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Acute Toxicant Identification in Whole Bodies and Baits Without Chemical Analysis

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ABSTRACT: We propose a system utilizing small color-coded plastic particles to identify acute toxicants in digestive tracts and baits without chemical analysis. Test results show that the coded particle is suitable for incorporation into various baits, does not cause bait aversion, and is readily recovered from digestive tracts and fecal samples without loss of code integrity. Toxicant identification in coyotes poisoned secondarily after eating rodents is demonstrated. The proposed concept of toxicant identification is feasible. We suggest that the identification system be included in the manufacture of toxic baits.

KEY WORDS: toxicant, marker, poison, bait, identification, zinc phosphide, 1080, diphacinone, Starlicide, Avitrol, rat, white-footed deermouse, Richardson's ground squirrel, red-winged blackbird, starling, coyote

Identification of acute toxicants in baits and animal bodies is a requirement in many activities. Researchers conducting poisoning investigations involving primary and secondary hazards to wildlife, domestic stock, and pets often make toxicant identifications. Persons involved in baiting studies and medical personnel concerned with human ingestion of toxic baits are also concerned. All have a need for a method of toxicant identification which is simple, rapid, and inexpensive. The Minnesota Mining and Manufacturing Co. has developed a small plastic particle[2] that is coded by means of colored layers. The fact that microscopic plastic particles can be coded suggests the possibility that specifically coded particles could be used for identification in formulations of toxic products such as rodenticides. The particles would provide identification of the toxicant by association.

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[2] Trade name "Microtaggant." (Reference to trade names does not imply endorsement of commercial products by the Federal Government or any of its agencies.)

This paper presents data that indicate the potential utility of this method of toxicant identification in baits and digestive tracts of species that have ingested baits. Dyes, fluorescent particles, and other markers historically have been used to identify baits and toxicants [*1–6*].[3] The marking system presented here is subject to limitations similar to those encountered in using previous particle marking techniques. However, the fact that the particles are coded overcomes some of these limitations. For example, problems caused by the need to have many toxicants or baits separately identified or the need for security in marking are removed. A particular code is sold to only one purchaser. The primary use of this system of identification is viewed as being in association with acute toxicants, since they normally cause mortality before all the bait has left the digestive tract. However, there could be some use for bait or even body identification with chronic toxicants where repeated ingestion occurs until death.

The Coded Particle

The particle was originally developed to provide a means of identifying the type and origin of explosives used in criminal activities. The particles have properties which make them suited for use in bait formulation and subsequent recovery from baits and digestive tracts. They are small. The standard manufacturing size is irregular flakes (Fig. 1), all of which will pass a 425-μm screen and 2 percent or less a 45-μm screen. By selective screening, various sizes can be obtained. The specific gravity is nominally 1.3 to 1.5. The color-coded layers are read with an X30 or greater optical magnifier. The number of layers used ranges from five to seven, and there are 10 colors available for the code. The colors are numbered from 0 to 9 with the color/number relationship based on the standard color code of the electronics industry [*7*]. When a code is purchased, a code number is generated and recorded by computer and remains uniquely the buyer's. A color is never used adjacent to itself but can be repeated. The number of codes available with 10 colors in different combinations and orders is in the millions.

Two features that make recovery of the particles easy are the incorporation of one or more layers that are fluorescent under ultraviolet light and a ferromagnetic layer. Visual and magnetic recovery can be made from a variety of materials. The manufacturer states that the particles are chemically stable; the base material is an inert thermoset plastic unaffected by most solvents, acids, and bases. All ingredients can be from the U.S. Food and Drug Administration's Generally Recognized As Safe (GRAS) list [*8*]. The particles are also claimed to be thermally stable to 200°C during extended exposures and to 350°C for 30 s.

Procedures

Animals, Baits, and Equipment—General Conditions

All test birds and animals except the coyotes (*Canis latrans*) were housed in individual, wire-floored indoor cages. Coyotes were held in individual, concrete-

[3]The italic numbers in brackets refer to the list of references appended to this paper.

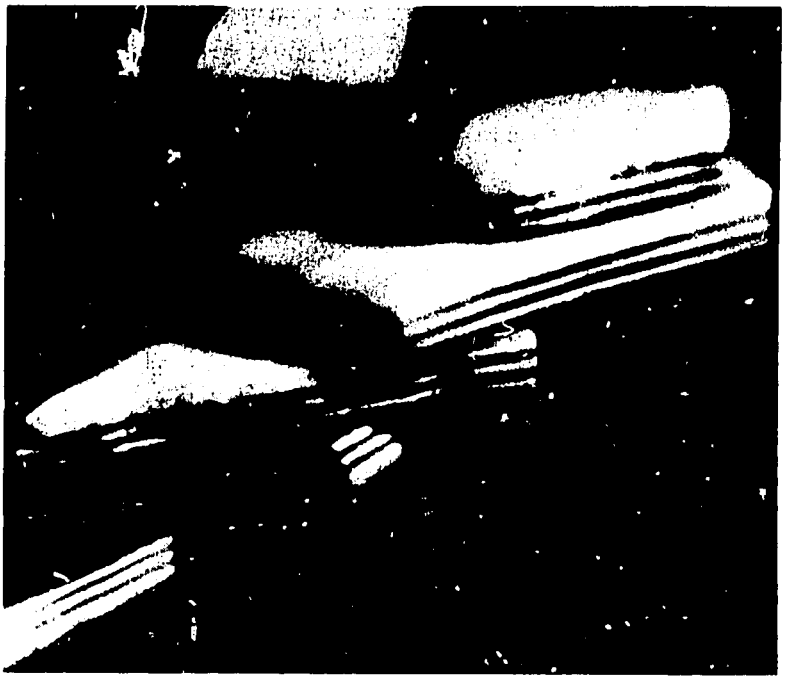

FIG. 1—*Coded plastic particles (thickness = 136 μm).*

floored outside animal pens. All test species were provided food and water *ad libitum* prior to the start of the respective studies. Rats and mice were on a 14/10 light/dark cycle with room temperature 21 to 27°C. Ground squirrels (*Spermophilus richardsonii*) were on an 8/16 light/dark cycle with room temperature about 20°C. Coyotes and birds were exposed to ambient daylight and temperatures. In all baits where glycerol was used, its function was to adhere the coded particles to the bait. A long-wave ultraviolet light was used to search for particles and an X30 binocular dissecting microscope provided the magnification to determine if the particles were intact with a readable code.

Acceptance of Nontoxic Bait—Six male and six female wild Norway rats (*Rattus norvegicus*), weighing 150 to 210 g, were prebaited for three nights. Then each rat was offered a treated and control bait in separate food cups for four nights. The cups were reversed each night to prevent position bias. The prebait, treated, and control baits, by weight, were 90 percent hulled rolled oats and 10 percent glycerol; the treated bait also contained 0.3 percent coded particles. No other food was offered during the test. Equal quantities of bait (40 g) were offered in each cup and consumption was recorded daily. Total consumption of bait per rat was used in a two-factor (sex and treatment) analysis of variance with repeated measures on the second factor [*9*] to determine consumption differences.

Acceptance of Toxic Bait—The test was conducted to determine if coded particles on bait might act as a cue that would cause the rat to ingest less than a lethal dose. Thirty male and 30 female rats (Sprague-Dawley albino), weighing 180 to 240 g, were divided into two treatment groups of 15 male and 15 female rats each. Group I was offered treated and control bait in separate food cups for one night. The control bait contained, by weight, 90 percent hulled rolled oats and 10 percent glycerol. The treated bait contained 97.7 percent control bait, 2 percent zinc phosphide, and 0.3 percent coded particles. Forty grams of bait was offered in each bait cup. Consumption and mortality were recorded the morning after offering the baits and survivors were observed for seven days.

Group II was an exact repeat of Group I except that treated bait did not contain coded particles.

Multiple Species Demonstration with Toxic Baits—The objectives of this section were (1) to demonstrate that the coded particles remain intact in the digestive tract, (2) to show the location of the particles in the digestive tract after death, and (3) to determine a practical recovery method.

In all tests, the bait was the only source of food. Rodent digestive tracts were examined at the stomach, cecum, and the location of the last few fecal pellets in the intestine. The gizzard, upper intestine, and lower half of the intestine were examined in birds. The entire length of the digestive tract from the stomach to the rectum was cut open and examined in the coyote. All species used were either adults or juveniles that had almost reached adult weight.

Acute toxic baits—

1. Three male and three female wild Norway rats were individually fed a bait consisting of 87.7 percent hulled rolled oats, 10 percent glycerol, 2 percent zinc phosphide, and 0.3 percent coded particles. The rats were prebaited for three nights with untreated hulled rolled oats.

2. Repeat of Step 1 with six female white-footed deer mice (*Peromyscus maniculatus*).

3. Two male and three female Richardson's ground squirrels were each fed a rolled oat-groat bait containing 0.067 percent Compound 1080 (sodium monofluoroacetate), 0.3 percent coded particles, and 10 percent glycerol. The animals were prebaited, offered the treated bait for two days, and then placed back on untreated food.

4. Two coyotes were each fed a 500-g hamburger bait containing Compound 1080 and 0.3 percent coded particles. The coyotes were prebaited for two days with 500 g of hamburger each day. Coyote 1 weighed 9.1 kg and received 0.5-mg/kg 1080. Coyote 2 weighed 8.6 kg and was fed 1-mg/kg 1080.

5. To test the potential of the particle as a secondary hazard marker, a coyote was fed Richardson's ground squirrels that died after feeding on 1080 treated rolled oat-groats containing 0.3 percent coded particles. The rolled oat-groat bait contained 0.067 percent 1080 and 10 percent glycerol. The coyote was fasted for three days. It weighed 7.7 kg at the end of the fast when it was fed five ground squirrels containing a maximum total of 3.6 mg of 1080 or a 0.46-mg/kg

dose for the coyote. The five ground squirrels had eaten a total of 4.8 g of 1080 grain, none of which was stored in cheek pouches. Fecal samples were collected from the pen after dosing.

6. Six red-winged blackbirds (*Agelaius phoeniceus*) were each force-fed two pieces of cracked corn each weighing about 200 mg and containing 3 percent Avitrol[4] (4-Aminopyridine), 10 percent glycerol, and 0.3 percent coded particles. The birds were fasted for 1 h before dosing.

7. Six starlings (*Sturnus vulgaris*) were each force-fed pelleted Starlicide[5] (3-chloro-4-methylbenzenamine HCl) bait containing 1 percent active ingredient. The pellets were crushed to a powder, 0.3 percent coded particles added, and repelleted. The birds were fasted for 1 h and each was given one pellet weighing approximately 200 mg. Untreated pellets were made available to the birds after dosing.

Chronic toxic baits—Three male and three female wild Norway rats were each fed a hulled rolled oats bait containing 10 percent glycerol, 0.3 percent coded particles, and 0.005 percent diphacinone. The rats were fed this bait as the only source of food until death occurred.

Retention Time—White-footed deer mice, white rats, and Richardson's ground squirrels were used. Three animals of each species were assigned to each of five examination periods: 0, 6, 24, 48, and 72 h after bait removal. The ground squirrels were not examined at 6 h. As the only source of food, all were fed a bait consisting of 89.7 percent hulled rolled oats, 10 percent glycerol, and 0.3 percent coded particles. The bait was fed overnight to the rats and mice, and to the ground squirrels for 24 h.

Results and Discussion

Acceptance of Nontoxic Bait

The wild Norway rats accepted the coded particles on a hulled rolled-oats bait. Although the particles were visible on the bait along with any tactile, olfactory, or gustatory sensation, they did not deter the rats' consumption (Table 1). The rats ate significantly ($P = 0.03$) more bait with coded particles, 28.1 g, during the four nights than control bait, 19.9 g. No other significant differences ($P > 0.05$)

TABLE 1—*Wild Norway rat consumption of nontoxic bait containing coded particles (mean grams eaten, ± standard deviation, total of four nights).*

	No.	Control Bait	Treated Bait	Total
Males	6	23.2 ± 5.6	25.1 ± 4.9	24.2 ± 5.1
Females	6	16.7 ± 6.2	31.2 ± 8.5	23.9 ± 10.4
Total	12	19.9 ± 6.6	28.1 ± 7.3	...

[4]Avitrol Corp.
[5]Ralston Purina Co.

occurred between sexes or interaction of sex and treatment. We believe that there will be no acceptance problem with wild Norway rats. On the contrary, if the results apply to the population as a whole, the particles may even enhance bait acceptance.

Acceptance of Toxic Bait

The two groups of white rats eating zinc phosphide baits with or without coded particles were not significantly different (P = 0.33) when the numbers of deaths per group were compared. Twenty-six of 30 control rats died and 22 of 30 treated. The control group consumed 78.1 g of plain bait and 20.0 g of zinc phosphide bait. The treated group ate 77.1 g of plain bait and 18.2 g of zinc phosphide bait containing coded particles.

Apparently the particles had no effect on bait consumption. However, numerous wild species need to be tested on various toxicant and bait combinations to prove this acceptance.

Multiple Species Demonstration with Toxic Baits

In all species tested in this section, the coded particles remained intact in the digestive tract. The coded particles could be read quickly and had no signs of color fade or erosion. With the exception of the coyote, the digestive tracts were best examined when placed in a shallow pan containing an absorbent towel. The ultraviolet light was placed directly over the pan and the room lights turned off. The tract could then be closely examined by dissecting the selected parts and, as needed, tap water could be squirted on lumps of tract contents to put them into suspension. Because of its size the coyote tract was best handled on a table, but otherwise the process was the same.

Acute Toxic Baits

1. All six wild Norway rats died by morning after eating an average of 1.4 g (range 0.5 to 4.4) of the zinc phosphide bait. Examination of the digestive tracts revealed all were marked. By location, five stomachs, five cecums, and four fecal pellet groups were marked. All but one rat had more than five particles in at least one location.

2. The six white-footed deer mice died by morning after consuming an average of 0.2 g (range 0.1 to 0.3) of zinc phosphide bait. All digestive tracts were marked—six stomachs, two cecums, and no fecal pellet groups. All mice except one had more than five particles in the stomach.

3. The five Richardson's ground squirrels died within four days of eating the 1080 bait. The average consumption was 0.3 g with a range of 0.05 to 0.59. All digestive tracts were marked—every stomach, cecum, and one fecal pellet group. Four of the animals had more than five particles in each of two locations. The fifth ground squirrel was the one that consumed only 0.05 g. However, it was marked with at least one particle in both the stomach and cecum.

4. Coyote 1 died within 20 h of eating the hamburger bait containing 0.5 mg/kg of 1080. The stomach was marked with over 100 particles, the intestine and appendix were labeled, and the rectum was void of any marker. Coyote 2 died within 6 h after eating a 1-mg/kg dose. Vomit in the pen contained many particles. The stomach held over 100 markers and 10 cm below the stomach the intestine was marked with two. From this point to just before the appendix, no markers were present. From the appendix to the rectum over five particles were found. The appendix was labeled with more than 25 particles.

5. The coyote that ate Richardson's ground squirrels, which died after eating 1080 treated grain with coded particles, died 48 h after dosing. Fecal samples were collected at 16, 24, 40, and 47 h postdosing. All the fecal samples contained more than five particles. They were visible on the surface of some fecal pellets under ultraviolet light. The stomach of the coyote contained more than five particles. Fifty centimetres down the intestine from the stomach two were found, and three more were present 60 cm from the rectum. The appendix was not marked. Dissection of fecal samples under ultraviolet light is an acceptable technique for particle recovery. However, the best method involves placing the sample in a glass beaker and adding tap water to make a suspension. The particles can then be observed by looking at the bottom of the beaker with the ultraviolet light. They can be removed with a rod magnet. Stirring of the suspension with a rod magnet also works, but not as quickly as observing the bottom of the beaker.

These results offer encouragement that the marking technique will be useful for secondary poisoning analysis. The ground squirrels were killed with 1080 grain that is used for ground squirrel control in the State of California. We modified this bait before feeding by overcoating with 10 percent glycerol and 0.3 percent coded particles, resulting in a final 1080 concentration of 0.067 percent instead of the 0.075 percent in the original bait. It is possible, in a field situation, that a predator would ingest sufficient marked, dead rodents to allow detection of the coded particles.

6. The six red-winged blackbirds fed Avitrol-treated cracked corn with coded particles died within 5 h after treatment. The gizzards of all contained more than five particles. The upper intestines of two birds contained one to five, and the lower intestines of three birds held one to four.

7. Three of the six starlings fed Starlicide pellets containing coded particles died during the 19 h between dosing and discovery. The gizzards contained one to four particles. The upper intestines were not marked, but the lower intestines of two held one to four particles. The other three starlings died 24 h after dosing and none had marked digestive tracts.

Chronic Toxic Bait—The six wild Norway rats fed hulled rolled oats bait containing diphacinone and particles died within 11 days. All rats consumed the bait well, eating about 20 g per day until the toxicant caused illness. Every rat was marked—four stomachs, six cecums, and five fecal pellet groups. All but one positive location in one rat contained more than five particles.

Retention Time

Consumption of bait containing coded particles was good for all species and the particle code remained intact. The mean consumption ± standard deviation was 1.2 g ± 0.6 for white-footed deer mice, 18.1 g ± 3.9 for white rats, and 17.2 g ± 9.8 for Richardson's ground squirrels. Table 2 illustrates how the particles were retained. Deer mice were marked with many particles in all locations at 0 and 6 h. By 24 h only one mouse had one particle in its stomach. White rats

TABLE 2—*Retention of coded particles in the digestive tracts of three species of rodents (values expressed as number marked versus number examined).*

Hours Post-bait Removal	Deer Mouse			White Rat			Ground Squirrel		
	Stomach	Cecum	Fecal	Stomach	Cecum	Fecal	Stomach	Cecum	Fecal
0	2/2	2/2	1/2	3/3	3/3	3/3	3/3	3/3	3/3
6	3/3	3/3	3/3	3/3	3/3	3/3	...	...	...
24	1/3	0/3	0/3	3/3	3/3	3/3	1/3	2/3	2/3
48	...	...	...	0/3	0/3	1/3	1/3	3/3	3/3
72	...	...	...	...	...	...	0/3	3/3	3/3

were well marked with many particles present in all locations from 0 to 24 h. At 48 h only one rat had one particle in a fecal pellet group. Ground squirrels were marked with many particles in all locations from 0 to 48 h. At 72 h the number of particles at each marked location became fewer, but still showed clearly.

Conclusions

The concept of using microscopic coded plastic particles to identify acute toxicants in baits and digestive tracts is feasible. Additional work is needed to determine the percent of marker to use in baits. Obviously 0.3 percent, as used for all tests, is too much for large coyote baits similar to the 500-g ones we used. The particles could have been used at one-quarter the rate and still have been very evident. In contrast, more particles may be needed for small mammals or when secondary hazard is in question. The research community will be able to use the concept as needed. However, if any wide-scale incorporation of coded particles into baits is to occur, it will require voluntary compliance by manufacturers or legislation mandating it.

We propose that this identification system be included in the manufacture of toxic baits. Each toxicant used by the industry would be given a code that is the same for all manufacturers. These codes could be on file in numerous places for ready access, in addition to the computer data base held by the manufacturer of the particle. It is conceivable that means of rapid code identification could be established at poison control centers.

TABLE 3—*Case reports from 580 poison control centers where humans made contacts regarding rodenticide incidents.*

	1973	1974	1975	1976
Calls	1770	1737	2019	1754
Symptoms	118	115	97	77
Hospitalized	163	139	118	82
Fatalities	3	2	2	2

Table 3 presents data regarding rodenticide case reports from poison control centers in the United States [*10–13*]. The data represent voluntary reporting to the Clearinghouse for Poison Control Centers.[6] It is not known what percentage of the total number of actual incidents these data represent. Human poisonings from toxic baits are a problem, but the true size of the problem and how the identification of toxicants might help are yet to be addressed.

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References

[*1*] Kalmbach, E. R. and Welch, J. F., *Journal of Wildlife Management*, Vol. 10, No. 4, 1946, pp. 353–360.
[*2*] New, J. G., *Journal of Mammalogy*, Vol. 39, No. 3, 1958, pp. 416–429.
[*3*] Linhart, S. B. and Kennelly, J. J., *Journal of Wildlife Management*, Vol. 31, No. 2, 1967, pp. 317–321.
[*4*] Nass, R. D. and Hood, G. A., *Journal of Wildlife Management*, Vol. 33, No. 3, 1969, pp. 584–588.
[*5*] Crier, J. K., *Journal of Wildlife Management*, Vol. 34, No. 4, 1970, pp. 829–834.
[*6*] Pank, L. F., *Journal of Wildlife Management*, Vol. 40, No. 4, 1976, pp. 769–774.
[*7*] International Telephone and Telegraph Co. Editorial Board, *Reference Data for Radio Engineers*, 5th ed., Howard W. Sams and Co., Inc., New York, 1973, p. 5–2.
[*8*] Code of Federal Regulations, 21:182.
[*9*] Winer, B. J., *Statistical Principles in Experimental Design*, 2nd ed., McGraw-Hill, New York, 1971.
[*10*] U.S. Food and Drug Administration, Poison Control Statistics, 1973.
[*11*] U.S. Food and Drug Administration, Poison Control Statistics, 1974.
[*12*] U.S. Food and Drug Administration, Poison Control Statistics, 1975.
[*13*] U.S. Food and Drug Administration, Poison Control Statistics, 1976.

[6]The clearinghouse is part of the Division of Poison Control, Bureau of Drugs, U.S. Food and Drug Administration.

Summary

Avian and mammalian toxicology is an important tool for the realistic evaluation of the effects of chemicals on characteristic animal representatives of the environment. Determination of toxic intake levels and realistic residue exposure levels of the chemical over a given period is the key to hazard evaluation.

The most common toxicity test methods are those used for the registration of pesticides since they have been standardized to some degree and have been required by the U.S. Environmental Protection Agency for several years, thus providing a data base for comparison of chemicals.

A tenable position for hazard evaluation decisions would be somewhere in between the extremes of zero risk and the "brush fire" type of reaction where significant hazards are identified after the use has been established. Hazards to endangered species are difficult to ascertain since the organisms are usually not available for test expenditure. The bird and mammalian data engendered must reflect judgment on toxicity to representative organisms using appropriate laboratory and field test methods for guidance on pesticide labels or other literature which recommend uses that do not threaten wildlife populations. The optimum selection of representative species and test methods is still undergoing evaluation and refinement to meet changing combinations of economic, ecological, and availability requirements as new scientific information is developed. These pesticide guidelines are also useful for the evaluation of toxic substances and natural toxicants.

Many toxic effects are based on lethality; however, more subtle effects are often detectible such as enzyme changes, cholinesterase depression, reproduction suppression, and repellency. Flexibility in test methodology is necessary for discovery of such effects.

Field evaluation of tests on toxicity of chemicals to birds and mammals is difficult to measure due to their migratory or traveling habits. Territories are often large and animals sparse for significant statistical differences to be apparent. Dead animals are difficult to find. Some useful data obtainable from field evaluation are residue analyses of blood, brain, eggs; nesting bird counts; trapping animals; caged animal field tests; and simulated field tests. Residue levels of chemicals in critical tissues such as brain or blood can be related to lethality.

Standardization of test methods will presumably lead to the generation of more accurate comparative toxicological data between chemicals; however, it also may lead to elimination of many of the variables that occur in nature. Among the variables affecting toxicological interpretation are the mode of oral intake of chemical, that is, dietary versus single oral doses; nonlethal or LC_5 data versus LC_{50} data; changes in age, species, and sex of the organisms; nutrition;

weather; habitat and natural history of the organism; territorial population interaction within and between species; changes in behavior and learning ability; and especially cellular and reproductive changes. Among the important variables related to dissipation of the chemical are weather; chemical and physical properties affecting stability and volatility of the compound; density of ground cover; and the type of treated media such as soil, water, and plants.

Residues of chemicals in nature are often rapidly dissipated, yet wildlife toxicological tests in the laboratory are often performed with diets containing a constant level of the chemical throughout the test, not only for chronic studies but even for acute studies. Thus, the toxic levels determined from such studies may be greatly exaggerated.

Toxicity studies with chlorpyrifos on mallards show that, by use of a declining 5-day half-life concentration in the diet, the initial concentration administered is twice that of the steady-state dietary level necessary to obtain an LC_{50} in 10 days. These data pose the concept of the use of the multiple of exposure time and average dietary concentration for an LC_{50} in which either can be varied within moderate limits to obtain the same product.

The concentration of pesticides applied to ground cover results in a wide variation in residue concentration on the food available by birds and other organisms, thus allowing a choice of treated food. Laboratory tests that allow an option of treated versus untreated food result in data that simulate extremes in variation in concentration of the pesticide occurring under normal conditions. Such tests can be used to measure repellency and food consumption changes by birds or other animals exposed to a given chemical.

A further step in simulating natural conditions for studying the effects of pesticides and other chemicals on birds is the use of a carefully designed field study. This includes the important nontarget species selected as an animal model and a test area habitat that is compatible with the test model selected and indigenous to the anticipated area of use. Simulation of standard agricultural or application practices, and the generation of replicate data on the observation parameters, can insure statistically reliable interpretation.

The study of chemical spills in water is epitomized by the massive oil contamination accidents that have occurred during ocean transportation of petroleum and have resulted in massive bird kills. Very little is known of the acute or chronic effects of low levels of oil on seabirds. The lack of oil residue data to match toxic effects is understandable because of the great differences in the viscosities and chemical composition of various lots of oil. A relationship between nasal gland size and body weight appears to be a readily available index of exposure to oil.

The metabolism of a given chemical in different species of closely related animals is usually the same or similar. Occasionally, however, a significant unexpected metabolite occurs such as with 12-ketoendrin, an endrin metabolite in rats which does not appear to occur in species representing four orders of birds, only very little in cows and rabbits, and in smaller amounts in mice than in rats.

In endrin-treated rats, 12-ketoendrin occurs in the brain and appears to be the ultimate cause of death whereas in the other species endrin is a major cause of death.

Chemical control of a widespread predator such as the coyote can result in widespread secondary poisoning of other animals. While the control of predators is just another aspect of toxicological tests, the ecological emphasis is on survival of the associated higher chain-of-life organisms. Simulating these secondary tests involves the residue levels of pesticides in dead animals such as coyotes and toxicity tests on surrogate or actual carnivorous animals representing consumers of such dead animals.

There is much to be learned from laboratory tests which help isolate the effects of the important variables of animal exposure and toxicity. There is still more to be learned about the effects of the multitude of environmental variables in natural field exposures of organisms to applied chemicals. The papers in this volume express the diversity of knowledge being developed which can be applied to the assessment of hazard of chemicals to wild birds and mammals.

The contents of this volume represent papers presented at the first ASTM Avian and Mammalian Wildlife Toxicology Symposium in New Orleans, October 1978. With the success of this symposium, we give generous thanks to the authors and all those who made it a reality.

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