Sheep Grazing on Shooting Ranges

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ABSTRACT

Shooting ranges contain contaminations of metals, such as lead and copper, from spent ammunition. In many countries, ruminants are free to graze on shooting ranges. It has been a concern whether the ruminants are at risk from metal poisoning. This combined literature and field study focused on sheep. The sheep did not seem to be attracted to the contaminated areas, but they did not shy away from them either. The soil ingestion found in sheep was very low (<2%) and showed little variation compared to previous studies (0.1-80%). The concentration of copper in grass did not correlate with the copper concentration in soil. For lead, there was a positive correlation between the concentration in plants and soil. The lead concentration in blood and liver samples from sheep that had grazed on the shooting ranges was under the normal concentrations, except one liver sample. A few of the animals that had grazed on the shooting range had copper concentrations in blood and liver exceeding the normal limits. However, this was not due to grazing on the shooting range, as the sheep had the highest copper concentrations in blood before the grazing period. A three-step risk assessment is suggested, where step 1 is general, and step 2 and 3 are site specific. Based on the information on grazing behavior, soil ingestion and accumulation of copper and lead in grass, it can be concluded that sheep grazing on shooting ranges are at little risk of metal poisoning.

1.0 INTRODUCTION

Shooting ranges contain spent ammunition, and is consequently contaminated with metals such as lead (Pb) and copper (Cu). In many countries, for instance Norway and Switzerland, shooting ranges are not fenced, and open to animals. Ruminants such as cattle and sheep often have shooting ranges as part of their rangeland pasture. There has been some incidents where ruminants have been poisoned when grazing on contaminated shooting ranges, for instance Braun et al. (1997). The risk of poisoning of ruminants using shooting ranges as part of their pasture has therefore become a concern in Norway. A study was conducted by the Norwegian Defence Research Establishment (FFI) (funded by the Norwegian Defence Estate Agency) to assess the risk to ruminants grazing on shooting ranges, the study focused on sheep.

The risk to ruminants that have a shooting range or other contaminated area, as a part of their pasture, depends on several parameters:

- Are the animals attracted to ammunition residues or soil contaminated with ammunition residues (or otherwise contaminated with copper and/or lead)?
- How much lead and copper can animals ingest when grazing on contaminated areas?
- How toxic is lead and copper for ruminants and can the animals bioaccumulate the metals?

These parameters will be discussed in the successive sections. The information will be used to suggest a method to conduct a risk assessment for sheep grazing on shooting ranges.

The study presented here, is a literature study, combined with field studies over two seasons. Five areas were included in the field studies, all located in Norway (Figure 1). Four of the studied areas were shooting ranges (Melbu, Hengsvann, Steinsjøen and Leksdal), and one was a cultivated pasture (Kjeller) (Johnsen and Aaneby, 2019, Johnsen et al., 2019). On Steinsjøen, Hengsvann, Leksdal and Kjeller, soil, grass and feces samples were collected once during the grazing season. In Melbu, soil, grass and feces samples were collected three times during the grazing season, and blood samples were collected before and after the grazing season. In Melbu and Leksdal, liver samples was collected from lambs slaughtered in the fall.

Figure 1: Map of Norway with the studied areas marked.

2.0 THEORY, METHODS AND FINDINGS.

2.1 Attraction

Are animals attracted to ammunition residues or soil contaminated with ammunition?

Metal contamination on shooting ranges can be severe, and the concentrations of lead and copper can be very high. Typical lead concentrations in soil on shooting ranges can vary from 100 mg/kg (dw) to more than 50 g/kg (dw). The copper concentrations are usually a bit lower, between 100 mg/kg (dw) to more than 5000 mg/kg (dw). However, the high metal concentrations are often limited to certain areas, such as the bullet trap and the firing point. The highly contaminated areas will therefore constitute a very small part of the total grazing area available to the ruminants. If the ruminants graze equally on the available area, the highly contaminated soil and grass will constitute a very limited part of the ruminant's diet. However, if the ruminants are attracted to the contamination, the lead and copper ingested from these areas might be substantial. Risk assessment for ruminants on contaminated areas should consider the grazing behavior of the animals (Roggeman et al., 2013). Incidents where ruminants have been attracted to areas contaminated with lead are known to have occurred, but all these incidents are related to cattle. For instance, five calves on a farm in Switzerland died from lead poisoning after grazing on an old shooting range (Braun et al., 1997). The contaminated areas on the shooting range only constituted 32 m^2 of the total grazing area of 2000 m^2. The contaminated areas were heavily grazed, while the rest of the area was almost untouched. Which indicated that the cattle might have been attracted to the contaminated soil. Cattle are known to be curious, and often ingest waste such as old car batteries and ash residue (Krametter-Froetscher et al., 2007, Wilkinson et al., 2003, Payne and Livesey, 2010). There are no reported observations of sheep being attracted to lead or other waste products. Sheep can, on the other hand, be attracted to shooting ranges for other reasons, such as the open, sandy space, and the high presence of grass, as opposed to shrubs and scrubs in the forest that often surrounds the ranges (Voie et al., 2010). However, shooting ranges are often situated on mire, which is not a preferred grazing area for sheep.

GPS and wildlife cameras were used to determine the grazing behavior in Melbu and Leksdal. The data was used to assess how much time the sheep grazed on the contaminated areas. The surveillance data from the two areas showed that sheep were attracted to certain areas, such as firing point houses and bullet traps. The attraction seemed to be for sheltering reason and was independent of the contamination in the areas. The results led to the conclusion that the sheep were not attracted to the contaminated areas, but they did not shy away from these areas either. However, the sheep did shy away from mire. The sheep did not graze equally on the available rangeland. They wandered until they found their preferred area, where they grazed for the season. For some sheep, this area was small, for others, it constituted a larger part of the total available area. Some sheep had the shooting range as their main grazing area throughout the season. Wildlife cameras monitored the most contaminated areas on the shooting ranges, and sheep were observed on these areas approximately 10% of the time.

2.2 Ingestion of Metals

How much metal can animals ingest when grazing on contaminated areas?

The amount of metal the sheep (and other ruminants) can ingest while grazing on shooting ranges is dependent on the grazing behavior (as described in the previous section). In addition, it depends on the concentration of lead and copper in the plants and soil, and the amount of soil they ingest.

In this study, samples of soil, grass and sheep feces were collected on all the ranges included in the study. On Melbu, samples were collected three times during the season (mid May-mid September). Samples were collected according to the multi increment sampling method (MIS)(Walsh and Voie, 2016). Copper and lead concentration in soil and grass was analyzed, and used for dose calculation and determination of metal accumulation in plants. In feces and soil, the titanium concentration was analyzed, and used to calculate the soil ingestion rate.

2.2.2 Soil Ingestion

It is assumed that the majority of the metal ruminants ingest from grazing on contaminated areas comes from the direct ingestion of soil (Smith et al., 2009). If the soil ingestion rate is low, a greater part of the ingested metal can come from grass/plants. The metals in plants are more bioavailable than the metal in soil. Sheep graze close to the ground, and as a consequence they might ingest more soil than cattle (Payne and Livesey, 2010). Some young animals, especially calves, might eat soil on purpose because of mineral deficiency, this is called pica (Zmudski et al., 1983, NAS, 1980). Mayland et al. (1975) described a method for determining the soil ingestion rate in ruminants, using titanium as a tracer. Soil usually contains relatively high concentration of titanium, while plants contain very low concentrations of titanium. Titanium is not taken up in animals, and if the titanium concentration in feces and soil is analyzed, the soil ingestion rate can be calculated. Figure 2 shows an illustration of the ingestion route of metals from spent ammunition and how soil ingestion can be found using titanium as a tracer. Studies have showed that soil ingestion varies a lot through the season and with weather. In sheep, soil ingestion from 0.1 – 80% has been found (Healy, 1967, Smith et al., 2009). Generally, the soil ingestion is highest during the winter and wet periods. Previous risk assessments have used 5-30% soil ingestion in calculations (Herling and Andersson, 1996, Bernhoft, 2011, Rupflin and Krebs, 2015).

The soil ingestion found in this study did not exceed 2% in any of the areas, and did not exceed 1% in the shooting ranges. Even in areas with high metal concentrations in the soil (>3000 mg Pb/kg and >1000 mg Cu/kg), calculations suggest that sheep are unlikely to ingest toxic amounts of metals trough soil, because of the low soil ingestion rate. In this study, the variation between the different soil ingestion rates was very low. Taking into account that the soil ingestion rates were based on samples collected from five different areas in Norway, in different weather conditions and at different times of the grazing season, the soil ingestion found should be considered a good estimate for Norwegian conditions.

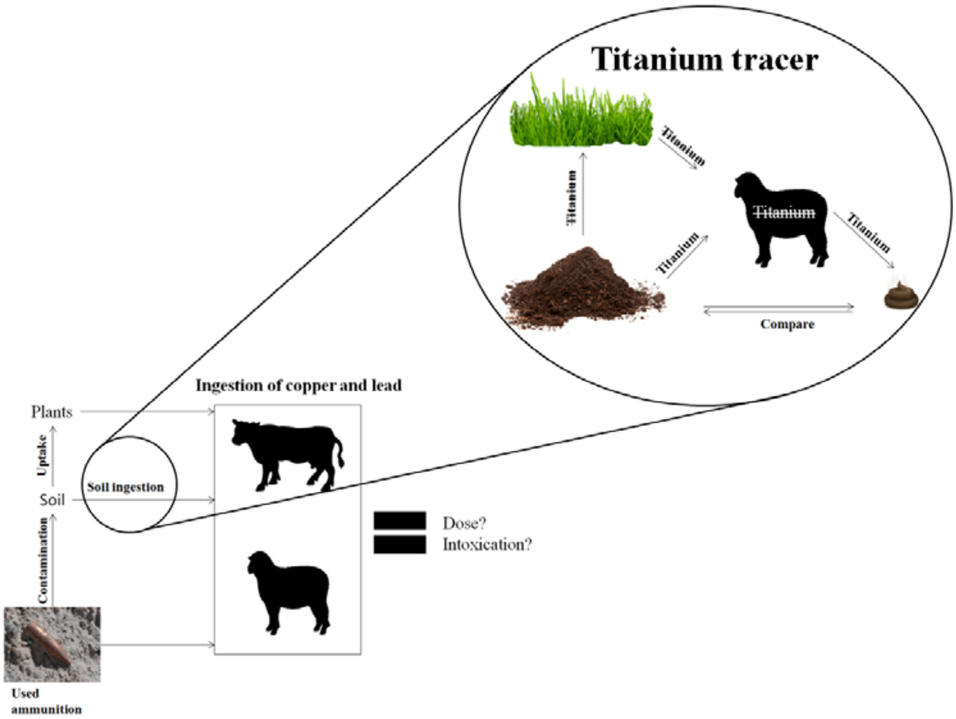

Figure 2: Route of exposure of used ammunition to ruminants, and the use of titanium as a tracer for the determination of soil ingestion rate. The figure has previously been published in Johnsen and Aaneby (2019).

2.2.2 Accumulation in Plants

The uptake and accumulation of ammunition related metals in plants vary between species, soil type, and the bioavailability of the metal. Copper is an essential element for plants. The uptake of copper is therefore regulated by the plant, and the copper concentration in the soil is of less importance (Evangelou et al., 2012). Lead has no known function in plants, and plants do not regulate the uptake if lead. A high concentration of lead in soil can lead to increased uptake of lead in plants (Evangelou et al., 2012, Cai et al., 2009).

Grass is another route of exposure to metals for ruminants. In this study, a positive correlation between the lead concentration in soil and grass was found, but such a correlation was not found for copper. Norway and EU have a limit for copper in fodder of 15 mg/kg. Switzerland has a limit for both sheep (17 mg/kg) and cattle (40 mg/kg)(Rupflin and Krebs, 2015). Several of the grass samples had copper concentration exceeding the Norwegian/EU limit for copper in sheep fodder. These samples were collected both from the areas with high soil copper concentrations, and from the reference areas outside the shooting ranges with low soil copper concentrations. The limit for lead in (green) fodder set by EU is 33.6 mg/kg (dw). Lead concentrations above the limit was found in 3/33 samples, all collected from areas with high lead concentration in the soil. Potentially, grass ingestion could cause lead poisoning, if the sheep grazed mainly on highly lead contaminated areas over a substantial period.

2.3 Toxicity and Bioaccumulation

How toxic is lead and copper to ruminants and can the metals bioaccumulate in the animals?

Lead poisoning is, according to monitoring of British cattle, the far most common poisoning in bovine (about 50%), while copper poisoning is less common, but still substantial (under 30%) (Payne et al., 2004, VIDA, 2006a, VIDA, 2014a). For sheep, copper poisoning is the most common type of poisoning (about 70%) (Guitart et al., 2010, VIDA, 2006b, VIDA, 2014b). Lead poisoning is more often acute than chronic. For acute lead poisoning, lead will mostly be found in liver and kidney. For long term exposure, lead will be stored in the bones. Sheep are particularly prone to copper poisoning because they have limited storage capacity in the liver (Bradley, 1993). Sheep can suffer from copper poisoning even when the copper concentration is below the recommended level, if the molybdenum concentration is too low, because molybdenum binds copper and makes it less bioavailable (Hidiroglou et al., 1984, Buck and Sharma, 1969). Copper poisoning is most often chronic.

In this study, liver samples were collected when lambs were slaughtered in the autumn (in Melbu and Leksdal). Blood samples were collected before and after the grazing period (May and September/October)(in Melbu).

The lead concentrations in the liver samples from lambs that had grazed on the contaminated shooting ranges were low. The concentrations were below the normal value (3 mg/kg [dw]) in all the samples except one (3.7 mg/kg [dw]), but also in this sample the concentration was far below the poisonous concentration (10 mg/kg [dw]) (NAS, 1980). The copper concentrations in the liver samples were above the limit for normal concentration (300 mg/kg [dw]) in several of the samples. The highest concentration was 1877 mg/kg (dw), and exceeded the limit for risk of poisoning (1000 mg/kg [dw]) (NAS, 1980). However, no correlation between the elevated copper concentrations and the grazing area was found. This indicated that the grazing on contaminated shooting ranges did not affect the copper concentration in the liver.

None of the sheep had elevated concentration of lead in the blood (normal <0.25 mg/kg), but some had elevated concentration of copper (normal <1.35 mg/kg) (Buck and Sharma, 1969). Contrary to the expected, the sheep had significantly higher copper concentration in blood before than after the grazing period. The results indicated that the copper concentration in the fodder given at the farm before the grazing period might have been elevated. This can also explain the elevated copper concentration in the liver samples.

3.0 RISK ASSESSMENT

When performing a risk assessment, several assumptions must be made. For instance, the toxic doses from literature is usually based on metal salts, which is more bioavailable than metals from ammunition.

The data collected in this study was used to conduct a risk assessment for sheep grazing on the shooting ranges in the study. Theoretical doses of ingested metal were calculated using Equation (1).

$$D = \frac{(S \times F \times SI) + (P \times F \times (1 - SI))}{BW} \times T \qquad (1)$$

D - Ingested dose per day (mg/kg bw/day)
S – Metal concentration in soil (mg/kg)
F – Amount of fodder the animals eat in a day (dw) (kg)
SI – Soil ingestion rate
P – Metal concentration in plant/grass (mg/kg)
T – Share of time spent grazing on the contaminated area
BW – Body weight of the animal (kg)

Even when assuming that the sheep grazed only on the most heavily contaminated areas, the doses calculated in this study were below both the chronic and acute toxic doses given in literature (Table 1). The reason for this was the low soil ingestion combined with the low accumulation of metals in the plants.

A general risk assessment method, inspired by the Swiss method (Rupflin and Krebs, 2015) was developed, suggesting a three step approach.

3.1 Step 1

Exclude areas that certainly will not give any effects.

This involves using a conservative soil ingestion rate, and assuming lambs, which are most susceptible to poisoning, only graze on contaminated areas. According to the findings in this study, this type of grazing behavior is not expected. However, only grazing on the contaminated areas is considered in this step, because it is an easy first step, and it will exclude areas that certainly will not poison the animals. If the values are under the risk levels in table 2, all other animals should also be protected. There is no reason to collect information on the grazing behavior on a specific range, if the concentrations does not exceed the ones described in table 2.

A conservative soil ingestion rate of 5% was used for the calculations in this section. Table 1 shows the other input data used in calculations. It is assumed that the sheep only graze on the contaminated areas. If the concentrations in the soil or plants exceed the values listed in table 2, one must proceed to step 2 of the risk assessment. No extra safety margin was used in this risk assessment. This was considered unnecessary because less than 100% of the copper and lead in the soil will be bioavailable, thus this serves as a natural safety margin.

Table 1: Data used in calculations for soil limit values showed in table 2.

		Lamb	Sheep
Chronic toxic dose (mg/kg body weight/day)	**Cu**	0.35	0.35
	Pb	1	4.4
Body weight (kg)		15	75
Intake of fodder per day (kg)		0.45	1.3

Table 2: Concentrations that should not be exceeded in soil and grass where sheep are grazing.

	Cu mg/kg	Pb mg/kg
Sheep (soil)	404	5077
Lamb (soil)	233	667
Plants (limit value in grass)	17	30

3.2 Step 2

Theoretic site specific approach.

In this step, the size of the contaminated area compared to the grazing area is taken into account. It is important not to use the whole available grazing area, as one sheep does not use several square kilometers as their primary grazing area. Mapping of the grazing pattern of the ruminants in the area of interest might be necessary for this step. The values from step 1 (table 2) were plotted against the time the animals grazed on the contaminated area (from 0.01=1% of the time to 1=100% of the time). This means that 5% soil ingestion was still used, which, according to this study, is quite conservative. The values for lambs were used, as they are most sensitive. One assumption made in this risk assessment is that the animals are not attracted to the contaminated areas, as our study showed that this was the case. If the risk assessment is in or near the black area (figure 3 and 4), one must proceed to step 3 of the risk assessment.

Examples:
If the soil contains 2000 mg/kg copper, but the lambs only use 5% of their time in the contaminated areas, you are in the grey area, end there should not be a risk of poisoning.

If the area has a soil lead concentration of 2000 mg/kg, and the lambs are grazing on the contaminated areas for 50% of their time, you are in the black area, and there is a risk of poisoning. Move on to step 3.

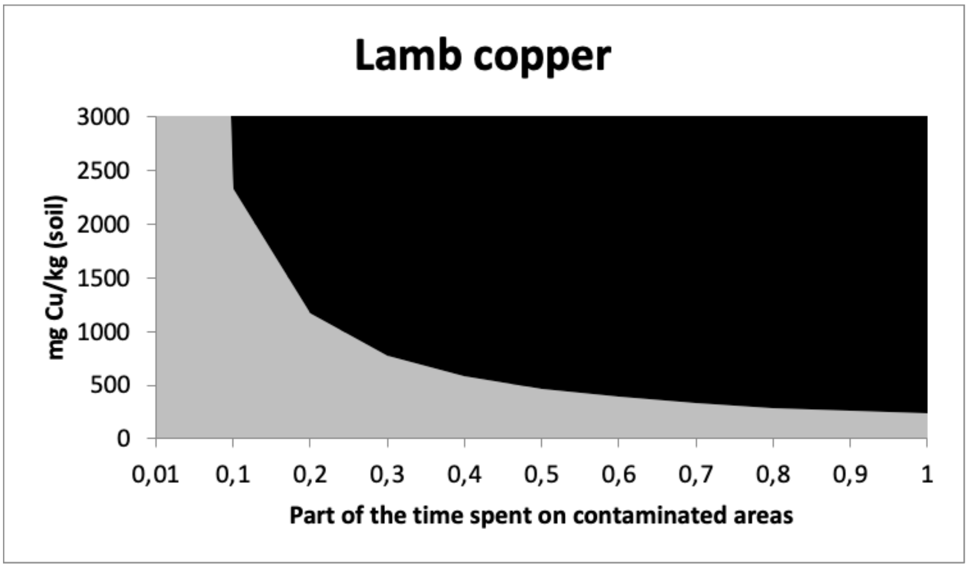

Figure 3: The soil copper concentrations from step 1 was used further in this step. The soil concentration is plotted against the amount of time the lamb grazes on contaminated area. Grey=no poisoning, black=risk of poisoning.

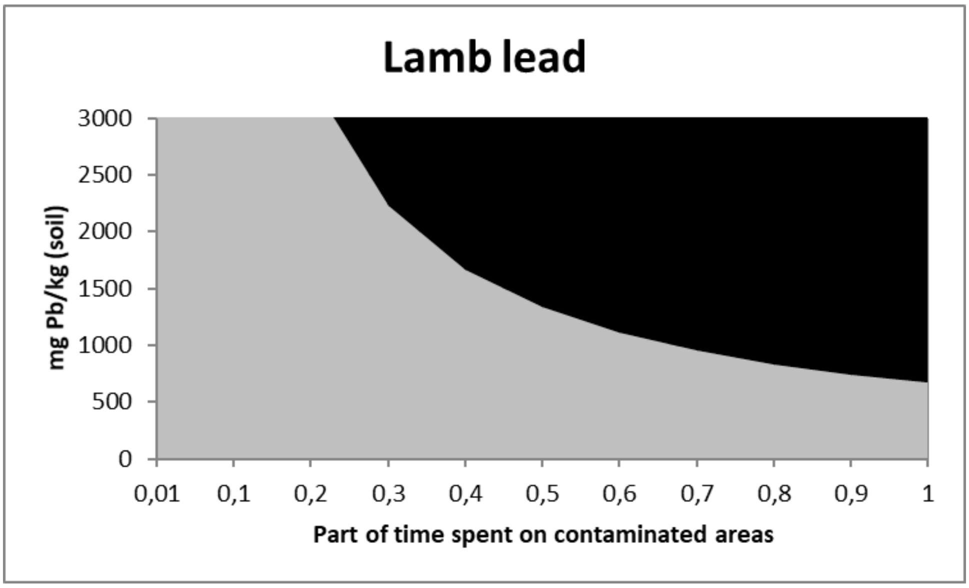

Figure 4: The soil lead concentrations from step 1 was used further in this step. The soil concentration is plotted against the amount of time the lamb grazes on contaminated area. Grey=no poisoning, black=risk of poisoning.

3.3 Step 3

Site specific data collection.

In most cases, step 1 and 2 will be sufficient to perform a risk assessment for sheep grazing on shooting ranges. If there is still a doubt, site specific data needs to be collected.

1. Quality of pasture
   a. Are several animals grazing in a small area?
   b. Does the pasture have good quality? Is the quality of the pasture on the contaminated areas better or worse than the surrounding areas?
2. Grazing behavior
   a. Ask farmer or shooting range officer
   b. GPS and/or wildlife cameras
3. Collect feces, soil and grass samples in the area to determine soil ingestion rate and metal accumulation in plants.
4. Collect blood and/or liver samples from animals after the grazing period.

The collected data can be used to calculate ingested doses specific for the area. If blood or liver samples are collected and the concentrations do not exceed the limit value for lead or copper, it can be assumed that the animals are not ingesting concentrations of metals that can lead to poisoning.

4.0 CONCLUSION

Based on the information on grazing behavior, soil ingestion and accumulation of copper and lead in grass, it can be concluded that sheep grazing on shooting ranges are at little risk of metal poisoning. Samples were only collected in 5 different areas, all in Norway, thus it cannot be concluded that this conclusion is valid everywhere. However, the data gathered is probably sufficient to recommend that the rigid risk assessments where 15-30% soil ingestion is used should be reconsidered. The copper and lead concentrations measured in blood and liver samples supported the dose calculations based on soil ingestion and grazing behavior. Instead of banning ruminants from grazing on shooting ranges, site-specific risk assessments should be performed.

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