University of Nebraska - Lincoln
DigitalCommons@University of Nebraska - Lincoln

Proceedings of the Seventeenth Vertebrate Pest Conference 1996 | Vertebrate Pest Conference Proceedings collection

1996

Zinc Phosphide Residues In Voles: Scenarios Showing Low Risks To Domestic Cats And Dogs

Ray T. Sterner
U.S. Department of Agriculture, Ray.T.Sterner@aphis.usda.gov

Follow this and additional works at: http://digitalcommons.unl.edu/vpc17

Part of the Animal Sciences Commons, Bioresource and Agricultural Engineering Commons, and the Environmental Engineering Commons

Sterner, Ray T., "Zinc Phosphide Residues In Voles: Scenarios Showing Low Risks To Domestic Cats And Dogs" (1996). *Proceedings of the Seventeenth Vertebrate Pest Conference 1996*. 49.
http://digitalcommons.unl.edu/vpc17/49

This Article is brought to you for free and open access by the Vertebrate Pest Conference Proceedings collection at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Proceedings of the Seventeenth Vertebrate Pest Conference 1996 by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.

ZINC PHOSPHIDE RESIDUES IN VOLES: SCENARIOS SHOWING LOW RISKS TO DOMESTIC CATS AND DOGS

RAY T. STERNER, United States Department of Agriculture, Animal and Plant Health Inspection Service, National Wildlife Research Center, Fort Collins, Colorado 80524-2719.

ABSTRACT: Zinc phosphide (Zn_3P_2, CAS #1314-84-7) is an acute rodenticide having numerous agricultural applications. This paper estimates the risk of mortality posed to domestic cats (*Felis domesticus*) and dogs (*Canis familiaris*) from ingestion of voles (*Microtus* spp.) that succumb to 2.0% Zn_3P_2 baits. Following a brief review of direct/indirect studies and incident reports relevant to nontarget-Zn_3P_2 effects and vole control, four scenarios of vole-carcass ingestions needed for light and heavy cat and dog predators/scavengers to receive approximate lethal doses (ALDs = 40 mg/kg) of undigested rodenticide are described. Scenarios were derived using values reported by Sterner and Mauldin (1995) as the maximum 8.2 mg Zn_3P_2 ingested (ad libitum) and average 1.7 mg Zn_3P_2 whole-carcass residue. Extrapolating these "worst-case" loads to 2 and 6 kg cats and 1 and 36 kg dogs showed that between 5 and 847 Zn_3P_2-baited vole carcasses must be consumed in fairly rapid succession for these nontargets to ingest cumulative ALDs. The likelihood that even light ($\leq$1-2 kg) cats and dogs will find and rapidly ($\leq$24 h) ingest multiple ($\geq$5) Zn_3P_2-dosed vole carcasses under registered applications seems remote.

KEY WORDS: hazards, rodenticides, residual effects, toxicity, zinc phosphide, pesticides, field rodents, voles

Proc. 17th Vertebr. Pest Conf. (R.M. Timm & A.C. Crabb, Eds.) Published at Univ. of Calif., Davis. 1996.

INTRODUCTION

Zinc phosphide is an acute rodenticide that has numerous applications in agriculture and public health (Gratz 1973, Marsh 1988, Sterner 1994). For example, current Animal and Plant Health Inspection Service (APHIS) registrations include: 1.82% and 2.0% on wheat and steam-rolled oats for mouse control (*Microtus* spp. and *Peromyscus* spp.) in orchards/groves (non-bearing phase), rangelands, etc. (EPA Reg. Nos. 56228-3, -5 or -6) and 2.0% on steam-rolled oats for prairie dog control (*Cynomys* spp.) on rangelands (Reg. No. 56228-14).

That Zn_3P_2 affords high acceptance and efficacy for numerous rodent species is well documented (e.g., Marsh 1988, Sterner et al. in press, Tietjen 1976); however, bait shyness (Marsh 1988, Sterner 1994) and broad-spectrum toxicity (Johnson and Fagerstone 1994, Marsh 1988) are recognized deficiencies. Mitigation of bait shyness usually involves pre-baiting to increase initial bait ingestion and reduce the frequency of sub-lethal dosings (Marsh 1988). Nontarget rodents are at risk, but selective use of baits reduces foraging by nontarget mammals and birds (Johnson and Fagerstone 1994, Marsh 1988). Additionally, residue hazards of Zn_3P_2 to nontarget mammalian predators and avian scavengers/raptors remain a concern—loads of undigested rodenticide in the gastrointestinal (GI) tracts of target animals can be fatal to predators/scavengers (Bell and Dimmick 1975, Sterner and Mauldin 1995, Tkadlec and Rychnovsky 1990).

This paper reviews selected literature on nontarget hazards posed by the use of Zn_3P_2 baits to control voles in agriculture. Scenarios of hazards that vole carcasses containing low ($\bar{x}$ = 1.7 mg) and high "worst-case" (maximum ingested = 8.2 mg) Zn_3P_2 loads pose to relatively light and heavy domestic cats and dogs are discussed.

Zn_3P_2 VOLE, CAT AND DOG TOXICITY

The mode of action of Zn_3P_2 involves hydrolysis to phosphine (PH_3) upon reaction with stomach acids; circulating PH_3 decreases electron transport and cellular respiration (Chefurka et al. 1976, Hazardous Substance Databank 1994, Murphy 1986). Acute-oral, median-lethal-dose (LD_{50}) values for Zn_3P_2 in diverse vole species are between 15 to 20 mg/kg; the LD_{50} for prairie and meadow voles are 16.2 and 15.7-18.0 mg/kg, respectively (see Bell 1972, Hood 1972). Hudson et al. (1984) reported Zn_3P_2 ALDs for both domestic cats and dogs of 40 mg/kg; to the author's knowledge, no LD_{50}s for these nontargets are available.

Zn_3P_2 FOR VOLE CONTROL: KEY NONTARGET LITERATURE

Johnson and Fagerstone (1994) provided a comprehensive review of the literature concerning primary and secondary hazards of Zn_3P_2 to nontarget wildlife. These authors identified 61 acute oral toxicity studies of Zn_3P_2 involving 28 mammalian and 16 avian species, plus 16 hazards studies involving 12 mammalian predators/scavengers, 6 raptor, 2 reptilian, and 1 amphibian species. Hazards of Zn_3P_2 to nontarget predators/scavengers are not strictly secondary; undigested rodenticide within target animals (a primary-type hazard) pose the danger. Because the objective focuses on nontarget risks posed by the use of Zn_3P_2 for vole control, a brief update of the literature relevant to voles as the source of Zn_3P_2 for felids and canids is provided here.

Information of Zn_3P_2-residue effects in voles and potential consequences for nontarget species can be categorized under three headings: direct-effect studies, indirect-effect studies, and nontarget-incident reports.

"Direct-effect" studies refer to those in which carcasses of voles that died following ingestion of Zn_3P_2 baits are fed to nontarget predators/scavengers. "Indirect-effect" studies refer to residue estimates of vole carcass Zn_3P_2/PH_3 extrapolated to nontarget predator/scavenger doses based upon published LD_{50} or ALD doses. Nontarget-incident reports refer to documented or anecdotal cases where sub-lethal signs or nontarget deaths were associated with Zn_3P_2 applications.

Direct-Effect Studies

Bell and Dimmick (1975) conducted the most often cited direct-effect study of Zn_3P_2. These authors force fed prairie voles fatal doses of Zn_3P_3 pellets (86.94 mg/kg) 5 h prior to use of the carcasses. A three-day period to condition nontarget experimental and control animals/ raptors to eating voles was used. Control nontargets were included to monitor food habits/behaviors of animals fed non-Zn_3P_2-dosed voles. Results showed that two red foxes (*Vulpes vulpes*), two gray foxes (*Urocyon cinereoargenteus*) and two great horned owls (*Bubo virginianus*) ate an average 11.5, 11.7, and 8.5 non-dosed vole carcasses, respectively, during this conditioning period. No deaths in these animals were observed during the experimental period after ingestion of 4 to 12 vole carcasses containing mean doses of 10.64, 8.60, and 22.31 mg/kg Zn_3P_2 for these species, respectively; however, some lethargy and altered behaviors occurred. For example, one red fox (♀) would neither eat nor cache a vole after the first test day; whereas, the owls roosted on the ground (beneath rain shelters), rather than on the rain shelters as observed prior to the first day's dosings.

Tkadlec and Rychnovsky (1990) studied both direct and indirect effects of 5.0% Zn_3P_2 baits in common voles (*M. arvalis*)—5.0% Zn_3P_2 baits are used for vole control in Czechoslovakia. In the direct-effects study, one cat died within a day after ingesting five vole carcasses that succumbed from eating 5.0% Zn_3P_2 baits. This amounted to a maximum 103.5 mg dose for the cat (37 mg/kg Zn_3P_2)—a dose near the reported 40 mg/kg ALD cited for this species (Hudson, et al. 1984). A second cat, two weasels (*Mustela nivalis*), and three kestrels (*Falco tinnunculus*) did not die following ingestion of multiple vole carcasses containing maximum 60, 160 to 182, and 77 to 88 mg/kg Zn_3P_2 doses, respectively.

Indirect-Effect Studies

In an indirect study, Tabata (1986) measured the dissipation and acid decomposition of Zn_3P_2/PH_3 in red-backed wood mice (*Apodemus speciosus*) dosed orally with 10 mg Zn_3P_2 (1.8 mg ALD). The mice exhaled a maximum 379 μg of Zn_3P_2 as PH_3; this is equal to about 1.4 mg of Zn_3P_2 or 14.4% of the total dose. Considerable undigested Zn_3P_2 was detected in GI contents.

As mentioned, Tkadlec and Rychnovsky (1990) also provided analytical data on Zn_3P_2 residues in common voles. Using a colorimetric method of PH_3 absorption, they reported that ~58% (±25%) of total ingested Zn_3P_2 was found in the GI tracts of Zn_3P_2-killed voles; only 0.3% (±0.3%) of ingested Zn_3P_2 was found in the remainder of carcasses.

More recently, Sterner and Mauldin (1995) attempted to develop improved cryogenic-preservation and gas-chromatographic techniques for estimating whole-carcass Zn_3P_2/PH_3 residues in a mixed sample of meadow (*M. pennsylvanicus*) and prairie voles (*M. orthogaster*). Voles ingested fatal doses of 2% Zn_3P_2/SRO-groats fed *ad libitum*. Cryogenic procedures did not enhance Zn_3P_2 recovery; the main difficulty with analyses seemed to result from inadequate homogenization and hydrolyzation of Zn_3P_2 trapped in the voles' pelts. Results showed that: 1) whole-carcass Zn_3P_2 residues averaged 1.73 mg (min-max: 0.31-4.95)—~25-50% of the calculated Zn_3P_2 intake—and PH_3 residues averaged 10.6 μg (min-max: 0.5-21.0); and 2) significant (positive) linear regressions were found between: 1) bait consumption/Zn_3P_2 intake * body weight (r^2 = 0.64, p ≤0.001); 2) carcass Zn_3P_2 * bait consumption/Zn_3P_2 intake (r^2 = 0.32, p ≤0.043); and 3) carcass Zn_3P_2 * body weight (r^2 = 0.60, p ≤0.002). Minimum and maximum Zn_3P_2 intakes observed for specific voles were 2.0 and 8.2 mg, respectively; whereas, calculated doses of Zn_3P_2 ingested by the voles averaged ≥134.2 mg/kg (min-max 79.2 to 243.2 mg/kg).

Incident Reports

Johnson and Fagerstone (1994) cited 12 published or unpublished accounts of Zn_3P_2 baitings and nontarget incidents involving 14 species/genus. Of the nontarget species/genus involved in these accounts, seven bird [i.e., Canada goose (*Branta candensis*), Snow goose (*Chen caerulescens*), ducks (e.g., *Anas* spp.), wild turkey (*Meleagris gallopavo*), partridges (e.g., *Perdix* spp., *Callipepla* spp., *Colinus* spp.), corvidae (*Corvus* spp.), chickens (*Gallus* spp.)] and seven mammal species/genus [i.e., red fox, domestic cat, domestic dog, gray squirrel (*Sciurus carolinensis*), cottontail rabbit (*Sylvilagus floridanus*), horse (*Equus caballus*)] were listed. With the exception of the data for corvidae and chickens, all nontarget avian effects occurred due to foraging on

Only four references (not provided here) cited by Johnson and Fagerstone (1994) deal with predator/ scavenger consumption of Zn_3P_2-dosed rodents. Specifically, two red foxes allegedly died after eating mice that consumed Zn_3P_2-treated grain bait, unspecified numbers of dogs died after eating ground squirrels poisoned with Zn_3P_2, two cat carcasses were recovered near a no-till corn field in Illinois treated with 2.0% Zn_3P_2 grain baits, and one cat death was noted in another poorly documented account.

Zn_3P_2-HAZARDS SCENARIOS: CATS AND DOGS

To provide some perspective concerning Zn_3P_2 residues in voles, the author prepared four "mortality-hazards scenarios" for two nontarget species—domestic cat and domestic dog. Mean (1.7 mg) and maximum (8.2 mg) Zn_3P_2 residues (100% retention) observed in fatally-dosed voles by Sterner and Mauldin (1995), plus representative light and heavy predators/scavengers, were varied to produce four scenarios of risk. These residues were then used to calculate total carcasses needed to dose light/heavy cats and dogs with 40 mg/kg (ALD) of Zn_3P_2

(Table 1). Tacit assumptions include: vole carcasses are consumed during continuous feeding and entire carcasses are ingested.

As shown, Scenario I reflects the hypothetical "worst case" situation—the least numbers of vole carcasses projected to deliver ALD doses to the nontargets. This scenario assumes that the maximum consumption of Zn_3P_2 by a vole (8.2 mg) noted by Sterner and Mauldin (1995) would be retained by voles and that light cats (e.g., kitten) and dogs (e.g., puppy, Chihuahua) would ingest these voles during relatively continuous feeding. Interestingly, the "worst case" intake of 8.2 mg Zn_3P_2 (assumed 100% retention and 2.0% bait) observed for a ole would equate to ingestion of ~12 to 13 voles for the cat reported by Tkadlec and Rychnovsky (1990).

Scenario II was developed using the same assumptions regarding Zn_3P_2, but hypothetical large cats (e.g., adult) and dogs (e.g., adult Labrador retriever) were substituted. As shown, the number of vole carcasses projected to cause mortality increased dramatically in this case to ~29 and ~176 for cats and dogs, respectively.

Scenarios III and IV are based on an assumption of the mean 1.7 mg Zn_3P_2 residue detected in voles by Sterner and Mauldin (1995). Using this value, ~5-fold increases in the Scenario I and II carcass ingestions would be needed to attain the ALD cumulative doses for light and heavy cats and dogs, respectively. Even lightweight cats and dogs would have to consume ≥24 vole carcasses in Amount of Zn_3P_2 in Vole(s) (mg) relatively continuous feeding bouts to ingest ALDs under Scenarios III and IV.

Table 1. Hypothetical hazards scenarios showing the numbers of vole carcasses that must be consumed (in relatively rapid succession) for domestic cats and dogs of different weight classes to ingest an ALD (Note: ALD for cat and dog = 40 mg/kg Zn_3P_2; Hudson et al. 1984).

	Assumptions			
Scenario	Amount of Zn_3P_2 in vole(s)[1] (mg)	Nontarget predator or scavenger	Nontarget weight (kg)	Estimated carcasses to ALD (#)[2]
I. High Zn_3P_2 load & light nontarget	8.2	Cat	2	~ 10
		Dog	1	~ 5
II. High Zn_3P_2 load & heavy nontarget	8.2	Cat	6	~ 29
		Dog	36	~176
III. Mean (low) Zn_3P_2 load & light nontarget	1.7	Cat	2	~ 47
		Dog	1	~ 24
IV. Mean (low) Zn_3P_2 load & heavy nontarget	1.7	Cat	6	~141
		Dog	36	~847

[1] From Sterner and Mauldin (1995).

[2] $$\text{Carcasses} = \frac{\text{ALD Dose (mg/kg) x Nontarget Weight (kg)}}{\text{Amount of } Zn_3P_2 \text{ in Vole(s) (mg)}}$$

CONCLUSIONS

Prior direct- and indirect-hazards studies, coupled with several incident reports, confirm that: 1) ingestion of multiple, Zn_3P_2-laden-vole carcasses can prove fatal to domestic cats in single-choice feeding situations (Bell and Dimmick 1975, Tkadlec and Rychnovsky 1990); 2) although toxic signs have been noted for nontarget wildlife species in direct-hazards studies (see Bell and Dimmick 1975), the procedures used have involved conditioning of nontargets to carcass-feeding regimen and single-choice tests; 3) while only about half ($\leq$69% or 2.2 mg) of ingested Zn_3P_2, and negligible amounts of PH_3 ($\leq$21 μg), have been recovered from carcasses using current analytical techniques (Sterner and Mauldin 1995, Tabata 1986, Tkadlec and Rychnovsky 1990), data suggest that undigested Zn_3P_2 in the GI tracts ($\sim$95% of the ingested amount) of target rodents pose the main potential hazard to nontarget predators/scavengers (Tkadlec and Rychnovsky 1990). Together, these results, and the lack of much unequivocal incident data, suggest that multiple dead or dying Zn_3P_2-baited voles must be consumed for representative predators/scavengers to ingest a cumulative lethal dose of Zn_3P_2/PH_3.

Scenario I is supported as a conservative estimate of hazards posed to cats and dogs by ingestion of Zn_3P_2-killed voles. Still, the likelihood of even lightweight cats and dogs ($\leq$1 kg) finding and rapidly (<24 h) ingesting multiple ($\geq$5) Zn_3P_2-dosed vole carcasses under field conditions seems remote. In a recent 14-day efficacy study involving a single 11.2 kg/ha broadcast application of 2.0% Zn_3P_2 oat groats within 7, 0.2-ha enclosures planted in alfalfa, Sterner et al. (in press) found only 25 exposed vole carcasses during daily post-baiting searches (51 to 76 h total) over a 14-day period. Moreover, expected onset of hydrolysis-induced illness in nontargets, <100% retention of Zn_3P_2 in carcasses, and selective avoidance of GI tracts containing undigested Zn_3P_2 by certain nontarget species should preclude many predators/scavengers from ingesting fatal doses.

ACKNOWLEDGMENTS

The author thanks Robert Phillips and Kathleen Fagerstone for helpful critiques of the manuscript; Dolores Steffen provided some slides used during the oral presentation of this paper.

LITERATURE CITED

BELL, H. B. 1972. The hazards of secondary poisoning from zinc phosphide to selected vertebrate species. Unpubl. MS Thesis, University of Tennessee, Knoxville, TN. 33 pp.

___, and R. W. DIMMICK. 1975. Hazards to predators feeding on prairie voles killed with zinc phosphide. J. Wildl. Manage. 39(4): 816-819.

CHEFURKA, W., K. P. KASHI, and E. J. BOND. 1976. The effect of phosphine on electron transport in mitochondria. Pest. Biochem. Physiol. 24:65-84.

GRATZ, N. G. 1973. A critical review of currently used single-dose rodenticides. Bull. Wld. Hlth. Org. 48: 469-477.

HAZARDOUS SUBSTANCE DATABANK [Databank Online]. 1993. Phosphine; CAS No. 7803-51-2. Natl. Lib. Med., Bethesda, MD. 13 pp.

HOOD, G. A. 1972. Zinc phosphide—a new look at an old rodenticide for field rodents. Proc. Vertebr. Pest Conf. 5: 85-92.

HUDSON, R. H., R. K. TUCKER, and M. A. HAEGELE. 1984. Handbook of toxicity of pesticides to wildlife (2nd ed.). Res. Publ. 153. U.S. Fish and Wildlife Service. Washington, DC. 90 pp.

JOHNSON, G. D., and K. A. FAGERSTONE. 1994. Primary and secondary hazards of zinc phosphide to nontarget wildlife—a review of the literature. Denver Wildl. Res. Rep. No. 11-55-005, U.S. Dept. Agric., Denver, CO. 26 pp.

MARSH, R. E. 1988. Relevant characteristics of zinc phosphide as a rodenticide. Gen. Tech. Rep. RM-154, U.S. Forest Service, Washington, DC. pp. 70-74.

MURPHY, S. D. 1986. Toxic effects of pesticides. *In* C. D. Klaassen, M. O. Amdur, J. Doull, eds. Casarett and Doull's toxicology: The basic science of poisons, 3rd ed. Macmillan, NY. pp. 566-567.

STERNER, R. T. 1994. Zinc phosphide: Implications of optimal foraging theory and particle-dose analyses to efficacy, acceptance, baitshyness, and nontarget hazards. Proc. Vertebr. Pest Conf. 16: 152-159.

___, and R. E. MAULDIN. 1995. Regressors of whole-carcass zinc phosphide/phosphine residues in voles: Indirect evidence of low hazards to predators/scavengers. Arch. Environ. Contam. Toxicol. 28: 519-523.

___, C. A. RAMEY, W. D. EDGE, T. MANNING, J. 0. WOLFF, and K. A. FAGERSTONE. (In Press). Efficacy of zinc phosphide to reduce vole populations in alfalfa—an enclosure study. Crop Prot.

TIETJEN, H. P. 1976. Zinc phosphide—its development as a control agent for black-tailed prairie dogs. Special Sci. Rept. (Wildl. No. 195), U.S. Dept. Inter., Washington, DC. 14 pp.

TKADLEC, E., and B. RYCHNOVSKY. 1990. Residues of Zn_3P_2 in the common vole (*Microtus arvalis*) and secondary poisoning hazards to predators. Folia Zool. 39(2): 147-156.

TABATA, K. 1986. Decomposition of the rodenticide Zn_3P_2 and its acute toxic symptoms in red-backed wood mice (*Apodus speciosus*) (in Japanese). J. Jpn. For. Soc. 68(1): 26-31.