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Toxicity of Compound 1080 Livestock Protection Collars to Sheep

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Abstract. The toxicity of Compound 1080 (sodium fluoroacetate) livestock protection collars (LPCs) to sheep was investigated. Lambs wearing punctured LPCs were observed to determine dermal toxicity, sheep were fed hay treated with LPC solution to find a lethal concentration, hay treated with a lethal concentration was subjected to sun and simulated rain to assess weathering influences, and sheep were held on pasture treated with LPC solution to evaluate grazing effects. Five lambs that wore punctured LPCs for up to seven days showed no dermal erythema or edema, but three died after ingesting 1080 from LPCs. All sheep died after eating 1.0 kg of hay treated with 3.75 ml, or more, of 1.0% LPC solution. Weathering 1.0 kg of hay treated with 3.75 ml of LPC solution in the sun for up to 12 weeks, reduced, but did not eliminate, toxicity; one inch or more of simulated rain eliminated toxicity. Survival of sheep in 250 m^2 pens containing 1.1 m^2 of forage treated with different amounts of LPC solution depended on the treatment and amount of treated forage consumed. LPC solution poses no dermal toxicity or irritation to sheep, and toxic effects on sheep from LPC solution on hay and forage was variable and situation dependent. Under conditions of exaggerated hazard, sheep can be poisoned by ingesting LPC solution, but adverse effects from normal LPC use are rare.

The livestock protection collar (LPC) containing 30 ml of a 1.0% solution of Compound 1080 (sodium fluoroacetate) was approved by the U. S. Environmental Protection Agency (EPA), Registration No. 56228-22, for managing predation by coyotes (*Canis latrans*) that attack domestic sheep or goats (Moore 1985). Two LPC configurations are available—a small collar for animals weighing under 22.7 kg (50 lbs); and a large collar, approved by EPA in July 1993, for larger sheep and goats. LPCs consist of two black rubber pouches, each holding 15 ml of solution. Velcro straps are sewn to the rubber portion and used to secure LPCs to the throats of sheep and goats. Coyotes that attack collared livestock usually puncture LPCs and ingest lethal doses of solution (Connolly and Burns 1990).

Compound 1080 is highly toxic to most mammals (Ward and Spencer 1947), including horses (Frick and Boebel 1946), cattle (Robison 1970), and sheep (Jensen *et al.* 1948). Collars are used primarily on sheep; hence, sheep are most likely to be exposed, directly or indirectly, to free LPC solution. In early investigations, six test lambs died within 2.5 days after removal of defective, leaking LPCs. It was apparent that the sheep died from eating 1080 (Connolly 1979 as cited in Connolly 1980:123), but little else was known about the danger to livestock from leaking LPCs or spilled collar solution. Although subsequent design modifications resolved the problems with leaking collars, operational use can occasionally expose livestock to solution from torn, or otherwise damaged, LPCs (Walton 1990).

The information reported here was collected on LPC solution toxicity, and on toxicity reduction by weathering, to assess the potential hazard of leaking collars and spilled LPC solution to sheep.

Materials and Methods

Investigations were conducted from September 1981 through June 1983 at a predator research site of the Denver Wildlife Research Center (DWRC) near Logan, Utah. Compound 1080 (Tull Chemical Co Inc, Oxford, AL)[1] that contained at least 90% active sodium fluoroacetate was used. LPCs, purchased from Ranchers Supply, Alpine, TX, were filled with a solution that contained 10 mg active ingredient 1080 and 5 mg rhodamine B/ml H_20. The rhodamine B, a purple dye, was included to indicate spilled collar solution.

Sheep were observed at least daily to check health and detect signs of 1080 intoxication. In mammals, signs vary from progressive depression to epileptiform convulsions and death (Ward and Spencer 1947).

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[1]Mention of commercial products for identification in this paper does not imply endorsement by the U. S. Department of Agriculture.

Sublethal indications include respiratory, central nervous system, and muscle involvement shown by dyspnea, ataxia, weakness, tremors, convulsions, and increased salivation, urination, and defecation (Hudson *et al.* 1984).

Tissue samples of skeletal muscle from hips or hips and necks of test animals that died from possible LPC-solution exposure were collected and analyzed for 1080 residue at the DWRC using a Hewlett-Packard Model 5880A gas chromatograph with a SPB-1 (30 ml) capillary column (Okuno *et al.* 1982). The process is capable of detecting 0.1 ppm (1 ppm = 1 mg/kg) 1080 in 1 g of animal tissue by extraction of 1080 with acetone-water, then evaporation of the acetone followed by extraction of 1080 as fluoroacetic acid from the water with ethyl acetate. Ethyl acetate is removed by volatilization from fluoroacetic acid which is retained as the triethanolammonium fluoroacetate salt. Fluoroacetic acid is subsequently derivatized with alpha-bromo-2,3,4,5,6,-pentafluorotoluene and quantified by gas-liquid chromatography with an electron capture detector.

Toxicity from damaged collars was evaluated using five lambs (25-45 kg) fitted with large LPCs containing 60 ml of solution (twice the amount currently registered). Each pouch of the LPCs was punctured with a scalpel leaving 1-cm slits in the side placed against the sheep to provide dermal exposure. The lambs were placed in a 1-ha pen for one week. Tissue samples of hip muscle were collected from all sheep when they died, either from exposure or following euthanasia by injection of T-61 at the end of the exposure period.

Effects of exposure to sheep from spilled LPC solution were examined in tests with baled alfalfa (*Medicago sativa*) hay and standing green forage. During tests with hay, seven adult ewes were confined individually in 2.6 m long × 1.4 m wide × 1.9 m high pens with concrete floors. The sheep had unlimited water and were fed alfalfa hay daily. Preliminary monitoring indicated that each sheep consumed about 1.0 kg (range [ra] = 0.9–1.1 kg) of hay per day.

First, one daily hay ration was treated with 0.94, 1.88, 3.75, or 15 ml of LPC solution. Each ration was air dried and offered to a ewe to determine the lethal treatment level. Two to three sheep were tested per treatment, and because of a shortage of test animals, two ewes that survived their first treatment and showed no signs of intoxication for 6-7 days were reused.

Second, daily alfalfa rations were treated with 3.75 ml of collar solution, the lowest treatment level fatal to all sheep tested above, and subjected to sunlight or simulated rainfall from a lawn sprinkler to investigate weathering effects on the toxicity of 1080-treated hay to sheep. Treated alfalfa (1.0 kg) was exposed to sun and protected from precipitation under clear glass for 2, 4, 6, and 11-12 weeks, and to simulated rain from a lawn sprinkler until rain gages on opposite sides of the treated hay registered an average of 0.32, 0.64, 1.27, 2.54, or 5.08 cm (1/8, 1/4, 1/2, 1, or 2 inches) of water. Sprinkler water accumulated at 2.54 cm per 40-45 min. The treated hay subjected to sunlight or simulated rain (after drying) was fed to ewes.

Earlier studies showed that areas of pasture contaminated by toxicant from coyote-punctured LPCs varied between 1.1 and 28 m^2 (Connolly 1980). Presuming that the hazard to sheep would be greatest where spills were concentrated, the smallest contaminated pasture area (1.1 m^2) was selected for hazard assessment with sheep. Trials were conducted with a single adult ewe in a 250 m^2 pen that supported alfalfa, grasses, and forbs. Vegetation on a 1.1 m^2 area in each pen was treated with LPC solution squirted from a syringe. The area was treated as evenly as possible using a needle with its tip flattened to produce a fine spray. A ewe was kept in each pen for seven days or until she died. The location of sheep feeding was determined by the clipped forage. The test schedule in 1982 included two ewes exposed to 30 ml LPC solution on 9 June, four ewes (2 on 22 June and 2 on 12 July) exposed to 20 ml, and two ewes exposed to 10 ml on 15 June. Additionally, a trial was conducted on 21 June 1983 to find if sheep were attracted to wet forage. Two sheep deprived of feed overnight and water for 3 h entered pens immediately after forage treatment with 30 ml of LPC solution containing only water and Rhodamine B (no 1080).

Table 1. Sodium fluoroacetate residue in duplicate analyses of skeletal muscle from lambs exposed to Compound 1080 solution from leaking Livestock Protection Collars

Lamb number	Exposure type	Amount detected (ppm)[a]	
		hip muscle	neck muscle
1	oral and dermal	0.24 0.22	0.19 0.36
2	oral and dermal	0.05 0.05	0.05 0.05
3	oral and dermal	TR[b] TR	TR TR
4	dermal	ND[c] ND	ND ND
5	dermal	ND ND	ND ND

[a] 1 ppm = 1 mg/kg
[b] Trace amount detected but not measurable
[c] None detected; if present, below detection limit of 0.05 ppm

Results

In the experiment with leaking LPCs, one lamb, number 2, was exposed to about 30 ml of collar solution, because only one of two LPC pouches drained. Each of the other four lambs was exposed to 60 ml of collar solution. Three of five test lambs died from ingesting 1080. Formulation dye indicated that the solution ran forward along the throat to the mouth, so that the lambs ingested lethal doses while feeding.

Muscle samples from the three orally contaminated lambs contained toxic residues that averaged 0.09 ppm (ra = trace [tr]-0.24) in hip muscle and 0.11 ppm (ra = tr-0.36) in neck muscle. The two surviving lambs had only dermal exposure and showed no detectable residue in muscle tissue samples (Table 1). At necropsy, none of the five lambs exhibited dermal erythema or edema on skin exposed to LPC solution.

Feeding hay treated with varying amounts of LPC solution showed that all four sheep fed hay treated with 3.75 ml of LPC solution, or more, died; two of three died at the 1.88 ml treatment; and one survived two separate feedings at the 0.94 ml treatment. Average toxicant residue in hip muscle from sheep that died was 0.20 ppm (ra = none detected-0.47) (Table 2).

Sheep that fed on hay treated with 3.75 mg LPC solution and exposed to sunlight for varying lengths of time showed the following: two weeks of sun exposure to hay, two of two sheep died; four weeks of sun exposure, one of two died; six weeks of sun exposure, two of two died; and 11–12 weeks of sun exposure, one of two died. Hence, the toxicity of 1080 to sheep appeared to have been slightly reduced by 12 weeks of exposure to sunlight. Hip muscle samples from dead sheep showed an average toxic residue of 0.11 ppm (ra = 0.06–0.17).

Sheep that fed on hay treated with 3.75 ml of LPC solution and subjected to simulated rainfall showed the following: 0.32 cm of water, one of two died; 0.64 cm of water, one of two died; 1.27 cm of water, two of four died; 2.54 cm of water, neither of two died; and 5.08 cm of water, neither of two died. Apparently 2.54 cm or more of simulated rain eliminated toxicity to sheep even though dye was still visible on some hay. Hip muscle samples from dead sheep had an average residue of 0.13 ppm (ra = 0.09–0.16).

Sheep that fed in pens containing 1.1 m^2 of forage treated with LPC solution showed varying results. Two of two sheep died when exposed to 30 ml of solution on forage. Treated forage was wet and the untreated forage was dry. The sheep appeared to feed selectively on treated forage. In a similar trial,

Table 2. Sodium fluoroacetate residue detected in hip muscle tissue samples from sheep that consumed hay treated with Livestock Protection Collar solution[a]

Amount applied (ml)	Date consumed	Sheep number	Response observed	Hip muscle residue (ppm)[b]
15.00	05-26-82	6	Died on 5-26	0.39
15.00	05-26-82	7	Died on 5-27	0.47
3.75	06-15-82	9	Died on 6-16	0.19
3.75	07-19-82	14	Died on 7-20	0.07
1.88	06-09-82	8	Died on 6-10	0.06
1.88	06-09-82	9	Survived, no signs of intoxication	NS[c]
1.88	07-28-82	12	Died on 8-01	ND[d]
0.94	07-19-82	15	Survived, no signs of intoxication	NS
0.94	07-26-82	15	Survived, no signs of intoxication	NS

[a] LPC solution contained 10 mg active ingredient 1080/ml and was applied to 1.0 kg of alfalfa
[b] 1 ppm = 1 mg/kg
[c] Not sampled; samples were not collected from survivors
[d] None detected; if present, below detection limit of 0.05 ppm

however, pasture treated with 30 ml of water and dye only neither attracted nor repelled two sheep that were deprived of feed overnight and water for three hours. One of four sheep died and the other three showed no apparent effects after exposure to 20 ml of solution that had dried on forage; two of the three survivors fed on treated forage. Neither of two sheep died or showed ill effects after exposure to 10 ml of LPC solution dried on forage; only one of the two fed on treated forage. Sheep that died from ingesting treated forage had hip-muscle residues averaging 0.36 ppm (ra = 0.21–0.47).

Discussion

Pattison (1959) reported that 1080 was not readily absorbed through intact skin. Results reported here corroborated Pattison (1959) and indicated that sheep would not be affected by dermal exposure to 1080 solution from damaged LPCs. The limited oral toxicity information, also reported here, suggested that the LC_{50} of 1080 in a daily ration of hay was slightly below 0.4 mg/kg, which is within the LD_{50} range, 0.25–0.50 mg/kg, for 1080 to sheep (Atzert 1971).

The toxicity of spilled LPC solution is apparently influenced little by sunlight, but can be substantially reduced by rain. Similar results were reported by McIlroy *et al.* (1988) for 1080 toxicity in meat baits affected by rainfall treatments, and by Griffiths (1959) for 1080 potency in oat and carrot baits influenced by sunny weather and 1 1/2 inch (3.81 cm) of rain.

The effects on sheep of standing forage contaminated with LPC solution was quite variable and depended on treatment quantity and amount of feeding on treated forage. In one test, sheep appeared to feed selectively on treated forage, but this behavior was not repeated. In general, more animals died with higher treatment levels, and residue levels tended to be highest in animals consuming greater amounts of toxicant; the results were consistent with earlier dose-residue information (Okuno *et al.* 1984).

Livestock poisoning can result from 1080 in LPC solution when exposure is exaggerated by leaking from large LPCs containing twice the registered amount, by feeding contaminated hay to confined sheep, and by restricting sheep to small areas with contaminated forage. However, such poisoning is extremely rare with LPCs used under field conditions (Connolly 1980, 1993; Walton 1992).

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