EUROPEAN CHEMICALS AGENCY

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.2

Additional environmental risks related to sports shooting ranges (soil/surface and groundwater)

3 June 2022

Contents

Attachment A

1. Description of the Work Package

1.1. Background

This Work Package WP A.2 is tasked to evaluate the Dossier Submitter's assessment that the use of lead in gunshot, bullets, and other projectiles poses a risk to the environment and human health via the intake of food and drinking water contaminated from shooting activities. In the absence of adequate data, the Dossier Submitter describes the risks to human health and the environment in a qualitative manner.

The key topics set for this work package evaluation are:

- Risks to soil
- Risks to surface and groundwater (including drinking water sources)

This WP A.2 evaluation relates to the use of lead ammunition in sports shooting.

The use of lead ammunition remains widespread in Europe despite its well documented hazard properties and adverse effects on both wildlife and human health. Approximately 39 000 tonnes of lead from projectiles (gunshot and bullets) are dispersed in the environment every year, 64% from sports shooting.

The Dossier Submitter has identified risks to the environmental compartments and indirectly the human health receptor from exposure to lead gunshot and lead contamination at shooting ranges. These risks arise predominantly from lead contamination of the soils of shooting ranges and associated risks to surface water and groundwater. Additionally, livestock and humans may be at risk from ingestion of lead via intake of contaminated food and drinking water.

In this work package WP A.2, RAC is evaluating the risks to the soil, surface and groundwater compartments resulting from the use of lead ammunition. The risks related to ingestion of lead by livestock and to humans via intake of food and drinking water contaminated with lead are described in the work package reports WP A.1 and WP A.5 respectively.

1.2. Objectives

The following topics are covered in the present work package:

1. Are the Dossier Submitter's identified risks to the environmental compartments of such significance at shooting ranges that they require Union-wide measures to curb lead emissions?
2. Is lead contamination of groundwater a significant issue at/under/adjacent to any shooting ranges/areas in the EU, and is there evidence to support the Dossier Submitter's conclusion that lead from ammunition is mobile in soils and drives lead contamination into groundwater and hence pollutes drinking water aquifers?

2. Summary of the Dossier Submitter proposal

The Annex XV restriction report states that metallic lead is released into the environment at shooting ranges via the following exposure pathways:

- Lead oxidizes and dissolves when exposed to acidic water or soil.
- Lead particles or dissolved lead can be moved by storm water runoff (horizontal migration).
- Dissolved lead can migrate through soils to groundwater (vertical migration).

However, the Dossier Submitter considers lead mobility may significantly differ among sites, based on site-specific conditions (pH, clay content, cation exchange). Lead contamination from shooting can occur during both service life and at the end of life (i.e., older/closed shooting ranges), and is expected to occur both on site and off site.

At a conceptual level, the Dossier Submitter [Background document, section 1.5.3.7.] considers environmental risks both during and after the service life of a shooting range/lands are:

- Risks to soil
- Risks to surface water and groundwater
- Risks to livestock in shooting ranges/areas used as agricultural land

Additionally, the Dossier Submitter rates (Background document, section 1.5.4.4) the potential impact of various shooting activities on soils and surface/groundwater by scale and intensity of shooting (deposition rates of lead onto surface), where shooting occurs under different scenarios, without RMMs (a and b) and with RMMs (c and d):

a) Temporary shooting areas (shooting intensity about 5 000 – 10 000 rounds per year) with no environmental RMMs in place;

b) Permanent outdoor shooting areas (shooting intensity about 10 000 rounds per year with a service life of 30 - 40 years) with no environmental RMMs in place (any type);

c) Permanent outdoor shooting ranges (shooting intensity about 10 000 – 100 000 rounds per year with a service life of 30 - 40 years) with environmental RMMs in place, as:

    - Measures to prevent rivers from crossing the lead deposition area
    - Control of water runoff
    - Lead shot deposition within the boundaries of the shooting range
    - Remediation plan upon closure.

d) Permanent outdoor shooting ranges with the following RMMs implemented (in addition to the RMMs listed in the above scenario [c]):

    - Regular (at least once a year) lead shot recovery with ≥ 90% effectiveness calculated based on mass balance of lead used vs lead recovered to be achieved by appropriate means (such as walls and/or nets, and/or soil coverage);
    - Monitoring and treatment of surface (runoff) water;

- Ban of any agricultural use within site boundaries.

Ultimately, the Dossier Submitter combines conceptualisation of the risks from shooting and the different types/intensity of shooting ranges to enable a qualitative risk assessment for soil, groundwater, and surface water (Background document, Table 1-31).

According to the WCA report (2021)[1] (Appendix 1 to the Background Document), the contamination of groundwater from lead shot beneath shooting ranges is site specific and can occur where overlying soils are shallow (less than 3m), and where soil pH is less than pH 6 (high risk scenario). The WCA report (2021) proposes to quantify the number of sites classifying as high risk by setting out the four hydrogeological scenarios (see below) where this is a likelihood, and specifying the areas using GIS (Geographical Information System). The four scenarios where lead can be a high risk to groundwater are:

1. Acidic soil (pH <6) with relatively high organic matter content and low iron, manganese and phosphate content;
2. Coarse (usually sandy) soils that allow vertical migration of dissolved or fine particulate lead;
3. Preferential flow pathways, including macropore flow down soil cracks, plant root channels and animal burrows; and,
4. Shallow depth to groundwater (< 3m).

Hence, according to WCA's findings, hydrogeological conditions control the potential for transport of lead through the vadose zone and into groundwaters.

A new WCA report (2022)[2] (Appendix 4 to the Background Document) concludes that the presence of iron will not increase, but perhaps rather decrease, the mobility of lead in soil.

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

The comments received under the scope of this work package relate to the environmental risks resulting from the deposition of lead on sports shooting areas and the measures in place to avoid/ minimise lead mobility and migration.

Comment #3192, specifies that in Poland all outdoor shooting ranges where projectiles containing lead can be used, must have at least 80 % of lead periodically removed from the

[1] WCA (2021). Contract/Project Number P0979 to ECHA. WCA Environment Ltd UK. *Assessment of the potential for the use of lead ammunition at shooting ranges to contaminate groundwater and drinking water.* Final Report to ECHA from WCA UK. August 2021 (Appendix 1 to the Background Document).

[2] WCA (2022). Contract/Project Number P0979 to ECHA. WCA Environment Ltd UK. *REACH restriction support – Lead in fishing tackle and ammunition (part 7).* March 2022. (Appendix 4 to the Background Document).

soil and soil acidity must be monitored and kept within pH range 6.5-8.5. This good practice agrees with the WCA report (2021) conclusion that specific groundwater vulnerability for lead arising from shooting activities will be high where there is a combination of high lead emission rate, driven by usage on acidic soils with moderately high organic carbon, in zones with high intrinsic groundwater vulnerability (*i.e.* shallow soils).

Comment #3240, specifies that in Finland the goal at the range area is to determine how the operations cause an environmental load (e.g., have pollutants migrated into surface waters, or on what timescale is it possible for the pollutants to migrate into the groundwater), and what impact this will have on the environment (e.g. impact on the aquatic ecosystem or changes to groundwater quality).

Comment #3483, also from Finland considers Finland is a wet country with acidic soils which increases mobility of lead in soils and via surface water.

The WCA report (2021) is in agreement with these two comments (#3240, #3483) and indicates the science behind lead migration in wet climates. Lead pollutants migrating into surface waters are facilitated by elevated rainfall (where precipitation is much greater than evapotranspiration), and hydrogeological conditions will control the potential for transport of lead through the vadose zone (soils above the water table) and into groundwaters in the following way:

- The key soil properties that may prompt lead movement from the soil surface to underlying layers are low pH (<6), coarse textured and freely draining soils with relatively high levels of dissolved organic carbon and low iron and manganese content.
- Transport directly to the groundwater body (aquifer) where there is a presence of shallow groundwater (< 3m).

Several stakeholder comments relate to the contention that the use of steel gunshot on shooting ranges, as an alternative to lead, will mobilise lead and other metals in soils at shooting ranges, and refer to recent open-source evidence produced by Lisin et al. (2022).

The WCA report (2022) 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. This is further discussed in the work package report WP B.2.

Further comments from the public consultation which are relevant for this work-package WP A.2 are listed under Attachment A.

4. Evaluation

Risks to soil

The Dossier Submitter determines that a typical shooting range can be divided into different segments based on the pollutant load, with a maximum distance of 300m affected, from the point of gun discharge. Terrain contours and trees have a significant effect on the spread of the shot, as do wind conditions.

The Dossier Submitter describes spent lead bullets and shot are most often deposited directly on and into soil during shooting. When lead is exposed to air and water, it may oxidize and form one of several compounds. The specific compounds created, and their rate of migration, are greatly influenced by soil characteristics, such as pH and soil types. There are two kinds of dust which are relevant to shooting ranges, soil dust and lead dust (Victorian EPA, 2019). When conditions are suitable, fine particles of contaminated soil may be blown from a shooting range as dust. Lack of wind breaks (such as trees, which can reduce windy conditions), lack of ground cover such as grasses and other vegetation will influence the likelihood that dust could become airborne and travel at distance.

The Dossier Submitter cites Lepke et al. (2006) who proposed a simplified segmentation for a typical (300 m) shooting range, to determine expected soil lead concentrations:

- Sector including backstop berm, target stand and a band of land about 5 to 10 meters wide around the berm: pollution from lead normally exceeds 1 000 mg Pb/kg. More than 20 000 mg of bullets or their fragments per kg of earthy material can be found in this area.

- The immediate surroundings of the backstop berm: here lead pollution often fluctuates between 200 and 1 000 mg Pb/kg.

- The areas farthest from the backstop normally show only concentrations of lead less than 200 mg Pb/kg.

Lead contamination of shooting ranges at 200 – 300 g of lead per square meter has been found at a site which had been in operation for 14 years (Adsersen et al., 1983).

EU Directive 2002/32/EC100, sets lead concentrations in harvested material (forage) should be below 30 mg/kg. As per the literature described by the Dossier Submitter, lead concentrations in material harvested on shooting ranges can have lead concentrations far in excess of 30 mg/kg, constituting therefore a risk and should not be used as animal forage.

Overall RAC concludes lead contamination of shooting ranges at 200 – 300 g of lead per square meter can be found, and constitutes a risk to on and off-site terrestrial receptors as applicable.

Risks to surface water

The Dossier Submitter states that surface water contamination is assumed for lead, from lead ammunition (gunshot and bullets) being deposited on or in the soil and subsequent corrosion and dissolution of the lead. The Dossier Submitter states risk level is assumed to increase with increasing amount of deposition. The more rainfall, the more likely it is that surface water will spread contaminants.

The dissolution rate of lead in aquatic environments is relatively slow but increases with acidity, low water hardness (< 25 mg/L $CaCO_3$), and greater water velocity, but these criteria are specific to only some geographic areas. Vegetation slows down surface water runoff, preventing the lead from migrating off-site. There are two factors that influence the amount of lead transported offsite by surface water runoff: the amount of lead fragments left on the range and the velocity of the runoff. Runoff control may be of greatest concern when a range is located in an area of heavy annual rainfall because of an increased risk of lead migration due to heavy rainfall events. For surface water with lower water velocities (e.g. lakes), lead particles and artefacts will become buried in bottom sediments, where they would move into the anoxic sediment layer and may be strongly adsorbed onto sediment and soil particles, and show reduced mobility, without mechanical disturbance.

Studies at shooting ranges cited by the Dossier Submitter illustrate the range of concentrations occurring downgradient. In the surface water of two shooting ranges in Florida (Ma et al., 2002), lead concentrations in retention ponds were measured with 289 μg/L and 694 μg/L. In another range, lead concentrations in a retention pond and a lake close to the range were low with 8 μg/L. According to investigations in Finnish shooting ranges (Kajander and Parri, 2014), the Dossier Submitter shows lead and other metals were found to migrate from the shooting range via surface water. Total lead concentration was >50 μg/L for 7/18 samples (39%) and 10-50 μg/L for 4/18 samples (22%).

After the end of life of a range without remediation, it is unlikely that maintenance will be made to control runoff, with increased risks for nearby surface water and other receptors. The Dosser Submitter determines RMMs applied during service life may need to be continued at the end of service life unless remediation is performed.

Overall RAC concludes surface water migrating from shooting ranges without RMMs, may constitute a risk of contamination at all receiving surface waters, and their off-site animal/bird/fish/drinking water receptors, as applicable. Monitoring and treatment of surface water will be important to control this risk.

Risks posed to groundwater

RAC has reviewed and evaluated the WCA reports (2021, 2022) and agreed with the WCA analysis of the risks posed by lead ammunition to an EU wide soil, surface water, and groundwater receptor (environment), and indirectly to human health receptors (use of groundwater as drinking water).

RAC supports that hydrogeological conditions typically control the potential for transport of lead through the vadose zone and into groundwaters. RAC noted that detailed GIS analysis would be required to estimate the number and location of the high risk areas characterised by the report, highlighting that this would be a complex task.

RAC agreed that the risk of groundwater contamination may vary from very low to high depending on the specific characteristics of the site. The combination of acidic soils, coarse soils, preferential flow pathways or macropores and shallow depths to groundwater (<3m) lead to high vulnerability to lead contamination. However, RAC noted it is difficult to estimate the prevalence and extent of groundwater vulnerability to lead contamination at shooting ranges at European, national or even regional scale. Local factors will always influence potential risks more than generic considerations, but some areas with high intrinsic vulnerability are likely to occur in all EU Member States, although to differing extents.

Overall, RAC concludes the risk of groundwater contamination may vary from very low to high depending on the soil characteristics.

RAC Qualitative Risk Assessment

RAC considers the conceptualisation of risks determined by the Dossier Submitter to the environmental compartments (and drinking water) from the use of lead in gunshot, bullets, and other projectiles should follow the approach specified in EC (2010) - Guidance Document No. 26. A conceptual model implemented with this guidance enables the risks of lead from gunshot hazards to be assessed, caused by diffuse (lead powder/dust dispersion/dilution/infiltration) and point source pollution (lead fragments/shot/dust as deposition/inhalation/ingestion), and at different scales, ranging from site scale (local) up to the scale of a groundwater body (regional or national scale).

RAC used the EC (2010) conceptual model approach to scrutinise the Dossier Submitter's qualitative evaluation of risks and applied the model to all environmental and human health risks resulting from the use of lead in ammunition and fishing tackle. This RAC full written analysis is detailed under Annex 1: RAC Qualitative Risk Assessment Approach, and is not repeated here.

5. Uncertainties

The number and the location of shooting ranges where there is a high risk for ground water contamination are not known and thus constitutes an uncertainty.

6. Conclusions

RAC agrees with the Dossier Submitter that it is not possible or feasible to perform a quantitative risk assessment for all risks identified. RAC has applied a conceptual model to scrutinise the Dossier Submitter's qualitative evaluation of risks to soil and groundwater related to the use of lead ammunition at sports shooting. Based on this, the following conclusions are made.

The risk of groundwater contamination at sports shooting ranges may vary from **very low** to **high** depending on the soil characteristics and hydrogeological conditions which typically control the potential for transport of lead through the vadose zone and into groundwaters. Four key factors can lead to **high** risks to groundwater, which influence the risk of mobilisation of lead and its migration through the vadose zone, and to groundwater as:

1. Acidic soil (pH <6) with relatively high organic matter content and low iron, manganese and phosphate content;

2. Coarse (usually sandy) soils that allow vertical migration of dissolved or fine particulate lead;

3. Preferential flow pathways, including macropore flow down soil cracks, plant root channels and animal burrows; and,

4. Shallow depth to groundwater (< 3m).

Although the number of shooting ranges where these four conditions occur are probably limited to a small fraction of total sites in Europe, this fraction may not be insignificant. Detailed GIS analysis would be required to estimate the number of these sites and hence determine the proportion of sites forming a high risk to groundwater.

Any surface water migrating from shooting ranges without RMMs, may constitute a risk of contamination at all receiving surface waters, and their off-site animal/bird/fish/drinking water receptors, as applicable. Monitoring and treatment of surface water will be important to control this risk.

Lead concentrations in soil and material harvested on shooting ranges can be high and constitute a risk to on and off-site terrestrial receptors.

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:

CIRIA C553 (2001). Contaminated land risk assessment. A guide to good practice. ISBN: 978-0-86017-552-0

Clausen JL, Bostick B, Korte N (2011). Migration of lead in surface water, pore water, and groundwater with a focus on firing ranges. Critical Reviews in Environmental Science and Technology. 41 (15), 1397-1448.

DIRECTIVE 2006/118/EC 12 December 2006. On the protection of groundwater against pollution and deterioration.

EC (2010). Guidance document No. 26. Guidance on Risk Assessment and the Use of Conceptual Models for Groundwater. Common Implementation Strategy for the Water Framework Directive (2000/60/EC). ISBN-13 978-92-79-16699-0.

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

GEMAS (2014). Spatial distribution of the pH of European agricultural and grazing land soil. GEochemical Mapping of Agricultural Soils (GEMAS) project 2008. Applied Geochemistry 48:207–216. September 2014.

Hartland, A., Lead, J. R., Slaveykova, V. I., O'Carroll, D. & Valsami-Jones, E. (2013). The Environmental Significance of Natural Nanoparticles. Nature Education Knowledge 4(8):7

ISO 21365:2019. Soil Quality – Conceptual Models for Potentially Contaminated Sites.

Lisin V, Chizhikova V, Lubkova T, Yablonskaya D. 2022. Experimental study of steel shot and lead shot transformation under the environmental factors. Pre-peer review article. doi:10.20944/preprints202201.0077.v1

ATTACHMENT A

Comments from the consultation on the Annex XV report relevant to Work Package WP A.2

Comment #3187 (Finland): Information on this topic is widely available and it is known that lead does not end up in groundwater supply from normal shooting range conditions (sand based backstops for projectiles). After reading into these, this whole endeavour seems completely political.

Comment #3192 (Poland): All outdoor shooting ranges where projectiles containing lead can be used, must have at least 80 % of lead periodically removed from the soil (frequency depends on the depth of the groundwater table) and soil acidity must be monitored and kept within pH range 6.5-8.5.

Comment #3198 (Germany): If no renovation takes place after a shutdown, the abandoned sites are monitored by means of a monitoring system. At regular intervals (3 to 8 years), soil and groundwater investigations and a risk assessment are carried out in accordance with the laws / ordinances applicable in Germany (Federal Soil and Contaminated Sites Act).

Comment #3228 (Belgium): "Agricultural activities' are a dominating main source of lead discharges to water in 1999/2000 for several countries of the OSPAR. This is due to the reported amounts of lead discharges from groundwater.

Comment #3240 (Finland): Sufficient protection level of the soil and groundwater, any structural protective solutions, and water management solutions for the range area must also be examined site-specifically. The goal is to determine how the operations cause an environmental load (e.g., have pollutants migrated into surface waters, or on what timescale is it possible for the pollutants to migrate into the groundwater), and what impact this will have on the environment (e.g. impact on the aquatic ecosystem or changes to groundwater quality). If there is reason to suspect that the soil or groundwater has been contaminated, the party responsible for the treatment shall establish the level of contamination of the area and the need for treatment. If the party responsible for the treatment fails to fulfill the obligation to establish the state of contamination, the state supervisory authority may order the party in question to fulfil this obligation. An assessment of the need for the treatment of contaminated soil and groundwater shall take into account the present and future use of the contaminated site, its surroundings and the groundwater, and any hazard or harm to the environment and health that would be caused by the contamination. The state supervisory authority shall order that treatment of contaminated soil or groundwater be undertaken if the party responsible for treatment does not take action. Any party whose operations have caused the contamination of soil or groundwater is required to treat the soil or groundwater (contaminated site) to a state where it does not pose a risk or cause harm to health or the environment.

Comment #3251 (Denmark): Activities at shooting ranges will often or always involve a risk of soil polution but rarely or never constitute a risk for polution of the groundwater.

Comment #3379 (Germany): If no remediation takes place, the abandoned locations are monitored by monitoring systems. At regular intervals (3 to 8 years), soil and groundwater investigations and a risk assessment are carried out in accordance with the applicable laws in Germany (Federal Soil and Contaminated Sites Act).

Comment #3426 (Finland): If there is reason to suspect that the soil or groundwater has been contaminated, the party responsible for the treatment shall establish the level of contamination of the area and the need for treatment. If the party responsible for the treatment fails to fulfill the obligation to establish the state of contamination, the state supervisory authority may order the party in question to fulfil this obligation. An assessment of the need for the treatment of contaminated soil and groundwater shall take into account the present and future use of the contaminated site, its surroundings and the groundwater, and any hazard or harm to the environment and health that would be caused by the contamination.

Comment #3483 (Finland): According to our study based on questionnaires and previous regional surveys, the total number of Finnish outdoor shooting ranges is between 2000 and 2500. Most of the ranges are small and only ca. 5% exceed 20 ha. Almost a third of the ranges can cause a groundwater pollution risk, while only few cause an immediate health risk. In the first instance, 50-60 shooting ranges identified as being high-risk areas should be investigated in detail. At present, the risk management options at Finnish shooting ranges are very limited. Hence, soil excavation combined with disposal is the most common remediation technique. Finland is a wet country with acidic soils which increases mobility of lead in soils and via surface water.