Vitenskapskomiteen for mattrygghet
Norwegian Scientific Committee for Food Safety

Risk assessment of lead exposure from cervid meat in Norwegian consumers and in hunting dogs

Opinion of the Panel on Contaminants of the Norwegian Scientific Committee for Food Safety

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Persons working for VKM, either as appointed members of the Committee or as ad hoc experts, do this by virtue of their scientific expertise, not as representatives for their employers. The Civil Services Act instructions on legal competence apply for all work prepared by VKM.

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Summary

Lead is a naturally occurring heavy metal found in small amounts in the earth's crust. Lead is also an environmental contaminant due to human activities. Humans and animals are exposed to lead through food, drinking water, air and dust.

Lead is accumulating in the body and is known to be harmful to humans and animals. In 2010 and 2011, respectively, both the European Food Safety Authority (EFSA) and JECFA (WHO) have concluded that there is no evidence for a threshold for critical endpoints of lead exposure i.e. under which there is no increased risk of adverse health effects. Public authorities work to reduce the lead exposure in the population.

Request from the Norwegian Food Safety Authority

Lead can be used in rifle ammunition for cervid hunting, but the use of lead shots for smaller animals including wild birds has been prohibited in Norway since 2005. Norwegian researchers have reported findings of high lead levels in minced meat from moose hunted by use of expanding lead-based ammunition. Maximum levels of lead (0.1 mg/kg) apply for meat from livestock animals, but not for game meat.

The Norwegian Food Safety Authority requested the Norwegian Scientific Committee for Food Safety (VKM) to assess the risk of lead exposure to the Norwegian population by consumption of cervid meat, including any subpopulations with an increased risk. Further, VKM was asked to describe the distribution of lead from ammunition in the carcass and to estimate the tissue area associated with the wound channel that has to be removed in order to reduce the risk. VKM was also asked to present, if any, other appropriate measures in addition to removing tissue in order to limit the content of lead residues from ammunition in cervid meat. Finally, VKM was asked to assess the significance of lead exposure to the health of dogs if they were fed with trimmings from the wound channel.

How VKM has addressed the request

The risk assessment of human lead exposure from cervid meat consumption has been performed by the VKM Panel on contaminants. The question regarding exposure in dogs has been addressed by members of the Panel on Animal Feed in collaboration with the VKM Panel on contaminants.

The current risk assessment is restricted to lead exposure from cervid meat consumption. Cervid animals include moose, red deer, fallow deer, roe deer, and wild reindeer. VKM has assessed the potential health risk associated with lead exposure from cervid meat, and not the benefits or nutritional value of eating cervid meat. Concentrations of lead in blood from several Norwegian studies in which cervid meat consumption also were reported were available and used in the present risk assessment.

When VKM perform a risk assessment, the experts review and assess available scientific documentation preferably from peer reviewed articles as well as international risk assessments and data from national and international surveillance and monitoring.

Use of lead-based hunting ammunition

Approximately 3% of the Norwegian population participated in one or more hunting activities during the hunting season 2011/2012. For cervid hunting, the use of rifle ammunition with expanding bullet/projectile of specific weight and impact energy is mandatory. More than 95% of Norwegian cervid hunters use lead based ammunition. Lead loss from bullets depends on the rifle calibre and bullet type used. A Scandinavian study with one commonly used calibre and different bullet types indicated a mean lead loss of 0.7 to 3.4 grams per bullet. One to two rifle shots are most often used to harvest a moose.

Expanding lead-containing bullets produce a cloud of lead particles in the meat around the wound channel. Lead fragments from disruptively-expanding, unbonded and some bonded expanding lead-containing bullets were found by radiography of various species (roe deer, red deer, wild board, sheep, chamois) in an average radius of 15 cm around the wound channel. The maximal penetration length of visible fragments was in average 29 cm. In a study on sheep, fragments from more stable types of expanding lead–containing bonded bullets were found at distances less than 5 cm. This is comparable to fragments from non-lead disruptively expanding bullets and non-lead expanding-nose bullets measured in the same study. Corresponding studies on moose have not been found. An available study indicate that lead concentrations above 0.1 mg/kg can be found at 25 cm distance from the wound channel in red deer and wild boar shot with various unknown ammunition. The majority of a limited number of hunting teams participating in a Norwegian study reported removal of meat in a radius of 10-20 cm from the wound channel. Some hunting teams reported removal of less than 10 cm.

Provided that farmed deer in Norway are harvested by headshot, it is not expected that lead is found in edible meat. However, if farmed deer are shot with lead-containing ammunition in the chest, it can be expected that the meat contain lead to similar extent as in wild cervids harvested in similar manner.

Lead in cervid meat and lead absorption

Whereas most cervid meat contains low levels of lead, high concentrations have been found in some samples, including Norwegian samples of minced moose meat, where lead concentrations from below 0.03 mg/kg to maximum 110 mg/kg have been reported. Ammunition commonly used for cervid hunting contains metallic lead. Metallic lead is less absorbed in the gastro-intestinal tract than ionic lead compounds. The absorption rate of ionic lead compounds has been found to be higher in children than adults. Metallic lead can be transformed to ionic lead in the stomach, as well as by acidic cooking conditions. Absorption of metallic lead increases with decreasing size of the lead particles. However, the present risk assessment is based on lead concentrations in blood, thus uncertainty related to bioavailability of metallic lead is not applicable.

Consumption of cervid meat in Norway

Lead exposure from cervid meat can be seen as an addition to the exposure from other food sources. According to a recent exposure assessment by EFSA, grains and grain products, milk and dairy products, non-alcoholic beverages, vegetables and vegetable products are the major dietary lead sources in the general population.

According to the most recent (2012) representative national dietary survey in Norway, mean game (including cervid) meat consumption was low, approximately 5-7 meals per year. However, in other Norwegian population studies including hunters, a large proportion (70%)

of the participants consumed cervid meat at least once a month or more often. No information on cervid meat consumption among Norwegian children has been found. However, it can be expected that children eat cervid meat equally often as the rest of the family.

Negative health effects associated with lead exposure

Lead concentration in blood is considered to be a good indicator of lead exposure. Lead exposure in Europe has decreased dramatically over the last three decades. In Norwegian studies, the mean or median concentrations of lead in blood were from 11 to 27 µg/L, which is in the same range as studies in most European countries the last 10 years. Blood lead concentrations were lower in pregnant women than in other adult population groups in Norway. No information on blood lead levels in Norwegian children has been found. Neurodevelopmental effects and increased blood pressure in adults were critical effects of lead exposure identified by both EFSA and JECFA. Children are more sensitive than adults to the effects of lead because their brain is under development. Increased blood pressure is not an adverse outcome by itself, but it is associated with increased risk of cardiovascular mortality. In addition, EFSA pointed out chronic kidney disease as a sensitive endpoint in adults.

Overview of reference values for blood lead concentrations associated with increased blood pressure and increased prevalence of chronic kidney disease in adults, and neurodevelopmental effects in children

Blood lead concentration (µg/L)	**Health effects at the population level**
12	1% reduction in full scale IQ in children (1 IQ point given IQ=100)
36	1% increased systolic blood pressure in adults (1.2 mmHg given a blood pressure of 120 mmHg)
15	10% increased prevalence of chronic kidney disease in adults

Lead exposure in cervid meat consumers

Associations between game meat consumption and blood lead concentration have been studied in four population studies in Norway. In the three studies performed in the years 2003-2005, a significant association between game meat consumption and higher blood lead concentration was only seen in the subgroup of male participants in one of the studies (the Norwegian Fish and Game study).

In the fourth study, the Norwegian Game and Lead study conducted in 2012, the median blood lead concentration was in the lower range of medians measured in most European and Norwegian studies over the past 10 years. This study also showed association between cervid meat consumption and concentrations of lead in blood. Those with frequent (monthly or more often) cervid meat consumption had about 30% higher average levels of lead in blood than those with less frequent consumption. However, there was a wide range, and many participants with high or long-lasting game meat intake had low blood lead concentrations. The increase in blood lead concentrations seemed to be associated with consumption of minced cervid meat, particularly purchased minced meat. Blood lead concentration was significantly higher in participants who reported self-assembling of lead-containing bullets.

Risk characterization

The blood lead concentrations measured in participants in the Norwegian population studies are in the range of, and partly exceeding, the reference values for increased risk of high blood pressure and increased prevalence of chronic kidney disease in adults, and for neurodevelopmental effects in children. The additional lead exposure from cervid meat in frequent (monthly or more often) consumers of such meat is therefore of concern.

At the individual level, the risk for adverse effect is likely to be small. At present lead levels, adults with for example normal blood pressure will most likely not experience any clinical symptoms by a small increase, although it may add to the burden of those individuals who are at risk of experiencing cardiovascular disease. A small reduction in the intelligence of children will not be notable at the individual level, but at the population level it can for instance increase the proportion not able to graduate from school. Lead exposure was declining in the population on which the reference value for increased prevalence of chronic kidney disease was based. EFSA noted that this reference value (15 µg/L) is likely to be numerically lower than necessary. The implications of having a concurrent blood lead concentration above the reference value cannot fully be interpreted, since it is not known when and at which level of lead exposure the kidney disease was initiated. However, an eventual increased risk of chronic kidney disease would be higher among those who consume cervid meat regularly or often than those who rarely consume such meat.

For these reasons, continued effort is needed in order to reduce lead exposure in the population.

Exposure reducing measurements

Removal of meat around the wound channel reduces the lead exposure from cervid meat consumption. Lead fragmenting and distribution is dependent on several variables, and there are no available studies in moose. The available studies do not allow a firm conclusion on the amount of meat needed to be trimmed around the wound channel in order to remove lead originating from the ammunition. Other possible measures to reduce lead exposure from cervid meat would be to use lead based ammunition with low fragmentation or ammunition without lead.

Risk of negative health effects in dogs

In dogs, metallic lead fragments most often pass through the gastrointestinal tract unretained. If larger lead fragments or particles are retained in the gastrointestinal tract for prolonged periods of time, this can result in a continual exposure and toxicity.

A daily dose around 1 mg lead acetate/kg bw is shown to increase the blood pressure in dogs after a few days of exposure, and is considered as a Lowest Observed Effect Level (LOEL). This corresponds to a lead acetate concentration of 10-20 mg/kg in fresh meat or offal when fed daily to dogs.

The uptake of lead from small metallic lead fragments in contaminated cervid products is probably lower than that of lead acetate. However, high metallic lead concentrations are expected to be present in meat trimmed from the wound channel. Even when a lower absorption of metallic lead than of lead acetate is taken into consideration, the risk for chronic health effects in dogs fed on trimmings of meat/offal from the wound channel from lead killed cervids can be considered as high. On the other hand, the risk for adverse effects after a single exposure of lead contaminated meat must be considered as low.

Data gaps in the risk assessments

VKM's Panel on contaminants has identified some data gaps during the course of this risk assessment. More data on lead concentration in Norwegian game meat, and in particular commercially available minced meat, are needed. There is a lack of data on fragmentation pattern of bullets in moose. Furthermore, more data are needed to assess bioavailability of metallic lead in food. Finally, no blood lead data or consumption data for children were available. This is needed for a refined risk assessment of lead exposure from game meat consumption in children.

Norsk sammendrag

Bly er et tungmetall som det naturlig finnes små mengder av i jordskorpen. Bly er også en miljøforurensning på grunn av menneskelig aktivitet. Mennesker og dyr får i seg bly gjennom mat, drikkevann, luft og støv.

Bly hoper seg opp i kroppen og er kjent for å være skadelig for mennesker og dyr. Både EUs mattrygghetsorgen (European Food Safety Authority, EFSA) og en ekspertkomite (Joint FAO/WHO Expert Committee on Food Additives, JECFA) i verdens helseorganisasjon (WHO) konkluderte i 2010 og 2011 at det ikke kunne fastslås en nedre grense for helseeffekter av bly, dvs. en blykonsentrasjon som ikke er forbundet med økt risiko for uønskede helseeffekter. Offentlige myndigheter arbeider med å redusere blyeksponering i befolkningen.

Oppdraget fra Mattilsynet

Bly er tillatt brukt i rifleammunisjon ved hjorteviltjakt, mens bruk av blyhagl ved småviltjakt (inkludert fuglejakt) har vært forbudt i Norge siden 2005. Norske forskere har rapportert funn av høyt blyinnhold i elgdeig etter bruk av ekspanderende blybasert ammunisjon. Grenseverdien for bly (0,1 mg/kg) er gjeldende for husdyrkjøtt, men ikke for viltkjøtt.

Mattilsynet ba Vitenskapskomiteen for mattrygghet (VKM) om å vurdere helsefaren for den norske befolkningen ved konsum av kjøtt og kjøttprodukter fra hjortevilt som er felt med blyholdig ammunisjon, og om å vurdere om det er grupper i befolkningen som er spesielt utsatt for helsefare ved slikt konsum. Videre ble VKM bedt om å beskrive spredning av bly fra ammunisjon i slaktet og anslå hvor mye av vevet rundt skuddkanalen som må fjernes for å redusere risikoen. VKM ble også bedt om å presentere andre passende tiltak enn bortskjæring av vev for å begrense innholdet av blyrester fra ammunisjon i hjorteviltkjøtt. Til slutt ble VKM bedt om å vurdere om det er fare for helsen til jakthunder hvis de ble fóret med avskjær fra skuddkanalen fra hjortevilt felt med blyholdig ammunisjon.

Hvordan VKM har besvart oppdraget

Vurdering av helserisiko er gjort av VKMs faggruppe for forurensninger, naturlige toksiner og medisinrester i matkjeden (Faggruppe 5). Spørsmålet om helsefare hos hunder har blitt beskrevet av medlemmer i faggruppen for fôr til terrestriske og akvatiske dyr i samarbeid med Faggruppe 5.

Denne risikovurderingen omhandler blyeksponering gjennom konsum av kjøtt og kjøttprodukter fra hjortevilt. Hjortevilt omfatter elg, hjort, dådyr, rådyr og villrein. VKM har vurdert den potensielle helserisikoen forbundet med blyeksponering fra konsum av hjorteviltkjøtt, og verken fordeler eller ernæringsmessig verdi av å spise slikt kjøtt er tatt med i betraktning. Risikovurderingen er basert på flere norske studier der både blykonsentrasjoner i blod og konsum av viltkjøtt hos deltakerne er tilgjengelig.

Når VKM utfører en risikovurdering, gjennomgår og vurderer ekspertene tilgjengelig vitenskapelig dokumentasjon om temaet, fortrinnsvis fagfellevurderte artikler, internasjonale risikovurderinger og data fra nasjonal og internasjonal kartlegging og overvåking.

Bruk av blybasert jaktammunisjon

Omtrent 3 % av den norske befolkningen deltok i en eller flere jaktaktiviteter i jaktsesongen 2011/2012. Ved hjorteviltjakt med rifle er det påbudt å bruke ammunisjon med ekspanderende kule som har definert vekt og slagkraft. Mer enn 95 % av norske hjorteviltjegere bruker blybasert ammunisjon. Blytap fra kulene avhenger av kaliber og kuletype som brukes. En skandinavisk studie med en vanlig kaliber og forskjellige kuletyper tydet på at det var et gjennomsnittlig blytap på 0,7 til 3,4 gram per kule. Ett til to rifleskudd blir oftest brukt for å felle en elg.

Ekspanderende blyholdige kuler gir fra seg en sky av blypartikler i vevet rundt skuddkanalen. Røntgenanalyse på flere arter (rådyr, hjort, villsvin, sau, gemse) har vist blyfragmenter fra lettekspanderende uloddede blykuler og fra noen typer ekspanderende loddede blykuler i en gjennomsnittlig radius på 15 cm rundt skuddkanalen. Synlige fragmenter ble i gjennomsnitt funnet maksimalt 29 cm fra skuddkanalen. Fragmenter fra mer stabile typer av ekspanderende loddede blykuler ble funnet i avstand mindre enn 5 cm fra skuddkanalen i en studie på sau. Dette er sammenliknbart med det som ble funnet med blyfrie lettfragmenterende kuler og blyfrie kuler med ekspanderende tupp i samme studie. Tilsvarende studier på elg har ikke blitt funnet. En studie som er gjort på hjort og villsvin, som ble skutt med forskjellige typer ukjent ammunisjon, tyder på at blykonsentrasjoner som er høyere enn 0,1 mg/kg kan finnes 25 cm fra skuddkanalen. Flesteparten av et begrenset antall jaktlag som deltok i en norsk undersøkelse rapporterte at de fjerner kjøtt i en radius på 10-20 cm fra skuddkanalen. Noen jaktlag rapporterte at de fjernet mindre enn dette.

Forutsatt at oppdrettshjort i Norge felles med ett hodeskudd, forventes det ikke at bly finnes i spiselig kjøtt. Men dersom oppdrettshjort blir felt med blykule i bogen, kan det forventes at kjøttet inneholder bly i samme grad som vill hjort felt på lignende måte.

Bly i hjorteviltkjøtt og blyopptak

Hjorteviltkjøtt inneholder stort sett lave nivåer av bly, men høye konsentrasjoner er funnet i enkelte prøver. I norske prøver av elgdeig har det blitt funnet blynivåer fra under 0,03 til 110 mg/kg. Vanlig brukt jaktammunisjon inneholder metallisk bly. Metallisk bly tas i mindre grad opp fra mage-tarmkanalen enn ioniske blyforbindelser. Barn tar opp mer av ioniske blyforbindelser enn voksne. Metallisk bly kan bli omdannet til ionisk bly i magen og dessuten under sure betingelser ved matlaging. Opptaket av metallisk bly øker med minkende størrelse på blypartiklene. Usikkerheten knyttet til opptak av metallisk bly er imidlertid ikke vesentlige i denne risikovurderingen, siden den er basert på blykonsentrasjoner i blod.

Konsum av hjortevilt i Norge

Blyeksponering fra hjorteviltkjøtt kan betraktes som et tillegg til eksponering fra andre matkilder. Ifølge en ny inntaksberegning fra EFSA er korn og kornprodukter, melk og melkeprodukter, alkoholfrie drikkevarer, grønnsaker og vegetabilske produkter de viktigste kostkildene til bly i den generelle befolkningen. Ifølge den nyeste (2012) representative landsomfattende kostholdsundersøkelsen i Norge er det gjennomsnittlige konsumet av viltkjøtt (inkludert hjorteviltkjøtt) lavt, ca. 5-7 måltider per år. I andre norske befolkningsstudier som inkluderer jegere, spiser imidlertid en høy andel (70 %) av deltakerne hjorteviltkjøtt minst en gang i måneden eller oftere. Det er ikke funnet informasjon om konsum av hjorteviltkjøtt blant norske barn, men det kan forventes at barn spiser hjorteviltkjøtt like ofte som resten av familien.

Negative helseeffekter forbundet med blyeksponering

Blykonsentrasjonen i blod er ansett å være en god indikator på blyeksponering. Blyeksponeringen i Europa har sunket dramatisk de siste tre tiårene. I norske studier var gjennomsnittlig eller median konsentrasjon av bly i blodet fra 11 til 27 µg/l, og dette er i samme størrelsesorden som i studier i de fleste europeiske land. Blykonsentrasjonene i blod var lavere hos gravide kvinner enn i andre grupper av voksne i Norge. Det er ikke funnet informasjon om blynivåer i blod hos norske barn. Både EFSA og JECFA identifiserte utvikling av nervesystemet og økt blodtrykk hos voksne som kritiske effekter av blyeksponering. Barn er mer følsomme enn voksne for virkningene av bly fordi hjernen deres er under utvikling. Økt blodtrykk er ikke å anse som en alvorlig helseskade i seg selv, men økt blodtrykk er forbundet med økt risiko for dødelighet fra hjerte-karsykdom. EFSA anså i tillegg at kronisk nyresykdom kan oppstå som et resultat av lav blyeksponering hos voksne.

Oversikt over referanseverdier for blykonsentrasjoner i blod som er forbundet med økt blodtrykk og økt forekomst av kronisk nyresykdom hos voksne og effekter på utvikling av nervesystemet hos barn

Blykonsentrasjoner i blod (µg/l)	**Helseeffekter på populasjonsnivå**
12	1 % senkning i fullskala IQ hos barn (1 IQ poeng ved IQ=100)
36	1 % økt systolisk blodtrykk hos voksne (1.2 mmHg ved blodtrykk på 120 mmHg)
15	10 % økning i forekomsten av kronisk nyresykdom hos voksne

Blyeksponering hos konsumenter av kjøtt og kjøttprodukter av hjortevilt

Mulige sammenhenger mellom konsum av viltkjøtt og bly i blod har blitt undersøkt i fire norske befolkningsstudier. Tre av studiene ble utført i årene 2003-2005. I en av disse (den norske fisk- og viltundersøkelsen) var det en signifikant sammenheng mellom konsum av viltkjøtt og økte blodkonsentrasjoner av bly kun hos menn.

Den fjerde studien (den norske hjortevilt- og blyundersøkelsen) ble utført i 2012. Middelverdien av blykonsentrasjonen i blodet hos deltakerne lå i den nedre delen av variasjonsbredden for middelverdiene i de norske og europeiske undersøkelsene som har vært gjennomført de siste 10 årene. I denne studien ble det vist sammenheng mellom konsum av hjorteviltkjøtt og konsentrasjoner av bly i blodet. De som spiste hjorteviltkjøtt hyppig (en gang i måneden eller oftere) hadde ca. 30 % høyere gjennomsnittlig blynivå i blodet enn de som spiste slikt kjøtt mindre hyppig. Det var imidlertid stor variasjon i blykonsentrasjonene og mange deltakere med høyt eller langvarig konsum av hjorteviltkjøtt hadde lave nivåer. Økningen i blykonsentrasjoner så ut til å være knyttet til konsum av kjøttdeig fra elg og hjort, og spesielt hvis deigen var kjøpt i butikk. Blykonsentrasjonene var betydelig høyere i blod fra deltakere som rapporterte at de ladet patronene selv.

Risikokarakterisering

Blykonsentrasjoner som er målt i blod blant deltakere i de norske befolkningsstudiene er i samme område som, og delvis over, referanseverdiene for økt blodtrykk og økt forekomst av kronisk nyresykdom hos voksne, og for effekter på utvikling av nervesystemet hos barn. Den ekstra blyeksponeringen fra hjorteviltkjøtt hos de som spiser slikt kjøtt hyppig (månedlig eller oftere) er derfor til bekymring.

Risikoen for negative helseeffekter er trolig liten på individnivå. Ved nåværende blynivåer vil for eksempel voksne med normalt blodtrykk sannsynligvis ikke få noen kliniske symptomer ved en liten blodtrykksøkning, selv om en liten økning kan være utslagsgivende for enkelte som fra før har høy risiko for hjerte-karsykdommer. En liten reduksjon i intelligens hos barn vil ikke være merkbar på individnivå, men på befolkningsnivå kan det for eksempel øke andelen som ikke vil være i stand til å gjennomføre obligatorisk skolegang.

Blyeksponering var synkende i befolkningen som referanseverdien for kronisk nyresykdom var basert på. EFSA bemerket derfor at denne referanseverdien (15 µg/l) sannsynligvis er lavere enn nødvendig. Virkningene av å ha en nåværende blykonsentrasjon i blod i befolkningen som er høyere enn referanseverdien kan derfor ikke tolkes fullt ut, ettersom det ikke er kjent når, og ved hvilket blynivå, nyresykdom oppsto. En eventuell økt risiko for kronisk nyresykdom vil imidlertid være høyere i befolkningsgrupper som spiser hjorteviltkjøtt hyppig (månedlig eller oftere) enn hos de som sjelden spiser slikt kjøtt.

Ut i fra dette er det behov for fortsatt innsats for å redusere blyeksponering i befolkningen.

Tiltak for å redusere blyeksponering

Fjerning av vev rundt skuddkanalen reduserer blyeksponeringen fra hjorteviltkjøtt. Blyfragmentering og spredning avhenger av flere variabler, og det er ikke funnet studier av dette i elg. De tilgjengelige studiene gir ikke grunnlag for en klar konklusjon angående hvor mye kjøtt rundt skuddkanalen som må kasseres for å fjerne blyrester fra ammunisjonen. Andre mulige tiltak for å redusere blyeksponering fra hjorteviltkjøtt kan være å bruke blyammunisjon som fragmenterer lite eller blyfri ammunisjon.

Risiko for negative helseeffekter hos hunder

Metalliske blyfragmenter vil som oftest passere uhindret gjennom mage-tarmkanalen hos hunder. Dersom større blyfragmenter eller partikler blir værende i mage-tarmkanalen i lengre perioder, kan det resultere i en kontinuerlig eksponering og toksisitet.

En daglig dose på rundt 1 mg blyacetat/kg kroppsvekt gir økt blodtrykk hos hunder etter noen dagers eksponering og kan betraktes som et lavest observert effektnivå (LOEL). Dette tilsvarer en blyacetatkonsentrasjon på 10-20 mg/kg ferskt kjøtt eller innmat som hunder fôres med daglig.

Opptaket av bly fra små metalliske blyfragmenter i kjøttprodukter fra hjortevilt er sannsynligvis lavere enn opptaket av blyacetat. Imidlertid kan det forventes høye konsentrasjoner av metallisk bly i avskjær fra skuddkanalen. Selv når lavere opptak av metallisk bly enn av blyacetat er tatt i betraktning, kan risikoen for kroniske helseeffekter hos hunder som fôres på avskjær av kjøtt/innmat fra skuddkanalen fra hjortevilt felt med blyholdig ammunisjon anses som høy. På den annen side må risikoen for uønskede helseeffekter etter en enkelt fôring med blyforurenset kjøtt betraktes som lav.

Kunnskapshull i risikovurderingen

VKMs faggruppe for forurensninger, naturlige toksiner og medisinrester har funnet noen kunnskapshull under arbeidet med denne risikovurderingen. Det er behov for flere data på blykonsentrasjon i norsk hjorteviltkjøtt, og spesielt i viltkjøttdeig som selges i butikk. Det mangler data om fragmentering av blykuler i elg. Videre er mere data nødvendig for å vurdere biotilgjengeligheten av metallisk bly i mat. Dessuten ble det ikke funnet data verken på blykonsentrasjon i blod eller på konsum av hjorteviltkjøtt hos barn. Dette er nødvendig for å gjøre en bedre risikovurdering av blyeksponering fra hjorteviltkjøtt hos barn.

Keywords

lead exposure, cervid/game meat consumption, lead-based ammunition, health risk

Abbreviations/Glossary

BfR	Bundesinstitut für Risikobewertung (Federal Institute for Risk Assessment)
BMD	Benchmark Dose
BMDL	Benchmark Dose Lower confidence limit
bw	body weight
Ca	chemical symbol for calcium
CDC	Centers for Disease Control and Prevention
CONTAM	Panel on Contaminants in the Food Chain
FFQ	Food Frequency Questionnaire
IARC	International Agency for Research on Cancer
IQ	Intelligence Quotient
JECFA	Joint FAO/WHO Expert Committee on Food Additives
LB	Lower bound
LOD	Limit of detection
LOAEL	Lowest Observable Adverse Effect Level
LOEL	Lowest Observable Effect Level
LOQ	Limit of quantification
MB	Middle bound
ML	Maximum level
NHANES	National Health and Nutrition Examination Survey
Pb	chemical symbol for lead
PTWI	Provisional tolerable weekly intake
SCF	European Commission's Scientific Committee for Food
SVA	National Veterinary Institute in Sweden
TOR	terms of reference
US ATSDR	United States Agency for Toxic Substances and Disease Registry
UB	Upper bound
US	United States
VKM	Norwegian Scientific Committee for Food Safety
MoBa	Norwegian Mother and Child Cohort study
MoBa Val	MoBa Validation study

Terms and expressions

BMD – Benchmark Dose

A dose or concentration that produces a predetermined change in response rate of an adverse effect (called the benchmark response or BMR) compared to background. The BMD approach estimates the dose that causes a low but measurable target organ effect (e.g. a BMR of 5% reduction in body or organ weight or a 10% increase in the prevalence of kidney toxicity).

BMDL – Benchmark Dose Lower confidence limit

By calculating the lower confidence limit of that estimated dose, the uncertainty and variability in the data is taken into account.

Brass

Brass is an alloy of copper and zinc with less than 70% copper

Carcass

The dead body of an animal, including one that has been slaughtered for food

Cervid meat

Cervid meat is meat from moose, red deer, roe deer

Frequent consumption

High and low frequency is study dependent, in the Norwegian Game and Lead Study defined as monthly or more often

Game meat

Game meat is meat from any wild animals including birds

Ground meat – see minced meat

Lower bound

Values below LOD or LOQ are set to zero

Middle bound

Values below LOD or LOQ are set to half of the LOD or LOQ.

Tombak

Tombak is an alloy of copper and zinc with more than 70% copper

Upper bound

Values below LOD or LOQ are set equal to the LOD or LOQ

Venison

Venison is prepared deer meat

Minced meat

Minced meat is grinded left-over meat from the whole slaughter, including edible meat located close to the wound channel (after trimming). Also called ground meat.

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Background

The Norwegian Food Safety Authority requests the Norwegian Scientific Committee for Food Safety (VKM) to perform a health risk assessment in the Norwegian population on consumption of cervid meat from moose and red deer shot with lead-based ammunition.

Norwegian analytical data for lead concentration in minced meat of moose harvested by lead-based ammunition have shown higher values than what allowed for livestock meat. Norwegian consumers may thus unintentionally be exposed to lead by consumption of game meat.

EU regulations give maximum limits for lead in livestock meat but not for game meat. The Norwegian Food Safety Authority has provided guidance to the education materials for competent hunters in Norway, which says, without further specification, that the wound channel of the projectile should be cut clean.

Lead is a heavy metal existing in the environment as a natural part of the Earth's crust, but also, and to a greater extent, as an environmental contaminant due to human activities. Lead has no natural physiological role in the human body and accumulates upon frequent and prolonged exposure. In sufficient concentration, lead may cause neurological and developmental problems in children and the foetus before birth and it may affect negatively the blood pressure and the kidney function in adults.

In 2010, the European Food Safety Agency (EFSA) published a scientific opinion on lead (EFSA, 2010). In 2011, the German risk assessment agency (Bundesinstitut für Risikobewertung, BfR) released a dietary advice where women of childbearing age, pregnant women and children are warned against eating game meat because of the lead content (BfR, 2011).

The Norwegian Food Safety Authority therefore requests VKM to perform a human health risk assessment adapted to Norwegian conditions for consumption of game meat from big game animals harvested with lead-based ammunition. Additionally, the significance of lead exposure to the health of dogs, such as hunting dogs, when they are being fed with trimmings from the wound channel of the carcass should be included.

The request from the Norwegian Food Safety Authority is answered by VKMs Panel of Contaminants (Panel 5). As basis for the characterisation of human lead exposure, VKM asked the Norwegian Institute of Public Health (NIPH) to compile their published and un-published data the last 10 years on game meat consumption and associations with blood lead concentrations in Norwegian population groups. Additionally, NIPH initiated a new population study of game meat consumption and blood lead concentrations in Norwegian cervid game hunters and non-hunters. Two members of the Panel on Animal's Feed (Panel 6) contributed to prepare the evaluation of hunting dog's exposure to lead by being fed with trimmings.

Terms of reference

The Norwegian Food Safety Authority requests the Norwegian Scientific Committee for Food Safety (VKM) to perform the following:

1. To assess the significance of lead exposure to the Norwegian population by consumption of cervid meat including meat from farmed red deer shot with lead-based ammunition. VKM is also requested to identify any subpopulations with an increased risk.
2. If a health risk concerning lead exposure is identified, VKM is requested to describe the distribution of lead from ammunition in the carcass of a newly shot animal. Furthermore, if it is possible to purify the cervid meat from lead residues, VKM is requested to estimate the tissue area associated with the wound channel that has to be removed.
3. To present, if any, other appropriate measures in addition to removing tissue in order to limit the content of lead residues from ammunition in cervid meat.
4. To assess the significance of lead exposure to the health of pets, such as hunting dogs, when they are being fed with trimmings from the wound channel.

Assessment

1 Introduction

Lead is a naturally occurring heavy metal which can be found in nearly all phases of the abiotic environment and in biological systems. Lead reaches the body through diet, drinking water, dust and air. The metal accumulates in several tissues and organs, but is particularly stored in bone. The most sensitive target organ following long-term, low level exposure to lead is identified to be the nervous system, and in particular the developing nervous system. The European Food Safety Authority has recently concluded that there is no evidence for a threshold for critical lead-induced effects.

After the phasing out of lead-containing petrol around 1980, and of lead-soldering in canned foods some years later, lead exposure has declined dramatically in most countries as shown by reduced blood lead levels. Low concentrations of lead have been measured in many foods, and relatively high lead concentration has been measured in minced game meat. Several publications and press releases the last couple of years have focused on the risk of higher lead exposure through regular consumption of game meat due to the use of lead-based ammunition.

The main focus in the present report is human exposure to lead through game meat consumption. Animal exposure to lead by consumption of game meat trimming from the wound channel is discussed in Chapter 8.

The present risk assessment of lead exposure from game meat consumption is based on hazard characterizations from the European Food Safety Authority (EFSA, 2010) and the Joint FAO/WHO Expert Committee on Food Additives (JECFA, 2011). Exposure data are mainly based on data from the Norwegian Institute of Public Health on consumption of game meat in Norway and lead concentrations in blood of the same consumers. For considerations of specific issues related to distribution of lead in cervids harvested with lead-based ammunition a report from the Federal Institute for Risk Assessment (BfR) in Germany (BfR, 2011) has provided valuable information. Other national reports addressing lead exposure and game meat consumption have also been considered (i.e. The Food Standards Agency, UK, 2012; Green P, 2009; Swedish National Food Agency, 2011).

1.1 Previous Risk assessments

1.1.1 Recent risk assessments on lead

In 2010, on request from the EU Commission, the Panel on Contaminants in the Food Chain (CONTAM) of the European Food Safety Agency provided an up-dated scientific opinion on the risks to human health related to the presence of lead in food including drinking water. In the exposure assessment non-dietary sources like air were addressed. All new developments regarding the toxicity of lead since the European Commission's Scientific Committee for Food (SCF) opinion of 1992 were taken into consideration. Critical effects for the risk assessment of lead were identified to be developmental neurotoxicity in young children and cardiovascular effects and nephrotoxicity in adults. For children, it was calculated that an average dietary intake of 0.5 µg lead per kilo body weight and day (kg bw/day) resulted in a 1 point decrease in intelligence quotient (IQ) (see Chapter 2.5 in this risk assessment for details). Cereal products were found to contribute most to the dietary lead exposure, whereas non-dietary sources such as dust and soil were suspected to be important exposure routes to lead in children. The report mentions that lead pellets ingested by, or imbedded in, animals that are used as food sources may also contribute to human exposure. The CONTAM Panel concluded that the provisional tolerable weekly intake (PTWI) of 25 µg/kg bw set by Joint FAO/WHO Expert Committee on Food Additives (JECFA) in 1993 is no longer appropriate as there is no evidence for a threshold for critical lead-induced effects. In adults, children and infants the margins of exposures were such that the possibility of an effect from lead in some consumers, particularly in children from 1-7 years of age, cannot be excluded. Protection of children against the potential risk of neurodevelopmental effects would be protective for all other adverse effects of lead, in all populations.

Lead was re-reviewed in 2010 by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) on request from the Codex Commission on Contaminants in Food (CCF) at its Seventy-Third Session (WHO food additives series; 960, 2011). All available data of toxicity and exposure (including bioavailability) of lead as well as other sources of lead exposure were taken into consideration for the evaluation. Adverse effects already at low blood lead concentrations are well documented for children. Especially the impairment of neurodevelopment and the reduction of the IQ in children are of concern, whereas lead-associated increase in systolic blood pressure in adults was identified to be the adverse effect associated with the lowest blood lead concentrations. JECFA concluded in accordance with EFSA, that the PTWI of 25 µg/kg bw (JECFA, 1993) no longer could be considered health protective and was withdrawn. The JECFA Committee concluded further that no new PTWI could be established since the dose-response analyses did not show indications of a threshold for critical effects of lead. The Committee reaffirmed that foetuses, infants and children are the most sensitive subgroups for lead exposure due to the neurodevelopmental effects of lead.

1.1.2 Previous risk assessments on lead exposure from game meat consumption

The Federal Institute for Risk Assessment in Germany (BfR) has assessed the additional health risk of lead exposure through the consumption of game meat in comparison to the mean lead exposure from the general diet, which previously had been evaluated by EFSA (2010). Lead-containing ammunition is widely used in game hunting of wild boar and deer in Germany, and bullet fragments may penetrate deeply into the surrounding muscle tissue, resulting in lead intake through game meat consumption.

The BfR has performed several scenario computations modelling the additional exposure to lead by game meat in different consumer groups based on a national survey on environmental contaminants in foods (LExUKon-Projekt, 2010). It was found that in view of the relatively high lead concentration in other types of food on the German market, such as grain products, fruit, and vegetables, the additional lead exposure by game meat represents a negligible contribution to the overall health risk for adult normal consumers (two portions per year) or high consumers (10 portions per year). However, families of hunters (50 to 90 portions game meat per year) have an increased risk. Children up to the age of seven and foetuses are subpopulations given special attention due to their enhanced sensitivity to lead. Therefore, the BfR-report concludes that women of childbearing age, pregnant women and children are especially vulnerable consumer groups and recommended to abstain completely from wild game meat consumption. Hunters are encouraged to avoid lead-containing bullets and rather use alternative ammunition.

A report (Green P, 2009) written for the British Deer Society reviewed the reported associations between use of lead ammunition and adverse health effects for humans, animals and the environment. This report concluded that lead-contaminated animal carcasses represent a significant risk for raptors and carrion eaters, and that for humans, only meat from regions more than 30 cm way from the radius of the wound channel would be safe to eat. Moderate consumption of minced meat from contaminated areas will lead to elevated lead concentrations in blood; however, the exposure from venison meat would be minor in comparison with the lead exposure caused by occupational, recreational, and environmental pollution.

A Swedish risk management report on lead in cervid meat was based on a Swedish pilot study where samples of minced meat from moose were mostly collected from private freezers and a few samples from game handling establishments ("slaughterhouses for game") were analysed for lead. The results were used to estimate human lead exposure from consumption of minced moose meat (Swedish National Food Agency, 2011). The National Food Agency issued the following advises for consumption of meat from cervid shot with lead-based ammunition: pregnant women, women planning pregnancy (three months before pregnancy) and children under the age of seven are advised to avoid consumption of cervid meat coming from parts of the animal which is close to the wound channel such as minced meat and pot pieces. Hunters, hunting families and other groups of the population are advised to limit their consumption of cervid meat coming from parts of the animal which is close to the wound channel such as minced meat and pot pieces to once a week. Other parts of the cervid (e.g. legs, neck, thighs, and fillets) are not expected to have elevated levels of lead from the ammunition and can therefore be consumed.

In the UK, the Food Standards Agency (FSA) in 2012 conducted a risk assessment on lead exposure from game meat consumption, based on a consumption survey of high-level consumers of lead-shot wild-game meat in Scotland and pre-existing data on lead levels in these types of food in the UK. The risk assessment concluded that regular consumption of game meat could increase exposure to lead, and that this increased exposure would be a concern in the case of toddlers, young children and pregnant women, because of the neurotoxicity of lead to the developing brain (FSA, 2012). The report highlighted that lead levels were higher in smaller game (birds) than larger game (venison). Following the risk assessment, the UK Food Standard Agency issued the following advice: “To minimise the risk of lead intake, people who frequently eat lead-shot game, particularly small game, should cut down their consumption. Pregnant women or women trying for a baby are particularly advised to minimise their exposure to lead” (FSA, 2012).

1.2 Legislation

The European Commission has established maximum levels in a number of commonly used foods and the Regulation (EC) No. 1881/2006 for determining the maximum of certain contaminants in foods (mg/kg wet weight) applies (see Table 1). However, game meat is not included in this regulation.

Table 1: Maximum levels for lead as lead down in Commission Regulation (EC) No 1881/2006.

Food	Maximum levels (mg/kg wet weight)
Raw milk, heat-treated milk and milk for the manufacture of milk based products	0.020
Infant formula and follow-on formula	0.020
Meat (excluding offal) of bovine animals, sheep, pig and poultry	0.10
Offal of bovine animals, sheep, pig and poultry	0.50
Muscle meat of fish	0.30

Food	Maximum levels (mg/kg wet weight)
Crustaceans, excluding brown meat of crab and excluding head and thorax meat of lobster and similar large crustaceans (Nephropidae and Palinuridae)	0.50
Bivalve molluscs	1.5
Cephalopods (without viscera)	1.0
Cereals, legumes and pulses	0.20
Vegetables, excluding brassica vegetables, leaf vegetables, fresh herbs and fungi. For potatoes the maximum level applies to peeled potatoes	0.10
Brassica vegetables, leaf vegetables and the following fungi: Agaricus bisporus (common mushroom), Pleurotus ostreatus (Oyster mushroom), Lentinula edodes (Shiitake mushroom)	0.30
Fruit, excluding berries and small fruit	0.10
Berries and small fruit	0.20
Fats and oils, including milk fat	0.10
Fruit juices, concentrated fruit juices as reconstituted and fruit nectars	0.050
Wine (including sparkling wine, excluding liqueur wine), cider, perry and fruit wine	0.20
Aromatised wine, aromatised wine-based drinks and aromatised wine product cocktails	0.20

See the original Regulation for further definitions and explanations of individual food commodities. ML: maximum level.

2 Hazard identification and characterisation

2.1 Lead Chemistry

Lead is a naturally occurring heavy metal with an atomic number of 82 and atomic mass of 207.2 g/mol. It is soft, has a low melting point (327.5°C), a high density, and is very resistant to corrosion but tarnishes upon exposure to air (Korn et al., 2006). Lead is rarely found naturally as a metal but usually occurs as ionic lead in minerals and salts in the main oxidation states +2 (most prevalent form) and +4. The solubility of lead salts such as lead sulphide, sulphate, phosphate and carbonate in water is a function of pKa, water hardness, salinity and the presence of humic material (EFSA, 2010).

Organic lead compounds such as tetraethyl lead and tetramethyl lead are industrially synthesised and have been widely used as fuel additives until the late 1980's. Human exposure by these highly volatile, lipophilic compounds occurs mainly through inhalation, but also through dermal exposure and ingestion of contaminated food and water (EFSA, 2010).

2.2 Toxicokinetics

The bioavailability of ingested lead from the gastrointestinal tract is very individual and depends on the physiochemical properties of the ingested material and the actual conditions of the consumer such as age, fasting, nutritional calcium and iron status, pregnancy, etc.

2.2.1 Absorption (oral, inhalation, dermal)

Metallic lead is poorly absorbed in the gastro-intestinal tract as compared to ionic lead compounds such as lead carbonate, lead sulphide, lead acetate, lead nitrate, lead phosphate, lead chromate, lead molybdate, lead oxide, lead chloride, and lead sulphate.

In a comparative study feeding rats with 0.075% of different lead compounds in the diet and measuring lead concentrations in kidneys, respectively 3-times, 5-times, 7-times, and 12-times more lead chromate, sulphide, acetate, and basic carbonate were absorbed than metallic lead with a particle size of 180 - 250 µm (Baltrop and Meek, 1975). The addition of 7.5% oil to the diet increased the absorption of lead acetate two-fold. An inverse relationship was found between the particle size of metallic lead and the absorption efficiency. A five-fold increase was observed with 6 µm lead particles compared to 200 µm particles (Baltrop and Meek, 1979). Lead particles in the nanometre range can be directly absorbed by pinocytosis in the rat duodenum (Jani et al., 1990). Absorption rates were about 7% for particles up to 50 nm and 2 - 7% for particles sized 50 - 500 nm. Metallic lead may remain for longer periods in the gut or may be oxidised into ionic compounds in the gastric environment. Small lead fragments have a high surface area-to-mass ratio and are as such more easily eroded by gastric fluids. In sum, metallic lead has been assigned a bioavailability coefficient of 0.2 as compared to lead acetate in rats (Baltrop and Meek, 1979).

The presence of food can decrease the absorbance of water-soluble lead compounds such as lead acetate depending on the food components (Rabinowitz et al., 1980; James et al., 1985; Maddaloni et al., 1998). The kinetic of isotope-labelled lead nitrate given in the diet was studied in healthy humans (n=5) up to 124 days and daily absorption rates of 6.5 to 11% were determined (Rabinowitz et al., 1976). Other studies using isotope-labelled lead have estimated the average bioavailability in humans to be 18 – 45% for different soluble salts (Blake et al., 1976; Chamberlain et al., 1978; Rabinowitz et al., 1980). It could be increased to more than 60% in fasting adults (Rabinowitz et al., 1980; US ATSDR, 2007; BfR, 2010). The absorption rate of ionic lead compounds has been found to be higher in children (James et al. 1985) and balance studies have determined an average bioavailability of 50% (Alexander et al. 1974; Ziegler et al, 1978; BfR, 2010). There is evidence for an age-dependency of the gastrointestinal lead uptake (Pounds et al., 1978).

The absorption of metallic lead has been studied in healthy volunteers with isotope-labelled tracers. A single dose of metallic lead was administered in beer. One study showed 1.3 - 16% absorption (n=3) (Hursh and Suomela, 1968), and in another study the average was 14% (n=9) (Newton et al., 1992). In another long-term study with metallic lead in the diet the mean absorption was 8% (Kehoe, 1961).

Plasma-bound lead crosses the placental barrier resulting in approximately the same blood levels in foetuses and mothers. An infant's blood lead at birth closely follows that of its mother even at high values (Clark, 1977).

The nutritional iron status is of importance for lead absorption which increases with iron deficiency (Bárány et al., 2005; Bannon et al., 2003). The same correlation has been observed for calcium deficiency (Blake and Mann, 1983; Mahaffey et al., 1986). Dietary vitamin D deficiency has been found to increase the absorption of lead nitrate from the gut due to prolonged gastrointestinal transit times, whereas parental vitamin D administration resulted in dose-related enhancement of lead excretion and changes in tissue-lead concentrations (Barton et al., 1980). Milk, which is a major source of calcium and which was used as treatment against lead poisoning for many years, has been shown to increase the uptake of lead (James et al., 1985), possibly because of lactoferrin (Henning and Cooper, 1988). The absorption of lead from ingested contaminated soil ranged from 2.5% to 26% dependent on the fasting status of the consumers and the particle sizes of the soil and the lead compounds (Maddaloni et al., 1998; Ryan et al., 2004; IARC, 2006).

Different cooking and food processing procedures have great influence on the transfer from metallic lead from shot and bullet splinters to cervid meat (Mateo et al., 2007). Small lead particles react with muscle tissue proteins under longer periods of meat-maturating processes as a proportion of time resulting in the formation of lead-proteinate precipitates (Hecht, 2000). Such precipitates dissolve in gastric juice more easily than metallic lead particles. Lead concentrations increased when cervid meat was cooked in acidic conditions such as in the presence of acetic acid or wine (Mateo et al., 2011).

The uptake of lead compounds by inhalation depends mainly on particle sizes and solubility. Approximately 30–50% of lead in inhaled air is deposited in the respiratory tract, depending on the size of the particles and the ventilation rate of the individual (IARC, 2006). Different chemical forms of inorganic lead seem to be absorbed equally (Morrow et al., 1980) and the half-life for lead retention in the lungs is about 15 h (Chamberlain et al., 1978; Morrow et al., 1980). Particles <1 µm might be deeply inhaled into distal parts of the respiratory tract, where they can be ingested by macrophages or dissolved in the extracellular fluid and absorbed. Up to 95% of lead inhaled as submicron particles is absorbed. Lead particles >5 µm such as in fumes and dusts are transported from the lining of the trachea and bronchi by mucociliary transport into the pharynx and are swallowed (EFSA, 2010).

Dermal absorption of lead compounds is less efficient compared to the other ways of exposure. Absorption through intact skin was 0.18 ± 0.15% of the applied lead acetate and through scratched skin 0.26 ± 0.46% (Moore et al., 1980). Exposure from the use of hair-colouring agents containing lead acetate was reported to be insignificant (Cohen & Roe, 1991, IARC, 2006). Factory workers handling lead batteries had high concentrations of lead in sweat (Florence et al., 1988). Finely-powdered lead metal and lead oxide (particle sizes < 0.45 µm) or lead nitrate solution placed on skin were rapidly absorbed and appeared in sweat, saliva (Lilley et al., 1988) and blood (Stauber et al., 1994). Increased sweating resulted in higher absorption. Already a short contact with lead compounds can result in elevated skin concentrations and percutaneous penetration even if quickly followed by washing (Filon et al., 2006). Decontamination after 30 min of exposure was unsuccessful even if detergent was used.

2.2.2 Distribution

Lead is rapidly absorbed into blood plasma and transported into the red blood cells where it is bound to haemoglobin (50%) and proteins such as delta-aminolevulinic acid dehydratase (ALAD) (Bergdahl et al, 1998; Patočka and Černý, 2003; BfR, 2010). ALAD exists in two polymorphic forms, which might have an impact on lead pharmacokinetics. In plasma, approximately 40-75% of lead is bound to plasma proteins, mainly albumin (EFSA 2010). Under steady-state conditions about 95-99% of the lead is taken up by the erythrocytes (Marcus, 1985c; Bergdahl et al., 1999; Manton et al., 2001). Lead transport into and out of the erythrocytes involves probably an anion exchanger and an ATP-dependent active transport via a Ca^{2+}-channel, respectively (Simons 1988; Simons 1993; Calderon-Salinas et al., 1999). Foetal haemoglobin has a higher affinity to lead than adult haemoglobin (Ong and Lee, 1980; BfR, 2010). Human blood lead concentrations are used as biomarker for lead exposure. Blood lead concentration reflects, however, only recent exposure to lead and is not suitable to fully show past exposure (Marcus, 1985b). At blood lead concentrations lower than 400 µg/L, blood lead concentration increases linearly with serum levels. At higher concentrations, binding in the erythrocytes is saturated so that the lead serum-to-blood ratio increases non-linearly.

Circulating blood-borne lead equilibrates rapidly with extracellular fluid, crosses the blood-brain and placental barrier, and accumulates in soft tissues such as liver and kidneys and hard tissues such as bones. The relative distribution of lead in the soft tissues with liver concentration (1 µg/g) as the reference unit value has been found as 0.8 for kidney cortex, 0.5 for kidney medulla, 0.4 for pancreas, 0.4 for ovary, 0.3 for spleen, 0.2 for prostate, 0.2 for adrenal gland, 0.1 for brain, 0.1 for fat, 0.08 for testis, 0.07 for heart, and 0.05 for skeletal muscle (EFSA, 2010).

Lead is usually incorporated into bones with relatively high turnover rates and is competing with dietary calcium. In adults, approximately 90-95% of the total lead body burden is disposed in the bones in contrast to 70-75% in children (EFSA, 2010; BfR, 2010). The skeleton cannot be considered as one pool since bone activities differ considerably. Using osteon formation rates as a measure, turnover rates of about 8% for spine, 2% for femur, tibia, radius and fibula, and < 2% for the skull have been determined. Furthermore, bone turnover rates decrease with age and health (Rabinowitz, 1991). Bone lead acts as reservoir and might be mobilised during periods of stress, fever, hyperthyroidism, long-time immobilisation, pregnancy and lactation (Patočka and Černý, 2003). Lead concentrations in bones give a record of past lead exposures as levels commonly increase with age reflecting the ratio of skeletal and lead half-lifes and the decrease of bone turnover rates (Marcus, 1985a). Furthermore, in growing children lead accumulates mainly in the inner, sponge-like trabecular part of the bone whereas it is distributed in both the trabecular and the outer, compact mantle-like cortical bone in adults (US ATSDR, 2007).

Lead distribution has been examined by using deterministic, stochastic and multi-compartment models (Rabinowitz et al., 1973; Batschelet et al., 1979; Marcus, 1985; Leggett 1993). Additionally, respiratory and gastrointestinal models have been described. The development of an age-specific biokinetic multi-component model has made it possible to describe successfully the time-dependent distribution and excretion of orally or intravenously administered lead (Leggett, 1993). The model defines blood circulation as the central compartment to which several paths, secondary-ranked (e.g. liver, kidney) and third-ranked compartments (trabecular bone, skin, hair, nails) are connected. Soft tissues are divided into such with rapid turnover, intermediate turnover, and tenacious retention. Transport of lead between the compartments is assumed to follow first-order kinetics provided that the concentration in the red blood cells stays below a threshold concentration (25 µg lead/dl blood). Transfer rates between the compartments are assumed to be age-dependent.

2.2.3 Excretion

Measurable blood lead levels reflect recent absorption since the half-life of lead in blood is about four weeks in mammals and two weeks in birds. In adult male humans half-life is about 25-40 days in blood and erythrocytes, 40 days in soft tissues and up to 28 years in bones (Patočka and Černý, 2003; Gulson, 2008).

Non-retained lead is excreted unchanged from the body in urine (65-75%) and faeces (25-30%) (Mushak, 1993). Excretion by the kidneys occurs probably by passive diffusion and in the liver by biliary excretion in a glutathione-dependent process (Alexander et al., 1986) or pancreatic juice (Ishihara et al., 1987). Faecal lead includes additionally the non-absorbed fraction and lead from the inhalation of submicron lead particles (EFSA, 2010).

Maternal lead can be transferred to infants during breastfeeding (EFSA, 2010). The milk/blood ratio is usually < 0.1 but can also considerably increase (Ettinger et al., 2006). Generally, lead elimination via breast milk, saliva, sweat, hair and nails is of minor importance in comparison to the other excretion routes.

2.3 Markers of lead exposure

For biological monitoring of metal exposure (e.g. in an occupational toxicology context), urine and especially whole blood samples are the most widely used matrixes to assess exposure. Blood was used in the recent survey by the Norwegian Institute of Public Health to assess lead exposure to provide background information for VKM to be used in the current risk assessment. There are, however also other possible markers or matrices for lead analyses.

2.3.1 Lead in blood

More than 90% of lead in blood is in the red blood cells. Furthermore, within the erythrocytes, there seems to be two important compartments for lead, one associated with the membrane and one with haemoglobin.

Absorbed lead is circulated in the blood primarily within erythrocytes and transferred to soft tissues (such as liver and kidneys), and to bone tissue, where it accumulates with age (se "Bone lead", below). Half-life for inorganic lead in blood is approximately 30 days and excretion is primarily in urine and faeces (see Chapter 2.2).

Lead in blood is considered to be the best indicator of the concentration of lead in soft tissues, reflecting recent and, to some extent, past exposure (EFSA, 2010). Thus, most of the information on human exposure to (and the health effects of) lead is based on blood-lead data. The concentrations of lead in plasma and serum are very similar. However, although there are indications that the lead concentration in plasma or serum could be an alternative for biological monitoring, there are very few epidemiological studies in which lead concentrations in these matrices have been used in exposure assessment. Thus, it is not known whether plasma or serum lead is a better marker of exposure than (whole) blood-lead for use in risk assessment.

2.3.2 δ-Aminolevulinic acid dehydratase (ALA-D)

Most of the lead in blood is present in the red blood cells (see above), as a result of its high affinity to δ-aminolevulinic acid dehydratase (ALA-D). Furthermore, environmental lead exposure measured from blood inhibits ALA-D and elevation of δ-aminolevulinic acid (ALA) level, because of inhibition of ALA-D enzyme, is a major neurotoxic mechanism for lead poisoning. In a population of mothers and new-borns who were exposed to low environmental lead level, Campagna et al. (1999) found a negative relationship between whole blood ALA-D activity and blood lead levels, and a potential threshold for this relationship. It has also been shown that ALA-D genotype predicts toxic effects of lead on human peripheral nervous system (Zheng et al. 2011). According to Chalevelakis et al. (1995), ALA-D activity has a high specificity (100%) but low sensitivity (37%) as an index of toxic lead exposure, and they suggest that ALA-D activity should be restricted to monitoring cases with moderate or severe lead poisoning. Conversely, findings by Takebayashi et al. (1993) suggest that ALA-D is a useful indicator for assessing the early effects of exposure to lead on haem biosynthesis.

2.3.3 Lead in urine

Renal excretion of lead is usually with glomerular filtrate with some renal tubular resorption. When blood levels are elevated, excretion may be increased by transtubular transport.

2.3.4 Bone lead

The largest and kinetically slowest pool for lead in the body is the skeleton with a half-life of more than 20 years and a much more labile soft tissue pool. Bone lead therefore reflects the long-term uptake and body burden. Primary teeth are thus an applicable matrix for lead exposure monitoring in children.

2.3.5 Lead in hair

Hair samples are also of interest with regard to metal exposure, because metallic cations form bonds with the sulphur of the keratin matrix of the hair.

While blood and urine concentrations reflect recent exposure, hair reflects past exposure providing an average of the growth period. Hair grows approximately 10 mm per month and may thus serve as a monitor of past and recent exposure (usually the previous two to three months).

2.4 Mechanisms of action

According to the recent review of lead by EFSA (2010), the toxicity of lead is in general linked to its affinity for thiol groups (-SH) and other organic ligands in proteins and to its ability to substitute for calcium. Additionally, lead may interfere with calcium, magnesium and zinc homeostasis in the body. Lead passes the blood-brain barrier, causing cell death and interferences with the transfer of signals between nerve cells and the myelin producing support cells.

There is evidence, or suggestions of evidence, for specific pathways behind lead-induced adverse effects in various organs and organ systems in the scientific literature. However, the specific mechanisms of actions behind all aspects of lead-induced toxicity in different organs still remain to be fully elucidated.

For details of the mechanisms by which lead may elicit toxicity in the nervous, renal, cardiovascular and haematological systems, please refer to EFSA (2010).

2.5 Lead toxicity in humans

Lead is not metabolised by the human body, but accumulates in various organs (see Section 2.2). The lead toxicity to humans has been extensively reviewed (CDC, 2005; US ATSDR, 2007; EFSA, 2010; JECFA, 2011). In 2006, the International Agency for Research on Cancer (IARC) concluded that inorganic lead is a class 2A carcinogen, i.e. insufficient evidence of human carcinogenicity, and that the mode of action most probably is epigenetic (i.e. non-genotoxic).

For the general population, the most common way of lead exposure is oral. Descriptions of lead toxicity in humans are summarised below.

The acute toxicity of lead is low. Acute lead poisoning occurs primarily accidentally after absorption of large quantities of lead over a short period of time resulting in high lead levels in blood and tissues. The main clinical symptom is abdominal pain (colic), but other gastrointestinal signs like constipation, nausea, and vomiting besides anorexia may emerge. In children, toxic encephalopathy and convulsions may occur, resulting in coma and death. This is, however, not relevant for dietary exposure to lead at current concentrations in food, including game meat.

Chronic lead toxicity is of most concern when the potential risk to human health is considered. Both EFSA (2010) and JECFA (2011) identified the most critical effect of lead to be developmental neurotoxicity and reduction of the Intelligence Quotient (IQ) in children up to the age of seven. No threshold for this critical lead-induced effect was found and foetuses, infants and children are considered to be the most sensitive subgroups for lead exposure. Both EFSA and JECFA used a benchmark dose (BMD) approach in their risk assessments of lead. The BMD approach makes extended use of the dose-response data from studies in experimental animals or from observational epidemiological studies to better characterise and quantify potential risks (EFSA, 2009). EFSA identified a $BMDL_{01}$ of 12 µg/L blood lead concentration as reference point for risk of intellectual deficits in children as assessed by a Full Scale IQ in the risk characterization of lead. According to EFSA and JECFA, a small IQ-decrease may be viewed as a small impact on an individual child, but is considered important as a reduction in a population's IQ[1]. The lead-associated reduction in children's IQ is regarded as a marker for other neurodevelopmental effects observed at approximately the same blood lead levels (e.g. attention deficit hyperactivity disorder, reading deficit, executive dysfunction, fine motor deficit), but for which the scientific evidence is not as robust as for the IQ.

EFSA (2010) pointed out that long term exposure to lead may cause adverse cardiovascular effects (increased systolic blood pressure) in adults. Increased blood pressure is not an adverse outcome by itself, it is however associated with increased risk of cardiovascular mortality. The EFSA CONTAM Panel chose a $BMDL_{01}$ of 36 µg lead/L blood for derivation of a reference point for increased blood pressure (EFSA 2010). JECFA (2011) also identified increased systolic blood pressure to be the adverse effect in adults associated with the lowest blood lead concentrations. Both EFSA (2010) and JECFA (2011) noted that corresponding to the lead-associated reduction in IQ in children, the increase in systolic blood pressure in adults is small individually seen (2 mmHg), but important when viewed as a shift in the distribution of blood pressure within a population.

EFSA (2010) in addition identified chronic kidney disease (defined as 50% reduction in glomerulus filtration rate to below 60 $mL/1.73m^2$ body surface/minute) as a sensitive endpoint in adults for lead toxicity, and identified a $BMDL_{10}$ of 15 µg lead/L blood for increased prevalence of chronic kidney disease. None of the benchmark models was acceptable at $P \geq 0.10$ (the criterion preferred according to EFSA (2009)). However, as the precision in the incidence rates in the dataset used for benchmark modelling was high due to

[1]EFSA (2010) chose a $BMDL_{01}$, i.e. a decrease of cognitive ability by 1 IQ point, to account for the fact that a shift of the distribution of the IQ by 1 IQ point to lower values would have an impact on the socioeconomic status of the population and its productivity. EFSA referred to one study which related a 1 point reduction in IQ to a 4.5% increase in the risk of failure to graduate from high school, and another study which showed that a decrease of 1 IQ in children can be associated with a decrease of later productivity of about 2%.

JECFA (2011) presents the following example: "If the mean IQ was reduced by 3 points, from 100 to 97, while the standard deviation and other characteristics of the distribution remained the same, there would be an 8% increase in the number of individuals with a score below 100. Moreover, there would be a 57% increase in the number of individuals with an IQ score below 70 (2 standard deviations below the expected population mean, commonly considered to be the cut-off for identifying individuals with an intellectual disability) and a 40% reduction in the number of individuals with an IQ score greater than 130 (considered to be the cut-off for identifying individuals with a "very superior" IQ)."

the large study population (almost 15 000) in the cross-sectional data from the National Health and Nutrition Examination Survey (NHANES) (1999-2006), the model acceptance criterion was reduced to P >0.01. EFSA noted that chronic kidney disease is clearly an adverse effect, and that the magnitude of the benchmark response (10% change in the prevalence of chronic kidney disease), is such that the response would be of potential concern. The $BMDL_{10}$ was based on concurrent concentration of lead in blood and accounted for a substantial proportion of inter-individual variation in toxicokinetics. Chronic kidney disease would depend on lead exposure over a prolonged interval of time, during which such exposure was declining appreciably in the population on which the $BMDL_{10}$ was based. Hence, the $BMDL_{10}$ for this endpoint is likely to be numerically lower than necessary to protect against lead-induced chronic kidney disease (EFSA 2010).

For further details, please refer to EFSA (2010) and JECFA (2011).

2.6 Summary of hazard identification and characterisation

Lead is a naturally occurring heavy metal which usually occurs as ionic lead in minerals and salts. The industrial application of lead is numerous. Human exposure occurs through inhalation, dermal exposure and ingestion of contaminated food and water.

The bioavailability of different ionic lead compounds in adults has been reported to be in the range 7-45%, but in average 60% in fasting adults. The average bioavailability of ionic lead is approximately 50% in children. Metallic lead is less absorbed and has been assigned a bioavailability coefficient in rats of 0.2 as compared to lead acetate. An inverse relationship was found between the particle size of metallic lead and the absorption efficiency. A five-fold increase was observed with 6 µm lead particles compared to 200 µm particles, and pinocytosis in the duodenum might be involved. Human studies investigating single or multiple administration of metallic lead in beer or the diet resulted in absorption rates of 1.3 to 16%.

Lead is rapidly absorbed into blood plasma and transported into the red blood cells. Circulating blood-borne lead equilibrates rapidly with extracellular fluid and crosses the blood-brain and placental barriers. The blood lead level of the new-born reflects that of the mother. In adults, approximately 90-95% and in children 70-75% of the total lead body burden is disposed in the bones. Lead half-life in human is about 25-40 days in blood and erythrocytes, 40 days in soft tissues and up to 28 years in bones. Non-retained lead is excreted unchanged from the body in urine (65-75%) and faeces (25-30%).

Lead in blood is considered to be the best indicator of the concentration of lead in soft tissues, reflecting recent and, to some extent, past exposure.

The acute toxicity of lead is low and not relevant for humans eating lead-shot game meat. Chronic lead toxicity is of relevance when the potential risk to human health is considered. The critical toxic effect of lead exposure is considered to be neurodevelopmental effects, and foetuses, infants and children are the most sensitive subgroups. In adults, increased blood pressure and chronic kidney disease are the critical effects. No threshold for lead-induced toxicity has been identified. A $BMDL_{01}$ of 12 µg/L lead in blood was identified by EFSA as reference point for the risk of intellectual deficits in children assessed by a full scale IQ, which was regarded as a marker for other neurodevelopmental effects observed at approximately the same blood lead concentration. Furthermore, a $BMDL_{01}$ of 36 µg/L lead in blood was chosen as a reference point for increased blood pressure by EFSA (2010). Increased blood pressure was also identified by the JECFA (2011) to be the adverse effect in adults associated with the lowest blood lead concentrations. EFSA identified in addition chronic kidney disease as a sensitive endpoint for lead toxicity, and identified a $BMDL_{10}$ for increased prevalence of chronic kidney disease of 15 µg/L lead in blood.

3 Cervid hunting and farming in Norway

3.1 Cervid hunting in Norway

Hunting is a widespread activity in many Norwegian regions and approximately 5% of the Norwegian population has a licence to hunt. Since 1986, all persons debuting as hunters have to pass a theoretical test about wild life, hunting, ammunition and legislation (i.e. in Norwegian: Jegerprøven). Additionally, all large game hunters yearly have to pass a shooting test (i.e. in Norwegian: Skyteprøven) (DN, 2013). Good hunting practice says that the animal preferentially should be killed with a side shot of the heart/lung region. In 2010/2011, 144 080 hunters (approximately 3% of the population) participated in one or more hunting events (Statistics Norway, 2012). Of these, in total 90 930 were registered as cervid hunters, distributed on 60 300 moose hunters and 41 680 red deer hunters (several registered for both). In typical hunting communities, cervid meat is the dominating type of meat eaten by many families.

Traditionally, the hunting dog plays a central role during moose hunting, but not during red deer hunting.

Hunt on cervids (i.e. "hjortevilt" in Norwegian) in Norway includes hunt on roe deer, red deer, moose, and wild reindeer (see Table 2). Wild reindeer are according to the web site of the Norwegian centre for wild reindeer mainly located in Southern Norway (Norsk villreinsenter).

Table 2: Hunt statistics 2005-2012 on cervids: Total number of animals per species harvested each year nationwide

Year	Roe deer[1]	Red deer	Moose	Wild reindeer
2005	29 920	27 635	36 026	4 817
2006	25 110	29 173	34 978	5 091
2007	29 840	32 646	35 657	4 670
2008	30 650	35 686	35 620	5 155
2009	30 790	37 709	35 971	5 098
2010	28 790	39 070	36 409	5 447
2011	25 880	36 829	36 435	5 423
2012	n.a.	35 078	34 611	5 451

[1] Hunting years for roe deer start in the second half-year and continue into the first half-year of the subsequent year. **n.a.**: not yet available for the hunting season 2012/2013. **Source:** Statistics Norway, 2013

3.2 Farmed cervids in Norway

According to the Norwegian Food Safety Authority, red deer, fallow deer, and reindeer are farmed in Norway. Farmed (tame) reindeer are mainly kept in Northern Norway. For overview, see Table 3.

Table 3: Overview of farmed game in Norway

Species	Number of farms	Mean number of animals	Estimation of the national stock of animals	Main location
Reindeer	**548[a] siidaparts[b] in 2010**		**240 to 250 000 [a]**	**Northern Norway (70% of the reindeer population)**
Red Deer	**70[c]**	**100**		**Mid-Norway**
Fallow deer	**1**	**155**		**West Norway**

[a] Statistics Norway (2011), [b] Reindeer are kept in seven reindeers areas (i.e. in Norwegian, reindriftsområder), where the herds roam almost freely. Each area is divided into zones, which are divided into districts, and further into siidar and siidaparts ("farms"), [c] The number is based on information from district employees of the Norwegian Food Authority. (Source: Data from the Norwegian Food Authority, 2011)

The first deer farms in Norway were established in the 1980s. According to the foundation Norwegian Deer Centre's web-site (i.e. Stiftelsen Norsk Hjortesenter) more than 85 farms are located across Norway today. Most farmers are members of the association Norsk hjorteavlslag (http://www.hjorteavl.org/).

Farmed deer are killed on-farm by shot, preferably in the head or, in special cases, in the chest if the range is too great for safely aiming at the head. Prior to shooting the animals are individually inspected ante-mortem by an Official Veterinarian or an Approved Veterinarian. The carcass is submitted to official meat control in slaughterhouses.

It is in general prohibited to hunt tame reindeer in Norway. Tame reindeer are transported alive to slaughterhouses and handled in the same way as other farm livestock including veterinary inspection of the carcass according to the hygienic regulations (Commission Regulation (EC) 854/2004). Traditional slaughtering by a special knife is allowed for the Sami population (FOR 2008-07-30 nr 866).

3.3 Ammunition for cervid hunting

Only rifles are allowed for the hunt on cervids in Norway with the exception of ordinary roe deer hunt, where two-shot shotguns are accepted. Lead ammunition for shotgun is totally prohibited for any kind of hunting, except for slugs used for hunting roe deer and wild boar.

3.3.1 Mandatory use of ammunition

Legislation from the Norwegian ministry of environment:

Act no 38 of 29 May 1981 relating to wildlife and wildlife habitats (The Wildlife Act) says (Chapter VI Hunting and trapping methods; section 20 Use of weapons during hunting):

> "*Only weapons loaded with gunpowder may be used to harvest wildlife during hunting. The use of shotguns with more than two shotshells and completely automatic rifles for hunting is prohibited. The use of spring guns for harvesting wildlife is prohibited. The same applies to the use of artificial lights for hunting purposes, with the exception of*

hunting foxes with bait when the source of light is permanently fixed to the wall of a house. The ministry shall issue specific regulations concerning the firearms and ammunition to be permitted for hunting, and how arms and ammunition shall be stored and carried during hunting."

The Norwegian Directorate for Nature Management (DN, 2013) has published guidance to the Wildlife Act: Regulation regarding practice of hunting, harvesting and catching, with comments. It says (translated from Norwegian):

§15. Weapons for hunting and harvesting (Amended by regulation 14 March 2006):

Under ordinary circumstances only rifles or gunpowder-loaded shotguns may be used for hunting. The use of pistols, revolvers, semi-automatic military-style weapons and automatic firearms is not permitted for hunting.

For hunting moose, red deer (Cervus elaphus), fallow deer, wild reindeer, wild sheep, musk ox, bear or wolf, only rifles are permitted. This also applies for hunting roebuck during its special hunting season.

[…]

§16. Requirements to rifle ammunition (Amended by regulation 16 Mai 2012):

For moose, red deer (Cervus elaphus), fallow deer (Dama dama), wild reindeer, wild boar, wild sheep, musk ox, wolf and bear, ammunition with expanding bullets weighing a minimum 9 grams is required.

a) *Ammunitions with bullets weighing between 9 and 10 grams (138,9 and 154 grains) must have an impact energy of at least 2700 joules (275 kg/m) at a range of 100 meters, E_{100}.*
b) *Ammunitions with bullets weighing 10 grams or more (154 grains or more) must have an impact energy of at least 2200 joules (225 kg/m) at a range of 100 meters, E_{100}.*

When hunting roe deer, beaver, wolverine and lynx with a rifle, expanding bullets with impact energy of at least 980 joules (100 kg/m) at a range of 100 meters, E_{100}, must be used.

When rifle is used, expanding projectiles are mandatory when hunting large game species and beaver. Hollow pointed bullets intended for practice/competitive shooting, are prohibited for hunting.

§17. Requirements for shotgun ammunition (Amended by regulation 16 Mai 2012):

During hunting and harvesting it is prohibited to use and carry lead ammunition for shotguns. Use of brennecke/slugs is allowed during hunting for roe deer. For hunting wild boar with shotgun, only brennecke/slugs are allowed as ammunition.

From January 1st 2005, it was prohibited to produce, import, export, sell and use lead ammunition for shotguns according to the regulation of June 1st 2004 regarding limitations in the use of hazardous chemicals and other products (the product regulation) […].

Since lead-containing brennecke/slugs are not defined as shots, and thereby not comprised by the prohibition, they may still be used for hunting and harvesting roe deer and wild boar.

3.3.2 Cartridges for cervid hunting

Rifle cartridges are commonly constructed as a brass case containing the actual bullet at the top, the propellant in the main part, and the ignition product at the base of the brass case (see

Figure 1). Rifle cartridges differ in calibre, design, weight, and material. The cartridge name often refers to both the firearm's chamber and the diameter of the bullet. It is expressed in inches or millimetres.

Common rifle cartridges for cervid hunting in Norway (and Nordic countries) are for instance the following:

- 6.5×55
- .30-06
- .308 win

6.5×55 means that the rifle fits cartridges with a bullet diameter (calibre) of 6.5 mm and case length 55 mm.

The .30-06 (Springfield) is an American term, where ".30" (short for .308) indicates the bullet diameter in inches (0.308 inches) and "06" indicates the year in which this cartridge was introduced (1906). Translated to European/Norwegian measures, this cartridge is 7.62×63.

Comparably, the .308 (Winchester) indicates the bullet diameter in inches (0.308 inches). Translated to European/Norwegian measures this cartridge is 7.62×51.

As such, "7.62 calibre" pertains to several common cartridges.

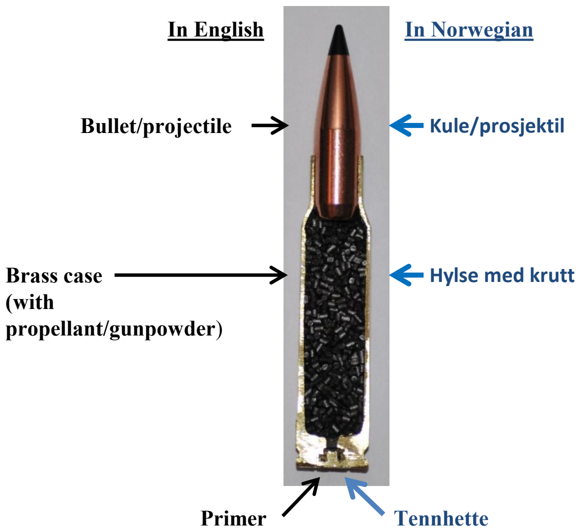

Figure 1: Illustration of a rifle cartridge .308win *(In Norwegian: riflepatron .308win)*. **(Source: Vidar Nilsen, Norwegian Hunting and Fishing Association, reprinted with permission.)**

3.3.3 Rifle bullet ballistics

Rifle hunting traditions vary considerably from country to country. In general, Europeans habitually use heavier bullets and lower muzzle velocities for shooting at shorter ranges than Americans, who prefer lighter bullets and higher velocities.

The different preferences affect the choice of ammunition because faster impacts require tougher bullets that do not disintegrate immediately. Impact velocity [m/s] is a function of muzzle velocity, shooting range, and the bullet's ballistic score, and impact energy [J] is in turn proportional to impact velocity and the bullet's impact mass [g] (Gremse and Rieger, 2012).

Whereas a bullet's effect is subjectively observed by the hunter, the bullet efficiency [J/cm] is a physical parameter characterized by the penetration length [cm], i.e. the length of the wound channel, the energy transfer to the surrounding tissue, and the distance of highest energy transfer [cm]. Considering the requirements for hunting in accordance with the animal welfare legislation specific limits for the relevant target ballistic parameters have been set: minimal penetration length > 30 cm, minimal energy transfer > 100 J/cm, and transfer distance 1-15 cm after entering (Gremse og Rieger, 2012; Chapter 3.3.1). It has been observed that bullet efficiency and the escape distance of the hunted animal, which is often considered as a variable for killing efficacy, are negatively correlated. The combination of the given minimum values for the ballistic parameters allows the determination of maximum shooting ranges for the individual bullet types.

3.3.4 Rifle bullet constructions

The different bullet constructions are available in many different materials and designs (see Table 4 in Chapter 3.3.5) resulting in a broad spectrum of bullet characteristics and performance. Expanding bullets are mandatory for cervid hunting (see Chapter 3.3.1).

Bullet weights are measured in grams or grains with a conversion factor of 1:15.38 (i.e. 1 gram is 15.38 grains). Besides the use of different materials and weights, bullet types vary in their internal and external design. The location of the priming mixture, which ignites the powder within the bullet, can also differ.

Expanding bullet types can be generally divided into three key categories regarding the construction and impact characteristics:

- Disruptively-expanding bullets fragment after impact, loosing considerable amounts of their weight. There are fragmenting and semi-fragmenting types.
- Expanding bullets are designed to expand while retaining most of their weight. There are bonded and unbonded types showing considerable differences with regard to the respective weight losses.
- Expanding-nose (petal-forming) bullets are generally lead-free and retain most of their weight.

3.3.5 Types of lead-based bullets

A variety of different lead-based rifle bullets has been developed for hunting ranging from older bullet types with steel jacket, softnose lead bullets, bullets with tombak half-mantle to modern gilding copper or brass jackets with bonded lead cores. Copper-sink alloys with less than 70% copper are called brass; alloys with more than 70% copper are called tombak. Bonding involves soldering together the bullet jacket and core to produce a uniform structure preventing separation or fragmentation on impact, even after striking dense bone (Figure 2a,b).

Some bullets have tips and fragment explosively on impact, others expand under fixed conditions. Softnose or softpoint bullets commonly have a lead top but the term is also used for expanding bullets with aluminium or plastic tops and includes both sharp and blunt pointed types. Roundnose bullets feature a rounded top whereas hollow pointed ones have an opening in place of a top. They have similar impact properties as common lead top bullets.

a  b 

Figure 2:

a. Illustration of an unbonded bullet (left; with green plastic tip), and a medium hard bonded bullet (right; brown plastic tip). The mantle/jacket of the bullet to the left has remained intact, whereas the lead core has been detached from the mantle/jacket and fragmented. In the bullet to the right, the lead core and the mantle/jacket are soldered together, giving controlled expansion with considerably less lead loss. Both bullets are produced with aerodynamic plastic tips, which do not deform as easily as lead. However, the mantles/jackets are still open on the top so that the bullets are termed half-mantled.

b. Illustration of an unbonded bullet with mechanical lead-lock (left) and a soft-bonded bullet (right). The mechanical lead-lock of the bullet to the left stops expansion at the lock, which is placed just above the "circle/ring" that is visible at the middle of the bullet. However, the lead core of the bullet tip has fragmented. The soft-bonded bullet to the right has kept together, although it has expanded to a large diameter. (Source: National Food Agency, Sweden 2012, with permission from Fredrik Widemo, Sweden).

Size and weights of the hunted animals and the expected shooting range determine the choice of the rifle and ammunition type in order to fulfil the demands for bullet efficiency. Optimally, the bullet should retain its weight and expand considerably on impact. This process is also called mushrooming with regard to the shape of the expanded bullet (Figure 3).

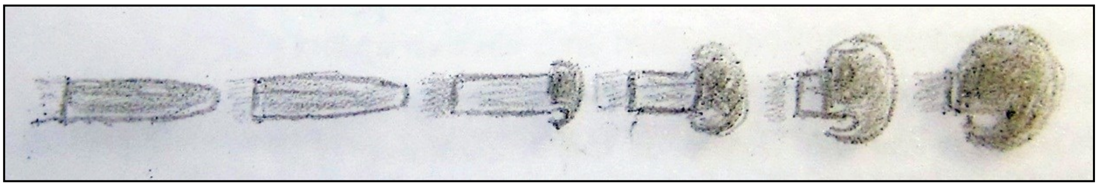

Figure 3: Illustration of mushrooming of a bullet.

The mushrooming of a bullet should start immediately on impact leading to symmetrical expansion without shattering, resulting in a maximal shock effect to the hunted animal.

Expanding bullets include lead top bullets, bullets with a partition or expanding homogeneous bullets. However, lead core expanding bullets (without bonding) may expand explosively or fragment at high velocity or when hitting bones. Therefore, "Disruptively expanding" and "Expanding" are not absolute categories (Table 4).

Cartridges that are most often used in Norwegian cervid hunt (6.5x55, .308win and 30-06) are available from many manufacturers, who offer a large variety of brands. Additionally, ammunition for European small-calibre rifles or combination firearms (rifle-shotgun) is available.

Table 4: Overview of common bullet constructions

Bullet type	Material	Design	Performance	Examples of typical brands
Disruptively-expanding	lead, lead alloys; lead-free: tin, zinc, copper jackets: none, brass, nickel-plated steel	half-mantle; partition; aluminium-tip, plastic-tip, lead-top, hollow-point, softpoint	fragmentation, semi-fragmentation	RWS Kegelspitz®, RWS H-Mantel®, Brennecke Torpedo Ideal (TIG)®, Brennecke TUG®, Nosler Partition®, Speer® TNT®, Hornady A-MAX®, Hornady Varmint®, Hornady V-MAX®, RWS ID Classic®, RWS UNI Classic®, Norma lead-top®, Våpensmia Odin®, Federal lead-top®, Winchester Super-X®, Remington Core-Lokt® lead-free (tin/zinc/copper): TNT Green, Brennecke TIG nature®, Brennecke TUG nature®, RWS Evolution Green®, RWS Bionic Yellow®, Möller KJG®, Reichenberg HDBoH®
Expanding	lead with brass or tombak jacket	bonded, unbonded; lead-top, lead-rear; softpoint, plastic-tip	expansion, disintegration of parts or fragmentation may occur, especially for unbonded bullets	Norma Alaska®, Norma Vulkan®, Norma Elite (improved)®, Speer Trophy bonded®, Sellier&Bellot SP®, Winchester xp3®, RWS Soft Point®, Sierra GameKing®, RWS Evolution®, Swift A-frame® (Norma TXP®), Remington A-frame®, Norma Oryx®, Nosler Ballistic Tip®, Federal Fusion®, Hornady Interbond®, Woodleigh soft core®, Trophy Bonded® Tip, Trophy Bonded® Bear Claw®, Sako Hammerhead®, Sako Super Hammerhead®, Nosler AccuBond®, Lapua Mega®, Brennecke TOG®, Hirtenberger ABC®, North Fork Softpoint®; Remington Premier® Core-Lokt ultrabonded
Expanding-nose	copper with lead or tungsten core, all-copper	front section cavity, plastic-tip, aluminium-tip	expansion by petal-forming, deformation	Barnes X®, Barnes Triple-Shock® X (TSX) Bullet®, Barnes Tipped Triple-Shock® X Bullet®, Brennecke TAG®, North Fork Solid®, Remington Premier® copper-solid, Impala®, Lapua Naturalis®, Hornady MonoFlex®, RWS Evolution Green®, RWS Bionic Black®, Reichenberg Universal HDB®, MEN SFS®, Nosler Ballistic Tip® lead-free

3.3.6 Alternatives to lead-based ammunition

The development of lead-free bullets started about thirty years ago with the aim to avoid jacket-core separation in the terminal ballistics of big-game bullets. Later, environmental and safety aspects with respect to lead toxicity became more important (Oltrogge, 2009). The main challenge was to find a material with comparable density and cost efficiency, and copper has emerged as the best choice. Its density is 1.27 times less than that of lead (8.96 g/cm^3 vs.

11.36 g/cm^3). For the production of copper bullets that match the standard weights of lead-containing bullets their length has been slightly prolonged and the shape boattailed. In expanding-nose copper bullets, the nose splits under impact into several petals that curl back and remain attached so that the total bullet weight is retained close to or equal to 100%. The petal-shaped nose has a higher drag effect than mushroomed lead-cored bullets so that they endure better to hit on bone, stop earlier in the animal, and transfer more destructive energy, i.e. have a higher bullet efficiency (see Chapter 3.3.3).

Apart from all-copper bullets there are several types with copper jackets and noses but containing heavy cores of e.g. tungsten (density: 19.30 g/cm^3). Other alternative materials that are considered by ammunition and gun manufacturers are tin (7.3 g/cm^3), steel (7.87 g/cm^3), nickel (8.90 g/cm^3), and bismuth (9.8 g/cm^3) (Knöbel, 2011). Other suitable high-density metals have too high price relative to the density. The toxicologial and ecotoxicological properties of some of these materials have to be studied in detail.

Some ammunition manufactureres are worried about practical aspects of non-lead ammunition with respect to trajectory stability over different distances, safety of ricochets, and compatibility with existing guns. Interestingly, it has been found that the ricochet range of copper bullets is the same as for bonded lead-containing bullets in small and medium rifle calibres, whereas it is somewhat higher for larger rifle calibres (Rottenberger, 2011). Copper bullets need higher flight velocity than lead bullets to compensate for their lower density if the same impact energy is to be achieved. This leads to a higher pressure resistance in the rifle barrel resulting in increased gas pressure, bullet abrasion, and barrel constriction, which reduces rifle life-time and is a safety issue. However, expanding-nose copper bullets have rather similar characteristics to bonded lead-containing bullets (Oltrogge, 2009).

In Germany, hunter organizations have expressed their positive disposition regarding the introduction of lead-free ammunition (Hammerschmidt, 2011). They are, however, concerned that any hunting ammunition has to comply with the national guidelines for animal welfare with regard to hunting and killing. Some preliminary results indicate that animal escape distances after impact may be increased by 5 to 10% (Gremse and Rieger, 2012). They point out that lead-free ammunition that deliver the required bullet efficiency of > 100 J/cm at E_{100} (see Chapter 3.3.1 and 3.3.3) is yet not available for all rifle calibres even a large number of different bullets from many manufacturerers is on the market.

In a recent study, the suitability of lead-free projectiles for hunting practice was studied by comparing the wounding potentials of lead-based and lead-free bullets under real-life hunting conditions (Trinogga et al., 2013). Wound dimensions were regarded as good markers of the bullets' killing potentials (Kneubühl et al., 2008). Wound diameters and maximum cross-sectional areas did not differ significantly between the two bullet types. Furthermore, fragmenting bullets were not superior to non-fragmenting expanding bullets. It was concluded that lead-free bullets are equal to conventional bullets in terms of killing efficiency and thus meet the German legal animal welfare requirements (Trinogga et al., 2013). Thomas (2013) concluded that given the large number of available lead-free bullet types and the proven effectiveness of high-quality ammunition, it is possible to phase out the use of lead-based hunting ammunition world-wide.

3.3.7 Ammunition used by Norwegian hunters

In a study started in 2004, including hunters from Norway (only in 2004), Sweden, and Finland, 1655 bullets retrieved from hunted moose were analysed (Stokke et al., 2010). 81% of the bullets collected were from Finland, 14% from Sweden and 5% were from Norway. In total, 81 different bullet constructions and 63 different cartridges were registered, of which in average 25% were disruptively expanding bullets and 10% were non-lead bullets (see also Chapter 3.4.1). Considering the participating countries separately, non-lead bullets amounted to 18% in Finland, 2% in Sweden and 4% in Norway.

In the Norwegian Lead and Game Study conducted in 2012, hunting team leaders reported in a questionnaire the ammunition used by their team. The majority of the hunting team leaders (48%) reported that they mainly used bonded ammunition (Table 1, Appendix II). The distribution of the bullets reported is shown in Figure 4 (see Appendix II for more information). The results indicate that although ammunition of the expanding type is mainly used (63%), also disruptively-expanding (fragmenting) ammunition is used in considerable scale (27%). Of the 355 bullets reported, 22 (7%) were lead-free.

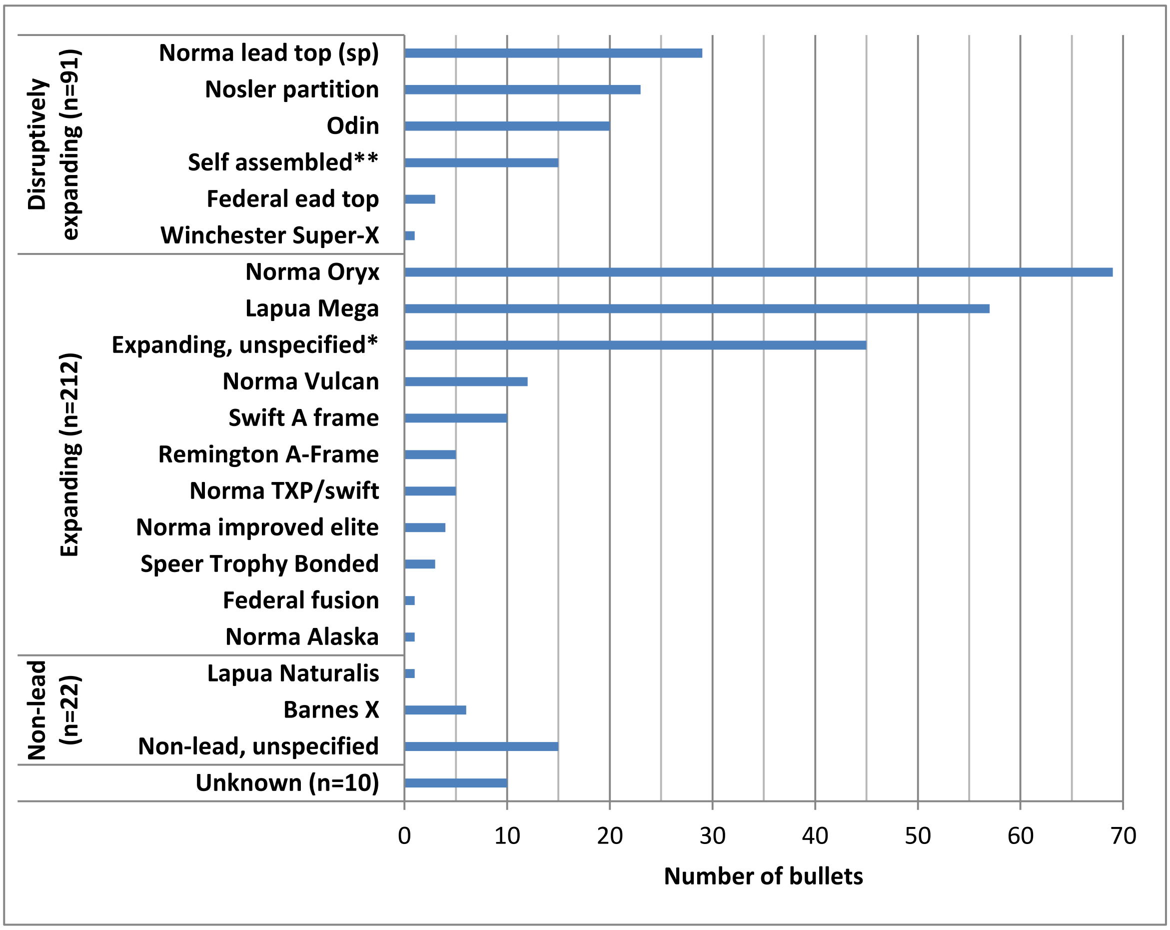

Figure 4: Distribution of 335 bullets reported used by 22 hunting teams in the Norwegian Game and Lead Study by type of bullet and bullet brand. Bullets from one hunting team, which reported that they used in total 11 bullets of type Speer Trophy Bonded, Winchester Super-X, Norma Vulcan and self-assembled ammunition, were not included because there was lacking information about the number of specific bullets used. *Combination of Speer Trophy Bonded and Norma Oryx. **Suggested to be disruptively-expanding. (Modified from Figure 1 in Appendix II.)

3.4 Distribution of lead in the carcass shot with lead-based ammunition

Rifle bullets transfer their immanent energy to the animal body by expansion or fragmentation. Depending on the bullet construction and the tissue that has been shot through bullet fragments will remain in the carcass and may contaminate the cervid meat (Moreth and

Hecht, 1981; Hecht, 1984; Hecht 2000; Hunt et al.; 2006; Pain et al., 2010). The extent of fragmentation is determined by the bullet's jacket thickness, core composition, impact velocity and the target's resistance as to whether bones or muscle are hit (Trinogga and Krone, 2008).

3.4.1 Fragmentation patterns of different bullet types

The expansion, fragmentation and splintering of bullets can be simulated by firing on gelatine blocks. Splint sizes may range from millimetres to micrometres producing a "lead cloud" or "snowstorm of lead particles".

The fragmentation of bullets and the rest weight of bullets have been studied by shooting with a 7x57R rifle on gelatine blocks, pig legs and cow livers (Moreth and Hecht, 1981 Hecht, 1984; Hecht, 2000). Bullet rest weights were for disruptively-expanding bullets about 60% (fragmenting types) and 60-90% (semi-fragmenting types), and for expanding bullets more than 90%.

In Norway, there are several dedicated websites where hunters can exchange information and experiences. The data found on such websites refer mainly to moose hunt with 6.5x55 and .308win. Their (unofficial) reports indicate that disruptively-expanding bullets may retain only 10% (fragmenting) or 20-80% (semi-fragmenting) of their original weight after impact, whereas expanding bullets (bonded and unbonded types) may retain 60-100% of their original weight.

In the study including hunters from Norway, Sweden, and Finland (see Chapter 3.3.7), the rest weight of 1655 bullets (distributed over 81 different bullet types and 63 different types of cartridges) retrieved from hunted moose were analysed (Stokke et al., 2010). Lead-free bullets and bullets with visible loss of the mantle or with separation of the mantle were excluded from the survey. The hunters reported that 41% of the bullets stopped in the moose. The data analysis showed that bullet lead loss depended on both calibre and types of cartridges used. Independent of bullet construction and target hit, mean losses were smallest for the 6.5x55 (1.5 g) and highest for .458 Winchester magnum (8 g). The commonly used cartridges such as .308 and 30-06 accounted to in average 3.2 g and 2.9 g lead loss, respectively. Lead loss was also strongly dependent on the bullet construction. Considering only the 7.62 calibre, lead losses of the different bullets ranged from 0.7 g to 3.4 g (Figure 5).

In average, 1.4 hits were necessary to harvest a moose, allotted to 68% harvested by one shot, 26% by two, and 5% by three. The maximum number of bullet used to kill one moose was nine. Of the moose taken down, 29% received an additional final bullet to the neck. Stokke et al. (2010) concluded that, in average, a moose was harvested by 1.4 shots and considering that the mean lead loss per bullet was calculated to 2.7 g, the average lead deposition in a harvested moose amounted to 3.8 g.

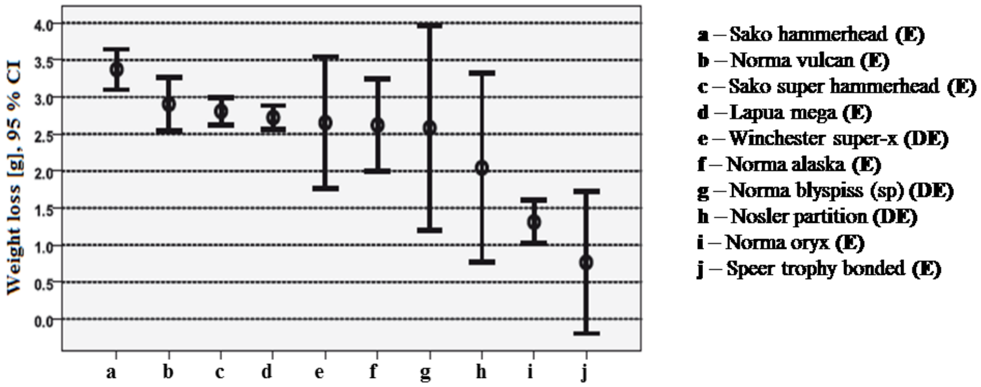

Figure 5: Lead loss from rifle bullets (calibre 7.62) used for moose hunt in Norway, Sweden and Finland and that were retained in the carcass. Target hit or type of cartridge is not taken into consideration. E – expanding, DE – disruptively expanding. (**Source:** Modified from Stokke et al., 2010, and reprinted with permission from the authors.)

3.4.2 Distances of bullet fragments from the wound channel

Lead bullets, especially those of the disruptively-expanding or the expanding unbonded types, fragment on impact in accordance to their construction (see Chapters 3.3.3 and 3.4.1) and might contaminate the edible meat of the hunted animal (see Chapter 3.4). Radiographic studies have shown that lead ammunition can cause a micronized "snow storm" of lead particles in the tissue centred around the wound channel (Moreth and Hecht, 1981; Dobrowolska and Melosik, 2008; Trinogga and Krone, 2008; Hunt et al., 2006; Hunt et al., 2009; BfR, 2010).

Wound ballistics, i.e. the characteristics of impact and tissue penetration, is dependent on a bullet's kinetic energy (Fackler, 1986). The mass of the bullet and especially the impact velocity (see Chapter 3.3.3), together with its fragmentation and mushrooming qualities, determine the depth of penetration (Stroud and Hunt, 2009). Thus, a slow bullet will cause a much narrower wound cavity than a high velocity bullet because of the reduced kinetic energy. An expanding, soft-nosed bullet disperses its energy into the surrounding tissue producing a radiating zone of expansion perpendicular to the wound channel, the "temporary wound cavity". Depending on their elasticity tissues may be torn or only expanded. As the bullet continues its progress and starts mushrooming and breaking apart, bullet fragments and disrupted bone pieces cause secondary damages, destroying tissue around the actual wound channel, thus producing a "permanent wound cavity".

In a study by Trinogga and Krone (2008), fragments from a number of commonly used disruptively-expanding (RWS Kegelspitz®, Brennecke TUG®) and expanding (Norma Vulkan® (unbonded), RWS Evolution® (bonded) lead-containing bullets, as well as lead-free disruptively-expanding (RWS Bionic Yellow®, Möller KJG®) and expanding-nose bullets (Lapua Naturalis®, Barnes TSX®), were determined in roe deer, red deer, fallow deer, wild boar, and chamois (in total 315 animals) by taking latero-lateral and ventro-dorsal radiographs and data imaging analysis. The "lead cloud" of lead-containing bullets could be seen along the whole wound channel and also in adjacent tissues. The lead-containing bullets (disruptively-expanding, and expanding unbonded or bonded) always fragmented, even without hitting bones, and 90 to 280 fragments/bullet were counted in average. Fragment sizes varied between < 1mm and up to 10 mm. Additional radiographs of game offal revealed hidden fragments and total counts of up to 600 fragments/bullet. The use of disruptively-expanding lead-free bullets produced a few relatively large fragments in a range of 6 to 23 fragments/bullets in the animal carcasses. Lead-free expanding-nose ammunition did not produce any fragments.

Distances from fragments to the centre of the wound channel were measured at right angles and with an accuracy of ± 0.5 cm (Trinogga and Krone, 2008). The maximum distance determined was 22 cm. Ventro-dorsal mean distances were in the range of 5.6 to 11.4 cm for lead-containing bullets (disruptively-expanding, and expanding unbonded or bonded) and 1.3 to 6.6 cm for lead-free bullets (disruptively-expanding). Latero-lateral mean distances were in the range of 6.4 to 15.5 cm (lead-containing) and 3.2 to 7.8 cm (lead-free), respectively (see Figure 6).

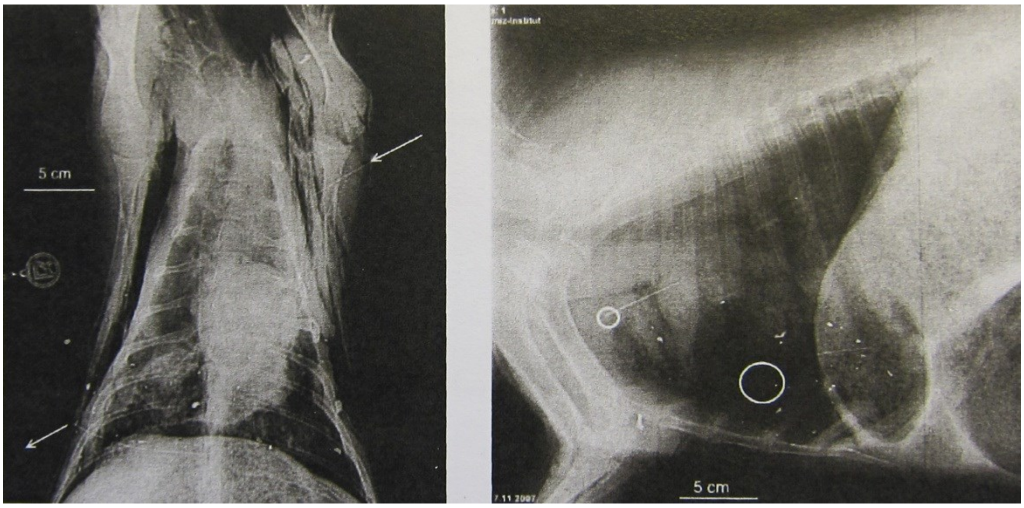

Figure 6: Ventro-dorsal (left) and latero-lateral (right) radiographs of a fallow deer calf shot with an expanding lead-containing bullet (Norma Vulkan®). About 80 bullet fragments have been detected (visible as white spots). The arrows mark the direction of the shot/wound channel. The small circle marks the entry wound and the large circle the exit wound**. (Source:** Trinogga and Krone, 2008. Reprinted with permission from the authors.)

In 2011, the National Food Agency in Sweden published on their website a risk management report on lead in cervid meat. At the same time, photos illustrating how lead from lead-based ammunition is distributed in the carcass were published as information to cervid hunters (see Figure 7).

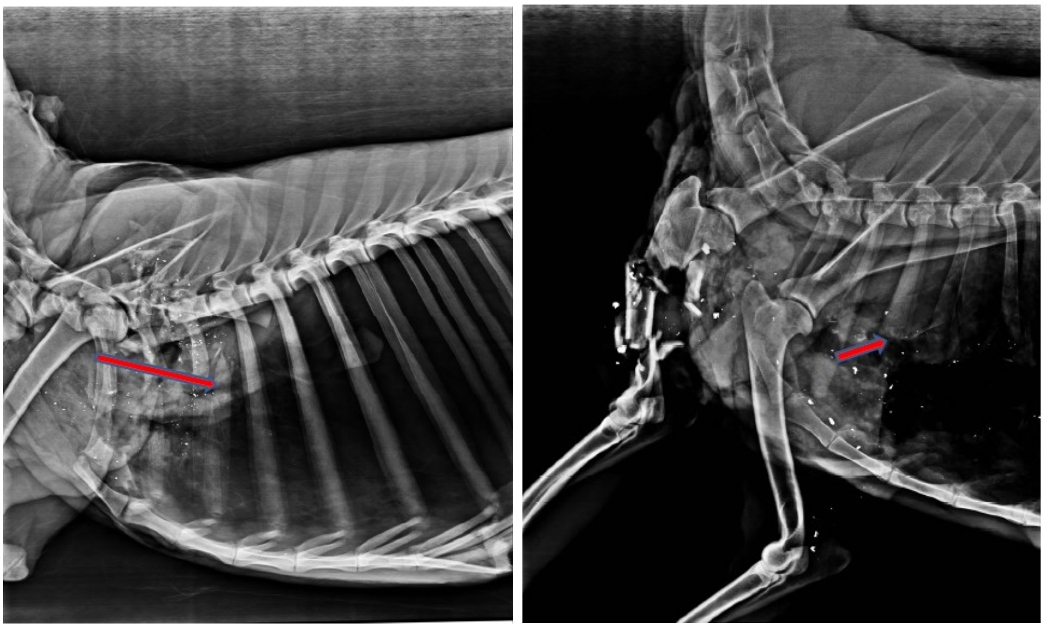

Figure 7: Roe deer shot with a bonded lead-containing expanding bullet (left). The bullet has entered into the animal's left shoulder; the exit wound is in the right shoulder (see arrow). Considerable fragmentation is visible, probably because bone was hit. Roe deer shot with traditional disruptively-fragmenting bullet with lead core (right). The bullet has entered into the animal's left shoulder; the exit wound is behind the right shoulder (see arrow). Considerable fragmentation is visible. (**Source:** The National Food Agency in Sweden, web site information for hunters. Reprinted with permission from National Veterinary Institute (SVA), Sweden).

In a radiographic study examining fragment distribution in white-tailed deer shot in normal hunting practices with standard deer cartridges using several brands of expanding copper-jacketed unbonded lead core bullets, in average >100 visible fragments were detected in the offal. In five whole carcasses 416-783 fragments were found. The lead-containing bullets included lead-top, plastic-top, and hollow-point designs. Additionally, a few expanding-nose copper bullets were used producing 0-2 fragments (Hunt et al., 2006). The lead fragments, mostly < 2 mm in size, were broadly distributed along the wound channel, and the fragments radiated as far as 15 cm (mean: 7 cm).

In a follow-up study, in average 136 visible lead fragments were found in eviscerated carcasses of 30 white-tailed deer killed with a single brand of a commonly used expanding unbonded lead-core copper-jacket bullets (9.72 g) (Hunt et al., 2009). The fragments were spread widely with a mean distance between fragment clusters of 24 cm and a maximal single fragment separation of 45 cm as revealed by two-dimensional radiography. When the edible deer meat was run through a meat processor, lead fragments were detected in the ground meat packages of 80% of the animals, and 32% of the packages per deer showed fragments.

Bullet-derived lead concentrations were measured in tissues from wild boar and red deer hunted with unspecified different brands of expanding lead-based ammunition routinely used in hunting practices in Poland (Dobrowolska and Melosik, 2008). Samples from animals (meat and/or offal, depending on bullet path) were collected at the entry and exit wounds and along the wound channel at distances of about 5, 15, 25, and 30 cm. A control sample was taken as far from the bullet channel as possible. Maximum concentrations measured at the entry wounds were ca. 1100 mg/kg wet tissue (wild boar) and 480 mg/kg (red deer) and at exit wounds 740 mg/kg (wild boar) and 120 mg/kg (red deer). In all samples taken at 5 cm and 15 cm distance from the wound channel, the tissue concentrations exceeded 0.1 mg/kg (the ML applicable for livestock meat in the EU, see Chapter 1.2). At 25 cm distance, nine of the 10 red deer and eight of the 10 wild boar samples were still over 0.1 mg lead/kg, and at 30 cm five (red deer) and eight (wild boar) of the 10 samples in each species were above (Figure 8). All animals showed the highest levels of contamination in tissues around the maximum expansion of the wound channel, i.e. the mushrooming site. The length of the wound channel depended on the animal's age, weight, skin and tissue resistance, and bone hardness.

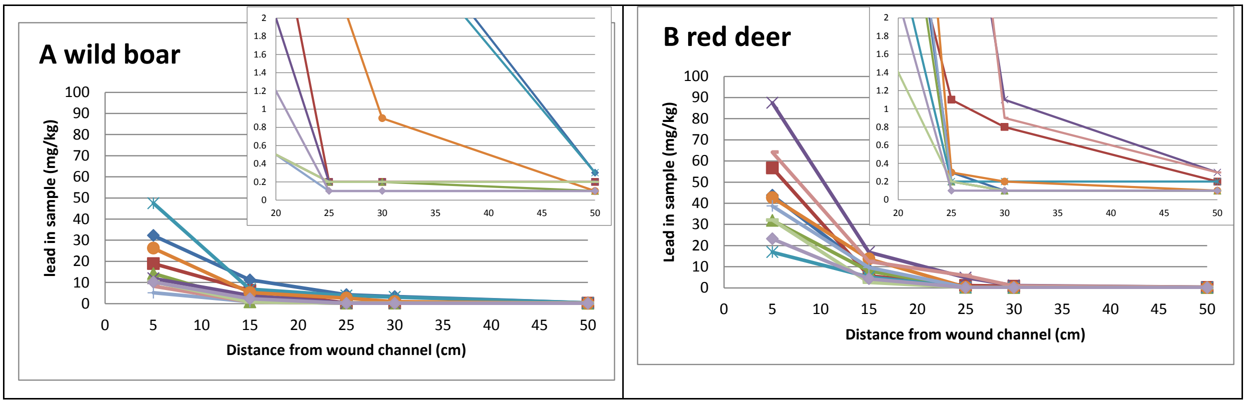

Figure 8: Lead concentration in meat from (A) wild boar and (B) red deer shot with different lead-based expanding ammunition. The distance 50 cm is fictive and serves to illustrate the concentration at the control site; a sample collected as far from the bullet channel as possible in each carcass. In the inserts the axis ranges have been altered in order to visualise lead concentrations below 2 mg/kg. (Source: The illustration was made based on Dobrowolska and Melosik, 2008.**)**

Similar results had been observed before in an older study on fragmenting characteristics of disruptively-expanding (RWS Teilmantel-Rundkopf®, RWS Kegelspitz®, RWS H-Mantel®, Nosler Partition®, Brennecke Torpedo Ideal®) and expanding lead-containing (unbonded) (Hirtenberger ABC®) bullets (average weight: 10 g) shot into gelatine blocks or in pig legs and cow livers (Moreth and Hecht, 1981). Radiographic analysis showed that even if only muscle tissue was hit, bullet fragments were found at distances of up to 23 cm from the edge of the bullet path. Some fragments penetrated as far as 30 cm into the tissue, and fragments were found in sizes ranging from 25 µm up to several millimetres.

When in total ten red deer and two roe deer were harvested with a single shot to the thorax using 0.270 calibre Norma Lead-Top ®130 grain disruptively-expanding lead-core copper-jacketed bullets, an average of 356 metal fragments were found by radiographic analysis in the carcass and of these were 180 fragments in the viscera (Knott et al., 2010). Differences in fragment counts in radiographs taken from the two sides of the same carcass suggested that considerable numbers of fragments were missed, possibly because they were too small, leading to an underestimation of total fragment numbers.

A study examined the fragmentation patterns of disruptively-expanding (Remington Core Lokt®) or expanding unbonded (Nosler Ballistic Tip®) or bonded (Winchester XP3®, Hornady Interbond®) lead-containing bullets as well as one non-lead bullet (Barnes TSX®) in 72 domestic sheep, previously euthanized and shot at a 50 m distance (Grund et al., 2010). Sheep carcasses were radiographed and tissue samples for lead analysis were collected along the abdominal cavity at perpendicular distances of 5, 25, and 45 cm from the exit wound. Additionally, eight white-tailed deer hunted with a .308 Winchester at a distance of about 110 m using expanding unbonded bullets (Nosler Ballistic Tip®) were similarly analysed. Bullet fragments were better visible in ventral-dorsal than in lateral radiographs and therefore further used. Approximately twice as many fragments were observed in sheep than in deer shot with the same expanding unbonded bullet type (Nosler ballistic tip). In the white-tailed deer, lead was not detected in samples at 25 cm, but in 12% of the samples at 5 cm (level of detection 1 mg/kg).

In sheep, the disruptively-expanding bullets produced in average more fragments (141) than the expanding lead-containing unbonded bullets (86) by ventral-dorsal view. Of the two expanding lead-containing bonded bullets, one (Hornady Interbond®) produced in average 82 fragments (ventral-dorsal view) and the other (Winchester XP3®) only nine. The lead-free bullets produced in average two fragments. Lead particles were most abundant around the exit wound. In sheep shot with disruptively-expanding and expanding lead-containing unbonded ammunition, lead concentration was above 1 mg/kg at a distance of 25 cm in 40-70% of the muscle samples. In sheep shot with bonded ammunition, 0-20% of the samples was above 1 mg/kg. Even at a distance of 45 cm, up to 10% of the samples still contained detectable lead concentrations, depending on the bullet type (Nosler ballistic tip®, Hornady Interbond®). Lead was not detected in any samples from sheep shot with the more stable bonded expanding lead-containing bullet or with non-lead bullets. Water rinsing of the carcass spread the contamination to other areas. It was concluded that all meat from a deer hunted by a lead-containing bullet potentially contains some lead.

A study on white-tailed deer that were culled by sharpshooting to head or neck using disruptively-expanding softpoint lead-containing bullets of three different calibres, and radiographed for analysis of fragment patterns, documented the importance of shot placement for lead contamination of the edible meat (Stewart and Veverka, 2011). In animals (n=30) shot in the head or the upper cervical spine from a distance of less than 100 m, none had lead fragments detected in the thoracic muscle, whereas eight of the ten animals shots to the lower neck region (shots that impacted any of the bottom three cervical vertebrae) had lead fragments in the thoracic muscle (all in extensor spinae muscle). The lead fragments travelled in average 21 cm from the entry wound into the thoracic cavity in deer shot in the lower neck region, and the maximum distance travelled was 40 cm.

3.4.3 Norwegian data on trimmings around the wound channel

Data on practice in Norway regarding trimming of meat around the wound channel has been obtained in the Norwegian Game and Lead study (see Appendix II).

With regard to the separate questionnaire sent to 37 hunting team leaders (Appendix II), 24 responded (see Table 5). The majority slaughtered the animal themselves (70%). Meat was removed around the wound channel with distances of less than 10 cm by 35%, 10-20 cm by 43%, and >20 cm by 22%. One of the 24 responding hunting teams did not answer this question. The majority (57%) of the responding hunting team leaders found it important to remove meat near the wound channel, whereas 9% considered it as insignificant.

The majority of the hunting teams brought the trimmings to waste disposal or left it in the nature. Also use of trimmings as dog's food or fox bait was reported.

Table 5: Answers from hunting team leaders (N=23) in the Norwegian Game and Lead study regarding bullet types and slaughtering practices (from Appendix II)

	Alternatives	Result, n (%)
Amount of meat removed around wound channel	0-10 cm	8 (35%)
	10-20 cm	10 (43%)
	>20 cm	5 (22%)
Importance of trimming	Important	13 (57%)
	Of minor importance	8 (35%)
	Insignificant	2 (8.7%)
Fate of trimmings	Left in nature	7 (30%)
	Dog feed	2 (8.7%)
	Waste disposal	10 (43%)
	Fox bait	2 (8.7%)
	Other	2 (8.7%)
Where slaughtered	Private	16 (70%)
	Slaughterhouse	3 (13%)
	Private and slaughterhouse	4 (17%)

3.5 Summary of cervid hunting and farming in Norway

Approximately 3% of the Norwegian population participated in one or more hunting activities during the hunting season 2011/2012. Cervid hunters use a large variety of expanding bullet types, which is mandatory[2] for cervid hunting. The majority of the bullets are lead-based disruptively expanding or expanding (unbonded or bonded). Limited data indicate that less than 5% of the Norwegian hunters use non-lead ammunition. Lead loss from bullets depends on the rifle calibre and bullet type used. A Scandinavian study with one commonly used cartridge and different bullet types indicated a mean lead loss of 0.7 to 3.4 grams per bullet. One to two bullets are most often used to kill a moose.

The extent of a bullet's fragmentation depends on the construction, weight, impact velocity, the size of the hunted animal, and target resistance. Data on the weight losses and fragmentation distances of hunting bullets have been published for roe deer, white-tailed deer, fallow deer, red deer, wild boar and chamois. Study data for moose hunt are lacking.

Characteristically, the impact of a lead-containing bullet results in the formation of a cloud of lead particles ranging from nanometre range up to 10 mm size around the wound channel. Disruptively-expanding bullets may retain down to 10% (fragmenting type) or 20-80% (semi-fragmenting type) of their original weight. Expanding bullets may retain 60-100% of their original weight, and some bonded types appear to be considerably more stable than unbonded types although great variations exist.

Disruptively-expanding, expanding unbonded and some expanding bonded lead-containing bullets produced in average 200 radiographically visible fragments/bullet (range of averages 90-370), and up to 800 fragments/bullet were detected for individual bullet types. Very small fragments presumably remain undetected. Other types of bonded expanding lead-containing bullets produced less than 10 fragments per bullet. Non-lead disruptively-expanding bullets produced in average 6 to 23 fragments. Non-lead expanding-nose bullets produced 0 to 2 fragments.

[2] With exception of brennecle/slugs, which is legal for hunting roe deer with shotgun (see Chapter 3.3.1)

Lead fragments from disruptively-expanding, expanding unbonded and some expanding bonded lead-containing bullets were found by radiography of various species (roe deer, red deer, wild board, sheep, chamois) in average in a radius of 15 cm (range of averages 5.6-24 cm) around the wound channel. The maximal penetration length of visible fragments was in average 29 cm (range of averages 15-45 cm). Fragments of more stable types of bonded expanding lead–containing bullets were found at distances less than 5 cm, which was comparable to fragments from non-lead disruptively expanding bullets and non-lead expanding-nose bullets measured in the same study. VKM considers that the intra-species variation, being in the same range as the inter-species variation, justifies the combination of data from different studies and species.

One study investigated fragment patterns of disruptively-expanding softpoint lead-containing bullets of three different calibres after shooting to head or neck of white-tailed deer. This study was identified by VKM to be of special relevance for farmed deer in Norway, since these are harvested preferably in the same manner (Chapter 3.2). Whereas in animals shot in the head or upper cervical spine contained no lead fragments as detected by radiography, eight of the ten animals shot to the lower neck region had lead fragments in the thoracic muscle.

In two studies, concentrations of lead were measured in tissue sampled at various distances perpendicular to the wound channel. One of these studies were on wild boar and red deer shot with various unspecified ammunition commonly used in Poland, and had a LOD of 0.1 mg/kg. Lead tissue concentrations were > 0.1 mg/kg in nine of ten of the samples from red deer and in 8 of the 10 samples from wild boar taken at 25 cm distance perpendicular to the wound channel. The other study was on sheep and white-tailed deer, and had a 10-fold higher LOD (1 mg/kg), but could differentiate between bullet types. Meat from white-tailed deer shot with expanding unbonded bullets contained less than 1 mg lead/kg when sampled 25 cm from the wound channel. A large proportion (40-70%) of muscle samples of sheep shot with disruptively-expanding and expanding unbonded lead-containing ammunition contained more than 1 mg lead/kg at a distance of 25 cm, whereas a lower proportion (0-20%) of the samples from sheep shot with bonded ammunition contained such levels. Furthermore, lead was not detected in any samples from sheep shot with more stable bonded expanding lead-containing bullets or with non-lead bullets.

The majority of a limited number of hunting teams participating in the Norwegian Game and Lead study reported removal of meat in a radius of 10-20 cm from the wound channel, but some (35%) reported removal of less than 10 cm.

4 Lead exposure

4.1 Environmental contamination of lead

Lead has a great number of industrial applications, both in its elemental form and in the form of alloys and compounds. The major use of lead is the manufacture of lead accumulators. Recent lead concentrations in air, water, and soil are presented in Table 6.

Table 6: Recent lead concentrations in air, water, and soil (EFSA, 2010)

Matrix	Lead concentration
Air	
European countries (outside industrial areas)	0.003 to 0.010 µg/m^3
European countries (outside industrial areas)	0.03 to 0.10 µg/m^3
Highly contaminated areas	>10 µg/m^3
Seawater	
Median concentration in worldwide ocean waters	0.03 µg/L
In the North Pacific Ocean	0.003 µg/L
The Baltic Sea water	0.005-1.33 µg/L
Black Sea Rivers	0.014-1.46 µg/L
For 9 European countries	0.02-14 µg/L
Soil	
Current levels	<10 to >70 mg/kg (median 23 mg/kg)
Vicinity of smelters, etc.	Up to 60,000 mg/kg
Surface soil in contaminated areas	From 100 to > 1,000 mg/kg

Source: Table slightly modified from EFSA, 2010.

Tetraalkyl lead, R_4Pb, mostly tetraethyl lead, is an organic lead species used in petrol. In 1972, around 400 000 tonnes of tetraethyl lead were consumed globally as anti-knocking agents in leaded gasoline. Since then, this application has declined dramatically due to restrictions imposed through environmental legislation, such as directives 85/210/EEC and 98/70/EC.

In Norway, it was e.g. shown that lead in primary teeth declined from the 1970s to the 1990s, by approximately 50% (Tvinnerheim et al., 1997). Tooth lead concentrations and atmospheric deposition of lead in the same areas were significantly and positively correlated, as shown by analysis of naturally growing moss.

In Norway, nationwide assessments of metals in moss (more specifically stair-step moss, *Hylocomium splendens*) are done in order to monitor long-range transported delivery of these elements. After the survey in 2005 it was noted that atmospheric deposition from other European countries still was a dominating source of lead in Norway (SFT, 2007). In Southern Norway, the deposition of lead in 2005 was only 5% of what it was in 1977. The relative decline after 2000 was however lower than earlier (Figure 9). Furthermore, monitoring has shown that the deposition of lead in Norway in 2010 is lower than in 2000, but at the same level as in 2005 (Steinnes et al., 2011). It was concluded that further decline can likely not be expected before the use of leaded petrol is terminated in some East-European countries (SFT, 2007; Steinnes et al., 2011).

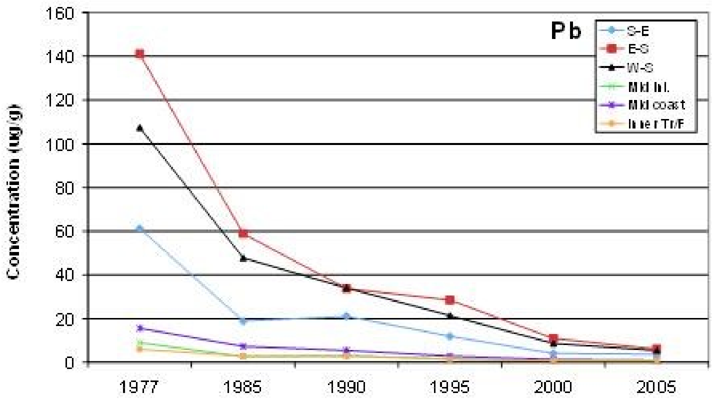

Figure 9: Temporal trend in atmospheric deposition of lead (Pb), depicted by concentrations in moss, from 1977 to 2005. (S-E = Southern part of East-Norway; E-S = Eastern part of South-Norway; W-S = Western part of South-Norway; Mid inl. = Mid-Norway inland; Mid coast = Mid-Norway coast, Inner Tr/Fi = Inner part of Troms and Finnmark counties, Northern Norway) (**Source:** modified from SFT, 2007).

4.2 Previously reported human dietary lead exposure

Human exposure to lead can occur via food, water, air, soil and dust; food being the major source. Non-dietary exposure is likely to be of minor importance for the general population in Europe (EU), while dust and soil can be an important source of exposure to lead for children. In a scientific opinion on lead in diet by the European Food and Safety in 2010, the population based evaluation of lead exposure through diet in Norway was reported, based on consumption figures from Norkost 1997 (EFSA, 2010). Mean lower bound[3] and upper bound[4] intake levels were estimated to be around 0.47 and 1.03 ug/kg body weight/day, respectively. Vegetables, nuts and pulses were considered the main exposure sources but it was noted that the concentration of lead in food was generally low and that it was rather equally distributed on many different food groups. In the most recent EFSA report on dietary exposure to lead (EFSA 2012), mean lifetime dietary exposure was estimated at 0.68 µg/kg bw per day in the European population based on middle bound[5] mean lead occurrence. Exposure was highest for toddlers and other children with 1.32 and 1.03 µg/kg bw per day, respectively, while the two infant surveys ranged between 0.83 and 0.91 µg/kg bw per day. Adult exposure was estimated at 0.50 µg/kg bw per day. The elderly and very elderly population groups had similar profiles to the adult age group, while adolescents had slightly higher estimated dietary exposure[6]. Food consumed in larger quantities had the greatest impact on the exposure i.e. grains and grain products, milk and dairy products, non-alcoholic beverages and vegetables and vegetable products, although this varied between age groups and countries.

[3] Lower bound: Values below LOD or LOQ are set to zero.
[4] Upper bound: Values below LOD or LOQ are set equal to the LOD or LOQ.
[5] Middle bound: Values below LOD or LOQ has been set to half of the LOD or LOQ.
[6] The following age classes have been considered: 1) Infants: up to and including 11 months, 2) Toddlers: from 12 up to and including 35 months of age, 3) Other children: from 36 months up to and including 9 years of age, 4) Adolescents: from 10 up to and including 17 years of age, 5) Adults: from 18 up to and including 64 years of age, 6) Elderly: from 65 up to and including 74 years of age, and 7) Very elderly: from 75 years of age and older. (For details, see EFSA, 2011.)

4.3 Occurrence of lead in game meat

4.3.1 Norwegian surveillance data on lead in meat from cervids

The official surveillance and control programmes for terrestrial and aquatic animals in Norway are conducted by the Norwegian Food Safety Authority and are planned and coordinated by the Norwegian Veterinary Institute as part of the legislation for terrestrial and aquatic animal health and food in Norway regulated under the Norwegian Food Law. In the programme for surveillance of residues in animals and animal products, Council Directive 96/23/EC, samples from hunted moose, roe deer, red deer and reindeer are included. Samples of liver, kidney and muscle are analysed for lead among other substances and results are reported annually.

No maximum level (ML) for lead has been established for meat from game animals (see Chapter 1.2). The Norwegian Veterinary Institute compares the analysed game animal samples with the MLs for lead set for livestock animals. In their annual reports the numbers of game samples exceeding the MLs are given, not the measured lead concentrations (see Table 7).

Chemical elements accumulate in inner organs (e.g. liver, kidney) of animals throughout life as a result of environmental pollution. Trace amounts of lead in samples from liver and kidney of cervids are thus expected, but not from the muscle samples. In cases where lead has been detected in the muscle sample but not in the liver sample, it cannot be excluded that the muscle samples have been collected close to the wound channel and thus been contaminated by lead from the ammunition used (see Chapter 3.4.2).

Table 7: **Number of cervid samples per year exceeding the maximum level (ML)* for lead given for livestock animals, distributed on species and matrixes with total number of animals analysed in parenthesis.**

Species/year	2008	2009	2010	2011
Moose				
Liver	1 (55)	1 (47)	2 (40)	0/36
Kidney	0 (55)	0 (47)	1 (40)	0/36
Muscle	5 (55) i.e. 9%	5 (47) i.e. 11%	9 (40) i.e. 23%	1/36 i.e. 3%
Roe deer				
Liver	1 (13)	0 (11)	0 (11)	1 (6)
Kidney	0 (13)	0 (11)	0 (11)	0 (6)
Muscle	3 (13) i.e. 23%	1 (11) i.e. 9%	2 (11) i.e. 18%	2 (6) i.e. 33%
Red deer				
Liver	0 (15)	0 (26)	0 (32)	0 (25)
Kidney	0 (15)	0 (26)	0 (32)	0 (25)
Muscle	2 (15) i.e. 13%	0 (26)	0 (32)	0 (25)

Species/year	**2008**	**2009**	**2010**	**2011**
Farmed reindeer				
Liver	0 (19)	0 (14)	0 (13)	1 (16)
Kidney	0 (19)	0 (14)	0 (13)	0 (16)
Muscle	0 (19)	0 (14)	0 (13)	0 (16)

*ML for lead in livestock animals: liver 0.50 mg/kg wet weight, kidney 0.50 mg/kg wet weight, muscle 0.10 mg/kg wet weight (Commission Regulation (EC) No 1881/2006). (**Source:** Surveillance and control programmes for terrestrial and aquatic animals in Norway, annual reports from 2008 to 2011. Norwegian Veterinary Institute, Oslo.)

4.3.2 Minced meat

Minced meat is grinded left-over meat from the whole slaughter, including meat located close to the wound channel. Results from a survey analysing lead concentrations in minced meat from Norwegian moose has recently been published (Lindboe et al., 2012). The samples were obtained from retails or directly from hunters (n=52). The researchers found relatively high levels of lead per kg minced game meat in many of the samples. The limit of quantification was 0.03 mg lead/kg meat (wet weight). Thirty one out of the 52 samples exceeded 0.1 mg/kg wet weight set as maximum level for lead in meat from domestic animals by the European Union (see Chapter 1.2), and the mean lead concentration was 5.6 mg/kg. Further details on the lead concentrations found in this study are presented together with data from other measurements of lead in game meat in Table 8.

A similar study on minced game meat has recently been performed in Sweden (National food agency, Sweden, 2012; Ankarberg and Bjerselius, 2013). In total 54 samples of minced moose meat were analysed with X-ray and chemical digestion using 15% nitric acid followed by inductively coupled plasma-atomic emission spectrometry (ICP-AES) analysis. The radioscopy detected metallic lead in 35% of the samples, whereas ICP-AES (limit of detection: 0.02 mg/kg wet weight) detected lead concentrations > LOD in 54% of the samples, and lead concentrations > 0.1 mg/kg (comparative ML for meat from domestic animals) in 33% of the samples. The background level in moose shot with non-lead ammunition was 0.002 mg/kg as measured by ICP-mass spectrometry. The median of the samples was 0.035 mg/kg and the maximum value was 31 mg/kg. In total, the results from Swedish samples were lower than those from the Norwegian survey (Table 8).

Furthermore, in a study from Michigan 87 packages of minced game meat were screened for lead fragments, which were found in 27 samples (Michigan Department of Community Health, 2010). In another screening study from North Dakota, 59% of randomly selected minced venison packages contained visible lead fragments, quantified at concentrations up to 55000 mg/kg (Cornatzer et al., 2009).

Table 8: Overview of reported lead levels in game meat in Europa (mg/kg wet weight)

Source	Sample	N	%>LOD/LOQ	Median	Mean	P95	Max
Norway [a]	Minced moose meat	52	81	0.3	5.6	79	110
Sweden [b]	Minced moose meat	54	54	0.027	0.9		31
EFSA, 2010 [c]	Game meat	2521	40.6	0.02	3.153	1.525	867 [i]
EFSA, 2012 [d]	Game mammals	3532	51		0.966 [j]	0.33	
	Wild boar	966	47		1.143	0.670	
	Venison (roe deer)	733	35		0.048	0.124	
	Elk meat	47	83		0.015	0.046	
	Reindeer	490	66		0.061	0.150	
	Hare meat	149	59		0.155	0.475	
Germany [e]	Wild boar			0.02	4.7		684 (1998), 288 (2007)
Germany [f]	Roe deer	549	98	0.015	9.65		4728
	Wild boar	185	94	0.025	2.15		276
	Red deer	6	83	24.6	45.0		133
Spain [g]	Red deer	61			0.326		4.6
	Wild boar	64			1.29		10.4
Poland [h]	Red deer	82			0.22		1.5

N – number, **% > LOD/LOQ** – per cent of the samples with higher concentrations than the limit of detection (LOD) or the limit of quantification (LOQ), **P95** – 95th percentile, **Max** – maximum value, [a] Lindboeet al. 2012, [b] National Food Agency, Sweden, 2012, [c] EFSA, 2010, [d] EFSA, 2012, [e] BfR, 2011, [f] Müller-Graf et al., BMELV/BfR Symposium, 18.3.2013, [g] Sevillano Morales et al., 2011, [h] Falandysz et al., 2005, [i] upper bound mean , [j] middle bound mean.

4.3.3 Other data on lead in game meat

In the EFSA opinion on lead in food 2010, measurements of lead concentrations in 2521 samples of game meat were included (reindeer, deer, wild pheasant). The lead concentration ranged from below the detection limit (<LOD) to 867 mg/kg, with a mean of 3.15 mg/kg (UB) (Table 8). The lead concentrations in the liver and kidney of game animals (reindeer, deer, wild pheasant) were also assessed (652 samples) and ranged from <LOD to 239 mg/kg (mean 1.26 UB).

The distribution across different food groups of samples with a lead concentration of more than 1 mg/kg was reviewed in a separate exercise in the 2010 report from EFSA. There were 771 results with lead concentration above 1 mg/kg (out of 94126 results). Of these, 17 samples characterised as outliers were excluded from further analyses. Those samples alone caused almost a doubling of exposure if left in the calculation. Of the remaining 754 samples, 14.1% exceeded 10 mg/kg with a maximum of 867 mg/kg in muscle of wild boar. Game meat and offal dominated this group of high-lead concentration samples, followed by non-algae based food supplements and fungi- and algae based food supplements. Some very high values were also recorded in the general offal category. Of the top ten food groups in which food items were ranked by mean lead concentration, most are rarely consumed or consumed in small amounts. Accordingly, the highest lead concentrations were found in meat from wild boar and pheasants in the EFSA 2012 report, where more detailed data on lead in game meat were presented (Table 8).

In a Canadian study on game mammals harvested with lead bullets, lead concentrations ranged from 0.3 to 867 mg/kg and from 1.0 to 5726 mg/kg in muscle tissues from white-tailed deer and caribou, respectively (Tsuji, 2009). Lead concentration in muscle tissues of red deer and wild boar shot with lead-based ammunition have recently been investigated in Spain, the mean being 0.32 and 1.3 mg/kg, respectively (Table 8). Similar concentrations have previously been reported in hunted red deer in Poland (Table 8).

In a recent study examining the lead content in three edible parts after trimming/discarding the meat associated with the wound channel (in vicinity of the wound channel, in the back fillet, and the leg) of roe deer, red deer, and wild boar hunted with lead-containing ammunition in six different German regions (Müller-Graf et al., 2013), statistically significant elevated lead levels were detected in all three sample types. Mean concentrations were highest in roe deer meat (n=549) from the vicinity of the wound channel (9.66 mg/kg), followed by the back fillet (0.91 mg/kg), and were lowest in the leg (0.22 mg/kg). There were notably many extreme values in the near-wound channel samples even if the median value was only a little over the legislative level of 0.1 mg/kg for meat from domestic animals (see Chapter 1.2). The analysis of the boar and red deer samples is not completed. Preliminary results show, however, high mean lead levels in meat from the vicinity of the wound channel (but not including meat trimmed from the wound channel) (boar: 2.15 mg/kg; red deer: 45.0 mg/kg).

4.4 Game meat consumption in Norway

4.4.1 Norwegian population studies

Game meat consumption has been assessed in several studies as outlined below.

A recent nationwide dietary survey, Norkost 3 (n = 1787), was conducted in 2010-2011 (Totland et al., 2012). The survey was based on two non-consecutive 24-hour recalls and therefore not designed to cover rarely eaten foods such as game meat. The Norkost survey did not include any measurement of blood lead concentration.

The Norwegian Institute of Public Health has conducted four population studies which assessed game meat consumption and also included measurement of blood lead levels:

- The MoBa Validation study (MoBa Val) was a sub-study in the Norwegian Mother and Child Cohort study (MoBa), conducted in order to validate the new food frequency questionnaire (FFQ) developed for use in pregnant women participating in MoBa. The study sample included 119 healthy women recruited at Bærum Hospital in gestational weeks 17-18 in 2003-2004. The participants completed an extensive FFQ and donated non-fasting blood samples. For more details see Appendix I.
- The Norwegian Fish and Game study was a three-stage survey (Part A, B and C), conducted in years 1999 to 2003, which aimed at obtaining information about the dietary intake of environmental contaminants in the Norwegian population. Part A was a national survey of the consumption frequencies, relating to specific foods considered to contain potentially high levels of environmental contaminants. Part B

was a regional survey in 27 selected inland and coastal municipalities with good access to hunting and fishing locations. The selection of municipalities (out of 430) was based on hunting statistics and contact with municipal food control agencies in Norway. Part C investigated in-depth a sub-population derived from Part B. The general aim of Part C was to carry out exposure assessments on people who frequently consume foods with a potential high level of environmental contaminants. Part A and B included a short report of habitual diet including game, whereas participants in Part C (n=184) completed a modified version of the FFQ developed for MoBa and donated non-fasting blood samples. For more details, see Appendix I.

- The Lake Mjøsa study was carried out in years 2004-2005 for surveillance of exposure to environmental toxicants in a population of frequent consumers of inland fish from Lake Mjøsa. Participants (n=64) were recruited among local hobby fishermen and women, and completed the same modified version of the FFQ as in the Norwegian Fish and Game study, and donated non-fasting blood samples. For more details, see Appendix I.
- The Norwegian Game and Lead study. This study was conducted between March and September 2012 with the aim to examine associations between consumption of cervid meat and blood lead concentrations in a study group comprising both hunters- and non-hunters (n=147). Participants were recruited by distribution of invitations through hunting team leaders in five typical cervid game municipalities, through direct contact with members in the Norwegian Hunting and Fishing Organization, and some participants were recruited at the Norwegian Institute of Public Health. The recruitment strategy secured inclusion of hunters and non-hunters with a wide range of game meat consumption. Only persons 18 years or older were invited to participate. Participants answered one question about cervid meat consumption in the invitation letter, and donated a non-fasting blood sample and completed a detailed four page questionnaire with questions about demography, diet, lifestyle and hunting practices. For more details, see Appendix II.

The FFQ used in the MoBa Validation study, the Norwegian Fish and Game study Part C, and in the Lake Mjøsa study was a 12-page semi-quantitative questionnaire that asked about habitual intake of 233 food items or meals adapted to Norwegian food traditions. Socio-demographic information was obtained from other questionnaires. The FFQ included six questions about consumption of game meat and offal.

A shorter questionnaire was developed for the Norwegian Game and Lead study. This questionnaire had 32 main questions and included questions about demography, hunting habits (number of years hunting, number of shots, type of hunting etc.), consumption of game (moose, deer, reindeer, small game) and factors which might modify lead levels in the body (dietary supplements, alcohol, smoking etc.). The eight alternative answers for frequencies of consumption were: never, 1-5 meals per year, 6-11 meals per year, 1 meal per month, 2-3 meals per month, and 1, 2 or ≥ 3 meals per week. In addition, the invitation letter included a global question about consumption of cervid meat: “How often do you eat cervid meat?” The four answering alternatives were: “never”, “some times a year”, “one to three times per month” and “one or several times per week”. The answers to this global question were used together with the more detailed consumption data.

A short description of the four population groups regarding the number of participants, sex, age, dietary assessment methods, period covered by the FFQ and the inclusion period is found in Table 9.

Table 9: Short description of the four population groups studied for associations between game meat consumption and lead concentration in blood.

	Fish and Game Part C		Lake Mjøsa		MoBa Val		Game and Lead	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Participants	184	100	64	100	119	100	147	100
Women	100	54	24	38	119	100	55	37
Men	84	46	40	62			92	63
Age, years								
≤ 25	6	3	1[a]	2	6	5	5	3
> 25-45	45	24	12	19	113	95	53	36
> 45-65	90	49	34	53			72	49
> 65	43	24	17	26			17	12
Median age (range)	55 (21 - 80)		59 (31 - 88)		31 (23 - 44)		48 (18 - 76)	
Dietary assessment	12-page FFQ [b]		12-page FFQ [b]		12 page FFQ [b]		4 page FFQ	
Period covered by the FFQ	12 months		12 months		4-5 months		1 and 12 months[c]	
Inclusion period	Feb-May 2003		Oct 2004 - May 2005		Jan 2003 - Feb 2004		April-Oct 2012	

[a] Excluded in further analyses, [b] The same Food Frequency Questionnaire (FFQ), [c] Additional question on years of game meat consumption. (**Sources**: Appendix I and II.)

4.4.2 Consumption data

In the National dietary survey, Norkost 3, the average consumption of game meat (meat from cervids and wild birds excluding minced meat) was approximately 3 g/day. This corresponds to a mean intake of 5-7 meals of game meat per year[7]. However, the number of game meat consumers was only around 5% and comparison with consumption data assessed by FFQs in the other Norwegian study groups is not feasible.

In the MoBa Val study and in Part A of the Norwegian Fish and Game study, the majority of participants never or rarely ate cervid meat, while more frequent consumption was seen in the other studies (Table 10).

It must be noted that the definition of game meat was not similar across all studies. In the MoBa Val study, the Norwegian Fish and Game study Part C and Lake Mjøsa study, game meat consumption denoted intake of meat from moose and/or red/roe deer and/or reindeer and/or grouse, while game meat reported in the Norwegian Game and Lead study denote cervid meat only.

[7] Game meat consumption was calculated by VKM based on reported consumption and reported standard portions sizes.

The proportion of participants reporting game meat consumption at least once a month was 43% in MoBa Val and 14% in the Norwegian Fish and Game study Part A. In Part B, 13% of the coastal population and 36% of the inland population ate game meat monthly or more. In Part C, the corresponding proportions were 68% in the representative group and 71% in high consumers. In the Lake Mjøsa 66% and in the Norwegian Game and Lead study 70% reported game meat consumption at least once a month (Table 10).

Table 10: Frequency of game meat consumption (% consumers) in the Norwegian population studies

Game meat consumption [a]	n	Never	A few times a year	1-3 times a month	Once a week or more
MoBa validation study	119	57		36	7
The Norwegian Fish and Game Study, Part A	6015	28	57	10	4
The Norwegian Fish and Game Study, Part B					
Coastal population	2681	31	56	10	3
Inland population	2818	12	52	21	15
The Norwegian Fish and Game Study, Part C					
Representative group	75	32		53	15
High consumers	109	30		43	28
Lake Mjøsa study	64	34		36	30
The Norwegian Game and Lead Study	147	10	20	33	37

[a] Game denotes meat from moose and/or red/roe deer and/or reindeer and/or grouse in all studies except the Norwegian Game and Lead study where game denotes cervid meat only. **Source:** Appendix I and Meltzer et al., submitted 2013.

More detailed descriptions of game meat consumption in the MoBa Val, the Norwegian Fish and Game study Part C and the Lake Mjøsa study populations are available in Appendix I. In short, in all three population groups the total consumption of game was mainly consumption of moose, red and/or roe deer, followed by reindeer, while intake of grouse was generally very low. In Part C of the Norwegian Fish and Game study, nine participants reported eating offal from game, while no participants reported such consumption in the two other population groups.

In the Norwegian Game and Lead study, men reported higher consumption than women of total cervid meat as well as of separate types of cervid meat and minced cervid meat. The median frequency of game meat consumption (including cervid meat) was 5.5 meals/month in men and 3.5 meals/month in women. The median frequency of minced meat from moose and/or deer was 2.1 meals/month in men and 1.2 meals/month in women. Forty-eight percent (n=71) of the participants reported that they ate moose meat once a week or more, while 15% (n=22) reported eating deer meat once a week or more. Only four reported monthly or weekly consumption of hare and bird game (small game). At all levels of game meat consumption, a considerable proportion of the intake was in the form of minced meat from moose or deer.

The majority, 89 persons (61%), reported that their source of game was their own hunting/hunting team, while 46 participants had purchased the meat they consumed in shops.

As the invitation to participate in the Norwegian Game and Lead study was directed towards hunters in particular, the pattern of game meat consumption is by no means representative of the general population. The larger number of male than female participants in the study, 63% and 37% respectively, primarily reflects a general gender distribution among hunters. In the hunting season 2011-2012 about 6% of the hunters were female hunters.

4.4.3 Game meat consumption in children

No information on game meat consumption among Norwegian infants and children has been found. However, it can be expected that children eat game meat equally often as the rest of the family.

4.5 Blood lead levels in Norway and other countries

Generally the concentration of lead in blood has decreased dramatically over the last three decades due to prohibition of lead in petrol, paint and seams of tinned food. In 1976-1980 the geometric mean blood lead concentration among children in the NHANES (US) was 150 µg/L but this has decreased to less than 20 µg/L today (US ATSDR, 2007). Similar changes have been seen in adults in Europe (Smolders et al., 2010, Grandjean, 2010). In Southern Sweden, the geometric mean blood lead concentration in school children decreased from 60 µg/L in 1978 to approximately 25 µg/L 15 years later (Gerhardsson et al., 1996), and the same trend was seen among adults (Wennberg et al., 2006). The Norwegian Game and Lead study comprised a large proportion of frequent consumers of cervid meat, but the median blood lead concentration was in the lower range of medians measured in most European and Norwegian studies over the past 10 years (Table 11).

Because of declining lead levels, the sampling period needs to be taken into consideration when lead concentrations in different studies are compared. With the exception of the recent study from Sweden with a median of 13.4 µg/L (Bjermo et al., 2013) the geometric mean or median concentration of lead in blood reported in most European countries has been in the range 20 to 30 µg/L. This range encompasses both the Norwegian Fish and Game study Part C and the Lake Mjøsa study (Table 11). Also women participating in the Norwegian HUNT2 (with earlier sampling period) had mean blood lead of approximately 20 µg/L. In comparison to this, blood lead concentrations were lower in pregnant women in MoBa Val, with median 11 µg/L and geometric mean 12 µg/L. Similar low blood lead level was reported in pregnant women in Southern Sweden sampled in approximately the same time period, median 11 µg/L, range 4-79 µg/L (Gerhardsson et al., 2010). The lower blood lead concentrations seen in pregnant women than in the general population may reflect age-related lower concentration of lead in blood among young women (Vahter et al., 2007) but may also be explained by plasma volume expansion caused by pregnancy, resulting in a general dilution of the blood (Faupel-Badger et al., 2007).

Table 11: Concentration of lead in blood in European adults

	Age (year)	Year/ sampled	n	Median µg/L	Geometric mean µg/L
The Norwegian Game and Lead Study [a]	18–76	2012	147	17	17
The Fish and Game Study [b]	21–80	2003	185	25	24
The Lake Mjøsa Study [b]	31–88	2004-2005	64	26	27
The MoBa Val study [b]	25-44 pregnant women	2003-2004	119	11	12
HUNT2 [c] **Norway**	20-55 women	1995-1997	257[f] 191[g]		19[h] 20[h]
France [d]	18-74	2006-2007	2029	27	26
Germany [d]	18-70	2005	130	20	19
Portugal [d]	18-65	2006	180	28	23
The Netherlands [d]	Adults	2001	1482	26	
Czech Republic [d]	Adult women	2005-2007	335	25	
Italy [d]	Adult women	2004	36	24	
Slovakia [d]	Adult women	2001-2005	98	28	
Sweden [d]	Adult women	2003-2004	47	15	
Sweden [e]	30 (19–44) pregnant women	2002–2003	100	11	
Sweden [i]	Adults	2010-2011	273	13	

[a] Meltzer et al., submitted 2013, [b] Appendix I, [c] Meltzer et al., 2010, [d] Smolders et al., 2010, [e] Gerhardsson et al., 2010, [f] women with serum ferritin < 12 µg/L, [g] women with serum ferritin ≥ 12 µg/L, [h] mean concentration, [i] Bjermo et al., 2013

4.6 Association between game meat consumption and blood lead concentration

A recent Swedish study examined the body burden of lead and other metals in blood among Swedish adults in a subgroup (n=273) of the national dietary survey Riksmaten 2010-2011 (4-day food records and questionnaire). Median (5-95 percentiles) blood lead was 13.4 (5.8 - 28.6) µg/L. Meat intake was not related to blood lead. However, when examining the impact of type of meat consumed (as assessed by a food frequency questionnaire) on blood lead concentration, frequency of game intake (but not reindeer, sheep, horse, bovine, pig, bird, or fish) was associated with blood lead levels (Bjermo et al., 2013). An association between game consumption and blood lead concentrations has also been reported from the US (Iqbal et al., 2009). Of 736 participants, aged 2-92 years, from six North Dakota cities, 80% reported consuming game meat (venison, moose, and birds harvested by hunting). After adjusting for age, sex, current and previous lead-related occupations and/or hobbies and other potential confounding variables, persons who consumed any such game meat had 3.0 µg/L (95% CI:

1.6, 4.4 µg/L) higher blood lead concentrations than non-consumers. Persons who consumed all three game meat types (venison, moose and birds) had 5.0 µg/L higher blood lead concentrations than those who did not consume any. The results also showed that recent game meat consumption (<1 month ago) and serving size was associated with blood lead (Iqbal et al., 2009).

4.6.1 The Norwegian Fish and Game study, the MoBa Validation study and the Lake Mjøsa study

None of the studies were designed specifically to examine associations between game meat consumption and blood lead concentration. However, all three studies had available data on blood lead concentrations and the consumption data were acquired using the same FFQ.

In the Norwegian Fish and Game and Lake Mjøsa studies, associations between game meat consumption and blood lead concentrations were studied in men and women separately, because statistical analyses showed an interaction with sex on the association between game meat consumption and blood lead concentrations in the Norwegian Fish and Game study.

Blood lead concentrations were higher in men than in women, median 28 versus 21 µg/L in the Norwegian Fish and Game study, and median 29 versus 22 µg/L in the Lake Mjøsa study. In unadjusted analyses in these studies there were no differences in blood lead concentrations between participants with regard to game meat consumption. However, when socio-demographic and lifestyle variables were taken into account, a consistent increase in blood lead concentrations in men in the Norwegian Fish and Game study was seen for increasing intake of total game meat as well as for the highest intake (more than one meal per week) of meat from moose and/or deer. Those who reported more than weekly intake of moose and deer meat (n=9) had significantly ($p<0.01$) higher blood lead concentrations than non-consumers (n=29), while no difference was seen for intake of one meal per month (n=13), two to three meals per month (n=15) or four meals per month (n=18). Intake of reindeer or grouse meat was not associated with blood lead concentrations, while intake of offal from game was significantly associated with higher blood lead concentrations (Appendix I). In Norway, reindeer meat for purchase in shops is mainly from tame reindeer slaughtered by professional butchers and not hunted (Chapter 3.2). Grouse was still shot with lead hail at the time of the study. The reported consumption was very low in all three population groups. Moose and deer are mainly hunted with lead-containing ammunition (see Chapter 3.3.7). It must be pointed out that none of the three studies were originally designed to study the association between game meat consumption and concentration of lead in blood.

No associations between game meat consumption and blood lead concentrations were observed in women in MoBa Val, the Norwegian Fish and Game and the Lake Mjøsa studies. Gender differences in the disposition and toxicity of metals are well known (Vahter, 2007). Men have generally higher blood lead level than women, partly due to higher exposure, but as lead in blood is bound to erythrocytes, also due to higher blood hematocrit levels (Pirkle, 1998; Becker, 2002). Hence, blood lead concentration is influenced by different factors in men and women and is not a direct result of external exposure only.

4.6.2 The Norwegian Game and Lead study

The study was conducted in 2012 to specifically study associations between game meat consumption and blood lead concentrations. The analysis also explored factors other than game meat consumption that contributed to the variation in blood lead levels.

The median blood lead concentration in the study population was 17 µg/L, 5 and 95 percentiles were 7.5 and 39 µg/L, respectively, range 6.0-69 µg/L. The study population (n= 147) included 92 (63%) men and 55 women (37%). The median age of men and women were 50 and 46 years, respectively. In line with the other studies, blood lead concentrations were higher in men (median 20 µg/L) than in women (median 13 µg/L). Blood lead concentration increased with increasing age and was significantly higher in participants who reported self-assembling of lead-containing bullets (median 31 vs 16 µg/L). In both crude and adjusted analyses, blood lead concentrations reflected how often the participants consumed cervid meat. Those who reported no cervid meat consumption (n=14) or just a few meals per year (n=29) had significantly lower blood lead concentrations (mean 15 and 14 µg/L, respectively) than those who reported monthly (n=49) or weekly intake (n=55) (mean 22 and 21 µg/L, respectively) (Figure 10, unadjusted values).

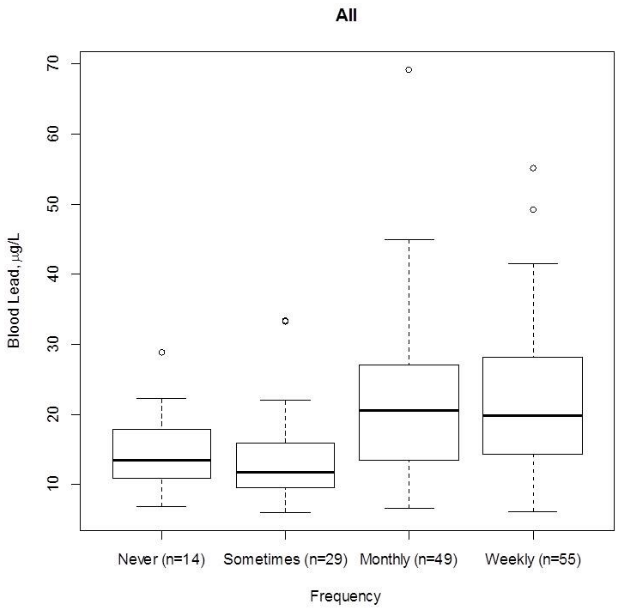

Figure 10: Concentration of lead in blood (µg/L) by self-reported frequency of cervid meat consumption in the Norwegian Game and Lead study. Box plot details: the horizontal lines indicate the median blood lead concentration; the box indicates the interquartile range (IQR) (IQR: 25th percentile to 75th percentile); the whiskers represent observations within 1.5-times the IQR; and the circles indicate observations more than 1.5 times the IQR away from the box, considered outliers.

There was no significant difference in blood lead between the two low consumption groups and no difference between the two groups of more frequent cervid meat consumption. Hence, participants who reported cervid meat consumption never or a few times per year were combined and participants who reported regular (monthly) or often (weekly) intake were combined in further statistical analyses.

In unadjusted analysis, participants reporting frequent (monthly or weekly) consumption of cervid meat had higher mean blood lead concentrations than those who never or sometimes ate cervid meat: 22 vs. 14 µg/L (median 20 vs. 12 µg/L). A statistically significant impact of frequent cervid meat consumption on blood lead concentrations remained also when other variables e.g. age and sex, were taken into account.

Multiple regression models were used to show the effects of several factors at the same time. Several models were explored to examine the association between cervid meat consumption and blood lead. In models adjusted for sex and age, the consumption frequency of minced meat from moose or deer resulted in a significantly better model (i.e. larger explained variance) than consumption frequency of non-minced cervid meat. Hence, the difference in blood lead between consumers and non-consumers of cervid meat seemed for a large part to be related to consumption of minced meat from moose or deer.

The best model fit was obtained by using log-transformed concentration of lead in blood as the dependent variable. The optimal model included the following explanatory variables: sex, age, regular (monthly/weekly) intake of cervid meat (yes or no), consumption of purchased minced cervid meat (meals per month), consumption of self-obtained minced cervid meat (meals per month), self-assembling of lead-containing ammunition (yes or no), wine consumption, number of bullets shot per year, years with game meat consumption, and smoking. Cervid meat consumption together with number of bullets shot per year, years with game consumption, self-assembling of bullets, wine intake and smoking jointly accounting for approximately 25% of the variation in ln-transformed blood lead concentrations, while age and sex accounted for 27% of the variance.

The effect estimates (betas) for the independent variables were reported as per cent change in blood lead concentration for a one unit change in the independent variable. The estimated effect of cervid meat consumption was 31% higher lead levels in frequent than in less frequent consumers. Two additional factors related to game meat consumption turned out to be of importance, first whether the meat was minced, and second, whether the minced meat was purchased or not. The differential influence between the impacts on blood lead concentrations of minced cervid meat versus cervid meat in general is of special interest. One extra meal with minced meat per month gave an expected increase in blood lead concentrations of approximately 2% if the meat came from the participant's own hunting party and 4% if it was purchased. Detailed analyses of the results indicated that in this study, the proportional consumption of minced cervid meat was reduced among those with a high cervid meat intake. This could be indicative of a greater relative consumption of meat taken far from the wound channel, reducing the relative lead exposure in the high consumer group.

Other factors related to game meat consumption and cervid hunting that influenced blood lead concentrations were the number of years of game meat consumption, self-production of ammunition, number of bullets fired per year, wine drinking and smoking. The number of years of game meat consumption was inversely related to blood levels, with about 5% decrease per decade of game meat intake. The phenomenon illustrates that game meat intake over time is not necessarily associated with higher lead accumulation in the body. Despite few subjects practicing it, self-assembling of lead-based ammunition was a very significant factor in the model and associated with approximately 52% increase in expected blood lead concentration. The number of bullets fired per year can be interpreted as one of several indicators of lead exposure through shooting activity, but the estimated effect was modest (100 shots more per year gave an expected increase in blood lead concentration of just above 2%) (Meltzer et al., submitted 2013, Appendix II).

4.7 Summary of human lead exposure from game meat consumption

Whereas most cervid meat contains low levels of lead, high concentrations have been found in some samples.

In the National dietary survey, Norkost 3, the average consumption of game meat was low, approximately 5-7 meals per year. In population studies addressing game meat consumption, the proportion of participants reporting game meat consumption at least once a month was up to 70%.

No information on game meat consumption among Norwegian infants and children or lead levels in blood from Norwegian children has been found. However, it can be expected that children eat game meat equally often as the rest of the family.

The concentration of lead in blood has decreased dramatically over the last three decades.

In Norwegian studies, the mean or median concentrations of lead in blood were from 11 to 27 µg/L, which is in the same range as studies in most European countries the last 10 years. Blood lead concentrations were lower in pregnant women in Norway and Sweden than in other population groups.

Consumption of game meat was shown to be associated with blood lead concentrations in a study from North Dakota as well as in a recent study in Sweden.

Associations between game meat consumption and blood lead concentration have been studied in four population studies in Norway. In the three studies performed in the years 2003-2005, a significant association between game meat consumption and higher blood lead concentration was only seen in the subgroup of male participants in one of the studies (the Norwegian Fish and Game study).

In the Norwegian Game and Lead study performed in 2012 the median blood lead concentration (17 µg/L) was in the lower range of medians measured in most European and Norwegian studies over the past 10 years. Median blood lead concentration was 14 µg/L in participants reporting no/seldom intake of cervid meat and 22 µg/L in those reporting monthly or weekly intake. Taking socio-demographic and lifestyle variables into account, frequent (monthly or weekly) cervid meat consumption was associated with about 30% higher levels of lead in blood than less frequent consumption. The increase seemed to be mostly associated with consumption of minced cervid meat, particularly purchased minced meat. However, many participants with high and long-lasting game meat intake had low blood lead concentrations. Self-assembling of lead-containing bullets was associated with 50% higher concentration of lead in blood. Other factors associated with blood lead concentrations were age, sex, smoking, years of game meat consumption, number of bullets used per year, and wine drinking. Age and sex accounted for 27% of the variance, while all factors combined accounted for 52% of the variation in the blood lead concentration. Overall, the results indicate that use of lead-based ammunition, self-assembling of lead containing bullets and use of lead-contaminated meat for mincing, to a large extent influence the exposure to lead from cervid meat consumption.

5 Risk characterisation

5.1 Humans

Recent risk assessments on lead from EFSA (2010) and JECFA (2011) have concluded that a safe level of lead exposure at which there is no increased risk of adverse health effects has not been identified. These risk assessments were based on lead levels in blood and/or skeleton, and the dietary exposures associated with such concentrations in blood and/or skeleton were calculated by toxicokinetic models.

Dietary exposure calculations from a range of European countries were recently updated by EFSA (EFSA 2012). EFSA based their dietary assessment on a large number of occurrence data in food from different food groups and a large number of dietary surveys conducted across European countries. Mean dietary exposure in the four older age groups (adolescents, adults, elderly and very elderly) did not exceed the $BMDL_{01}$ and $BMDL_{10}$ of 1.50 and 0.63

µg/kg bw per day established for cardiovascular effects and for nephrotoxicity in adults, respectively. However, mean dietary exposure for the three lowest age groups (up to 10 years) exceeded the $BMDL_{01}$ of 0.50 µg/kg bw per day for developmental neurotoxicity in young children. There are no recent national Norwegian data available on lead exposure from the diet. The Norwegian data on lead concentration in blood in different population groups are in the same range as in the rest of Europe (Chapter 4.5, Table 11) and it is therefore no reason to believe that lead exposure in the general Norwegian population is substantially different from the rest of the European population.

VKM has used concentration of lead in blood from Norwegians together with available data on cervid meat consumption in the general population and in adult high consumers groups in the present risk characterization. Concentrations of lead in blood have been compared with reference concentrations in blood used by EFSA in their risk characterization of lead exposure in 2010. The BMDLs derived by EFSA were for developmental neurotoxicity 12 µg/L ($BMDL_{01}$); for effects on systolic blood pressure 36 µg/L ($BMDL_{01}$); and for effects on prevalence of chronic kidney disease 15 µg/L ($BMDL_{10}$). The BMDLs are based on the lower 95-percentile confidence interval of a blood lead concentration that is associated with a low increased risk, and using the lower confidence interval ensures that the most sensitive part of the population groups are also taken into consideration.

In Norwegian population studies a considerable proportion of the population exceeds the abovementioned BMDLs (Table 13 in Appendix I). This lead exposure is of concern since it can increase the proportion of the population having an increased risk of cardiovascular disease or kidney disease. However, at the individual level, a small increase in e.g. systolic blood pressure, is of low clinical importance.

Bearing in mind that the present risk assessment address lead exposure from cervid meat, and not lead exposure as such, it also needs to be emphasised that blood lead levels available from Norwegian population groups reflect both dietary exposure and other sources such as inhalation exposure. There is a strong correlation between lead concentration in blood and age. This can partly be explained by equilibrium with lead accumulated in the skeleton over time. The higher variability in blood lead concentration with age may be related to difference in porosity of skeleton with age resulting in higher release of lead from bone to blood. Lead exposure shows a downward trend in Europe, which is associated with the ban of leaded petrol, thus higher levels with age might also reflect higher exposure in the past.

5.1.1 Adults

The consumption of game meat (including cervid meat) is generally low in Norway, and at least 2/3 of the population consume such meat maximally a few times per year, and more than 90% never eat liver or kidney from game animals. No association between low consumption of game meat and lead concentration in blood has been revealed. Game meat consumption is not a major contributor to lead exposure in the general population.

5.1.1.1 *High consumers of game (including cervid) meat*

Results from both the Norwegian Fish and Game study and the Norwegian Game and Lead study show higher blood lead levels in frequent cervid meat consumers than in participants who seldom or never eat such meat. A similar association was recently reported from Sweden. Since the Norwegian Game and Lead study is the most recent study and was specifically designed for investigation of association between game consumption and blood lead levels, this study is used as major basis in the present risk characterization. As expected, bearing the higher blood lead concentrations from other Norwegian population studies in mind, a high proportion of the participants in the Norwegian Game and Lead study exceeded the $BMDL_{10}$ for chronic kidney disease (15 µg/L). As noted by EFSA (2010), the $BMDL_{10}$ for this endpoint is likely to be numerically lower than necessary to protect against lead-induced chronic kidney disease, since lead exposure was declining in the population on which the BMDL was based (see Chapter 2.5). However, based on current dietary lead intake in Europe, EFSA concluded that the possibility of an effect in some consumers with high lead exposure cannot be excluded. A decrease in lead exposure comparable to that observed in the NHANES has occurred among Norwegians. The implications of having a concurrent blood lead concentration above 15 µg/L cannot fully be interpreted since it is not known when and at which level of lead exposure the kidney disease was initiated. However, in the Norwegian Game and Lead study almost twice as many of those who consumed cervid meat regularly or often exceeded this value compared with those who never or sometimes consumed such meat (68% and 35% exceeded 15 µg/L, respectively) (Meltzer et al., submitted 2013), and an eventual increased risk of chronic kidney disease would be higher among those who consume cervid meat regularly or often.

None of the participants among the low consumers (never or sometimes game meat) exceeded the $BMDL_{01}$ for increased systolic blood pressure (36 µg/L), but 4% of the frequent (monthly or more) consumers exceeded this value (Figure 11).

Of importance, the data showed that factors associated with cervid meat consumption and other lead exposure played a major role in explaining the variation in blood lead levels. The data also pointed towards minced cervid meat as an important factor. Frequent (monthly or more) cervid meat consumption, and in particular minced cervid meat consumption, was associated with higher lead concentration in blood. This indicates that minced cervid meat contains more lead than non-minced cervid meat.

Relative to the historically much higher and varying environmental lead exposure, the lead exposure from game meat including cervid meat is low. However, whereas the contribution from game meat consumption has remained constant in frequent consumers, the general background exposure has been declining. Thus, a possible association between game meat consumption and lead in blood might have been masked in the studies previously conducted in Norway such as the Lake Mjøsa study, when the lead concentrations in blood were higher. The lead exposure from game meat (including cervid meat) comes in addition to that from the general background, which is already higher than desirable. Consequently, based on the results from the most recent Norwegian population study, frequent (monthly or more) consumers of cervid meat (and in particular minced cervid meat) are at risk in having higher lead exposure than those with lower consumption (never or sometimes).

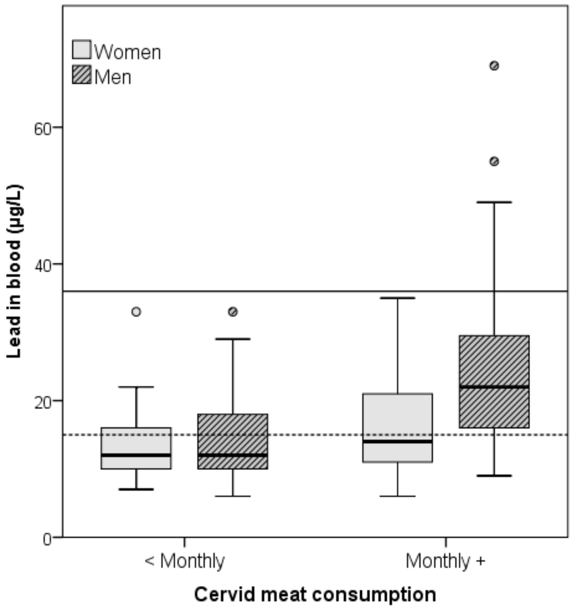

Figure 11: Blood lead concentrations in men and women in the Norwegian Game and Lead Study in relation with frequency of cervid meat consumption. The dashed horizontal line indicates EFSA's $BMDL_{10}$ for chronic kidney disease at 15 µg/L and the solid horizontal line indicates EFSA's $BMDL_{01}$ for increased blood pressure of 36 µg/L. Box plot details: the horizontal lines indicate the median blood lead concentration; the box indicates the interquartile range (IQR) (IQR: 25th percentile to 75th percentile); the whiskers represent observations within 1.5-times the IQR; and the circles indicate observations more than 1.5 times the IQR away from the box, considered outliers.

5.1.1.2 *Hunters vs. non-hunters*

Hunting activity by itself measured as the number of shots fired per year was only modestly associated with increased blood lead levels among participants in the Norwegian Game and Lead study. However, despite few subjects practicing it, self-assembling of ammunition was a very significant factor associated with higher blood lead concentration. It is not known if exposure from such activity is dermal, oral (resulting from hand-to-mouth activity) or if it is inhalational.

5.1.2 Infants and children

No information on game meat consumption or lead levels in blood has been found for Norwegian infants and children. However, it can be expected that children eat game meat equally often as the rest of the family, and that the association between cervid meat consumption and lead concentration in blood would be applicable for children as well. The lowest reference concentration ($BMDL_{01}$ of 12 µg/L for developmental neurotoxicity) would have been most appropriate for risk characterization of children's exposure. The lack of data from infants and children hinders a further risk characterization of lead exposure from game consumption in this group of the population.

5.1.3 Pregnant women and the developing foetus

Due to physiological differences women have in general lower blood lead concentrations than men. According to EFSA (2010), the foetal blood lead concentration is approximately 90% of the maternal blood lead concentration, and EFSA made the assumption that the developing foetus is as least as sensitive to neurodevelopmental toxicity of lead as a young child. The reference concentration of 12 µg/L for neurodevelopmental toxicity ($BMDL_{01}$) is therefore regarded by the VKM Panel on Contaminants as appropriate for risk characterization of prenatal exposure. In pregnant Norwegian women (MoBa Val study), 45% of the women had blood lead concentration above 12 µg/L (Appendix I).

There was no significant association between game meat consumption and lead concentration in blood from women in the MoBa Val study (Chapter 4.5). These women had, however, low game meat consumption and the lack of correlation is in accordance with what was found for participants with low game meat consumption in the other Norwegian population studies.

Although there are no available data on the exposure to lead from high consumption of cervid meat in pregnant women, the VKM Panel on Contaminants expects that the association between game meat consumption and higher blood lead levels would be similar in pregnant women as in the rest of the population. Frequent game meat consumption in women in child bearing age is of concern because it can increase the proportion of the population of children having lead exposure that can be associated with increased risk of neurodevelopmental impairments. It should be kept in mind that a small reduction in the intelligence of children will not be notable at the individual level.

6 Uncertainty

There is uncertainty related to how practice of meat removal around the wound channel affects lead exposure.

There is uncertainty associated with the amount of cervid meat consumption, since both over- and under reporting is expected to occur. The reporting of frequency of game meat consumption is dependent on the participants' memory of consumption and their ability to transfer consumption into frequencies. The conversion from frequency to g/day is based on standard portion sizes, which in itself is associated with high uncertainty.

There is uncertainty associated with the release of lead from different bullet types. Furthermore, types of bullets used could not be associated with the participants in the Game and Lead study, and could not be taken into account in regression analyses.

The VKM concludes that the uncertainties mentioned above most likely attenuate the associations between cervid meat consumption and lead concentrations in blood, and would thus underestimate the impact of cervid meat consumption on lead concentrations in blood.

This assessment is based on lead concentrations in blood, thus uncertainty related to bioavailability of metallic lead is not applicable.

7 Data gaps

- More data on lead concentration in cervid meat, and in particular commercially available minced cervid meat, are needed.
- More data are needed to assess bioavailability of metallic lead in food.
- No blood lead data or game meat consumption data for children were available, and this would be needed for a refined risk assessment of lead exposure from game meat consumption in children.
- There is a lack of data on fragmentation pattern of bullets in moose.

8 Significance of lead exposure to the health of dogs fed with trimmings from the wound channel

8.1 Lead toxicity in dogs

Similarly to humans, lead poisoning in dogs most often occur as a result of oral exposure of lead through items such as contaminated water, lead containing paint, or other lead containing particles. The present assessment concerns the potential health risk for dogs ingesting small lead particles in contaminated meat or offal from cervids killed with lead-based ammunition, particularly if they are fed with trimmings from the wound channel.

8.1.1 Acute toxicity in dogs

Lead poisoning due to ingestion of lead containing particles has been reported on multiple occasions for dogs, particularly young dogs with aberrant eating habits (Berny et al., 1992) and a lowest lethal dose for the dog has been suggested at 300 mg lead acetate/kg body weight (CDC, 1994). Metallic lead has lower absorption and the lowest lethal dose of metallic lead is not known. It can be difficult to propose a clear demarcation between acute or chronic lead poisoning (Ghisleni et al., 2004). If larger lead fragments or particles are retained in the stomach or in other parts of the gastrointestinal tract for prolonged periods of time, this can result in toxicity of non-acute nature. Radio-opaque materials in the gastrointestinal tract are frequently reported as part of the diagnostic picture in lead poisoning in companion animals accounting for up to 20% of the cases (Morgan et al., 1991). In a comparison between two animal poison control centres in the United States and France, ingestion of bullets accounted for 3.3% and 17.6% of dog lead poisoning cases in the US and France, respectively (Berny et al., 1992). However, most often larger lead fragments pass through the gastrointestinal tract unretained.

8.1.2 Chronic toxicity in dogs

Lead concentrations in blood above 400 µg/L can be considered an indicator of lead poisoning in dogs (Morgan, 1994) although blood lead levels does not necessarily correlate with the severity of clinical signs (Huerter, 2000, Ghisleni et al., 2004). The clinical picture of lead poisoning in dogs is related with that of humans and suggests a similar mode of action of lead in humans and dogs. Gastrointestinal and neurological symptoms are the most prevalent clinical signs of lead poisoning, and lead has been proposed as the single most prevalent cause of poisoning in dogs (Berny et al., 1992). Gastrointestinal disorders were more frequent than neurological disorders which were more frequent in younger (< 5 years old) than in older dogs (Berny et al., 1992). Table 12 summarises reported clinical findings in lead poisoned dogs.

There is very little information on the bioavailability of lead to dogs. Absorption of lead will depend on many factors such as chemical form, particle size, age and nutrition (Barltrop and Meek, 1975, Hamir et al., 1982, Mahaffey, 1974). Most experimental data on effects of lead exposure are on lead acetate but lead ingestion in dogs will in many cases, as with meat from lead-shot game, be in the form of metallic lead. In the rat, the absorption of metallic lead has been measured to 14% relative to lead acetate (Barltrop and Meek, 1975). A large surface area of the small lead fragments from the bullets in the meat, often present as dust at microgram levels, will certainly increase the lead absorption relative to the absorption from larger fragments. Elevated blood levels of lead are shown in pigs fed with meat from lead-hunted roe deer (Hunt et al., 2009), and the association between human blood lead levels and the consumption of lead-hunted game meat is reported elsewhere in this risk assessment (see Chapter 4.6). The relatively low pH of the gastric juice of dogs renders possible a higher absorption and bioavailability of the bullet lead in dogs compared with pigs and men. Once inside the body, the distribution of lead in different body compartments of dogs shows preferential accumulation in bone >> liver > kidney > spleen > pancreas > blood > brain (Stow et al., 1973, Lloyd et al., 1975). Residence time of lead in different body compartments show slow and fast pools with relatively rapid elimination from blood and very slow elimination from bones (Rabinowitz, 1998). The biological half-life for loss of lead from the skeleton of dogs was 346 days as reported by Black (1962). Lead is eliminated mainly through biliary clearance to faeces but also through urine; Lloyd et al. (1975) injected radiolabelled lead (^{210}Pb) intravenously to beagle dogs and found about 75% of the excreted ^{210}Pb in the faeces.

Table 12: Clinical symptoms of lead poisoning in dogs

Symptom	Signs	Reference
Gastrointestinal distress	Vomiting, diarrhoea, abdominal pain ("lead colic"), delayed gastric emptying	Berny et al., 1992 Morgan, 1994 Srebocan et al., 2001
Neurologic aberrations	Tremor, Spasms, Epileptic seizures, Hysteria, Lethargy, Ataxia, Anorexia, Cortical neuronal necrosis	Morgan, 1994 Berny et al., 1992 Zook 1972
Renal effects	Altered proximal tubuli epithelium, enlarged kidney and proximal tubuli necrosis	Zook, 1972 Stowe et al., 197
Bone changes	Sclerosis, delayed closure of vertebral epiphyses, lead lines	Zook, 1972 Stowe et al., 197
Haematological changes	Mild anemia (reduced erythrocyte, lowered haemoglobin, elevated mean cell volume), basophilic stippling, nucleated erythrocytes, elevated leukocyte count	Srebocan et al., 2001 Morgan, 1994 Zook, 1972
Biochemical changes	Blod lead levels > 400 µg/L, Reduced ALA-D activity, Increased urinary delta-aminolevulinic acid, hypoproteinemia	Morgan, 1994 Srebocan et al., 2001 Fine et al., 1988 Huerter, 2000 Stowe et al., 1973
Cardiovascular symptoms	Hypertension, damaged blood vessels in brain, capillary proliferation in brain.	Fine et al., 1988 Zook 1972

Gastrointestinal distress is a profound manifestation of lead poisoning in dogs although lesions in gut epithelium are generally not found in the gastrointestinal tract. Gastro-oesophageal ulcers have been reported but not with a high frequency. It has been suggested that lead induced colic is mainly the result of vascular spasms (Zook, 1972).

Dogs with symptoms of neurologic disorders had a high degree of degeneration and necrosis of cortical neurons. These lesions mainly occurred in the occipital and parietal lobes but similar changes were also found in the hippocampus and cerebellar Purkinje cells (Zook, 1972). In dogs with a prolonged course of nervous disorders, swollen astrocytes, thickened meninges and oedematous separation of connective tissue fibers were observed. Furthermore, damaged blood vessels and capillary proliferation in brain was observed in dogs with neurological symptoms for more than eight days. It has been suggested that the vascular lesions may reduce the blood-brain barrier and that the adverse effects on brain are caused by other substances since low concentrations of lead are found in the brain (Zook, 1972). However, elevated brain levels are found in lead exposed dogs, particularly in the occipital grey matter (Stowe et al., 1973).

Hepatic lesions reported mostly consist of degenerative changes or necrosis but congestion and hemosiderosis has also been reported (Zook, 1972). In the kidney, lesions seem to be mainly in the proximal tubuli epithelium and affect both nuclei and cell morphology (Zook, 1972). Stowe et al. (1973) fed a calcium and phosphorus deficient diet with or without 100 mg lead acetate/kg diet to littermate mongrels from 6 to 18 weeks of age. The average lead acetate dose was around 3.3 mg/kg bw/day (estimated). The major clinical findings were increased liver, kidney and brain weight with concomitant histopathological liver and kidney lesions, and bone malformation. In addition, altered blood chemistry (hypoproteinemia, moderate electrolyte and enzyme alterations) was found. A low dietary intake of calcium (Ca) enhances the susceptibility to lead intoxication and may partly explain this pronounced lead intoxication (Mahaffey, 1974).

Elevated levels of d-aminolevulinic acid (ALA) are commonly found in lead poisoned dogs, detectable both in blood and urine samples (Huerter, 2000) due to interference in the conversion of ALA to porphobilinogen by δ-aminolevulinic acid dehydratase (ALA-D). However, increased urinary ALA is not necessarily a consistent finding (Canfield et al., 1984), particularly in dogs with a relatively low blood lead concentration, although ALA-D activity in blood is a commonly used marker of lead toxicity in dogs. Penumarthy et al. (1980) fed 0, 2 and 5 mg lead acetate/kg bw/day to two month old beagles for 13 weeks and found reduced body weight and ALA-D activity as well as elevated nucleated erythrocyte count, erythrocyte protoporphyrins and urinary ALA in dogs exposed to lead at both levels. Although blood lead levels in the 0, 2 and 5 mg lead/kg bw/day were 70, 330 and 580 µg/L, the observed effects were on the same order of magnitude for the lead exposed animals and the clinical signs were not considered as a severe lead intoxication.

Similar as for humans, long term exposure to lead may cause cardiovascular effects in dogs. Fine et al. (1988) showed that a daily oral dose of 1 mg lead acetate/kg bw for 5 months in 3 month old dogs led to an increase in blood pressure after 10 days of treatment. This elevation was sustained at approximately 10% above the blood pressure of paired control animals throughout the study. This increase in blood pressure was associated with a small increase in the activity of the renin-angiotensin system but there were no indication of renal damage or alterations in renal function since no effects on extracellular fluid volumes, glomerular filtration rate or renal plasma flow were detected. Blood lead levels ranging from 250-400 µg/L and decreased ALA-D activity indicated a state of mild lead poisoning. Similarly, Mouw et al. (1978) showed elevated plasma renin activity in dogs given 3 mg lead acetate/kg intravenously but also increased urinary excretion of sodium, potassium, calcium and water due to reduced hepatic reabsorption of these electrolytes.

Although the lead dose necessary to establish adverse effects in dogs seems to vary, e.g. depending on factors such as dietary calcium and phosphate, a dose around 1 mg lead acetate/kg bw/day can be considered as a Lowest Observed Effect Level (LOEL) since clinical signs of increased blood pressure are observed after few days at this dose.

8.2 Lead exposure in dogs

The normal daily feed intake of dogs is 1.5-3% dry matter related to their body weight (Pond et al., 1995). With a dry matter ratio of fresh meat and offal at approximately 1/3, a lead dose of 1 mg/kg bw corresponds to approximately 10-20 mg lead /kg in fresh meat/offal fed to dogs[8]. However, the LOEL at 1 mg/kg bw is based on lead acetate, and the meat/offal is contaminated with metallic lead. The concentration of metallic lead in meat trimmings from the bullet channel is not known, but since the maximal concentration in Norwegian minced moose meat for human consumption was 110 mg/kg (Chapter 4.3.2, Table 8), it can be assumed that meat directly from the wound channel may contain much higher lead concentration and would lead to higher exposure[9]. Results from the Norwegian Game and Lead study show that trimmings from the wound channel are used as dog feed (Chapter 3.4.3, Table 5).

8.3 Risk characterisation - dogs

A lead dose around 1 mg lead acetate/kg bw/day can be considered as a Lowest Observed Effect Level (LOEL) in dogs for cardiovascular effects. This dose corresponds to approximately 10-20 mg lead acetate/kg fresh meat/offal per day for dogs (see above). High metallic lead concentrations are expected to be found in meat trimmed from the wound channel. However, the LOEL is based on lead acetate which probably has a higher uptake than the metallic bullet lead fragments, even though the fragments may be characterised as dust at microgram level. Even when a lower absorption of metallic lead than of lead acetate is taken into consideration, the risk for health effects in dogs fed repeatedly on trimmings from the wound channel or offal from cervids killed with lead containing ammunition can be considered as high.

On the other hand, the risk for adverse effects after a single exposure of lead contaminated meat must be considered as low, except if bullet fragments are retained in the gastrointestinal tract.

[8] Calculation of lead concentration in meat that will give exposure similar as the LOEL of 1 mg/kg/day: 1.5% dry matter/kg bw corresponds to 0.045 kg meat/kg bw. 1 mg lead/kg bw/day / 0.045 kg meat/kg bw/day = 22 mg lead/kg feed. 3% dry matter/kg bw corresponds to 0.09 kg meat/kg bw. 1mg lead/kg bw/day / 0.09 kg meat/kg bw/day = 11.1 mg lead/kg feed.

[9] Example: Lead from two bullets (9 g bullet, 66% loss = 6 g lead per bullet) in meat fed to a dog (20 kg) over 10 days: 6000 mg lead*2/20 kg/10 days = 60 mg/kg bw/day.

9 Conclusions

9.1 Humans

The present risk assessment is restricted to lead exposure from cervid meat consumption. However, lead exposure from cervid meat can be seen as an addition to the exposure from the environment, which includes food consumed in larger quantities, i.e. grains and grain products, milk and dairy products, non-alcoholic beverages and vegetables and vegetable products, that are found to be major dietary lead sources in the general population (EFSA, 2012).

The risk assessments of lead performed by EFSA (2010) and JECFA (2011) have been used as basis in the current assessment of lead exposure from cervid meat consumption. Neurodevelopment effects and increased blood pressure were critical effects identified by both EFSA and JECFA, and EFSA in addition pointed out chronic kidney disease as a sensitive endpoint. Reduction in Full Scale IQ in children was regarded as a marker for other neurodevelopmental effects observed at approximately the same blood lead concentration, and a $BMDL_{01}$ of 12 µg lead/L blood was identified by EFSA (2010) as a reference concentration for the risk of intellectual deficits in children. At the population level, a $BMDL_{01}$ of 36 µg lead/L blood was derived as a reference concentration for increased blood pressure, and the $BMDL_{10}$ for increased prevalence of chronic kidney disease was 15 µg lead/L blood.

The concentration of lead in blood has decreased dramatically over the last three decades. In Norwegian studies, the geometric mean or median concentrations of lead in blood were from 11 to 27 µg/L, which is in the same range as in studies in most European countries the last 10 years. Blood lead concentrations were lower in pregnant women (11 µg/L) than in other adult population groups in Norway. In the most recent population study, the Norwegian Game and Lead study performed in 2012, the median blood lead concentration was 17 µg/L. In this study, blood lead concentration was 12 µg/L in participants reporting no/seldom intake of cervid meat and 20 µg/L in those reporting monthly or weekly intake.

Ammunition commonly used for cervid hunting contains metallic lead. Metallic lead is less absorbed in the gastro-intestinal tract than ionic lead compounds. However, this assessment is based on lead concentrations in blood, thus uncertainty related to bioavailability of metallic lead is not applicable. Lead in blood is considered to be a good indicator of the concentration of lead in soft tissues, reflecting recent and, to some extent, past exposure.

Cervid hunting, ammunition, bullet fragmentation and tissue lead concentrations

- Approximately 3% of the Norwegian population participated in one or more hunting activities during the hunting season 2011/2012.
- Cervid hunters use a large variety of expanding bullet types (mandatory). The majority of the bullets are lead-based disruptively expanding or expanding (unbonded or bonded). Limited data indicate that less than 5% of the Norwegian hunters use alternative non-lead ammunition. Lead loss from bullets depends on the rifle calibre and bullet type used. A Scandinavian study with one commonly used cartridge and different bullet types indicated a mean lead loss of 0.7 to 3.4 grams per bullet. One to two shots are most often used to kill a moose.
- Expanding lead-containing bullets produce a cloud of lead particles around the wound channel. In radiography studies in roe deer, red deer and wild boar lead fragments from disruptively-expanding, expanding unbonded and some types of expanding bonded lead-containing bullets were on average found in a radius of 15 cm around the wound channel.

The maximal penetration length of visible fragments was in average 29 cm. VKM considers that the intra-species variation, being in the same range as the inter-species variation, justifies the combination of data from different studies and species. A study on more stable types of expanding bonded lead–containing bullets found fragments at distances less than 5 cm, which was comparable to fragments from non-lead disruptively expanding bullets and non-lead expanding-nose bullets measured in the same study.

- Removal of meat around the wound channel reduces the lead exposure from cervid meat consumption. Studies available indicate that lead concentrations above 0.1 mg/kg can be found at 25 cm distance from the wound channel in red deer and wild boar shot with various unknown ammunition. There are no available studies in moose. The data do not allow a firm conclusion on the amount of meat needed to be trimmed around the wound channel in order to remove lead originating from the ammunition
- A limited number of Norwegian hunting teams reported removal of meat most often in a radius of 10-20 cm from the wound channel, but 35% reported removal of less than 10 cm.
- Provided that farmed deer in Norway are harvested by headshot, it is not expected that lead is found in edible meat. However, if farmed deer are shot with lead-containing ammunition in the chest, it can be expected that the meat contain lead to similar extent as in wild cervids harvested in similar manner.

Lead exposure from game (including cervid) meat consumption

- Whereas most cervid meat contains low levels of lead, high concentrations have been found in some samples.
- In the national dietary survey, Nordkost 3, the average consumption of game meat was low, approximately 5-7 meals per year. In population studies addressing game meat consumption, the proportion of participants reporting game meat consumption at least once a month was up to 70%.
- No information on game meat consumption among Norwegian infants and children or blood lead levels has been found. However, it can be expected that children eat game meat equally often as the rest of the family.
- In the Norwegian Game and Lead study, frequent (monthly or more often) consumption of cervid meat, and in particular minced cervid meat, was significantly associated with increased blood lead concentrations. Whether the meat was purchased or self-obtained was also of influence.

Risk characterisation

VKM has compared concentrations of lead in blood among population groups in Norway with frequent and less frequent consumption of cervid meat with the reference concentrations (BMDLs) for increased risks for various health outcomes derived by EFSA, 2010.

- The available Norwegian data on blood lead concentrations in adults indicate a concern because the current concentrations are in the same range as those associated with a low increased risk of cardiovascular and/or kidney diseases at the population level.
- In the Norwegian Game and Lead study, frequent consumers (once a month or more) of cervid meat, and in particular minced cervid meat, were more likely to have higher blood lead concentrations and thus increased health risk than less frequent consumers. Lead

exposure was, however, not associated with cervid meat consumption among less frequent consumers.

- Hunting activity by itself was only modestly associated with increased blood lead concentrations among participants in the Norwegian Game and Lead study. However, self-assembling of ammunition markedly increased the blood lead concentration.
- For pregnant women a similar association between frequent game meat (including cervid meat) consumption and blood lead concentrations as in the rest of the population is expected. Therefore, frequent game meat consumption in women in child bearing age is of concern because it may increase the proportion of the population of children having an increased risk of neurodevelopmental impairments. It should be kept in mind that a small reduction in the intelligence of children will not be notable at the individual level.

9.2 Dogs

No data on blood lead concentrations in dogs being fed trimmings of cervids harvested with lead-based ammunition were available for the present risk assessment. In the scientific literature, gastrointestinal distress, neurological disorders, hepatic and kidney lesions as well as cardiovascular effects have been reported in lead exposed dogs.

- A daily dose around 1 mg lead acetate/kg bw is shown to increase blood pressure in dogs after a few days exposure, and considered as a Lowest Observed Effect Level (LOEL). This corresponds to a lead acetate concentration of 10-20 mg/kg fresh meat or offal. The uptake of lead from small metallic lead fragments in contaminated cervid products is probably lower than for lead acetate. However, high metallic lead concentrations are expected to be present in meat trimmed from the wound channel.
- Even when a lower absorption of metallic lead than of lead acetate is taken into consideration, the risk for increased blood pressure in dogs fed on trimmings from the wound channel from cervids harvested with lead-based ammunition can be considered as high, and thus of concern.
- Larger lead fragments most often pass through the gastrointestinal tract in dogs unretained. If such lead fragments or particles are retained in the gastrointestinal tract for prolonged periods of time, this can result in toxicity over time.
- The risk for adverse effects after a single exposure of metallic lead-contaminated meat must be considered as low, except if bullet fragments are retained in the gastrointestinal tract.

10 Answers to the terms of reference

TOR 1: "To assess the significance of lead exposure to the Norwegian population by consumption of cervid meat including meat from farmed red deer, which are shot with lead-based ammunition. VKM is also requested to identify any subpopulations with an increased risk."

VKM identified Norwegian studies suitable to assess the influence of game (including cervid) meat consumption on lead concentration in blood in the population including pregnant women and consumers of such meat. The results show that among frequent (monthly or more) consumers of cervid meat, and in particular consumers of minced meat from cervids, lead concentration in blood was higher than in the rest of the population. In addition, those who assemble lead-based ammunition themselves had higher levels of lead in blood. As lead exposure among Norwegians is in the range of, and partly exceeding, concentrations that are associated with low increased risk (BMDLs, explained in Chapter 2.5) of elevated blood pressure, kidney disease and neurodevelopmental effects in children, the additional contribution from cervid meat consumption among frequent consumers of such meat is of concern.

TOR 2: "If a health risk concerning lead exposure is identified, VKM is requested to describe the distribution of lead from ammunition in the carcass of a newly shot animal. Furthermore, if it is possible to purify the cervid meat from lead residues, VKM is requested to estimate the tissue area associated with the wound channel that has to be removed."

The extent of a bullet's fragmentation depends on the construction, weight, impact velocity, target resistance and the size of the hunted animal. Data on the weight losses and fragmentation distances of hunting bullets is available for roe deer, white-tailed deer, fallow deer, red deer, wild boar and chamois. Corresponding data for moose hunt are lacking.

Characteristically, the impact of a lead-containing bullet results in the formation of a cloud of lead particles ranging from the nanometre range up to 10 mm size around the wound channel. Disruptively-expanding bullets may retain only 10% (fragmenting type) or 20-80% (semi-fragmenting type) of their original weight. Expanding bullets may retain 60-100% of their original weight, and bonded types appear to be considerably more stable than unbonded types, although great variations exist.

Lead fragments from disruptively-expanding, expanding unbonded and some expanding bonded lead-containing bullets were found by radiography in average in a radius of 15 cm (range of averages 5.6-24 cm) around the wound channel. The maximal penetration length of visible fragments was in average 29 cm (range of averages 15-45 cm). Fragments of more stable types of expanding bonded lead–containing bullets were found at distances less than 5 cm, which was comparable to fragments from non-lead disruptively expanding bullets and non-lead expanding-nose bullets measured in the same study. VKM considers that the intra-species variation, being in the same range as the inter-species variation, justifies the combination of data from different studies and species.

Removal of meat around the wound channel reduces the lead exposure from cervid meat consumption. One study indicate that lead concentrations above 0.1 mg/kg can be found at 25 cm distance from the wound channel in red deer and wild boar shot with various unknown ammunition, but there are no available studies in moose. The data do not allow a firm conclusion on the amount of meat needed to be trimmed around the wound channel in order to remove lead originating from the ammunition

Farmed deer in Norway are harvested by a shot preferably in the head or, in special cases, in the chest if the range is too great for safely aiming at the head. One study in white-tailed deer did not detect lead by radiography in edible tissue in animals harvested by headshot. However, if farmed deer are shot with lead-containing ammunition in the chest, it can be expected that the meat contain lead to similar extent as wild cervids harvested in similar manner.

TOR 3: "To present, if any, other appropriate measures in addition to removing tissue in order to limit the content of lead residues from ammunition in game meat."

Sufficient removal of meat around the wound channel can reduce the lead exposure from cervid meat consumption, but the amount needed to be removed is not fully known. Other appropriate measures would be to use lead-based ammunition with low fragmentation such as certain types of bonded expanding bullets, or non-lead ammunition.

TOR 4: "To assess the significance of lead exposure to the health of pets, such as hunting dogs, when they are being fed with trimmings from the wound channel."

The risk for chronic health effects in dogs repeatedly fed on cervid meat or offal originating from trimmings from the wound channel after use of lead-based ammunition can be considered as high and of concern. On the other hand, the risk for adverse effects after a single exposure of lead contaminated meat is considered as low, except if bullet fragments are retained in the gastrointestinal tract.

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Appendix I

Game consumption and concentration of lead in blood - an exploration of the association in three Norwegian population groups

1. Background

Several publications and press releases the last couple of years have focused on the risk of higher body lead burden through regular consumption of game. High consumers of game, and hunters and hunter's associations in particular, have accordingly been discussing the issue and shown concern and worry. In the autumn of 2011 The Norwegian Food Safety Authority (Mattilsynet) commissioned the Norwegian Scientific Committee for Food Safety (VKM) to perform a risk assessment of lead exposure in relation to consumption of game meat. As few data exist on consumption of game in the Norwegian population, and even less data exist which enables investigation of game consumption in relation to blood lead levels, VKM asked the Norwegian Institute of Public Health to compile published and un-published data from relevant studies performed at the Institute the last ten years. This document was prepared in response to the request. The aim is to provide background information for VKM to be used in their risk assessment.

Norwegian Institute of Public Health 2012
Division of Environmental Medicine
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2. Aim

The aim is to analyse the association between game consumption and concentration of lead in blood in three different Norwegian population groups.

The specific study questions in each population group are:

1) What is the frequency of game consumption (moose and deer (red and/or roe), reindeer, grouse and offal from game, and what is the consumption of game (g/week) divided by sex and age groups?

2) What is the concentration of lead in blood when considering different socioeconomic factors?

3) What is the concentration of lead in blood within different consumption groups of game?

4) Do the concentrations of lead in blood among men and women reflect the consumption of game when adjusted for relevant confounders (age, smoking etc)?

5) Does the concentration of lead in blood in the three population groups exceed official guidelines?

3. Study populations and methods

This study examines the associations between consumption of game and concentration of lead in blood in three population groups: The Fish and Game Study, The Lake Mjøsa Study and the Norwegian Mother and Child Validation Study (MoBa Val).

3.1 The Norwegian Fish and Game Study

The Norwegian Fish and Game Study (NFG Study) is a three-stage survey (Part A, B and C). The aim of the study was to obtain information about the levels of dietary intake of environmental contaminants in the Norwegian population. Biological material (blood and urine) was collected in Part C of the NFG study, and thus only subjects in Part C is included for investigation of game consumption in relation to blood lead concentrations. A brief description of Parts A and B of the study is also presented here as background for Part C.

Part A of the NFG study was a national survey of the consumption frequencies, relating to specific foods, considered to contain potentially high levels of environmental contaminants. Ten thousand people were invited to participate, and the response rate was 60%. One of the main findings of Part A was that regional differences is the main explanation for differences in the consumption of fish and game [1]. The study also confirmed that the consumption of food with potentially high levels of contaminants was skewed in the population, and that parts of the Norwegian population might thus be highly exposed to environmental contaminants. The consumption of game in Part A of the study is described in Table 1.

Part B was a regional survey in 27 selected inland and coastal municipalities with good access to hunting and fishing locations. The selection of municipalities (out of 430) was based on hunting statistics and contact with municipal food control agencies in Norway [2]. Due to the ample supply of seafood and/or game in these municipalities, it was expected that consumption of relevant foods would be higher than in the majority of the population. In the year 2000, 10 000 individuals aged 18–79 living in the 27 municipalities were selected by random draw from the Norwegian Population Registry and invited to participate in the study. The response rate was 55%. The questionnaire used in Part B was more detailed as regards both frequencies and types of foods than the one used in Part A.

The participants answered a simple questionnaire that covered the consumption of different freshwater and saltwater fish species, fish liver, crustaceans, seagull eggs and game. None of the participants were living in areas of known contamination by persistent organic pollutants or heavy metals greater than what could be considered a background level. One of the main findings from Part B, which supported the finding from Part A, was that regional differences explained much of the variation observed for consumption of seafood and game. On basis of data from part B it was possible to identify individuals in the population with high intakes of foods with potentially high levels of heavy metals and persistent organic pollutants. The consumption of game in Part B of the study is described in Table 1. The information for Part A and Part B are adapted from Bergsten et al. (2005) [2].

Table 1. Consumption (%) in the nation wide Part A (N=6015) and Part B including 27 municipalities (n=2681 coastal n=2818 inland) of the Fish and Game Study[2]. Part C (n=75 representative group n=109 high consumers).

	Part A	Part B		Part C	
		Coast	Inland	Representative group	High consumers
Game [a]					
Never	28.4	31.4	12.2	32	30
A few times a year	57.4	55.9	51.7		
1-3 times a month	10.4	9.7	21.1	53	44
Once a week or more	3.7	2.9	15.0	15	28
Liver of game				[b]	[c]
Never	94.2	94.3	91.4		
A few times a year	5.4	5.4	7.9		
1-3 times a month	0.4	0.3	0.5		
Once a week or more	0.1	0	0.1		
Kidney of game					
Never	98.6	99.0	98.2		
A few times a year	1.2	0.9	1.7		
1-3 times a month	0.1	0	0		
Once a week or more	0	0	0		
Heart of game					
Never	93.6	92.7	82.1		
A few times a year	6.2	7.0	17.1		
1-3 times a month	0.2	0.2	0.7		
Once a week or more	0	0	0.1		

[a]Meat from moose and/or deer and reindeer
[b]No participant in the representative group reported consumption of offal from game;
[c]Nine participants report intake of offal from game 1-3 times per month in the high consumers group (5%).

Part C was conducted in 2003, and investigated in-depth a sub-population derived from Part B. The general aim of Part C was to carry out exposure assessments on people who frequently consume foods with a potential high level of environmental contaminants. The exposure assessments are based on self-reported habitual food consumption, an extensive database of contaminant concentrations measured in Norwegian foods, and data obtained by analyses of a large number of substances, compounds and relevant metabolites in the blood and urine samples. The data collected in Part C has so far been used to investigate intake distributions and whether it was possible to establish dose-response relationships between food consumption and blood concentrations of mercury, cadmium, brominated flame retardants, polychlorinated biphenyls and dioxins [3-6]. The concentrations of several other compounds and contaminants in blood were measured, among them lead.

A two-stage inclusion strategy was used in Part C to recruit participants. Rough estimates of the individual intakes of these contaminants by the Part B participants were calculated on the basis of the concentrations of PCBs, dioxins, mercury and cadmium in the relevant foods. Based on estimated high exposures, 434 subjects were invited to participate in Part C as consumers with high intake. A reference group of 267 additional subjects (the representative consumers) was randomly selected from the remaining population of part B and invited to participate. Of the 701 subjects invited in total, 211 (30%) gave informed consent, and 195 (28%) completed data collection. The study group thus consisted of 78 representative-consumer participants and 117 high-consumption participants. Although the representative consumers (n=78) were drawn at random, they constituted a rather low percentage of the total population invited to participate in the study. However, they were comparable to the participants in Part B of the study as regards location (coast/inland), age, gender, body weight (bw), body mass index (BMI), smoking habits, and total fish consumption. Accordingly, we have taken the liberty of calling them representative consumers, although the group is small and may be skewed when it comes to other conditions that were not addressed.

The data collection was carried out in the spring of 2003. After invitation letters were sent out, the participants submitted contact information for their primary physician together with their informed consent. The primary physician was then sent information about processing and postal arrangements, vacutainers for blood sampling, tubes for transportation of blood, serum and urine specimens, and envelopes for returning the material. The participants received a package containing a detailed Food Frequency Questionnaire (FFQ), a one-page questionnaire covering demographic data (age, smoking, etc.), and a urine specimen kit. The FFQ and the demographic questionnaire were completed at home and submitted by means of a pre-paid envelope. The participants themselves made appointments with their physicians, who drew the blood samples, redistributed blood and urine samples into the transportation tubes, and posted these. The biological material was processed, redistributed and frozen within two hours of arrival by mail. The median transit time at ambient temperature between blood collection and storage in the freezer was one day (mean 1.6 days and 75 percentile 2 days, range 1–11 days). The study protocol was approved by the Regional Committee for Medical Research Ethics and the Norwegian Data Inspectorate (id: S-02138).

3.2 The Lake Mjøsa Study

Data collection was carried out from October 2004 to May 2005 [7,8]. The study population comprised frequent consumers of inland fish from Lake Mjøsa. This is a lake contaminated with brominated flame retardants (BFR) and polychlorinated biphenyls (PCBs). The participants were recruited among 122 local hobby fishermen and women, of whom 74 responded positively to the invitation (61%). Of these, 65 persons (89%) provided blood samples, and filled in detailed questionnaires on dietary habits, and a special questionnaire on intake of fish from the lake as well as a questionnaire on personal background data. The participants scheduled an appointment with their family doctor for blood sampling. The family doctor was provided sampling equipment from the Norwegian Institute of Public Health and sent the samples back by surface mail. Samples were stored at –20°C until analysis. Informed consent was obtained from all the participants and the project was approved by the Regional Committee for Medical Research Ethics (id: S-04142).

3.3. The Norwegian Mother and Child (MoBa) Validation Study

Data collection was carried out from January 2003 to February 2004 [7,8]. This study was a subproject in the Norwegian Mother and Child Study (MoBa), a large prospective pregnancy population group initiated by the Norwegian Institute of Public Health [9]. Women participating in MoBa were invited to participate in the study for validation of a new food frequency questionnaire[10]. Healthy pregnant women were recruited to the validation study when they came for routine ultrasound examination at Bærum Hospital (Norway) in 17^{th}-18^{th} weeks of gestation. Exclusion criteria were hyperemesis and anorexia. Before inclusion the subjects had to have completed the MoBa Food Frequency Questionnaire (FFQ) [10-12].

The women participating in the validation study were asked to keep a 4-day weighed food diary, to wear a motion sensor for the same 4 days, and to provide one 24-hour urine collection and a blood sample. They were given detailed information and materials for data collection. The weight, height and age were recorded. Data pertaining to parity, marital status, smoking, and education were collected from a separate questionnaire in which MoBa participants answer questions related to lifestyle, health and demographic factors.

Of the 120 women included in the study, one dropped out due to illness and 119 completed the food diary and the 24-hour urine collection, while 112 completed the motion sensor assessment according to the instructions. The average time interval between completion of the FFQ and participation in the study was 24 days (standard deviation (SD) ± 12 days). In this study we only include dietary information from the FFQ. The FFQ was mailed to all participants around the 15th week and completed around 16-18th week of gestation. Non-fasting blood samples were drawn at the time of recruitment, then separated into aliquots of serum and plasma within two hours of venipuncture and stored at –70 °C until analysis. Informed written consent was obtained from all participants and the study protocol was approved by the Regional Ethics Committee of Southern Norway.

Validation study participants were not representative of all MoBa participants, and included a higher proportion of women in the highest age groups, women with high education, non smokers and lean subjects [10]. However, representativity was not considered important for evaluating the associations between external and internal exposures to foods, nutrients and compounds.

3.5 Dietary exposure assessment

The same FFQ was used in all three population groups [3,7,10,11,13]. It was a 12-page semi-quantitative questionnaire containing questions about 233 food items or meals adapted to Norwegian food traditions, including six questions on consumption of game (Question numbers 14;19-22, 25, 32). The frequency of consumption was reported by selecting one out of eight to ten frequencies ranging from never to several times monthly, weekly or daily. Food frequencies were converted into consumption (g/day) by multiplying by standard, gender-specific portion sizes. Questions about the use of dietary supplements were also included. Food and beverages consumption (g/day) were aggregated into 41 non-overlapping food groups, based on structure, nutrient profile or culinary usage, of these four pertained to game: a) moose and deer, b) reindeer, c) grouse and d) offal from game.

The FFQ was developed for the Norwegian Mother and Child Cohort Study (MoBa) and was thoroughly validated [10-12] The validation study demonstrated that, relative to a dietary reference method and several biological markers, the MoBa FFQ produces a realistic estimate of habitual intake, and is a valid tool for ranking pregnant women according to high and low intakes of energy, nutrients and foods.

The FFQ covered consumption over the last 12 months in the Fish and Game Study and in the Lake Mjøsa Study, while in the MoBa Val Study women were asked about their diet since the beginning of the pregnancy, approximating 4-5 months of recall.

The questionnaires were checked for completeness and were optically read and FoodCalc[14] was used for estimating intake of nutrients (and contaminants). The Norwegian food composition table[15] was used for calculating nutrients from foods. For the calculation of nutrients from dietary supplements, a database containing details of the declared content of supplements was used. Participants who reported food intakes that resulted in implausible energy intakes (less than 4.5 MJ/day or more than 20 MJ/day) were excluded from analysis. Currently, no database for content of lead in Norwegian food is available.

3.6 Chemical analyses of lead in blood

Blood and urine concentrations of Pb were determined by inductively coupled plasma-sector field mass spectrometry using an Element 2 mass spectrometer (Thermo Electron, Bremen, Germany) following previously described method [16]. In brief, 1,5 mL of 65% ultrapure nitric acid was added to 1 mL of whole blood in a polypropylene digestion tube and the tube was heated to 95 ^{0}C for 1 hour. After cooling the digested blood sample was added an internal standard solution containing ^{206,207,208}Pb before dilution to volume (10 mL). The instrument was calibrated with whole blood matrix matched standard solutions and the accuracy was determined by use of Seronorm Trace Elements human whole blood quality control samples (Sero Ltd., Asker, Norway). The measured values were on average within $\pm$5 % of the recommended values supported by the producer. The within assay precision was typically 3-10 %.

3.7 Statistical analyses

Concentration of lead in blood was not normally distributed in any of the population groups (see Figure 2A-C) and variables for all the dietary intakes of game were skewed. Therefore the median as well as 5th and 95th percentiles are presented throughout, using geometric mean and standard deviation when appropriate. Outlying observations were evaluated. No participants were excluded from the analysis on the basis on outlying observations, but 10 participants were excluded from the Fish and Game Study on basis of unlikely energy intakes (<4.5MJ or > 20MJ). Furthermore, two participants were excluded due to missing values for lead in blood, one in the Fish and Game Study and one in the Lake Mjøsa Study. In the Fish and Game Study, the reference group and participants with presumed high intake of contaminants were combined and analysed as one group.

Differences between population sub-groups were tested two-sided using non-parametric tests: Mann-Whitney/Kruskal-Wallis and the Chi-square test for nominal/ordinal variables. We used multiple linear regression to identify associations between consumption of game and concentration of lead in blood. All models were run twice including concentration of lead in blood as continuous and as log variable. Furthermore, consumption of game as g/day was run as such as well and divided into five groups. In the regression models, we adjusted for the socio-democratic factors, total energy intake and intakes of food items and nutrients known from previous studies to be associated with the concentration of metals. Finally, we also included and evaluated the blood concentrations of other metals among potential covariates. As there was a statistically significant interaction between gender and consumption of game in relation to concentration of lead in blood, all models were run for men and women separately.

The assumptions of linearity and homoscedacity for all models were graphically tested by plotting predicted values against standardised residuals. We also applied Cook's distance and delta-beta plots to check the influence of outliers on the models. Furthermore to check for multicollinearity we used variance inflation factor using four as cut off. No co-linearity was detected in the models. Statistical significance was set at 5% (two-tailed) for the variables of interest. The statistical analyses were carried out using SPSS (version 17.0), SPSS Inc. Chicago, IL, USA.

4. Results

4.1 Characteristics of the study populations

An overview of socio-demographic factors, inclusion period and the dietary assessment method used in all three population groups is found in Table 2. Median (range) age in the tree population groups was 55 (21-80) years, 59 (31-88) years and 31 (23-44) years in the Fish and Game Study, the Lake Mjøsa Study and MoBa Val, respectively. The MoBa Val Study only included women while the other two population groups included both men and women.

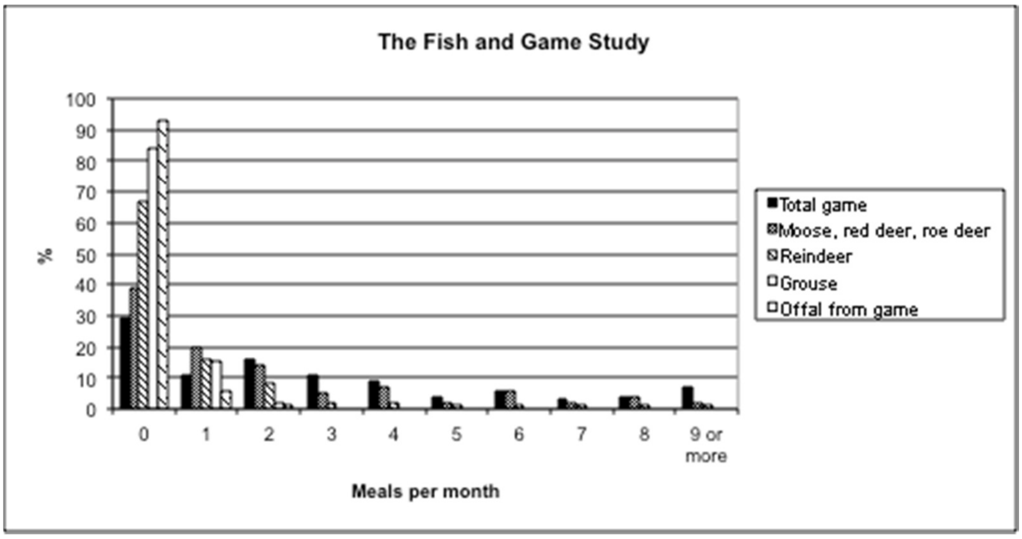
Table 2. Description of three population groups

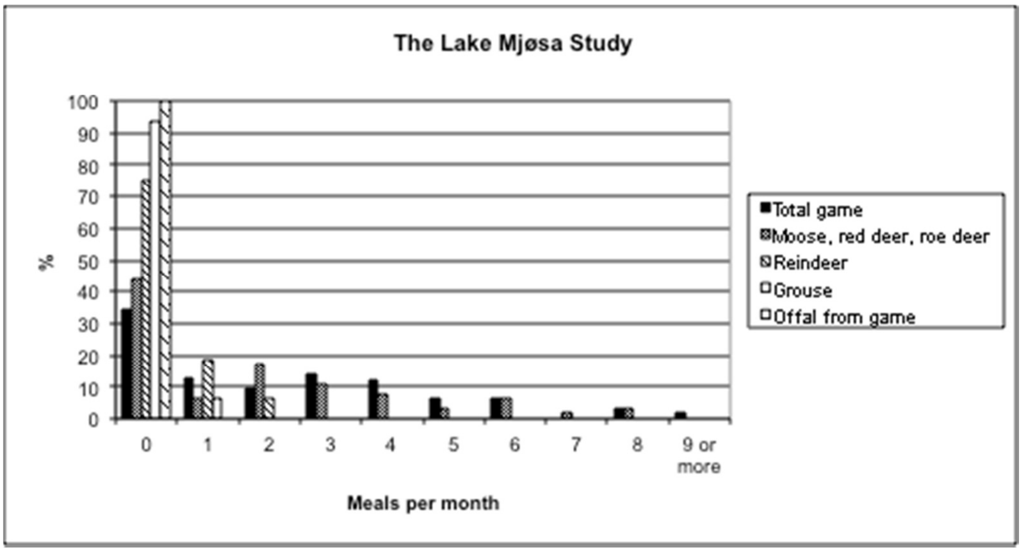
	Fish and Game n=184		**Lake Mjøsa n=64**		**MoBa Val n=119**	
	n	%	n	%	n	%
Sex						
Women	100	(54)	24	(38)	119	(100)
Men	84	(46)	40	(62)		
Age, years						
≤ 25y	6	(3)	1	(1)	6	(5)
> 25-35y	19	(10)	2	(3)	94	(79)
> 35-45y	26	(14)	10	(16)	19	(16)
> 45-55y	41	(22)	11	(17)	0	
> 55-65y	49	(27)	23	(36)	0	
> 65y	43	(24)	17	(27)	0	
BMI, kg/m^2						
≤ 25	103	(56)	22	(34)	94[a]	(79)
> 25-30	62	(34)	29	(45)	19	(16)
> 30	19	(10)	13	(20)	6	(5)
Education,						
Basic studies	52	(28)	21	(33)	0	
High school	62	(34)	24	(38)	78	(66)
University or college	66	(36)	18	(28)	41	(34)
Not known	4	(2)	1	(1)	0	
Smoking						
Non-smoker	72	(39)	38	(59)	95[a]	(80)
Smoked earlier in life	65	(35)	14	(23)		
Occasional smoker	7	(4)			13	(11)
Smokes daily	38	(21)	12	(18)	11	(9)
Not known	2	(1)				
Dietary assessment[b]	FFQ		FFQ		FFQ	
Period covered by the FFQ	12 months		12 months		3-4 months	
Inclusion period	Feb-May 2003		Oct 2004-May 2005		Jan 2003-Feb 2004	

[a] Pre-pregnant BMI and smoking status
[b]The same Food Frequency Questionnaire (FFQ) used in all studies

4.2 Game meat consumption

Frequency of game consumption in each of the three population groups is found in Figure 1. The Frequency of consumption was highest in the Fish and Game Study, with 6% consuming a game meal equal to or more often than nine times per month, or up to 17 times per month. In the Fish and Game Study, nine participants reported eating offal from game, while no participants reported such consumption in the two other population groups. Frequency of game consumption was lowest among the pregnant women in the MoBa Val Study (42%), compared to 65% in the Lake Mjøsa Study and 70% in the Fish and Game Study.





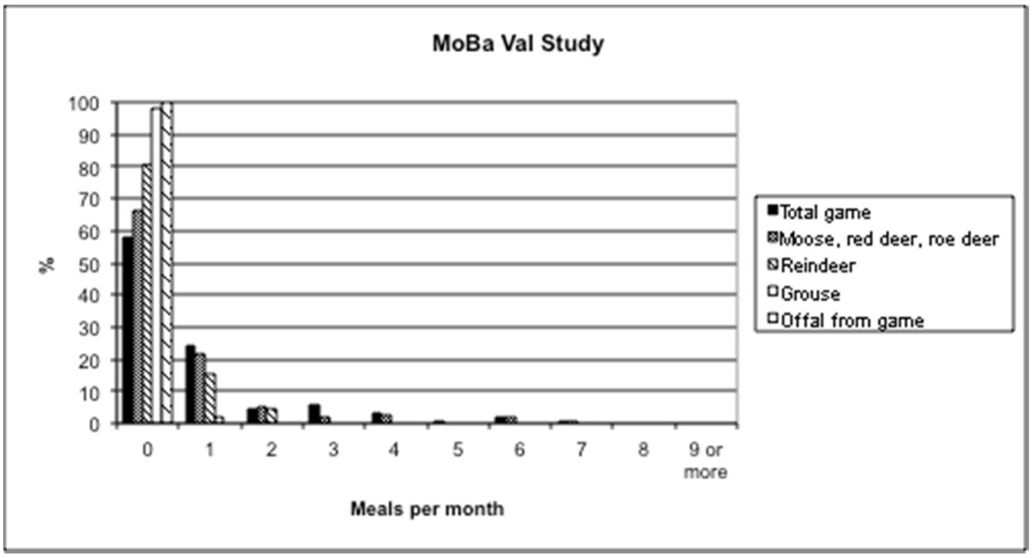


Figure 1. Monthly frequency of game meat consumption in the three population groups

Further division of game consumption, now in g/day, by sex and age can be found in Table 3 Meat from moose and/or deer was consumed in larger amounts than reindeer in all population groups, while intake of grouse was even lower. Consumption of game among consumers only is found in Table 4.

Table 3. Consumption of game by age[a] and gender (g/day) 25th - 50th (bold) - 75th percentile and maximum

		Fish and Game Study				Lake Mjøsa				MoBa Val	
		n	Men	n	Women	n	Men	n	Women	n	
Total game[b]											
	>25-35y	10	2-**6**-11-21	15	0-**4**-11-14					100	0-0-3-15
	>35-45y	8	0-**0**-3 -7	18	0-**3**-6-31	7	0-**6**-10-10	6	3-**5**-6-6	19	0-0-2-17
	>45-55y	22	2-**5**-9-27	19	0-**4**-8-26	8	0-**2**-7-9	3	9-**20**-29-29		
	>55-65y	20	1-**6**-13-28	29	0-**1**-6-16	12	2-**9**-15-24	11	0-**9**-14-20		
	>65y	24	0-**3**-7-51	19	0-**1**-5-23	13	0-**0**-2-27	4	0-**0**-3-7		
Moose and/or deer											
	>25-35y	10	2-**3**-6-14	15	0-**4**-10-14						
	>35-45y	8	0-**0**- 1-4	18	0-**2**-6-30	7	0-5-7-10	6	0-3-6-6	100	0-0-1-15
	>45-55y	22	0-**4**-9-23	19	0-**2**-8-18	8	0-2-7-9	3	6-20-28-28	19	0-0-2-17
	>55-65y	20	<1-**3**-13-29	29	0-**0**-3-11	12	0-7-23-24	11	0-6-18-20		
	>65y	24	0-**3**-7-50	19	0-**0**-4-23	13	0-0-9-27	4	0-0-7-7		
Reindeer											
	>25-35y	10	<1-**1**-2-5	15	0-**0**-0-2					100	0-0-0-3
	>35-45y	8	0-**0**-1-4	18	0-**0**-<1-2	7	0-0-2-4	6	0-0-2-4	19	0-0-0-4
	>45-55y	22	0-**0**-0-7	19	0-**0**-<1-3	8	0-0-0-0	3	0-0-0-0		
	>55-65y	20	0-**0**-<1-5	29	0-**0**-<1-10	12	0-0-2-4	11	0-0-2-4		
	>65y	24	0-**0**-0-2	19	0-**0**-<1-9	13	0-0-2-8	4	0-0-0-0		
Grouse											
	>25-35y	10	0-**0**-2-4	15	0-**0**-0-2					100	0-0-0-1
	>35-45y	8	0-**0**-0-3	18	0-**0**-0-1	7	0-0-0-0	6	0-0-0-1	19	0-0-0-2
	>45-55y	22	0-**0**-0-3	19	0-**0**-0-3	8	0-0-0-0	3	0-1-3-3		
	>55-65y	20	0-**0**-0-3	29	0-**0**-0-3	12	0-0-0-0	11	0-0-0-0		
	>65y	24	0-**0**-0-16	19	0-**0**-0-1	13	0-0-0-0	4	0-0-0-0		
Offal from game[b]											
	>25-35y	10	0-**0**-0-3	15	0-**0**-0-0					100	0
	>35-45y	8	0-**0**-0-0	18	0-**0**-0-0	7	0	6	0	19	0
	>45-55y	22	0-**0**-0-10	19	0-**0**-0-6	8	0	3	0		
	>55-65y	20	0-**0**-0-0	29	0-**0**-0-6	12	0	11	0		
	>65y	24	0-**0**-0-6	19	0-**0**-0-0	13	0	4	0		

[a] Only 6 ≤ 25y, included in the age group >35-45y (Fish and Game); Only 3 ≤ 35y, included in the age group >35-45y (Lake Mjøsa); Only 6 ≤ 25y and are included in the group >25-35y (MoBa Val), [b]Game is moose, roe deer, red deer, reindeer or grouse.

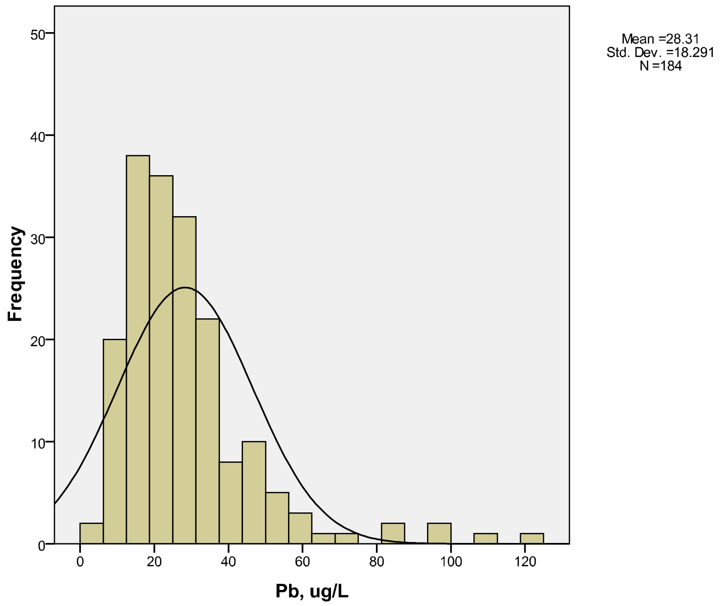
Table 4. Consumption of game (g/day) as median, 5th, 25th, 75th and 95th percentile, game consumers only, men and women, the Fish and Game Study, the Lake Mjøsa Study and the MoBa Val Study

	n	% consumers	5^{th} or min if n<20	25^{th}	50^{th}	75^{th}	95^{th} or max if n<20
Fish and Game Study							
Men							
Total game	62	100	2	3	6	11	25
Moose and/or deer	55	89	1	3	5	11	23
Reindeer	28	45	<1	1	2	3	6
Grouse	14	23	1	2	3	3	16
Offal from game	6	10	1	1	2	6	10
Women							
Total game	65	100	1	3	5	11	21
Moose and/or deer	56	86	1	2	5	11	21
Reindeer	31	48	<1	<1	1	2	9
Grouse	15	23	1	1	2	2	3
Offal from game	4	6		3	5		6
Lake Mjøsa Study							
Men							
Total game	25	100	2	5	7	11	24
Moose and/or deer	20	80	3	6	7	10	26
Reindeer	12	48	<1	1	3	4	8
Grouse	0	0	0	0	0	0	0
Offal from game	0	0	0	0	0	0	0
Women							
Total game	17	100	2	6	9	14	29
Moose and/or deer	16	94	2	5	6	16	28
Reindeer	4	24	-	2	3	4	-
Grouse	3	18	-	1	1	3	-
Offal from game	0	0	0	0	0	0	0
MoBa Val Study							
Total game	51	100	<1	2	3	4	10
Moose and/or deer	40	78	1	2	2	3	12
Reindeer	23	45	0	0	2	3	3
Grouse	2	4	-	1	1	2	-
Offal from game	0	0	0	0	0	0	0

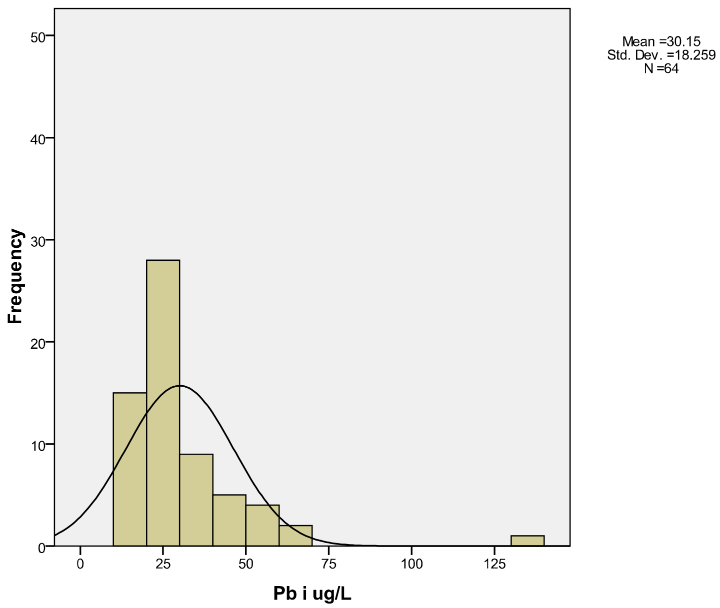
4.3 Blood lead concentrations

The geometric mean of lead in blood in the tree population groups was 24.1, 26.8 and 11.7 μg/L, for the Fish and Game Study, Lake Mjøsa Study and the MoBa Validation Study, respectively. Concentration of lead in blood, presented as median, 5th and 95th percentiles, by sociodemographic factors is found inTable 5. In both the Fish and Game Study and the Lake Mjøsa Study men had significantly higher blood lead concentrations than women. Higher concentrations were also indicated among previous and present smokers than in non-smokers in both the Fish and Game Study and the MoBa Val Study. Histograms showing blood lead concentrations revealed skewed distribution are presented in Figure 2 (A-C).

A. Fish and Game Study (n=184)



B. Lake Mjøsa Study (n=64)



C. MoBa Validation Study (n=119)

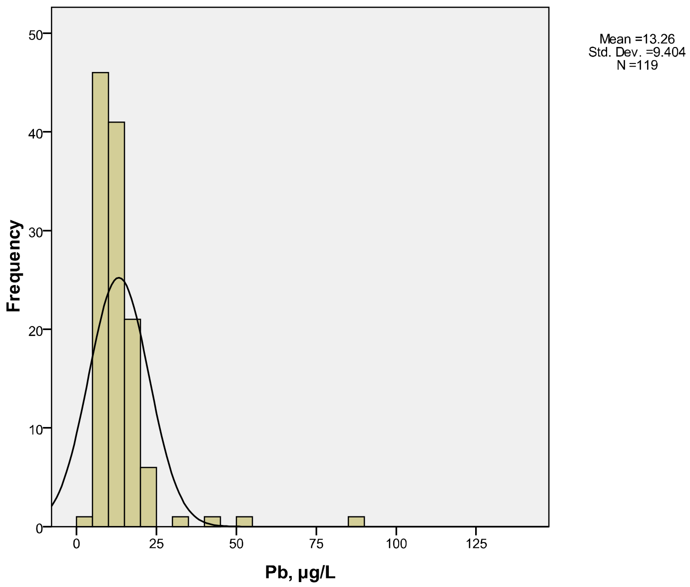


Figure 2. Histograms for concentration of Pb in blood in the three population groups

4.4 Associations between game meat consumption and blood lead concentrations

Concentration of lead in blood by frequency of game consumption, divided in three groups by sex, is given in Table 6 and Table 7. Non-consumers are compared with participants consuming game one to three times per month as well as to those consuming game once per week or more often. The concentration of lead in blood increased with increasing frequency of total game consumption as well as with consumption of moose and/or deer in men in the Fish and Game Study, but not in women or the other two population groups. Blood lead concentrations were higher in game consumers than in non-consumers (median 28.5 µg/L versus 24.9 in men and 22.7 µg/L versus 16.6 µg/L in women) but these differences were not statistically significant, although indicated for women (p=0.080). Only ten participants reported consuming offal from game, six men and four women. However, the concentration of lead in blood was higher in the consumers of offal from game (median 32.6 µg/L), than in non consumers of game (n=59, median 23.0 µg/L) (p=0.053).

Consumption of game meat and concentration of lead in blood among men and women in the Fish and Game Study is shown in Figure 3, Figure 4, Figure 5 and Figure 6. The regression analysis, stratified by gender (due to interaction), showed that high consumption of game meat was associated with higher lead concentration among men only in the Fish and Game Study. Significant differences in blood lead were seen only for high moose and/or deer consumption (more than weekly) and in men only (Table 8), not in women (Table 9) or in the other population groups (Table 10, Table 11, Table 12). Consumption of game up to 4-5 times per week were reported by one participant in the Fish and Game Study which also had the highest concentration of lead in blood (108 µg/L).

No associations between consumption of game and concentration of lead in blood were found in the Lake Mjøsa or the MoBa Val Study, although the different covariates contributed to explain the variation in blood lead in the models. When joining the participants in Lake Mjøsa and the Fish and Game Studys (Figure 7) the crude association between intake of game and lead in blood was still significant for men (Beta 0.5; 95% CI: 0.1, 1.0).

Table 5. Uadjusted concentration of lead in blood (µg/L) by sociodemographic factors

	Fish and Game				Lake Mjøsa				MoBa Val			
	N	**median**	**5th**	**95th**	**N**	**median**	**5th**	**95th**	**N**	**median**	**5th**	**95th**
Sex												
Female	100	21.3	7.8	59.0	24	22.3	11.5	52.9	119	11.1	6.4	24.4
Male	84	28.3	14.0	66.5	40	28.7	14.4	65.1				
P-value		***<0.001***				***0.004***						
Age, years												
≥ 25y	[a]				[b]				[c]			
> 25-35y	25	18.2	7.7	52.9	[b]				55	10.8	6.3	23.9
> 35-45y	26	26.3	10.1	61.0	13	25.4	13.8	134.7	64	13.5	6.6	87.1
>45-55y	41	24.6	12.8	66.5	11	22.4	16.1	42.0				
>55-65y	49	26.7	9.0	82.3	23	24.4	19.1	53.1				
>65y	43	23.3	9.2	50.5	17	27.9	10.9	65.3				
P-value		***0.18***				***0.31***				***0.034***		
BMI, kg/m^2												
Normal weight ≤ 25	103	23.1	8.0	56.0	22	25.5	15.7	56.3	94	11.8	6.7	24.8
Overweight 25.1-30	62	24.5	12.0	66.5	29	24.4	14.6	53.1	19	9.9	6.4	16.8
Obese > 30	19	28.9	8.0	82.3	13	27.0	10.9	134.7	6	10.0	5.8	16.8
P-value		***0.25***				***0.90***				***0.095***		
Education												
Basic studies	52	24.1	10.3	82.3	21	24.4	13.3	49.5				
High school	62	28.0	10.1	56.0	24	25.0	14.6	62.0	20	11.2	6.9	29.2
University or college	66	21.5	8.0	74.0	18	26.3	13.8	134.7	99	11.0	6.4	24.4
P-value		***0.082***				***0.88***				***0.85***		
Smoking												
Non-smokers	72	21.0	7.8	74.0	23	27.6	14.6	53.1	95	10.8	6.4	21.5
Has smoked previously	65	26.7	9.8	58.6	15	25.5	19.1	49.5				
Occasional smokers	7	21.3	6.8	81.3					13	15.6	6.2	22.6
Daily smokers	38	27.7	13.8	57.0	26	24.6	13.8	65.3	11	13.2	7.7	87.7[d]
P-value		***0.021***				***0.83***				***0.028***		
Living condition												
Inland	99	24.8	7.7	82.3								
Coast	85	23.7	10.1	52.4								
P-value		***0.46***										

[a] Only 6 ≤ 25y, included in the age group >35-45y, [b] Only 3 ≤ 35y, included in the age group >35-45y, [c] Only 6 ≤ 25y and are included in the group >25-35y, [d] Few participants means that the 5th and 95th percentile becomes end or range

Table 6. Unadjusted concentration of lead in blood (µg/L) divided by frequency of game consumption – men

	Fish and Game				Lake Mjøsa			
	N	**median**	**5th**	**95th**	**N**	**median**	**5th**	**95th**
Consumption of total game[b]								
Non consumers	21	24.9	16.2	58.4	15	27.1	13.5	63.8
1-3 times per month	35	25.5	11.0	55.2	16	27.4	11.5	48.1
Once per week or more	28	32.7	10.8	103	9	24.4	15.7	135
P-value		***0.057***				***0.85***		
Consumption of moose and/or deer [a]								
Non consumers	28	25.3	12.7	63.0	20	27.1	13.8	60.8
1-3 times per month	37	27.1	11.7	50.6	14	26.4	11.3	123
Once per week or more	19	32.7	9.8	108.6	6	23.6	15.7	62.0
P-value		***0.035***				***0.83***		
Consumption of offal from game[b]								
Non consumers of game	22	25.3	16.2	58.2				
Consumers	6	54.3	19.3	109		-		
P-value		***0.039***						

[a]Generally hunted using lead shots. [b]Game is moose, roe deer, red deer, reindeer or grouse.

Table 7. Unadjusted concentration of lead in blood (µg/L) divided by frequency of game consumption – women

	Fish and Game				Lake Mjøsa				MoBa Val			
	N	**median**	**5th**	**95th**	**N**	**median**	**min**	**95th**	**N**	**median**	**5th**	**95th**
Consumption of total game [a]												
Non consumers	33	16.6	5.0	67.4	7	21.9	13.3	53.1	68	11.8	6.7	23.0
1-3 times per month	35	23.3	7.7	70.4	7	18.6	10.9	28.1	43	10.8	7.0	40.0
Once per week or more	32	21.3	8.7	86.2	9	23.4	16.1	27.0	8	8.7	5.7	29.4
P-value		***0.26***				***0.74***				***0.49***		
Consumption of moose and/or deer [b]												
Non consumers	44	17.8	5.8	77.0	8	23.2	13.3	53.1	79	11.5	6.6	22.6
1-3 times per month	33	21.3	7.6	41.7	8	21.5	10.9	28.1	26	11.0	6.8	44.8
Once per week or more	23	24.5	10.7	81.3	7	22.4	16.1	27.0	14	9.8	5.8	24.4
P-value		***0.41***				***0.84***				***0.56***		
Consumption of offal from game[a]												
Non consumers of game	35	16.6	5.2	65.2								
Consumers	4	29.6	24.5	95.3		-				-		
P-value		***0.068***										

[a] Game is moose, roe deer, red deer, reindeer or grouse. [b]Generally hunted using lead shots.

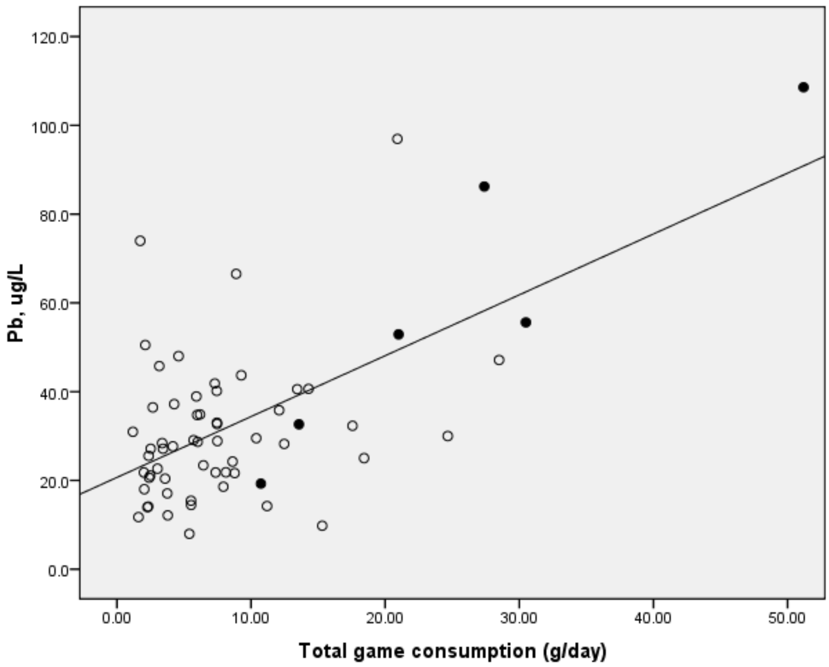


Figure 3. Fish and Game Study – men, consumption of game (g/day) and unadjusted concentration of lead in blood (µg/L). Consumers of offal from game are marked with a black dot.

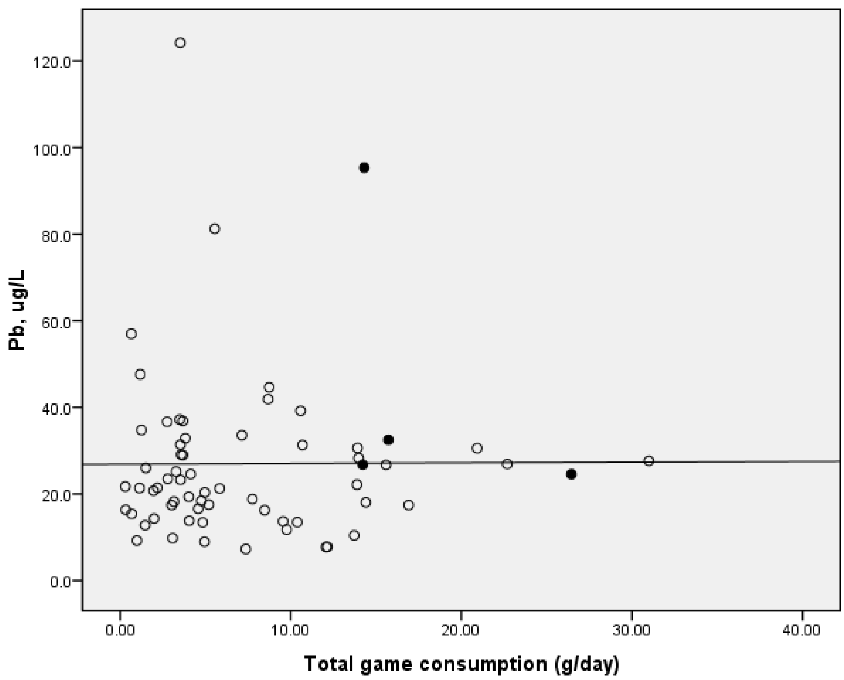


Figure 4. Fish and Game Study – women, consumption of game (g/day) and unadjusted concentration of lead in blood (µg/L). Consumers of offal from game are marked with a black dot.

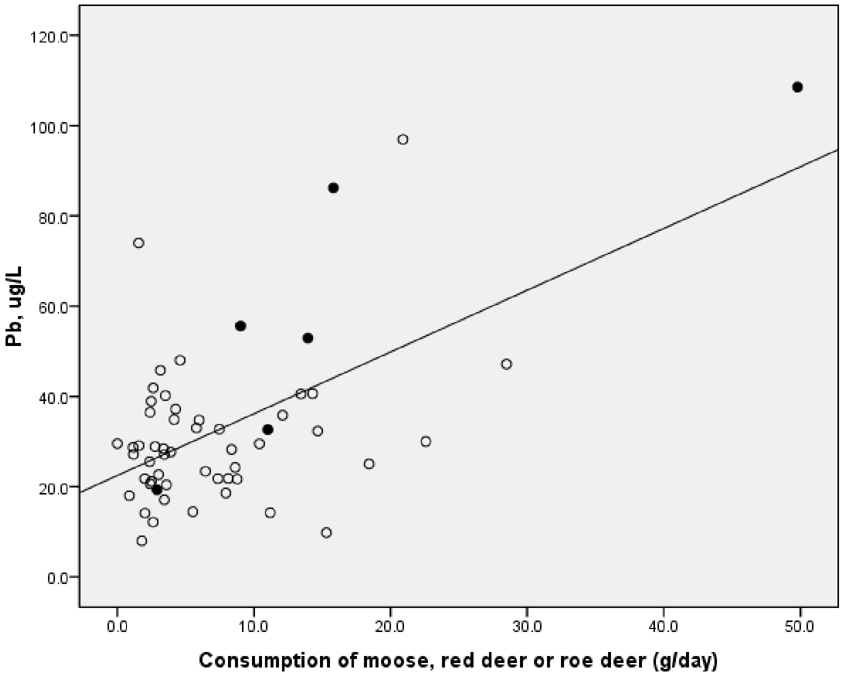


Figure 5. Fish and Game Study – men, consumption of moose and/or red deer or roe deer (g/day) and unadjusted concentration of lead in blood (µg/L). Consumers of offal from game are marked with a black dot.

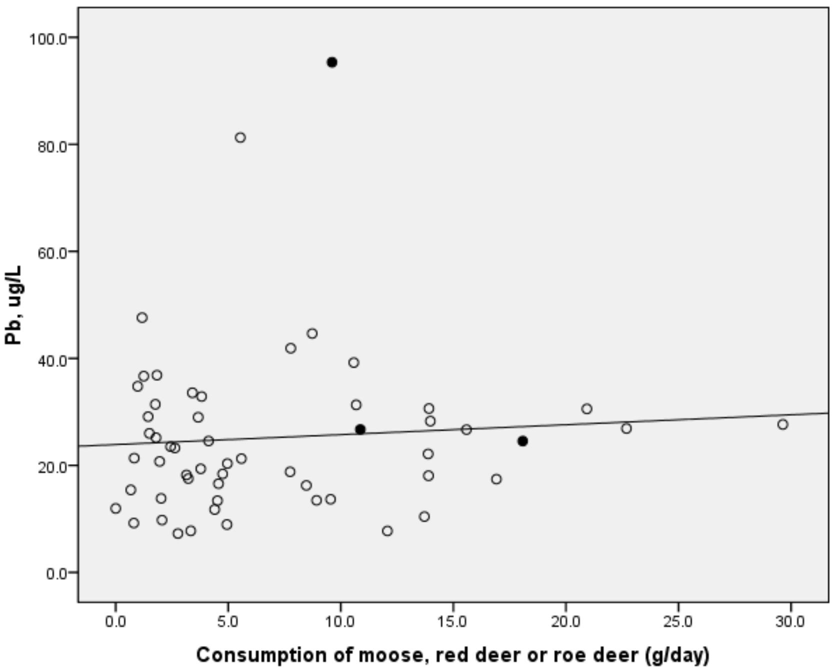


Figure 6. Fish and Game Study – women, consumers of moose and/or red deer or roe deer. Consumption of moose and/or deer (g/day) and unadjusted concentration of lead in blood (µg/L). Consumers of offal from game are marked with a black dot.

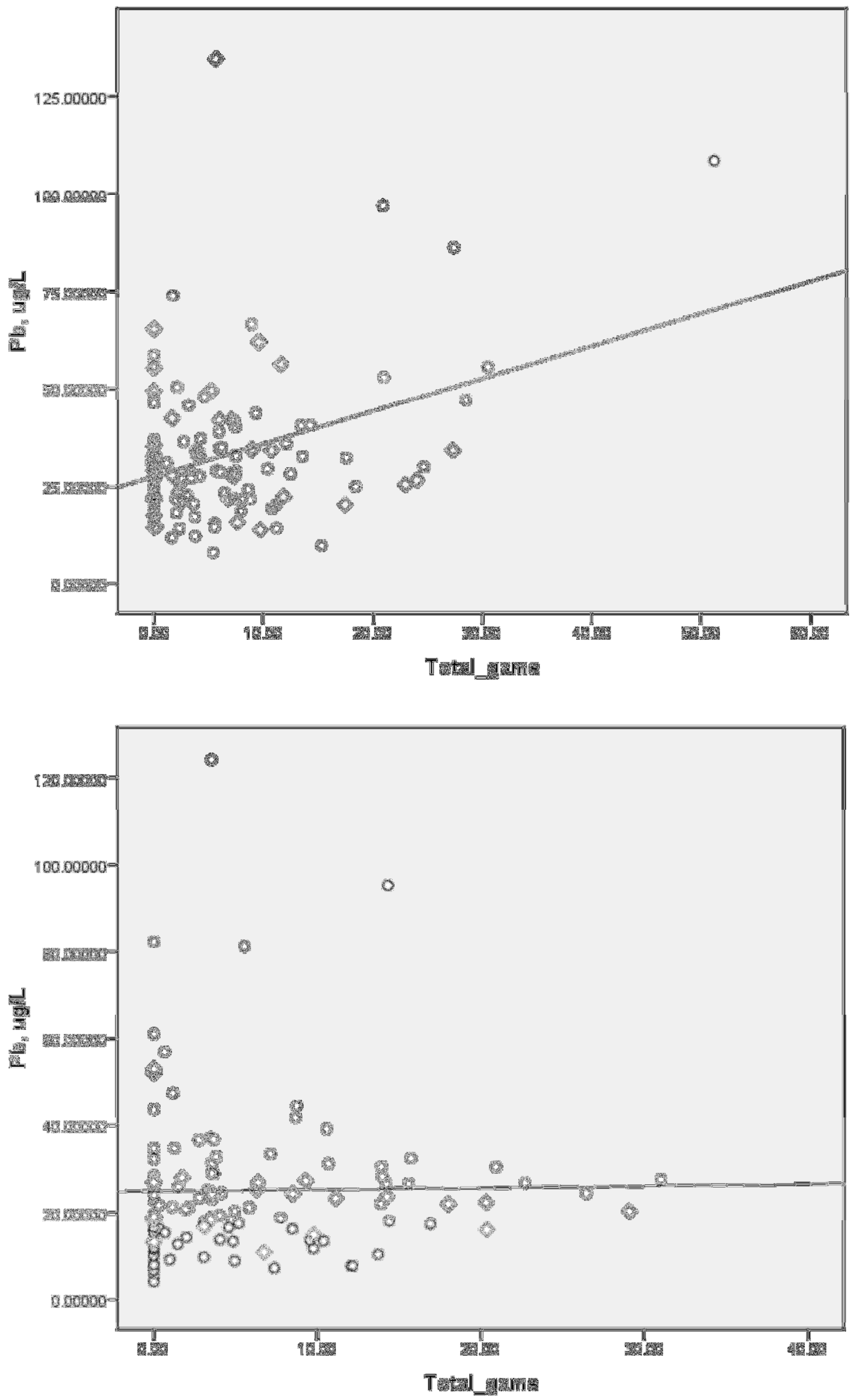


Figure 7. Fish and Game Study (circle) and Lake Mjösa Study (diamond) pooled – men (upper) and women (lower). Consumption of total game and unadjsuted concentration of lead in blood (µg/L).

Table 8. The Fish and Game Study – men. Multiple linear regression analysis of concentration of lead in blood (dependent variable) and association with consumption of game (exposure variable)

	N (%)	Crude			Adjusted[a]		
		Beta	(95% CI)	R^2	Beta	(95% CI)	R^2
Model A							
Total Game (g/day)	83 (100)	0.8	(0.4, 1.3)	0.14	0.9	(0.4, 1.4)	0.30
Model B[b]							
Moose and/or deer:							
Non-consumer	29 (35)	Ref		0.20	Ref		0.32
1 meal per month [c]	13 (16)	-0.6	(-12.3,11.1)		0.8	(-11.3,12.9)	
2-3 meals per month [c]	15 (18)	-1.3	(-11.9,9.2)		0.8	(-10.3,11.7)	
4 meals per month [c]	18 (21)	-4.9	(-15.2, 5.2)		-4.5	(-15.3, 6.4)	
> weekly [c]	9 (10)	16.0	(3.3, 28.7)		19.5	(5.5, 33.5)	
Reindeer (continuous)	19 (35)	1.8	(-1.7, 5.4)		1.4	(-2.2, 5.2)	
Grouse (yes/no)	15 (18)	-6.5	(-18.1,5.1)		-6.4	(-18.7, 5.9)	
Offal from game (yes/no)	6 (7)	22.4	(7.7, 37.2)		22.2	(7.2, 37.3)	

[a] Adjustment for relevant sociodemographic factors and intake of relevant food groups and beverages as well as other potential covariates did not change the crude results to any significant degree. Final model includes age, education, smoking, energy intake and alcohol.
[a] Model B. Dividing total game into consumption of moose and/or deer, reindeer, grouse or offal from game.
[c] Based on reported frequency, calculated backwards from consumption in g/day.
[d]n=83 One participant excluded due to high influence on the estimate

Table 9. The Fish and Game Study - women. Multiple linear regression analysis of the association between consumption of game and the concentration of lead in blood (n=100)

	Crude			Adjusted		
	Beta	95% CI	R2	Beta	95% CI	R2
Total Game (g/day)	0.2	(-0.4, 0.8)	0	-0.1	(-0.6 0.5)	0.26

[a]Adjustments for relevant sociodemographic factors and intake of relevant food groups and beverages as well as other potential covariates. Final model includes age, education, smoking, energy intake, shrimps and alcohol.

Table 10. The Lake Mjøsa Study-men. Multiple linear regression analysis of the association between consumption of game and the concentration of lead in blood (n=40)

	Crude			Adjusted [a]		
	Beta	95% CI	R2	Beta	95% CI	R2
Total Game (g/day)	0.0	(-1.0, 0.9)	0.00	0.1	(-0.6, 0.5)	0.09

[a]Adjustments for relevant sociodemographic factors and intake of relevant food groups and beverages as well as other potential covariates. Final model includes age, smoking, alcohol and cereals.

Table 11. The Lake Mjøsa Study-women. Multiple linear regression analysis of the association between consumption of game and the concentration of lead in blood (n=23)

	Crude			Adjusted [a]		
	Beta	95% CI	R2	Beta	95% CI	R2
Total Game (g/day)	-0.3	(-1.2, 0.23)	0.06	-0.1	(-0.6, 0.5)	0.27

[a]Adjustments for relevant sociodemographic factors and intake of relevant food groups and beverages as well as other potential covariantes. The final model includes age, smoking, alcohol and cereals.

Table 12. The MoBa Validation Study. Multiple linear regression analysis of the association between consumption of game and the concentration of lead in blood (n=119)

	Crude			Adjusted 1			Adjusted 2			Adjusted 3		
	Beta	95% CI	R2	Beta	95% CI	R2	Beta	95% CI	R2	Beta	95% CI	R2
Total Game (g/day)	-0.0	(-0.6, 0.6)	0.0	-0.0	(-0.6, 0.6)	13.2	-0.1	(-0.5, 0.4)	45.8	-0.1	(-0.5, 0.4)	46.3
Moose and/or deer	0.1	(-0.6, 0.7)	0.0	0.0	(-0.6, 0.66)	16.1	-0.7	(-0.5, 0.4)	48.5	-0.1	(-0.5, 0.4)	49.5

Adjusted 1. Relevant sociodemographic factors (In the model: age and smoking)
Adjusted 2. Energy and intake of relevant food and beverages (potential covariates) (In the model: energy intake (NS) and wine)
Adjusted 3. Intake of relevant nutrients and other chemicals in blood known to be associated with lead in blood (potential covariates)

The percentage of persons in each population group exceeding the Bench Mark Dose and the Lower Bench Mark Dose for concentration of lead in blood is found in Table 13. With higher lead values in the Fish and Game Study and the Lake Mjøsa study, more participants exceeded the $BMDL_{10}$ for effects on systolic blood pressure and an even larger number of participants exceeded the $BMDL_{01}$ for prevalence of chronic kidney disease in these population groups.

Table 13. Percentage of participants exceeding the Lower Bench Mark Dose (BMDLs)[17] for concentration of lead in blood in the three population groups for two different health conditions

		Fish and Game N=184	Lake Mjøsa n=64	MoBa Val n=119
Effects on systolic blood pressure	$BMDL_{01}$ 36µg/L	22%	19%	3%
Effects on prevalence of chronic kidney disease	$BMDL_{10}$ 15µg/L	81%	90%	26%

4.5 Comments to the results

Strengths of the current study include the comparability of the dietary intake as the same FFQ is used in all study groups as well as same method of analysis for concentration of lead in blood. Therefore more detailed information is found in this study than in comparable studies. Furthermore, it is a strength that one of the studies included participants living in areas where hunting is common.

However, other factors might affect the reliability and validity of the results. The half life of the concentration of lead in blood is 30 days. The participants were asked about their intake either the previous one year (Fish and Game Study and Lake Mjøsa Study) or 3-4 months back in time (MoBa val). This might affect the results as the participants would have to divide the consumption over the year, although the food was eaten seasonally. In a study by Iqbal and co-workers, those reporting consuming game meat within a month prior to the study had significantly higher lead blood concentration than those who did not consume wild game within that time frame[18]. Previous studies have for example found higher lead levels among participants immediately after the hunting season, when consumption of wild game is highest [18,19] and most frequent shooting episodes takes place. Data collection in the Lake Mjøsa Study was carried out through a period of eight months from October to May, i.e., including the hunting season for some and not for other participants. Data collection in the Fish and Game Study was carried out in March to May, not close to the hunting season. It is possible that this might partly explain the difference in results among men in the two cohorts. As all food frequency questionnaires it is dependent on memory of participants and under-reporting is a known factor, specially among women.

The alternatives given for frequency of consumption in the FFQ might have affected the answers for game consumption, the lowest frequency alternative being once a month. Therefore, those consuming each of the type of game (six questions) less than 12 times per year, will either mark that box or "never" depending on individual feeling. For example, the participants in the Fish and Game Study part C had answered the question regarding consumption of game three years earlier in another questionnaire where there was an additional possibility of marking on >0-5 times per year and <5-11 times per year (part B).

Comparing these data revealed that while 70% reported game consumption in the current FFQ, 90% reported game consumption three years earlier (part B). Those defined as non-game consumers in the studies might therefore potentially consume each of the types of game in question up 11 times per year.

Portion sizes for game used in the study are average portion sizes for meat, ground meat, bird and offal in a meal for men and women based on results from other studies [10]. We do not have information regarding actual portion sizes for each participant which might affect the results. Furthermore, data is self-reported and may be subject to recall or information bias. As portion sizes behind each question is different (steak, stew, offal) the intake in g/day cannot be estimated directly only from information on frequency of game intake. However, a approximate estimate is that 10g of game meat per day represents 3 game meals per month.

Lead is ubiquitous in foods, but at very low concentrations. Generally cereals, vegetables and tap water are considered to contribute most to the dietary exposure to lead for most Europeans [17]. However, only consumption of wine/alcohol was found to be associated with the concentration of lead in blood in all three population groups, although only indicative. It must also be pointed out that none of the tree studies were originally designed to look at the question of game and concentration of lead in blood specifically.

5. Concluding remark

High consumption of game, mainly moose and/or deer and offal from game, was associated with an increase in the concentration of lead in blood in men. No significant increase was seen for game consumption less than five meals per month. Other life style factors related to hunting may also contribute to higher blood lead in frequent game consumers. Although no statistically significant association was found in women, this study cannot exclude a relationship in women.

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Appendix II

The Norwegian Game and Lead Study. *Game consumption and concentration of lead in blood - results from an investigation of high- versus low-consumers of moose and deer meat.*

1. Background

Several publications and press releases the last couple of years have focused on the risk of higher body lead burden through regular consumption of game. High consumers of game, and hunters and hunter's associations in particular, have accordingly been discussing the issue and shown concern and worry. In the autumn of 2011 The Norwegian Food Safety Authority (Mattilsynet) commissioned the Norwegian Scientific Committee for Food Safety (VKM) to perform a risk assessment of lead exposure in relation to consumption of game meat. As few data exist on consumption of game in the Norwegian population, and even less data exist which enables investigation of cervid meat consumption in relation to blood lead levels, VKM encouraged the Norwegian Institute of Public Health to perform a monitoring of blood lead concentrations in high-consumers of game meat and collect data to investigate whether comsumption of game meat can be related to blood lead levels. This report is written in response to the request and the objective is to provide background information for VKM to be used in their risk assessment.

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2. Aim

The aim of the Norwegian Game and Lead study was to assess whether high consumption of game meat increases the risk of high levels of lead in blood in a group of Norwegian hunters and non-hunters with a wide range of game consumption. The report also relates this to gender, age and other factors apart from game meat consumption, to assess their joint contribution to explaining observed variability in blood lead levels.

3. Participants and Methods

3.1 Participants

The Regional Ethics Committee (2012/100/REK) gave consent to the project on the condition that recruitment was to be done through hunting-team leaders (jaktlagsledere) and not directly. Based on geographical distribution and hunting statistics we contacted the forestry manager (skogbruksansvarlige) in five typical cervid game municipalities (Aurskog-Høland, Bygland, Bindal, Stor-Elvdal and Tingvoll) for contact information about hunting area leaders (vald-ledere), who in turn informed about hunting team leaders in their area. A random selection of these was contacted, partly by phone, partly by e-mail. Those who were positive to participate were sent envelopes and invitation letters which they were to distribute to members of their hunting team. In addition, the Norwegian Hunting and Fishing Organization (NJFF) put us in contact with their own members. Totally we sent 354 invitation letters to different hunting group leaders. We also recruited participants at our own Institute to ensure a wide range of game meat consumption. Only persons 18 years or older were invited to participate. The inclusion period lasted from primo April till mid October 2012. All together we received 224 participation consents (samtykkeerklæringer), which is a participation rate of 64% of those invited. Complete questionnaire answers and blood samples were obtained for 147 participants, of which 104 were recruited trough hunting team leaders and 43 were recruited at the Norwegian Institute of Public Health.

3.2 The letter of invitation and the participation consent form

The invitation letter was developed in co-operation with the Communications Department (SIKO) at the Norwegian Institute of Public Health and the Norwegian Hunting and Fishing Organisation (NJFF) (Annex 1). It contained information about hunting in Norway and health risks related to high lead exposure in addition to information about the project. Recipients willing to participate filled a consent form and returned it to the Institute.

In addition to the name address and blood sampling location, the consent form included one question about consumption of cervids: "How often do you eat cervid meat?" with four answering alternatives: "never", "a few times during a year", "one to three times per month" and "one or several times per week". The answers to this global question were used together with the more detailed consumption data.

3.3 Background, hunting habits and dietary exposure assessment

A self-administered four page questionnaire was sent to all who had delivered a consent form (Annex 2). The questionnaire had 32 main questions, and included questions about background (weight, height, occupation, household, municipality), hunting habits (number of years hunting, number of shots, type of hunting etc), consumption of game (moose, deer, reindeer, small game) and factors which might modify lead levels in the body (dietary supplements, alcohol, smoking etc). Since lead levels in blood have a half-life of approximately 30 days, we asked about consumption of game both last month and last year.

The eight alternative answers for frequencies of consumption were: never, 1-5 meals per year, 6-11 meals per year, 1 meal per month, 2-3 meals per month, and 1, 2 or ≥ 3 meals per week.

For figure and table presentations, the corresponding per month figures were used.
We did not include questions about age of home, paint or renovation etc. because Norway phased out paint with pigments containing lead already in the 1920s, so this has not been an issue in Norway.

A separate questionnaire was sent to the hunting team leaders (Annex 3), which focused on general use and attitudes in the hunting party regarding types of ammunition, discarding of meat around the bullet hole etc.

3.4 Chemical analyses of lead in blood

Blood samples were drawn at the Medical Centre or doctor's office provided on the participant's consent form (Annex 1). These offices were sent an information letter and some days later blood tubes and return envelopes. The blood sample tubes were sent directly to Fürst Medical Laboratory in Oslo for analyses.

Lead in blood was determined with ® Elan DRC ™ II (PerkinElmer SCIEX, Ontario, Canada) Inductively Coupled Plasma - Mass Spectrometry. Samples, standards and quality controls were diluted 1:20 with deionized water (> 18 M ®, Millipore, Billerica, USA) and was added 0.1% (v / v) nitric acid (65% w / v, Suprapur ®, Merck, Darmstadt, Germany) and 0.2% (v / v) Triton ® X -100 (Ph Eur, NF, Merck, Darmstadt, Germany). As internal standard, 10 g / L Thulium (Tm) PerkinElmer Pure Atomic Spectroscopy Calibration Standard in 10% HCl, 1000 microgram / mL (Shelton, USA) was added directly to the diluent. The sum of 206Pb, 207Pb and 208Pb was measured. External calibration with two point calibration curve (blank + standard) was used and the standard was made by adding Lead (Pb) PerkinElmer Pure Atomic Spectroscopy Calibration Standard in 2% HNO3, 1000 micrograms / mL (Shelton, USA) to Auto Norm ™ (Billingstad, Norway). The limit of detection (LOD) and limit of quantification (LOQ) were calculated as 3*SD and 10*SD respectively of 10 replicates of a blood sample with lead concentration 16.1 µg/L. The LOD was 1.77 µg/L, and the LOQ was 5.89 µg/L. An internal quality control sample containing 18.72 µg/L Pb was analysed during 2012 (n=111) with a SD of 3.74 µg/L (RSD 20%). All the samples analysed in this study contained lead concentrations above the LOQ.

3.5 Statistical analyses

The aim of this study design was to collect data for assessment of possible associations between game consumption and blood lead concentrations. Because it was a priori known that low doses of game meat normally contributed small amounts of lead, regression models were chosen as analysis tools. Thus all participants were treated as one group independent of game consumption and whether they had been recruited at the Norwegian Institue of Public Health or through hunting team leaders.

All statistical analyses was done in the program R. Throughout, the blood lead concentration is the dependent variable. Blood lead concentration was used both without and with natural log transformation in various models. Because there was a strong association between blood lead and age, age-adjusted blood lead was used in most bivariate models assessing associations between game consumption and blood lead.

4. Results

4.1 Information from hunting team leaders

As to the separate questionnaire sent to hunting team leaders, we received a response from 23 out of 37 leaders in total. The answers were not possible to merge with the individual participant questionnaires, mostly because many participants did not fill in the question about which hunting team they belonged to. The majority (48%) of the hunting team leaders reported that they mainly used bonded ammunition, and the majority reported that the meat was cut privately. Eight (35%) of the hunting team leaders reported removal of less than 10cm meat around the wound canal, while a majority (57%) reported that removal of meat near the wound canal was important. A majority of hunting teams brought the trimmings to waste disposal or left it in the nature (Table 1).

Table 1 Hunting team leaders answers to separate questionnaire

		N	(%)
More than one type of ammunition used	Yes	17	(74)
	No	6	(26)
Main group of ammunition	Bonded	11	(48)
	Unbonded	6	(26)
	Bonded and unbonded	4	(17)
	Homogenous lead free	1	(4.3)
	Missing	1	(4.3)
Where slaughtered	Private	16	(70)
	Slaughterhouse	3	(13)
	Private and slaughterhouse	4	(17)
Amount of meat removed around wound channel	>20 cm	5	(22)
	10-20 cm	10	(43)
	0-10 cm	8	(35)
Fate of trimmings	Left in nature	7	(30)
	Dog feed	2	(8.7)
	Waste disposal	10	(43)
	Fox bait	2	(8.7)
	Other	2	(8.7)
Importance of trimming	Of importance	13	(57)
	Of less importance	8	(35)
	Not of importance	2	(8.7)

Furthermore, the hunting team leaders were asked to report the amount of meat distributed in the hunting team in the hunting season 2011, and the type of ammunition used to obtain this meat. The responses to this question comprised 346 bullets, but 11 bullets from one team was excluded because of insufficient information (Figure 1). When head-shots were included, a mean of 74 kg meat was obtained per bullet used (Figure 2).

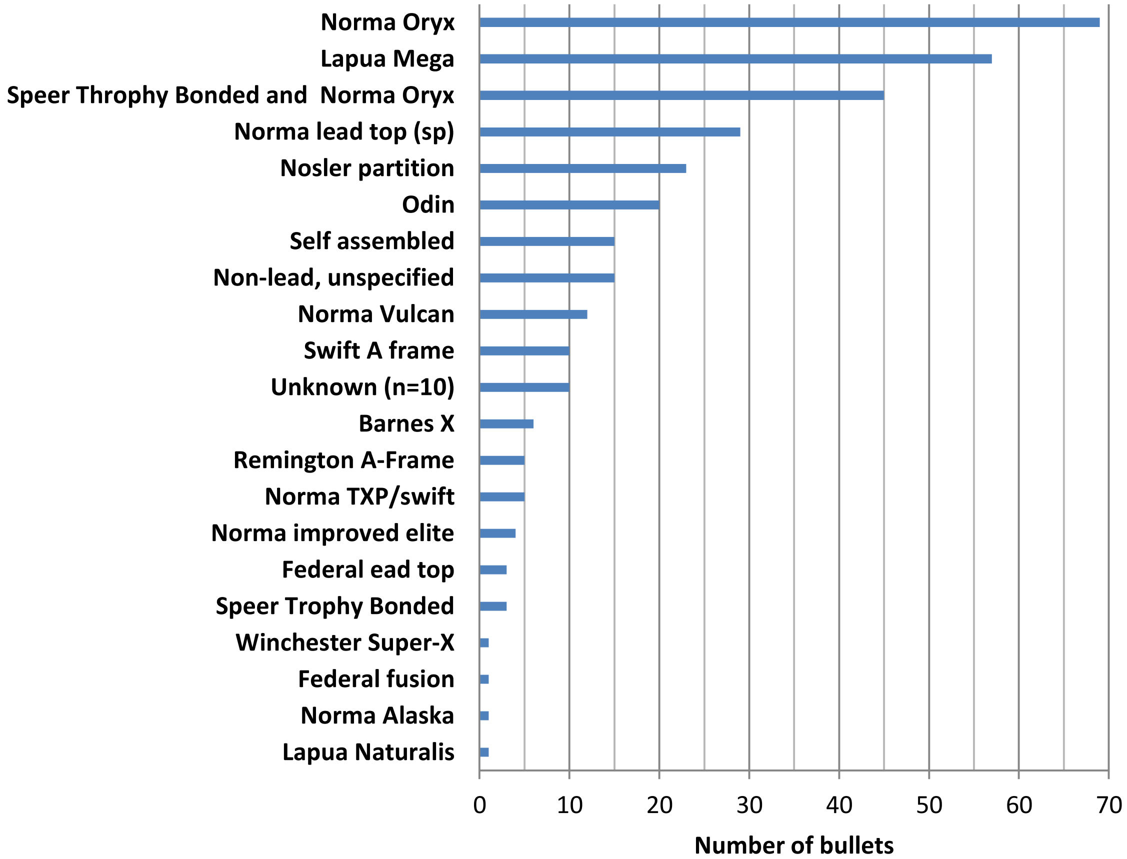

Figure 1 Distribution of 335 bullets reported used by 22 hunting teams in the Norwegian Game and Lead Study by bullet brand. Bullets from one hunting team, which reported use of 11 bullets of types Speer Trophy Bonded, Winchester Super-X, Norma Vulcan and Self assembled ammunition, were not included because the distribution between the 11 bullets was not given.

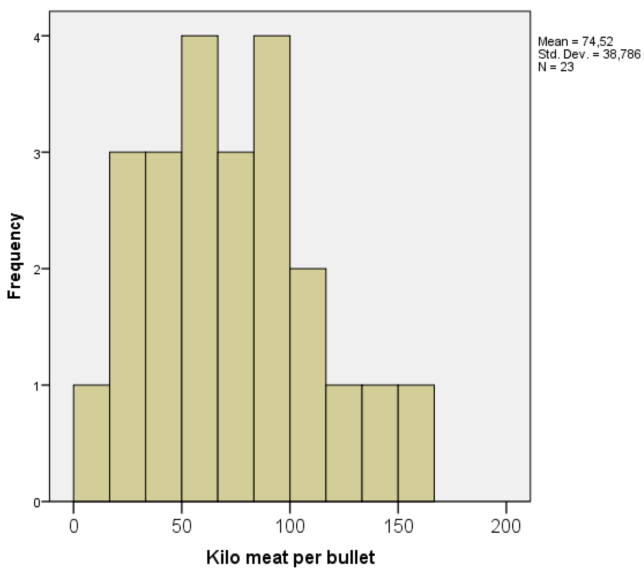

Figure 2. The total amount of meat obtained by each hunting team divided by the number of bullets used to obtain the meat (head shots included), as reported by 23 hunting team leaders participating in the Norwegian Game and Lead Study.

4.2 Characteristics of the study population

The study population is described in Table 2. We had far more male than female participants, 63 and 37% respectively, of a total of 147 participants. This reflects a generally skewed distribution among hunters, the hunting season 2011-2012 had about 6% female hunters. While 104 participants (73%) reported upon recruitment that they ate cervid meat at least once per month, 43 participants (27%) ate these foods rarely and ensured that we achieved recruiting participants with a wide range of cervid meat consumption. There were high- and low-consumers of game meat irrespective of recruitment pathway.

Most of the participants had higher education (56%) and only 14% reported to have primary education. There were far more participants from Eastern Norway than from other parts of the country. Although effort was put into recruiting deer hunters on the west coast, we focused primarily on recruitment of persons who ate moose and deer meat regularly, but also included a small group from Finnmark (the northernmost county in Norway) who were high-consumers of reindeer meat (n = 7). Thirteen (9%) of the participants reported self-assembling of lead-containing ammunition.

Table 2. Characteristics of the participants, total n = 147

	N	%
Sex		
Women	55	37.4
Men	92	62.6
Age, years		
< 40	35	23.8
40-60	73	49.7
> 60	39	26.5
Body Mass Index		
≤ 25	73	49.7
> 25 - 30	60	40.8
> 30	20	13.6
Education		
Primary	21	14.3
Upper secondary	46	31.3
Higher education	82	55.8
Region		
Oslo/Akershus	63	42.9
East, other than Oslo/Akershus	44	29.9
Southern/Western Norway	16	10.9
Trøndelag	19	12.9
Northern Norway	21	14.3
Self-assembled lead ammunition		
No	134	91.2
Yes	13	8.8
Smoking		
Never	85	57.8
Former	42	28.6
Occasionally	6	4.1
Daily	14	9.5
Snus		
Never	113	76.9
Former	6	4.1
Daily	28	19
Cervid consumption reported upon recruitment		
Rare (never/occasionally)	43	29.3
Frequent (monthly or more)	104	70.7

Game meat consumption in the detailed questionnaire		
Moose		
Never/occasionally	54	36.7
Monthly	22	15.0
Weekly	71	48.3
Deer		
Never/occasionally	105	71.4
Monthly	20	13.6
Weekly	22	15.0
Reindeer		
Rare (never/occasionally)	140	95.2
Frequent (monthly or more)	7	4.8
Small game and offal		
Rare (never/occasionally)	138	93.9
Frequent (monthly or more)	9	6.1

Only twenty participants (14%) said they smoked occasionally or daily, while 19% reported use of snus[1].

The average age (range) was 50 (18-76) years in men and 46 (19-70 years) in women. There were many more participants in the age groups above 40 than below, ¾ versus ¼ respectively (Figure 3A).

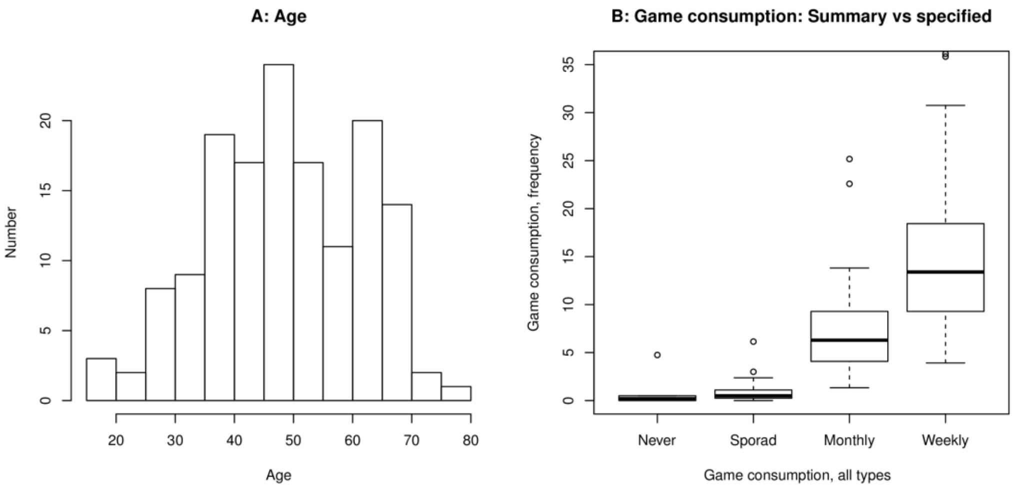

Figure 3. Characteristics of the participants

A: Age distribution

B: Monthly frequency of game intake vs self-classification upon recruitment.

[1] A moist powder tobacco product originated from a variant of dry snuff.

4.3 Game meat consumption

Figure 3B shows that cervid meat consumption reported upon recruitment (Annex 1) was consistent with the frequencies calculated from the detailed questionnaire (Annex 2). Upon recruitment 14 participants reported “never”, 29 reported “a few times a year”, 49 reported “monthly” and 55 reported “weekly” intake of cervid meat. In the detailed questionnaire, the median frequency of game meat consumption (including cervid meat) was 5.5 meals/month in men and 3.5 meals/month in women. Forty-eight percent (n=71) of the participants reported that they ate moose meat once a week or more, while 15% (n=22) reported eating deer meat once a week or more. Only four reported monthy or weekly consumption of hare and bird game (small game).

At all levels of game consumption, a considerable portion of intake was in the form of minced meat from moose or deer. The median frequency of minced meat from moose and/or deer was 2.1 meals/month in men and 1.2 meals/month in women. Among those with high intakes of game meat, there was a tendency for the proportion of minced cervid meat to decrease slightly, i.e. one percent point per extra monthly game meal in the upper tertile, while at the lower intakes there was a postive association between total game consumption and fraction eaten as minced meat, the fractions being 25%, 28% and 46% in the three tertiles of game consumption, respectively.

The majority, 89 persons (61%), reported that their source of game was their own hunting/hunting team, while 46 participants had purchased the meat they consumed in shops.

4.4 Blood lead concentrations

The median blood lead concentration in the total study sample was 16.6 µg/L, 5 and 95 percentiles were 7.5 and 39 µg/L, the range was 6 to 69.3 µg/L, the mean was 19.4 µg/L and the geometric mean was 17 µg/L (Figure 4A).

Blood lead concentrations were significantly higher in men (median 19.9 µg/L, mean 22.3 µg/L) than in women (median 12.9 µg/L, mean 14.7 µg/L). The lead concentrations in blood increased significantly with age. Markedly higher blood lead concentrations were observed in participants reporting self-assembling of lead-based bullet ammunition. Smokers had significantly higher blood lead concentrations than non-smokers (23.8 vs 17.9 µg/L). This difference persisted upon age adjustment, while there was no similar association for snus.

There were no regional differences in blood lead concentrations (Figure 4B). There was no clear association between years of game consumption and age-adjusted lead (Figure 4C).

Men reported higher shooting activity (median 58 shots annualy vs 5.5 in women), more long time use of lead bullets (median 31 years versus 5 years in women), more years with game intake (median 35 years vs 20 years in women) and higher frequency of meals with game meat (median 5.5 meals per month vs 3.5 in women) as well as minced meat of moose/deer (2.1 vs 1.2).

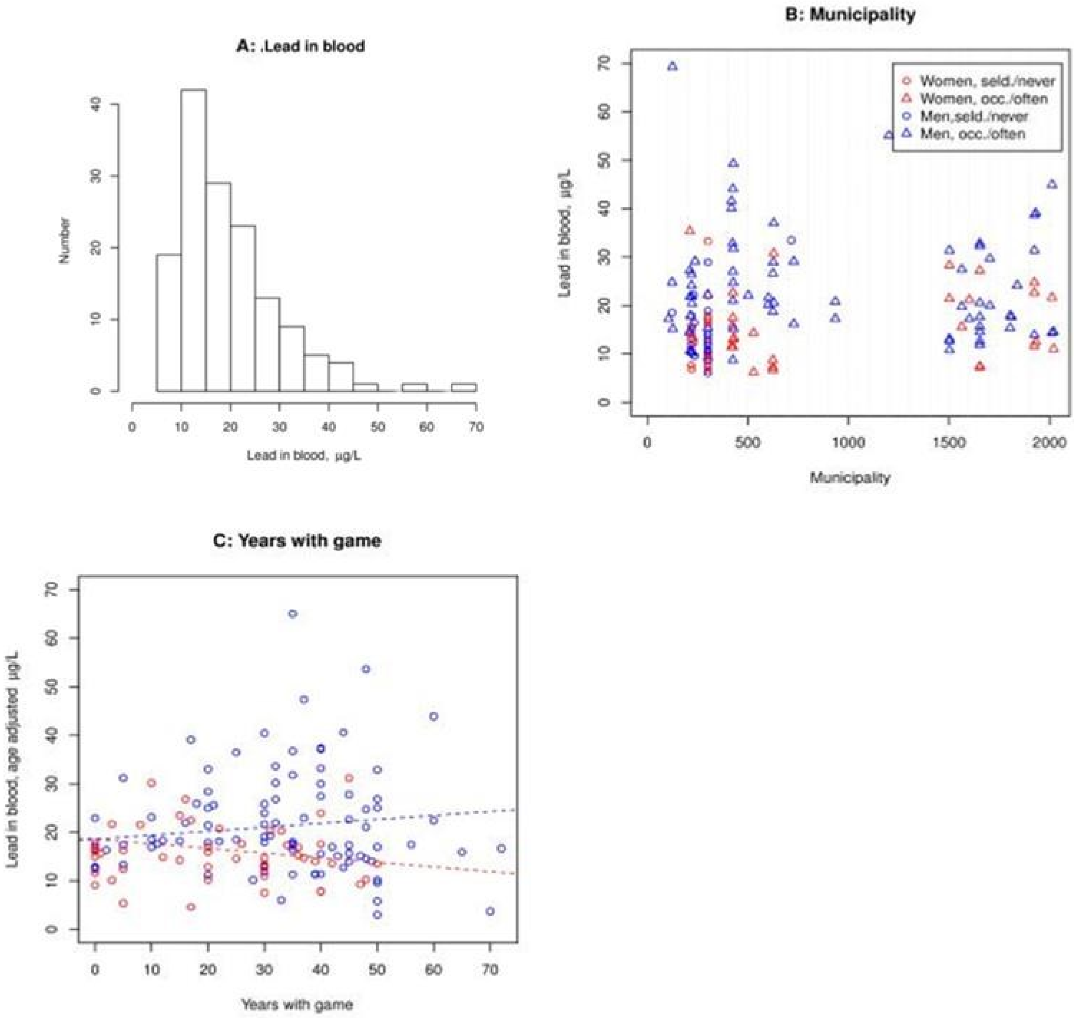

Figure 4. Scatterplots for lead in blood.

A: Distribution of blood lead concentration values, µg/L.

B: Blood lead concentration vs municipality (code) of the participants, by sex and game intake. Ordered by counties: 100 – Østfold, 200 – Akershus, 300 – Oslo etc.

C: Age-adjusted blood lead concentration vs reported number of years with game consumption. Regression lines for men (blue) and women (red).

4.5 Associations between game meat consumption and blood lead concentrations

Blood lead concentrations by the four categories of cervid meat consumption reported upon recruitment were: 13.5, 11.9, 20.6 and 19.8 µg/L for never, occasionally, monthly or weekly consumption, respectively. The corresponding mean values were: 15.0, 13.5, 22.0 and 21.4 µg/L (Figure 5).

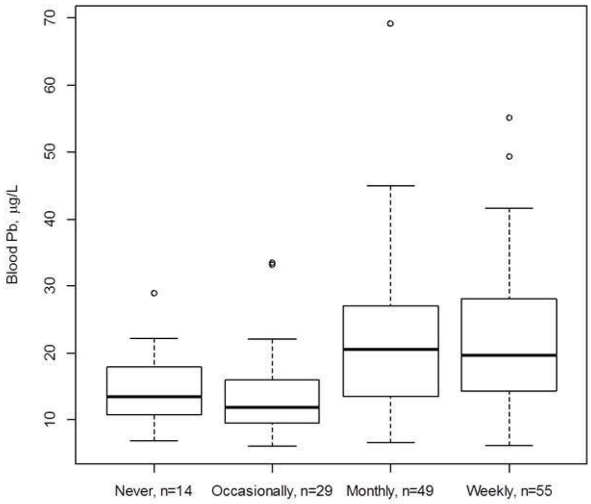

Figure 5. Distribution of blood lead (Pb) by self-reported frequency of cervid meat consumption

There was no statistically significant difference in blood lead between the two lower consumption groups and no difference between the two groups with more frequent cervid meat consumption. Hence, for statistical analyses those who reported never or occasional cervid meat intake were combined (n=43, mean and median blood lead: 14 and 12 µg/L) and those who reported monthly or weekly intake were combined (n=104, mean and median blood lead: 22 and 20 µg/L). The difference in blood lead levels between frequent (monthly or more often) and rare (less than monthly) cervid meat consumers remained significant in analyses adjusted for sex and age.

Several regression models were explored to examine the association between cervid meat consumption and blood lead. The results indicated a differential influence on blood lead concentrations of minced meat vs non-minced meat from moose or deer. In models adjusted for sex and age, the frequency of meals with minced meat from moose or deer resulted in a significantly better model fit (i.e. larger explained variance) than the frequency of meals with non-minced cervid meat. Hence, the difference in blood lead between frequent and rare consumers of cervid meat seemed for a large part to be related to consumption of minced meat from moose or deer.

The detailed analysis suggested that those who ate a lot of minced moose/deer meat had no tendency to increased lead levels at higher intake of other game meat. The large variation in blood lead (standard deviation for predicted lead in simple regression on minced meat intake approximately 9 µg/L) turned out to be in part associated with source of meat: Blood lead concentration increased about twice as much per extra monthly meal, ($P<0.001$ in bivariate regression) in those who had purchased the meat compared with those who consumed self-procured meat. Those who had purchased the meat consumed a somewhat larger fraction as minced meat (46% vs 39%), but this difference did not reach significance ($P=0.08$). The impact of cervid meat consumption, minced meat of moose and/or deer and source of meat consumed were confirmed in the final regression model. In this model, the impact of minced cervid meat was not as evident as in the preliminary models. The optimal regression model is presented in Meltzer et al., (submitted paper[2]).

In the optimal model, adjusted R square for the number of explanatory variables was 0.52, which may be interpreted as the model covering 52% of the variation in lead (measured logarithmically). Age and sex alone accounted for 27% of the variance, and hence cervid meat consumption together with number of bullets shot per year, years with cervid consumption, self-assembling of bullets, wine consumption and smoking jointly accounting for a substantial proportion of the variation in ln-transformed blood lead concentrations.

In this model with blood lead on the ln-scale, frequent (monthly or more often) consumption of cervid meat was associated with 31% higher blood lead concentrations than no/occasional consumption. In addition to frequent cervid meat consumption, the monthly meal frequencies minced meat from moose and/or deer were included in the model. It was especially the purchased minced meat that had an impact, with on average 4% higher blood lead concentration per additional monthly meal vs. 2% for subjects consuming self-procured products. Self-assembling of ammunition was associated with 52% higher blood lead concentration. The number of years with game meat consumption was associated with a small but significant reduction in blood lead. Number of shots fired per year was associated with 2% higher blood lead concentrations per 100 shots.

Men had 30% higher blood lead concentrations than women. Age was positively correlated with blood lead, with 18% higher blood lead concentrations per decade. Wine consumption (but not beer or spirits) was associated with 9% increase per increasing category of wine consumption. Smokers had 17% higher blood lead concentrations than non-smokers.

Major strengths of this study include the large number of factors considered and the wide range of game meat consuming practices represented. The optimal model explained more than half of the variation in ln-transformed blood lead, indicating that the most important factors influencing blood lead concentrations in the study population were captured. It should, however, not be extrapolated to the general population, as there may be sources of lead exposure not adequately represented in our material.

5. Concluding remark

This study showed that frequent consumption of cervid meat (once a month or more often), and in particular minced cervid meat, was significantly associated with higher levels of lead in blood. Other factors contributing to explaining the variance in blood lead were age, sex, smoking, self-assembling of lead-containing ammunition, years with game consumption, number of bullets fired per year, and wine intake. While age and sex accounted for 27% of the variance, cervid meat consumption together with the number of bullets shot per year, years with game consumption, self-assembling of bullets, wine intake and smoking jointly accounted for approximately 25% of the variation in ln-transformed blood lead concentrations.

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[2] Meltzer HM, Dahl H, Brantsæter AL, Birgisdottir BE, Knutsen HK, Bernhoft A, Oftedahl B, Lande US, Alexander J, Haugen M, Ydersbond TA. Consumption of lead-shot cervid meat and blood lead concentrations in a group of adult Norwegians. Submitted paper 2013.

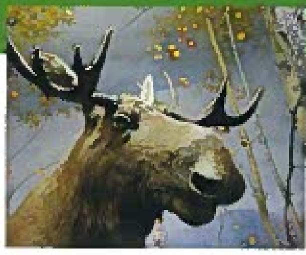
Annex 1: The letter of invitation and consent form.

Annex 2: The detailed questionnaire answered by participants.

Annex 3: The questionnaire sent to the hunting team leaders.

Hjortevilt og bly-undersøkelsen





INVITASJON TIL STUDIE

Er bly i viltkjøtt en helserisiko?

Kjøtt fra vilt er en svært verdifull matvare i kostholdet. I enkelte tilfeller kan vilt skutt med blyammunisjon inneholde høyere nivåer av bly enn ønskelig. Vi mangler kunnskap om hvilken betydning bly fra vilt har for helsen vår. For å kunne vurdere den helsemessige betydningen av bly fra viltkjøtt, har Vitenskapskomiteen for mattrygghet (VKM) gitt Nasjonalt folkehelseinstitutt i oppdrag å undersøke om inntak av viltkjøtt kan settes i sammenheng med blynivåene i blodet.

Flere detaljer om prosjektet finner du inne i denne invitasjonen.

folkehelseinstituttet

INFORMASJON OM
HJORTEVILT OG BLY-UNDERSØKELSEN

Til deg som er storviltjeger

Vi ønsker herved å invitere deg til å delta i en undersøkelse for å avdekke om det er en sammenheng mellom konsum av kjøtt fra hjortevilt og blykonsentrasjonen i blodet ditt.

Dette invitasjonsbrevet sendes ut til deg via din jaktlagsleder. Dette innebærer at Folkehelseinstituttet ikke har navnet og adressen din før du eventuelt sier deg villig til å delta i undersøkelsen. Det er selvsagt helt frivillig å delta og du kan se bort fra denne henvendelsen dersom du ikke ønsker å være med i prosjektet.

Dersom du er positiv til å delta i undersøkelsen og ikke bor alene, hadde det vært fint å få med hele eller deler av familien din også. Vi ønsker å få med begge kjønn og så stor spredning i alder som mulig, så sant personen er over 18 år.

Hva innebærer det å være med?

Hvis du ønsker å delta må du fylle ut og returnere den vedlagte svarlappen (samtykke-erklæringen). Deretter sender vi deg spørreskjema og instrukser for hvordan blodprøven skal tas. Vi sender med flere svarlapper i tilfelle noen flere i husstanden din også vil være med.

Når vi har mottatt svarbrevet ditt, får du tilsendt et nytt brev fra oss. Dette brevet vil inneholde følgende:

- Et spørreskjema om jakten 2011 og inntak av vilt med spesiell vekt på hva du har spist den siste måneden.
- Et informasjonsskriv som forklarer hvordan blodprøven skal tas.

Vi ber deg så kontakte en helsestasjon eller nærmeste lege for å ta blodprøven. Du betaler selvsagt ikke noe for dette legebesøket.

Navn og adresse til lege/helsestasjon må du føre inn på svarslippen i angitt felt, slik at vi kan kontakte dem på forhånd og informere om undersøkelsen. Vi vil ikke gi ut noen opplysninger om deg, men gi generell informasjon om undersøkelsen og om hvor/hvordan prøvene skal tas og sendes. På denne måten vil de være forberedt når du bestiller time.

Hva får du igjen for å delta?

Hvis du sier ja til å delta vil du bidra til å frembringe kunnskap om mulige betenkeligheter ved å spise hjortevilt. Resultatene fra undersøkelsen skal brukes av Vitenskapskomiteen for Mattrygghet (VKM) til å vurdere eventuell risiko ved å spise slikt kjøtt. Målet er å kunne gi klare råd om inntak av viltkjøtt innen høstjakten 2012.

Utgifter med transport til lege/annet helsepersonell for å få tatt blodprøven, vil refunderes. Vi ber deg sende oss kvitteringer/billetter som dokumentasjon.

Dersom du ønsker det, vil det være mulig å få resultatene fra blodanalysen gjennom fastlegen din når resultatene foreligger.

For å gjennomføre denne undersøkelsen, trenger vi din hjelp. **Deltakelse er frivillig**, og selv etter at du har samtykket i å delta kan du når som helst trekke deg fra undersøkelsen uten begrunnelse.

Anonymitet

Opplysningene du gir oss vil ikke bli benyttet til andre formål og vil behandles konfidensielt.

Kun prosjektleder vil ha tilgang til navn og adresse til deltakerne. Det vil ikke være mulig å identifisere enkeltpersoner under bearbeiding av resutltatene eller i sluttrapporten.

Nærmere opplysninger om undersøkelsen kan fåes ved henvendelse til:

prosjektkoordinator
Hildegunn Dahl,
tlf 21 07 62 45
hildegunn.dahl@fhi.no
eller
prosjektleder
Helle Margrete Meltzer
tlf 21 07 63 37
helle.margrete.meltzer@fhi.no

Folkehelseinstituttet
Postboks 4404 Nydalen
0455 Oslo

Hvilke spørsmål ønsker vi å få besvart med denne studien?

- Hvor ofte spises hjortevilt i grupper av befolkningen med høyt konsum?
- Kan høyt konsum av hjortevilt føre til et så høyt inntak av bly at det utgjør en helserisiko?

Hvorfor er vi bekymret for bly?

Bly er et giftig tungmetall som i høye konsentrasjoner kan gi nerveskader. Maten er den viktigste kilden for bly i våre dager, men eksponering kan også forekomme fra andre kilder som for eksempel luftforurensning. Bruken av bly i bensin har helt opphørt, noe som har redusert betydningen av denne eksponeringskilden.

Bly lagres i skjelettet vårt og står i likevekt med konsentrasjonene i blodet. Blyinnholdet i blod er derfor en god indikator på blyeksponering.

Vi har relativt lite kunnskap om de generelle nivåene av bly i blod hos personer i Norge.

De kunnskapene vi har så langt sannsynliggjør imidlertid at risiko for helseskader fra bly i den norske befolkningen er relativt liten.

De mest utsatte gruppene er fostre og små barn.

Denne undersøkelsen vil bidra til å avklare om det er grunnlag for si at viltkjøtt har betydning for tilførselen av bly og om nivåene i så fall kan medføre en helserisiko.

Samarbeidspartnere

Undersøkelsen blir gjennomført i samarbeid med Norges Jeger- og Fiskerforbund og lokale jaktlagsansvarlige. Navnene til jaktlagsledere er innhentet via kommunen og gjennom valdansvarlige/jaktfeltsansvarlige. Prosjektet skal gjennomføres våren 2012.

Ferdig frankert svarkonvolutt til svarlappen ligger vedlagt. Svar oss helst innen to uker.

KOPI AV SVARLAPP/SAMTYKKERKLÆRING

Ja, jeg ønsker å delta i undersøkelsen av hjortevilt og bly:

Navn: ______________________________

Adresse: ______________________________

____

Telefon/mobil: ____________

Jeg tilhører gruppen som spiser hjortevilt:

En gang i uken eller oftere ☐
En – tre ganger i måneden ☐
Noen ganger i året ☐
Aldri ☐

Helsestasjon eller fastlege som kan ta blodprøve av meg:

Navn: ______________________________

Adresse: ______________________________

____

Telefon: ____________

☐ Jeg ønsker å få mine blodresultater sendt min fastlege etter analysering.

☐ Jeg ønsker å få tilsendt generelle resultater fra undersøkelsen den dagen disse er klare.

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25. Har du brukt kosttilskudd den siste måneden? Ja ☐ Nei ☐ Hvis nei, gå til spørsmål 26.

Hvis ja, ber vi deg svare på type og mengde nedenfor.

	Antall ganger pr uke							
	0	1	2	3	4	5	6	7
Tran, flytende eller som kapsler	☐	☐	☐	☐	☐	☐	☐	☐
Fiskeoljekapsler/omega-3 tran	☐	☐	☐	☐	☐	☐	☐	☐
Sanasol, Biovit	☐	☐	☐	☐	☐	☐	☐	☐
Multivitamin-mineral-tablett	☐	☐	☐	☐	☐	☐	☐	☐
Jerntilskudd	☐	☐	☐	☐	☐	☐	☐	☐
Andre kapsler/tabletter	☐	☐	☐	☐	☐	☐	☐	☐

Hvis andre kapsler/tabletter, navn på disse:..

26. Røyker du regelmessig? ☐ **Nei, jeg har aldri røkt.** ☐ **Ja, jeg begynte å røyke da jeg var** ☐☐ **år.**

☐ **Jeg røyker fremdeles.** ☐ **Røyker bare i jaktsesongen.** ☐ **Sluttet å røyke for** ☐☐ **år siden.**

Jeg røyker/røkte ☐ **Sigaretter** ☐ **Pipe** ☐ **Rullings** **Antall pr. dag** ☐☐☐

Hvis du ikke røyker hver dag, angi antallet for en hel uke. ☐☐☐

Under jaktsesongen røyker/røkte jeg ☐ **som vanlig** ☐ **mer** ☐ **mindre enn vanlig.**

27. Snuser du regelmessig? ☐ **Nei, jeg snuser ikke.** ☐ **Ja, jeg begynte å snuse da jeg var** ☐☐ **år gammel.**

☐ **Jeg snuser fremdeles.** ☐ **Snuser bare i jaktsesongen.** ☐ **Sluttet å snuse for** ☐☐ **år siden.**

Antall snusinger pr. dag ☐☐☐ **Hvis du ikke snuser hver dag, angi antallet for en hel uke** ☐☐☐

Under jaktsesongen snuser jeg ☐ **som vanlig** ☐ **mer** ☐ **mindre enn vanlig.**

28. Vet du om andre mulige kilder til bly i hverdagen din enn fra jaktaktivitet, for eksempel via yrke eller hobby?

Ja ☐ **Hvis ja, spesifiser med blokkbokstaver.** **Nei** ☐ **Vet ikke** ☐

....

....

29. Har du noen kroniske sykdommer? Ja ☐ **Nei** ☐ **Hvis ja, hvilke:**..

....

30. Bruker du medisiner regelmessig? Ja ☐ **Nei** ☐ **Hvis ja, hvilke:**..

....

....

31. Har du født barn? Ja ☐ **Nei** ☐ **Hvis ja, hvor mange?** ☐☐

32. Hvis du har ammet, i hvilket år ammet du sist? ☐☐☐☐

Oppgi dag, måned for utfylling av skjemaet: ☐☐ ☐☐ 2 0 1 2

Takk for at du tok deg tid til å fylle ut skjemaet!

Nasjonalt folkehelseinstitutt

Hjortevilt og bly-undersøkelsen 2012

Skjemaet skal leses av en maskin.
Det er derfor viktig at du:

- **Bruker blå eller sort kulepenn**
- **Setter kryss ☒, ikke slik ☐X**
- **Skriver tallene slik**

0	1	2	3	4	5	6	7	8	9

ID-nummer: ☐☐☐☐☐

1. Kjønn **Kvinne** ☐ **Mann** ☐

2. Alder ☐☐ **år** **Høyde** ☐☐☐ **cm** **Kroppsvekt** ☐☐☐ **kg**

3. Postnummer (bosted): ☐☐☐☐

4. Utdannelse: Grunnskole ☐ Videregående skole ☐ Høgskole, universitet, ol ☐

5. Yrke (spesifiser med blokkbokstaver):...

6. Har du jobbet i dette yrket de siste 5 årene?

Ja ☐ Nei ☐ Hvis nei, hva annet?...

7. Antall voksne (18 år og over) i husholdningen: *Antall:* ☐☐

8. Antall barn (under 18 år) i husholdningen: *Antall:* ☐☐

9. Deltok du som aktiv storviltjeger* jakten 2011? Ja ☐ Hvis ja, fortsett til spørsmål 10

** Med aktiv storviltjeger mener vi at du må ha avlagt storviltprøve, i tillegg til å ha hatt minst én dag på jakt.* Nei ☐ Hvis nei, gå til spørsmål 17

10. Hvilket jaktlag tilhører du?

Jaktlagets navn/nr.. Kommune...

11. Hva jaktet du hovedsaklig jaktsesongen 2011? Elg ☐ Hjort ☐

12. Har du deltatt på annen jakt enn elg og hjort i 2011? Ja ☐ Nei ☐

Hvis ja; hvilken jakt har dette vært?

☐ Annet hjortevilt enn elg og hjort. ☐ Småvilt (uten blyammunisjon).

☐ Småvilt (med blyammunisjon) (Bly i hagl er lovlig i Sverige).

13. Hvor mange jaktdager i 2011/2012 hadde du hvor du benyttet blyholdig ammunisjon? ☐☐☐

(Dette inkluderer blyhagl og alle varianter av blyholdige riflekuler inklusive loddede kuler)

14. Hvor mange blyholdige skudd avfyrte du i 2011? ☐☐☐☐

(Inkluder alle typer skytteraktivitet)

15. I hvor mange år har du benyttet blyholdig ammunisjon, inkludert småviltjakt med blyhagl? ☐☐

16. Lager du din egen blyholdige jaktammunisjon? Ja ☐ Nei ☐ Vet ikke ☐

17. Driver du med innendørs skytteraktivitet hvor det benyttes blyammunisjon? **Ja** ☐ **Nei** ☐

18. I hvor mange år har du spist viltkjøtt* minst to ganger pr år? ☐☐

** Med viltkjøtt mener vi kjøtt av både stor- og småvilt.*

19. Hvor skaffes hjorteviltkjøttet du spiser? *(flere avkrysningsmuligheter)*

Eget eller familiemedlems jaktlag ☐ Andre jaktlag ☐ Kjøpt i butikken ☐ Vet ikke ☐

20. Noen generelle kostspørsmål.

	Aldri	Antall ganger i året 1–5	6–11	Antall ganger i måneden 1	2–3	Antall ganger i uken 1	2	≥3
Hvor ofte spiser du hjortevilt som hovedrett (til lunsj eller middag)?	☐	☐	☐	☐	☐	☐	☐	☐
Hvor ofte spiser du hjortevilt som pålegg?	☐	☐	☐	☐	☐	☐	☐	☐
Hvor ofte spiser du annet kjøtt til middag (fjørfe, svin, annet rødt kjøtt)	☐	☐	☐	☐	☐	☐	☐	☐
Hvor ofte spiser du fisk til lunsj, middag og som pålegg?	☐	☐	☐	☐	☐	☐	☐	☐
Hvor ofte spiser du reker og/eller andre skalldyr?	☐	☐	☐	☐	☐	☐	☐	☐

21. Hvor ofte har du spist følgende de siste 30 dagene?

	Ikke spist	Antall ganger i måneden 1	2	3	Antall ganger i uken 1	2	≥3
Elg, retter med kjøttdeig/karbonadedeig fra eget vilt	☐	☐	☐	☐	☐	☐	☐
Elg, retter med kjøttdeig/karbonadedeig fra butikk/oppdrett	☐	☐	☐	☐	☐	☐	☐
Elg, gryterett/skav	☐	☐	☐	☐	☐	☐	☐
Elg, pålegg/spekemat	☐	☐	☐	☐	☐	☐	☐
Elg, helt kjøtt (stek, biff o.l.)	☐	☐	☐	☐	☐	☐	☐
Elg, innmat	☐	☐	☐	☐	☐	☐	☐
Annet elgkjøtt	☐	☐	☐	☐	☐	☐	☐
Hjort, retter med kjøttdeig/karbonadedeig fra eget vilt	☐	☐	☐	☐	☐	☐	☐
Hjort, kjøttdeig/karbonadedeig fra butikk/oppdrett	☐	☐	☐	☐	☐	☐	☐
Hjort, gryterett/skav	☐	☐	☐	☐	☐	☐	☐
Hjort, pålegg/spekemat	☐	☐	☐	☐	☐	☐	☐
Hjort, helt kjøtt (stek, biff o.l)	☐	☐	☐	☐	☐	☐	☐
Hjort, innmat	☐	☐	☐	☐	☐	☐	☐
Annet hjortekjøtt	☐	☐	☐	☐	☐	☐	☐
Annet vilt enn elg og hjort, helt kjøtt (for eksempel rein, rådyr, fugl)	☐	☐	☐	☐	☐	☐	☐
Annet vilt enn elg og hjort, kjøttdeig (for eksempel rein, rådyr, fugl)	☐	☐	☐	☐	☐	☐	☐
Innmat fra annet vil enn elg og hjort (for eksempel rein, rådyr, fugl)	☐	☐	☐	☐	☐	☐	☐

22. Hvor ofte har du i gjennomsnitt spist følgende de siste 12 månedene?

	Aldri	Antall ganger i året 1–5	6–11	Antall ganger i måneden 1	2–3	Antall ganger i uken 1	2	≥3
Elg, kjøttdeig	☐	☐	☐	☐	☐	☐	☐	☐
Elg, helt kjøtt	☐	☐	☐	☐	☐	☐	☐	☐
Elg, gryterett	☐	☐	☐	☐	☐	☐	☐	☐
Hjort (vill), kjøttdeig	☐	☐	☐	☐	☐	☐	☐	☐
Hjort (vill), helt kjøtt	☐	☐	☐	☐	☐	☐	☐	☐
Hjort (oppdrett), kjøttdeig	☐	☐	☐	☐	☐	☐	☐	☐
Hjort (oppdrett), helt kjøtt	☐	☐	☐	☐	☐	☐	☐	☐
Kjøttdeigblanding av elg og hjort	☐	☐	☐	☐	☐	☐	☐	☐
Rådyr	☐	☐	☐	☐	☐	☐	☐	☐
Tamrein (helt eller oppmalt kjøtt)	☐	☐	☐	☐	☐	☐	☐	☐
Villrein (helt eller oppmalt kjøtt)	☐	☐	☐	☐	☐	☐	☐	☐
Hare	☐	☐	☐	☐	☐	☐	☐	☐
Innmat fra vilt	☐	☐	☐	☐	☐	☐	☐	☐
Innmat fra oppdrettshjort	☐	☐	☐	☐	☐	☐	☐	☐
Vill fugl	☐	☐	☐	☐	☐	☐	☐	☐

23. Hvor ofte har du drukket kaffe og te de siste 30 dagene? *Hvis du ikke drikker kaffe/te hver dag, oppgi hvor mange kopper du pleier å drikke de dagene du drikker kaffe/te.*

	Aldri eller sjelden	Noen ganger i mnd	**Antall ganger i uken** 1–2	3–4	5–6	**Hver dag**	Antall kopper/krus
Kaffe (inkl. alle kaffeformer/typer)	☐	☐	☐	☐	☐	☐	☐☐
Vanlig te	☐	☐	☐	☐	☐	☐	☐☐
Urte/frukt/grønn te	☐	☐	☐	☐	☐	☐	☐☐

24. Hvor ofte har du drukket alkoholholdige drikker de siste 12 månedene?

Hvis du ikke drikker alkoholholdig drikke hver dag, oppgi hvor mange glass du pleier å drikke de dagene du drikker alkoholholdige drikker.

	Aldri eller sjelden	Noen ganger i mnd	**Antall ganger i uken** 1–2	3–4	5–6	**Hver dag**	Antall glass
Øl (3,3 dl pr. glass), alle typer (inkl. alkoholfritt øl)	☐	☐	☐	☐	☐	☐	☐☐
Vin (1,5 dl pr. glass)	☐	☐	☐	☐	☐	☐	☐☐
Brennevin (30 cl pr. glass)	☐	☐	☐	☐	☐	☐	☐☐

ID-nummer:

Hjortevilt og bly-undersøkelsen 2012

Som jaktlagsleder inviteres du herved til å svare på noen ekstra spørsmål **relatert til ammunisjon og håndtering av slakt/kjøtt innad i jaktlaget.** Dette vil gi verdifull tilleggsinformasjon som kan bidra til bedre å forstå eventuelle unormale blyverdier i blodet.

1) **Hvilket jaktlag er du leder i?**

   Jaktlagets navn og nr:

   Jaktkommune:

2) **Hvor mange kilo kjøtt ble fordelt i jaktlaget jaktsesongen 2011?** __|__|__|__|

3) **Ca hvor mange skudd ble det benyttet for å oppnå dette?** __|__|__|__| (regn med alle kuler, også fangskudd mot hodet, ekskluder derimot bomskudd)

4) **Bruker dere flere typer ammunisjon i jaktlaget?** Ja ☐ Nei ☐ Vet ikke ☐

5) **Hvilken hovedgruppe av ammunisjon bruker dere i jaktlaget?**
   - Loddede ☐
   - Uloddede ☐
   - Homogent blyfrie ☐

6) **Hvilke ammunisjonstyper ble dyra skutt med og ca antall av hver type?**

Speer Trophy Bonded	☐ __|__|__|	Lapua Mega	☐ __|__|__|
Norma Oryx	☐ __|__|__|	Sako Super Hammerhead	☐ __|__|__|
Nosler Partition	☐ __|__|__|	Norma Vulcan	☐ __|__|__|
Norma Blyspiss (sp)	☐ __|__|__|	Sako Hammerhead	☐ __|__|__|
Norma Alaska	☐ __|__|__|	Selvladet blypatroner	☐ __|__|__|
Winchester Super-X	☐ __|__|__|		

   Annet (spesifiser) ……………………………………………………….. __|__|__|

   ……………………………………………………….. __|__|__|

   ……………………………………………………….. __|__|__|

ID-nummer:

7) Hvor parteres kjøttet etter at hjortedyret er felt?

Privat ☐ Slaktemottak ☐ Annet ☐

8) Hvor mye av kjøttet som er påvirket av sammenstøt med prosjektilet blir fjernet under partering?

Mye	☐	20 cm eller mer
Middels	☐	10-20 cm
Lite	☐	0-10 cm
Usikker	☐	

9) Hva gjøres med avskjæret av kjøttet?

Forlates i naturen ☐ Kjøttdeig ☐ Hundemat ☐ Avfallsdunk ☐ Annet ☐

10) Hvor viktig anser jaktlaget det er å fjerne kjøtt nær sårkanalen?

Viktig ☐ Litt mindre viktig ☐ Uvesentlig ☐

Takk for hjelpen!

Vennligst send skjemaet i retur til Folkehelseinstituttet så snart som mulig.