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ABSTRACT: Tracerite®,the chemical marker used in M-44 cyanide capsules, contains cadmium which the Environmental Protection Agency identified as an inert ingredient of toxicological concern. An alternative nontoxic marker was identified and tested. In a weathering test, capsules with Day-Glo® performed as well as those containing Tracerite, and presence of potassium chloride in the capsules did not improve capsule function. Day-Glo was further tested by allowing captive coyotes to discharge M-44s containing sodium cyanide and various colors of Day-Glo. Twelve of 13 coyotes that died or were euthanized soon after recovering from sublethal doses had obvious marks in their mouths for 4 to 5 weeks. On the basis of these tests, the registered formulation for M-44 capsules was changed; Tracerite and KC1 were deleted and Day-Glo Blaze Orange was added.

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INTRODUCTION

Various types of sodium cyanide (NaCN) ejectors have been used for coyote (Canis latrans) damage control since about 1940 (Connolly and Simmons 1984). These devices, including the present M-44, are set in the ground with the baited tops exposed. When a coyote bites and pulls the top, a spring-loaded plunger expels a lethal dose of cyanide from a sealed capsule into the coyote's mouth. The M-44 is an important tool in the federal Animal Damage Control (ADC) program (Connolly 1988). There have been many attempts to improve the M-44, including evaluation of toxicants other than sodium cyanide (Connolly et al. 1986), but marking agents have received little attention.

The cyanide formulation used in M-44 capsules was registered by the Environmental Protection Agency (EPA) in September 1975 (Train 1975). The formulation included a zinc-cadmium sulfide complex called Tracerite® (Metronics Associates, Palo Alto, CA)[1] to help identify animals killed by M-44s used in the ADC program. Subsequently, EPA identified cadmium as an inert ingredient of toxicological concern (Moore 1987). Continued use of Tracerite in any pesticide formulation will require extensive and expensive studies. Additionally, Tracerite is not an ideal marker because it is only visible under ultraviolet (UV) light and is difficult to detect under field conditions.

Field personnel need a visual marker to help identify animals killed by M-44s, reduce the likelihood of erroneously attributing deaths of nontarget animals to M-44s, and deter thefts of coyotes killed by M-44s. Theft is a problem when fur is prime and valuable. The ideal marker should be detectable in either normal or UV light on all animals killed by M-44s.

The foregoing considerations prompted the Denver Wildlife Research Center (DWRC) to seek a new marking agent for M-44 capsules. After discussions with colleagues, we decided to assess Day-Glo® (DG) fluorescent particles (Day-Glo Corporation, Cleveland, OH) for this purpose. DG is used in a wide range of commercial products, and has been used in wildlife research to mark roosting red-winged blackbirds (Agelaius phoeniceus) and weaver finches (Quelea quelea) in movement studies (Knittle et al. 1987, Johns et al. 1989). We evaluated DG in a weathering test of M-44 cyanide capsules and in a marking test where penned coyotes discharged M-44s.

[1]Mention of manufacturers' names in this paper does not imply endorsement by the U. S. Government.

METHODS

Weathering Test

The registered formulation for M-44 cyanide capsules was compared with two modified formulations in a field weathering test to determine if changes in ingredients would influence cyanide stability in capsules under field conditions. Capsules were placed outdoors for 4 to 6 months, then examined for caking (solidification of contents), discoloration, or other deterioration that might adversely affect efficacy. The test was replicated geographically to encompass the range of environmental conditions in which M-44s are used by the ADC program. One site each was selected in western Oregon, southern Arizona, southern Texas, and eastern Montana. All weathering trials were conducted between August 1984 and March 1985. Actual dates of capsule exposure at each site were: 8/13/84 to 2/27/85 (AZ); 8/19/84 to 1/4/85 (TX); 8/30/84 to 2/1/85 (OR); and 9/13/84 to 3/27/85 (MT).

Capsules were loaded in a climate-controlled room at the Pocatello Supply Depot, Idaho, with relative humidity maintained at 30 to 40% while capsules were being filled. Three formulations were compared: (1) the standard registered formula, (2) the standard formula without KCI, and (3) the standard formula with KCI deleted and DG substituted for Tracerite (Table 1).

Weathering sites and cooperators were identified in consultation with personnel in ADC state and district offices. Before trials began, plots were selected that could be protected from human interference for 6 months and permission obtained for their use. The 50 x 60-foot (or larger) plots were fenced to exclude livestock or other animals that might disrupt the test and posted with M-44 warning signs.

As mentioned, the test included 3 treatments at each of the 4 sites. The experiment was laid out in 2 replications, with 25 capsules in each of the 3 treatments in each replication. This resulted in 50 capsules per treatment at each of the 4 sites (600 capsules total).

Table 1. M-44 cyanide capsule formulations subjected to "weathering" (outdoor exposure) for 4 to 6 months in 4 western states between August 1984 and March 1985.

Lot number	Capsule description	Capsule formulation: Ingredient	Percent[a]
1	Standard product (registered formulation)	NaCN[b] (99% A.I.)[c]	89.52
		Celatom MP-78[d]	5.59
		KCl	4.66
		FP Tracerite yellow (Net weight: 0.91 g per capsule)	0.23
2	Standard product minus KCl	NaCN (99% A.I.)	93.46
		Celatom MP-78	6.29
		FP Tracerite yellow (Net weight: 0.81 g per capsule)	0.25
3	Standard product minus KCl and Tracerite and plus Day-Glo	NaCN (99% A.I.)	91.82
		Celatom MP-78	6.18
		Day-Glo AX-17N	1.00
		Day-Glo AX-15 (Net weight: 0.86 g per capsule)	1.00

[a]Percent by weight.
[b]NaCN contains 99% A.I. and is manufactured by Mallinkrodt Inc., Paris, KY.
[c]A.I. = active ingredient.
[d]Celatom MP-78 contains 92% diatomaceous silica and is manufactured by Eagle-Picher Industries Inc., Cincinnati, OH.

Capsules were set in blocks to keep them upright (simulating normal orientation in M-44 ejectors) and placed inside the fenced plots. Subsequently, at about 14-day intervals, 20 capsules (5 from each of 4 selected lots) in each plot were examined for evidence of deterioration. When deterioration was detected on an individual plot, the experiment was terminated at that site and all capsules were packaged and shipped to the DWRC field station in Twin Falls, Idaho, for evaluation. Daily weather records for the dates of capsule exposure were obtained from nearby weather stations. After the test, each plot was restored to its original condition.

Capsules were evaluated at the DWRC field station in Twin Falls, Idaho. Each capsule was opened and its contents evaluated visually for signs of discoloration and caking of the cyanide mixture.

Marking Test

During the M-44 pen tests, captive coyotes were maintained in sheltered kennels that were cleaned daily. They had continuous access to fresh water, were fed daily (except Sunday), and were checked daily for general well-being. For each test, a standard model M-44 ejector loaded with a capsule containing NaCN and a DG marker was set inside a 250 m^2 chain-link fenced enclosure and baited with a familiar food. Test coyotes were individually released into the enclosure and observed from an overlooking building until they discharged the M-44 or showed no interest in the device after it was detected. After each trial the ground around any discharged M-44 was heavily watered to remove any residual NaCN.

Three combinations of colors were tested with NaCN in M-44 capsules: 0.050 g Blaze Orange (GT-15-N) with 0.750 g NaCN, 0.025 g each of Blaze Orange and Saturn Yellow (GT-17-N) with 0.750 g NaCN, and 0.030 g Blaze Orange with 0.810 g NaCN. The GT pigments were used in preference to the AX pigments listed in Table 1 because the GT pigments are physically more stable.

Following death, the heads were cut from the carcasses and the mouths propped open. The heads were placed in direct sunlight in an outdoor enclosure that protected them from scavengers. They were examined weekly for 4 or 5 weeks for evidence of DG. Observations recorded included: results of any discharge, time to death (if the coyote died), and the presence of DG in the mouth and around the face and head. Examinations for DG were conducted with the unaided eye in daylight and in the dark with a black-ray ultraviolet (UV) lamp (long wave: 366nm).

Maximum and minimum temperatures were recorded each 1 to 4 days during the observation period. The coyote-marking test was conducted at the Logan Predator Research Field Station of the DWRC near Millville, Utah, during November 1988 to February 1989.

RESULTS AND DISCUSSION

Weathering Tests

The capsules weathered in Arizona, Texas, Oregon, and Montana were opened and inspected at Twin Falls during the week of April 8 to 12, 1985. Some capsules disappeared from each site during the test, so the number evaluated was 521 instead of 600.

The results (Table 2) indicate that weather conditions at the 4 test sites did not affect capsule contents. Quality of standard capsules produced in 1984 was very good (97% normal). There was speculation that KCl was included in the cyanide formulation to retard caking, but capsules with and without KCl (lots 1 and 2) weathered equally well, suggesting KCl was not necessary. Additionally, capsules with DG weathered as well as those containing Tracerite (lots 1 and 3), indicating that neither marker adversely influenced the formulation under field conditions.

Table 2. Numbers of M-44 cyanide capsules examined and percentages with normal contents after 4 to 6 months of outdoor exposure.

Lot number	Formulation tested	Number examined	Percent normal[a]
1	Standard registered product	168	97
2	Standard product minus KCl	174	97
3	Standard product minus KCl and Tracerite plus Day-Glo	179	99

[a]Normal indicates the NaCN was a dry white powder with no caking, discoloration, or other visual indication of deterioration.

Marking Test

A total of 20 M-44 trials were run; in 11 the coyotes died from discharging M-44s (10 within 1 to 5 min and 1 after 2.5 hrs), 4 trials resulted in sublethal discharges (in the first 2 the coyotes were euthanized with T-61 euthanasia solution soon after recovery), and 5 ended without coyotes discharging M-44s. The 10 coyotes that died quickly and the 2 coyotes that were euthanized showed fluorescent marks in their mouths that were readily evident for 0 to 5 weeks in sunlight and 4 or 5 weeks under UV. No attempt was made to determine how much longer DG remained visible because 4 weeks is more than adequate to meet ADC program requirements.

DG on the coyote that had a prolonged death (#5013) was detected only under UV and only for 1 week (Table 3). In 10 of the 13 heads checked (77%), marks were detected in daylight with the unaided eye. The marks were more obvious in darkness under UV than in daylight, and Blaze Orange was slightly better than Saturn Yellow.

Temperatures were cold during the test, ranging from -23 to +15 C. Deterioration of heads did not occur during the 4 to 5-week observation period. Under warmer conditions decomposition might quickly destroy most soft tissue and reduce detectability of DG marks.

Table 3. Observed presence (+) or absence (-) of Day-Glo (DG) (Blaze Orange and Saturn Yellow) on coyotes killed by M-44s in pen trials between November 1988 and February 1989.

Test date	Coyote # and sex[a]	DG color and weight		Weeks DG detected post death 1	2	3	4	5	Total weeks
11-04-88	5004 M	orange	L[b]	+	+	+	+		4
		.050g	D[c]	+	+	+	+	+	5
11-07-88	5003[d] F	orange	L	-	-	-	-	-	0
		.050g	D	+	+	+	+	+	5
11-16-88	5014 M	yellow	L	+	+	+	+		4
		.050g	D	+	+	+	+		4
11-16-88	5006 M	orange	L	+	+	+	+		4
		.050g	D	+	+	+	+		4
11-17-88	5005[d] F	orange	L	-	-	-	-		0
		.050g	D	+	+	+	+		4
11-25-88	5012 M	yellow	L	+	+	+	+	+	5
		.050g	D	+	+	+	+	+	5
11-25-88	5009 F	yellow	L	+	+	+	+	+	5
		.050g	D	+	+	+	+	+	5
12-02-88	5013[e] M	orange &	L	-	-	-	-		0
		yellow	D	+	-	-	-		1
		.025g ea.							
12-02-88	5010 F	orange &	L	+	+	+	+		4
		yellow	D	+	+	+	+		4
		.025g ea.							
12-12-88	5001 F	orange &	L	-	-	-	-	-	0
		yellow	D	+	+	+	+	+	5
		.025g ea.							
12-14-88	D658 M	orange	L	+	+	+	+	+	5
		.030g	D	+	+	+	+	+	5
01-05-89	D670 F	orange	L	+	+	+	+	-	4
		.030g	D	+	+	+	+	+	5
01-05-89	3349 F	orange	L	+	+	+	+		4
		.030g	D	+	+	+	+		4

[a]M = male and F = female.
[b]Observations made outdoors in sunlight with unaided eye.
[c]Observations made in the dark with a ultraviolet lamp.
[d]Sublethal discharge of M-44, coyote euthanized soon afterwards.
[e]Coyote died after prolonged period.

CONCLUSIONS

From the weathering tests, we concluded that removing KCl and substituting DG for Tracerite in capsule formulations would not impair M-44 function. Pen tests indicated coyotes that died after discharging M-44s containing Blaze Orange had effective marks that were easily detected in the dark under UV light, but frequently were also visible in daylight with the unaided eye. Blaze Orange appears to be an excellent replacement for Tracerite in M-44 devices.

Based on these conclusions, the formulation for M-44 capsules was changed to delete KCl and replace Tracerite with Blaze Orange. EPA authorized the change in January 1990 and the Pocatello Supply Depot began producing capsules with the new formulation by March 1990 (Table 4).

Table 4. Approved formulations for M-44 cyanide capsules (EPA Registration Number 56228-15).

Component	Contents per capsule			
	Old formulation		New formulation	
	Percent	Grams	Percent	Grams
Sodium cyanide (99% technical)	89.52	0.815	92.09	0.82
Celatom MP-78 (Silica)	5.59	0.051	5.65	0.05
Potassium chloride	4.66	0.042	--	--
Tracerite yellow	0.23	0.002	--	--
Day-Glo GT-15-N (Blaze Orange)	--	--	2.26	0.02
Totals	100.00	0.910	100.00	0.89

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