April 1987

Relevant Characteristics of Zinc Phosphide As a Rodenticide

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Abstract.--Zinc phosphide has a long history of use and remains an important rodenticide for both commensal and select field rodents. A long list of significant characteristics contributes to its relative safety to nontarget species. It is zinc phosphide's relative safeness to humans, most livestock, and nontarget wildlife that has kept it in vogue. A most relevant and highly proclaimed characteristic is its general lack of potential secondary hazard to predators and scavengers. Poor or inconsistent efficacy on certain field rodents is a major shortcoming that can, in part, be compensated for by prebaiting. Zinc phosphide's favorable characteristics support its continued use, and its future prospects appear good.

INTRODUCTION

Zinc phosphide has a relatively long history of use as a rodenticide, and over time its characteristics concerning efficacy, safety and hazards, and environmental associations have been observed and studied. Zinc phosphide has many good characteristics and is widely used for rodent control around the world. Much of its popularity is due to its relatively low cost, although its efficacy is often not as high as is desirable. Its favorable characteristics generally outweigh its shortcomings.

Zinc phosphide was thought to have been first synthesized by Marggraf in 1740 (Wood and LaWall 1926). It was first used as a rodenticide in 1911 to control field rodents in Italy and later in other European countries (Chitty 1954, Freeman et al. 1954, Schoof 1970). Zinc phosphide's use became more extensive during and following World War II.

EARLY USE

Although mentioned in our literature as early as 1935, it appears not to have been used in the United States much before 1939-40 (Munch et al. 1936, Garlough 1941, Schoof 1970). Its use expanded during World War II when thallium sulfate and imported rodenticides like strychnine and red squill were difficult to obtain in adequate quantities. In this country zinc phosphide was first used for the control of commensal rats and mice and shortly thereafter was explored for field rodents.

In 1942 Joseph Keyes evaluated zinc phosphide in extensive field studies involving 58 tons of squirrel bait used in a 5-county area of California (Kalmbach 1942). In May 1942 Doty (1945) commenced studies of its use for the control of rats in the sugarcane fields of Hawaii. It was also early evaluated for vole control in eastern apple orchards.

IMPORTANT CHARACTERISTICS

Zinc phosphide has many good characteristics that sustain its continued use. Many of these are highly relevant to field rodent control as well as commensal rodent control. The following are the most significant of the favorable characteristics:

1. A broad-spectrum rodenticide.
2. Reasonably economical.
3. Relatively safe to humans.
4. Versatile for bait formulations.
5. Relatively slow acting.
6. Reasonably well accepted by many, but not all, target species.
7. No genetic resistance has developed.
8. No acquired tolerance develops.
9. Selectivity protects some nontarget species.
10. Potential secondary hazards are minimal.
11. Can be used in a manner that minimizes hazards to most nontarget species.

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[1]Paper presented at the Eighth Great Plains Wildlife Damage Control Workshop (Rapid City, South Dakota, April 28-30, 1987).
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12. Not accumulative in animal tissues to any degree.
13. Detoxifies in the primary target animal carcass over time.
14. Decomposes in the bait form and in the environment, reducing long-term potential hazard and contamination.
15. Translocation in plants minimal or nonexistent.
16. Residue tolerances are established for some crops.
17. Adequately stable when stored under dry conditions (i.e., good shelf-life).
18. Only moderately toxic on an mg/kg basis when compared to some other rodenticides.
19. Generally a good past safety record.

CURRENT USES

In the United States zinc phosphide is used for the control of commensal rodents (house mice, Norway and roof rats), but its use is relatively limited according to most estimates, as anticoagulant rodenticides make up 95% of the baits used for these species.

In agriculture, zinc phosphide finds much greater use for field rodent control, especially for control of rats (Rattus spp.), voles, ground squirrels, prairie dogs, and cotton rats To a lesser extent it is used for woodrats, pocket gophers, nutria, muskrats, and moles. It has also been evaluated on jackrabbits.

Many, like myself, are not overjoyed by zinc phosphide's effectiveness, at least for some species; however, because of its other good characteristics, it is often used when other rodenticides are inappropriate for some reason or where alternatives are unavailable.

SPECIES SUSCEPTIBILITY

Zinc phosphide is considered a broad-spectrum rodenticide and is used worldwide to control a wide number of native and introduced pest rodent species. LD_{50} values exist for some 22 rodent species; however, it is used for a far greater number of pest rodent species than is suggested by the published LD_{50} values. For the most part, the LD_{50} values for rodents fall between 10 and 40 mg/kg. The nutria has been found the most susceptible of the pest rodent species (LD_{50} 5.6) (Hood 1972). Voles, genus Microtus, are also quite sensitive to zinc phosphide with LD_{50} values for four separate species ranging from 12.4 to 18.0 mg/kg.

The desert kit fox (Vulpes macrotis arsipus) has an LD_{50} of 93 mg/kg, and the introduced mongoose (Herpestes auropunctatus) in Hawaii has an LD_{50} of 82 mg/kg (Keith et al. 1987), indicating that neither of these species is very sensitive to zinc phosphide. It is generally thought that mammalian predators are not very susceptible to zinc phosphide, and this in part is due to its emetic action. However, there are few precise LD_{50} values established for this group of animals.

Several avian species, particularly geese, are very susceptible in the range of 7.5 to 12.0 mg/kg, but most other bird species tested are less susceptible. Caution is advised when making generalizations concerning susceptibility, as considerable variation between species exists--even closely related species.

BAIT TYPES

The versatility of zinc phosphide as a rodenticide is evident by the type of bait formulations and grooming toxicants that are prepared. Whole or crimped grain baits are generally used for voles, ground squirrels, prairie dogs, and rats in agricultural situations, although cereal-based pelleted baits are marketed for the same purposes. Various meal and pelleted baits are used for the control of commensal rodents. Zinc phosphide is sometimes used in grains and incorporated with melted paraffin to form moisture-resistant solid bait blocks, and weather-resistant pelleted baits of other types are also marketed. Chunk or bait cakes are another form of solid baits used in Pakistan (Smythe and Khan 1980).

Perishable baits of fresh fruit, such as apples, oranges, and bananas, and vegetables, including tomatoes, sweet potatoes, cabbage, corn, and carrots, are sometimes used for such species as rats, voles, nutria, and jackrabbits. Fresh or canned meat and fish are used in Norway rat control. Concentrates are sold for preparing perishable-type baits.

Zinc phosphide concentrations used in baits vary greatly throughout the world, from 1 to 15% active ingredient, and this, again, demonstrates its versatility (Gratz 1973). In the U.S. it is generally used at a 1 or 2% concentration in cereal baits.

In Russia zinc phosphide has been explored as a foliar spray for microtine rodents (e.g., Microtus and related species) much the way we have used endrin and chlorophacinone as foliar sprays. The Russians have also used it as a rodent repellent for acorns destined for planting.

As a grooming toxicant, it is used as a tracking powder for house mice (Marsh 1972). It has also been evaluated in a grease base and placed at burrow entrances for rabbit control in Bangladesh (Poché et al. 1979).

WEATHERABILITY

Because zinc phosphide breaks down under wet and acid conditions, it was early thought that rapid decomposition occurred under field situations (Garlough and Spencer 1944, Doty 1945). Evidence to the contrary indicates that zinc phosphide can take a relatively long time to significantly detoxify under field conditions even when subject to moderate rainfall (Elmore et al. 1943, Hayne 1951, Guerrant and Miles 1969). This belief that zinc phosphide breaks down rapidly when exposed to rainfall still persists and has been responsible, in part, for accidental bird losses that resulted from inadequate precautions being taken.

Physical erosion may account for most of the decrease in the toxicity of weathered baits over an extended period of time when baits are protected from rainfall.

TOXICITY TO HUMANS

Accidental poisonings of an occupational nature are rare (Haynes 1982). Stephenson (1967) reported that over a period of 48 years (1917-1965), 26 fatalities were attributed to zinc phosphide poisoning in humans; of these, 18 (70%) were suicides and 3 were murders. The fact that zinc phosphide baits are grayish-black in color and have an odor that is not particularly pleasant may contribute to few accidental ingestions. An emesis action may occur in humans from ingesting zinc phosphide, and such elimination may assist in reducing fatalities. Early characteristics of poisoning are nausea, vomiting, abdominal pain, chest tightness, excitement, and a chilly feeling. If vomiting occurs within an hour after ingestion, the chances of surviving are improved. The garlic-like smell of phosphine on the breath or vomitus of the patient is common.

POOR AND/OR INCONSISTENT EFFICACY

With species such as the California ground squirrel (Spermophilus beecheyi), the control results are often very inconsistent and erratic for reasons that seem to defy an ability to identify them, or at least all of them. It is not uncommon to have control vary from 25 to 75% for ground squirrels even on the same ranch in different years, or on adjacent ranges in the same year at the same time period. While some lack of uniform squirrel control is also experienced even with the best of acute toxicants (e.g., 1080 and strychnine), generally the reduced control can be attributed to known factors. Variabilities seen with 1080, for example, are usually very much less than with zinc phosphide.

Rarely do we achieve much better than 75 to 80% squirrel control with zinc phosphide under the best of control conditions, whereas with 1080 under similar conditions, 85 to 98% control is not uncommon.

Prebaiting, of course, can significantly improve efficacy of zinc phosphide for ground squirrels and prairie dogs just as it can with other acute toxicants. Prebaiting is often recommended, although one prebaiting may increase the cost of control by as much as 80%. In some situations, the additional cost of prebaiting may make control uneconomical.

As the same principles apply to target as well as nontarget animals, it remains unclear whether prebaiting significantly increases the hazards to certain nontarget species.

Repeated annual use over a long period of time often decreases efficacy. This has been observed in ground squirrel and vole control in California. This is due, in part, to bait shyness resulting from previous sublethal exposures. However, there seem to be other contributing factors, possibly a more discriminating population evolves. This diminished efficacy resulting from long-term use is very real, and frequently the only solution to regain reasonable control is to switch to another rodenticide.

POTENTIAL NONTARGET PRIMARY HAZARDS

Domestic mammals are rarely endangered by properly placed bait (Ingram 1945, Chitty 1954). However, fowl are highly susceptible, and there are a number of instances of chickens (Hare and Orr 1945) and domestic geese being killed where bait was accessible to unconfined, free-roaming poultry (Bubien et al. 1970).

Incidental nontarget wildlife losses are infrequent and usually involve few animals. Exceptions generally involve other seed-eating rodent species occupying the same habitat. Of the game species, geese, which are more susceptible than most target rodent species, may be the most vulnerable of all wild bird species at risk from primary poisoning (Marsh 1985). Goose mortality has occurred in the past where adequate precautions were not taken. Such past mistakes now provide a basis for specific precautionary measures. Potential hazard to ducks and pheasants (Hayne 1951, Collins 1966) has foundation, although incidental kills in the U.S. are few and relatively minor.

SECONDARY POISONING MINIMAL

Secondary poisoning of dogs and cats is not nearly as likely with zinc phosphide as with 1080 or strychnine, although the hazards of the latter two are often exaggerated. Nonetheless, on rare occasions dogs and cats have consumed poisoned rodents and died (Chitty 1954, Storer and Jameson 1965, White and Vonesch 1970, Stowe et al. 1977). Srinath (1977) mentions losses of cats and pigs in India due to secondary poisoning. Another atypical case of secondary poisoning occurred to chickens on a poultry farm in India where the birds were seen pecking at rat carcasses. About 10 chickens died as a result (Christopher et al. 1982).

Studies by a number of researchers of hazards to confined nontarget wildlife reveal minimal hazards. Siberian ferrets, a close relative of black-footed ferrets, survived the feeding of five zinc phosphide-poisoned rats, although some blood chemistries were altered (Hill and Carpenter 1982).

Zinc phosphide-poisoned prairie dogs fed to five mink for 30 days resulted in no visible symptoms of intoxication (Tietjen 1976). Coyotes receiving multiple feedings of zinc phosphide-poisoned jackrabbits showed no visible symptoms (Evans et al. 1970). Schitoskey (1975) demonstrated that kit foxes survived repeated feedings of kangaroo rats killed with massive doses of zinc phosphide. Red and gray foxes survived feedings of zinc phosphide-killed voles with no mortality (Bell and Dimmick 1975). Domestic cats and mongooses were not poisoned when fed rats poisoned with zinc phosphide (Doty 1945). Bald eagles and black vultures were not poisoned when fed zinc phosphide-killed nutria (Tietjen 1976). Those knowledgeable of rodenticides generally agree that secondary hazards to wild predators are minimal (Hegdal et al. 1980).

FUTURE PROSPECTS

There are several major shortcomings of zinc phosphide that influence its use. Relatively poor initial bait acceptance occurs in some species such as ground squirrels and prairie dogs, and serious bait and toxic shyness results from sublethal exposures in most all rodents. These contribute to the most significant shortcoming: the lack of a high degree of control effectiveness. A number of methods are thus used to overcome these shortcomings including prebaiting, microencapsulation of the active ingredient, improved bait formulations, reducing available alternate food, and better timing of application. But none of these improves efficacy to the degree that zinc phosphide could be called highly efficacious for certain field rodents. In spite of this, zinc phosphide will remain a viable rodenticide or alternate rodenticide because of its general safety.

Because of its favorable characteristics, the future of zinc phosphide will probably be good, and it will undoubtedly play about the same role in field rodent control as in the past decade. If, however, we should lose strychnine or 1080 for specific uses in controlling field rodents, then the use of zinc phosphide bait would increase substantially. Only the development of a new safer, more effective, and equally economical rodenticide would diminish the future use of zinc phosphide baits for field rodents.

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