phase out of lead because of the reduction in the availability of lead in the larger European market and the wider development and use of alternatives.

Impact on birds

The number of individual terrestrial birds at risk of poisoning across the UK from lead ammunition can be found in Section 1.4.5. The assessment considered different relevant exposure sources and a list of bird species identified as most at risk due to their feeding ecology. These values may underestimate the actual number of impacted birds as they do not include the immature population, all immigrant wintering populations, game birds bred for hunting, wetland birds that may be exposed whilst feeding outside of wetlands or other ground foraging species that may also be exposed. Further details can be found in Section 1.4.5.

Table 2.2 Estimate of individual terrestrial birds at most risk of lead related ammunition poisoning via primary or secondary routes

Type of risk	Estimate of individuals in UK at potential risk	Proportion assumed to be exposed	Estimate of individual birds exposed
Primary poisoning	16,000,000	0.1 - 5.0 %	16,100 – 804,000
Secondary poisoning	9,250,000	Not defined	Not defined

The BOCC and IUCN listing for each of the terrestrial bird species considered at highest risk of primary and secondary lead poisoning are shown in Table *2.3* and Table *2.4*. Further details of this assessment can be found in Section 1.4.5.

Table 2.3 Number of species in each BOCC category at most risk of lead exposure in the UK

BOCC categories*	Number of species at risk from primary and secondary poisoning
Red	9
Amber	9
Green	14
Not included	4

*Species are assigned to either a red, amber or green list, based on an objective set of criteria. Green indicates that there is no significant concern for conservation, and amber and red indicate increasing levels of concern due to declines in number or range based on the available monitoring data.

Table 2.4 Number of species in each IUCN category at most risk of lead exposure in the UK

IUCN categories	Number of species at risk from primary and secondary poisoning
Critically endangered	2
Endangered	6
Vulnerable	6
Near threatened	6
Least concern	12
Not included	4

2.4 Options description

There are uncontrolled risks to the environment arising from the use of lead ammunition, and to human health from exposure to lead in game meat (see Sections 1.4 and 1.5). The Agency has therefore produced a list of potential options that may be appropriate to reduce these risks. The options identified include the same options as ECHA (2021c) but also include some additional options that are not feasible at a continental scale. The options considered are not mutually exclusive, and a combination of different options may be considered to provide the most appropriate risk management. An analysis of each of these options was undertaken for each use, underpinned by information on uses, releases and availability of alternatives. The options considered effective were then taken forward for assessment of the socio-economic impacts.

The options were assessed qualitatively against the criteria outlined in Annex 15 of REACH for assessing the appropriateness of a REACH restriction: effectiveness (i.e. targeting, risk reduction and proportionality to the risk), practicality (e.g. implementability, manageability) monitorability and enforceability.

- Effectiveness: The restriction must be targeted to the effects or exposures that cause the risks identified, capable of reducing these risks to an acceptable level within a reasonable period of time and proportional to the risk (also with regards to the costs). For an option to be considered effective it must significantly reduce the risks to human health and/or the environment. If there is a lower reduction, or a reduction in only environmental or human health risk it will be concluded to be only partially effective and if there is little to no reduction then it will be concluded to be not effective. As lead is considered to be a non-threshold chemical, for the purposes of this assessment a reduction in exposure is considered to be equivalent to a reduction in risk. Effectiveness should also include an assessment of the proportionality, which is considered later in the impact assessment as part of the socio-economic analysis.

- Practicality: the restriction must be implementable, where the technologies and alternatives must be available and economically feasible, enforceable, the authorities must be able to check compliance and manageable, whereby the options should be understandable, and the means of implementation should be clear. It also includes considerations on the transition time required to implement the proposed restriction option. For an option to be considered practicable there must be feasible risk management measures, either management systems or installation of abatement measures which would significantly reduce the risks. If the installation of abatement or management measures would have a lower reduction, or a reduction in only environmental or human health exposure it will be concluded to be only partially practicable. If there is little to no reduction, then it will be concluded to not be practicable.

- Monitorability: the authority must identify methods to monitor the result of the implementation of the proposed restriction. For an option to be considered monitorable it must be possible to set up a clear mechanism to monitor the effectiveness of the option. If the option only allows a lower amount of monitoring it will be concluded to be only partially monitorable and if there is little to no monitoring possible then it will be concluded to be not monitorable.

- Enforceability: for each option to be considered enforceable the enforcing authorities must be able to ensure compliance by a clear and efficient supervision mechanism and have the required resources to do so. If the option does not have a clear mechanism, or there are potential loopholes, it would be concluded to be only partially enforceable. If there is no possible mechanism for ensuring compliance the option is concluded to be not enforceable.

Following the completion of the analysis of all the identified risk management options, the options that the Agency concluded would be effective and either fully or partially practicable, monitorable and enforceable were taken forward for further assessment in the impact assessment. This includes a consideration of the costs and benefits of the options.

The analyses for each of the use scenarios detailed in Table 1.4. have been completed below

2.4.1 Lead in hunting

2.4.1.1 Shot (Use #1)

In this Section the Agency reviews the options to mitigate the risks posed by lead shot cartridges when shooting live quarry (for hunting and pest control).

2.4.1.1.1 RO1: Voluntary measures

Effectiveness

In February 2020 a number of UK shooting and rural organisations produced a joint statement (BASC, 2020) which commits to using alternatives to lead ammunition for the hunting of live quarry by 2025. This is a potentially effective option to reduce risks. However, voluntary agreements only work when all organisations and individuals who carry out the activity agree and are committed to change their behaviour. There is no single umbrella organisation to impose such measures. Those who disagree with voluntary measures may ignore them or set up their own membership organisations. For example, the Scottish Gamekeepers Association voiced their opposition when the announcement was made (Shooting UK, 2021). In addition, some individuals who participate in shooting activities will not be members of a club or organised group and therefore would not be covered by this voluntary agreement. The sale of lead shot cartridges for other purposes (such as clay pigeon shooting) is not affected by the voluntary action, and its availability might be a temptation for people to carry on using it for hunting.

Voluntary measures are therefore unlikely to be fully effective by themselves. A REACH restriction could ensure compliance with a voluntary phase out, potentially with a different timescale depending on the proposed transition period. The existing voluntary commitment is expected to reduce the use of lead shot to a limited extent (assumed to be around 10 % as discussed in Section 2.3).

Practicality

The Agency assumes that a voluntary phase out is practical, since the shooting organisations would not otherwise have announced their commitment to it. The use of lead shot is already banned over wetlands in GB, so non-lead alternatives are already available on the market and in use. In addition, Denmark banned the use of lead shot for hunting in 1992 (Kanstrup (2018)), showing that hunting with alternatives is feasible and not significantly detrimental to the sport.

Monitorability

The success of this option is potentially monitorable as the carcasses of shot game can be sampled to ensure they do not contain any lead shot or fragments. However, if hunters choose not retrieve to carcasses in some circumstances (for example, shot pests may not be collected), sampling would not be possible.

Enforceability

Voluntary agreements are not underpinned by regulation and so cannot be enforced by regulatory bodies. It is possible that shooting organisations could perform spot checks during events or set up their own administrative compliance mechanisms, but these would need to be developed.

2.4.1.1.2 RO2: Fiscal measures

The introduction of a tax on the sale of all lead shot could be used to influence the choices made by individual hunters by increasing their costs and thereby making alternatives more attractive. This tax would be a form of the “polluter pays” principle. A tax on organised shooting events that still wanted to use lead shot could also encourage the organisers to switch to alternatives. Any revenue raised could potentially be used to support a consumer awareness programme.

There are several concerns regarding this option. For example, a loophole could develop whereby people would import cartridges illegally from cheaper countries to avoid paying tax. Wealthy groups or individuals might not see a tax as a barrier and so it could have little effect in changing behaviour. A tax could also lead to stockpiling in advance of its introduction.

There is therefore significant uncertainty about how much impact this option would have on reducing the actual use of lead shot cartridges. For this reason, effectiveness, practicality, monitorability and enforceability have not been considered.

2.4.1.1.3 RO3: Require specific design / construction of lead shot

Effectiveness

Lead shot coated with either copper or nickel is available, although the Agency does not have any information on the UK market share of such ammunition. Coating increases the hardness of the pellet and reduces deformity in the barrel to create a higher density of pellets and a cleaner kill, and appears to be marketed mainly for specialist types of hunting (such as hitting high flying birds) and clay pigeon shooting (Shooting UK, 2018). A requirement for all lead shot used in hunting to be coated could reduce the initial environmental exposure since in theory a lower proportion of lead-containing pellets would miss the target if accuracy is improved. However, since only a small proportion of the pellets in a cartridge hit the target, the majority of pellets would still be emitted to the environment. It would also not prevent lead intoxication in birds following direct ingestion of pellets, as the coating is likely to be destroyed in the highly acidic environment of the gizzard. It would also not prevent lead fragments from occurring in the quarry, thereby leading to secondary poisoning and contamination of game meat. As with other options, there would also have to be no possibility of buying non-coated lead shot used for other purposes (e.g. clay pigeon shooting).

This option is therefore not considered to be sufficiently effective.

Practicality

This option is practical as coated lead shot is available, although the Agency does not have any information on the UK market share of such ammunition.

Monitorability

In practice this option would be difficult to monitor, as although sales data might be available from industry sources or retail outlets and sampling of shot cartridges available for sale could be undertaken to confirm that only coated ones were being sold, it would not confirm that only coated shot was being used for hunting., Monitoring of game carcasses could provide evidence that coated shot was being used. Monitoring of ingestion using birds that are found dead would not be possible, because any shot in the gizzard is likely to have lost its coating, and so would be indistinguishable from non-coated shot.

Enforceability

This option would only be enforceable by regulatory bodies if all types of shot had to be coated. It is possible that shooting organisations could perform spot checks during events or set up their own administrative compliance mechanisms, but these would need to be developed.

2.4.1.1.4 RO4: Ban on the placing on the market of game meat containing lead shot

Effectiveness

This option would effectively prevent exposure for the general consumer. However, since it would only apply at the point of sale it would not protect individual hunters and their families and friends from exposure, as they generally consume their own kills (and consume more game meat than average consumers). In addition, this option would not prevent lead shot from being used for other hunting or pest control activities where the quarry is not intended for human consumption, and so environmental exposure would continue from these uses. This could reduce the quantity of lead shot used on estates supplying the meat trade, but it is difficult to quantify this reduction. There would be no additional reduction in the quantity of lead used for other purposes.

This option is therefore not considered sufficiently effective to eliminate all risks.

Practicality

There are existing food regulations in place (Commission Regulation (EC) No. 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs, as retained in GB law) which prohibit the sale of specific food commodities containing lead above maximum specified levels, and in theory these could be amended to include game meat.

At the time of writing (December 2021) a number of suppliers have announced controls on the levels of lead in game meat. For example, one major supermarket chain started to phase out the use of lead shot at the shooting estates from which it sources game meat in 2019, and expects all game meat it sells to be lead-free by the 2021/2022 season (Don, 2019). The Game Traders Association also announced that its members would only source game from lead-free supply chains from 1 July 2022[6].

This option is therefore considered to be practical, although it would have to involve amendments to food safety legislation, rather than a REACH restriction, and different bodies are involved in different parts of GB. Co-ordination would therefore be

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[6] https://www.nationalgamedealersassociation.co.uk/news/54-great-response-from-the-public-at-country-file-live-2019 [accessed 28th January 2022]

required to ensure consistency.

Any additional testing requirements to ensure compliance could also increase costs (either to the buyers of the meat or to the surveillance authorities).

Monitorability

Game meat bought from a commercial operator could be subject to the same market surveillance as other meat products. However, due to the size of game birds, fragmentation of the shot within the carcass and the variability in measured concentration as a result of the sample location this option has been discounted by the Food Standards Agency (personal communication). In addition, monitoring would not be possible for meat consumed by hunters and their families and friends.

Enforceability

In principle this option is enforceable by the Food Standards Agency and related agencies in the devolved administrations. However, the inclusion of a concentration limit in game meat has been discounted by the Food Standards Agency. Contracts between the hunters and suppliers can also require the use of "lead-free" ammunition to ensure compliance. This option only covers those carcasses sold commercially and therefore would not protect the health of hunters who eat their own kills.

2.4.1.1.5 RO5: Introduce a maximum level of lead in game meat

Effectiveness

The Food Standards Agency already provides advice to consumers to minimise their consumption of game shot with lead (FSA, 2017). This advice does not set a limit in game meat. A statutory limit could therefore be introduced using food safety legislation, and in theory could be effective in reducing exposure to general consumers. This option is not necessarily the same as a ban, because the level could be set such that some types of game meat could still be legally sold even if lead shot is involved (e.g. by removing affected pieces). A limit is also very difficult to set as the lead is present in fragments and therefore the result of any analysis is based on the sample location.

However, a Wild Justice report (2021) found that despite the physical removal of lead shot pellets from game meat sold by one specific supermarket, 24 samples out of 30 (80 %) still contained lead above the maximum level of 0.1 mg/kg ww which applies to non-game meats. Removal of visible lead pellets is therefore not sufficient to eliminate the risk to consumers of that meat (see Section 1.5.2).

A concentration limit would only apply to meat bought from a commercial operator, so would not protect individual hunters and their families and friends from exposure arising from consuming their own kills. In addition, this option would not prevent lead shot from being used for other hunting or pest control activities where the quarry is not intended for human consumption, and so environmental exposure would continue from these uses. There would be no additional reduction in the quantity of lead used for other purposes.

A concentration limit is therefore not considered sufficiently effective to eliminate all risks.

Practicality

The same comments apply as for option RO4.

Monitorability

The same comments apply as for option RO4.

Enforceability

The same comments apply as for option RO4.

2.4.1.1.6 RO6: Advice to cut away meat when handling game killed with lead shot

Effectiveness

The Food Standards Agency already provides online guidance about the removal of lead-contaminated portions of game meat in GB (FSA, 2015). Assuming that the public is fully aware of the guidance (which may not always be the case), this option could theoretically be effective for hunters and their families and friends when consuming their own kills. It could also be a parallel option for use alongside a maximum concentration limit for commercial food businesses (see option RO5). However, the shooting of smaller game species with lead shot results in lead particles throughout the carcass (see Section 1.5.2) which are much more difficult to remove entirely. In addition, as noted in option RO5, existing practices to remove visible shot pellets are not sufficient to eliminate the risk to consumers of that meat. This option would also not prevent lead shot from being used for other hunting or pest control activities where the quarry is not intended for human consumption, and so environmental exposure would continue from these uses. There would be no additional reduction in the quantity of lead used for other purposes.

Therefore, this option is not considered sufficiently effective to eliminate all risks.

Practicality

This option would require clear guidance on steps to take to remove lead shot from meat, and a publicity campaign to ensure the message gets to the people affected. For example, leaflets could be provided at the point of sale of game meat to butchers and other suppliers. However, removal of all lead shot fragments from small game species is impractical, and removal of visible shot may still not sufficiently reduce exposure to lead. This option is therefore considered to be insufficiently practical.

Monitorability

The same comments apply as for option RO4.

Enforceability

A requirement to remove portions of meat is not enforceable, unless accompanied by a concentration limit (and even then, the same comments apply as for option RO4).

2.4.1.1.7 RO7: Training programmes for hunters and pest control operators

Effectiveness

Information on the hazards of lead and the risks of using lead ammunition could be incorporated into training programmes for hunters. To be effective, the initial education would need to be reinforced regularly by communications from the shooting organisations, shooting press, and peer pressure. While there is no requirement in GB for compulsory training or testing prior to members of the public taking up shooting, a code of good practice provides an overview of responsible shooting, and recommends that new shooters either undertake training or are mentored by more experienced hunters[7]. Requiring training for new members of shooting clubs or events could be possible, but this would not reach existing members or those hunters who are not members of clubs or do not attend events.

Reliance on awareness training might not be effective based on evidence of limited compliance with the existing restriction of lead shot over wetlands. Although the hunting of wildfowl with lead shot has been illegal for a long time, the proportion of ducks killed with lead shot increased from 68 to 77% over surveys carried out from 2001 to 2013 (see Section 1.4.4).

This option is not considered sufficiently effective to eliminate all risks, but it could be a supplemental approach to more rigorous measures.

Practicality

This option is practical in principle, but would require investment of significant

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[7] https://basc.org.uk/training-and-education/basc-training-courses/ accessed 14/12/2021.

administrative resources from the shooting industry, with uncertain returns on that resource.

Monitorability

In principle this option is monitorable, in terms of the number of people who complete the training (for example, a certificate could be issued only if all modules have been successfully completed). Surveys to check the understanding and behaviour of hunters could also be carried out periodically by shooting organisations.

Enforceability

This option is potentially enforceable following the introduction of a mandatory scheme.

2.4.1.1.8 RO8: Mandatory labelling of cartridge boxes and cartridges

Effectiveness

This option would require the manufacturers to include information on the packaging regarding the hazards and risks of lead. A further iteration could involve indelible marking of the shot cartridges themselves. This would inform users about the negative consequences of using lead shot for hunting (like the warning labels on cigarette packets).

Since users could choose to ignore the warnings, this option is not expected to have a large impact on the amount of lead released into the environment, but it would be effective at raising awareness of the toxicity and risks. It could also encourage the shooters to try the alternative ammunition or communicate the timelines for transition to alternatives, if that risk management option is proposed.

Practicality

This option is likely to be feasible, although there would be an associated cost to industry. It would require a transition time to allow implementation by the manufacturers. The practicality of including the required information on small packaging would also need to be considered.

Monitorability

This option is monitorable as the labelling of both packaging and cartridges is easy to check.

Enforceability

This option is enforceable as it applies to new products placed on the market.

However, it might be difficult to distinguish non-labelled products from those that were legally on the market before the requirement was introduced.

2.4.1.1.9 RO9: Buy-back scheme for lead shot cartridges

Some gun owners may buy large quantities of lead ammunition at a time, which could remain unused for several years. In addition, hunters may import lead shot from abroad (e.g. as unused cartridges following a shooting holiday). To encourage a faster transition to lead alternatives, one option would be for either lead manufacturers or government to offer a buy-back scheme. This could also be implemented to support either a full or partial restriction, for example during or at the end of a transition period.

This option has not been fully explored or costed so no assessment of effectiveness, practicability, monitorability or enforceability has been made. This will be reviewed following analysis of information gathered during the consultation stage. This option could be used in conjunction with other options to enhance the overall reduction of lead releases.

2.4.1.1.10 RO10: Ban on placing on the market and use of lead shot for hunting

Effectiveness

A full ban on the placing on the market and use of lead shot cartridges for hunting would result in a 100 % reduction in release of lead shot (6,357 tonnes per year) and would therefore be effective in reducing the risks to the environment. Human exposure via game meat consumption would also be prevented. It could also come into force before 2025, which is the current target date for a voluntary phase out announced by shooting organisations. A UK REACH restriction would also come into effect across GB without the need for further action by the devolved administrations.

To make it completely effective, there would have to be no possibility of buying lead shot for other purposes (e.g. clay pigeon shooting). Additional steps may also be necessary to minimise the risk of individual hunters building up large stocks of ammunition before a sales ban comes into effect.

Practicality

Alternative ammunition is readily available. As discussed for option RO1, the main UK organisations representing shooting interests have acknowledged that a switch is feasible. The Danish experience also shows that hunting with alternatives is not detrimental to the sport. 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). As the use of lead shot over wetlands is already banned throughout GB this demonstrates that alternatives already exist and are in use now.

Monitorability

A ban on sale of shot cartridges is monitorable as the suppliers of ammunition (retail outlets) can be monitored directly and game carcasses can be sampled to ensure they do not contain lead shot or fragments.

Enforceability

This option is enforceable by regulatory authorities (for example the Environment Agency in England) as it involves control at the point of sale. Compliance visits could be carried out at relevant premises, and compliance reports could also be submitted by the shooting industry and ammunition suppliers.

2.4.1.1.11 Summary of risk management options for hunting with lead shot

Table 2.5 Restriction options for hunting with lead shot

Risk Management Option		**Effective?**	**Practical?**	**Monitorable?**	**Enforceable?**
1	Voluntary measures	Partially	Yes	Partially	No
2	Fiscal measures	Not considered	Not considered	Not considered	Not considered
3	Require specific design / construction of lead shot	No	Yes	No	Only if all shot is coated
4	Ban on the placing on the market of game meat containing lead shot	Partially	Yes	No	Yes

Risk Management Option		Effective?	Practical?	Monitorable?	Enforceable?
5	Introduce a maximum level of lead in game meat	Partially	Yes	No	Yes
6	Advice to cut away meat when handling game killed with lead shot	No	No	No	No
7	Training programmes for hunters and pest control operators	No	Yes	Yes	Yes
8	Mandatory labelling of cartridge boxes and cartridges	No	Yes	Yes	Partially
9	Buy-back scheme for lead bullets[8]	Not considered	Not considered	Not considered	Not considered
10	Ban on placing on the market and use for lead shot for hunting	Yes	Yes	Yes	Yes

The only option to reduce risks to both wildlife and human health that would be fully effective, practical, monitorable and enforceable is a ban on the placing on the market and use of lead shot for shooting live quarry (RO10). The same conclusion was drawn by LAG (2015a), (Green and Pain, 2019) and (ECHA, 2021a). The avoided lead release from this option would be a maximum of 85,815 tonnes over 20 years. This is based on releases of 5,721 tonnes per year for the 5 years of the transition period (28,605 tonnes) and then 0 tonnes per year for the following 15

[8] This assessment will be done when we have gathered data from the consultation stage

years, compared to the baseline estimate of 114,420 tonnes released over 20 years.

The costs and benefits of the preferred option are assessed in Sections 2.5 and 0.

To avoid the possibility of people buying lead shot for other purposes but continuing to use it for hunting, the restriction would also need to include non-hunting uses of lead shot.

Some other options (such as introducing a maximum level of lead in game meat, mandatory product labelling, training for hunters and potentially a buy-back scheme) could provide useful supplementary options to support the restriction. A restriction would be a legally enforceable version of the shooting industry's own commitment to phase out lead shot for this purpose.

As the lead-free alternatives are already available, a transition period of 18 months is proposed for this option. This will give the manufacturers time to scale up the production of the alternative shot.

2.4.1.2 Bullets (Use #2a and #2b)

In this section the Agency reviews the options to mitigate the risks posed by lead-containing bullets when shooting live quarry (for hunting and pest control).

2.4.1.2.1 RO1: Voluntary measures

Effectiveness

The voluntary phase out announced by the shooting industry in 2020 only covers the use of lead shot in live quarry hunting and therefore would not be effective in the mitigation of risks from lead bullets. The Agency does not know whether shooting organisations would be prepared to extend their voluntary measures to include bullets.

According to ECHA (2017b), Forest Enterprise England required their staff to use non-lead ammunition for deer and boar culling in 2016, based on concerns for the health of consumers of game meat, and to protect this organisation's marketing position. Other organisations could in theory follow a similar path, but this would be piecemeal.

Overall, this option is not considered effective for similar reasons as for lead shot.

Practicality

According to ECHA (2017b), Forest Enterprise England considered that proven alternatives are available for deer and boar culling, so a voluntary phase out would be practical in theory for these purposes. However, the availability of suitable alternatives varies depending on the size of bullet.

Monitorability

The success of this option is potentially partially monitorable as the carcasses of shot game can be sampled to ensure they do not contain any lead bullets or fragments. However, if hunters choose not to retrieve carcasses in some circumstances, sampling would not be possible.

Enforceability

Voluntary agreements are not underpinned by regulation and so cannot be enforced by regulatory bodies. It is possible that shooting organisations could perform spot checks during events or set up their own administrative compliance mechanisms, but these would need to be developed. In additional those hunters who did not take part in organised events would not be covered by this measure.

2.4.1.2.2 RO2: Fiscal measures

Similar to lead shot (see Section 2.4.1.1.2 RO2: Fiscal measures), a tax on the sale of lead bullets could be used to influence the choices made by individual hunters by increasing their costs and thereby making alternatives more attractive. Since bullets may be sold for other purposes (such as sports shooting), an increase in price may also encourage a switch to non-lead alternatives for other uses. Taxation of organised shooting events involving the use of lead bullets might be an alternative, but this option would face similar issues as for lead shot and so effectiveness, practicality, monitorability and enforceability have not been considered.

2.4.1.2.3 RO3: Require specific design / construction of lead bullets

Effectiveness

Jacketed bullets are available that have a lead core coated with a metal jacket, often copper alloy or copper plated soft steel. Lead core bullets fragment in the carcass and studies show that designs made to limit the deposition of lead do not sufficiently reduce the risk, studies have shown that bonded lead core bullets can lose 10 – 24 % of their mass in fragmentation (ECHA, 2021c). This option is therefore not effective.

Practicality

This option is practical as lead core bullets are available.

Monitorability

In practice this option would be difficult to monitor, as although sales data might be available from industry sources or retail outlets, it would not confirm that only lead core bullets were being used for hunting as lead bullets would still be available for use in indoor ranges. As lead core bullets still result in lead fragments being present in the carcass, monitoring of game carcasses would not unequivocally show whether the animal was shot with a bonded bullet.

Enforceability

This option would only be enforceable by regulatory bodies if all types of lead bullet available to the consumer had to be bonded. It is possible that shooting organisations could perform spot checks during events or set up their own administrative compliance mechanisms, but these would need to be developed. In additional those hunters who did not take part in organised events would not be covered by this measure.

2.4.1.2.4 RO4: Ban on the placing on the market of meat collected with lead bullets

This option is identical to that presented for lead shot (see Section 2.4.1.1.4). In summary, a ban is not considered sufficiently effective to eliminate all risks as it would only apply to meat that is sold to consumers and would not reduce the risk to those eating meat they have shot or to the environment. It could be practical, has limited monitorability but would be enforceable.

2.4.1.2.5 RO5: Introduce a maximum level of lead in game meat

This option is identical to that presented for lead shot (see Section 2.4.1.1.5). In summary, a concentration limit is not considered sufficiently effective to eliminate all risks, could be practical, has limited monitorability but would be enforceable.

2.4.1.2.6 RO6: Advice to cut away meat when handling game killed with lead bullets

For the same reasons as for lead shot (see Section 2.4.1.1.6), this option is not considered sufficiently effective to eliminate all risks. Although removal of lead bullets is practical in large game animals (see section 1.5.2), hunters prize the meat of the animals they shoot and therefore discarding additional meat containing lead fragments is unlikely to happen (ECHA, 2021c). For the same reasons as for lead shot, this option has limited monitorability and a requirement to remove portions of meat is not enforceable, unless accompanied by a concentration limit, so would effectively be a voluntary measure.

2.4.1.2.7 RO7: Training programmes for hunters and pest control operators

This option is identical to that presented for lead shot (see Section 2.4.1.1.7). In summary, it is not considered sufficiently effective to eliminate all risks. It could be practical, monitorable and enforceable.

2.4.1.2.8 RO8: Mandatory labelling of packaging

This option is identical to that presented for lead shot (see Section 2.4.1.1.8). In summary, it is not considered sufficiently effective to eliminate all risks. It could be practical, monitorable and enforceable (although it might be difficult to distinguish non-labelled products from those that were legally on the market before the requirement was introduced).

2.4.1.2.9 RO9: Buy back scheme for lead bullets

Some gun owners may buy large quantities of lead ammunition at a time, which could remain unused for several years. In addition, hunters may import lead ammunition from abroad (e.g. as unused bullets following a shooting holiday). To encourage a faster transition to lead alternatives, one option would be for either lead manufacturers or government to offer a buy-back scheme. This could also be implemented to support either a full or partial restriction, for example during or at the end of a transition period. The offer price would have to be lower than the market cost of lead bullets for sports shooting, to avoid unscrupulous individuals from taking advantage.

This option has not been fully explored or costed so no assessment of effectiveness, practicability, monitorability or enforceability has been done. This will be done following analysis of information gathered during the consultation stage. This option could be used in conjunction with other options to enhance the overall reduction of lead releases.

2.4.1.2.10 RO10a: Ban of small calibre lead bullets for hunting

Effectiveness

A ban on the use of small calibre lead bullets (<5.6 mm centrefire and rimfire in general) would be effective in removing both the environmental and human health risks. A full ban on the use of lead bullets for hunting would result in a 100 % reduction in release of lead bullets (14.5 tonnes per year). However, we have no information on the split between large and small calibre bullets so cannot conclude on the reduction in the release of lead from a ban on small calibre bullets. A UK REACH restriction would also come into effect across GB without the need for further action by the devolved administrations.

To make it completely effective, there would have to be no possibility of using lead bullets sold for other purposes (e.g. sports shooting). Additional steps may also be necessary to minimise the risk of individual hunters building up large stocks of ammunition before a ban comes into effect.

Practicality

There are fewer alternatives for small calibres than for the larger calibres. Although there are now some alternatives available (such as copper plated zinc bullets) there is still a lack of field testing data available on them (see Annex C). Some non-lead air rifle pellets are commercially available, but no information has been found on their adequacy for hunting. This option may therefore have limited practicality for the time being. **Further information on alternatives for small calibre bullets (including air rifles) will be requested during the consultation stage.**

Monitorability

It may be possible to monitor this option as game carcasses can be sampled to ensure they do not contain lead bullets or fragments.

Enforceability

The enforceability of this option by regulatory authorities (for example the Environment Agency in England) as a standalone approach would be difficult because lead bullets would still be available for use at indoor ranges (for which the environmental and human health risks arising from lead exposure from lead ammunition are negligible if the appropriate risk management measures are applied). Compliance visits could be carried out at the sites of organised shoots, and compliance reports could be submitted by the shooting industry and ammunition suppliers.

2.4.1.2.11 RO10b: Ban of large calibre lead bullets for hunting

Effectiveness

A ban on the use of large calibre (≥5.6 mm centrefire) lead bullets would be effective in removing both the environmental and human health risks. A full ban on the use of lead bullets for hunting would result in a 100 % reduction in release of lead bullets

(14.5 tonnes per year). However, we have no information on the split between large and small calibre bullets so cannot conclude on the reduction in the release of lead from a ban on large calibre bullets. A UK REACH restriction would also come into effect across GB without the need for further action by the devolved administrations.

To make it completely effective, there would have to be no possibility of using lead bullets sold for other purposes (e.g. sports shooting). Additional steps may also be necessary to minimise the risk of individual hunters building up large stocks of ammunition before a ban comes into effect.

Practicality

As discussed in Annex C, there are a range of lead-free alternatives to large calibre bullets and field trials have shown that they can be as accurate as lead-based bullets. Therefore, the Agency considers that this option is practical.

Monitorability

It may be possible to monitor this option as game carcasses can be sampled to ensure they do not contain lead bullets or fragments.

Enforceability

The enforceability of this option by regulatory authorities (for example the Environment Agency in England) as a standalone approach would be difficult because lead bullets would still be available for use at indoor ranges (for which the environmental and human health risks arising from lead exposure are negligible if the appropriate risk management measures are applied). Compliance visits could be carried out at organised hunts, and compliance reports could be submitted by the shooting industry and ammunition suppliers.

2.4.1.2.12 Summary of risk management options for lead in shot cartridges

Table 2.6 Restriction options for hunting with lead bullets

Risk Management Option		Effective?	Practical?	Monitorable?	Enforceable?
1	Voluntary measures	Partially	Partially	Partially	No
2	Fiscal measures	Not considered	Not considered	Not considered	Not considered

Risk Management Option		Effective?	Practical?	Monitorable?	Enforceable?
3	Require specific design / construction of lead bullets	No	Yes	No	No
4	Ban on the placing on the market of game meat collected with lead bullets	Partially	Yes	No	Yes
5	Introduce a maximum level of lead in game meat	Partially	Yes	No	Yes
6	Advice to cut away meat when handling game killed with lead bullets	No	No	No	No
7	Training programmes for hunters and pest control operators	No	Yes	Yes	Yes
8	Mandatory labelling of cartridge boxes and cartridges	No	Yes	Yes	Partially
9	Buy-back scheme for lead bullets[9]	Not considered	Not considered	Not considered	Not considered

[9] This assessment will be done when we have gathered data from the consultation stage.

Risk Management Option		Effective?	Practical?	Monitorable?	Enforceable?
10a	Ban of small calibre lead bullets for hunting	Yes	No	Partially	Partially
10b	Ban of large calibre lead bullets for hunting	Yes	Yes	Partially	Partially

The only option the Agency identified that is likely to be effective in reducing risks to both wildlife and human health is a ban on the use of lead bullets for shooting live quarry. However, this is currently impractical for small calibres as the alternatives are in an earlier stage of development and testing than for larger calibre bullets. Restricting the small calibre bullets with a longer transition period would give sufficient time to test the alternatives, while ensuring that pressure is created to phase out lead. The same conclusion was drawn by LAG (2015a) and (ECHA, 2021a). A transition period of 18 months is appropriate for the large calibre bullets and 5 years for the small calibre bullets, to allow additional time for the development and testing of them. The avoided lead release from this option would be a maximum of 217.5 tonnes over 20 years. This is based on releases of 14.5 tonnes per year for the 5 years of the transition period (72.5 tonnes) and then 0 tonnes per year for the following 15 years, compared to the baseline estimate of 290 tonnes released over 20 years.

The costs and benefits of the preferred option are assessed in Sections 2.5 and 0.

A use ban is monitorable in principle, but since lead bullets would still be available for sports uses, enforceability could be compromised without implementation of additional options (such as introducing a maximum level of lead in game meat, mandatory product labelling, training for hunters and potentially a buy-back scheme).

2.4.2 Lead in sports shooting

2.4.2.1 Shot (Use #3)

In this Section the Agency reviews the options to mitigate the risks posed by lead shot cartridges used for sports shooting.

2.4.2.1.1RO1: Voluntary measures

The voluntary phase out announced by the shooting industry (BASC, 2020) only covers the use of lead shot in live quarry hunting and therefore would not be effective in the mitigation of risks from sports shooting. Although a similar voluntary phase out could be feasible for at least some types of sports shooting, such as clay pigeon shooting, comments received during the call for evidence suggest there is currently little appetite for such an approach within GB. Effectiveness is therefore likely to be low, and practicality, monitorability and enforceability have not been considered further.

2.4.2.1.2 RO2: Fiscal measures

The introduction of a tax on the sale of all lead shot could be used to influence the choices made by individual shooters by increasing their costs and thereby making alternatives more attractive. This tax would be a form of the “polluter pays” principle. A tax on organised shooting events that still wanted to use lead shot could also encourage the organisers to switch to alternatives. Any revenue raised could potentially be used to support a consumer awareness programme.

There are a number of concerns regarding this option. For example, a loophole could develop whereby people would import cartridges illegally from cheaper countries to avoid paying tax. Wealthy groups or individuals might not see a tax as a barrier. A tax could also lead to stockpiling in advance of its introduction.

There is therefore significant uncertainty about how much impact this option would have on reducing the actual use of lead shot cartridges. For this reason, effectiveness, practicality, monitorability and enforceability have not been considered.

2.4.2.1.3 RO3: Mandatory labelling of cartridge boxes and cartridges

Effectiveness

This option would require the manufacturers to include information on the packaging regarding the hazards and risks of lead. A further iteration could involve indelible marking of the shot cartridges themselves. This would inform users about the negative consequences of using lead shot for sports shooting (similar to the warning labels on cigarette packets).

Since users could choose to ignore the warnings, this option is not expected to have a large impact on the amount of lead released into the environment, but it would be effective at raising awareness of both the toxicity and risks. It could also encourage the shooters to try alternative ammunition or communicate the timelines for transition to alternatives, if that risk management option is proposed.

Practicality

This option is likely to be feasible, although there would be an associated cost to industry. It would require a transition time to allow implementation by the manufacturers. The practicality of including the required information on small packaging would also need to be considered.

Monitorability

This option is monitorable as the labelling of both packaging and cartridges is easy to check.

Enforceability

This option is enforceable as it applies to new products placed on the market. However, it might be difficult to distinguish non-labelled products from those that were legally on the market before the requirement was introduced.

2.4.2.1.4 RO4: Buy back scheme for lead cartridges

Some gun owners may buy large quantities of lead ammunition at a time, which could remain unused for several years. In addition, shooters may import lead shot from abroad (e.g. as unused cartridges following a shooting holiday). To encourage a faster transition to lead alternatives, one option would be for either lead manufacturers or government to offer a buy-back scheme. This could also be implemented to support either a full or partial restriction, for example during or at the end of a transition period.

This option has not been fully explored or costed so no assessment of effectiveness, practicability, monitorability or enforceability has been done. This will be reviewed following analysis of information gathered during the consultation stage.

2.4.2.1.5 RO5: Ban on placing on the market and use of lead shot for sports shooting

Effectiveness

A full ban on the use of lead containing shot cartridges for sports shooting would result in a 100 % reduction in release of lead shot (1,680 tonnes per year) and would therefore be effective in reducing the risks to the environment. A UK REACH restriction would also come into effect across GB without the need for further action by the devolved administrations.

To make it completely effective, there would have to be no possibility of buying lead shot for other purposes (e.g. hunting). Additional steps may also be necessary to minimise the risk of individual shooters building up large stocks of ammunition before a sales ban comes into effect.

Practicality

Alternative ammunition is readily available. The Danish experience (Kanstrup, 2018) also shows that sports shooting with alternatives is not detrimental to the sport.

Monitorability

A ban on sale of shot cartridges is monitorable as the suppliers of ammunition (retail outlets) can be monitored directly. Clay pigeon and target shooting generally takes place on an organised basis involving either fixed or mobile locations, so the operators on these ranges could check the shooters are not using lead shot cartridges.

Enforceability

This option is enforceable by regulatory authorities (for example the Environment Agency in England) as it involves control at the point of sale. Compliance visits could be carried out at relevant premises, and compliance reports could also be submitted by the shooting industry and ammunition suppliers. Compliance visits could also be done at the ranges to ensure that they have the appropriate measures in place to ensure no lead shot is being used on site.

2.4.2.1.6 RO6: Ban on placing on the market and use of lead shot for sports shooting with a derogation for licenced suppliers and athletes

Effectiveness

This option is a ban on the placing on the market and use of lead shot for sports shooting but with a derogation for licenced suppliers to sell and licenced individuals to use lead shot. This would allow individuals – for example, athletes subject to specific national or international sporting requirements – to train and compete in sports where lead shot is still required by the relevant governing bodies (for further information see Annex C). Recreational sports shooters who are not required to use lead shot would have to use alternatives (as in option RO5).

The number of professional, semi-professional and amateur athletes in GB who are required to use lead shot in their sport is unknown. ECHA (2021c) estimated there were approximately 12,000 athletes recognised by the International Olympic

Committee (IOC) who participate in international competitions in the EU, who ‘typically fire 40 000 to 60 000 “rounds” per year during training and competition and one “round” is consisting of 24 to 28 g of lead gunshot, would result in an annual emission of 11 520 to 20 160 tpa lead to the environment. Assuming that 5 % of the released lead shot would be recovered (regularly collected from a surface), in total 10 944 to 19 152 tpa of lead would be released to soil without frequent recovery. Compared to the baseline of 31 754 tpa. Consequently, this risk option would result in a reduction of release to soil between 40 to 66 %, roughly 50 %.’ ECHA (2021a) estimated a total use of 35,000 tonnes per year lead shot from all sports shooters (professionals and non-professionals) so this derogation would apply to between 32.9 % and 57.6 % of the total lead shot used in sports shooting at EU level.

By analogy with the EU, based on the proportion of shot cartridges used by professional athletes in the EU of between 32.9 and 57.6 % the quantity used by athletes in GB (1,680 tonnes per year) would be 552 – 968 tonnes per year. Therefore, this derogation would reduce the releases by between 712 and 1,128 tonnes per year.

Although this option would reduce the risks to the environment, as the amount of lead shot used would reduce from baseline, without additional risk management measures at shooting ranges to recover lead risks to the environment would remain.

Practicality

A regulatory system would need to be set up to implement this option which would identify the relevant authority(ies) responsible for granting licences to suppliers and individuals. However, as this would be a new requirement, issues around which organisations would be responsible, the frequency of renewal and administrative costs (and their recovery) would all require further consideration. For example, different authorities might have to be involved in different parts of GB, or to license suppliers compared to individuals. The practicalities of this process will be developed over the coming months and additional views will be gathered during the consultation stage. This option could impose considerable administrative and cost burdens that may not be considered proportionate.

Monitorability

This option is monitorable as the relevant authority(ies) would grant licences to individual athletes and their suppliers, which could involve annual reporting of the number of suppliers licenced to sell lead shot (and the amounts involved) as well as the number of licenced individuals.

Enforceability

This option is enforceable as checks could be made on both suppliers and individuals to ensure they have the appropriate licences in place and that the lead shot is only being used for sports shooting by the licenced individuals.

2.4.2.1.7 RO7: Ban of use of lead shot with a derogation for licenced sites

Effectiveness

This option is a ban on the use of lead shot with a derogation for shooting ranges that have adequate risk management measures in place to limit lead releases. This would not remove all the risks associated with this use but would reduce them. This would allow the continued use of lead shot cartridges at specific locations. This option would allow use of lead shot by all users at these sites, and therefore ensure that sportsmen and women can continue to train with the ammunition required by their governing bodies.

Relevant conditions would need to be specified: ECHA (2021c) considered a situation that would reduce the quantity of lead being released into the environment by 90 %, by requiring regular (at least annual) recovery of lead shot (with an efficiency of at least 90 %), together with additional arrangements for surface water and avoidance of agricultural uses within the site boundaries. ECHA (2021c) provided the following justification for these conditions:

- 'To avoid corrosion of lead shot deposited on the surface of the range, an appropriately short frequency of recovery is required… recovery of lead shot one to three time a year is performed on shotgun ranges with shot trap systems made of vertical nets or walls.
- Even in case of frequent lead shot recovery, there might be a risk of surface water contamination by lead particles or lead dust. To minimise this risk and to ensure compliance with the Environmental Quality Standards, appropriate risk management measures would be required to monitor and treatment of surface water.
- Since the upper soil layer of the whole range is expected to be contaminated above background levels from lead dust from shooting and unrecovered shot, any agricultural use (including hay and silage production) within site boundary should be banned to minimise the risk for human via environment (food) and livestock and to ensure compliance with the respective legislations such as the Regulation 1881/2006 that limits lead in food for human consumption, Regulation 1275/2013 that limits lead in animal feed, and DIRECTIVE 2002/32/EC on undesirable substances in animal feed.
- The risk to birds from intake of lead shot and consequent primary poisoning cannot be eliminated because lead shot may always be on the surface of the deposition area of a range. The risk may be reduced e.g., by nets that trap, and

collet shot and by conditions that make the ranges less attractive for birds to enter. Since birds are attracted by vegetation and trees, vegetation should be avoided as far as possible on ranges. A surface coverage is also expected to reduce the attractivity for birds.

- In the CSR (2020) a remediation plan at the end of service life is required. In case of regular recovery of >90 % of lead shot, the remaining risk for soil contamination is expected to be limited.'

Practicality

A relevant authority(ies) would have to be responsible for granting licences to sites. Similar questions would need to be resolved as for RO6.

The success of this option also depends on the ability of site operators to achieve 90 % recovery. ECHA (2021c) states: 'To achieve the recovery effectiveness of >90 %, combinations of different risk management measures such as walls and/or berms and/or nets (shot curtains) and/or surface coverage are required and would need to be installed taking into account the specific conditions of the site. Usually, a combination of two or three measures is required, that allows an efficient concentration of lead shot at limited area(s) with easy recovery. It should be noted that an already contaminated soil should not be covered with an airtight surface coverage to avoid anaerobic mobilisation of lead in the contaminated soil'.

ECHA (2021c) states that recovery of 90 % can be readily achieved for the Olympic disciplines of trap and skeet and gives examples of sites in Germany that have achieved this. There is no specific information for GB in ECHA (2021a). Information provided in the GB call for evidence (Section 1.4.3.1) indicated that the risk management measures in place at each shooting range varied widely, with some sports shooting sites reporting no recovery of the lead shot.

Site-specific applications would need to be assessed by the relevant authority on a case-by-case basis, which could be complicated and require guidance about the type and level of evidence required. A licensing system could increase the costs for shooting ranges to ensure that they can provide sufficient evidence to show that they meet the requirements.

In addition, the recovery of lead pellets may be complicated by the presence of other forms of ammunition. Unless the shooting range separates athletes using lead shot from those using non-lead alternatives, the recovered pellets will be a mixture of lead and the alternative used. This could potentially complicate the recovery process and increase the clean-up price.

Recovery of 90 % of the lead shot is likely be a significant challenge for shooting ranges that are either temporary or sited in more natural locations such as woodlands. It is therefore unlikely that such ranges would be able to take advantage of the derogation.

Monitorability

This option is monitorable as the relevant authority(ies) would grant licences to individual sites, which could involve annual reporting of the amount of lead shot used at each site. The site operators would need to demonstrate that the necessary operational conditions and risk management measures were in place to ensure a minimum of 90 % recovery. This information could be made publicly available, either by the site operator or the relevant authority(ies).

Enforceability

This option is enforceable as checks could be made that site operators have the appropriate licences in place. Issues around which organisations would be responsible would require further consideration. However, unless the lead shot were only made available via the site operator, athletes could still buy lead shot from suppliers and use it at non-licensed sites (or for other uses e.g. hunting), and this could be more difficult to check.

2.4.2.1.8 RO8: Ban on placing on the market and use of lead shot for sports shooting with a derogation for licenced suppliers and licenced athletes at licenced sites

Effectiveness

This option is a combination of RO6 and RO7, whereby only licenced athletes are allowed to purchase from licensed suppliers and allowed to shoot at licensed ranges with appropriate risk management measures in place. This option would be more effective than RO6 or RO7 as it would limit the number of potential users as well as requiring a high level of mitigation of the risk through site-specific operational conditions, whilst ensuring sportsmen and women can continue training if their governing body insists on the use of lead shot. This option should result in the lowest release of lead to the environment, other than a full ban (RO5).

Practicality

This option combines the practicality issues identified in RO6 and RO7, concerning issues around the identification and costs of setting up an appropriate licensing authority (which may differ for individuals and sites, and between GB nations) and the ability of GB site operators to meet the necessary conditions (with their associated costs). This option could impose considerable administrative and cost burdens that may not be considered proportionate.

Monitorability

This option is monitorable as the relevant authority(ies) would grant licences to individual athletes, suppliers and shooting ranges, which could involve annual reporting of the number of licenced individuals as well as the amount of lead sold and shot used at each site (with publication of operational conditions and risk management measures as for RO7).

Each site would also need to keep records showing that the only people allowed to shoot with lead shot are the professional athletes who hold a license. This could include mass balance calculations or other records to show compliance. This issue can be further developed during the consultation stage.

Compared to scenario RO7, this option makes the monitoring of lead shot cartridge sales easier as only licenced athletes would be able to purchase such cartridges.

Enforceability

This option is enforceable as checks could be made on both individuals and site operators to ensure they have the appropriate licences in place.

2.4.2.1.9 Summary of risk management options for lead shot for sports shooting

Table 2.7 Restriction options for sports shooting with lead shot

Risk Management Option		**Effectiveness**	**Practicality**	**Monitorability**	**Enforceability**
1	Voluntary measures	No	No	No	No
2	Fiscal measures	Not considered	Not considered	Not considered	Not considered
3	Mandatory labelling	No	Yes	Yes	Partially
4	Buy back scheme[10]	Not considered	Not considered	Not considered	Not considered

[10] This assessment will be done when we have gathered data from the consultation stage.

Risk Management Option		Effectiveness	Practicality	Monitorability	Enforceability
5	Ban on placing on the market and use of lead shot for sports shooting	Yes	Yes	Yes	Yes
6	Ban on placing on the market and use of lead shot with a derogation for licenced suppliers and licenced athletes	Partially	Partially	Yes	Yes
7	Ban on use of lead shot with a derogation for licenced sites	Partially	Partially	Yes	Partially
8	Ban on placing on the market and use of lead shot with a derogation for licenced suppliers and licenced athletes at licenced sites	Partially (more effective than RO6 or RO7)	Partially	Yes	Yes

The only option to reduce risks to wildlife that would be fully effective, practical, monitorable and enforceable in principle is a ban on the placing on the market and use of lead shot for sports shooting. The same conclusion was drawn by LAG (2015a), Green (2019) and ECHA (2021a)). To avoid the possibility of people buying lead shot cartridges for other purposes but continuing to use it for sports shooting, the restriction would need to include the use of lead shot for hunting. The avoided lead release from this option would be 1,680 tonnes per year.

However, the use of lead shot cartridges is currently required by some sport's governing bodies (such as the IOC) and so a derogation could be considered to allow athletes to train and compete. The implementation of this derogation would mean that the restriction would not be fully effective in reducing risks to the environment, so this would be decision based on socio-economic arguments. This could be time-limited and subject to review. A campaign to influence the governing bodies to change their rules could speed up this process. The most effective derogation would be a licensing scheme for licenced suppliers to supply licenced individual sportspeople, combined with a licenced scheme for shooting ranges that can show a high level of lead recovery. This requires further analysis, as such a licensing process does not currently exist.

If this optional derogation was selected, a transition period of 5 years is proposed to give the shooting ranges time to install the recovery systems required and for a licensing scheme to be developed and implemented. In this situation, the transition period for the use of lead cartridges for *hunting* should also be extended to 5 years as it would not be practical for the suppliers to sell only for sports shooting in the absence of appropriate vetting processes. Nevertheless, existing voluntary commitments by industry could still significantly reduce the risks arising from hunting during this period.

The avoided lead release from this optional derogation (assuming >90 % recovery from the licenced athletes) would be between 23,748 and 24,372 tonnes over 20 years compared to the baseline of 33,600 tonnes over 20 years. This figure is based on releases of 1,680 tonnes per year for the 5 years of the transition period (8,400 tonnes) and then an estimated annual release of 552 – 968 tonnes per year (8,280 – 14,520 tonnes over 15 years) as described in Section 2.4.2.1.6, which would be reduced by 90 % (due to recovery) to 828 – 1,452 tonnes over 15 years.

The costs and benefits of the preferred options are assessed in Sections 2.5 and 0.

2.4.2.2 Bullets (Use #4)

In this Section the Agency reviews the options to mitigate the risks posed by lead bullets used for sports shooting.

2.4.2.2.1 RO1: Voluntary measures

The voluntary phase out announced by the shooting industry (BASC, 2020) only covers the use of lead shot in live quarry hunting and therefore would not be effective in the mitigation of risks from lead bullets in sports shooting. Although a similar voluntary phase out could be feasible for at least some types of sports shooting, comments received during the call for evidence suggest there is currently little appetite for such an approach within GB. Effectiveness is therefore likely to be low, and practicality, monitorability and enforceability have not been considered further.

2.4.2.2.2 RO2: Fiscal measures

The introduction of a tax on the sale of all lead bullets could be used to influence the choices made by individual shooters by increasing their costs and thereby making alternatives more attractive. This tax would be a form of the "polluter pays" principle. A tax on organised shooting events that still wanted to use lead bullets could also encourage the organisers to switch to alternatives. Any revenue raised could potentially be used to support a consumer awareness programme.

There are a number of concerns regarding this option. For example, a loophole could develop whereby people would import bullets illegally from cheaper countries to avoid paying tax. Wealthy groups or individuals might not see a tax as a barrier. A tax could also lead to stockpiling in advance of its introduction.

There is therefore significant uncertainty about how much impact this option would have on reducing the actual use of lead bullets. For this reason, effectiveness, practicality, monitorability and enforceability have not been considered.

2.4.2.2.3 RO3: Mandatory labelling of packaging

This option is identical to that presented for lead bullets for hunting (see Section 2.4.1.2.8). In summary, it is not considered sufficiently effective to eliminate all risks. It could be practical, monitorable and enforceable (although it might be difficult to distinguish non-labelled products from those that were legally on the market before the requirement was introduced).

2.4.2.2.4 RO4: Buy back scheme for lead bullets

Some gun owners may buy large quantities of lead ammunition at a time, which could remain unused for several years. In addition, shooters may import lead bullets from abroad (e.g. as unused bullets following a shooting holiday). To encourage a faster transition to lead alternatives, one option would be for either lead manufacturers or government to offer a buy-back scheme. This could also be implemented to support either a full or partial restriction, for example during or at the end of a transition period.

This option has not been fully explored or costed so no assessment of effectiveness, practicability, monitorability or enforceability has been done. This will be reviewed following analysis of information gathered during the consultation stage.

2.4.2.2.5 RO5a: Ban of small calibre lead bullets for sports shooting

Effectiveness

A use ban on the use of small calibre lead bullets (<5.6 mm centrefire and rimfire in general) would be effective in reducing environmental risks. A full ban on the use of lead bullets for sports shooting would result in a 100 % reduction in release of lead bullets (28.8 – 72 tonnes per year). However, we have no information on the split between large and small calibre bullets so cannot conclude on the reduction in the release of lead from a ban on small calibre bullets. A UK REACH restriction would also come into effect across GB without the need for further action by the devolved administrations.

To make it completely effective, there would have to be no possibility of using lead bullets sold for other purposes (e.g. hunting). Additional steps may also be necessary to minimise the risk of individual shooters building up large stocks of ammunition before a ban comes into effect.

Practicality

There are fewer alternatives for small calibres than for the larger calibres. Although there are now some alternatives available (such as copper plated zinc bullets) there is still a lack of field testing data available on them (Annex C). This option may therefore have limited practicality for the time being. As the development of the alternatives has started a transition period of 5 years would allow the development and testing to be completed and sufficient supply to be made available.

Monitorability

A ban on use of lead bullets would be difficult to monitor as the suppliers of ammunition (retail outlets) would still be able to supply use for indoor ranges (for which the environmental and human health risks arising from lead exposure are negligible).

Enforceability

The enforceability of this option by regulatory authorities as a standalone approach would be difficult because lead bullets would still be available for use at indoor ranges (for which the environmental and human health risks arising from lead exposure are negligible). Compliance reports could be submitted by the shooting industry and ammunition suppliers.

2.4.2.2.6 RO5b: Ban of large calibre lead bullets for sports shooting

Effectiveness

A ban on the use of large calibre (≥5.6 mm centrefire) lead bullets would be effective in reducing environmental risks. A full ban on the use of lead bullets for sports shooting would result in a 100 % reduction in release of lead bullets (28.8 – 72 tonnes per year). However, we have no information on the split between large and small calibre bullets so cannot conclude on the reduction in the release of lead from a ban on large calibre bullets. A UK REACH restriction would also come into effect across GB without the need for further action by the devolved administrations.

To make it completely effective, there would have to be no possibility of using lead bullets sold for other purposes (e.g. hunting). Additional steps may also be necessary to minimise the risk of individual shooters building up large stocks of ammunition before a ban comes into effect.

Practicality

As discussed in Annex C, there are a range of lead-free alternatives to large calibre bullets and field trials have shown that they can be as accurate as lead-based bullets. Therefore, the Agency considers that this option is practical.

Monitorability

A ban on the use of lead bullets would be difficult to monitor as the suppliers of ammunition (retail outlets) would still be able to supply use for indoor ranges (for which the environmental and human health risks arising from lead exposure are negligible).

Enforceability

The enforceability of this option by regulatory authorities as a standalone approach would be difficult because lead bullets would still be available for use at indoor ranges (for which the environmental and human health risks arising from lead exposure are negligible). Compliance reports could be submitted by the shooting industry and ammunition suppliers.

2.4.2.2.7 RO6: Ban on placing on the market and use of lead bullets with a derogation for licenced suppliers and licenced athletes

Effectiveness

This option is a ban on the placing on the market and use of lead bullets for sports shooting but with a derogation for licenced suppliers to sell and licenced athletes to use lead bullets for sports shooting. This would allow individuals – for example, athletes subject to specific national or international sporting requirements – to train and compete in sports where lead bullets are still required by the relevant governing bodies. Recreational sports shooters who are not required to use lead bullets would have to use alternatives. As the use of lead bullets indoors is not part of the scope of this restriction a licencing system for lead bullets for outdoor shooting only would be very complicated and difficult to monitor and enforce, so this is not considered further.

2.4.2.2.8 RO7: Ban on use of lead bullets with a derogation for licenced sites

Effectiveness

This option is a ban on the use of lead bullets with derogation for ranges that have adequate risk management measures to limit lead releases. Risks to soil and livestock are expected to occur if lead bullets are left uncollected over longer periods of time. It is therefore considered possible to mitigate against the identified risks to soil and livestock by the implementation of appropriate risk management measures at shooting ranges. This option would allow the continued use of lead bullets at specific locations by all users of these sites, and therefore ensure that sportsmen and women can continue to train with the ammunition required by their governing bodies.

Relevant conditions would need to be specified. As discussed in Section 1.3.4 the risks posed by lead bullets can be reduced by using bullet containment and recovery that allows a regular (at least one a year) recovery of lead bullets (>90 %). Risk management measures are already included in the EU REACH registration dossier for metallic lead to ensure safe use, and the Agency anticipates that these will also be included in the full UK REACH registration dossier when it is submitted in due course. In the EU REACH CSR, bullet containment is a requirement for all ranges and therefore in theory the recovery rate should be closer to 100 %.

ECHA (2021c) identified that even ‘in case of 100 % lead bullet recovery, there are remaining risks for example from lead dust from shooting that is deposited on the ground of the range. Therefore, any agricultural use (including hay and silage production) within site boundary of the range is to be banned. A remediation plan at the end of service life is required according to the CSR (2020)’. The Agency has reviewed this and agrees with their assessment.

Practicability

As for other options with proposed licensing requirements (e.g. RO7 for sports shooting with lead shot), a relevant authority(ies) would have to be responsible for granting licences to sites. Similar questions would need to be resolved as for RO6 for sports shooting with lead shot.

The success of this option also depends on the ability of site operators to achieve 90 % recovery. There is no specific information for GB in ECHA (2021c). ECHA (2021c) states that in the '*CSR (2020) bullet containment is required*' and therefore this option is practicable. Responses to the GB call for evidence (Section 1.4.3.1) indicated that risk management measures achieving 90 % lead recovery are already in place at some shooting ranges in GB, indicating that this appears to be a practical option. However, it is not known how achievable such measures are in general. Recovery of 90 % of the lead bullets is likely be a significant challenge for shooting ranges that are either temporary or sited in more natural locations such as woodlands. It is therefore unlikely that such ranges would be able to take advantage of the derogation.

As some GB sites already have lead recovery systems in place, this indicates that costs of installing sufficient risk management measures are not prohibitive. In addition, as the costs of installing risk management measures to meet this derogation could be avoided by shooting ranges switching to alternatives to lead bullets, the upper cost of this restriction option is bounded by the costs associated with the complete ban.

Site-specific applications would need to be assessed by the relevant authority on a case-by-case basis, which could be complicated and require guidance about the type and level of evidence required. A licensing system could increase the costs for shooting ranges to ensure that they can provide sufficient evidence to show that they meet the requirements.

In addition, the recovery of lead bullets may be complicated by the presence of other forms of ammunition. Unless the shooting range separates athletes using lead bullets from those using non-lead alternatives, the recovered metal will be a mixture of lead and the alternative used. This could potentially complicate the recovery process and increase the clean-up price.

This restriction option allows the continued use of lead bullets at licenced sites by all users, ensuring that international competitors can continue to train with the required ammunition.

Monitorability

This restriction option is monitorable as the sites would have to apply for licences to use lead on their sites and would need to demonstrate that the necessary operational conditions and risk management measures were in place to ensure a minimum of 90 % recovery and have no agricultural land within the shooting area. This volume of lead used on each of these sites would be reported to allow the GB authorities to ensure compliance.

Enforceability

This option is enforceable as checks could be made that site operators have the appropriate licences in place to allow the continued use of lead bullets. Issues around which organisations would be responsible would require further consideration, together with how the scheme would be operated.

2.4.2.2.9 Summary of risk management options for lead in bullets

Table 2.8 Restriction options for sports shooting with lead bullets

Risk Management Option		**Effectiveness**	**Practicability**	**Monitorability**	**Enforceability**
1	Voluntary measures	No	No	No	No
2	Fiscal measures	Not considered	Not considered	Not considered	Not considered
3	Mandatory labelling of bullet boxes	No	Yes	Yes	Partially
4	Buy back scheme for lead bullets[11]	Not considered	Not considered	Not considered	Not considered

[11] This assessment will be done when we have gathered data from the consultation stage.

Risk Management Option		Effectiveness	Practicability	Monitorability	Enforceability
5a	Ban of small calibre lead bullets for sports shooting	Yes	No	Partially	Partially
5b	Ban of large calibre lead bullets for sports shooting	Yes	Yes	Partially	Partially
6	Ban on placing on the market and use of lead bullets with a derogation for licenced suppliers and licenced athletes	No	Not considered	Not considered	Not considered
7	Ban of lead bullets with derogation for licenced sites	Yes	Yes	Yes	Yes

The preferred risk management option for outdoor sports shooting using bullets is RO7. This option is considered effective, monitorable, practical and enforceable in principle. Due to the risks identified and the range of risk mitigation measures available, the Agency considers that the environmental risks from this use can be managed via the use of risk management measures at the shooting ranges.

Therefore, a derogation allowing the use of lead-containing bullets at licensed ranges only, where risks to the environment from this activity are minimised by the use of appropriate lead collection systems and the land is not also used for agricultural purposes, is proposed (RO7). The same conclusion was drawn by ECHA (2021a). These measures are already recommended in the EU REACH registration dossier for metallic lead to ensure safe use, and the Agency anticipates that they will also be included in the full UK REACH registration dossier when it is submitted in due course. This option requires further analysis, as such a licensing process does not currently exist

Sports shooting ranges would need to demonstrate that the necessary operational conditions and risk management measures are in place to ensure a minimum of 90 % recovery of deposited lead (e.g. using appropriate lead collection systems). Information provided during the call for evidence indicated that risk management measures achieving 90 % lead recovery are already in place at some shooting ranges in GB.

The use of lead bullets is currently required by some sport's governing bodies and so this derogation would allow athletes to continue to train and compete at shooting ranges that have the appropriate risk management measures in place.

Transition periods have been proposed to allow for the implementation of appropriate risk management measures at sites which do not already have these in place, and taking into consideration the availability of non-lead alternatives. A transition period of 18 months is appropriate for sports shooting with the large calibre bullets and 5 years for the small calibre bullets, to allow additional time for the development and testing of them. A transition period of 18 months is proposed for the ban on the use of large calibre lead bullets for sports shooting, due to the availability of substitutes and the expectation that shooting ranges may already have risk management measures in place sufficient to meet the proposed derogation or that these can be readily installed. A transitional period of 5 years is proposed for the ban on the use of small calibre (including air rifles) lead bullets for sports shooting, to allow additional time for the development and testing of alternatives.

The avoided lead release from this option (RO7) (assuming >90 % recovery) would be a maximum of 972 tonnes over 20 years. This is based on releases of 72 tonnes per year for the 5 years of the transition period (360 tonnes) and then 7.2 for the following 15 years (108), compared to a baseline of 72 tonnes per year or 1,440 over 20 years. These reductions are based on the worst case of all of the bullets being small calibre with a transition period of 5 years as the Agency does not have data on the quantities of each calibre used. The costs and benefits of the preferred option are assessed in Sections 2.5 and 0.

2.4.2.3 Air rifles/guns/pistols (Use #5)

The number of air weapons and their associated lead pellets used for sports shooting is unknown. Further information on this use will be gathered during the consultation stage so that the risks posed by this use can be assessed. In the absence of specific information on this use, the environmental risk assessment (Section 1.4) identified the same risks as for sports shooting with bullets. The conclusions drawn on the most appropriate risk management options for these uses are therefore also considered appropriate for this use.

2.4.3 Shooting with historical weapons (Use #6)

The number of historic firearms used for historic re-enactments or other purposes is unknown, as is the quantity of lead ammunition used for this purpose. The Agency assumes that lead ammunition is not used during historical re-enactments as blanks would be used for safety reasons. The Agency therefore considers that most use of lead ammunition with historical weapons will occur at shooting ranges. Further information on this use will be gathered during the consultation stage.

A separate consideration of the risk management options for shooting with historical weapons has not been undertaken at this time. Although this is a niche use, the environmental risk assessment (Section 1.4) identified the same type of risk as for sports shooting with bullets. The conclusions drawn on the most appropriate risk management options for these uses are therefore also considered appropriate for this use. As alternative lead-free ammunition may not be available for historical weapons, the proposed restriction option would allow continued use of lead ammunition at a shooting range that has the appropriate risk management measures in place.

2.5 Impacts of a restriction of lead in hunting

As discussed in the previous section, the preferred restriction option for lead in hunting is a combination of the following elements:

- A ban on placing on the market and on the use of lead shot for hunting.
- A ban on the use of lead bullets for hunting.

The impact assessment therefore considers the impacts of what this would mean for those affected by first considering what alternatives are available in the event of the restriction.

2.5.1 Alternatives

Hunters affected by the proposed restriction would have to switch to alternative ammunition. The most frequently used alternatives for lead gunshot are steel gunshot, bismuth gunshot and copper and brass bullets. These alternatives are already widely used in the EU and internationally. Their suitability depends on their availability, their performance, and on their price compared to lead. This section looks at the cost of alternatives compared to the cost of lead ammunition. Details on the other aspects of suitability and the technical specifications of alternatives can be found in Annex C.

2.5.1.1 Gunshot

A comparison of prices for lead and non-lead shot was presented by Thomas (2014) and is shown in

Table *2.9*.

Table 2.9 Comparison of price for lead shot and non-lead shot ammunition

Shot type	**Manufacturer**	**Price per box of 25**	**Price per case of 250**
Steel shot	3 different UK makers	£8 - 9	£74 - 80
Bismuth-tin shot	Eleyhawk	£42	£374
Hevi-Shot	Loaded in the UK	£65	£575
Tungsten Matrix	Gamebore	£81	£725
Lead shot (across 4 UK makers):			
Lead	Gamebore	£8	£70-72
Lead	Eley	£8	£72-73
Lead	Hull	£11	£94-96
Lead	Lyavale	£9-11	£84-100

Table *2.9* shows that while the price of steel is directly comparable to the price of lead, the other alternatives, bismuth, hevi and tungsten are significantly more expensive, ranging from 5 to 10 times the price of lead.

2.5.1.2 *Bullets*

Table 2.10 lists the costs of different types of lead and lead free bullets. This information was provided by the NSRA during the GB call for evidence. More information can be found in Annex C.

Table 2.10 Costs of lead and non-lead bullets

Ammunition type	**Cost (per box of 50 rounds)**
.22LR cartridges	
Lead Rounds:	
Eley Club	£ 5.25
Eley Tenex	£11.75
Lead-free Rounds:	
CCI Copper	£11.95
RWS Green HV	£10.50
Norma Eco Speed	£8.07
.177 pellets	
Ammunition type	**Cost (per 500)**
Lead Rounds:	
H and N Finale Match light	£10.00
JSB Exact	£11.00
Lead-free Rounds:	
RWS Hypermatch (made of tin)	£17.98
RWS Hyperdome (tin alloy)	£18.73
H and N Field Target Trophy	£19.90

Source: Call for evidence

In preparation of the restriction dossier, ECHA (2021a, 2021c) undertook a market analysis of its own to validate some of the comments submitted in the ECHA 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 EU.

ECHA surveyed more than 120 online retail stores located in the EU. While performing online searches, ECHA collected information on prices for both lead-based ammunition and non-lead alternatives. The result of this analysis underlines the findings of Thomas: on average the prices of lead bullets and non-lead bullets are comparable, especially for large calibres, whereas for small calibres the prices for non-lead bullets are higher. In Table 2.11 the price difference between lead bullets and non-lead bullets is outlined for different calibres and the respective game type. The prices have been taken from the ECHA restriction report, converted to GBP and inflated to current prices.

Table 2.11 Price difference per cartridge for different calibres found in market analysis between non-lead and lead equivalent (excluding VAT)

Calibre	Prices lead-containing	Prices non-lead	Price difference with lead equivalent (2021 prices, in GBP)	Game type
17 HMR	£1.19	£3.78	£2.60	Small
.222 REM	£1.45	£2.20	£0.75	Large
.243 Win	£1.98	£2.51	£0.53	Large
6.5x55	£2.24	£3.78	£1.54	Large
7x64	£2.77	£3.12	£0.35	Large
.30-06 Spr.	£2.64	£2.86	£0.22	Large
.308 Win.	£2.51	£3.17	£0.66	Large
0.3 Win.Mag	£3.25	£38.97	£35.72	Large
8x57	£2.82	£3.43	£0.62	Large
9.3 x 62	£3.21	£4.05	£0.84	Large

2.5.2 Costs and other economic impacts

The following categories of costs, related to the ban on the use of lead shot for hunting and ban on the use of lead bullets (small and large calibres) for hunting have been taken into account:

- Research and Development (R&D) costs
- Industry compliance costs, i.e. raw material costs, energy costs, loss of recycling benefits and manufacturing equipment costs (aka capital costs)
- Suppliers' compliance costs
- Enforcement costs
- Substitution costs (costs to hunters)

2.5.2.1 R&D costs

Companies that are manufacturing lead shot and lead bullets will incur R&D costs from developing new alternatives. Within this context however it has to be noted that many of the manufacturers already have set up lines for the production of lead-free shot and lead-free bullets, therefore the assumption is that most of the R&D costs have already been incurred before this restriction. In addition, manufacturers regularly design and develop new products, to stay innovative and gain market share, so they are not expected to have any additional R&D costs.

2.5.2.2 Industry compliance costs

According to the ECHA (2021a) report, there will be no net compliance costs to the industry from the restriction both domestically and in terms of exports. This assessment adopts the ECHA approach and assumes the same will be applicable to GB. According to the ECHA (2021a) report, steady growth in the target shooting market is expected to mitigate any shifts in hunting equipment sales. Lead ammunition supplies are expected to continue to be in demand by target shooters, personal protection for consumers, and hunters from abroad. With the phase-in of the proposed restriction, hunters may be expected to purchase more non-lead ammunition at higher per unit costs, which should yield higher per unit margins until manufacturer competition and higher production runs reduce costs. Further research and evidence is needed to validate these assumptions and to assess the costs to industry for GB.

2.5.2.3 Suppliers' compliance costs

Suppliers are known to keep stocks of ammunition (bullets and shot) to satisfy local customer demand. In the ECHA call for evidence many suppliers (mostly SMEs) stepped forward to highlight the potential negative consequences a ban on the use of lead in hunting would have for their business.

Ammunition has a limited shelf life and cannot be stored or kept forever. Several manufacturers give advice on the maximum shelf life their ammunition may have: Lapua for example advises that Lapua products have been designed to be usable several years. The condition of cartridges strongly depends on the storage conditions. In good conditions (about 10 – 15 °C and in normal humidity), the cartridge can be used for at least 5 years.

Furthermore, regulations are in force concerning the safe storage of ammunition that limit the amount of ammunition a store can keep. Therefore, with a long enough transition period this impact may be limited. In all cases, given the scope of the restriction, lead ammunition can still be used in shooting ranges that can comply with the conditions of the derogation.

2.5.2.4 Enforcement costs

In terms of enforcement costs, it is assumed that UK REACH enforcement authorities would conduct spot checks of imported hunting ammunition (customs), site inspection of manufacturers and suppliers, and inspection of suppliers' websites once the restriction has entered into force (i.e. after the transition period).

In addition, it is assumed that the preferred restriction option would also allow inspections to be performed at the site of use by the relevant national enforcement authorities (environmental regulators or local area authorities). The details of how this system would work are currently being developed and further information will be gathered during the consultation stage.

Enforcement costs (administrative, testing, and on the field) for enforcement authorities and industry have not been calculated but it is assumed, as was done for the ECHA (2021a) report that they will be negligible and covered under enforcement activities that are already in place. Further information and evidence on enforcement costs will be sought during the consultation stage and developed by enforcement specialists.

2.5.2.5 Costs for hunters

In accordance with the approach of ECHA (2021b), once the restriction enters into force, it is assumed that hunters will continue to consume the same quantity of bullets and shot to continue their activity. As a result of the restriction, hunters will need to therefore use alternatives to lead ammunition, thereby imposing any associated substitution costs.

The approach taken to the assessment of substitution cots follows that of ECHA (2021b). The main elements included in the substitution cost assessment are (details are presented in Annex D):

Hunters will face two kinds of increased costs: “one-off” costs in order to adapt and/or replace their current stock of guns which will not be suitable for alternative ammunition, but also ongoing “operational” costs incurred as a result of switching to alternative ammunition. The information that is needed to calculate the substitution costs is:

- **‘one-off’ costs** for the adaptation and/or replacement of the current stock of gunsunsuitable to use non-lead alternatives
- incremental **‘operational’ costs** incurred as a continuous consequence of switching to alternative ammunition,

The cost for hunters thus consists of increased prices for alternatives as well as the cost associated with having to buy a new gun earlier than anticipated because of this restriction.

The ECHA approach and analysis is based on the availability of detailed information on hunting, shooting and costs that were not available for GB. In order to reproduce this analysis, where GB data was not available, costs have been apportioned to UK hunters as follows: there are 6.7m hunters in the EU (FACE, 2017) and 800,000 (FACE, 2017) in the UK, which means that the UK accounts for 12 % of all EU hunters. As a simplification, we have therefore attributed 12 % of ECHA calculated costs to the UK. GB accounts for 97 % of the UK population, so 97 % of the UK costs have been apportioned to GB. Further evidence on the number of hunters in GB will be sought in the consultation stage in order to update the calculation. The following sections outline the approach to the two sets of substitution costs.

One-off costs

A fraction of the hunters will have to change their shotguns. Even though standard proofed guns can fire standard steel there may still be a fraction of hunters that have shotguns that are not suitable for steel, although these hunters may use bismuth as an alternative. One-off costs consist of any modification that a hunter must make to their shotgun in order to fire steel shot which is the most likely alternative: these include any cost incurred by a hunter to adapt their shotgun so it can use steel gunshot, or, where hunters are unable to adapt their shotgun, the cost for prematurely replacing a shotgun that is unsuitable for use with standard steel gunshot. It also includes the costs some hunters may incur for testing (re-proofing) to ensure that their shotgun is suitable for use with standard or high-performance steel gunshot. Importantly, not all hunters will need to replace, re-proof or modify a shotgun that is not suitable for use with steel gunshot as they may switch over to bismuth shot or other alternative ammunition that can be used in any existing shotgun that is currently used with lead gunshot.

For large calibre rifles, existing non-lead bullets can be used without adaptation. A decision to ban the use of lead bullets would imply that the need would arise to replace certain rifles for small calibre bullets. Copper bullets with small calibres may not stabilize when fired from the same rifle barrel, which relates to the function of the twist rate of the barrel’s rifling.

However, for those small calibre rifles that may not fire copper bullets as accurately, the rifle should be either substituted, or the barrel be changed to one having the appropriate rifling (Caudell *et al*., 2012). Depending on the restriction option that is preferred, hunters may be confronted with the need to purchase a new gun.

The ECHA methodology is based on the fact that there is already a full ban on lead in some EU countries and an EU-wide restriction on lead in wetlands which of course has an impact on the amount of guns that have already been replaced. We follow the same methodology for GB and follow the same assumptions. This is to simplify the analysis but further information will be sought in the consultation stage to validate these assumptions, even though some information is already available - the BSSC in their submission to ECHA estimate that there are approximately 324,000 shotguns in the UK that are not suited to currently produced steel shot cartridges. 40,000 of these may be modified and then tested, so that leaves 284,000 guns that will need to be replaced. That figure adjusted for GB is 275,480. In addition, the BSSC also provide costs for the replacement of the guns. However, these costs are extremely high compared to the ones used by ECHA and while they were considered for use in a GB specific analysis, the assessment conducted here uses the costs produced by ECHA (adjusted for GB gun volumes) for consistency, pending further information from the consultation stage for a more robust GB price estimate.

Operational costs

Those hunters that hunt with lead ammunition will face an increased cost for using lead-free alternatives, the cost of such alternatives varies. These differences are described in Section 2.5.1. Details of the assumptions and the scenarios in the cost calculations can be found in Annex D.

2.5.2.6 Total costs of substitution

Gunshot

The information that was submitted in the call for evidence as well as the market analysis performed by ECHA, highlights that the costs for steel shot are comparable to the costs of lead shot, although there may exist some regional differences.

To study the costs of a regulatory action best-, central-, and worst-case scenarios were developed. The scenarios vary according to the extent of any regulation on the use of lead shot that already exists, the average prices of steel compared to lead shot and the need for testing and need to purchase new guns. The outcome of this assessment is shown in Table 2.12.

The main assumptions concerning the need for gun replacement, cost associated with using alternatives and adaptation that hunters already may have made as a consequence of the restriction of lead shot in wetlands are described in Annex D.

Table 2.12 presents the total costs of substitution for gunshot, both one-off and operational. It has been adapted from the ECHA report using a proportion of the population for GB. We know that there 800,000 hunters in the UK, which corresponds to 12% of the EU hunters. We have used this proportion to calculate the numbers of hunters, guns and the costs in the table below. The numbers have then been calculated for GB (97% of UK population) and have been converted to GBP and inflated to current prices.

Table 2.12 Substitution scenarios for hunting with gunshot

Scenario	Best-case	Central-case	Worst-case
Number of hunters impacted	419040	442320	477240
Number of shotguns to be replaced	0	22,124	48,103
One-off cost for premature replacement of shotguns	£ -	£13,098,906	£14,146,819
Annual operational cost (i.e. annual incremental cost to be spent on shot)	£ -	£6,913,813	£10,048,075
Annualised one-off cost for testing	£209,582	£209,582	£209,582
Annualised one-off cost for new guns	£ -	£ 943,121	£2,200,616
Total annualised cost to hunters	£209,582	£8,066,517	£12,458,274

Scenario	Best-case	Central-case	Worst-case
Annual emission reduction from replacement	n/a	n/a	n/a
Additional cost per hunter (p.a.)	£0.50	£18.24	£26.10
Average hunter’s budget (p.a.)	£2,701	£2,701	£2,701
Fraction of average hunter’s budget	0	0.7%	1.0%

Bullets

To study the costs of the proposed restriction, three scenarios (‘best case’, ‘central case’ and ‘worst case’) were developed by ECHA (2021b). Under the best-case scenario, the assumption is made that the fraction of hunters already using non-lead bullets is as high as 15 %, which may be an overestimate. The fraction of hunters using non-lead bullets further decreases in the central (10 %) and worst-case scenario (5 %). These assumptions are based on information from the ECHA call for evidence. GB information is not currently available but will be sought during the consultation stage.

Concerning small calibres, it is assumed that hunters will have to buy new guns or change barrels for calibre sizes lower than 5.6 mm. Hunters will at most change barrels and not the stock of the guns, because the stock of a gun is often chosen to fit the anatomy of a hunter and will not easily be changed. ECHA has considered this in its cost assessment assuming a change of barrels for the low impact scenario, and a change of guns in the middle and higher impact scenarios. The price difference in the low, medium and high scenarios for substitution and associated costs are summarised in Table 2.13. As information for GB is not available, Table 2.13 lists the costs produced by ECHA adjusted for GB hunting population and converted to GBP 2021.

Table 2.13 Substitution scenarios and associated cost for hunting with bullets

CONVERTED FROM ECHA TO GB (2021 PRICES)			
Scenario	**Best case**	**Central case**	**Worst case**
Small calibre (up to 5.5 mm) prices per bullet	£2.08	£ 2.22	£2.36
Large calibre (5.5 mm and larger) prices per bullet	£0.58	£1.06	£1.54
Small calibre			
Number of guns to be replaced	46,982	70,473	140,947
One-off cost for premature replacement of guns with small calibre	£5,017,000	£34,200,000	£127,176,000
Annualised one-off cost for new guns	£1,024,000	£2,253,000	£3,686,000
running cost (ammunition)	£1,229,000	£2,765,000	£3,481,000
Total	£2,253,000	£5,017,000	£7,168,000
Large calibre			
Running cost (ammunition)	£922,000	£1,843,000	£2,867,000

2.5.2.7 Cost-effectiveness and affordability

Affordability considerations

According to ECHA (2021b), examples from Denmark and the Netherlands for lead shot and in Germany where similar restrictions of lead in bullets (albeit with different scope) are already in place, indicate that switching to alternative materials is possible and affordable for hunters. The analysis shows that when the restriction costs are passed through to hunters (via price increments for ammunition), these costs are low compared to the average hunting budget spent yearly by hunters. Based on the compliance cost estimates reported and the average yearly expenses per hunter reported by ECHA (2021b), the purchase of non-lead alternatives to both shot and bullets would induce an additional expense (operational cost only) as per the overview in

Table *2.14*.

Table 2.14 Yearly cost per hunter per restriction option

Restriction Option	Annualised cost of restriction per hunter		
	Best case	Most likely	Worst case
Ban on marketing and use of lead shot for hunting	£0	£19	£34
Ban on use of bullets - small calibre - for hunting	£11	£24	£36
Ban on use of bullets - large calibre - for hunting	£2	£6	£6

This section is taken from the ECHA restriction dossier as similar information is not available for GB. The proposed measures are estimated to only impose a limited cost on the individual hunter. Based on the cost estimates presented in

Table *2.14* of this restriction report, it can be expected that the additional cost to an average hunter for purchasing non-lead shot ammunition rather than lead shot ammunition will range from £0 (best case) to £36 (worst case) per year. The worst case corresponds to 1.3% of the average annual hunting budget of a European hunter, which is in the order of €3,000 or £2,700 (converted from Pinet, 1995).

This additional cost seems economically reasonable even for subsistence hunters with asignificantly lower hunting budget. ECHA recognises that the budget of a hunter may differ per hunting culture and could vary from as low as €500 per year to €2,000 per year.

A hunter typically spends money on several items in the pursuits of their activity. These expenditures can be broken down in the following cost items: Legal expenditure, Expenditure on yearly hunting rights, Expenditure on equipment, expenditure on transport, dog-related expenditure, miscellaneous.

Although affordability considerations do not imply that a regulatory measure entails a net welfare gain, the analysis suggests that the preferred restriction would be unlikely to exert disproportionate costs to society overall, but hunters may be impacted differently.

Further evidence on the affordability of the restriction specifically for GB hunters will be sought during the consultation stage.

Cost – effectiveness considerations

The proposed restriction is anticipated to reduce lead emissions to the environment according to the estimates in Table *2.15*. Over the 20-year study period, the expected impact is a reduced emission of lead of about 86,000 tonnes in GB.

Considering the aggregated costs imposed on hunters (in terms of more expensive ammunition and the premature replacement of shotguns that cannot fire non-lead shotammunition), these abatement figures suggest that the total cost per tonne of lead emission avoided is in the range of £1.8/kg to £463/kg.

Table 2.15 Overview of cost and cost effectiveness

Risk Option	Yearly cost	Cost over 20- year period (NPV, 4%)	Emission avoided over 20-year period (tonnes)	Cost-effectiveness (£ / kg avoided release)
Ban on marketing and use of lead shot for hunting	8,066,517	152,447,293	85,815	£1.78
Ban on use of bullets for hunting - small calibre -	5,017,420	73,805,427	218	£462.92
Ban on use of bullets for hunting - large calibre -	1,843,134	27,112,198		

There is a lot of uncertainty around these results given that we don’t have an accurate separation for emissions from small and large calibre bullets. However, even taking the uncertainties into consideration, these results are comparable to ECHA’s results.

Overall, the preferred restriction for lead in shot and in bullets appears to be in the same order of cost effectiveness as the ECHA restriction on Lead in Ammunition. However, since no benchmark of cost-effectiveness exists for emissions related to lead, it is not possible to ascertain whether it is a cost-effective measure in absolute terms.

Cost benefit considerations

Whilst it is difficult to accurately predict all the welfare impacts induced by the current restriction proposal, some elements on both the benefit and the cost side have been quantified. In particular, it has been possible to estimate the cost to hunters from prematurely replacing shotguns when these are not suitable to fire any form of steel gunshot, as well as the annual cost increment associated with the switching to non-lead (steel and bismuth) shot.

A key objective of the restriction proposal is the reduction of lead poisoning in both terrestrial birds (including predatory/scavenging birds) and wetland birds in GB because of the ingestion of lead ammunition.

Partial monetisation of this impact of the use of lead shot is possible at least for terrestrial birds ingesting lead shot under the following assumption. Under one possible measure of benefit, 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 species for which lead gunshot ingestion represents a risk have been gathered by ECHA through a market survey made in the EU 27-2020. However, these 17 species do not represent the total number of species at risk of lead poisoning.

Whereas the human health impacts have been quantified in Section 2.5.3, there are a number of other impacts that have not.

In its opinion on lead in shot over wetlands, SEAC (2018d) considered as well that a restriction will also reduce lethal and sub-lethal effects of lead on predatory and scavenging birds, which are exposed through eating birds, and which have ingested lead gunshot or have embedded lead gunshot in their tissue. These impacts have not been quantified.

Other non-quantified impacts of the proposed restriction include potential impacts on other wildlife than birds (exposed through the food chain) as well as on wetland ecosystems at large. Also, lead gunshot as a potential source of lead contamination of (drinking) water resources was not assessed.

In terms of social welfare, the reduction of the adverse effects from the use of lead gunshot in wetlands has multiple consequences, such as increased (long-term) opportunities for hunting, leisure activities, e.g. bird watching and reduced amount of lead released in the environment and related contamination of water resources (avoided remediation costs).

2.5.3 Quantified benefits

The benefits of the restriction can be assessed in terms of avoided impacts to wildlife, the environment and human health. Sections 1.41.4.4 and 1.5 lists the impacts of lead. Some of the benefits cannot be quantified or monetised but they are still important to consider.

Irrespective of the source of lead release to the environment, its hazard (particularly its hazard via ingestion) is similar. Therefore, a single generic environmental risk assessment was conducted for all uses that could result in primary and secondary poisoning of wildlife (with a focus on birds). This was done on the basis that it was not practicable or meaningful to disaggregate the risks to birds resulting from the different uses. Other risks relevant for the sports shooting sector only, as for example risks to livestock (ruminants) and the soil compartment in general, were also assessed at a qualitative level.

2.5.3.1 Impacts to wildlife

The ECHA (2021c) report values the impact of the use of lead shot for terrestrial birds ingesting shot by assuming that 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 species for which lead gunshot ingestion represents a risk have been gathered through a market survey made in the EU-27 in 2020 by ECHA. GB data on the population of birds at risk includes 16 out of the 17 species that were valued in the ECHA survey.

Table *2.16*, replicated from Table 1.16 from Section 1.4.5.2, shows the species and number of terrestrial birds that are at risk in the UK.

Table 2.16 UK population of terrestrial bird species identified as being at high risk of lead poisoning due to primary ingestion via the terrestrial environment

Latin name	Common name	Breeding population estimate
Alectoris rufa	Red-legged Partridge	145,494
Columba livia	Rock Dove (wild)	6,000
Columba livia	Rock Dove (feral)	920,930
Columba oenas	Stock Dove	643,560
Columba palumbus palumbus	Common Woodpigeon	10,310,120
Coturnix coturnix	Common Quail	748
Lagopus lagopus hibernica	Willow Grouse	404
Lagopus lagopus scotica	Red Grouse	529,530
Lagopus muta	Ptarmigan	17,000[a]
Lyrurus tetrix britannicus	Black Grouse	9,654
Perdix perdix	Grey Partridge	74,254
Phasianus colchicus	Common Pheasant	1,681,458
Scolopax rusticola	Eurasian Woodcock	114,216
Streptopelia decaocto	Eurasian Collared Dove	1,617,794
Streptopelia turtur	European Turtle Dove	7,176
Tetrao urogallus	Western Capercaillie	1,114
TOTAL breeding population		**16,079,452**

[a] Not listed by ECHA but has a similar feeding ecology to other swans.

[b] Not listed in data submitted to the European Environment Agency (EEA) under Article 12 of the Birds Directive, but included in Woodward *et al*. (2020)

Table 2.17 presents the values calculated for the population of birds in GB at risk of lead poisoning using the values produced by ECHA (2021a). The average number of birds at risk for each species is calculated by taking the average estimate out of 3 exposure scenarios: a 0.1% exposure scenario, a 0.5% exposure scenario and a 5% exposure. For more details on the calculations see Annex D.

Table 2.17 Value of birds at risk in GB (annual) in £ 2021

Common name	Average number of birds at risk	Low value	Medium value	High value
Red-legged Partridge	3,058	26,899	53,799	94,147
Rock Dove (wild)	126	444	1,886	3,328
Rock Dove (feral)	19,355	68,105	289,448	510,791
Stock Dove	13,525	23,797	35,695	59,491
Common Woodpigeon	216,684	3,431,085	6,862,169	14,296,186
Common Quail	16	14	41	138
Willow Grouse	8	97	97	97
Red Grouse	11,129	332,862	332,862	332,862
Ptarmigan	357	4,086	11,629	19,801
Black Grouse	203	24,096	47,834	79,426
Grey Partridge	1,561	10,983	27,456	64,523
Common Pheasant	35,339	93,262	559,569	1,554,359
Eurasian Woodcock	2,400	52,791	52,791	63,350
Eurasian Collared Dove	34,001	59,820	149,551	209,371

Common name	Average number of birds at risk	Low value	Medium value	High value
European Turtle Dove	151	1,857	1,857	11,277
Western Capercaillie	23	n/a	n/a	n/a
Total	**337,936**	**4,130,197**	**8,426,686**	**17,299,147**

Pain *et al*. (2019a) review the literature and the evidence on 4 types of costs relating to the impacts on wildlife: replacement costs, treatment costs, cost of services lost and willingness to pay to avoid these impacts. The most reliable estimates can be found on replacement costs for pheasants and red-legged partridges which sum to a total of €3.4m annually for the UK only. This translates to £3m annually for GB in 2021 prices.

Adding the Pain *et al*. value to the ECHA values in Table 2.17 we get the total value of avoided impacts on birds from a ban on lead which ranges from £7m for the low value to £16m for the high value annually. In order to avoid double counting the total value does not include the values of pheasant and partridge from the ECHA survey as there is more accurate data in Pain *et al.* for these species. Using the medium values the total benefits of a ban on lead are estimated to be over £11m annually. This is of course a huge underestimation as (as discussed in section 1.4.4) it only captures breeding populations and it does not include secondary poisoning or impacts on raptors and other scavenging birds. More details on some of the available valuation data can be found in Annex D.

2.5.3.2 Impacts to human health

The most relevant health endpoints associated with exposure to lead are neurotoxic effects in children aged 7 and younger, as well as increases in the incidence of chronic kidney disease (CKD) and in cardiovascular effects (increase in systolic blood pressure) in adults. For details on the assessment of human health impacts see Section 1.5.

IQ loss

The implication of exposure to lead has been estimated as a 1 point or more decrease in IQ in children, which can have a significant cost to society. Green and Pain (2015) estimated that somewhere in the region of 4,000 – 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. BASC and Countryside Alliance estimated in 2014 that 9,000 (midpoint of the range 5,500 – 12,500) children under the age of 8 from the UK shooting community consumed at least one game meal per week (all types of game, one portion assumed to be ≥ 100 g), averaged over the year (cited in (LAG, 2015a) and (Green and Pain, 2019)). The percentage of high-level consumers of game in the UK (adults and children) seems to lie between 0.084 – 2.52% of the population (Green and Pain, 2019). In the UK, the number of children 8 years or younger at risk is estimated to be more than 10,000 (Pain et al., 2019a). ECHA report (2021c) uses a range of values €8,000 -10,000 per IQ point lost. Applied to the GB numbers for children that are frequent game consumers (hunter families), the value of IQ loss associated with the median lead intake by any birth cohort is £93m.

CKD impacts

The ECHA report tries to provide an indicative valuation for CKD impacts.

For the purpose of an indicative valuation of CKD impact, ECHA (2021b) assumed that the number of attributable cases of CKD across the EU is between 100 and 1,000. These are cases based on prevalence (i.e. the number of current cases of CKD over a specified period of time) and should not be confused with new cases which would have to be calculated based on incidence (i.e. the number of new cases of CKD during a specified period of time). Hence, instead of valuing new cases, one may turn to disability-adjusted life years (DALYs) and value those alongside the estimates based on prevalence.

Both the European Burden of Disease (EBD) study as well as the Global Burden of Disease study provide collated disability weights for kidney disease (see Pain *et al*., 2019a). For primary/disseminated/terminate CKD, the EBD study finds average disability weights of 0.27/0.36/0.52. As CKD stage 3 will be more prevalent than CKD stages 4 or 5, an aggregate disability weight of 0.3 will here be assumed. Based on this disability weight, the attributable cases are associated with roughly 30 - 300 DALYs. As an approximation, these may be monetised by multiplication with the value of a statistical life year (VSLY). Following ECHA (2021a), the current VSL (€3.5 million – 5 million) endorsed by SEAC corresponds to a VSLY of €200,000 to €290,000. Applying a central value of €250k per VSLY, the DALYs associated with lead intake via game meat correspond to an indicative value of €7.5 million to €75 million. These numbers, converted to GBP and adjusted for the population of GB produce a value of £38m (mid point of the range). Importantly, it should be stressed that many assumptions have been made to arrive at this estimate and the scientific evidence on which those assumptions were based is less robust than the scientific evidence underpinning the neurotoxicity assessment. Further evidence regarding the assessment of these health impact will be sought during the consultation stage.

2.5.3.3 Impacts to the environment

Impacts of lead to the environment have not been quantified in this assessment. Pain and Dickie (2019a) refer to costs of clean-up using one estimate from the US, but they are based on one estimate only and therefore there is a large margin of error. Costs of clean-up will be associated with individual situations, and few estimates exist based upon a cost per tonne of lead ammunition contaminating the land. Kays ((2018)) that the clean-up costs of an estimated 60 tons of lead bullets (54.4 tonnes) was US $500,000 (£374,000). Extrapolating this to the 10,000–20,000 tonnes of lead gunshot used by sports shooters in the EU annually would suggest that, were all lead contamination to be mitigated, annual costs would be in the region of £68–137 million. This estimate is for bullets and clean-up of gunshot is likely to require that larger areas be treated as gunshot are more dispersed than bullets. Furthermore, there is a large margin of error associated with this estimate as it is based on just one recent decontamination example, but it gives a very broad indication of hypothetical annual costs. While it would not be practical or economically feasible to clean-up the 21,000 tonnes of shot used annually for hunting, it seems reasonable to assume that at least a similar cost would likely be required to reduce risks in the most contaminated areas.

2.5.4 Proportionality

Taking all the non-quantified benefits discussed earlier in addition to the quantified benefits in section 2.5.3 it seems plausible to conclude that the societal benefits of the proposed restriction will outweigh its costs. The total cost of substitution is approximately £253m, which is very close to the total expected benefits of £246m.

Given that the quantified expected benefits are an underestimate as discussed above and that a number of the types of benefits were not quantified and /or monetised at all, this means that this cost-benefit ratio makes it plausible that this restriction is proportionate.

Table *2.18* provides a comparison of the total calculated costs and benefits, both quantified and not quantified, of the proposed restriction

Table 2.18 Costs and benefits comparison of the preferred restriction

Costs (PV over 20 years)		Benefits (PV over 20 years)	
		Use value	
Costs to hunters (gunshot)	£152,447,293	Avoided opportunity cost associated with the annual mortality of terrestrial species	£114,932,637
Cost to hunters for hunting with small calibres	£73,805,427	Beneficial impacts on leisure activities including bird watching	Non-quantified
Cost to hunters for hunting with large calibres	£27,112,198	Human health benefit of avoided IQ loss (shot and bullet)	£93,089,301
		Human health benefit of CDK	£38,425,435
		Human health benefits of reduction to lead dust during shooting	Non-quantified
		Non-use value	
		Protection of wildlife and ecosystem services	Non-quantified
		Protection of rare bird species	Non-quantified
Total societal cost	**253,364,918**	**Total societal benefit**	**£246,447,373**

2.6 Impacts of restriction of lead in sports shooting

2.6.1 Alternatives

For gunshot, the ECHA report and the information from the GB call for evidence conclude that the possibilities to substitute lead exist but using alternatives would have consequences for the ISSF and other shooting federations who's rules currently specify the use of lead ammunition. The use of lead shot in sports shooting is therefore not limited by technical barriers but rather dictated by the current organisational rules on competitive shooting.

For bullets, and in particular for rifle and pistol projectiles, the ISSF rules state that projectiles made of "lead or other (similar) soft material" are permitted. However, the GB call for evidence and other sources highlighted claims that tests with lead-free bullets have shown that lead-free bullets have an accuracy that is sufficient for hunting but not sufficient for sports shooting purposes.

The main drawback that lead-free bullets exhibit in sports shooting conditions is that the systematic grouping is larger than the size of the target. In shooting sports, a shot grouping, or simply group, is the pattern of projectile impacts on a target from multiple shots taken in one shooting session. The tightness of the grouping (the proximity of all the shots to each other) is a measure of the precision of a weapon, and a measure of the shooter's consistency and skill. On the other hand, the grouping displacement is a measure of accuracy.

Further evidence of the claim that the alternatives for bullets are not suitable will be sought during the consultation stage (for more information on the alternatives see Annex C).

2.6.2 Costs

2.6.2.1 Gunshot

Substitution costs

The details of the calculations for the cost involved with a ban on the use of gunshot is presented in Annex D. The following considerations were made:

- Bismuth and tungsten are, for their high price, not considered as viable alternatives for lead in sports shooting
- Although in principle no gun replacement appears to be needed (see Annex C onalternatives), a conservative replacement rate of 10 % was used.
- Cost and emission reduction over a 20-year period are assumed to occur after

the first 5 years. In the first 5 years no cost or emission reduction are assumed.

Similar assumptions have been used to estimate the impacts of a ban on lead gunshot for sports shooting but with an exception for shooters that compete at international level. The costs have been calculated by estimating the difference between the price of lead and the price of steel which is the alternative. For the minimum scenario, the price is assumed to be 1% higher for steel, for the middle scenario 2% higher and for the maximum 5% higher.

Since detailed information on cartridges and users are not available for the UK to enable the Agency to conduct a similar analysis, we have attributed a proportion (12 %) of the ECHA costs to the UK.

Table 2.19 Costs associated with the ban on shot for sports shooting

Parameter	**Data**		
Price difference	Minimum	Middle	Maximum
Compliance costs	Nr of cartridges * price difference		
	£573,419	£1,136,599	£2,846,618
Costs for premature replacement	£1,157,078		
Cost per year after the transition period	£1,730,498	£2,293,678	£3,993,456
Cost over 20-year period (NPV)	£19,148,112	£25,496,684	£44,542,399

Table 2.20 presents the costs of a ban with a derogation for international athletes. The methodology is similar but the cost are about 20% less. However, a derogation will mean that the shooting ranges will need to implement risk management measures to meet the conditions of the derogation (90% recovery).

Table 2.20 Costs of derogation for international athletes

Parameter	Data		
Price difference	Minimum	Middle	Maximum
Compliance costs	Nr of cartridges * price difference		
	£241,655	£623,594	£1,911,739
Costs for premature replacement	£1,157,078		
Cost per year after the transition period	£1,402,830	£1,781,696	£3,071,890
Cost over 20-year period (NPV)	£15,461,844	£19,762,490	£34,097,974

Costs of Risk Management Measures

This section is completely taken from ECHA as no detailed design of risk management options and costs has taken place for GB at this stage.

To achieve a lead shot recovery rate of > 90 % measures such as berm and/or shot nets and/or surface coverage are required to reduce the shot fall zone and to enhance regular recovery of lead shot. Information on the costs of such measures are very limited for GB is very limited. ECHA (2021) have produced some rough estimates of these costs to show the potential scale of the costs rather than exact calculations. The costs are based on the Finnish BAT (Kajander and Parri, 2014), which reports cost for installation of a berm between €300 000 and €600 000. Adding groundworks, ECHA calculates the costs at €3.5m per berm not including installation of shot nets.

Another solution is placing a net at a suitable distance and combine it with suitable surface coverage of the impact zone. ECHA estimates the costs of such nets based on a unit price of €250 per m^2 (source KNSA). Assuming this to be installed with aheight of 5 meters high over ¼ of a circle at 150-metre distance and correcting for inflation would give investment costs of **€300 000 - €400 000** for shot nets. Other costs might arise, that have not been calculated, such as materials, costs for containment, monitoring and, where necessary, treatment of surface (run-off) water to ensure compliance with the environmental quality standard (EQS) for lead specified under the Water Framework Directive.

ECHA takes forward the costs provided by the Finnish BAT for design and implementation of **measures for pollutant management (€1 500 000)**, and the costs for **maintenance (€50 000** for a 10-year period) and assumes that such measures would be suitable to achieve a recovery rate of > 90 %.

Furthermore, the costs for a final clean-up of the range need to be considered. Two case studies have been found that describe the cost of remediation to remove lead contamination at end of service life. Based on those examples, the total costs of soil removal to recover lead from the main impact areas of one range at the end of service life are assumed to be €750 000 - 950 000. For remediation of the whole area of a shooting range (of about 60 000 m^2) more than €1 million is assumed.

To calculate the costs for regular soil removal each 5 to 15 years, the second example provides information implying that the cleaning of contaminated soil would cost at the minimum **€126 per m^3**.

Further justification and evidence, including on costs and benefits to support a possible derogation will be sought during the consultation stage.

Costs for the impact on the environment

Contaminating soil with lead has a negative impact on the environment because it can beassumed that a fraction of the lead deposited will be mobilized over the time leading to increased lead concentrations in water, soil, plants and consequently entering the food chain. No monetisation of this negative impact was performed as the necessary information on costs of remediation is not available at this stage. More information will be sought through the consultation stage.

Total costs of RMMs

The ECHA report estimates the total cost to implement RMMs to all sites in the EU27 at €6.2bn - 11bn. The purpose of this estimate is not to give an exact cost but rather to obtain an order of magnitude estimation that can be refined further with information coming from the consultation.

Those costs are calculated for the assumption that all sited will be equipped with RMMs to achieve lead recovery of high effectiveness (> 90%). The value that was deduced 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/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.

2.6.2.2 Bullets

The ECHA report has examined the cost and other economic impact for the measures for lead abatement with regards to the derogation from the ban on the use of lead bullets under strict conditions (such as regular bullet recovery of > 90 % by means of bullet trap).The calculations for the costs involved with such a strict derogation are presented in Table 2.21 and

Table *2.22* for both small calibre and large calibre bullets. The data is not available to perform the same type of analysis for GB, therefore Table 2.21 and

Table *2.22* present an indication of costs for GB calculated as a proportion of the ECHA costs, converted into GB and inflated to current prices.

Table 2.21 Calculation of costs associated with different bullet traps for small calibre bullets

Parameter	**Data**		
Releases	n/a		
Type of RMM	Steel container, €2,000 basic cost, adaption needed	Stapp bullet trap	Sacon bullet trap
Number of ranges in GB	n/a	n/a	n/a
% already installed with suitable bullet trap	n/a	n/a	n/a
Number of stands per range	n/a	n/a	n/a
Cost 20 year period (NPV, 4%), low	2,867,097	14,335,485	31,538,066
Cost 20 year period (NPV, 4%), high	5,734,194	28,670,969	63,178,529

Table 2.22 Calculation of costs associated with different bullet traps for large calibre bullets

Parameter	Data		
Volume of lead	n/a		
Type of RMM	Steel container, €2,000 basic cost, adaption needed	Stapp bullet trap	Sacon bullet trap
20 year cost (per stand)	£410	£2,048	£4,505
Yearly cost	£21	£103	£228
Number of ranges in GB	n/a	n/a	n/a
% already installed with suitable bullet trap	n/a	n/a	n/a
Number of stands per range	n/a	n/a	n/a
Cost 20 year period (NPV, 4%), low	£3,174,286	£16,281,015	£35,941,108

2.6.2.3 Cost – effectiveness and cost- benefit considerations

Assessing the cost-effectiveness of the proposed restriction on shooting for GB is very difficult due to the lack of information on the costs and especially the risk management measures, but also because of the uncertainty around releases. The ECHA report has assessed cost-effectiveness of the proposals and finds the restriction on shooting with gunshot to be as cost- effective as cost effective as previous REACH restrictions. Table 2.23 summarises the costs of the different proposals. However, the restriction with derogation and RMMs for lead shot is estimated to have very high costs. Further information to calculate these costs is needed but it seems that substitution would be a more cost-effective option. For the restriction of shooting with bullets, cost-effectiveness is not possible to assess for GB due to lack of accurate data on releases from the different calibres. The ECHA assessment is presented and shows that the proposal is cost-effective.

Table 2.23 Cost effectiveness

Risk Option	Emission avoided over 20-year period (t)	Cost over 20- year period	Cost-effectiveness (£/kg avoided release)
Ban on marketing and use of lead shot for sports shooting	25,200	£25,496,684	£1.01
Ban on marketing and use of **lead shot** for sports shooting with derogation under strict conditions (> 90% recovery)	24,060	Costs of RMMs have not been calculated but ECHA estimates ~8billion euro	ECHA estimate of cost-effectiveness is ~17€/kg
Ban on use of **bullets - small calibre** - for sports shooting with derogation under strict conditions (> 90 % recovery)	389-972*	£14,335,485 – 28,670,485	no reliable estimate for GB but ECHA finds a range of 0.66 - 1.32 €/kg for small and 1.01 – €2.01 €/kg for large calibre
Ban on use of **bullets - large calibre** - for sports shooting with derogation under strict conditions (> 90 % recovery)		£16,281,015	

* very uncertain data that cannot be split between large and small calibre

Cost benefit considerations

For sports shooting a number of benefits were identified such as avoided impacts to the environment and wildlife The impacts have not been quantified and monetised.

Proportionality

ECHA finds that comparing the costs to sport shooters with the overall benefits of this proposal makes it plausible that this restriction is proportionate. However, for GB we don't have enough information to assess proportionality. More evidence from the consultation stage will update the analysis.

2.7 Uncertainties and sensitivity

There are several uncertainties around the impacts of the restriction, which the Agency is hoping to reduce by collecting more evidence through the consultation stage. These are mainly:

- Transition period: What would be the impact on releases?
- The impact of voluntary measures and the impact of the ECHA restriction coming into force.
- Lack of evidence around some of the key metrics of usage, especially for bullets.

At this stage because of the uncertainties and the lack of GB data, the Agency has not done a sensitivity analysis. The Agency is planning to include a sensitivity analysis in the next update of this assessment following the review of evidence from information gathered from the consultation stage.

3 Conclusions

For all the uses of lead included in this dossier, the Agency concludes that the use of lead shot and bullets pose a risk to the environment and/or human health that is not adequately controlled and needs to be addressed at a GB level.

3.1 Hunting

The Agency concludes that the use of lead ammunition for shooting live quarry presents a risk to both the environment (particularly birds) and human health (via secondary exposure through the consumption of lead-shot game) that is not adequately controlled and needs to be addressed. No risk management measures were identified that would adequately address the risks to either the environment or human health to allow continued use.

Lead shot is already banned for use over wetlands in GB, so alternatives are already available on the GB market, especially steel shot. Some shooters have already made the transition to these, and a number of UK shooting and rural organisations have voluntarily committed to using alternatives to lead shot for the hunting of live quarry by 2025, whilst some supermarkets have also committed to only selling game meat from animals killed using non-lead ammunition. Alternative larger calibre bullets are already available, but alternative small calibre bullets are not yet widely available. There is a move to lead-free ammunition, with the in-progress EU restriction also proposing a ban on lead bullets for hunting. It is therefore likely that more alternatives will be developed and brought to market over time, and that prices for non-lead bullets will eventually decrease. A ban on the use of lead ammunition for hunting is therefore considered practical, with appropriate transition periods. As lead-free alternatives are already available for lead shot and large calibre bullets, a transition period of 18 months is proposed. A longer transition period of 5 years is proposed for small calibre bullets (including air rifles).

Banning the use of all forms of lead ammunition for hunting will remove the risks from this source of lead posed to humans via the consumption of game meat. Banning lead shot would prevent the primary poisoning of many bird species via ingestion of lead shot, and together with a ban on the use of lead bullets for hunting, raptor and scavenging species would also be protected from secondary poisoning. Compliance with the existing lead shot bans over wetlands is thought to be low, so a total ban on the sale and use of lead shot would also tackle this issue.

A ban on the placing on the market and use of lead ammunition for hunting purposes is monitorable and enforceable in principle, as inspections can be made at the point of sale. It would be a legally enforceable version of the shooting industry’s own commitment to phase out lead shot for this purpose, though extended to include bullets. Game carcasses could also be monitored for lead shot, bullets or bullet fragments and inspections made of organised hunts.

Some other options (such as mandatory product labelling, training for hunters and potentially a buy-back scheme) could provide useful supplementary options to support the restriction, especially since lead bullets in particular would still be readily available for sports uses (see below).

The proposal is estimated to reduce the amount of lead released in shot and bullets by up to around 75 % over a 20-year period (compared with the baseline estimate of 114,420 and 290 tonnes for shot and bullets, respectively). The figures for bullets in particular are uncertain. The socio-economic analysis shows that even with a very partial monetisation of the benefits from this restriction, the costs of the restriction are very close to the benefits.

3.2 Sports shooting

3.2.1 Lead shot

The Agency has concluded that the use of lead shot for sports shooting presents a risk to the environment (particularly birds, soil, vegetation and livestock) that is not adequately controlled and needs to be addressed. No risk management measures were identified that would adequately address the risks to the environment to allow continued use.

Banning the use of lead shot for sports shooting will prevent the primary poisoning of many bird species via ingestion of lead shot, and therefore also protect raptor and scavenging species from secondary poisoning. In addition, a ban would prevent the build-up of lead shot in areas of high use, avoiding an increase in lead concentrations in soil and vegetation over time and reducing the risks posed to grazing livestock (and other animals).

Alternatives to lead shot are already available. A ban on the placing on the market and use of lead shot is therefore considered practical, monitorable and enforceable in principle, as inspections can be made at the point of sale. Sports shooting ranges can also be checked to ensure that they have appropriate measures in place to prevent the use of lead shot at their sites.

A complete ban would be the most effective risk management option. However, the Agency is aware that the use of lead shot is required for national and international competitions in some shooting disciplines. To enable GB athletes to continue to train and compete, an optional derogation for a licensing system allowing the relevant athletes to continue training, and suppliers to continue sales to these authorised athletes, could be considered. This optional derogation would also include a licensing system for the ranges where this training takes place to ensure that the risks to the environment from this activity are minimised by the use of lead collection systems. This optional derogation would not be fully effective at removing all the environmental risks identified. The feasibility of any licensing system needs further consideration.

The complete ban is estimated to reduce the amount of lead released as shot by up to around 95 % over a 20-year period (compared with the baseline estimate of 33,600 tonnes), based on a transition period of 5 years. The optional derogation is estimated to reduce the amount of lead released as shot by around 70 % over a 20-year period (compared with the baseline estimate of 33,600 tonnes). The socioeconomic analysis shows the total ban will be cost-effective, but more information is required on the costs of risk management measures in order to assess the optional derogation.

3.2.2 Lead bullets

Alternatives to large calibre and small calibre bullets with adequate performance are not yet widely available for sports shooting. The Agency has concluded that the use of lead bullets for sports shooting presents a risk to the environment (particularly soil and vegetation). A complete ban would be the most effective risk management option. However, the Agency is aware that the use of lead bullets is required for national and international competitions in some shooting disciplines. Since bullets are generally used at specific shooting ranges, the Agency considers that a licensing system for suppliers and athletes is not necessary. Instead, the risk can be adequately controlled by the use of appropriate risk management measures at shooting ranges, as recommended in the EU REACH registration dossier for metallic lead to ensure safe use (the Agency anticipates that these will also be included in the full UK REACH registration dossier when it is submitted in due course). To ensure compliance, the proposal is to restrict the use of lead bullets for sports shooting, with a derogation if the sports shooting range can demonstrate appropriate containment and collection of the bullets and the site is not also used for agricultural purposes. The proposed derogation would allow continued use of lead bullets by all sportsmen and women, so long as this occurs at licenced sites that have appropriate risk management measures in place.

This proposal is considered to be enforceable and monitorable in principle as shooting ranges can be inspected to confirm the presence of the risk management measures and environmental monitoring of lead could give further data to demonstrate compliance. As for lead shot, the feasibility of any licensing approach needs to be examined further.

A transition period of 18 months is considered appropriate for sports shooting with the large calibre bullets and 5 years for the small calibre bullets, due to the availability of substitutes.

The proposal is estimated to reduce the amount of lead released in bullets by up to around 67% over a 20-year period (compared with the baseline estimate of 1,440 tonnes). Initial estimation of the costs show that the proposal would be cost-effective, but more information on releases by calibre is needed for a more robust estimate.

4 Glossary

AEWA	African-Eurasian Migratory Waterbirds
AHVLA	Animal Health and Veterinary Laboratories Agency
ATSDR	Agency for Toxic Substances and Disease Registry
BASC	British Association for Shooting and Conservation
BLL	Blood Lead Levels
BOCC	Birds of Conservation Concern
CKD	Chronic Kidney Disease
CLP	Classification, Labelling and Packaging of substances and mixtures
COT	Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment
CPSA	Clay Pigeon Shooting Association
CSR	Chemical Safety Report
DALYs	Disability Adjusted Life Years
Defra	Department for the Environment, Food and Rural Affairs
ECHA	European Chemicals Agency
EFSA	European Food Safety Authority
EiF	Entry into Force
EQS	Environmental Quality Standard
EU	European Union
FACE	European Federation for Hunting and Conservation
FITASC	Federation International des Armes de Chasse
FSA	Food Standards Agency
GB	Great Britain
GBP	Great British Pounds Sterling
HSE	Health and Safety Executive

IQ	Intelligence Quotient
ISSF	International Sports Shooting Federation
IUCN	International Union for the Conservation of Nature
JECFA	Joint FAO/WHO Expert Committee on Food Additives
LAG	Lead Ammunition Group
MCL	Mandatory Classification and Labelling
NPV	Net Present Value
PACEC	Public and Corporate Economic Consultants
PHE	Public Health England
PNEC	Predicted No Effect Concentration
PV	Present Value
RAC	Risk Assessment Committee
RMM	Risk Management Measure
TP	Transition Period
UK	United Kingdom
VSLY	Value of a Statistical Life Year

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