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 report WP A.3

Human health risks due to shooting

3 June 2022

Contents

1. Description of the Work Package

1.1. Background

Hunting or sports shooting with lead-containing ammunition may lead to the uptake of lead fumes and dust from the ammunition while shooting. The type of firearm, calibre and the facility where it is used influence the potential magnitude of exposure. In addition to the lead projectiles, lead in primers also have an impact on the total exposure to lead from lead ammunition. Exposure to lead during the shooting may result in the accumulation of lead in the body of sports shooters and hunters and in adverse health effects associated to the body lead burden.

This work package report presents the risks to human health resulting from the act of shooting. Other human health risks associated with hunting and sports shooting such as the risks resulting from the melting of lead by hunters to prepare ammunition (termed 'home-casting') as well as from the consumption of game meat containing fragments of lead gunshots or other lead projectiles or other food or drinking water containing lead are not part of this work package report.

1.2. Objectives

The main objective of this work package report is to describe and assess the lead exposure and risks of sport shooters and hunters due to inhalation and dermal contact when practising shooting.

2. Summary of the Dossier Submitter proposal

Inhalation exposure can result from lead fumes, aerosols and/or dusts from shooting during sports shooting or hunting. Oral exposure can result from intake of lead dust (hand-to-mouth) while shooting or handling lead gunshot or bullets when eating, drinking or smoking in an environment containing lead dust, or from chewing or swallowing lead fragments.

Analysis of lead in whole blood (PbB) is the most common and accurate method of assessing lead exposure. When evaluating PbB levels the following has to be noted:

- PbB levels provide information mostly on recent exposure; to assess cumulative exposure from previous years or decades, lead levels in bone would need to be measured. However, gradual release of accumulated lead from bone stores results in endogenous exposure and may keep PbB levels elevated for long periods after the cessation of the exposure.
- PbB levels in the EU general population have been decreasing over the last 40 years.
- PbB levels in males are generally higher than in females.
- Based on data from Germany, recent statistically derived reference lead background values (95th percentile) for the general population are 4 µg/L for adult men, 3 µg/L for adult women and 3.5 µg/L for children (HBM4EU, 2019).
- To analyse the risk of a specific exposure scenario, the increase in the PbB level resulting from this exposure source was compared to the reported control/ background level.

With regards to shooting, the risks for elevated PbB levels depends very much on the frequency and the conditions of shooting and can range from low risks (low increases in PbB levels) to very high increases reaching even toxic PbB levels. According to the Dossier Submitter, based on the information from Demmeler et al. (2009), Laidlaw et al. (2017), Mathee et al. (2017), and Mühle (2010) the factors contributing to exposure to lead in shooting and elevated PbB levels are:

- use of firearms (with lead-containing primer) compared to use of air guns;
- increasing calibre of the gun;
- increasing shooting frequency;
- reduced ventilation.

The use of lead-containing primer increases lead exposure significantly (Lach et al., 2015). However, primers are outside the scope of the restriction proposal because lead styphnate has already been identified as a substance of very high concern (SVHC) and is on the candidate list for authorisation (Annex XIV of REACH).

High exposure and risks have been reported for shooters training indoor and, depending on the shooting intensity, ventilation might not (always) be sufficient to reduce exposure to required levels. However, indoor shooting is out of scope because the request from the Commission to ECHA to develop this restriction proposal speaks about 'terrains', which is interpreted as referring to 'outdoor'. For shooters training outdoors the database is insufficient to draw a firm conclusion. Due to natural ventilation in outdoor shooting ranges, exposure could be expected to be lower than reported for indoor shooting. However, in one study the measured lead concentrations outdoors were even higher than indoors with ventilation and was considered to be due to missing natural ventilation (wind) (Wang et al., 2017).

Insufficient information is available or has been provided to the Dossier Submitter on the association between the use of different specified types of shot or bullets under standardised conditions and resulting lead levels in air and/or resulting PbB levels in shooters.

In the case of hunters, since it is not possible to separate between the risk attributed to training, hunting and consumption of game meat, it is considered together.

Different studies show significant increase in PbB level among hunters (up to 53 µg/L) compared to the levels of inhabitants of a highly industrialised city. PbB level increments of 53 µg/L are associated with an increase in the prevalence of chronic kidney disease of 35%, and with increase in systolic blood pressure of 1.8 mmHg.

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

Several comments were submitted by sector associations and individuals on lead exposure of outdoor sports shooters. In contrast to known lead exposure from indoor sports shooting, several comments considered that lead exposure from outdoor sports shooting is negligible. However, new data provided on exposure of shooters was very limited although some comments indicated that regular PbB monitoring of sports shooters is performed. The Muzzle Loaders Associations International Federation (comment #3277) provided information on the blood lead level of one shooter in Austria (concurrent PbB of 72 µg/L) who does intensive shooting (muzzle, black powder, big and small-bore pistol and rifle, military rifle, air pistol) and related activities (home casting, re-loading).

Another comment (comment #3237) reports the results of a small-scale survey of middle-aged men eating a significant amount of game meat and engaged in sports shooting, and half of them also engaged in cartridge recharging. Their blood lead levels ranged from 0.09 to 0.19 µmol/L [4 to 39 µg/L], averaging 0.13 µmol/L [27 µg/L]. One person, who also carried out casting work, had a blood lead content of 0.7 µmol/L [145 µg/L]. FITASC/ISSF (comment #3221) commented that there is no possible emission of lead dust in clay target sports shooting using lead shot cartridges. This is because in modern cartridges that use plastic wads there is no contact between the barrel's bore and the lead load. Furthermore, when a lead pellet hits the ground, it has close to zero speed and zero energy. To support this statement, reference was made to a professional Olympic skeet shooter with 'perfectly normal' blood lead levels.

Several reasons were brought forward contributing to the low exposure such as:

- Open air environment with natural ventilation
- Technical measures to limit exposure of outdoor shooters meaning that:
    - lead is contained in the cartridge (comment #3194)
    - shooting positions are minimum 2 to 2.5 metres apart
    - minimum firing distance to the target to prevent exposure from the projectile splashing on the target or berm.

A single blood lead level measurement of one Olympic medallist in shotgun shooting was also provided in the consultation (comment #3518). The result was below the LOQ (32µg/L).

4. Evaluation

Sports shooters

There is clear evidence from the literature showing that the practice of shooting results in an increase of the lead body burden. This is caused not only by lead shots/bullets but also lead primers used in guns. How much lead-containing primers vs gunshot/bullets contribute to the total lead emissions/exposure is not clear, but according to some papers a significant proportion of lead may come from primers (Laidlaw et al., 2018).

The literature data show that lead exposure is generally higher at indoor shooting. In indoor shooters, blood lead levels may easily exceed 150 µg/L, which is the limit proposed by RAC[1] for occupational exposure to lead and which is linked to the increased risk of neurological effects in adults. Even levels higher than 400 µg/L have been reported in several instances. The EU Chemical Agents Directive[2] defines 400 µg/L as the blood lead level limit above which

[1] RAC Opinion on scientific evaluation of occupational exposure limits for Lead and its compounds: https://echa.europa.eu/documents/10162/ed7a37e4-1641-b147-aaac-fce4c3014037

[2] Council Directive 98/24/EC of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work (fourteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC): https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31998L0024:EN:HTML

medical surveillance of workers is needed. Additionally, the Directive sets a binding biological limit value for lead in blood of 700 µg/L. If workers exceed this level, they should be immediately removed from the tasks involving exposure to lead. As discussed in the RAC opinion on Occupational Exposure Limit Values for Lead (2020), the present limit values defined by the EU Chemical Agents Directive are far too high in light of the current understanding of the health risks of lead. Therefore, RAC has proposed to decrease the present binding biological limit value for lead in blood to 150 µg/L. However, this limit value will apply only to adults and does not protect from the developmental neurotoxicity of lead. In addition, it should be noted that the limits and requirements for health surveillance in the EU Chemical Agents Directive apply only to workers employed in shooting ranges or practising shooting as part of their job (like police). There are no legal requirements for health surveillance or blood lead measurements of "leisure" shooters or athletes practising shooting regularly even though their exposure can be as high as those professionals mentioned earlier, especially if they train indoors (Laidlaw et al., 2018). The registry data collected by Gelberg and DePersis (2008) from the New York State Heavy Metals Registry indicates that hobbyists involved in target shooting have higher lead levels in blood than range employees (208/348 had PbB 250-390 µg/L, 108/348 had PbB 400-590 µg/L and 26/348 had PbB>600 µg/L). However, these data also included lead measurements in blood of indoor shooters.

Overall, in a significant number of cases it is difficult to differentiate the contribution of outdoor and indoor shooting to the total lead exposure of sports shooters since a large number of them may practise both indoor and outdoor depending on the season. Based on the available information, exposure to lead in outdoor shooting can be estimated to be generally lower than in indoor shooting (Lach et al., 2015, Mathee et al. 2017). However, depending on the shooting place and e.g., weather conditions, high exposure levels have also been measured in outdoor shooting.

The main studies providing information on lead air emissions during outdoor shooting include Lach et al., 2015, Bonanno et al., 2002; Tripathi et al., 1989, Chun et al., 2018 and Wang et al., 2017.

Lach et al., 2015 made industrial hygiene measurements in both indoor and outdoor gun shooting ranges. In indoor shooting ranges using lead ammunition (lead both in primers and bullets), air levels of 70 µg/m^3 of lead were measured immediately behind the shooter, whereas in outdoor shooting ranges, levels of 10 µg/m^3 on average were measured about 3 m behind the shooter. Higher levels have been, however, measured in personal air sampling. Bonanno et al. (2002) measured lead concentrations of 286 and 235 µg/m^3 in the breathing zone of shooters using a 22 calibre weapon, and 579 and 1 558 µg/m^3 for shooters using 45 calibre weapons in an outdoor covered pistol range. The use of larger calibres also resulted in higher concentrations of lead dust on the hand of the shooters (324 and 353 µg) compared to 233 and 50 µg for the smaller calibre. In an older study by Tripathi et al. (1989) average air levels of 128 µg/m^3 were reported in the personal air samples of shooters in a covered outdoor shooting range. Wang et al. (2017) measured respirable airborne lead concentrations of 200 and 1 700 µg/m^3 during two-hour shooting sessions in an outdoor shooting range, higher levels were detected during rifle shooting than during pistol shooting. In this study, the levels during outdoor rifle shooting range were even higher when compared to the levels they measured in one indoor shooting range during rifle shooting. This suggests that, under condition of low natural ventilation (low wind), outdoor shooting is not safer than indoor shooting.

Chun et al. (2018) measured lead exposure levels up to 292 µg /m^3 in personal air samplers and 18.7 µg /m^3 in stationary samplers in a covered outdoor shooting range for clay shooters using gunshot ammunition.

The RAC opinion on Occupational Exposure Limit Values for Lead (2020) concluded that occupational lead exposure as 8 h TWA should be reduced below 4 µg/m^3 in order to prevent an increase of PbB levels >150 µg/L in long-term occupational exposure occurring 5 d/week. Compared to this, if a typical shooting session lasts 1 h/day, inhalation exposure should remain below 32 µg/m^3 if shooting is regularly occurring 5 d/week in order to prevent an increase of PbB above 150 µg/L. Naturally, if the shooting is less regular/more occasional, the risk for lead accumulation is lower. In addition, the type of gun may have a significant impact on the lead emissions; high calibre guns seem to result in higher lead emissions than smaller calibre guns and rifle shooting results in higher emissions than pistol shooting (Bonanno et al., 2002, Wang et al, 2017).

Overall, based on the available air measurement data it can be concluded that shooting outdoors may result in significant lead emissions in the breathing zone of the shooter, although the exposure is lower than in indoor shooting and depends e.g., on ventilation and the number and proximity of shooters. In addition, according to information submitted in the consultation of the Annex XV report, the plastic cartridge may reduce the lead emissions in gunshot shooting but RAC notes that there is no measured data provided on this.

The fumes formed when shooting may be inhaled, and they may contaminate hands and clothes resulting in hand-to-mouth exposure. The relative importance of primer vs bullet/shot on the total lead emissions caused by shooting is not clear from the available data. According to Bonanno et al. (2002), the use of specific low lead ammunition with brass bullet and lead-free primer resulted in up to 99 % reduction of lead in the breathing zone air. Tripathi et al. (1990) evaluated the impact of jacketing of bullets and concluded that copper-jacketed bullets significantly reduced airborne lead levels by a factor of 21 in the personal breathing zone samples (lead levels of 5.88 µg/m^3 were measured in personal breathing zone samples). In a study by Lach et al. (2015), the use of lead-free primer resulted in lead levels of 2.2 µg/m^3 in an indoor shooting range whereas the use of lead ammunition resulted in lead levels of 72 µg/m^3.

Specific biomonitoring data in outdoor shooting has been summarised by Ladlaw et al. (2018). Overall, data concerning specifically outdoor shooting is very limited; most of the data is from shooters performing indoor shooting or both indoor and outdoor shooting. In a study by Mathee et al. (2017), twelve shooters at an outdoor shooting range had on average 43 µg/L higher PbB level (70 ± 42 µg/L, range 20-172 µg/l) when compared to 20 archers (27 ± 14 µg/L). PbB levels of shooters training in three indoor shooting ranges were 105 ± 70 µg/L, 161 ± 98 µg/L, 192 ± 163 µg/L, respectively. Shooters with higher shooting frequency (more than monthly) showed higher PbB levels compared to shooters shooting less frequently; higher PbB levels were also associated with casting of own bullets, hunting and placing bullets in the mouth.

Tripathi et al. (1989) measured PbB levels in six cadets after shooting exercises using non-jacketed lead bullets at a covered outdoor shooting range. An increase in lead levels in blood from 50-80 µg/L (at day 0) to 90-260 µg/L (at day 5) was seen. At day 69 after the shooting, the levels had decreased to 60-140 µg/L. Gulson et al. (2002) measured the variation of PbB levels with time after shooting in one subject. After four months without shooting, one week after an outdoor shooting session, the PbB level of the subject was 32 µg/L and increased to 67 µg/L following four visits to an outdoor shooting range during four months. Indoor shooting with copper jacketed bullets (Cu coating up to 1 mm thick electroplated onto a Pb core) did not seem to increase the PbB levels. The PbB levels dropped to 38 µg/L after two months without shooting.

Löfstedt et al. (1999) reported a positive correlation between PbB levels and consumed bullets in police officers practising shooting. PbB levels of 50 µg/L (10–182 µg/L) were measured in male officers (n=575), which were higher than in female officers (37 µg/L, n=53).

Turmel et al. (2010) noted that mean PbB levels in biathletes (18 ± 3.1 µg/L; 0.087 ± 0.015 µmol/L), were slightly but significantly higher compared to the cross-country skiers (< 8.3 µg/L; < 0.04 ± 0.0 µmol/L).

Regarding the use of gunshot in sports shooting, Chun et al. (2018) measured mean PbB levels (±SD) of 45.2 ± 16.0 µg/L in Korean clay shooters (n=14). Mean PbB levels in the general population of Korea (2010 to 2011) were reported to be 18.3 ± 7.9 µg/L for females and 22.2 ± 10.4 µg/L for males (Eom et al., 2017). PbB levels increased with increasing training frequency. It should be, however, noted that the numbers of clay shooters studied were low.

A few measurements of lead in blood for shooters were provided in the consultation on the Annex XV report. However, the data submitted was very limited and therefore did not provide much additional information; a PbB measurement in one shooter using muzzle-loading guns supported the increase in PbB levels when practising shooting.

Shooting with air rifle seems to result in lower lead emissions and no clear increases in PbB levels have been observed in the available studies (Svensson et al., 1992; Demmeler et al., 2009) but the data is very scarce.

The overall conclusion is that outdoor shooting using firearms (both gunshot and single projectile shooting) results in exposure to lead and elevation of blood lead levels in shooters. Increases in PbB levels up to 30 µg/L seem likely. In very frequent shooters using high calibre/rifle guns, PbB levels may even increase higher than this. In some cases, levels close to (or even above) 150 µg/L have been suggested but in these cases contribution of indoor shooting cannot be excluded. It should be, however, noted that background PbB levels in the population vary between regions/countries due to other environmental sources of lead and it is the total cumulative body burden which affects the risk. Therefore, it is often difficult to assess the contribution of shooting based on single PbB measurements.

Developmental neurotoxicity is an effect of lead causing concerns at very low PbB levels and it is not possible to identify a threshold for this effect. Therefore, it is important to recognise young females who may become pregnant as a special sensitive subgroup of sports shooters whose exposure is of special concern.

Lead emissions caused by shooting are not derived from gunshot/bullets only, but a significant proportion of lead may come from lead primers. It is not possible to estimate for certain how much the primer vs the gunshot/bullet contributes to final lead exposure. RAC notes that primers are out of scope of this restriction proposal, which may have an impact on the effectiveness of the restriction to reduce shooters' exposure to lead.

Hunters

Hunters are exposed to lead not only during hunting, but also during practising and via the consumption of game meet and casting of ammunition. Contribution of these different sources is difficult to separate. The highest increases in PbB related to hunting have been seen in studies with native Canadian, Alaskan and Greenland populations, who also consume high amounts of game meat and may also practise home-casting. In these populations, elevated blood lead levels have been seen also in samples taken from cord blood and lead isotope studies have shown a strong indication that the source of lead is lead ammunition. Most of the studies have evaluated the contribution of game meat consumption on PbB levels in these populations. Only one of these studies provides some information on the potential contribution from hunting itself. This is the study by Liberda et al. (2018), who studied Canadian native populations and found significantly increased relative risk for elevated PbB lead levels among those who performed hunting (n=689) when compared to those not performing hunting (n=723). The Relative Risk (RR) of PbB exceeding 0.24 µmol/L (50 µg/L) in hunters was 1.75 (95% C.I. 1.444–2.122) when compared to non-hunters. However, it is not stated whether the game meat consumption patterns of hunters vs non-hunters were similar. Similarly, subjects who used a firearm compared to non-firearm users had a RR of 2.073 (C.I. 0.983–4.373; p = 0.031) of having PbB that exceeded 0.24 µmol/L (50 µg/L).

In Europe, Fustinoni et al. (2017) measured lead levels in blood in 74 males and 21 females in Italy, of which 69 were hunters (hunting mammals and birds) and 26 non-hunters. For non-hunting subjects, the median PbB levels were 14 µg/L in subjects with (n=8) and 15 ug/L in subjects without (n=18) game meat consumption. For hunters, the median PbB levels were 36 µg/L with game meat consumption (n=62) and 40 µg/L without (n=7) game meat consumption. PbB levels were correlating with hunting and wine consumption but not e.g. with game meat consumption. Since the sampling was made outside the hunting season, the PbB levels represent the long-term body burden of lead rather than recent (peak) exposures.

In the correlation analyses performed by Mathee et al. (2017, see above) hunting was associated with higher B-Pb levels among the shooters.

One comment from the consultation of the Annex XV report provided the results of a small-scale survey of middle-aged men eating substantial amounts of game meat and engaged in sports shooting, and half of them also engaged in cartridge recharging. Their blood lead levels ranged from 4 to 39 µg/L, averaging 27 µg/L. One person, who also carried out casting work, had a blood lead content of 145 µg/L.

Overall, the data on the lead exposure due to hunting *per se* is very limited but it suggests that also hunting may result in some increase in blood lead levels, if done frequently. Hunters' exposure is affected not only by hunting, but also by possible home-casting and game meat consumption. Based on available data it is not possible to establish a difference between hunting with gunshot or with bullets.

5. Uncertainties

The following uncertainties have been identified within the scope of the present report:

- There are several variables which have an impact on the exposure to lead due to outdoor sports shooting, including jacketing of the bullets, closed plastic cartridges, shooting frequency, type of the arm used, facilities and ventilation/wind in shooting facilities.

- It is not clear the impact of lead-containing primer vs shot/bullet on the total lead emissions and exposure.

- In the case of hunting, the specific data is very limited. Hunters' exposure is affected not only by hunting, but also by possible home-casting and game meat consumption.

6. Conclusions

1. Outdoor sports shooting using firearms (both gunshot and single projectile shooting) may result in exposure to lead and elevation of blood lead levels in shooters. Increases in PbB levels up to 30 µg/L seem likely and even above 30 µg/L is possible in frequent shooters. This results in a medium to low risk in the RAC qualitative risk assessment for non-pregnant adults.

2. RAC notes that even small increases of lead in blood may cause a risk for the foetus of the pregnant shooter since no threshold has been identified for the neurodevelopmental effects of lead.

3. Jacketing of lead bullets reduces lead emissions but does not prevent those totally. An undefined proportion of lead emissions is caused by lead primers. Although plastic cartridges used nowadays in shotguns may limit lead emissions, there is no measured data available on this.

4. Shooting with airguns seems to result in clearly lower lead emissions and no clear increases in PbB levels have been observed in the available studies.

The data on lead exposure due to hunting *per se* is very limited but it suggests that also hunting may result in a relative increase in blood lead levels if performed regularly.

7. References

All references cited are included in the Background Document to the Opinion on the Annex XV dossier proposing restrictions on lead in outdoor shooting and fishing.