Committee for Risk Assessment (RAC)

Ad-hoc RAC Supporting Group

Evaluation of an

Annex XV dossier proposing a restriction on

Lead and its compounds

in outdoor shooting and fishing

Work Package WP B.2

Risk of alternatives to lead in ammunition and fishing tackle

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Contents

1. Description of the Work Package

1.1. Background

As a consequence of the proposed restriction, hunters and fishers affected will have to switch to alternative ammunition and fishing tackle. According to the Dossier Submitter, there are various alternatives to lead in ammunition and fishing sinkers e.g. steel, copper, bismuth, tungsten.

This work package report describes the alternatives to lead ammunition and fishing tackle available and their risks to human health and the environment.

1.2. Objectives

The following topics are covered in the present work package:

- Relative risk reduction from use of alternatives:
  - Human health
  - Environment: birds, aquatic / terrestrial compartment
- Does the use of alternatives affect (increase) the mobility of lead in soils at existing shooting ranges?
- Ricochet
- Noise
- Other externalities (GHG potential, circularity)

2. Summary of the Dossier Submitter proposal

Based on the analysis performed of the available information, the Dossier Submitter concludes that alternatives to lead gunshot, in particular **steel gunshot**, can be used effectively in hunting and sports shooting. Other alternatives, such **as bismuth or tungsten-based gunshot**, can also be used to replace lead gunshot. Among the alternatives for lead gunshot, the Dossier Submitter includes in its assessment coated lead which has been placed on the market on various forms, i.e., **coated with nickel or copper.**

Lead bullets are usually semi-jacketed which consist of a hard lead alloy core and a jacket partly surrounding this core. The semi-jacket of most bullets consists of tombac, a copper-zinc alloy with a copper content of >80 %. In addition, there are semi-jacketed lead-containing bullets with a semi-jacket consisting of steel for hunting (Gerofke et al., 2018). The Dossier Submitter states that most of the non-lead bullets developed to replace lead are made from **pure copper or copper-zinc** alloy (brass), with or without other metal jacket coatings. Polymers are also used in the manufacture of bullets, for example, as a polymer shell to encase the lead projectile or as a major component of the bullet. According to the Dossier Submitter, a wide variety of non-lead bullets already exist for most larger game; the challenges in substitution are within the smaller calibres that are used for hunting smaller game and pests and the calibres used at sports shooting.

Additionally, alternatives to lead fishing sinkers and lures are widely available on the EU market including, for example**, bismuth, ceramic/glass, copper and its alloys (such as brass and bronze), concrete, high density polymers, iron, reinforced bars (rebar), (stainless) steel, stones or pebbles, tin, tungsten, zamac (zinc-aluminium alloy), and zinc.**

In their assessment of the risks of the alternatives to lead ammunition and fishing tackle, the Dossier Submitter has identified potential human health risks related to inhalation exposure to particles or fumes from alternative substances while shooting or home-casting. Potential health effects of alternative metals include respiratory tract irritation (e.g., copper), metal fume fever (mainly zinc) and risk for carcinogenic effects in the respiratory tract (e.g., nickel). With regards to dermal exposure, the handling of ammunition and fishing tackle is not expected to pose a human health risk for the majority of alternative substances, except in the case of nickel, which has skin sensitising properties. Furthermore, the consumption of meat from game hunted with non-lead ammunition is not likely to result in a health risk for consumers if game meat hygiene measures have been properly applied.

The major environmental risks identified by the Dossier Submitter for alternative materials are related to the aquatic environment and to wildlife feeding on wounded or dead birds or on the viscera of game left in the field.

The Dossier Submitter notes that zinc and copper are classified for aquatic toxicity in powder form. Additionally, nickel, zinc and lead-coated ammunition and fishing tackle may result in a risk to wildlife if ingested. Birds may pick up the shot/weights from the ground or from the bodies of wounded or dead birds. Spent alternative bullets and their fragments may also be ingested by scavengers from discarded gut piles, non-retrieved killed or wounded animals. The lead coating will be abraded by the gizzard action once ingested by the bird and the lead core will be dissolved in the highly acidic environment of the avian stomach, as tested by Irby et al. (1967).

3. Relevant information from the consultation of the Annex XV restriction report

Numerous comments were submitted regarding the availability and suitability of alternative materials. The main comments related to the risks from the alternatives to lead are discussed in section 4 below.

4. Evaluation

4.1. Background information on alternatives

Gunshot in hunting

In the case of gunshot, lead has historically been used as gunshot in cartridges (TemaNord, 1995) because of its:

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

Based on these properties, lead is often considered to be an ideal material for use in ammunition. Other materials often have somewhat different ballistic behaviour to lead but this does not necessarily result in a conclusion that they are technically inferior to lead gunshot. Among the alternatives for gunshot, the Dossier Submitter includes in its assessment coated lead which has been put on the market on various forms, i.e., coated with nickel or copper.

Non lead options were widely assessed in the restriction proposal for lead in shot over wetlands. The main alternatives for lead in shot are based on the use of different metals with steel and bismuth as the most commonly used materials, although tungsten-based cartridges are also available.

The European markets are dominated by **steel** shot because of price, availability (Thomas, 2019) and also performance, which is seen comparable to lead (Scheuhammer, 1995; Pierce, 2014)[1].

Bismuth is recognised to have good performance provided the shot size is increased to allow for density lower than lead. Originally used in its pure form, nowadays it is generally alloyed with 3–6 % tin to reduce its frangibility. This material has been considered suitable and fully approved in USA and Canada (Thomas 2019). According to the Dossier Submitter, bismuth can be used as alternative to lead without concerns over compatibility with guns. The Dossier Submitter considers that 100 % of new guns currently on the market are compatible with steel gunshot and that a maximum of 15 % of existing (old) guns (pre 1961) may not be compatible with steel gunshot. In this case, bismuth can be a solution. It is available in most gauges and with a wide variety of loadings. Main issue with bismuth is that it is a scarce metal, which is produced as a by-product of lead production as pointed out in several comments in the consultation on the Annex XV report.

Tungsten has a density which makes it favourable for good ballistics and performance, so the percentage of tungsten in shot material is important for alloys. This alternative is suitable for use in appropriately proved guns and widely available, and in the US for example, it has been approved as nontoxic alternative by the US Fish and Wildlife Service. As for bismuth, the availability of tungsten is limited globally and its price is higher than steel.

Other alternatives are proposed by the Dossier Submitter, including copper and its alloys, zinc and its alloys or tin. As described later on, some of these alternatives are not recommended because of their (eco)toxicity (i.e., zinc).

In terms of the suitability or performance of alternative shot in killing game, this has already been evaluated in the Annex XV restriction report on the use of lead in shot over

[1] Steel is one hundred times harder than lead, with only two-thirds its density, resulting rather different ballistic properties when compared to lead. Therefore, rather than steel, “soft iron” is used for shots, which is manufactured by annealing iron containing approximately 1 % or less carbon (Thomas, 2019)

wetlands (ECHA, 2018b), and by ECHA's Committees for Risk assessment (RAC) and Socio-Economic Analysis (SEAC). The conclusion of SEAC on alternative ammunition was that steel gunshot has a comparable performance once shooters have adjusted to its ballistic properties, e.g., in terms of patterning.

Gunshots in sports shooting

According to the Dossier Submitter, although the evidence concerning the use of alternative shot in competitive clay target shooting is less clear than for hunting, Thomas and Guitart (2013) report that **steel** shot meet all the ISSF technical requirements. The rules on firearms and the corresponding ammunition that can be used in Olympic events is given in the "official statutes, rules and regulations" developed by the International Sports Shooting Federation (ISSF). For all disciplines, lead or other soft material must be used as the projectile but an approval of the material by the ISSF is required.

In non-Olympic events, governing rules are set out by the FITASC, who in their rules state that the use of lead is mandatory. This means that ISSF and FITASC rules encourage the use of lead both in official and non-official events.

Nevertheless, there are possibilities to substitute lead by steel, provided the ISSF and other federations (IOC) would allow it, as shot made from steel is currently not approved by the ISSF.

Bullets in hunting

The Dossier Submitter summarises the alternatives to lead bullets which include coated lead bullets and non-lead alternatives. **Coated lead bullets** are usually semi-jacketed bullets which consist of a hard lead alloy core and a jacket partly surrounding this core. The percentage of other metals (mainly antimony, arsenic and zinc) determines the degree of hardness of the alloy. The semi-jacket of most bullets consists of tombac, a copper-zinc alloy with a copper content >80 %. Additionally, Tombac always contains arsenic, which determines the hardness of the material. Furthermore, there are semi-jacketed lead-containing bullets with a semi-jacket consisting of steel for hunting. Semi-jacketed bullets are expanding bullets. However, there are also full metal jacket bullets (FMJ), which have lead core surrounded by an outer shell ("jacket") of harder metal (gilding metal, cupronickel, or, less commonly, a steel alloy). These are not expanding bullets and are allowed for hunting of specific game in Nordic and Baltic countries only. FMJ bullets are also commonly used by the military (military uses are outside the scope of this proposal).

The main non-lead alternatives on the market developed to replace lead are made from **pure copper** or **copper-zinc alloy**, with or without other metal jacket coatings (Paulsen et al. 2015; Thomas et al. 2016). Non-lead monolithic bullets consist of almost pure copper (density 8.96 g/cm^3) or 100 %-electrolyte copper. Copper can also be alloyed with approximately 5 % (up to 40 %) zinc brass to make similar non-lead bullets (Thomas, 2019). **Bronze**, which is made out of 90 % copper and 10 % tin is potentially suitable for bullets, although metal hardness can be problematic. **Tombac** is another material used which consist of copper mixed with a higher zinc content (5 to 20 %). In tombac there is additionally always arsenic present which determines the hardness of the material. The semi-jacket of most bullets consists of tombac (Gerofke et al., 2018).

Other materials include **polymers** which can be used differently. Polymers can be used as a shell to encase the lead projectile, as nose of the bullet or as a major component of the bullet. **Tungsten** can be used at any concentration as a densifier with other approved material (Thomas, 2019).

Although viable alternatives exist for most cases, the present state of industry capabilities suggests that the following types of hunting would be mostly impacted in case of a ban on the use of lead bullets:

- Rimfire hunting (22 LR, etc.), used for hunting the smallest game species and when shooting small predators caught in cage traps.
- Full Metal Jacket (FMJ) bullets in small game hunting, e.g., Nordic bird hunting. This type of bullet is used for long distance shooting and high accuracy is demanded.
- For seal hunting (where this is allowed for population management purposes), lead bullets are stated to be required for the high precision needed.

For calibre 5.6 mm (centrefire) and larger, it is generally accepted that modern, well-maintained, rifles can be used to fire accurately non-lead as well as lead bullets within most hunting situations.

The use of air rifles for hunting is practically zero, although some use is authorised for pest control. Unlike for lead bullets, there are no known studies or peer reviewed tests that would compare the performance of lead and non-lead (often tin) based airgun pellets for hunting.

Hunting with muzzle loading, historic arms can be grouped under the ‘black powder hunting ‘category. This modality of hunting is only authorised in Finland, UK, France, Spain, Italy, Hungary and Denmark. Muzzle-loading shotguns are used for hunting live quarry and for clay pigeon shooting. The number of these types of guns in Europe is unknown.

Bullets in sports shooting

The Dossier Submitter indicates that for the rifle and pistol projectiles, the ISSF rules state that the projectiles made of “lead or other (similar) soft material” are permitted. However, the viable alternatives for the bullet calibres used in sports shooting providing the level of accuracy needed are limited.

Fishing sinkers and lures

Lead has remained very popular with fishers because it is cheap, performs well, is versatile and none of the non-lead alternatives currently offer the overall performance of lead sinkers and lures in terms of mass density, malleability, ease of production and cost. Nevertheless, there are functional alternative with a competitive price on the market. These alternatives include bismuth, brass, bronze, ceramic/glass, copper, concrete, high density polymer, stainless steel / rebar, stones or pebbles, tin, tungsten, zamac, and zinc. Lead coated with plastic is also used.

Among the alternatives, **bismuth** has successfully been used for some fishing sinker applications (e.g. nail sinker type), and seems suitable as sinkers and lures according to Thomas (2019). Yet, the use of bismuth as an alternative is rare.

Ceramic sinkers are also reported to be an adequate alternative in fisher blogs, despite their larger size, which could be a disadvantage.

Stones seem to be a popular alternative among the carp fishers especially in soft or muddy bottoms. They offer good camouflage for the fish and can be made by the fishers themselves or purchased from retailers that are specialised in this type of alternatives. Similar to stones, concrete is also used.

Another alternative is **steel** which has also successfully been used as a replacement for lead for some fishing sinker applications. In order to prevent corrosion, the steel weights must be coated or be made from stainless steel.

Tin is also widely used as an alternative for lead split shot fishing sinkers because its softness and ductility/malleability meet the requirements of this application (i.e., it can be pinched repeatedly on and off fishing lines).

Also **tungsten** has successfully been used as a replacement for lead for some fishing tackle applications. This material has the advantage of being smaller and harder than lead and therefore less likely to get stuck on rocks. Its price is, however, higher. Powdered tungsten can be mixed with a soft polymer putty that can be squeezed around fishing lines, and then be removed and re-used later. Such putty could be used to replace lead split shot for example. Tungsten powder can also be mixed with hard plastic polymers and shaped into many forms designed for use as fishing sinkers using thermoforming technology.

Other reported alternatives include **brass, bronze, iron, high density polymer, glass, zinc** or other approved material.

4.2 Risk of alternatives

For the analysis on the risks of alternatives to human health and the environment, the Dossier Submitter combines the hazard and exposure data of alternatives and compares them with the main risks identified for lead both for human health and for the environment. The analysis is supported by data on the alternatives assessed and listed as non-toxic for wildlife by the US Fish and Wildlife Service (US FWS, 1997).

Table 1 below (Table C.3-1 from Annex 3 of the Background Document) summarises the risk reduction potential of the alternatives described by the Dossier Submitter.

Table 1: Toxicity of the alternative substances compared to lead

Alternative material	Human health inhalation (mg/m^3; inhalable)	Human health Game meat (game meat)	Aquatic toxicity	Wildlife toxicity (ingestion)
Lead	**Yes**, risk increases with calibre, frequency, low ventilation	**Yes**	Depending on Pb release from shot: Pb metal not classified; Pb powder Aquatic Acute/Chronic 1	**Yes**
Alternative shot for hunting				
Lead, coated	Risk seems low	**Yes**	Depending on release of and risk of coating material and release of Pb over time	**Yes**
Bismuth-tin (3-6 %) alloy	>13 (Bi)	No	No: Bi not classified	No
Brass (copper-zinc alloy)	>1 (Cu) >2 (Zn)	No	Depending on Cu, Zn (and Pb) release from shot	
Bronze (copper-tin alloy)	>1 (Cu) >2 (Sn)	No		
Copper (Cu)	>1 (Cu)	No (based on data generated with Cu bullets)	Depending on Cu release from shot: Cu metal not classified; Cu granulated Aqua Chronic 2; Cu powder self-class. Aqua Acute/Chronic 1	No
Nickel (Ni) (alloying metal)	**>0.03; carc (Ni)**	**>4 µg/kg**	Depending on Ni release from shot: Ni metal not classified; Ni powder Aquatic Chronic 3; Ni release from shots	**Yes**

Alternative material	Human health inhalation (mg/m^3; inhalable)	Human health Game meat (game meat)	Aquatic toxicity	Wildlife toxicity (ingestion)
Steel (soft iron >99 % Fe)	>3 (Fe)	No oral	No: Fe not classified	No
Tin (Sn)	>2 (Sn)	No hazard identified	No: Sn not classified, Sn release from W shot under anaerobic conditions	
Tungsten (W)	>5 (W)		No: W not classified; no W release from shots	No
Tungsten - bronze	>5 (W) >1 (Cu)		No: Cu release 30-50-times lower than from Cu shot	
Zinc (Zn)	>2 (Zn); zinc fever		Depending on Zn release from shots: Zn metal not classified Zn powder Aquatic Acute/Chronic 1	**Yes**
Alternative bullets for hunting				
Lead, coated	Low	**Yes (based on Pb data)**	n/a	**YES**
Copper, pure	>1 (Cu)	No (based on data)	n/a	No
Brass (copper-zinc <40 %)	>1 (Cu) >2 (Zn)	No (assumed based on Cu and Zn data)	n/a	
Bronze (copper-tin 10 %)	>1 (Cu) >2 (Sn)		n/a	
Tombac (copper-zinc up to 20 %)	>1 (Cu) >2 (Zn)	No	n/a	

Alternative material	Human health inhalation (mg/m^3; inhalable)	Human health Game meat (game meat)	Aquatic toxicity	Wildlife toxicity (ingestion)
Tungsten (often used as alloying metal)	>5 (W)	>0.48 mg/kg bw (DNEL oral)	n/a	
Zinc	>2 (Zn); zinc fever	No (based on data)	n/a	**YES**
Alternative fishing tackle				
Lead, coated		n/a	Depending on releases of coating material and Pb over time + Might fall under the microplastics definition	**YES** **+** Might fall under the microplastics definition
Bismuth	>13 (Bi)	n/a	Bi not classified	
Brass	Home-casting less likely	n/a	Cu, Zn (and Pb) release under certain conditions	
Ceramic/Glass		n/a		
Copper	Home-casting less likely	n/a	Cu metal not classified; Cu granulated Aqua Chronic 2; Cu powder self-class. Aqua Acute/Chronic 1; Cu release from shot under certain conditions	No
Concrete		n/a		
High density polymer	Home-casting not likely	n/a	Might fall under the microplastics definition	Might fall under the microplastics definition
Iron	Home-casting less likely	n/a	Fe release but Fe not classified	

Alternative material	**Human health inhalation (mg/m^3; inhalable)**	**Human health Game meat (game meat)**	**Aquatic toxicity**	**Wildlife toxicity (ingestion)**
Rebar (for reinforcing bar)	Home-casting not likely	n/a		
Stainless Steel (e.g., 11 % Cr, 8 % Ni)	Home-casting not likely	n/a	Corrosion resistant: no releases of Fe, Cr or Ni	
Steel (Fe, <2 % carbon; 1 % Mn)	Home-casting not likely	n/a	Not corrosion resistant: releases of Fe (not classified) and Mn (Mn self-classified Aquatic Chronic 2 or 3)	
Stones and pebbles				
Tin	>2 (Sn)	n/a	Sn not classified, Sn release from W shots under anaerobic condition	
Tungsten	Home-casting not likely	n/a	W not classified; no W release from shot	No
Zamac or Zamak™	>2 (Zn);	n/a		
Zinc	>2 (Zn) zinc fever;	n/a		**YES**

Human health risks of alternatives

The Dossier Submitter considers that potential human health risks related with the use of alternative substances could result from inhalation of fumes/dusts from shooting and home-casting and from the consumption of game bagged with such alternative substances.

As discussed in the work package report WP A.3, airborne lead exposure and related risks can be significantly reduced by using a non-lead primer and jacketed or non-lead bullets. On the basis of the available data, it is however not fully clear how much primer vs shot/bullet impacts on the total emissions caused by shooting.

For the case of non-lead alternatives only limited information is available on the metal emissions following controlled shooting with defined alternative shot and/or bullets compared to lead shot or bullets.

One series of publications suggested a health risk from exposure to copper and possibly zinc in volunteers from controlled shooting with alternative bullets (Voie et al., 2014). However, the exposure scenario of this study reflects a military use, and therefore the results are most probably less relevant for hunting or outdoor sports shooting activities especially when considering that the shooting was performed in semi-air-tight tent made of plastic and wood. Yet, in the absence of reliable data on exposure following hunting and outdoor shooting activities, the Dossier Submitter considers that it provides information that may be considered as “worst case” for the general population (hunter or sports shooter). In the study, 54 to 55 healthy men per study were shooting in a semi-airtight tent for 60 min with either leaded (SS109, RUAG), non-leaded (NM229, NAMMO), or modified non-leaded ammunition (n= 19; NM255, NAMMO). Especially the copper levels in air exceeded the DNEL derived by industry (1 mg/m^3, fraction not specified) in the case of both leaded and non-leaded ammunition, being two times higher in the case of non-leaded ammunition. It should be noted that SCOEL has given an IOELV recommendation of 0.01 mg/m^3 for respirable fraction of copper. Also, the zinc concentration exceeded the German MAK value for respirable (0.1 mg/m3) but not for inhalable fraction (2 mg/m^3), the levels in the case of non-leaded ammunition being higher.

In 42 of the 54 volunteers, general symptoms such as chills, headache and/or malaise appeared 3–12 h after shooting. More symptoms were reported when non-leaded ammunition was used compared with leaded and modified non-leaded ammunition (Voie et al., 2014). Copper and zinc fumes are known to cause so-called metal fume fever when exposed at high level especially after a break in exposure (e.g., in occupational settings typically after holidays). A follow-up study evaluated the effects of shooting with leaded and non-leaded ammunition on the respiratory function and did not detect any difference between the type of bullets (Borander et al., 2017 [2]). RAC concludes that also when using non-leaded bullets, it is important to ensure good ventilation and follow-up the levels of air impurities, including copper and zinc fumes. However, the risk for elevated levels is higher in indoor shooting which is outside the scope of this restriction. In outdoor shooting the levels are expected to be significantly lower when compared to the levels measured

[2] https://pubmed.ncbi.nlm.nih.gov/28408655/

in confined spaces with poor ventilation. In addition, the hazards related to zinc and copper fumes are mainly limited to non-cancer lung effects (including inflammation, and metal fume fever after high exposures). Neither of them is accumulating in the human body.

No information could be retrieved on the metal concentration in the air while home-casting bullets or fishing sinkers and lures. Based on their melting points, bismuth (271°C), tin (232°C), zinc (420°C), and zamac (380-390°C) could be considered to be potentially used for home-casting of bullets and/or fishing sinkers and lures. Antimony (630°C), aluminium (660°C), copper (1085°C) and its alloys such as brass (900-940°C) or bronze (950°C) would require specific equipment for home-casting. Fumes formed in home-casting from metals like zinc cannot to be excluded. However, since there is no data on exposure levels, no conclusion whether this poses a risk to human health can be reached. As mentioned above, hazards related to zinc fumes are mainly inflammatory lung effects and metal fume fever (at levels above 2 mg/m^3).

Further to the inhalation assessment, the Dossier Submitter evaluates the risk of handling alternative ammunition and fishing sinkers and lures and concludes that the handling of ammunition containing nickel is of potential risk with regards to skin sensitisation. RAC wants to emphasise that this applies only to alloys likely to release relevant amounts of nickel. Alloys containing nickel are classified for skin sensitisation when the release rate of 0.5 µg Ni/cm^2/week, as measured by the European Standard reference test method EN 1811, is exceeded. The handling of alternative ammunition or fishing sinkers and lures containing iron (steel), copper, bismuth, tin, tungsten is considered to be of no relevant risk.

In the case of the risks from meat consumption from game hunted with alternative ammunition, the use of semi-jacketed expandable bullets may not have risk-reduction benefits since this coating allows expansion of the lead bullet and thereby does not prevent contamination of the game meat with lead. Most of the coated bullets used for hunting are semi-jacketed bullets. Full metal jacket (FMJ) bullets can be used for the hunting of specific game in Nordic countries. The Finnish Hunting association (comments #3255) performed a field test suggesting that FMJ, open tip match bullets (OTM) and .22 LR bullets do not cause lead contamination in game meat. In field tests the weight difference of FMJ, OMT and .22LR before and after impact was negligible (some bullets were even reported with higher weight after impact due to meat remnants that got stuck in the bullet). This suggests that these bullets do not cause significant contamination of game meat with lead. Small calibres and FMJ or OTM bullets are allowed only for use in the hunting of small game or seals in some countries (Scandinavia, Baltic countries).

For non-lead alternatives, data available on the contamination of meat is limited. No data on bismuth levels in game meat hunted with bismuth ammunition are available. However, bismuth has shown a low toxicity in sub-chronic toxicity study in rats even when a water-soluble salt has been administered. It is therefore considered to cause a low concern for human health due to the consumption of meat from game hunted with bismuth.

Reliable data on the metal concentration in game meat following the use of alternative shot or bullets are only available for game hunted with copper and zinc bullets. The most comprehensive study, by Schlichting et al. (2017), examined the contamination of copper and zinc in game meat from roe deer, wild boar and red deer hunted either with lead bullets (surrounded by a tombac jacket with a high copper and zinc content) or non-lead ammunition (solid bullets made of copper or alloys of copper and zinc). The outcome of this study shows that the use of both lead-based ammunition and alternative non-lead ammunition results in the contamination of edible parts of the game with copper and zinc at levels similar to those reported in other studies and comparable to the levels regularly detected in meat and its products from livestock (pig, cattle, sheep). If the mean or median values are considered, then the intake of copper is between 0.2 and 0.5 mg and the intake of zinc is between 5.2 and 7.5 mg per day for average consumption. The authors of the study conclude that a health risk for the consumer due to an average consumption of game meat with the reported content of copper or zinc is unlikely. The authors further highlight that the intake of copper through the consumption of farm animals is much higher than it is through the consumption of hunted game meat. This only applies, of course, if game meat hygiene measures have been properly applied, i.e., the meat close to the wound channel has been widely cut out and areas with hematomas have also been widely removed.

RAC agrees with the Dossier Submitter that copper and zinc levels in game meat do not cause health concern for humans. This is further supported by the maximum residue level (MRL) for copper permitted in food of animal origin from pigs, cattle, sheep, goats, horses, poultry and other farm animals which is 5 mg/kg (fresh weight) according to regulation (EC) No 149/2008 and the amending regulation (EC) No 149/2008. Mean, median and 95th values of copper amounts in game meat from the studies available are far from these values. Further, EFSA found that the contribution of the proposed MRL to total consumer exposure to copper was negligible. It amounts up to 0.7 % of the Acceptable Daily Intake (ADI) of an adult (Schlichting et al., 2017).

During the consultation of the Annex XV restriction report, it was noted that the maximum concentration of lead in ammunition specified in the restriction conditions should be increased from 1% to 3%, since up to 3% of lead in brass is common. There is no quantitative data to estimate the impact of this difference (1% vs 3%) to human exposure to lead via game meat or to risks to wildlife. The impact is estimated to be low especially when considering that in alloys, other alloying metals may limit the release of individual metal components. Considering that copper-based bullets are the main alternative for lead bullets, RAC supports this request.

Other alternatives assessed by the Dossier Submitter include steel and tungsten. Iron has a lower oral toxicity compared to lead, copper or zinc. Like zinc and copper, iron is an essential element in humans with regulated gastrointestinal absorption. The potential health risk from the consumption of meat from game hunted with steel ammunition is not expected to be higher than that for zinc or copper bullets in case appropriate meat hygiene is applied.

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

Environmental risks of alternatives

Aquatic toxicity

For aquatic toxicity, the Dossier Submitter presented information on the toxicity of shot alternatives to lead. In two studies, the leaching behaviour of various metals (lead, bismuth, copper, steel, zinc and tungsten) and their toxicity to *Daphnia magna* (EC50 value for 48 h immobilisation) of commonly available gunshot pellets was investigated under standardised medium for daphnids (Fäth et al., 2018) and under different water conditions (geology/redox conditions) (Fäth and Göttlein, 2019).

These studies used a high pellet/water ratio and concluded on the inadvisability for copper- and zinc-based as well as zinc-coated gunshot based on the high risks they pose to the aquatic environment.

Bismuth is considered a safer alternative than lead. No detectable leaching rate of bismuth or other metals (tin, nickel, iron, lead) was identified and therefore no immobilisation effects over Daphnia.

Stainless steel can be used to manufacture fishing sinkers and lures. It has been noted that stainless steel sinkers can leach cadmium and other elements under acidic conditions. However, the pH required is unlikely to be encountered during most fishing uses (Katz and Jelinski, 1999).

In the case of steel, when testing the leaching rate of two commercial steel shot, the leaching of iron itself was not reported (Fäth and Göttlein, 2019).

The same occurs with tungsten. When testing the leaching rate of a commercial tungsten shot (Ultimate) no leaching was observed. However, leaching of tin occurred under anaerobic conditions (Fäth and Göttlein, 2019). In its analysis the Dossier Submitter concludes that based on the available data there are no indications for aquatic toxicity, or other environmental hazard of tungsten used in shot and fishing tackle. The reported risk for aquatic toxicity of tin under anaerobic condition (Fäth and Göttlein, 2019) would require further investigations.

Results are summarised in Table 2 (Table C.3-2 from Annex C from the Background Document) with grey values representing those that exceeded the EC50 for *Daphnia magna* according to Khangarot and Ray (1989).

Table 2: Metal concentrations (in µmol/L) for different shot types during short- and long-term exposure leaching tests[1]

Shot type (main component)	Leached element	Metal concentration (µmol/L), mean ± standard error				
		ADaM	Siliceous (pH 6.5) aerobic	Calcareous (pH 7.6) aerobic	Siliceous (pH 6.5) anaerobic	Calcareous (pH 7.6) anaerobic
Short term period (1 day; 8 days)						
PL (Pb)	Pb Sn	**1.81±0.26** <LOD[b]	**1.77±0.36** <LOQ	0.32±0.15 **0.39±0.06**	<LOQ <LOQ	<LOQ[a] **0.31±0.08**
Blind Side (Fe)	Zn	**13.39±3.35**	**11.82±3.91**	2.47±0.26	0.21±0.01	<LOD

Shot type (main component)	Leached element	Metal concentration (µmol/L), mean ± standard error				
		ADaM	Siliceous (pH 6.5) aerobic	Calcareous (pH 7.6) aerobic	Siliceous (pH 6.5) anaerobic	Calcareous (pH 7.6) anaerobic
Hubertus (Zn)	Zn	**33.79±4.56**	**29.99±9.02**	3.96±0.81	1.33±0.19	<LOQ
Silver (Pb)	Ni	0.59±0.08	**0.68±0.09**	0.55±0.06	**1.56±0.47**	**0.65±0.10**
Sweet Copper (Cu)	Cu	**1.91±0.51**	**3.53±1.06**	**2.63±1.12**	0.14±0.01	<LOQ
Ultimate (W)	Sn	<LOD	<LOD	<LOD	0.89±0.29	0.89±0.44
Long-term period (15 days; 22 days)						
PL (Pb)	Pb Sb	0.60±0.25 <LOQ	**4.30±1.12** <LOQ	0.20±0.09 **0.75±0.05**	<LOQ <LOQ	<LOQa 0.59±0.05
Blind Side (Fe)	Cr Zn	<LOQ **34.70±0.92**	<LOQ 24.82±1.29	<LOQ 3.78±0.16	0.10±0.01 0.49±0.11	<LOQ <LOD[b]
Hubertus (Zn)	Zn	30.48±1.79	**55.71±3.75**	4.83±0.15	0.69±0.10	<LOQ
Silver (Pb)	Ni	**1.34±0.19**	0.52±0.02	0.31±0.04	**1.20±0.23**	<LOQ
Sweet Copper (Cu)	Cu	4.11±0.37	**5.92±0.27**	**6.35±0.10**	<LOQ	<LOQ
Ultimate (W)	Sn	<LOQ	<LOD	<LOD	**1.23±0.07**	0.65±0.08

Notes: [1] information as provided by (Fäth and Göttlein, 2019) including data from (Fäth et al., 2018);

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

Overall, RAC notes the aquatic toxicity of gunshot metal alternatives such as copper, zinc, nickel or brass will depend on the metal release and the characteristics of the environment to which these particles are released. These alternatives are not recommended for gunshot due to their risk to the aquatic compartment. Other alternatives such as steel, tungsten, tungsten-bronze or bismuth are considered of low risk for the aquatic environment. Data available show that these alternatives do not classify for the aquatic compartment and have low leaching rates (Fäth and Göttlein, 2019).

The Dossier Submitter considers that – in contrast to gunshot – aquatic toxicity of alternative bullets is less relevant because bullets might either remain in the carcass of the bagged animal or in the soil. In addition to exposure considerations, RAC also notes that copper and zinc massive are not classified for the aquatic compartment. When zinc is alloyed with copper to produce brass, its mobility in solution is lowered. Also, copper and brass bullets fragment less.

For fishing tackle, the Dossier Submitter considers that the available alternatives present less risk than lead from a human health and environmental standpoint, though there are some data gaps for zamac, zinc, ceramic, tin and bismuth, which makes a full comparison difficult. Further, many of the alternatives reported, such as tungsten, bismuth or tin were assessed as non-toxic for the wildlife in the US (US FWS, 1997) as alternatives to lead gunshot. The same conclusion can be reached for fishing sinker and lures. Also, none of the alternatives for sinkers and lures are classified for the aquatic environment in their massive form. Yet, this does not mean they are harmless, since metals such as zinc and brass, although less than lead, are toxic to wildlife.

In the case of fishing sinkers made of polymer, the Dossier Submitter mentions that they could fall under the definition of the restriction proposal on microplastics and could therefore not be placed on the market once the microplastic restriction is adopted and published in the official journal.

RAC agrees with the above reasoning and considers the alternatives available for fishing tackle present a risk reduction both for human health and the environment compared to lead. RAC also notes that losses of fishing tackle, no matter the material used, will continue, since the loss of fishing material in inherent to the fishing activity.

Potential of lead mobilising other metals in soil

The FITASC report (FITASC, 2020) states that shooting steel shot in areas where lead shot has previously been fired can be harmful for the environment. The literature review of field evidence from two lead-contaminated soil types with different soil chemistries (peatland with low pH and high organic matter; sandy moraine with neutral pH low organic matter) presented in the Ramboll report commissioned by the Dossier Submitter (Appendix 3 to the Background Document) shows the addition of steel shot has no significant effect on lead mobilisation, compared to steel-free samples. According to this study, there is no significant theoretical evidence of soil acidification related to the chemical reactions of iron in steel shots, due to both the fundamental chemistry of iron oxidation, the buffering capacity of soils and the greater contribution of other natural processes to soil acidification (e.g., microbes and acid rain). Ultimately there is little evidence that steel-induced acidity in soils would promote the mobility of lead.

Several stakeholder comments on this issue refer also the recent open-source evidence produced by Lisin et al. (2022), which they consider supporting the claim that the use of steel gunshot on shooting ranges will mobilise lead and other metals in soils at shooting ranges. This study was carefully evaluated by WCA (2022, Appendix 4 of the Background Document). The WCA (2022) analysis counters this view showing that field-based evidence does not support the claims in Lisin et al. regarding acceleration of lead migration or iron, impacts upon surface and ground waters. The weathering of soils and the binding of lead species to arising organic matter or iron hydroxide precipitates (from steel shot) reduces the potential for lead to be mobilised or cause toxicity. In fact, where iron hydroxide precipitates are present, they are a more important binding phase for lead species than organic matter.

RAC agrees with the Dossier Submitter and the recent analysis by WCA (2022) that there is no evidence that steel-induced acidity in soils would promote the mobility of lead.

Toxicity to wildlife

The toxicity to wildlife of alternatives was also assessed by the Dossier Submitter. For the case of coated lead alternatives, it is reported that attempts to coat lead shot to prevent the degradation and uptake of lead while in the gizzard/stomach of birds have all failed (USFWS, 1986), (Scheuhammer and Norris,1995), (Friend et al., 2009), Thomas (2019). The coating (if used for shot or fishing tackle) will wear off or will be dissolved in the highly acidic environment of the avian gizzard and stomach, exposing the lead core to the digestive actions of the gut. Some coatings of fluoropolymers, such as Teflon, have been assessed as non-toxic for wildlife and are approved by the US Fish and Wildlife Service but only on non-toxic cores made of material approved by the US Fish and Wildlife Service.

For non-lead alternatives, information is already available on eleven accepted (non-toxic) alternatives for hunting fowl (US FWS, 1997). These alternatives, used for hunting with shot, should also be safe for hunting with bullets. In addition, the Dossier Submitter presented data on the toxicity of various alternatives to birds which were fed with copper, iron/steel shot, tin, tungsten, etc (see Thomas, 2019; Franson et al. 2012; Krone et al., 2009b, Brewer et al., 2003, Thomas, 2016, Grandy IV et al., 1968, Pamphlett et al. 2000; Stoltenberg et al. 2003). RAC notes that the studies presented mainly involve dosing of birds with non-lead gunshot and the subsequent monitoring of acute endpoints, including mortality or body weight loss over periods of 30 days. From the alternatives assessed (copper, tungsten, tin, brass, zinc, bismuth and its alloys) only zinc showed toxicity to birds. Feeding of six zinc shots to 10 ducks did not results in mortality but in 80 % body weight loss during a four-week retention period. Presumably, discarded small fishing weights made of zinc would be also toxic to waterbirds that might ingest them. Further, tungsten alloys showed also carcinogenicity which derives from their nickel and cobalt content, and not the tungsten.

Chronic data was also presented. Chronic studies in which pure tungsten-based shot are placed, continuously, in the foregut of ducks over 150 days indicate that there are no adverse physiological effects, nor disruption of ducks' reproduction and development of their progeny (Thomas, 2016). When shot made of bismuth-tin alloy was implanted into mice intra-peritoneally for extended periods of time no toxic effects were reported (Pamphlett et al., 2000; Stoltenberg et al., 2003). Although mobilisation of bismuth from the shot occurred over months, no detrimental effects on weight gain, movements, and appetite were observed.

Substitutes for lead sinkers are made from e.g., pure tin, stainless steel, tungsten-plastics, and bismuth-tin alloys, all of which are non-toxic to wildlife

Nevertheless, RAC highlights uncertainties related to the chronic exposure of birds to the alternatives and to the toxicity of alternatives to raptors and scavengers which may consume spent bullets or their fragment and who usually have a lower stomach pH than the birds tested, increasing the probability of bullets being dissolved in their stomachs.

Other risks related to the alternatives

Concerns with steel relate to its potential to cause some choke expansion ("bulging"), particularly with heavy loads in very old traditional lightweight guns. Nevertheless, bulging was found not to be a significant issue over the twenty or so years since steel shot was introduced (Coburn, 1991). In comments received in the consultation of the Annex XV restriction report, it was highlighted that care is needed when shooting steel shot as it could ricochet more than lead (see e.g., comments by the Finnish Hunting Association, comments #3240, #3226). Ricochet was for instance a central part of the Danish debate during the transition from lead to non-lead gunshot in the 1990s since many actors were concerned that steel shot, would create an increase in ricochet accidents. Today, there is no evidence that the change from lead to non-lead shot has caused any change in risk of injury. Research from DEVA (DEVA, 2013) concluded that ricochet from lead and steel is comparable.

RAC notes that when hunting, in theory the risk of ricochet depends on the physical environment, i.e., the risk of hitting rocky surfaces and obstructions like bushes and trees. RAC is of the opinion that ricochet of steel does not represent a higher risk than if using lead. A further issue related to the substitution of lead with steel is the increase in generation of noise because of the increased pressure generated in the gun when using steel. RAC notes this can be an issue in particular if people are living in close proximity to shooting ranges.

Finally, the Dossier Submitter remarks that some of the comments received in the consultation of the Annex XV restriction report (comments by AFEMS, #3246) highlighted alternatives to lead could play a role in the ignition of forest fires by means of their ricochets causing sparks. The Dossier Submitter investigated these claims and found that (Finney et al., 2013):

"As with all fire behaviour and ignition research, moisture content of the organic material will be an important factor in ignition. Peat moisture contents of 3-5 %, air temperatures of 34-49 °C (98-120 °F), and relative humidity of 7 to 16 % were necessary to reliably observe ignitions in the experiments. Peat moisture contents above this (perhaps 8 %) did not produce ignitions. Field conditions matching the experimental range would imply summer-time temperatures, as well as solar heating of the ground surface and organic matter to produce a drier and warmer microclimate where bullet fragments are deposited."

RAC notes and agrees with the Dossier Submitter that is highly unlikely that when the European hunting season opens (legal hunting periods) these conditions will be met regularly. However, if hunting occurs outside the official season and alternatives indeed cause relatively greater sparks, this might result in an increased risk for forest fires.

4.3. Environmental Footprint of alternatives

In addition to the above assessment, the Dossier Submitter presented an analysis of the environmental footprint of the alternatives against the following criteria (see Wood E & IS GmbH, 2020):

- Toxicity and risk for human health
- Toxicity and risk for the environment (both aquatic and wildlife ingestion)

- Sourcing of the raw material to manufacture fishing tackle and ammunitions (extraction vs recycling)

- Resource depletion associated to the sourcing/production of the raw material and the manufacturing of fishing tackle and ammunition (at the end of the supply chain)

- Impact on climate change and in particular emission of greenhouse gases from the sourcing/production of the raw material, and the manufacturing process of fishing tackle and ammunition.

The analysis is not exhaustive and does not include a full Life Cycle Assessment but provides an indicative impact assessment of alternatives compared to lead using a qualitative approach. Although outside the remit of the restriction, it is considered relevant within the context of the future EU Chemicals strategy, and the EU Green Deal policy developed at the European level.

The outcome of this qualitative assessment presented by the Dossier Submitter is summarised in Table 3 below (Table C.4-7 from Annex C from the Background Document).

Table 3: Summary of the global environmental footprint of lead and its alternatives

Material	HH toxicity	Env toxicity (aqu.+wildlife)	Sourcing	Resources depletion	CO_{2e} emissions
Lead	High (1)	High (1)	Low (3)	Moderate (2)	Moderate (2)
Alternative metals					
Bismuth	-	-	High (1)	High (1)	High (1)
Copper	Moderate (2)	Moderate (2)	Moderate (2)	Moderate (2)	High (1)
Iron	-	-	Moderate (2)	Moderate (2)	Moderate (2)
Nickel	High (1)	Moderate (2)	Low (3)	High (1)	Moderate (2)
Tin	-	-	Low (3)	Moderate (2)	High (1)
Tungsten	-	-	Moderate (2)	Moderate (2)	High (1)
Zinc	Moderate (2)	High (1)	High (1)	Moderate (2)	Moderate (2)
Alternative alloys					
Brass (copper-zinc alloy)	-	-	Low (3)	Moderate (2)	Moderate (2)

Bronze (copper-tin alloy)	-	-	Low (3)	Moderate (2)	High (1)
Zamac (zinc-aluminium alloy)	-	-	Low (3)	Moderate (2)	Moderate (2)
Alternative steels					
Rebar	-	-	Low (3)	Moderate (2)	Moderate (2)
Stainless Steel (e.g., 11 % Cr, 8 % Ni)	-	-	Low (3)	Moderate (2)	Moderate (2)
Steel (Fe, <2 % carbon; 1 % Mn)	-	-	Low (3)	Moderate (2)	Moderate (2)
Other Inorganic					
Ceramic / glass	-	-	High (1)	Moderate (2)	Moderate (2)
Concrete	-	-	High (1)	High (1)	Low (3)
Stones / pebbles	-	-	Low (3)	Low (3)	Low (3)
Other Organic					
High density polymer	-	High (1)	Moderate (2)	Moderate (2)	High (1)

Source: based on Annex C, section C.3 from the Background Document, (Wood E & IS GmbH, 2020),and (Ichlokmanian; Bert, 2017)

RAC has no possibility to perform any detailed life-cycle analysis of these alternatives but in general supports the Dossier Submitter's view that there are alternatives (e.g., steel for gunshot, brass for bullets and several alternatives for fishing tackle) which are likely to result in clearly lower environmental footprint when compared to lead. However, the environmental footprint of bismuth and tungsten is, in combination with limited availability such, that the use of these metals should be limited to 'antique' shotguns that are not fit for steel gunshot.

5. Uncertainties

RAC acknowledges that information on alternatives have uncertainties associated with:

- Lack of reliable information on the concentration of metals in the air following controlled shooting with defined alternative shot and/or bullets compared to lead shot or bullets in outdoor shooting.
- Limited data on the metal concentration in game meat following the use of alternative shot or bullets other than copper and zinc bullets.
- Lack of sufficient studies on the potential hazard for the environment of some of the alternatives.
- Lack of data on the effects of chronic exposure of birds to alternatives and on the toxicity of alternatives to raptors and scavengers which may consume spent bullets or their fragments and who usually have a lower stomach pH than the birds tested increasing the probability of bullets being dissolved in their stomachs.

6. Conclusions

RAC concludes that in general the potential human health and environmental risks related to the use of alternative substances to lead are low. Many of the alternatives proposed present a lower risk to human health and the environment than lead. This is the case of the most common used alternatives for gunshot, i.e., bismuth, tungsten and steel as well as for copper and zinc and their alloys, which are used as an alternative for bullets. The same materials can be used also for fishing sinkers and lures and other types of ammunition.

The main human health concerns are related to the fumes/dusts from shooting, but these concerns are mainly related to indoor shooting or shooting in other poorly ventilated spaces which fall outside the scope of the present restriction proposal. Although home-casting of e.g., zinc materials may in principle result in the formation of zinc fumes, it is not even known if home- casting of zinc occurs. The main health concerns associated with zinc fumes are however related to inflammatory lung effects or metal fume fever caused by acute high-level exposures. Additionally, the risks presented by alternative non-lead - containing shot/bullets resulting from the consumption of contaminated game meat are estimated to be low compared to lead.

RAC concludes that for the environment, potential risks of alternatives are related to the aquatic toxicity and toxicity to wildlife. Especially discarded small fishing weights made of zinc may cause toxicity to waterbirds if ingested. Toxicity of both zinc and copper to the aquatic organisms depends on the rate of metal release and the characteristics of the environment to which these particles are released. Release is reduced with increasing particle size (from fine powder to massive particles like shot) and also with alloying. When zinc is alloyed with copper or tin to make brass or bronze, respectively, its mobility in solution is lowered. Therefore, brass and bronze, whether used in bullets or fishing weights, exhibit less potential toxicity to aquatic environment than fine zinc powder. RAC also concludes that there is no evidence to support the claim that steel-induced acidity in soils would promote the mobility of lead and therefore increase lead-caused risks to the environment.

RAC notes that the evaluation of the Dossier Submitter is also supported by the North America list of approved substances where alternatives were evaluated for non-toxicity.

7. References

Additional references not included in the Background Document to the opinion on the Annex XV dossier proposing restrictions on lead in outdoor shooting and fishing:

Fetter CW, Boving TB, Kreamer DK (2018). Contaminant Hydrogeology, 3rd edn. Waveland, Long Grove. ISBN-10: 1478632798