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BACK TO THE FUTURE FOR APHIS'S VERTEBRATE PESTICIDES

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ABSTRACT: Many vertebrate pesticides used by the Bureau of Biological Survey at the turn of the century were registered by the U.S. Fish and Wildlife Service (USFWS) beginning in 1960 with the U.S. Department of Agriculture (USDA). A review of archives and other documents at the Denver Wildlife Research Center (DWRC) has shown that a total of 72 federal registrations were established by the USFWS between 1960 and 1985. Because of increased regulation by the U.S. Environmental Protection Agency (EPA), selective transfers from USFWS to USDA, voluntary cancellations, conversions to state local need registrations, and a reduced development pace, there are now only 21 federal vertebrate pesticide registrations. They are maintained by the Animal and Plant Health Inspection Service (APHIS) for the Animal Damage Control (ADC) program. As a result of a 1988 Amendment to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA 88), DWRC initiated in 1989 an extensive reregistration program for ADC's vertebrate pesticides. In the past three years, DWRC and its cooperators have submitted 188 studies in support of the reregistration of products containing strychnine, sodium cyanide, zinc phosphide, compound 1080, sodium nitrate, carbon, DRC-1339, and PA-14. Since 1989, the reregistration of these 8 active ingredients has taken priority over the development of new vertebrate pesticides at DWRC in order to concentrate on gathering data for these chemicals of the past. New tools to mitigate human and wildlife conflicts must continue to be the goal of present and future federal research.

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INTRODUCTION

This paper will emphasize the past, present, and future of major chemicals that comprise the federal (Section 3) vertebrate pesticide registrations of the Animal Damage Control (ADC) program, administered by the Animal and Plant Health Inspection Service (APHIS), U.S. Department of Agriculture (USDA). The goal of the ADC Program and some elements of its predecessors, including the U.S. Fish and Wildlife Service (USFWS) and Bureau of Biological Survey, has been to control damage caused by vertebrate pests.

At the First Vertebrate Pest Conference, Howard (1962) defined a vertebrate pest as any native or introduced, wild or feral, non-human vertebrate species that is currently troublesome to one or more persons, either by being a health hazard, general nuisance, or by destroying food, fiber, or natural resources. Today, the definition of a vertebrate pest has taken on different meanings. Rather than managing vertebrate pests on a species level, current wildlife management deals selectively with problem animals or problem situations on a localized basis. In contrast, the public's definition is more a matter of value-based personal perceptions about the species that can evoke negative feelings from one individual, and neutral or even positive feelings from another. Wildlife managers must recognize these varying points of view as they make decisions on the development and use of pesticides. Yet, pesticides have a place in today's society, as expressed by Matheny (1980). He presented the U.S. Environmental Protection Agency's view that vertebrate pesticides, when properly used, may benefit man and, if improperly used, may also endanger life. He further explained that vertebrate pesticides, as regulated by the EPA, include many products—lethal agents, anesthetizing chemicals, irritants, repellents, reproductive inhibitors, and fumigants.

PAST USE AND REGULATION OF FEDERAL VERTEBRATE PESTICIDES

Vertebrate pest controls have probably been part of the human experience from the earliest of times. A knowledge of the history of federally registered vertebrate pesticides will require a brief introduction to the agencies involved in animal damage management, the regulation of vertebrate pesticides, and the evolution of the active ingredients used in the present list of APHIS's vertebrate pesticides.

Federal Agencies Involved in Animal Damage Control

The first extensive Federal Government involvement in wildlife damage control began in 1886 with the formation of USDA's Division of Economic Ornithology and Mammalogy. Its responsibility was to educate farmers about wildlife damage control techniques. The Division underwent several name changes before it became the Bureau of Biological Survey in 1905. Some of the Bureau's objectives were to study the economic destructiveness of birds and mammals, to determine effective control methods for reducing vertebrate pest numbers, and to prevent damage to agricultural crops and livestock production (USDA 1990). The Animal Damage Control Act of March 2, 1931 gave USDA the authority to conduct wildlife damage control activities. It remains the primary statutory authority for the current ADC program. These activities were transferred from USDA to the USFWS, U.S. Department of Interior in 1939 (USDA 1990). An amendment to the 1986 Federal Budget Resolution transferred all ADC program resources, including the Denver Wildlife Research Center (DWRC), to the USDA (Wade 1986). The transfer was completed in March 1986 and included 21 federal vertebrate pesticide registrations maintained for mammals and birds by the USFWS (Donner per. commun. 1987).

Federal Regulation of Vertebrate Pesticides

The history of pesticide regulation dates from the passage of the Federal Insecticide Act of 1910, which made it unlawful to sell adulterated products and protected purchasers of insecticides and fungicides from fraud (Fagerstone et al. 1990). Shortly thereafter, mammal control specialists in the Bureau of Biological Survey and in the U.S. Public Health Service began to recognize the need for a regulated system to control pesticide use on wild animals. A Federal Rodenticide Act was drafted, but it was not enacted until passage of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947 which brought rodenticides and rodent repellents under Federal control. FIFRA was administered by USDA (Fagerstone et al.1990), and its limited scope was not increased until 1961 to include other mammals, birds, fishes, reptiles, amphibians, invertebrates, plants, and viruses. In 1970, the U.S. Environmental Protection Agency (EPA) was created and all pesticide registration functions were transferred from USDA. Concurrently, public attention was focusing on predacides and in 1971 a federal committee was formed to investigate federal predator control. The committee's Cain report resulted in the President signing an Executive Order in 1972 banning the use of toxicants such as strychnine, 1080, thallium sulfate, and sodium cyanide for predator control by federal agencies or on federal lands. This ban was relaxed in 1975 to permit the use of sodium cyanide in the M-44 (Connolly 1978).

The Federal Pesticide Act of 1978 directed the EPA to evaluate the environmental and human health hazards associated with registered products; however, the reevaluation was very slow. In 1988, Congress amended FIFRA (FIFRA 88) to strengthen and accelerate EPA's reregistration program (Fagerstone et al. 1990). FIFRA 88 required a comprehensive reevaluation of pesticide safety for each registered product containing an active ingredient (AI) registered before November 1, 1984 (EPA 1989). It established a five phase reregistration process that must be accomplished by 1997. These phases are briefly described below:

Phase 1. Requires EPA to publish lists of active ingredients subject to reregistration and to ask registrants whether they intend to seek reregistration of the technical pesticide.

Phase 2. Requires registrants to declare their intent to reregister the technical pesticide, to identify missing and inadequate data, and commit to provide those data.

Phase 3. Requires registrants to submit reformatted summaries of acceptable existing studies, generate new data, and identify any adverse effects of the pesticide.

Phase 4. Requires EPA to review all Phase 2 and 3 submissions, and requires registrants to meet any unfulfilled data requirements.

Phase 5. Requires EPA to review all studies that have been submitted and decide if the technical pesticide is eligible for reregistration. If so, a Reregistration Eligibility Document (RED) will be issued and a Data Call-In (DCf) will be issued for any end-use product (EUP) data that are required prior to a final regulatory decision.

The Evolution of ADC's Vertebrate Pesticide Active Ingredients

In the 1930s, nine vertebrate pesticides were in general use by the Bureau of Biological Survey including: strychnine alkaloid, strychnine sulfate, barium carbonate, thallium sulfate, sodium cyanide, calcium cyanide, red squill, carbon disulphide, and phosphorus (Ward 1962). Of these, only strychnine alkaloid and sodium cyanide are APHIS registrations today. Two others, thallium sulfate and red squill, were registered by the USFWS between 1960-1966 for field rodent control and between 1961-1972 for rat control, respectively. The historical development of thallium sulfate and red squill are discussed elsewhere (Crabtree 1962, Savarie 1981).

Strychnine alkaloid was discovered by Pelletier and Caventou in 1817 as a natural constituent in the seeds of *Strychnos nux-vomica* (Henry 1913). These seeds had been used in Europe since 1640 for killing dogs, cats, and birds. Strychnine was introduced into the United States about 1847 and became the principal pesticide of the professional wolfer in eradication campaigns between 1860 and 1885 (Young and Goldman 1944). In the early history of the Bureau of Biological Survey, strychnine was its primary control tool. Even though strychnine has had a long federal history of use for predator, field rodent, and pigeon control, its current uses are greatly restricted. The 1972 Presidential Executive Order led to cancellation of strychnine's use as a predacide on federal lands or by federal agencies. The above-ground use of strychnine was suspended by a 1988 U.S. District Court injunction and a 1988 temporary cancellation notice by EPA, but below ground uses (primarily for pocket gophers) have been retained.

Sodium cyanide has been an important tool in coyote depredation control since 1939 when the coyote getter was introduced (Marlman 1939). In the coyote getter, sodium cyanide was placed in a .38 caliber cartridge case and expelled by the explosive force of the primer and a small powder charge into the mouth of the predator (Robinson 1943). The coyote getter was used by the USFWS from the late 1930s to 1970 (Connolly and Simmons 1984). Because of the danger involved in the use of a powder charge in the coyote getter, the M44 was developed in the 1960s to replace the coyote getter. The M-44 uses a plunger (spring) mechanism for injecting the sodium cyanide (Poteet 1967) and was federally registered by the USFWS in 1975 for canids.

During the Second World War, shortages of strychnine and red squill in the United States and England necessitated the development of other control chemicals such as zinc phosphide and sodium monofluoroacetate (compound 1080). Zinc phosphide is a nonspecific inorganic toxicant. It was first synthesized in 1740 by Marggraf (Wood and LaWall 1926), but was not used as a rodenticide until 1911 in Italy. It was introduced for vertebrate pest control in the United States in 1942. Compound 1080 was first prepared by Swartz in 1896 (Pattison 1959), but its toxicity was not exploited until the U.S. Chemical Warfare Service suggested its use as a rodenticide to the USFWS during World War II. This compound was subsequently developed as a vertebrate pesticide (Crabtree 1962), but the two USFWS predacide uses were cancelled in 1972 by the Presidential Executive Order. By 1975 all three USFWS rodenticide registrations for 1080 had been voluntarily cancelled. In 1990, EPA cancelled all other federal, state, and private registrations for 1080 with the lone

exception being APHIS's Livestock Protection Collar (LPC). The LPC was patented by McBride in 1974 and further developed by DWRC; it is a plastic collar containing 2 bladders filled with 1080. It is placed around the neck of lambs in areas where coyote predation has been occurring. When the coyote attacks the lamb in a characteristic behavior by biting (he throat, the coyote receives a lethal dose of 1080 (Connolly 1978).

The gas cartridge was also developed during the 1940s by the Bureau of Biological Survey. It is a pyrotechnic that was used to control burrowing mammals. Upon combustion, the gas cartridge produces carbon monoxide and a variety of other toxic gasses. The rodent gas cartridge was registered in 1960 by the USFWS. The gas cartridge for coyotes was developed by the DWRC and was registered in 1981 (Savarie et al. 1980).

By 1962, the USFWS had 38 products registered with USDA that used strychnine alkaloid, compound 1080, zinc phosphide, thallium sulfate, red squill, sodium cyanide, and the gas cartridge in various formulated products; however, there were no registered avicides. During the mid to late 1960s, a major effort was undertaken by the DWRC to develop avicides that were selectively toxic to birds, particularly pest bird species, and relatively nontoxic to mammals and other organisms (Schafer 1991). These initiatives produced USFWS registrations for DRC-1339 (3-chloro-p-toluidine hydrochloride) in 1967 and PA-14 (Tergitol 15-S-9®) in 1974.

PRESENT USE OF USDA/APHIS'S VERTEBRATE PESTICIDES

APHIS presently has 21 federal low volume minor use vertebrate pesticide registrations. Most of these registrations are formulated products consisting of one or more of 8 active ingredients (strychnine, sodium cyanide, zinc phosphide, compound 1080, sodium nitrate, carbon [charcoal], DRC-1339, and Compound PA-14) that are currently undergoing reregistration by the EPA. To date, DWRC and its cooperators have submitted 188 studies to the EPA toward the reregistration of these active ingredients. The data requirements for registration and reregistration are specified in 40 CFR (Part 158) of FIFRA and include product and residue chemistry, product performance, hazard evaluation, and environmental fate studies (EPA 1991). Data collection using EPA's Good Laboratory Practice standards (40 CFR 160) is required for all studies. APHIS estimates that 0.5 to 5.0 million dollars may be needed to complete all the data requirements to reregister each active ingredient and associated end-use products (EUP). The modes of action, uses, and current reregistration status are described below for these 8 active ingredients.

Strychnine

Strychnine is a nonspecific single dose poison that is highly toxic to mammals, birds, and other animals. It is rapidly absorbed from the gastro-intestinal tract. The principal symptoms of strychnine poisoning are convulsive seizures commonly appearing within minutes after ingestion. Death usually occurs from a tetanic arrest of respiration during a major convulsion. Strychnine is currently restricted to underground use until a court injunction prohibiting above ground uses is overturned. A Strychnine Consortium was formed in 1988 consisting of APHIS, state agencies, and private companies and is coordinated by the DWRC. Its purpose is to generate funds to produce data required by EPA for the Strychnine Settlement Agreement and the reregistration of strychnine active ingredient. The Consortium has submitted 33 studies to EPA with three pending completion and is awaiting the reregistration Phase 4 Data Call-In (DCI) that will probably require submission of additional data.

Sodium cyanide

Sodium cyanide's mode of action involves the production of hydrocyanic acid. It produces rapid death by asphyxiation by hindering the oxidative processes of cells, and therefore has been classified a general protoplasmic poison (Crabtree 1962). The M-44 has been described by Connolly (1978) as one of the most important techniques for controlling livestock losses by coyotes. Sodium cyanide is currently in Phase 3 of the reregistration process after the submission of 28 studies. APHIS is awaiting the Phase 4 DCI that may outline additional required studies.

Zinc phosphide

Zinc phosphide is a single dose toxicant that is generally less toxic than 1080 or strychnine and is slower acting. When it is ingested and comes into contact with water and hydrochloric acid in the gastrointestinal tract, highly toxic phosphine gas is formed (Henderson and Boggess 1979). Because the phosphine gas does not accumulate in tissue of poisoned animals, zinc phosphide has a low risk of secondary poisoning (Savarie 1981). Previously, 35 studies were completed in support of the reregistration of zinc phosphide. In May 1991, a Zinc Phosphide Consortium was formed by APHIS, state agencies, and private industry to generate funds to acquire data required by a March, 1991 EPA DCI requesting at least 9 more studies for the active ingredient. The EUP requirements are not yet known.

Compound 1080

Sodium monofluoroacetate is a potent single dose acute toxicant. Tissue enzymes metabolize it into fluorocitrate (Peter 1952), which disrupts the Krebs cycle and results in the inhibition of cellular energy production (Savarie 1981). Death results from respiratory paralysis in carnivores, from cardiac fibrillation in herbivores, and from both causes in omnivores (Crabtree 1962). Perhaps the outstanding characteristic of the toxicology of compound 1080 is the extreme variation in the susceptibility between species or even within a species, and the divergence in the symptoms exhibited among species (Chenoweth 1950). Compound 1080 is nonspecific and can cause primary and secondary poisoning (Colvin et al. 1988). Therefore, its use is currently very limited in the U.S. even though 1080 has been perhaps the most successful lethal pesticide ever employed for predator and rodent control. Compound 1080 is in Phase 3 of the reregistration process, with 18 studies submitted to EPA. APHIS is awaiting the Phase 4 DCI for the active ingredient.

Gas Cartridge (Sodium Nitrate and Carbon)

APHIS has registrations for two gas cartridges for underground use to control burrowing rodents and coyotes. The gas cartridge is ignited, placed into burrows or dens, and the burrow or den is covered to prevent the escape of toxic gasses generated by the burning cartridge. Carbon monoxide is probably the primary toxic gas that produces mortality by combining preferentially with hemoglobin to form

carboxyhemoglobin upon inhalation (Swinyard 1975). Death results from tissue hypoxia because the blood cannot carry sufficient oxygen to sustain normal metabolic processes. The APHIS coyote gas cartridge consists of two active ingredients (sodium nitrate and carbon/charcoal) that are undergoing reregistration and are in Phase 5. Reregistration Eligibility Documents (REDs) have been received for both active ingredients. The RED represents the culmination of the initial phase of the reregistration process. In the sodium nitrate and carbon RED documents, EPA indicated that the data submitted for the technical products meet current registration requirements and EPA therefore proposed to reregister both active ingredients. Issuance of the REDs completed the initial phases of the reregistration process for these active ingredients. The simultaneous issuance of a DCI, requiring data for each EUP manufactured with these active ingredients, will complete the reregistration process. Thirty-eight studies have been requested by the EPA to support the reregistration of the gas cartridge EUPs, in addition to the 22 studies already submitted for the reregistration of the active ingredients.

APHIS's four-active ingredient gas cartridge for burrowing rodents is being converted to a two-component cartridge, like that registered for coyotes, to simplify reregistration data requirements. The application for the new Gas Cartridge II for rodents was forwarded to EPA in 1991 along with 7 supporting studies. When the Gas Cartridge II is registered, the present four-ingredient gas cartridge will be voluntarily cancelled.

DRC-1339

The primary mode of toxic action in birds following ingestion of DRC-1339 is irreversible necrosis of the kidney and the inability to excrete uric acid, resulting in uremia and death. DRC-1339 is rapidly metabolized in the body, excreted, and does not accumulate in body tissues (Cunningham et at. 1981). It is a restricted use slow acting avicide registered for selective control of pest birds. It is highly toxic to most passerines, columbids, and corvids, but only moderately toxic to most raptors and mammals. Therefore, DRC-1339 is considered selective for many target species and the risks of primary or secondary hazards to non-target vertebrates are low (Schafer 1991). APHIS maintains 2 federal registrations using DRC-1339 and is trying to consolidate most of its state registrations into 3 new federal registrations (Knittle et al. 1990). DRC-1339 is being reregistered through a joint effort between DWRC and Purina Mills, Inc., the technical registrant. Jointly, 42 studies have been completed with 2 additional studies nearing completion. Phase 5 data requirements for EUPs are unknown.

PA-14

PA-14 is a surfactant that removes much of the natural oils from the feathers of birds, leading to a reduction of the insulating qualities of the bird's feathers; death occurs from hypothermia due to exposure during cold weather (Lefebvre and Seubert 1970). PA-14 was registered in 1974 for use as a spray for large blackbird roosts where they are a nuisance or cause human health hazards. PA-14 is only slightly toxic when ingested. DWRC's reregistration activities have concentrated on reformatting and summarizing studies previously submitted to the U.S. Food and Drug Administration (FDA) by other companies registering PA-14 as a surfactant; as a result, 26 data submissions to EPA have been completed. A Phase 4 DCI is expected that will contain additional data requirements.

THE FUTURE OF USDA/APHIS VERTEBRATE PESTICIDES

The DWRC is the major federal research center that focuses on methods development for alleviating damage caused by wildlife (Reidinger 1990). Currently, about half of DWRC s research budget is used to generate data to reregister the 8 active ingredients used in ADC's registrations. Maintenance of these pesticides from the past continues to be the DWRC's highest research priority; however, the development of a stronger discovery-research component at DWRC that will focus on the latest technology and its potential applications to vertebrate pest management is also underway.

According to Merrill (1970), past control methods development has been too often based solely on an assessment of target species efficacy and not on an assessment of their effects on the environment. The evolution of many of ADC's present pesticides seems to support this view; however, the search for new methods, that are effective and socially acceptable, is a continuing goal of ADC's vertebrate pest managers. A key issue in recent years has been the selection criteria for new vertebrate pesticides (Hood 1972, Savarie and Connolly 1984). The authors believe there should be at least four basic criteria: 1) proven efficacy; 2) species or individual selectivity; 3) safe to humans, animals, plants and the environment; and 4) a humane mode of action.

Based on increasing numbers of requests for assistance from federal agencies, State and local governments, and the public, it is apparent to wildlife managers that the need for the next generation of vertebrate pest control methods and products is increasing. While considerable research has gone into development of Integrated Pest Management (IPM) programs for control of insects and weeds, vertebrate IPM research and development has lagged. Research needs include increasing the accuracy of wildlife damage assessments before and after control activities, understanding the population dynamics of pests and their interactions with non-pest species, determining the effects of environmental manipulation, and defining the human and domestic animal hazards associated with epizootics in disease-bearing pests.

APHIS, through the DWRC, is currently exploring a number of candidate vertebrate pesticides for possible future registration including alpha-chloralose, the tranquilizer trap tab, and immunocontraceptive vaccines. In October 1989, APHIS applied to the FDA for an Investigational New Animal Drug Application to use alpha-chloralose as a tranquilizer for capturing and relocating waterfowl. All FDA-required research studies have been completed and a New Animal Drug Application was submitted to FDA in September, 1991. APHIS is awaiting authorization for use of this product. DWRC is conducting research to identify a suitable drug for use in a tranquilizer trap tab to be placed on leg-hold traps. The trapped animal would chew on the tab and receive a dose of tranquilizer, thereby reducing the possibility of trap related injury and stress. Recent advances in immunology also present an opportunity to develop immunocontraception as a technique for the nonlethal regulation of wildlife populations. DWRC has begun to explore development of an immunocontraceptive vaccine plus delivery system to allevi-

ate problems caused by overpopulation of white-tailed deer. DWRC is also expanding its repellent research. Future repellents such as methyl anthranilate (MA) and DRC-156 may be used to lessen bird airplane strikes, reduce nuisance goose problems, or decrease bird contacts with toxic ponds. Conversely, attractants may be helpful for increasing the selectivity of other control methods. Resources for development of these future techniques to help mitigate human and wildlife conflicts are being carefully balanced with the effort to maintain current APHIS vertebrate pesticide registrations.

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