A critical review of currently used single-dose rodenticides

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The introduction of the anticoagulants in the early 1950s, with their much greater safety to nontarget animals, resulted in a general decline in the use of single-dose rodenticides. However, the appearance of rodent resistance to the anticoagulants, first in the United Kingdom, later elsewhere in Europe, and still more recently in the USA, has revived interest in the use of single-dose rodenticides. Unfortunately, owing to their danger to nontarget mammals, the use of several of these compounds must be restricted; others, despite their long use, are now recognized to be unsatisfactory because of their poor acceptance or reacceptance by rats and mice. Thus, only very few compounds of this type are available for unrestricted use and there is an urgent need for the development of effective alternatives.

Virtually any mammalian poison can be considered as a potential rodenticide; there are, however, certain highly selective criteria that must be applied to any candidate compound that quickly eliminate all but a few of the enormous number of available chemical and biological products. The number of single-dose rodenticides in common use, and the length of time that these compounds have been in use, shows that the situation is surprisingly stable, especially compared with that for other pesticides, particularly insecticides. This does not mean that the available rodenticides are completely satisfactory; each of them has certain shortcomings and, in fact, none will give satisfactory control of even a single species in all circumstances.

The ideal characteristics of an acute rodenticide would be a high degree of toxicity to rodents, a very ready acceptability, the failure to induce " bait shyness " when sublethal quantities are consumed or, in other words, a high degree of reacceptance, and as high a degree as possible of specificity to rodents. The relative importance of other characteristics, such as persistence in baits, solubility, cost, availability, ease of use, etc. would vary from one set of circumstances to another.

There are considerable variations among rodent populations, between sexes, and often among individuals in their response to the single-dose rodenticides. In addition, the effectiveness of even the best rodenticides will be negated if they are offered in an unattractive or repellent bait, or if they are presented in a manner that does not allow full expression of the efficacy of the compound—e.g., at too low a dosage.

With the introduction of the anticoagulant rodenticides in the early 1950s, the use of single-dose rodenticides declined to some extent. Since most of the latter are toxic to a broad spectrum of warm-blooded animals, there is almost always a risk of accidental poisoning of man, his domestic animals, or desirable wild species. In addition, the frequent development of bait shyness to several single-dose toxicants also favoured the use of anticoagulants in many circumstances where either group of compounds could be utilized. There are however, many situations where rodenticides applied in a single dose (as opposed to the multiple dosing required with anticoagulants) may be used to advantage. Many large-scale rodent control campaigns against field or domestic rodent species are expensive in labour and baiting materials and the costs of multiple rebaiting may prove excessive, especially in the developing countries. In the case of outbreaks of disease, where immediate rat control is required, the use of single-dose toxicants will usually provide a more rapid reduction in the rodent population. In epidemics of plague, rodent control should, of

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Table 1. Summary of the main characteristics and recommendations for use of the most important available single-dose rodenticides

Rodenticide	Lethal dose for rats mg/kg	Concentration used in baits %	Time to death [a] h	Degree of effectiveness in rats [b]	Acceptance	Reacceptance	Tolerance developed	Soluble in oil or water	Hazard to man	Accepted LD_{50} for man [c] mg/kg	Weight (g) of bait containing lethal dose for a 68-kg man	Recommendation
antu	7–8[d]	1–3	12–36	good	good	poor	yes	neither	moderate	unknown	probably large	against urban Norway, single application
arsenic (III) oxide	25–250+[e]	1–3	5–48	fair	fair	fair	yes	water	moderate	1.5–15.0	3.4–34.6	not recommended
barium carbonate	700–1 480	20	2–24	poor	fair–poor	fair–poor	unknown	neither	moderate	800	280.6	not recommended
norbormide	12[d], 35–40[f]	0.5, 1.0[f]	0.5–4.0	good[g]	fair	fair–poor	unknown	oil	low	unknown (probably no effect)	large	against Norway
phosphorus (yellow)	6–100	1–3	12–48	fair	fair	poor	no	oil	moderate–extreme	approx. 10	6.8	not recommended
red squill [h]	400–600	10	6–120	fair	fair	poor	no	both	low	unknown	unknown	against urban Norway
sodium fluoroacetate	0.22–5.00	0.22–0.32	1–72	good	good	good	no	water	extreme	5	89.2	restricted use against all species
fluoroacetamide	13–15	2	3.5–96.0	good	good	good	no	water	extreme	probably the same as with sodium fluoroacetate		restricted use against all urban species
strychnine	4.8–6.0	0.6	0.2–2.0	poor	poor	poor	yes	water	moderate–extreme	1	22.7	not recommended
thallium sulfate	15.8–31.0	0.5–1.5	12–120	good	good	good	no	water	extreme	20	90.6	restricted use against all species
zinc phosphide	40	1.0	12–120	good	good	good	no	oil	moderate	40	138.9	against all urban and rural species

[a] See Mallis, A. (1960).
[b] After US Department of the Interior (1968).
[c] After Ward, J. C. (1916).
[d] Norway rats only, first exposure.
[e] LD_{50} depends on fineness of arsenic particles.
[f] For roof rats.
[g] Rattus only.
[h] For details of the active ingredient scilliroside see text.

course, follow the use of insecticides to control the ectoparasites.

The appearance of rats resistant to the entire gamut of anticoagulant rodenticides in areas of Denmark and the United Kingdom, however, has virtually excluded the use of this group of compounds in these places. Anticoagulant resistance has also appeared in the Netherlands but the resistant population appears to have been eliminated by the rapid use of a single-dose rodenticide—fluoroacetamide— in the town in which the resistance had appeared (Ophof & Langeveld [1]). More recently, resistance to the anticoagulant rodenticides has appeared in *Rattus rattus* in the Liverpool dock area of England (*Wkly epidem. Rec.*, 1971) and has been detected for the first time in the USA, in North Carolina, in *R. norvegicus* (Jackson et al., 1971). There is, therefore, most decidedly a place for the single-dose rodenticide in modern rodent control campaigns.

In this paper only those single-dose rodenticides whose use is widespread or that are likely to be available to anyone considering the use of one of this group of compounds have been reviewed; some have almost completely fallen out of use or are used only in limited areas and, therefore, have not been considered. Chemosterilants have not been discussed since they have been reviewed by Howard & Marsh (1972). The characteristics of the most important of the compounds reviewed are summarized in Table 1.

RED SQUILL

Red squill is the oldest of the rodenticides in current use. Its rodenticidal properties were known in the Mediterranean area in mediaeval times and it was recommended for rodenticidal use in a number of eighteenth and early nineteenth century publications. Despite this long history, it did not come into large-scale use until the late nineteenth century (Chitty, 1954). The slowness with which it was adopted may well have been due to the very considerable variations in the potency of the different batches prepared at that time. The need to ensure a minimum efficiency of the prepared material led to the development of biological standardization tests that require a given lot of red squill to have an LD_{50} of not more than 500 mg per kg of body weight for wild Norway rats. Specifications have

been prepared for red squill powder by WHO (Specification No. WHO/SRT/4) reading as follows:

The material shall consist essentially of the dry, powdered, fleshy inner-bulb scales of the red variety of *Urginea maritima*, fortified when necessary with the alcohol-soluble extract of the same...

A description then follows of the chemical, physical, and biological requirements.[2]

Perhaps the main reason for the continued use of red squill in Norway rat control has been its limited acceptance by animals other than rodents. It will cause vomiting in many animals but it is effective against rodents since they cannot vomit and thus eliminate the material. However, cases have been reported of poisoning of cattle, sheep, chickens, and dogs. Red squill is extremely irritating to the skin and rubber gloves should be worn when preparing baits from this material.

A serious limitation to the use of red squill is its comparative ineffectiveness against *R. rattus*; much higher doses are necessary to achieve a kill of this species and these high concentrations are not readily accepted by the roof rat or the mouse. Its use is therefore restricted to Norway rat populations. An additional limitation is the fact that individual rats that have ingested a sublethal dose of red squill will develop an aversion or bait shyness that is likely to last for several weeks.

Koren & Good (1964) have described a community programme in Philadelphia, USA, where red squill was widely used for rat control: 10% by weight of fortified red squill powder was mixed with 27% of rolled oats and 63% of mixed cracked corn and cornmeal; corn oil was added as a binder instead of water and it was found that this prevented baits from becoming mouldy for 2–4 weeks. In a test comparing red squill with an anticoagulant, pindone, the authors concluded that the red squill formulation, which required 1 visit per station only as opposed to 3 for the anticoagulant, was considerably cheaper in material and labour and even more effective than the anticoagulant. Dykstra (1957) reported that red squill applied as a tracking powder against house mice provided excellent control but pointed out that this usage was unlikely to be acceptable in food industries or other circumstances where the dust might be tracked into foodstuffs.

Red squill baits are still being distributed in a

[1] Ophof, A. J. & Langeveld, D. W. (1968) *Warfarin resistance in the Netherlands*, Geneva (World Health Organization mimeographed document No. WHO/VBC/68.109).

[2] World Health Organization (1961) *Specifications for pesticides*, 2nd ed., Geneva. In subsequent editions this specification has been omitted.

number of other municipalities in the USA and it is reported to be in use in India, Hungary, and other countries. Trahanov (1963) stated that satisfactory control was obtained in the USSR when 10% red squill baits were used. Two countries, England and Israel, have banned its use owing to the prolonged and violent reaction often caused in rats poisoned with this material.

A recent significant development in the use of red squill is a new method for stabilizing the active ingredient—scilliroside. Maddock & Schoof (1970) have reported on field and laboratory tests with this preparation against *R. norvegicus*. In the laboratory, the effect of the stabilized scilliroside was superior to that of fortified red squill against Norway rats, though not against roof rats and mice. In the laboratory, females accepted the 0.015% bait more readily than males but, in field tests in Georgia, USA, excellent control was achieved with a 0.015% cornmeal, oatmeal, and corn oil bait in most of the 20 rural premises treated. If work in other areas substantiates the potential shown in these trials, this preparation could certainly be recommended for mass campaigns against Norway rat populations.

ANTU

This rodenticide was developed over 20 years ago by Richter (1945). It is effective against Norway rats but roof rats and house mice are much more resistant to its action. Antu is fairly well accepted by Norway rats but has the decided disadvantage of producing a long period of bait shyness among survivors of treatment; in fact, it is usually not recommended for re-use within a year of the previous application. Young Norway rats are fairly tolerant to this compound. Its action on rats is slow: 12–48 hours, and occasionally even several days, elapse before death.

Since it cannot be used in areas with mixed rat populations and gives rise to such a marked bait shyness, there seems to be little reason to use this compound other than for occasional campaigns in those cities where pure *R. norvegicus* populations exist. It should also be remembered that the compound is comparatively toxic to cats, dogs, pigs, and chicks. Owing to its several drawbacks use of this compound has already substantially declined.

ARSENIC(III) OXIDE

At one time arsenic(III) oxide and closely related compounds were widely used rodenticides. Owing,

however, to the general restrictions imposed by most countries on the sale of arsenical compounds their use has sharply decreased in recent years. Arsenic (III) oxide is very effective against rats, but ineffective against mice. It is also dangerous to man and other mammals and birds, and frequent cases of accidental human death have been associated with its use (Hayes, 1963). Baits prepared with this compound should also include tartar emetic.[1] It certainly should not be made generally available for commercial purchase and it has no advantages that would justify its use in mass campaigns, especially in areas where there is a danger that baits might be consumed by man or domestic animals.

BARIUM CARBONATE

This compound may be dealt with briefly. Its use was once widespread in Europe, including the United Kingdom, and it is still occasionally used in Burma, India (Deoras, 1964), and elsewhere. It is a weak rodenticide, of uneven performance, probably easily detected by rats in many baits, and toxic enough to represent a hazard to domestic animals. Pollitzer (1954) stated that " in the opinion of most recent workers, in view of the availability of more efficient rodenticides, barium carbonate should not be used any more ". The present author's experience confirms this view.

PHOSPHORUS (YELLOW)

Yellow phosphorus has been mainly utilized as " ready-to-use " commercial preparations sold in the form of a 1% or 2% paste to be spread on bread, vegetables, or other suitable baits. In this manner it has been reasonably effective against rats, though it is not acceptable to house mice. However, phosphorus is extremely hazardous and cannot be used in any area where the poisoned baits might be accessible to children or domestic animals. There is no effective antidote to phosphorus. It certainly should not be considered for use in large-scale urban campaigns, although it has been used against rats in cane fields in Queensland (Redhead, 1968). Its use by householders should be strongly discouraged in favour of the anticoagulants or other less hazardous single-dose poisons. The household use of this substance is banned in Great Britain and the USA.

Yellow phosphorus is available as a paste formulation; the unformulated element must be handled

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[1] Potassium bis[μ-tartrato(4-)diantimonate(2-) dihydrate.

with great caution, since it ignites spontaneously in air at about 30°C and can produce very severe skin burns. No attempt should be made to prepare phosphorus paste other than on a commercial scale or under safe laboratory conditions.

SODIUM FLUOROACETATE

Sodium fluoroacetate is a highly effective rodenticide, developed by the US Fish and Wildlife Service through the screening of over 1 000 potentially rodenticidal compounds (Kalmbach, 1945). It causes death rapidly in rodents, often within 1 hour, after the consumption of very small quantities (the LD_{50} for *R. norvegicus* is about 3–5 mg/kg). Unfortunately, it is also almost as toxic to man and other animals, through either direct or secondary poisoning. It does not penetrate unbroken skin. In many countries restrictions are such that it may only be used by trained rodent control specialists, either commercially or governmentally employed. With such limitations, there are many " safe " areas, either not readily accessible to the public or easily placed under the surveillance of the operator, where this compound has been and may be used with considerable success, including ships (Hughes, 1950), sewers (Bentley et al., 1961), and closed warehouses. Precautionary measures are of the utmost importance and should include the strictest control of poisoned baits and liquid, and the prevention of access to the carcasses of poisoned rodents by cats or dogs (by burning or deep burial of the carcasses) in order to exclude the possibility of secondary poisoning. It should be emphasized that no specific antidote to this compound is available; there have been a number of cases of human death resulting from its use. Sublethal doses do not appear to lead to any tolerance in rodents and it is apparently not detected by them in liquid or solid baits, at least until a lethal amount has been ingested. There appears to be little, if any, aversion to the toxicant in baits. Liquid baits are preferable to solid baits as the rodents consume the poison on the spot and cannot carry it to a place from which it may be difficult to recover.

FLUOROACETAMIDE

Fluoroacetamide is closely related to sodium fluoroacetate and is said to have a number of advantages over the latter compound. Its use as a rodenticide was first suggested by Chapman & Phillips (1955). Its toxicity to mammals is somewhat lower than that of sodium fluoroacetate and it is probably safer to handle. Bentley & Greaves (1960) studied its effect on enclosed colonies of *R. norvegicus*. They estimated that the LD_{50} was 13 mg/kg and that the speed of action of a dose of twice the LD_{50} was somewhat slower than that of sodium fluoroacetate. The compound was palatable to the rats tested. Bentley et al. (1961) compared sodium fluoroacetate, fluoroacetamide, zinc phosphide, and arsenic (III) oxide in field trials against rats in sewers; 3 monthly treatments with either 0.25% sodium fluoroacetate or 2% fluoroacetamide gave a more complete kill and a longer effect than 6 monthly treatments with 2.5% zinc phosphide or 10% arsenic (III) oxide; 2% fluoroacetamide gave better results than 0.25% sodium fluoroacetate. Since no information is available on the effect of this compound on man, it should be handled with the same care and with the same restrictions as sodium fluoroacetate. While its mammalian LD_{50} is lower, the recommended dosage is higher and thus the hazards involved in its use are probably similar. Braverman (1968) refers to cases of poisoning of cattle in Israel with fluoroacetamide where the compound is used in poisoned grain against field mice.

STRYCHNINE

This alkaloid is a constituent of the seeds of *Strychnos nux-vomica*; these seeds have been used for killing dogs, cats, and birds in Europe since as early as the seventeenth century. Strychnine is still widely used against vertebrate pests, mainly against such animals as jackrabbits (Wetherbee, 1967), coyotes, and wolves, but also against bird pests (Crabtree, 1962). The bitter taste of this compound may interfere with its success in rodent control campaigns, since it appears that rodents quickly associate it with the toxic effect caused by consuming strychnine baits. The material is hazardous to man and to domestic animals either through direct consumption or by secondary poisoning; it has, however, a low toxicity to gallinaceous birds. The open sale of strychnine has been banned in many countries but its extremely bitter taste makes it in any case unlikely that it will be readily consumed by man. There seems to be little or no advantage in its use today in commensal rat control campaigns and one can only agree with Pollitzer (1954) that " in view of its poor acceptance by commensal rats it is unsuitable for the control of these species ".

THALLIUM SULFATE

At one time, this compound achieved a considerable degree of popularity as a rodenticide owing to the readiness with which it is accepted in baits and its high toxicity to all rodent species. It is one of the most effective of all rodent poisons (Mallis, 1960). The action of the compound is slow, at times extending, in the case of the Norway rat, from 1½ days to as long as 6 days. Field trials and field experience with this compound have generally produced excellent results when proper baiting procedures have been followed. Despite the excellent record of this compound for the control of rodents and such other animals as coyotes, jackals, and pest birds, it is unfortunately one of the most hazardous compounds to nontarget species including man, both through direct or chronic poisoning and through secondary poisoning, and its use is now being greatly restricted. The compound gives no warning since it lacks an unpleasant taste or odour and is not irritating to the skin. Further, it is readily absorbed through the unbroken skin. Symptoms of poisoning in man and animals may not occur for some time after exposure. The compound is cumulative and the handling, absorption, or consumption of sublethal doses may only later give rise to serious, painful poisoning and death. In animals, sublethal doses may cause irreversible damage to the central nervous system. Cases of thallium poisoning in man and domestic animals have been so widespread that its household use has recently been banned in the USA by action taken under the Federal Insecticide, Fungicide, and Rodenticide Act. Elsewhere, as in France (Lhoste, 1972), its use is severely restricted. If use is made of this otherwise excellent compound, at least the same stringent safety precautions practised with sodium fluoroacetate or fluoroacetamide must be observed. It should not be used in large-scale campaigns, and baits should only be prepared by trained staff completely conversant with its hazards.

ZINC PHOSPHIDE

While reports differ somewhat, it is generally accepted that zinc phosphide is an efficient rodenticide. Though it is rather less effective than thallium, the toxic hazards involved in its use are considerably smaller. When moist, the chemical slowly releases phosphine, whose garlic-like odour is repellent to man and domestic animals but seems to have no adverse effect on consumption by rats and may even be attractive to them. Baits exposed in the field will deteriorate over 2–3 days. It has been suggested that the keeping qualities will be extended if the bait is prepared with a mineral oil, rather than with water, and distributed in paper-wrapped " torpedos ". Care must be taken that domestic fowls do not have access to baits as zinc phosphide is highly toxic to them. In some municipal rodent control campaigns (Emlen & Stokes, 1947), 1 % of tartar emetic was added to baits in order to increase their safety to man and domestic animals. However, the acceptability of the baits to rats was reduced by this treatment and the results of the campaigns were poor. In campaigns elsewhere, zinc phosphide has been used in considerable quantities without tartar emetic and without serious mishap. It remains one of the most widely used rodenticides today owing to its fairly good safety record, low cost, and reasonably high effectiveness. Kuzjakin (1963) concluded that zinc phosphide is a most effective zoocide provided it can be used at a concentration of 7–15 %. It is one of the few single-dose rodenticides that can currently be recommended for large-scale use against rats. Specifications for zinc phosphide for use as a rodenticide have been established by WHO (1973).

NORBORMIDE

This comparatively recently developed rodenticide, described by Roszkowski et al. (1964), is characterized by a high degree of specificity for the genus *Rattus*, with an LD_{50} of 12 mg/kg for wild *R. norvegicus* and 60 mg/kg for *R. rattus*, but no effect on dogs, cats, or monkeys at doses as high as 1 000 mg/kg. Death in poisoned rats occurs rapidly, generally within 4 hours of consumption of a lethal dose. Such a high degree of species specificity (and, consequently, a very low hazard to animals other than the genus *Rattus*) is attractive and numerous field and laboratory trials have been carried out with this compound. The results have been variable, ranging from excellent to poor. Crabtree et al. (1964) carried out a number of simulated and actual field trials and concluded that the compound was practical for use against Norway and roof rats at a bait concentration of 0.5 %. Since then the variable results against *R. rattus* have led to the recommendation that norbormide be used against this species at a concentration of 1.0 %. Brooks et al. (1966) conducted three field trials against Norway rats, one of which was successful and two of which gave unsatisfactory results. The poor results were ascribed to refusal of

the baits by the rats. Mice in the trial area survived unharmed. Drummond (1966) described comparative trials in which it was found that norbormide was less effective than zinc phosphide for the control of rats and also stated " there seemed to be relatively few places where norbormide could be put where zinc phosphide could not be put and be adequately protected; in any case both poisons needed equal protection to prevent them being eaten by other animals before the rats could reach them. It seems that what is needed is not so much specific poisons but baits that are only attractive to pest species ".

Maddock & Schoof (1967) carried out field and laboratory tests against both roof rats and Norway rats; a variety of norbormide baits along with unpoisoned food were available. Mortality was low in both species, indicating that the rats detected the poison and mostly ceased feeding upon the poisoned baits before a lethal amount had been consumed. Of the 33 field trials conducted in the southern states of the USA against Norway rats, 21 gave poor results and in 18 trials against roof rats only 3 gave good results. Freshly prepared attractive baits gave better results than commercial baits.

A number of field trials have been carried out in cooperation with WHO in Czechoslovakia, Denmark, France, and Israel. In all of these tests, acceptance of the norbormide baits was poorer than might have been expected especially where alternative food supplies were readily available. Although the results of some of the trials were good, it appears that the rats were able to detect the presence of norbormide in the baits.

Norbormide seems to have most potential as a household rodenticide or for use in such critical areas as food plants where low toxicity to nontarget species is extremely important. Its greatest effect is against Norway rats; for the present, its cost and high species specificity probably exclude it from use in any public health rodent control work in rural areas or in urban areas where other genera of rats are a problem. Schoof & Maddock (1968) also noted that its lack of action against house mice is a disadvantage in commercial pest control operations.

OTHER RODENTICIDES

A number of other rodenticides have seen occasional or localized use, among them crimidine, which was developed in Germany during World War II. Although it is more toxic to laboratory rats than sodium fluoroacetate, thallium sulfate, or antu, it has not proved satisfactory in field use

against Norway rats; it is, however, highly effective in grain baits against mice (Wichmand, personal communication, 1966). Its only possible advantage over sodium fluoroacetate or fluoroacetamide is that it has an effective antidote in pentobarbital sodium—at least as seen from work on rats and dogs, even when 10 times the LD_{50} of the poison is consumed. It is also decomposed in the intestines so that the risk of secondary poisoning is lessened.

Still other compounds, among them a number of derivatives of fluoroacetic acid, some nitro dyes, and several organophosphorus insecticides, have been proposed as rodenticides or actually tested in the field; none has shown characteristics more desirable than those of single-dose rodenticides already in use. Endrin dust and 50% DDT dusting powder have been satisfactorily used on occasions for both mouse and rat control, but the use of both of these compounds as rodenticides is likely to be circumscribed by fear of contamination of the environment. A comparatively recently developed organophosphorus rodenticide is 0,0–bis(4–chlorophenyl) (1–iminoethyl)phosphoramidothioate (Gophacide) (Richens, 1967); its toxicity to rats is similar to that of sodium fluoroacetate but it has the additional hazard of being readily absorbed through the skin. However, its action is relatively slow, and atropine can be used as an antidote in case of accidental poisoning. The compound is used primarily for the control of gophers; Schoof & Maddock (1968) found that acceptance was fair for Norway rats and mice in the field but less satisfactory for roof rats. It has not yet come into use against domestic rodent species.

Another single-dose rodenticide recently developed is 1-(4-chlorophenyl) 2,8,9-trioxa-5-aza-1-silabicyclo-[3.3.3]undecane (RS-150). This compound has a very high toxicity for mammals—1–4 mg/kg for Norway laboratory rats and 14.0 mg/kg for monkeys, putting it into the same class as sodium fluoroacetate with respect to limitations to its general use and the precautions that must be observed. However, the manufacturer claims that owing to the rapid hydrolysis of the compound prepared baits are self-detoxifying within 3 days and that there is little hazard of secondary poisoning. Further field studies are under way in Norway rats and mice.

α-Chloralose is essentially a narcotic rodenticide that acts by retarding metabolic processes, reducing blood pressure, and lowering the body temperature (Cornwell & Bull, 1967). This effect is marked in smaller animals, whose body surface area is relatively large compared with their weight; consequently the

compound is most effective against mice. It acts quickly and mice become unconscious within an hour of consuming the bait. One of its most obvious drawbacks is that it is primarily effective below 15.6°C and thus may find little use in areas where night-time temperatures are higher than this. It may be particularly effective against mice in such situations as cold stores.

When one considers the magnitude of the rodent problem in both urban and rural areas, the relative paucity of satisfactory compounds available is striking; in comparison with insecticides, extremely few new single-dose rodenticides have been developed in recent years, and there is clearly an urgent necessity for more research in this field. The WHO scheme

for the evaluation and testing of new insecticides now includes rodenticides and new compounds—submitted for the most part by industry—are being screened by a number of collaborative laboratories both in the laboratory and in the field.

It must, however, be emphasized that, to obtain the maximum effect from any of the rodenticides listed, the utmost advantage must be taken of knowledge of the target rodent's biology. Where this is inadequate, large-scale rodent control campaigns must be preceded by ecological studies. Finally, it should be remembered that, for the control of domestic rodents, rodenticides are not a desirable substitute for good environmental sanitation and rodent exclusion.

RÉSUMÉ

REVUE CRITIQUE DES RODENTICIDES ACTIFS À DOSE UNIQUE D'USAGE COURANT

Un grand nombre de composés ont été utilisés comme rodenticides et certains d'entre eux le sont depuis plusieurs siècles. Un défaut commun à la plupart des poisons à action aiguë est leur toxicité non seulement à l'égard des rongeurs mais aussi pour d'autres mammifères, y compris l'homme et les animaux domestiques, auxquels ils ne sont pas destinés. Certains produits, bien qu'en usage depuis longtemps, ne sont pas aisément acceptés par les rongeurs. D'autres ne sont actifs dans un secteur géographique donné que lors de la première application; ils provoquent un phénomène de répulsion pour l'appât chez les individus survivant au traitement et une nouvelle application dans le même secteur restera inefficace tant que ne sera pas apparue une nouvelle génération vierge de toute exposition antérieure au poison. En raison de ces limites, l'emploi des rodenticides à toxicité aiguë a considérablement diminué dès l'introduction, au début des années 50, des rodenticides anticoagulants, remarquables par leur sécurité d'emploi pour l'homme et les animaux domestiques, leur grande acceptabilité par les rongeurs et leur taux élevé d'efficacité. Cependant, depuis la fin des années 60, une résistance aux anticoagulants s'est manifestée au Royaume-Uni chez *Rattus norvegicus*, *Mus musculus* puis *R. rattus*, et un phénomène analogue a été décelé dans des populations de *R. norvegicus* au Danemark, aux Pays-Bas,

en Allemagne septentrionale et, plus récemment, aux Etats-Unis d'Amérique. Il en est résulté un regain d'intérêt pour les rodenticides à toxicité aiguë dans les régions où la résistance des rongeurs a contraint à renoncer à l'emploi des anticoagulants.

Le souci croissant de protéger les mammifères non concernés contre les risques d'intoxication a cependant conduit à restreindre fortement l'utilisation de plusieurs rodenticides à action aiguë dans de nombreux pays. Ainsi, la vente et l'utilisation du sulfate de thallium, des arsénicaux, de la strychnine et du phosphore sont strictement contrôlées ou interdites et, presque partout, seules les personnes dûment qualifiées peuvent se procurer et utiliser le fluoracétate de sodium. L'emploi de la scille rouge, active contre *R. norvegicus* mais peu efficace contre *R. rattus* et *M. musculus*, est prohibé au Royaume-Uni et en Israël.

Les rodenticides à toxicité aiguë susceptibles d'un usage général sont actuellement en petit nombre. Le présent article expose leurs caractéristiques et les limites à leur emploi. Il est devenu nécessaire de mettre rapidement au point de nouveaux composés dont on espère qu'ils feront preuve d'un haut degré de spécificité et d'acceptabilité par les rongeurs.

REFERENCES

Bentley, E. W. & Greaves, J. H. (1960) *J. Hyg. (Lond.)*, **58**, 125

Bentley, E. W. et al. (1961) *J. Hyg. (Lond.)*, **59**, 413

Braverman, Y. (1968) *Refuah vet.*, **25**, 166

Brooks, J. E. et al. (1966) *Calif. Vect. Views*, **13**, 3

Chapman, C. & Phillips, M. A. (1955) *J. Sci. Food Agric.*, **6**, 231

Chitty, D. (1954), ed., *Control of rats and mice*, Oxford, Clarendon Press

Cornwell, P. B. & Bull, J. O. (1967) *Pest Control*, vol. 35, No. 8, p. 31

Crabtree, D. G. (1962) In: *Proceedings of the First Vertebrate Pest Control Conference, Sacramento, California, February 6-7, 1962*, Elizabeth, N.J., National Pest Control Association

Crabtree, D. G. et al. (1964) *Pest Control*, vol. 32, No. 5, p. 26

Deoras, P. J. (1964) *Indian J. Ent.*, suppl., pp. 1-14

Drummond, D. C. (1966) *Chemy Ind.*, p. 1371

Dykstra, W. W. (1957) *Pest Control*, vol. 25, No. 1, p. 16

Emlen, J. T. & Stokes, A. W. (1947) *Amer. J. Hyg.*, **45**, 254

Hayes, W. (1963) *Clinical handbook of economic poisons*, Atlanta, Ga., US Public Health Service (Publication No. 476)

Hughes, J. H. (1950) *Publ Hlth Rep. (Wash.)*, No. 65

Jackson, W. B. et al. (1971) *Pest Control*, vol. 39, No. 9, p. 13

Kalmbach, E. R. (1945) *Science*, **102**, 232

Koren, H. & Good, N. E. (1964) *Pest Control*, vol. 32, No. 8, p. 24

Kuzjakin, A. P. (1963) *Učenye zapiski Moskovskogo Oblastnogo Pedagogičeskogo Instituta*, **126**, 39

Lhoste, J. (1972) *Les rongeurs nuisibles*, 2nd ed., Morières, Rullière-Libeccio

Maddock, D. R. & Schoof, H. F. (1967) *Pest Control*, vol. 35, No. 8, p. 22

Maddock, D. R. & Schoof, H. F. (1970) *Pest Control*, vol. 38, No. 8, p. 32

Mallis, A. (1960) *Handbook of pest control*, 3rd ed., New York, MacNair–Dorland

Marsh, R. E. & Howard, H. E. (1973) *Bull. Wld Hlth Org.*, **48**, 309

Pollitzer, R. (1954) *Plague*, Geneva (*World Health Organization : Monograph Series*, No. 22)

Redhead, T. D. (1968) In: *Proceedings of the Asia-Pacific Interchange on Rodents as Factors in Disease and Economic Loss, 17-27 June 1968*, Honolulu, Institute for Technical Interchange

Richens, V. B. (1967) *Pest Control*, vol. 35, No. 9, p. 28

Richter, C. P. (1945) *J. Amer. med. Assoc.*, **129**, 927

Roszowski, A. P. et al. (1964) *Science*, **144**, 412

Schoof, H. F. & Maddock, D. R. (1968) In: *Proceedings of the Asia-Pacific Interchange on Rodents as Factors in Disease and Economic Loss, 17-27 June 1968*, Honolulu, Institute for Technical Interchange

Trahanov, A. G. (1963) *Trudy Vsesojuznogo Naučno-isslegovatel'skogo Instituta Veterinarnoj Sanitarii*, **221**, 162

Ward, J. C. (1916) *Amer. J. publ. Hlth*, **36**, 1427

Wetherbee, F. A. (1967) In: *Proceedings of the Third Vertebrate Pest Control Conference, March 7, 8, and 9, 1967, San Francisco, California*, Elizabeth, N.J., National Pest Control Association

Wkly epidem. Rec. (1971), **46**, 461

World Health Organization (1973) *Specifications for pesticides used in public health*, 4th ed., Geneva