Section 5
Physical/chemical hazards

30. Risk analysis of game meat-borne hazards induced by hunting rifle bullets: intermediate report on German field studies

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Summary

Meat from wild game may contribute to alimentary lead exposure of consumers. Lead causes adverse effects to the human central nervous as well as cardiovascular/renal systems. Wild game is usually killed by shooting in the anterior body region, where the penetrating bullet damages vital structures and effectuates death. In the past, selection of bullet materials and construction has mostly been governed by cost and applicability to hunting practice, and lead has been a major compound in rifle bullets. The annual number of downed game animals in Germany exceeds 1.5 million for the species roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), red deer (*Cervus elaphus*), and fallow deer (*Dama dama*). In 2006 and 2010, the German federal and state governments launched extensive research programmes on the suitability of bullets for hunting, and for a better understanding of the terminal ballistics needed for quick, humane kills. Furthermore, in 2012 a research programme into the deposition of bullet material into marketable meat was launched by German federal and state governments in cooperation with the private sector (meat processors, vendors and ammunition manufacturers, and federal and state non-governmental organisations). The scope of this study (not yet completed) was to monitor the content of lead (Pb), copper (Cu) and zinc (Zn), in marketable game meat and to determine which fractions are attributable to bullets and which to other environmental sources. Based on our initial results, we propose to use terminal ballistic data and computer tomography of ballistic test media to further understand the mechanisms of contamination of game meat via bullet material.

Keywords: Germany, hunting, game meat, bullets, lead, food chain

30.1 Introduction

In 2010, the European Food Safety Authority (EFSA) published a scientific opinion on lead in food (EFSA, 2010) reporting that the Panel on Contaminants in the Food Chain no longer supported the current provisional tolerable weekly intake (PTWI) of 25 μg/kg body weight because there was 'no evidence for a threshold for critical lead-induced effects'. The panel 'identified developmental neurotoxicity in young children and cardiovascular effects and nephrotoxicity in adults as potential critical effects as the critical effects for the risk assessment'. Food was identified as 'the major source of exposure to lead'. In this opinion, it was reported that of 139,113 food samples of different categories, only 771 samples contained more than 1 mg/kg lead. Tap water, beer, cereals, potatoes as well as leafy vegetables were identified as food categories contributing most to the total lead exposure of consumers. Although these foods have generally very low lead contents, they are consumed more frequently than e.g. game meat and game offal, which tended to have higher lead contents.

In an attempt to further reduce alimentary lead exposure, especially for young women, infants and children, the Federal Institute for Risk Assessment (Bundesinstitut für Risikobewertung, BfR) published a risk assessment in December 2010 (BfR, 2010) and a press release in 2011 (BfR, 2011a) regarding lead content levels in game meat. Hunting bullets used to kill game animals were identified as a potential source of lead exposure for consumers who consume meat from wild game frequently. In December 2011, the BfR organised a conference in Berlin, where an interdisciplinary view on health and environmental aspects of the utilisation of lead in bullets used for hunting was given (BfR, 2011b). As a result of this conference a public-private partnership project was launched early in 2012 under the title 'Food safety of game meat' (Lebensmittelsicherheit von jagdlich gewonnenem Wildbret).

Already in 2006, the German state of Brandenburg started a research project into the 'Aspects of the use of lead-free projectiles in hunting practice in the Brandenburg state forest service' (Soziodynamische und jagdtechnische Aspekte des Einsatzes bleifreier Jagdmunition in der Landesforstverwaltung Brandenburg). In this project, the Faculty of Wildlife Biology, Management and Hunting Practice (FWWJ) of the University of Applied Sciences Eberswalde analysed over 6,000 standardised reports of individual game animals shot by hunters. This study did not report a striking difference in making quick, clean kills between animal killed with 'lead-free' vs. 'leaded' bullets, whereas bullet construction and ballistic issues (i.e. shot distance and velocity at impact) had some influence. In 2010, the work was continued in the framework of an – ongoing – study 'Further investigations into the killing effects of lead-free hunting ammunition' (Ergänzende Untersuchungen zur Tötungswirkung bleifreier Geschoβe), funded by the German Federal Ministry for Food, Agriculture and Consumer Protection (Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz, BMELV), which is carried out by FWWJ in cooperation with 'Bundesforst' (i.e. the German Federal Forest service).

In the present contribution, an introduction is given in the ongoing 2 studies 'Food safety of game meat' and 'Further investigations into the killing effects of lead-free hunting ammunition'. In addition, it is outlined how the results of aforementioned studies can be combined to better understand the mechanisms by which bullet material may get into game meat.

30.2 Food safety and game meat

At the BfR conference 'Health and environmental aspects in the use of lead ammunition in hunting' (BfR, 2011b) a number of questions were raised relating to the exposure of the game meat to bullet-borne contaminants:

- What are the levels of lead, copper and zinc in game meat?
- Are the levels of lead, copper and zinc in ungulate game species different related to their different digestive systems, choice of feed, or total feed intake?
- What are the natural background levels of lead, copper and zinc in game meat caused by feed intake?
- Are there regional differences in levels of lead, copper and zinc of game meat, and do these correlate with different levels in the soil?
- Are there differences in lead, copper and zinc of game meat due to the use of lead or lead-free ammunition?
- Can other bullet-related factors help explain the variation in metal fragment-contamination of game meat by comparing shots with a similar point of impact?
- Is the level of contamination influenced by the types of hunting (stand, stalking or drive hunt)?

Several questions were raised concerning consumer exposure:

- What, if any, is the additional consumer exposure to lead, copper and zinc caused by the consumption of game meat?
- How much of the ingested lead remains in the human body?
- What should the consumer keep in mind when buying and consuming game meat?
- What should the hunter keep in mind regarding shooting, butchering and selling game meat?
- What does the BfR recommend?

Several questions were raised concerning the health risk assessment by EFSA and BfR:

- Which health problems are caused by the intake of the metals lead, copper and zinc in humans?
- Is there an increased health risk for certain consumer groups?

One outcome was that the forum demanded proper science-based knowledge for the pending political decisions. In March 2012, a public-private partnership has been formed, following the BfR's initiative, to launch a research project under the title 'Food safety of game meat' (Lebensmittelsicherheit von jagdlich gewonnenem Wildbret).

30.2.1 The project objectives

Based on the questions collected at the BfR conference in December 2011, we focus on 3 main aspects of contamination of game meat with lead, copper and zinc:

- How far does bullet-borne contamination spread through the body of the shot animal?
- Can bullet-borne contamination and general environmental sources be differentiated as sources for contamination of game meat? If so, how can source attribution be done?
- Can bullet construction and bullet materials be designed to avoid metal contamination of game meat?

30.2.2 The project participants

The project was carried out by a public-private partnership consisting of the BMELV, the BfR, the States of Mecklenburg Vorpommern, Lower Saxony, Saxony-Anhalt, Hessen, Bavaria, Bremen, Hamburg and North Rhine-Westphalia and FWWJ from the public sector. The private sector contribution came from the German Hunting Association (Deutscher Jagdverband, DJV), Bavarian Hunting Association (Bayrischer Jagdverband, BJV), the Federal Association of German Professional Hunters, the European Poultry, Egg and Game Association (EPEGA), the Association of the Manufacturers of Hunting and Sporting Arms and Ammunition (Verband der Hersteller von Jagd- und Sportwaffen und Munition, JSM). Each partner contributed labour, expertise, logistics or goods from their field of experience, or money towards the projects objectives.

30.2.3 The project process

The project partners aimed at collecting data from marketable meat from the game species roe deer (*C. capreolus*), wild boar (*Sus scrofa*) and red deer (*Cervus elaphus*) which had been harvested using both lead-free and leaded projectiles. To reduce variation and allow more powerful statistical tests, the ammunition was supplied by the JSM and was distributed by the FWWJ to the participating hunters. These were staff and guests of the forestry services of the 3 federal states where the study was conducted (Mecklenburg Vorpommern, Lower Saxony and Saxony-Anhalt). Six project regions were identified based on lead contamination level in the top soil (3 contamination levels: low, medium and high with 2 regions per level). The participating hunters were instructed by FWWJ staff and were equipped with ammunition. For each game animal shot, the hunters had to record all data concerning the killing of the animal such using a standardised report (date, time, type of hunt, shot distance, ammunition used, location of the shot, and the distance the animal moved after the shot). This record accompanied the carcass when it was handed over to the butcher. Carcasses were processed according to commercial practice; the butchers had been instructed to collect 3 muscle samples of 100 g. The first sample was taken from the hind leg, just above the hook. The second sample was taken from the *longissimus* muscle. The third sample was taken from the region around the shot wound channel. All knives and equipment were cleaned between samples to avoid cross-contamination. The 3 samples from each carcass and the record form were then sealed in a suitable bag and deep-frozen before being transported to the laboratory. Here, the samples were analysed for lead, copper and zinc content. The laboratory data and the record form were sent to FWWJ, checked, and entered in a data base. The data sets were sent to the BfR for statistical analysis.

To ensure high statistical power, 120 roe deer and 120 wild boars from each region were to be shot with lead-free ammunition and with leaded ammunition. Thus a total of 2,880 game animals or 8,640 muscle samples were studied. In addition, red deer were included if financial resources permitted so.

30.3 Further investigations into the killing effects of lead-free hunting ammunition

In 2010, the BMELV asked FWWJ to continue research on the killing effects of lead-free projectiles. This study was done to advance knowledge gained from field studies for the federal state Brandenburg, which had been conducted in 2006-2009 and which provided over 6,492 standardised field harvest records by forestry staff and hunting guests (Figure 30.1).

In this form (Figure 30.1), the following data are recorded:
- ammunition, especially the type of bullet and barrel length of rifle used;
- location of shot wound (both entry wound and exit wound);
- game species;
- body weight of animal;
- shot distance;
- distance that the game moved after the shot (escape route/flight trail);
- size of exit wound;
- signs found on the spot where the animal was standing when being hit by the bullet (hair, blood, tissue, tracks);
- organ damage;
- status of game meat;
- behaviour of animal before the shot;
- behaviour of animal after the shot;
- information on the flight trail;
- miscellaneous information (bone hit, obstacle in bullet path before striking animal);
- room for further notes;
- grading of bullet performance;
- whether report refers to skinned or skin-on carcass.

The same record form was used in the federal study 'Further investigations into the killing effects of lead–free ammunition (2010-ongoing). In this study, additional 4,902 records were collected until March 2012. Thus a total of 11,371 standardised field reports have been generated from all federal states of Germany, for the 4 major game species (roe deer, fallow deer, red deer and wild boar). Sixty-eight different bullet types were used, calibres ranging from 6.5 mm to 11.6 mm. This is, to our knowledge, the most extensive data set available from which to judge killing effects of hunting rifle bullets on wild game species.

Ballistische Daten:	FWWJ	Abschussbericht	Posteingang (nicht ausfüllen)
Patrone/Kal. : ____ Geschossart : ____ Gewicht (g) : ____ Lauflänge (mm) : ____ Industriell geladen : □ Fert. Zeich. : ____ Gewerbl. wiedergeladen: □ Selbst wiedergeladen: □ V_0: ____ ____ m/s	Reg. Nr.:	Name des Erlegers : ____ Strasse : ____ Wohnort : ____ ____ Telefonnummer: ____-____ Jagdbezirk/ OBF Nr. : ____ ____ ____	Fachgebiet Wildbiologie, Wildtiermanagement & Jagdbetriebskunde (FWWJ) Prof. Dr. S. Rieger Carl Gremse, Dipl. Forstw. Hochschule für nachhaltige Entwicklung Eberswalde (HNEE)

Datum :___ . ___ . 20 ___ Uhrzeit: ____ :____ | Jagdart: Ansitz : □ Pirsch: □ Bewegungsjagd: □ Nachsuche: □

beschossenes Wild			Aufbrechgewicht			Schussentfernung			Fluchtstrecke		
Rehwild	001		bis 10kg	007		unter 50m	013		am Anschuss	019	
Rotwild	002		11-20kg	008		51-100m	014		bis 15m	020	
Schwarzwild	003		21-45kg	009		101-150m	015		16-40m	021	
Damwild	004		46-75kg	010		151-200m	016		41-75m	022	
Sikawild	005		76-120kg	011		201-250m	017		76-150m	023	
Muffelwild	006		>120kg ____ kg	012		> 250 m____ m	018		> 150m ____ m	024	
Ausschussgröße (s. u.)			Schusszeichen (Anschuss)			Verletzte Organe			Organverletzungen		
ohne	025		Herzschweiß	031		Herz	038		normal	044	
bis 20mm	026		Lungenschweiß	032		Lunge	039		stark beschädigt	045	
21-35mm	027		Leberschweiß	033		Leber	040		nicht verwendbar	046	
36-60mm	028		Pansen/Gescheide	034		Niere	041		Wildbretzustand		
61-100mm	029		Schnitthaare	035		Gr. Gescheide	042		gut	047	
> 100mm____ mm	030		Knochensplitter	036		Kl. Gescheide	043		befriedigend	048	
Bitte Maßband mitführen!			Wildbret	037					mangelhaft	049	
Verhalten des Wildes vor dem Schuss			Verhalten des Wildes nach dem Schuss			Angaben zur Flucht - u. Schweißfährte			Sonstige Angaben 1		
ziehend	050		nicht gezeichnet	055		kein Schweiß	061		Hämatome /Blutergüsse	067	
flüchtig	051		gezeichnet	056		wenig Schweiß	062		Rückgrattreffer	068	
äsend / vertraut	052		nicht beobachtet	057		reichlich Schweiß	063		Rippentreffer	069	
alarmiert / gestreßt	053		bleibt stehen	058		regelmäßig Schweiß	064		sonst. Knochentreffer	070	
vor dem Hund	054		taumelt/bricht zusammen	059		Nachsuche erfolgreich	065		Schuss d. Hindernis	071	
			Flucht	060		Nachsuche ohne Erfolg	066		Entfern. Hind. zum Ziel		m

Sonstige Angaben 2:

Gesamtbeurteilung (abschließend bitte unbedingt ausfüllen!)					Berichterstatter hat das Wild aus der Decke geschlagen beurteilt
□ sehr gut	□ gut	□ befriedigend	□ schlecht	□ sehr schlecht	ja □ nein □

Figure 30.1. Field harvest record for observations of animal reactions before and after the shot.

Furthermore, in this study we gathered data on the performance of 15 projectiles (both leaded and lead-free) over a wide range of expected impact velocities. This analysis was done in a standardised, homogeneous material calibrated to offer resistance to the passing projectile similar to that of living animal muscle tissue (i.e. glycerine soap). Shots are fired from a proof barrel from 10 m distance with a calibrated impact velocity. Sensors measured the velocity of the bullet 2.5 m in front of the block and 0.8 m behind the block of soap. Each block was 25×25×40 cm (width × height × depth) and weighed close to 27 kg. The bullet entered the block and penetrated the soap leaving a cavity inside the soap block. Exiting bullet fragments were caught and their weight was measured which allowed computation of the deposited energy as difference of the energy upon entrance and exit. By measuring the cavity diameter based on a calibrated photograph with a special software, a three-dimensional model of the cavern could be generated by assuming piecewise truncated cones (Kneubuehl *et al.*, 2008). Assuming a relationship between cavern volume and deposited energy (Kneubuehl *et al.*, 2008), the total amount of energy expended along the z-axis (depth) of the soap block could be determined. This data set therefore reveals bullet behaviour, especially regarding depth and straightness of penetration, and the energy expended along the path of penetration (Figure 30.2).

The primary goal for the federal study was to test for relationships between observable animal reactions after being hit (mainly length of flight distance) to the bullet performance as measured by the experiments with soap blocks (penetration depth and energy release). To achieve this, we calculated the impact velocities of bullets used in the field reports data set using manufacturer values for muzzle velocity and ballistic coefficients of each bullet-cartridge combination. The ballistic coefficient of a bullet describes its potential to pass through the resistance of the air compared to a standard projectile. It is needed, in combination with the bullet's initial velocity (measured at the muzzle of the rifle barrel) and the estimated distance from the barrel tip to the game animal (estimated by the hunter), to calculate the impact velocity. We calculated this for all bullets tested in the soap block experiments. Visual

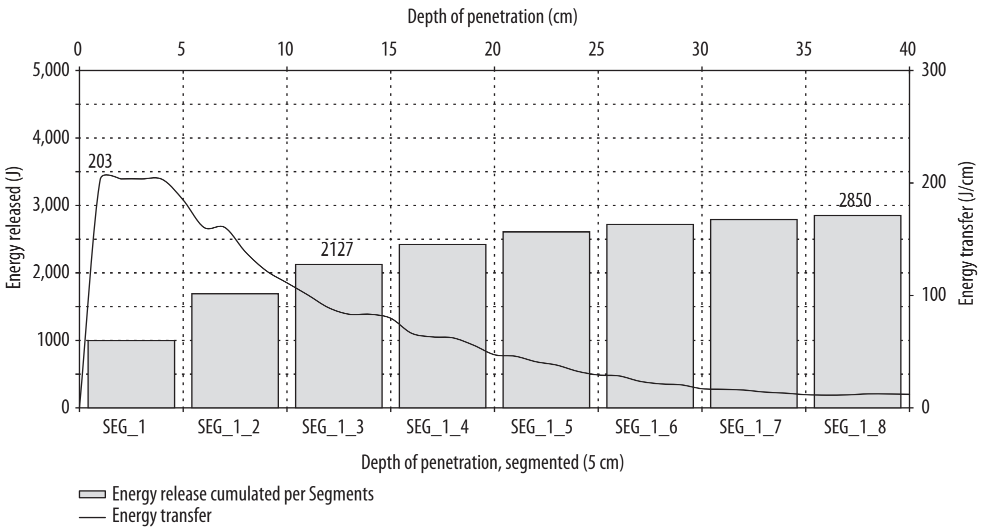

Figure 30.2. Example of an energy profile measured in ballistic soap. X-axis on top is the penetration depth in 5 cm segments. Bullet entry is at the left end of the figure. Cumulative energy release is shown (e.g. 1,000 J in Segment 1, 600 J in Segments 1 and 2). The line graph shows a measure of the bullet's effectiveness, i.e. energy transfer (J/cm).

estimation of the shot distance by the hunters would introduce some uncertainty as well as possible differences between 'typical' (specified by the manufacturer) and the actual muzzle (depending on the rifle used) velocity. These variations were regarded as most likely being relatively small compared to other sources.

We were able to relate 2,881 field reports to ballistic results from soap blocks, based on matching bullet type and impact velocity. In other words, we linked the observations reported by the hunter referring to the behaviour of the hit game, and carcass damage, achieved with a certain cartridge, at a certain shooting distance (Figure 30.1) to the experimental data on ballistic performance in standardised media, for the identical bullet type and velocity at impact.

This is to our knowledge a novel approach to assessing bullet performance by linking observations of terminal effects of a bullet used to an occurrence of specific ballistic data derived from standardised, repeatable experiments. We aim at providing a repeatable test regimen from these data so as to objectively evaluate bullet performance and how it varies with impact velocity. Unlike other countries, the German Protection of Animals Act (Tierschutzgesetz) covers killing of game animals by hunting. It is required that the person doing the killing has the necessary knowledge and skills and that only unavoidable pain is caused to the animal. Thus, our research will provide hunters with the essential knowledge to select the most suitable bullet for the task of harvesting their game humanely. The field data collection process ended on March 31st, 2012. The laboratory testing was finished on April 30th, 2012.

30.4 Proposal to combine data from the two studies to assess influence of ballistic factors on game meat contamination with bullet material

From the study 'Food safety of game meat', started in 2012, we expect data about the level of contamination caused by bullet material deposited in game meat. The method of data collection provides information on the bullet used, shot placement, structures hit (bone, tissue, organs, muscle), cartridge used and shot distance. In the study 'Further investigations into the killing effects of lead-free hunting ammunition' we used ballistic testing material (glycerine soap) to analyse bullet performance as a function of impact velocity and other factors. In order to study characteristics of bullet material dispersal in tissue simulants and later in tissues, 4 different bullet types (3 lead-free, 1 leaded) were fired on soap blocks, with a different impact velocities representative for hunting practice. A total of 36 soap blocks was obtained and examined by computer tomography (CT). Although analyses are not yet completed, preliminary results give evidence that: (1) bullet material dispersal seems to be dependent on impact velocity and bullet construction; and that (2) CT-analysis is well-suited to assess particle dispersal, number and size of distribution in the test medium.

30.5 Conclusions

30.5.1 What has been achieved?

A status report for the projects 'Food safety of game meat' and 'Further investigations into the killing effects of lead-free hunting ammunition' is presented. We propose a combined analysis of the data from both projects, especially the levels of lead, copper and zinc in game meat and the CT results with data of particle dispersal and size as a function of bullet construction and impact velocity. Projects are still ongoing and final analyses will be presented in 2014.

30.5.2 What has been neglected?

For a long time, there has been little concern about food safety aspects of hunting rifle bullets as vehicles of chemical hazards introduced into edible tissues. Since meat from wild game is enjoying increasing interest from consumers, it became clear that there is uncertainty about the extent of bullet-borne metal contamination in game meat compared to 'background' levels.

30.5.3 What needs to be done?

Further research will have to focus on determining relationships of net material loss of bullets in ballistic simulant material depending on material group (leaded vs. lead-free) and bullet impact velocity. These data need to be referenced with field hunting data, in order to derive frequency scales of occurrences of introduction events based on bullet choice and shot distance. Observations on particle size from ballistic testing and introduction of CT analysis of soap blocks should be used as routine tools to discern size and distribution of deposits in ballistic testing media, and then, the results should be compared with effects on animal tissue.

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