1984

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Criteria for the Selection and Development of Predacides

REFERENCE: Savarie, P. J. and Connolly, G. E., **"Criteria for the Selection and Development of Predacides,"** *Vertebrate Pest Control and Management Materials: Fourth Symposium, ASTM STP 817*, D. E. Kaukeinen, Ed., American Society for Testing and Materials, Philadelphia, 1983, pp. 278–284.

ABSTRACT: Since 1940, the Denver Wildlife Research Center has been evaluating toxicants for the control of coyotes. These lethal agents for coyotes and other predators are commonly called predacides. This paper describes our current criteria for the selection and development of predacides. Efficacy standards under practical working conditions, human and environmental safety factors, and compliance with registration requirements established by the U.S. Environmental Protection Agency (EPA) under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) are important criteria. Most of the criteria were developed for chemicals that would be used in the livestock protection collar (toxic collar), but they also apply to other predacidal techniques such as single lethal dose baits and large baits.

The first criterion is that the chemical be toxic to coyotes, although tests on coyotes may be precluded for chemicals that are hazardous to humans. Of prime importance is that the chemical not be dermally toxic or carcinogenic. An antidote is highly desirable but not essential. A predacide should be tasteless and odorless so that it is well accepted and should be effective at low oral doses so that the amount used is not excessive and bulky. A predacide should be effective within 24 h so that predation can be stopped as soon as possible. Chemicals that are economical and commercially available are highly desirable. Residue levels in poisoned coyotes should not be toxic to scavengers. For livestock-borne devices such as the toxic collar, the toxicant should not leave harmful residues of chemical in sheep exposed to sublethal doses. The presence of such residues could prevent marketing of sheep that had worn toxic collars. If the sheep dies, residues in or on the sheep should not be toxic to scavengers. Selective toxicity to coyotes is desirable so that nontarget species will not be poisoned if they come in contact with the chemical. Last, the chemical should be registerable and fulfill requirements as set forth by regulatory agencies.

KEY WORDS: vertebrate pest control, predacides, standard evaluations, criteria, acute oral toxicity, toxic collar, single lethal dose baits, Compound 1080, methomyl, carbofuran, sodium cyanide, diphacinone

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Toxic chemicals have been used to kill mammalian predators (such as coyotes, foxes, wolves) in the United States for at least 135 years. Toxicants for predators are commonly called predacides, and the first toxicant for this purpose, strychnine, was used as early as 1847 [*1*]. Strychnine alkaloid and strychnine sulfate have been used extensively to kill coyotes and many other mammals. Thallium sulfate [*2*] has also been used as a predacide but was discontinued in 1967 by the U.S. Fish and Wildlife Service (FWS) [*3*] because it was considered to be too hazardous. Sodium monofluoroacetate (Compound 1080) was used for coyote control from 1946 to 1972, but Executive Order No. 11643 [*4*] banned the use of all predacides in federal programs and on federal lands. The U.S. Environmental Protection Agency (EPA) then suspended interstate shipment and canceled registration of all chemicals for predator control. The executive order was modified in 1975 [*5*] and 1976 [*6*] to allow the use of sodium cyanide in a mechanical device known as the M-44, and currently sodium cyanide and a gas cartridge containing sodium nitrate and charcoal are the only predacides registered by the EPA.

In the 1950s and 1960s, Compound 1080, strychnine, and sodium cyanide were the most commonly used predacides. Cancellation of their use spawned efforts to find replacements that would be just as effective and "registerable" by federal and state regulatory agencies. In 1974 the Denver Wildlife Research Center of the FWS began research on chemicals [*7,8*] that could be used in the toxic collar, a technique developed by McBride [*9*] to deliver toxicant to coyotes as they attack sheep or goats. This research led to an EPA experimental use permit (No. 6704-EUP-14) under which the FWS evaluated Compound 1080 in these collars. The research culminated in submission by the FWS in September 1981 of an application to the EPA to register Compound 1080 for this purpose.

Since 1974 we have established criteria that serve as guidelines for the research and development of the "ideal" predacide. These criteria consider efficacy standards under practical working conditions, human and environmental safety factors, and regulations as established by the EPA under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Some criteria are specific to chemicals for the toxic collar, but most are applicable to other predacidal applications such as the M-44, small or large baits, licking stations, or toxic bait posts.

Methods

Procedures for maintenance of coyotes and conducting acute oral LD_{50} (lethal dose, in milligrams per kilogram, that kills 50% of a test population) tests have been described [*10*]. Toxic collars were tested with captive, penned coyotes and under field conditions [*7,8,11,12*]. Small baits were prepared with either edible beef tallow or a mixture of 90% beef tallow and 10% beeswax and

weighed about 9 g. Information about chemicals was obtained through computer searches of literature references and personal communication with representatives from private industry and other governmental agencies.

Criteria Used to Evaluate the Candidate Predacides

Low Oral Dose Effectiveness

It is important that predacides be potent to the target animal so that the bulk of the chemical does not cause formulation and delivery problems. The acute oral LD_{50} of Compound 1080 in coyotes is 0.12 mg/kg, and a solution of 10 mg/ml is adequate to achieve consistent mortality in the toxic collar. Only 5 mg is needed for a single-dose coyote bait [*13*]. In contrast, the acute oral LD_{50} of para-aminopropiophenone (PAPP) is 5.6 mg/kg, and 400 mg/ml is required in the collar and at least 150 mg in a single-dose bait. The acute oral LD_{50} for methomyl is 5.6 mg/kg, and collars must contain 400 mg/ml of it to kill attacking coyotes. The acute oral lethal dose is probably a good indicator of the actual dose needed for the collar, but it may be misleading when applied to baits. For example, tallow and meat baits containing 170 mg (about three LD_{50}s for a 10-kg coyote) of methomyl were not lethal to two coyotes [*14*]. Methomyl can be metabolized rapidly [*15*], and it appears that coyotes absorb it slowly from baits and detoxify it quickly.

Taste and Odor of Chemicals

Experience with a broad class of chemicals including organophosphates, carbamates, organofluorines, and anticoagulants indicates that chemicals with noxious taste or odor are likely to be rejected by coyotes in either bait or toxic collar formulations. A solution of 33% sodium cyanide in collars was used in penned tests, and 75% (nine out of twelve) of the coyotes that bit the collars died [*11*]. But it was noted that the solution had repellent properties because after receiving a dose coyotes frequently pawed at their mouths and rubbed their muzzles on the ground. This solution has a discernible odor, an alkaline pH of 14, and is caustic. Wild coyotes apparently were more sensitive to these properties; in field tests, eight collars were punctured, but no dead coyotes were recovered [*7*]. Lethal doses of sodium cyanide immobilize coyotes within 3 min [*11*], and dead coyotes should have been recovered near the site of the bitten collar. In contrast to the offensive taste and odor of sodium cyanide, the anticoagulant diphacinone is odorless and probably tasteless because rats eat baits containing it without developing an apparent bait-shyness. Coyotes readily attack and hold onto collars that contain it [*8*]. Compound 1080, methomyl, carbofuran, ethylene glycol, and PAPP are other chemicals that are well accepted by coyotes.

Speed of Predacide Action

The speed of action of predacides varies widely. Some are effective within a few minutes whereas others are delayed in action for several days [*7,8*]. Both methomyl and carbofuran can immobilize coyotes within 3 to 5 min [*14*], and death usually occurs within 1 h. The death times of three coyotes that punctured Compound 1080 toxic collars ranged from 2½ to 5¼ h [*8*], whereas diphacinone usually kills within 5 to 10 days but can take as long as 17 days [*10*]. One disadvantage of diphacinone in the toxic collar is that lethally dosed coyotes may continue to kill sheep before they succumb [*16*]. In the toxic collar, a fast-acting predacide is needed to stop further depredations by any coyote that attacks livestock. Moreover, a predacide that killed within minutes would permit recovery of poisoned coyotes near the scene of collar attacks. This would provide proof of efficacy and also permit proper disposal of poisoned carcasses. For other predacidal techniques, such as baiting to reduce coyote numbers on spring lambing ranges before livestock arrive there, slow-acting toxicants such as diphacinone may be acceptable.

Not Hazardous to Humans

Any chemical, including table salt, can be misused so as to cause harm to humans. But with common sense many chemicals can be safely handled and used as predacides. In screening new chemicals, we avoid any that have high dermal toxicity or are known or highly suspect of being carcinogens. For example, nicotine could be a desirable predacide because it acts rapidly and coyotes would be expected to be found within a few feet of the site of contact with it. But nicotine is absorbed from the respiratory and gastrointestinal tracts and intact skin [*17,18*]. As little as 60 mg (1 mg/kg) or less can be fatal to an adult human. Therefore, we have not seriously considered nicotine for predacidal applications. Metabolites of the fungus *Aspergillus flavus* called aflatoxins are highly toxic but are also some of the most potent carcinogens known [*19*]. Methomyl and carbofuran, carbamate insecticides that are widely used, have low dermal toxicity [*18*] and have been evaluated as predacides with some success. High acute oral toxicity *per se* does not automatically rule out the use of a chemical, because some highly acute toxicants such as Compound 1080 have proved through their historic use not to pose a hazard to humans.

Antidote or Statement of Practical Treatment

An antidote is highly desirable but not an absolute necessity because several registered vertebrate pesticides do not have antidotes. Zinc phosphide is an acute rodenticide that does not have an antidote, but it does have a statement of practical treatment to alleviate poisoning symptoms. Many

commercial products that lack antidotes do have effective first aid and emergency treatment procedures [*17*].

Environmental Safety

Selective toxicity to the target animal is desirable to prevent poisoning of nontarget animals. However, the mode of application has equal or greater influence on nontarget hazards. With the toxic collar, for example, exposure to nontarget animals is minimal [*7,8*]. Exposure of nontarget animals to toxic baits presents a greater hazard, so the need for selective toxicity is probably greater for baits than for toxic collars. Nontarget poisoning has not been observed with the use of toxic collars, but it has been reported for bait stations [*2*]. The accumulation of residues in vegetation and soil is an important consideration in assessing potential environmental impacts, but all the evidence indicates that it does not occur with the normal operational predacidal use of sodium cyanide or Compound 1080. After two days' exposure on vegetation and soil, only very small amounts of sodium cyanide were detected [*20*], and Compound 1080 is degraded by microorganisms in the soil [*21*].

To prevent the potential poisoning of scavengers, residue levels in coyotes at the time of death should not be harmful. And with the use of toxic collars there should be no residues or only a minimal tolerance level, so that surviving collared livestock could still be marketed. If collared livestock die after an attack, as is usual with Compound 1080 collars, residues in or on the carcass should not be poisonous to nontarget animals.

Cost of Chemical and Availability

For obvious economic reasons, it is desirable that predacides be inexpensive and readily available from commercial sources. The cost of Compound 1080 is $25 per pound, and about $0.02 worth is needed to fill a toxic collar. In contrast, the experimental chemical PAPP costs $737 per pound, and the amount in one toxic collar costs about $19.50. In a single-dose bait containing 5 mg of Compound 1080, the toxicant cost per bait is only 0.03 cents, but the cost of PAPP in a drop bait is 0.24 cents. Based on these figures, PAPP may be cost-effective for baits but not for toxic collars. The popular carbamate insecticides methomyl and carbofuran may have uses as predacides and are readily available from agricultural supply stores at $13 to $25 per pound.

Chemicals such as PAPP, which do not have established commercial uses, are usually high priced and available in only small quantities. The logistics of getting them into predator control use could be burdensome and because of the political, emotional nature of predator control, especially with toxicants, some chemical companies do not want to be associated with predacidal applications and will not provide their chemicals to be used even for laboratory tests.

Regulatory Affairs

When all efficacy, safety, and environmental hazard criteria appear to be met, it is still necessary to obtain EPA registration for use of any predacide. Before the product can be registered, the applicant may be required to evaluate the chemical under actual field conditions under an EPA experimental use permit. Field tests may require years of expensive work in different geographical regions. Experimental use of Compound 1080 in toxic collars, for example, has been continuous from May 1978 to the present time. As of March 1982, there are three active experimental use permits in the United States. Test results show that the Compound 1080 toxic collar can be used in many situations to stop predation on livestock but that it is not a panacea for all livestock operations [*17*]. The FWS submitted an application to register the Compound 1080 toxic collar in September 1981, and an EPA decision on this application is not expected before late 1982.

We believe that the eight criteria presented in this paper represent the most important factors needed to select, test, and develop predacides for registration and ultimate operational use. These criteria are only broad categories which represent the more than 150 tests that may be required by the FIFRA. The final selection of a predacide is a compromise because no chemical fully meets all the criteria. In reviewing the various criteria to reach a final decision, human and environmental safety receive the highest priority.

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