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ABSTRACT: The M-44 sodium cyanide (NaCN) ejector is an important tool for coyote damage control. For greatest effectiveness, the ejected NaCN mixture must be a dry powder. NaCN readily absorbs and reacts with moisture to cause solidification or "caking" in M-44 capsules. Because it is difficult to seal the capsules water tight, caking has been a chronic problem ever since NaCN ejectors were introduced over 40 years ago. The toxicity and caking properties of three alternate compounds are reported in this paper.

Comparative toxicity tests were made with M-44 ejectors containing NaCN, potassium cyanide (KCN), calcium cyanide (CaCN), and methomyl. Five to eight pen tests on coyotes or dogs were conducted with each compound. NaCN was tested on both coyotes and dogs. Except for one coyote that survived a dose of CaCN, each test animal died after pulling an M-44 and receiving a full charge of ejected toxicant. Average lapsed times from pull to first observed symptoms were 31 seconds for NaCN, 34 seconds for KCN, 63 seconds for CaCN, and 2 minutes for methomyl.

Both NaCN and methomyl were lethal in all pen tests, yet coyote recovery rates (carcasses found/ coyote pulls) in the field were 80% for NaCN and only 24% for methomyl. This difference was attributed to the faster action of NaCN. KCN and CaCN were not field-tested, but results from captive coyotes indicate that KCN would be about as effective as NaCN and CaCN would be less effective. None of the three alternate compounds offers enough advantage over NaCN to warrant the expense of registration, since NaCN is already registered.

INTRODUCTION

The M-44, or spring-activated sodium cyanide (NaCN) ejector, is an important coyote control tool. Its history and performance have been described at previous Vertebrate Pest Conferences (Matheny 1976, Connolly and Simmons 1984) and need not be reiterated here. Ever since its adoption by the U.S. Fish and Wildlife Service, Animal Damage Control (ADC) program, M-44 effectiveness has been hampered by caking of toxicant inside ejector capsules. Caking occurs when moisture penetrates the capsule seal and reacts with the NaCN mixture. The frequency of caking increases with time in the field, and can be as high as 47% in capsules placed outdoors for 6 weeks (Connolly and Simmons 1984).

An M-44 ejects toxicant into a coyote's mouth. Dry, powdered NaCN is rapidly lethal, but caked NaCN can be spit out so that the coyote M-44 escapes. Thus, it is critical that M-44 capsules maintain their contents in dry, powder form for a reasonable period of time (1 to 2 years from date of manufacture).

Through 4 decades of experience with NaCN ejectors, ADC personnel have made numerous attempts to solve capsule caking problems, first with the coyote getter (Kalmbach 1941, Robinson 1941, Bush 1958) and later with M-44s and other spring-activated models (Anonymous 1966, Bacus 1969, 1971; Keenan 1979). Yet, as recently as 1984, NaCN caking was identified as the M-44 problem most in need of solution (Connolly and Simmons 1984).

One way to circumvent the caking problem would be to switch to another toxicant, but the historical record indicates little experimentation with alternate toxicants. A "Liquid Humane Coyote Getter," marketed in the 1960s by Humane Coyote Getter, Inc., Pueblo, Colorado, used a solution of potassium cyanide (KCN) in water. And the Texas Department of Agriculture used dry KCN experimentally in M-44s during 1974 to 1975. Over 11,000 KCN capsules were distributed and some 3,340 animals including 2,540 coyotes were taken (Ivie 1982), but no data were collected to permit comparison with results from NaCN capsules that were used concurrently elsewhere in Texas. Other than these examples with KCN, we have found no record of alternate M-44 toxicants. This paper reports investigations of three alternatives--KCN, calcium cyanide (CaCN), and methomyl. Each was compared to NaCN, both for propensity to caking under field conditions and for toxicity to captive coyotes or dogs. Efficacy of methomyl and NaCN for taking coyotes under field conditions was also compared.

MATERIALS AND METHODS

Compounds Tested

Sodium cyanide (NaCN): Standard production capsules loaded at Pocatello Supply Depot (PSD), Pocatello, Idaho, for use in the ADC program were used as the standard for evaluation of alternate

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toxicants. PSD capsules contain 88.78% NaCN, 5.98% diatomaceous silica (Celatom MP-78), 4.99% potassium chloride, and 0.25% tracerite yellow fluorescent particles. Based on laboratory analysis of 15 capsules sampled in September 1982, actual NaCN content (active ingredient = A.I.) averaged 0.75 grams per capsule (S.D. = 0.043 grams). Analyses were performed by Industrial Laboratories, Inc., Denver, Colorado, using standard AOAC procedures.

Reagent grade NaCN (J. T. Baker Chemical Co., 96.7% A.I.) was also used in weathering tests for comparison with other cyanide compounds.

Potassium cyanide (KCN): Reagent grade KCN (J. T. Baker Chemical Co., 97.8% A.I. or Mallinckrodt Chemical Co., 99.0% A.I.) was used.

Calcium cyanide (CaCN): The chemical formula for calcium cyanide is $Ca(CN)_2$, but for convenience in this paper it is abbreviated as CaCN. The product from ICN Pharmaceuticals, Inc., contained 90% A.I.

Methomyl: S-Methyl-N-[(methylcarbamoyl)oxy]thioacetimidate, commonly called methomyl, is a broad-spectrum carbamate insecticide that is used on approximately 30 different human food crops. Methomyl is marketed by Shell Chemical Company under the trade name "Nudrin." The product used in this study was Nudrin water-soluble powder (W.S.P., 90% A.I.).

Methomyl was first suggested as a candidate predacide by Peoples (1977). Tests on three coyotes indicated an acute, oral LD_{50} of 5.0 mg/kg (Savarie 1980). Livestock protection collars containing methomyl solutions were rapidly lethal to coyotes that punctured them, but meat or tallow baits containing methomyl were not lethal (Connolly 1982). Compared to NaCN, methomyl is less soluble in water and therefore was expected to be less prone to caking.

Weathering Tests

To test caking under field conditions, M-44 capsules containing various mixtures were placed outdoors in Texas for 21 or 28 days (Table 1). Capsules were kept upright (top seal up) in plastic shotshell loading trays just above ground level to simulate the position of capsules in set ejectors. Following exposure, each capsule was opened and its contents were rated subjectively as normal (dry powder, same color and consistency as when loaded), part caked, or caked.

Table 1. Relative frequency of caking of toxicant mixtures in M-44 capsules during outdoor exposure.

Toxicant	Load[a] details	Number exposed	Conditions after exposure: Percent normal	Percent part caked	Percent caked
Test 1: Port O'Connor, Texas; 21 days in February 1982					
Methomyl	(1)	10	100	0	0
Sodium cyanide	(2)	174	59	11	30
Test 2: College Station, Texas; 28 days in February-March 1983					
Sodium cyanide	(3)	50	24	18	58
Sodium cyanide	(4)	50	16	12	72
Sodium cyanide	(5)	50	30	8	62
Potassium cyanide	(6)	50	28	54	18
Potassium cyanide	(7)	50	24	52	24
Calcium cyanide	(8)	50	78	22	0
Calcium cyanide	(9)	50	78	22	0

[a]Load details: All were standard production polyethylene capsules sealed with 3M #4693 adhesive diluted with painter's naptha (2 parts #4693:1 part naptha). This sealer was standard on PSD capsules produced from 1974 to December 1982. Capsule contents were as follows:

(1) Each capsule contained 0.70 grams Nudrin W.S.P.
(2) PSD capsules loaded in October 1981.
(3) PSD capsules loaded in December 1982.
(4) Each capsule contained 0.73 grams of a mixture containing 85% NaCN (96.7% A.I.) and 15% Diatomaceous silica (Celatom MP-78; Eagle-Picher Industries).
(5) Each capsule contained 0.75 grams of a mixture containing 85% NaCN (96.7% A.I.) and 15% synthetic silica (Sipernat; Degussa Inc.).
(6) Each capsule contained 0.86 grams of a mixture containing 85% KCN (97.8% A.I.) and 15% Diatomaceous silica.
(7) Each capsule contained 0.88 grams of a mixture containing 85% KCN (97.8% A.I.) and 15% synthetic silica.
(8) Each capsule contained 0.98 grams of a mixture containing 85% CaCN (90% A.I.) and 15% Diatomaceous silica.
(9) Each capsule contained 0.91 grams of a mixture containing 85% CaCN (90% A.I.) and 15% synthetic silica.

Pen Tests to Determine Toxicity

Coyotes or dogs were released into outdoor pens where one or more M-44s had been set and baited with fetid or food lures to stimulate pulls. Each animal pulled the ejector voluntarily. The more convenient method of simply discharging M-44s into the mouths of restrained animals was avoided because it would not have represented field conditions adequately.

Most tests with cyanide compounds were recorded on videocassettes to facilitate repeated study and measurement of animal reaction times. Methomyl tests were not videotaped, but most were timed by a concealed observer. Animals were considered dead when heartbeat could no longer be detected and the eye blink reflex was lost.

All pen tests but one were made in Fish and Wildlife Service (FWS) predator research facilities near Logan, Utah. The first methomyl test was made at the U.S. Sheep Experiment Station, Dubois, Idaho. Coyotes were captured from the wild or reared in captivity, whereas domestic dogs were obtained from local animal shelters. Coyote-sized dogs (15 to 40 pounds; 7 to 18 kg) were selected.

Test capsules, other than PSD capsules, were assembled by the investigators using the same empty capsules, sealing agents, and procedures as for PSD capsules. The intent was to make test loads that resembled PSD capsules as closely as possible, except for the experimental, formulations being tested.

In preparing test capsules, difficulty was encountered in attempting to standardize the amounts of different cyanide compounds. Three conditions for standardization were considered—constant volume, constant content of active ingredient by weight, and constant cyanide content by weight. It proved impossible to accommodate all 3 conditions simultaneously due to variations in density and percent active ingredient of different cyanide compounds, and because the percentage of cyanide differed among compounds. As calculated from atomic weights, NaCN contains 53%, KCN 40%, and CaCN 56% cyanide. Moreover, the PSD capsules used as standard for comparison contained several inert ingredients in addition to NaCN. Therefore, KCN and CaCN capsules were loaded to the same volume as PSD capsules. The resulting differences in active ingredient doses and cyanide doses are presented in Table 2 along with observations of toxic effects.

For methomyl pen tests, each capsule contained 0.50 grams Nudrin loaded over inert filler as needed to fill the capsule. In weathering and field tests, methomyl capsules were simply filled to capacity with Nudrin.

For the compounds tested, we speculate that the differing amounts of active ingredient per capsule had little effect on observed efficacy since all capsules contained substantial overdoses, based on available toxicity values. However, the effect of dose variations on efficacy has not been studied for any toxicant in the M-44.

Efficiency in Taking Wild Coyotes

Methomyl was field tested in comparison with NaCN (PSD capsules) in Texas during February to April 1982. Methomyl M-44 capsules were loaded at College Station, Texas, and distributed to selected ADC field men who were asked to compare methomyl to PSD capsules in M-44s set during their normal damage control work. Cooperators were asked, insofar as possible, to record the animal species responsible for each M-44 discharge and to recover all animals killed.

RESULTS

Weathering Tests

Ten methomyl capsules were included in an evaluation of PSD capsules at Port O'Connor, Texas, in February 1982 (Table 1, test 1). All methomyl capsules were normal after 21 days of exposure, whereas only 59% of PSD capsules were normal. These results imply that, as expected, methomyl was less prone to caking. In subsequent field tests, however, a few methomyl capsules caked.

The three cyanide compounds were compared at College Station, Texas, in February to March 1983 (Table 1, test 2). Both in PSD capsules (load 3) and other mixtures (loads 4 and 5), NaCN caked badly; 58 to 72% of these capsules were caked after 28 days of exposure. KCN, in contrast, was caked in only 18 to 24% of capsules exposed and no CaCN capsule was fulled caked. Based on these results, NaCN is most prone to caking and CaCN least prone, with KCN intermediate.

Each cyanide compound was tested in mixtures with two inert substances—diatomaceous silica (as used in PSD capsules) and synthetic silica. Either additive would be expected to inhibit caking. No consistent difference could be seen between the two additives. Further studies of inert ingredients in M-44 capsules will be reported elsewhere.

Toxicity in Pen Tests

Based on data from eight coyotes and five dogs, these species are equally susceptible to NaCN in the M-44 (Table 2). The average lapsed time from pull to first observed symptoms was 32 seconds for coyotes and 30 seconds for dogs. The average time from pull until animals went down was 46 seconds for coyotes and 40 seconds for dogs. These values do not differ significantly between species. However, the average observed time to death was appreciably shorter for coyotes (127 seconds) than for dogs (182 seconds).

Table 2. Coyote and dog pen tests with M-44s containing cyanide compounds.

Date	Test Animal Sex/Wt (lbs)	Toxicant[a] dose mg/kg	Cyanide[b] dose mg/kg	Time after pull (seconds) First Symptoms	Animal down	Animal dead
Sodium cyanide (Coyotes)[c]						
7/27/83	F/16.5	100	53	33	38	90
5/23/84	M/23	72	38	45	49	145
5/23/84	F/21	79	42	39	46	153
6/11/85	M/23	72	38	11	37	98
6/11/85	M/25	66	35	28	40	149
6/12/85	F/20	83	44	68	74	150
6/12/85	F/23	72	38	17	35	128
6/13/85	F/21	79	42	17	46	102
Averages	22	78	41	32	46	127
Sodium cyanide (Dogs)[c]						
8/22/85	M/24.5	67	36	30	40	151
9/09/85	M/22	75	40	23	31	173
9/09/85	M/28.8	57	31	45	55	259
9/09/85	F/18.5	89	48	15	30	145
9/25/85	F/23	72	38	36	44	184
Averages	23	72	39	30	40	182
Potassium cyanide (Coyotes)[d]						
7/02/85	F/29.8	111	45	30	45	255
7/02/85	F/23.5	94	38	41	46	593
7/02/85	F/18.2	121	48	35	40	103
7/09/85	M/22	100	40	27	32	398
7/09/85	F/20	110	44	36	43	829
Averages	21	107	43	34	41	436
Calcium cyanide (Coyotes)[e]						
7/27/83	M/19.8	161	91	72	85	205
7/28/83	M/20/2	158	89	65	84	389
7/29/83	F/17.2	186	105	58	65	120
8/10/83	F/21.5	149	84	58	66	1250
8/02/83	F/20.8	154	87	95	--[f]	--[f]
Averages[g]	19.7	164	92	63	75	491

[a]Based on active ingredient of 0.75, 1.00, and 1.45 grams per capsule for NaCN, KCN, and CaCN, respectively, and assuming that each animal received entire capsule contents.

[b]Based on cyanide (CN) content of 0.40, 0.40, and 0.82 grams per capsule for NaCN, KCN, and CaCN, respectively, and assuming that each animal received entire contents of capsule.

[c]PSD capsules. Cyanide (CN) content = 0.40 grams per capsule.

[d]Each capsule contained 1.01 grams of KCN (99.0% A.I.). Cyanide (CN) content = 0.40 grams per capsule.

[e]Each capsule contained 1.61 grams of calcium cyanide (90% A.I.) and 0.067 grams of Auromine 0 Basic Yellow #2 dye (Sigma Chemical Co.). Cyanide content = 0.82 grams per capsule.

[f]Coyote survived even though it made a pull that should have been fatal.

[g]Fatal tests only.

KCN was tested only on coyotes. Lapsed times from pull to first observed symptoms and from pull until animals went down did not differ significantly between KCN and NaCN, although the time to death was much longer for KCN.

CaCN likewise was tested only on coyotes. CaCN was much slower-acting than either NaCN or KCN, and one coyote survived a dose of CaCN.

Methomyl was tested on two coyotes and four dogs (Table 3). Though fatal to all test animals, it was much slower-acting than any cyanide compound. The average time from pull until animals went down was 11 minutes, compared to less than 1 minute for NaCN and KCN. The average time to death also was much longer for methomyl. Time values were obtained for only one coyote.

Table 3. Coyote and dog pen tests with M-44s containing methomyl.

Date	Load[a]	Test animal[b] Sex/Wt (lbs)	Time after pull (minutes) First symptoms	Animal down	Animal dead
7/15/81	A	M/18.5*	NR[c]	NR[c]	NR[c]
11/10/81	B	M/25.2	2	12	150
11/10/81	B	F/31.5	2	8	21
11/10/81	B	F/28.5	5	12	>200
11/10/81	B	M/38.5	2	21	104
11/11/81	B	M/23.5*	1	1	5
Averages[d]		29.4	2	11	> 96

[a]Load A consisted of 0.50 grams Nudrin W.S.P. (90% A.I.) loaded over 0.20 grams of corn meal filler. Load B contained the same amount of Nudrin loaded over 0.22 grams of diatomaceous silica.

[b]Subjects marked with asterisk were coyotes; the others were dogs.

[c]NR = not recorded. Pull was not observed. Dead coyote was found 126 feet (38 m) away from the pulled M-44.

[d]Load B only.

Efficiency in Taking Wild Coyotes

Methomyl and NaCN (PSD capsules) were compared in three regions of Texas. Test highlights are given here; a detailed unpublished report (Connolly and Simmons 1982) is available from the investigators. Some 2,355 exposure nights with methomyl and 722 exposure nights with NaCN were recorded (Table 4). The best comparison was achieved in Lubbock district, where 2 coyotes were recovered from 16 coyote pulls on methomyl, compared to 16 coyotes recovered from 20 coyote pulls of NaCN ejectors. Overall, the recovery rate for coyote pulls was 80% (20/25) for NaCN and only 24% (8/33) for methomyl. Average recovery distances (from ejector to coyote carcass) were 26 yards (24 m) for NaCN and 105 yards (96 m) for methomyl. This difference is not surprising considering the slower action of methomyl in pen tests. We speculate that actual coyote mortalities from the two toxicants did not differ as much as recovery data suggest. Nevertheless, high recovery is a distinct asset under field conditions as it confirms that equipment is functioning properly and enhances documentation of animal species taken.

Table 4. Field comparisons of methomyl and sodium cyanide M-44s in Texas, February to April 1982.

	Texas ADC Districts College Station	Lubbock	Orange Grove	All Districts
Methomyl[a]				
Unit nights[b]	995	497	863	2355
Total pulls	60	18	15	93
Probable coyote pulls	3	16	14	33
Animals recovered (total)	28	3	5	36
(Coyote)	1	2	5	8
(Opossum)	17	1	0	18
(Skunk)	8	0	0	8
(Raccoon)	2	0	0	2
Exposure nights/coyote pull	332	31	62	71
Coyotes recovered/coyote pull	0.33	0.12	0.36	0.24
Sodium cyanide[c]				
Unit nights[b]	149	484	89	722
Total pulls	0	20	6	26
Probable coyote pulls	0	20	5	25
Animals recovered (all coyotes)	0	16	4	20
Exposure nights/coyote pull	-	24	18	29
Coyotes recovered/coyote pull	-	0.80	0.80	0.80

[a]Each capsule contained 0.70 grams Nudrin W.S.P. (90% A.I.)

[b]One unit night = 1 M-44 set for 1 night.

[c]PSD capsules.

Inexperienced persons may suppose that, if M-44s function as intended, the recovery rate from coyote pulls should approach 100%. However, we are unaware of any sizeable compilation of field records showing such high recovery, except for research studies with more frequent inspection than is common in operational use. In our view, the 80% recovery rate and 26-yard average recovery distance indicate excellent performance of PSD capsules.

In the Texas field test, observers recorded 28 nontarget animals killed by methomyl, but none by NaCN (Table 4). The nontarget take included 18 opossums, 8 skunks, and 2 raccoons. Except for 1 opossum, all nontarget animals were taken in College Station district where opossums and skunks were particularly abundant.

Our limited data also imply that methomyl may have repelled coyotes, particularly in the Orange Grove district where we recorded one coyote pull per 18 exposure nights for NaCN, but only one pull per 62 nights for methomyl. However, the difference was much smaller in the Lubbock district where sample sizes were larger.

DISCUSSION

Speed of action is a desired attribute for M-44 toxicants. Fast-acting chemicals are regarded as most humane and they facilitate recovery of animals killed. Based on our results, NaCN and KCN may be regarded as fast-acting, with CaCN intermediate and methomyl slow-acting. CaCN and methomyl appear to be less susceptible to caking, but this advantage probably is offset by their slower action. The toxicity of methomyl appeared to be poor in the field, though it undoubtedly killed more coyotes than our 24% recovery rate implied.

This study was part of a larger effort to improve M-44 performance. While evaluating alternate toxicants, we tried in other studies to resolve NaCN caking problems by improving the capsule seal. The improved beeswax seal mentioned by Connolly and Simmons (1984) has turned out to be very effective. With this improved seal, it does not now appear necessary to adopt other measures such as changing to a different toxicant. And based on this study, it seems unlikely that M-44 performance would be improved significantly by changing from NaCN to any of the three alternatives we tested. Moreover, any new toxicant would require registration by the Environmental Protection Agency prior to use. Registration costs would be substantial and NaCN already is registered. For these reasons, we plan no further effort toward alternate M-44 toxicants at this time. If an alternative becomes necessary, however, our preferred candidate would be KCN.

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