

THE CONTROL OF RATS WITH RODENTICIDES: A COMPLETE GUIDE TO BEST PRACTICE

These guidelines contain information on rat control based on extensive R&D carried out by CSL over many years. They should be useful to anyone, amateur or professional, who needs to control rats with rodenticides, particularly in rural areas and especially on farms. The information presented is comprehensive and includes some aspects of rat biology and control that experienced pest controllers may want to skip.

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INTRODUCTION



Rattus norvegicus, generally known as the
Brown, Common, Norway or Sewer rat

There has been a considerable amount of research on how to control populations of the Common or Norway rat (*Rattus norvegicus*) with rodenticides and anticoagulant rodenticides in particular. Following their introduction over 50 years ago, **anticoagulants** revolutionised the practice of rodent control leading to far more effective control than there had ever been. Subsequent research helped devise the best methods of applying these products and no doubt led to the practice of rodent control being viewed all too often as a routine procedure. Despite the advances, rodent problems have not gone away, partly because rats are highly adaptable and often refuse to eat the bait or seem to eat it endlessly without suffering any ill effects. In such circumstances, techniques other than rodenticide baiting may have to be used to break

the cycle of increasing the potency of the rodenticide to counter the 'resistance' of the rodents.

Rodenticide use may be avoided altogether if action is taken to prevent rat infestations developing in the first place. Potential food sources and **harbourage** for rats should be removed wherever practicable, or protected by physical barriers if it is not. Similarly, once infestations have been eliminated, there should be opportunities to alter conditions sufficiently to prevent the problem arising again. The availability and ease of use of rodenticide products should not be used as an excuse to avoid tidying up a site. If after all considerations, rodenticides seem the best option, then these guidelines should help to maximise control while minimising risks to other animals.

To ensure a high level of control, it is essential to anticipate how rats are going to react to baits, containers and traps, so as to increase the likelihood of attracting the animals to them. For example, highly palatable baits do not always draw rats away from what may appear to be unappetising food, such as rotting grain. In their natural habitats, social pressures, fear of predators, or simply not recognising the bait as a food item may stop some rats from approaching it. The solution may need to be tailored to that specific population.

Although rodenticides remain the most frequently used tools for control, they are hazardous to other animals and public concern about the risks of children, pets, livestock and wildlife eating the bait or in some cases eating poisoned rodents has inevitably brought their use under more scrutiny. Nevertheless, concern about safety has to be balanced against the consequences of not controlling rats, such as damage to structures, contamination of food supplies and increased risks of contracting rodent-borne disease.

Given that rodenticides are at present an economical means of tackling infestations, professional and amateur pest controllers should be aware of what is currently considered to be the best advice available on their use. This includes getting the most out of existing products and techniques, as well as offering solutions to the most common problems encountered during rodent control operations.

This guide is intended to provide information on the control of rats and to complement the leaflet from DEFRA RDS (formerly MAFF FRCA) on **Rats** (WM4), the Agriculture Information Sheet No 31 from HSE on **Safe use of rodenticides on farms and holdings**, the DEFRA (MAFF) booklet **Code of Practice for the prevention of rodent infestations in poultry flocks** and the HGCA booklet **Rodent control in agriculture – a guide**.

1. WHERE RATS ARE LIKELY TO OCCUR

Rats survive best where the supply of food, water and harbourage is uninterrupted. Under these conditions, they can breed all year round and substantial populations can develop. Farm buildings often supply suitable harbourages, with an abundance of food present, either seasonally or permanently. Other favourable habitats include refuse tips and sewer systems.



Strips of maize or kale grown as cover for pheasants provide food for rats long after the main crop has been harvested. Water-filled ditches around fields are ideal habitats for rats.

Hedgerows and ditches bordering arable fields also offer permanent harbourage, but the food supply may be limited to summer and autumn as crops ripen and seeds or fruits develop. Rats will also take advantage of grain and cover crops, such as kale, left for game-birds both before and during the shooting season. During spring and autumn, recently sown seed may be dug up for food. Thus, rats living along field margins may be able to find sufficient food to support them throughout the year. They may, however, move into farm buildings and

grain stores in early winter if food becomes short, only to move back to the fields later when all the stores are emptied. In contrast, livestock farms, particularly intensive rearing units, may maintain a year-round supply of animal feeds that rats can exploit. Hence, there is no need for rats to move out in spring and an infestation may persist throughout the summer.

In urban areas, other than sewers, rat colonies tend to be much smaller than those on farms and may be found in gardens, parks, warehouses, factories and restaurants. Some of these surface infestations, particularly in central urban areas where sewer systems are older, may originate from movements of rats through defective sewers.

2. ASPECTS OF RAT BIOLOGY RELEVANT TO CONTROL



Rats tend to be very wary of new objects (e.g. bait containers) that appear in their home range particularly if all other objects are rarely moved.

The most well known characteristic attributed to rats is their avoidance of new objects (**neophobia**). Bait containers, unfamiliar foods, traps and even totally harmless objects may be avoided for days or weeks, particularly if there is no incentive (e.g. hunger, seeking shelter) for the animals to investigate them. However, the response to new objects is not consistent in all situations and the context in which an object first appears may determine the speed with which it is approached. Thus, in rapidly changing environments, such as a rubbish tip face where fresh rubbish is continually deposited, neophobic responses may be short-lived and perhaps do not occur at all.

At the other extreme, an environment such as a grain store may be undisturbed for many weeks, so that rats may become very familiar with its layout. Consequently, new objects may be easily distinguished from the background, leading to active avoidance. Sometimes the response is mixed with rats apparently more willing to approach containers in some parts of a site and less willing elsewhere. Around livestock units the constant movement of animals and turnover of food stocks maintain a degree of habitat instability that makes bait containers less readily distinguishable from other new objects.

Rats tend to avoid a new **bait container** for far longer than they will avoid a new food. If bait is placed directly on the ground, it may be

approached relatively quickly, but it will not be readily eaten until the rats are sure that it is safe to eat. They will eat small quantities at first, which, if followed by unpleasant symptoms, will deter them from eating any more. Hence, the best rodenticides should not produce symptoms of poisoning within the first 24 hours, unless a lethal dose is likely to have been ingested by the time symptoms occur. Anticoagulants are poisons that are **slow-acting** and normally, by the time symptoms appear, a sufficient dose has been consumed. Other rodenticides, such as calciferol, act relatively quickly and if the rat recovers from the illness, any future encounters with the same **formulation**, or even the same bait base, or the poison in a different base, are likely to be avoided. This learned aversion (sometimes called '**bait shyness**') may extend to the type of bait container used as well as the location of the bait point and may last for the lifetime of the affected animals. The use of plain bait for a period before laying the poison bait (i.e. **prebaiting**) often increases bait consumption and consequently effectiveness, but it is seldom completely successful at eradicating infestations.

Although neophobia is commonly cited as a cause of bait or trap avoidance, it is not the only reason. Social pressures within a rat population may prevent some individuals from approaching baits, but the way they operate in the field is largely unknown. Competition between rats over access to bait may explain why treatments with

potent anticoagulants are not noticeably shorter than those with the less toxic compounds, given that less bait has to be eaten in order to receive a lethal dose. Some individuals may only get to the bait once others have succumbed to the effects of the poison.

Perhaps because rats are naturally antagonistic towards each other, they tend to make several brief visits to a food source in order to obtain a meal and avoid confrontations. At each visit they pick up a mouthful and then often take it somewhere else to eat. Small particles, such as grains of wheat, may be consumed entirely after being transported, but larger items may be partially eaten only and the remains abandoned. Transferring food is therefore normal for a rat, but such behaviour poses a risk to other animals if the abandoned food is poison bait. Placing bait directly into a rat's burrow may make feeding 'safer' for the occupant, but unfortunately it does not stop visitors 'stealing' bait particles. (See below: S.4 –[Selecting the best bait to use](#))

The majority of commercially available rodenticide products to control rats contain one of several anticoagulants. Anticoagulants have had a good track record with regard to safety and efficacy compared with many earlier rodenticides (e.g. zinc phosphide, red squill (the former soon to be withdrawn from sale, the latter no longer approved)).

To overcome resistance to the first anticoagulants, such as warfarin, more potent compounds with the same mode of action ('second-generation' anticoagulants) were developed, although rats have also now developed resistance to some of these. Resistance is an inherited trait, so that through a process of selection, successive treatments with anticoagulants may lead to populations that are not controlled at all. How quickly this can occur is not fully understood. Partly, it depends on the proportion of resistant survivors after each treatment and subsequently how many breed successfully with other resistant rats. Furthermore, resistance to the 'second-generation' anticoagulants, such as difenacoum and bromadiolone seems to be a matter of degree with some individuals more or less resistant than others. If most rats in an infestation are highly resistant to one or both of them, then very little control may be expected. Where the majority have a lesser degree of resistance, the outcome is less certain and may depend on the rate at which individual rats consume bait.

It is a fundamental biological principle that reliance on one class of pesticides (i.e. anticoagulant rodenticides) will exert a continuing selection pressure on rat populations towards increased resistance. Using more potent ('second-generation') compounds may, temporarily, remove the practical problems associated with control failure but is likely to increase the selection pressure and eventually select for higher

degrees of resistance. This may be avoided if steps are taken to eliminate resistant survivors by means other than the use of anticoagulant rodenticides.

Resistance for some rats comes at a price, in that they require above average amounts of dietary vitamin K₁ in order to maintain normal blood clotting function. They may obtain this from several sources, but of concern to the pest controller should be any proprietary animal feed that contains relatively large quantities of the vitamin (particularly pig and poultry food), as rats may be able to get the antidote at virtually the same time as getting the poison!

3. SELECTING THE RIGHT RODENTICIDE

Despite the problem of anticoagulant resistance, nearly all currently registered rodenticide products contain an anticoagulant. This group of poisons is commonly divided into 'first-' and 'second-generation' compounds, largely distinguished by the greater potency of the latter, which were developed to overcome rodents resistant to the former.

A list of rodenticides and formulations approved for use to control rats is given below. For anticoagulants, a further distinction is sometimes made between those that can cause mortality after only one feed and

those that require several feeds over perhaps 2 or more days. Broadly, rats will eat about 10% of their body weight each day and to obtain a diet containing all the essential nutrients for a healthy life, they will probably have more than one source of food. Thus, where rats only take part of their daily requirement from the bait point, it is an advantage if that part contains a lethal dose of poison. **Brodifacoum** and **flocoumafen** are typically described as '**single-feed**' anticoagulants, meaning that rats can receive a fatal dose in one feed, not that, in practice, they always will. However, the symptoms of anticoagulant poisoning normally take 2 or more days to appear, so that many rats may consume more bait than is needed to kill them, increasing the potential threat to predators and scavengers. This risk of **secondary poisoning** means that products containing these active ingredients are restricted to indoor sites only, such as within enclosed buildings or in sewers. During treatments with any anticoagulant rodenticide, livestock, pets, wildlife and humans must be considered at risk and bait should be placed in such a way that non-targets cannot gain access. An antidote, vitamin K₁, is readily available to treat cases of accidental poisoning.

Rodenticides and formulations currently available for rat control

Type of rodenticide	Active ingredient	Formulations
First-generation anticoagulant	Warfarin	Loose grain
	Coumatetralyl	Loose grain, Contact powder
	Chlorophacinone	Liquid concentrate
Second-generation anticoagulant	Difenacoum	Loose grain, Pellets, Wax blocks, Place packs
	Bromadiolone	Loose grain, Contact powder, Pellets, Wax blocks, Place packs
	Brodifacoum	Loose grain, Pellets, Wax blocks, Place packs
	Flocoumafen	Wax blocks
Non-anticoagulant	Calciferol	Liquid concentrate, Pellets
Fumigant	Aluminium phosphide	Tablets

Note: Manufacturers may vary the availability of active ingredients and formulations. Products containing the first-generation anticoagulant, diphacinone, may also be available.

The choice of which anticoagulant to choose depends on the likelihood that rats resistant to it are present. The full extent of anticoagulant resistance in the UK is not known, but populations wholly resistant to particular compounds have been found. However, it is more likely that when 'resistant' populations are encountered, some rats will be susceptible, so that a degree of control is usually possible in the short term, but repeated use of the same active ingredient will increase the proportion of resistant rats in the population and subsequent control

attempts will be prolonged or may fail. Hence, it is difficult to recommend a particular anticoagulant, unless a sample of the population is tested first. Always choosing the least potent anticoagulant first may waste much time and money before discovering that it isn't working. Nevertheless this is likely to pose a lower risk to humans, pets, livestock and wildlife. The aim is to strike the right balance between efficacy and safety. If resistance is anticipated, difenacoum or bromadiolone should be selected instead, but rats with a degree of resistance to at least one of these rodenticides have been found across much of central southern England, in parts of East Wales and the West Midlands and in the counties of Norfolk, Humberside, North Yorkshire, Kent and Sussex. However, only in a small area of NW Berkshire or Humberside is it likely that treatments with difenacoum or bromadiolone will fail completely due to resistance. Elsewhere, provided rats consume sufficient bait, some degree of control can be expected. Brodifacoum and flocoumafen should be fully effective against most, if not all, rat populations across the whole country, but the restrictions on their use mean that they cannot be used to control rats living outdoors.

If for some reason anticoagulants are not available or cannot be used or significant resistance is known to be present, then rodenticide formulations based on [calciferol](#) are an alternative option. These are able to kill both anticoagulant-resistant and non-resistant rats, but

particular care is required in their use. They are toxic to other animals and antidotes are not readily available. As they produce symptoms quicker than anticoagulants, those rats not killed after their first or second feed are likely to develop bait aversions. To minimise that effect, it is advisable to prebait for at least several days with plain bait, so helping to increase subsequent takes of poisoned bait. Care has to be taken that prebaiting does not also encourage non-target animals to eat the poison bait. It is usually not worth keeping the poison bait down for longer than 5-7 days with calciferol, because any rats not poisoned by then are unlikely to be controlled – the product label should give advice on this matter.

4. SELECTING THE BEST BAIT TO USE

Rodenticide baits are formulated as loose-grain, pellets, wax blocks and place-packs. All are cereal-based and manufacturers' ready-made formulations may contain additives such as flavourings and mould inhibitors. Whether rats will eat a bait or not depends both on what they are used to eating and on their individual preferences. Within a wild rat population, baits highly palatable to some individuals may not appeal to others. It is not practicable to test a range of bait bases before a treatment begins and with ready-made baits there is no alternative but to use the product supplied by the manufacturer.

If it is possible to purchase a rodenticide concentrate, this should be mixed with food that the rats are currently eating (provided that food does not contain large amounts of vitamin K₁). Alternatively, use processed cereals, such as oatmeal and cut wheat, for making up baits. In general, finely-ground cereals, which tend to be dry and 'dusty' are less acceptable to rats than coarser-grained ones. Adding corn oil and sugar, which may also mask the taste of a rodenticide, can enhance bait palatability. Wheat grains, made succulent by soaking in water overnight, are particularly attractive to rats. However, damp wheat rapidly dries out in hot weather and may either sprout or go mouldy, necessitating frequent bait replacement. Damp wheat is more suitable for mixing with dry concentrates than liquid (oil) ones. (**Note:** It is a breach of the approval conditions of a ready-to-use product to add attractants, flavour-enhancers, etc. in order to 'improve' a bait's palatability.)

The cereals used for baits must be free from insects and mites so that these pests are not spread to the sites that are being treated. A mite infestation in the bait will also make it unpalatable to rats.



Rat removing a pellet from a box: rats will remove any kind of food from any location where they don't want to stay for more than a few seconds. Preventing such transfer does not always persuade them to eat food on the spot; they may ignore it instead.

The efficiency of a rodenticide treatment is greatly enhanced if rats start to eat the bait as soon as it is laid. Although rats appear to eat anything they fancy, they are essentially seedeaters, hence grain-sized bait particles are ideal. Larger food items, such as blocks, may be less readily recognised as being edible and may cause a delay in bait uptake. Moreover, as such items take some time to eat, rats may prefer to eat them somewhere else, rather than risk attack from other rats or predators. Thus, wax blocks and place-packs (sachets) are particularly prone to being carried away. To counteract bait transfer, commercially available bait boxes may have a rod inside them for holding blocks to encourage a rat to eat them *in situ*, but this is not always successful. Some rats, unable to remove a secured block will

break it into smaller pieces and carry each piece away separately or ignore it altogether. Rats may also carry away whole-wheat baits.

If, when bait points are inspected, any containers seem to be unusually clean, with no crumbs of bait remaining and few smear marks on them, then it should be suspected that the bait has been transferred elsewhere. Wood mice (*Apodemus sylvaticus*) are also prone to hoard food and may carry away rodenticide baits: they may be present in and around farm buildings alongside a light infestation of rats. If bait is being moved or hoarded, a search for it should be carried out, so that it can be picked up before other animals find it.

5. CARRYING OUT THE TREATMENT

5.1 Surveying the site

Typical signs of rat presence such as burrows, runs and fresh droppings define the limit of an infestation. The density of fresh signs broadly indicates the density of rats. Around farmsteads, these may be distributed inside and outside buildings and over adjacent ground. If field boundaries, particularly hedgerows and ditches, radiate out from buildings they too may be infested. Occasionally, infestations may appear to extend continuously along connecting hedgerows, although

the frequency of fresh signs may vary considerably. In these circumstances, it may be impracticable to treat the entire infestation. Moreover, rats can move long distances in one night (500 m is common, but 3 km or more is possible), and it may not be apparent that rats from distant colonies are visiting the main population. Also, such visits may not occur every night. Thus, even if it is not cost-effective to treat outlying infestations, their existence should be noted, because they may help to explain an unusually prolonged treatment.

As part of the preparation for a rodenticide treatment, it is worthwhile drawing an accurate sketch map of the site. When the treatment begins the location of bait points can be plotted on the map as well as indicating them with a chalk mark on walls, fence posts, or on the cover over the point. It might also be useful to mark on the map the distribution of rat signs and any obvious food sources such as stored grain and animal feed. To assess the progress of a treatment, simple techniques can be used, such as weekly counts of the number of active burrows or the presence/absence of fresh footprints on patches of smoothed mud or sand laid at key points around a site.

5.2 Applying the bait

Rats are more likely to eat the bait sooner if it is laid beside runs, in holes, along walls and in sheltered places, but it is not safe just to lay

rodenticide bait on the ground without some kind of cover to stop other animals eating it. The HSE leaflet **Safe use of rodenticides on farms and holdings** gives good advice on suitable bait containers and the use of naturally occurring objects to protect the bait.



Two types of bait box: the one on the left has a lockable lid and high internal baffles to prevent children, pets and wild animals bigger than rats from reaching the bait – such containers are often described as ‘tamper-resistant’.

The box on the right has a low baffle and is less resistant to non-target interference, but is probably more ‘rat-friendly’.

Rats typically visit bait containers for a few seconds only, time enough to eat a grain of wheat or pick up a bait particle to take away. They may stay longer if other (friendly) rats are with them, so that bait boxes that allow ‘communal’ feeding may be better than ones with high internal baffles that rarely allow more than one rat to feed at a time, although such designs do discourage non-target animals from reaching the bait. Whatever container is used, it will be very difficult to prevent animals smaller than rats from entering.

Regardless of container type, if the rats are not already familiar with it, they may avoid it initially, which will delay bait uptake and possibly extend treatment time. It is therefore worthwhile setting out the bait containers several days in advance of laying the bait so that the animals become familiar with their presence. As a guide, trays should be laid at least 3-5 days and boxes at least 5-7 days before the treatment begins. If despite such actions, the majority of rats take little or no bait over the first 2 weeks, then such treatments will probably make slow progress and baiting tactics should therefore be changed immediately (see [Section 7.1](#)). Otherwise, the long bait exposure periods will put non-target animals at potentially greater risk.

Alternatively, on sites that seem prone to re-infestation, empty boxes or other types of container can be positioned after an infestation has been eradicated and before a new one appears. Immigrant rats are unlikely to distinguish containers from any other object and thus should not specifically avoid them. Baiting can then begin as soon as rat signs appear. It is of course essential to site the containers in places that invading rats are likely to colonise and to check them regularly to make sure that access has not been blocked by growing vegetation. The presence of rats in and around the containers can be monitored with

tracking patches made of fine sand or smoothed mud to record footprints or **indicator bait** blocks that show tooth marks.

5.3 How many bait points?

Bait points should be sited close to fresh rat signs, such as by the side of, or on, well-used runs, near active burrows or gaps in vegetation. If rats are running along the inside or outside walls of a building, the containers should be placed so that their entrances are adjacent to the wall to allow rats running close to it to easily enter them. It is not advisable to site points immediately next to piles of stored grain or other edible commodities, as the baits may then be in direct competition with the animals' usual food source, as well as presenting a possible contamination risk. Points should be sited so that they intercept rats on their way to their normal feeding location. Suitable places for baits should be where rats might nest such as junk piles, dung heaps, under pallet stacks, beneath discarded machinery and rubbish tips. Bait points can also be laid around the bottom of straw stacks, along field boundaries (ditches, hedgerows) and around ponds.



Bait containers will normally be spaced several metres apart, but they can be closer together if rat activity locally is intense.

In environments where food and harbourage are unevenly distributed, it is likely that the density of rats, and hence bait points, will also be distributed irregularly. As a rough guide, an average density of 2 points per 10 x 10 m square or 1 point every 5 m should be sufficient to treat most infestations, but in places where rats appear to be very numerous, baits can be laid as close as 1 m apart. Increasing the number of bait points above this average density does not appear to increase the speed or degree of control, but conversely the density cannot be reduced indefinitely without any effect on the treatment outcome. The location of the individual points and the willingness of rats that find them to take the bait are probably of more importance.

If too few points are laid, this will only become apparent after the treatment has started. If more than one quarter of the points with a bait take are 'complete' (i.e. all the bait has been eaten by rats) at one inspection visit, more points should be added. On the other hand, it would be a mistake to remove too early baits that have not been touched, as rats need time to find them and overcome any hesitancy about approaching them. Generally during anticoagulant treatments, errors of bait placement can be rectified with some loss of efficiency, but not overall effectiveness. This is not necessarily true for treatments with **fast-acting** rodenticides that require rats to be conditioned to feed at a bait point in order that they eat sufficient of the poison bait.

5.4 How much bait per point?

The amount of bait to place at each point depends on the replenishment schedule, the toxicity of the rodenticide and the infestation size. Guidance will normally be present on the product label. With the less toxic anticoagulants such as warfarin, **coumatetralyl** or **chlorophacinone**, the aim is to maintain an uninterrupted supply of bait as individual rats may need to feed on it continuously for 3 or 4 or more days. Relatively large quantities (200-400 g) should therefore be laid at each point initially, particularly if the site is one where rats are likely to be less wary of containers (e.g. on a refuse tip, some livestock farms).

When inspecting the baits, the quantity of bait should be doubled where complete takes occur. Other bait points with partial takes should be topped up to maintain a surplus. With the more toxic anticoagulants, such as difenacoum and bromadiolone, quantities of bait can be smaller at first, (e.g. 100 g), particularly if all the rats are known or are likely to be susceptible. Initial bait size may be even smaller (50 g) if the most potent anticoagulants, brodifacoum and flocoumafen, are used against indoor infestations. The important point is that rats should be able to find sufficient bait whenever they want to, so that they ingest a lethal dose as soon as possible. This may mean that baits are replenished more frequently at first in order to keep the amount of bait in line with the rats' needs. Moreover, by matching bait quantity to the numbers of rats willing to eat it, there will be less surplus bait available should non-target animals accidentally get access to it.

As rats start to die, replenishments should become less frequent and simultaneously the amount of bait per point can be reduced. If rats appear reluctant to eat any bait, as they may do around a grain store, the size of baits can be reduced to a token amount (say, 25 g) or alternatively the bait replaced with plain food until such time as the rats start to take it (see below).

Treatments with calciferol produce better results if effective prebaiting with unpoisoned (plain) bait is undertaken first. This poison can be used without a prebait, but the outcome is less certain. At all bait points, it is best to lay plain food of the **same type** that will be mixed with the poison (or of similar type to the ready-to-use bait) until as many rats as possible are eating it. The delay in finding these new food sources and then the suspicious nature of the animals towards them means that takes build up slowly and only as the rats' confidence grows does the total bait take begin to stabilise. The initial size of prebaits can be any amount, but 100-200 g is usually sufficient. Thereafter, a surplus should be maintained by 'doubling up' all 'complete' takes. For large rat populations, prebaiting may need to continue for up to 3 weeks, although smaller ones may need only 3-5 days. The plain bait should be checked daily, especially if the rats are readily attracted to it. If the rats appear reluctant, then less frequent checks can be made until the takes start building up. The rats may be judged to be feeding freely when about the same total amount of bait has been eaten for 2-3 consecutive days. Then all the prebait can be replaced with poison bait at all points at which it was eaten. Those rats accustomed to feeding on the prebait should eat the poison bait on the first night.

The quantity of calciferol bait at each point should be equal to that on the last night of prebaiting. It is a false economy to cut the

prebaiting period short as this may increase the proportion of rats that are sublethally poisoned and hence likely to become bait shy. If non-target animals visit the same bait points as rats, those points should be moved or provided with more protection. If non-target activity still persists, poison bait should not be placed at the affected points.

5.5 How often should baits be inspected?

The frequency of bait inspections largely depends on the rats' response, but also the likelihood of non-targets taking bait or eating poisoned rats. During anticoagulant treatments, some or all of the rats may ignore the bait completely or eat it without hesitation. During the first week of baiting, at least two visits may be required to see how the rats are reacting.

If the rate of bait uptake is slow and control is not urgently required, a visit once a week thereafter may be sufficient to check that the baits are still fresh, search for dead rats and ensure that other animals have not found the bait.

If bait uptake is rapid, the first rat dead or dying of anticoagulant poisoning may appear after about 4 days and then others in the population may succumb over the following days and continue doing so for several days after the last take of bait. While rats often die

underground, many do not and thus a search for bodies must be carried out and any carcasses found should be disposed of safely to prevent predators and scavengers eating them. Hence, during the first 2 weeks, 5 or more visits may be necessary not only to maintain a constant supply of bait, but also to recover dead or dying rats. If all is well and bait take and rat signs are clearly decreasing, 1-2 visits per week may suffice thereafter, unless there are concerns about the safety of the baits, in which case extra visits should be made.

Anticoagulant treatments can take as little as 2-3 weeks to be effective, but those lasting 5 weeks should not be regarded as abnormally long, particularly if the infestation is heavy. When a rat population appears to be responding well and the number of animals is clearly declining, bait points that have not had a take for 2-3 days may be removed.

Calciferol baits can be left down for about 5-7 days, but should be checked daily. Rats may die 4-10 days after consuming a lethal dose, thus searching for bodies may need to continue beyond the end of the treatment. As soon as takes cease at individual points, all bait remaining in them should be removed.

When control is achieved, the options are:

1. to remove all remaining bait and containers;

2. to leave some containers in place and bait them with plain food (e.g. indicator blocks/pellets), which should be monitored regularly to check for signs of reinvasion;
3. following an anticoagulant treatment only, to leave some containers with rodenticide in them for a further 6-8 weeks to provide a source of bait should rapid immigration to the site seem likely (these semi-permanent baits should be adequately protected and further visits made to the site to monitor for signs of reinfestation);
4. to establish permanent bait stations that contain an anticoagulant formulation at all times (the number of stations will usually be less than the number required to treat an active infestation). **Note: the non-anticoagulants are not suitable for permanent baiting.**

Option 4, permanent baiting using a few well-constructed, well-sited bait boxes each containing a small quantity (say, 50 g or less) of bait, is a preventative measure to control the occasional intruding rat in order to stop a new infestation arising, but carries some risks if care is not taken. When no rats are present, permanent baits should not be placed around a site in the numbers and of a size needed to control an active infestation in the expectation that they will prevent a rat population becoming established at some time in the future. Other

animals, particularly small mammals and small birds, may enter bait stations if there are no rats to deter them. Both they and the predators that feed on them may subsequently be poisoned. Permanent baiting is also ill advised if reinvasion is more or less constant and anticoagulant resistance is suspected or known to be in the area. Such baiting potentially maintains the selection pressure favouring resistant rats and in time may seriously jeopardise the effectiveness of future anticoagulant treatments. Also, any rats that are poisoned may be a hazard for predators and scavengers if dead bodies are not found and removed. To minimise the risk of non-target poisoning, permanent baits should be well protected and frequently inspected, especially if rats and other wild animals are likely to be short of alternative food. For example, birds such as finches and hedge sparrows are prone to enter bait boxes during frosty weather. In other circumstances, less frequent inspections may suffice. In general, permanent baits outdoors will probably require checking more often than those placed indoors, provided the risk of non-target animals entering treated buildings is low.

5.6 Monitoring the treatment

If a treatment fails, it is necessary to ascertain why. The more information that can be collected during the course of a treatment, the easier it will be to diagnose the problem. The minimum information should be:

1. a map of the site showing all the bait points;
2. the name of the product being used or the active ingredient and the bait base;
3. the date the treatment started;
4. the quantity of bait laid at each point;
5. the dates of subsequent bait inspections and the condition of each bait (i.e. not touched, completely eaten, partially eaten, non-target interference).

Additionally, if it can be done cost-effectively, an independent assessment of rat numbers before and after 2-3 weeks of treatment would also be useful. It is good practice to monitor treatments regardless of the final outcome as well-kept records

1. indicate the rate of progress;
2. help to optimise the amount of bait laid;
3. verify the need to change, if necessary, the treatment strategy;
4. indicate when dead rats are likely to appear and therefore the need to search for them.

Good records also provide information in cases where accidental poisoning has occurred and to indicate what actions were taken in response. In the long-term, sufficiently detailed records may help to spot a gradual loss of efficacy perhaps through increasing prevalence of

resistance. Before that loss becomes serious, alternative methods of control should be implemented.

6. IS THE TREATMENT WORKING? SIGNS OF SUCCESS

Rats die, on average, 5-7 days after eating a lethal dose of anticoagulant and then often underground, so there may be little visible evidence of success during the first week. By the end of the second week, however, there should be clear signs that the treatment is being effective. With rat populations that are relatively easy to attract to bait points, the peak consumption of bait and the maximum number of bait points visited often occur within the first week or soon after. Thereafter, there should be a steady decline in takes and points visited. A small rise in takes during, say, the third, fourth or fifth weeks should not be regarded as unusual, provided the general trend is downward. The signs of an effective treatment are:

1. >50% of 'active' points have a take within the first 2 weeks of the treatment ('active' refers to bait points that have been 'found' by rats i.e. those on or near fresh rat signs);
2. there are no 'complete' takes (i.e. all bait eaten) at each inspection visit, or that the number of such takes is decreasing;
3. during the first two weeks each 'active' point has a take >50 g over 2-3 days;

4. most fresh rat droppings are coloured by the warning dye that is incorporated into commercial products;
5. dead rats appear, but if not, fresh rat signs are diminishing.



When rats eat poison baits, their droppings may be coloured by the warning dye that manufacturers add to their products. A **BLUE** dye is common, but other dyes (e.g. **RED**) may also be used. The difference between coloured and normal droppings can clearly be seen in the picture.

After treatment with calciferol, success is apparent if:

1. most of the bait has been eaten at all points with a good prebait take on the first or second night (baits may be eaten over another 2-3 nights);
2. dead rats appear within a week;
3. within two weeks following the first application of poison bait, fresh signs are difficult to find.

7. IS THE TREATMENT WORKING? INDICATORS OF POOR CONTROL

7.1 No take at all/small, sporadic takes

Symptoms

- a) Few, if any, 'active' points (i.e. baits with fresh rat signs near them), but infestation persists.
- b) Less than 50% of the 'active' bait points have a take, especially during the first 2 weeks.
- c) The amount eaten at each point is insignificant (<50 g over 2-3 days) in relation to the number of rats as indicated by the density of signs.
- d) Fresh droppings show no signs of dye.

[Note: a – c will also apply to the period of prebaiting before a zinc phosphide or calciferol treatment.]

Possible causes

1. Errors in bait placement

- Too many points have been located in places that rats visit infrequently or where rats feel too exposed to attack.
- Bait points have been placed just off well-used runs so that they tend to be inadvertently missed rather than actively

avoided. If an infestation is light, fresh signs may be difficult to find and the best place for a point is not immediately obvious.

- Bait containers have been put in place on the first day of the treatment instead of several days in advance.
- Rats have been moving in inaccessible places such as in hollow walls, above false ceilings, in drains or in narrow 'dead' spaces inside and outside buildings.

2. Neophobia towards container/novel food

- Rats have found the bait points, but then actively avoided them as seen by the appearance of a 'bypass' (trampled soil/flattened grass/smear marks) around each container. Without space to divert, the run has been abandoned. Prone to occur on sites with little disturbance and abundant resources.

3. Unattractive formulation

- The formulation is unpalatable or not attractive enough to divert rats from their usual food. Tracks indicate that rats have visited bait stations, leaving bait undisturbed, walked over or spread about over the floor of the container.
- Baits have been placed too close to the rats' normal food source, which the animals visit first to feed on and then are not hungry enough to want any bait.

- Rats used to feeding on loose grain have not recognised rodenticide baits as edible if presented as wax blocks or sealed inside a plastic bag.

Remedies

Depending on the urgency with which the infestation has to be controlled:

- Re-site bait containers as necessary to correct misplacements, but quicker results will be achieved by transferring bait from containers to active rat burrows. Use a loose-grain (e.g. whole wheat) or pelleted formulation in preference to other types and lightly block the burrows with grass or hay/straw or cover the entrances with material such as corrugated sheets or wooden boards. Do not stamp on the entrance as this may cover the



Placing bait inside active burrows is the most effective means of encouraging rats to consume lethal amounts, but avoid overfilling or blocking the entrance with heavy objects as the burrow may be abandoned before any bait is eaten.

- If active burrows are difficult to find, do not exist, or for safety reasons bait must only be presented in suitable containers, change the formulation to loose grain or pellets, which rats are more likely to recognise as edible. If either of those is already being used and control is imperative, trapping or fumigating rat burrows with **aluminium phosphide** may be the only options. To make a significant impact with traps in a short time, some skill is required. **Fumigation** (gassing) is only appropriate where rat burrows are located away from buildings and should only be carried out by fully trained operators.
- If the only option is to persist with the treatment and after 2 weeks no bait has been eaten, either reduce the quantity of poison bait to a token amount, say 25 g, or alternatively replace it with plain bait. This reduces the risk of other animals being accidentally poisoned while waiting for rats to start taking bait. This is especially relevant to outdoor bait points. When rats eventually start to feed, increase the amount of poison bait or switch back to the original formulation.

- Destabilising the habitat by moving objects around can sometimes increase bait uptake at sites where little changes from day to day. For example, stacks of bales that rats live in can be dismantled, or bulk grain or animal feeds moved around in a storage facility. Such a drastic change in the rats' environment may only need to be done once, provided that it immediately produces substantial bait takes.
- If there has been a poor response to the prebait prior to a calciferol treatment, there is little point in applying the poison bait. Doing so will kill only a few rats and may induce bait shyness in any rats consuming the bait. Continue with the prebaiting, changing the method of baiting as described above, but if this is not feasible and anticoagulants cannot be used, trapping and/or gassing may be the only practicable option.

7.2 Good takes initially, partial control, then poor bait takes

Symptoms

- a) During anticoagulant treatments, baits found by rats have good takes that may rise during the first 1-2 weeks before falling away quickly to insignificant levels. Thereafter, small takes continue sporadically at some points. Inspection of the baiting records may show that

particular points, or several adjacent points, have had very little bait taken since the treatment began.

- b) During a calciferol treatment (and after an effective prebaiting period), bait takes drop rapidly after 1-2 days reaching near zero by the end of the first week.
- c) Dead rats are found and some areas become clear of infestation. Elsewhere, fresh signs of rats are still present.

Possible causes

1. Neophobia, unattractive baits

- The reasons given under **1** above also apply, but the effects of neophobia or unattractive bait vary across the infested area. Typically, on farms with both grain stores and livestock-rearing areas, rats can be more difficult to attract to bait in the former, but much easier in the latter.

2. Bait aversion

- Some rats have become bait shy, because they felt ill within a few hours of eating a small quantity of bait and linked their symptoms to it (**learned aversion**). Bait aversion is especially likely during treatments with relatively fast-acting poisons such as calciferol. It does not normally occur with anticoagulants, although the possibility is not entirely ruled out.

- If an anticoagulant formulation is being used, a more probable explanation is poor acceptance to some rats in the target population. Wide variation between individuals in their acceptance of a single type of bait is common among wild rats. Also, different anticoagulants are not all equally palatable to rats.

Remedies

- If the survivors of a partially successful calciferol treatment have developed an aversion, change not only the active ingredient and bait base, but also the container and the location of the bait point. A follow-up anticoagulant treatment is probably the most practicable option to eliminate the remaining rats provided they are susceptible. Baiting active burrows, if possible, is preferable to setting out new stations, as this will eliminate any container neophobia. Trapping may be quicker if only a few animals are left, but may be the only option if the rats are anticoagulant resistant.
- Survivors of an anticoagulant treatment are unlikely to have developed an aversion due to sublethal poisoning. Thus it is not necessary to change the containers or the location of baits. Try another bait: if difenacoum in cut wheat seems unacceptable,

use bromadiolone on whole wheat, or vice versa. If that does not work, bait active burrows, covering them as necessary. If the burrow baits are rejected, the rats may have unusual taste preferences or they may indeed have developed an aversion. Trapping or gassing may then be the only option.

7.3 Good takes continuing

Symptoms

- a) Persistent (i.e. >2 weeks) partial or complete takes at specific points.
- b) Several adjacent bait containers empty at each inspection visit.
- c) Bait takes cease at specific points, but then recur after 7 days.
- d) After 2 weeks rat signs not diminishing, very few dead rats seen.
- e) Most fresh rat droppings are coloured by the dye in the rodenticide bait.

Possible causes

1. Under-baiting (a, b)
 - The commonest cause of a poor treatment is too little bait at too few points in relation to the number of rats. The first rats to encounter the bait consume it completely, leaving nothing for those that come later. Should they die, other rats may find sufficient bait and start to feed. The treatment may still succeed but only slowly. Alternatively, most rats may make many short

visits to the bait points consuming a small quantity each time, so that by the time the bait runs out, the majority have not acquired a lethal dose. In this case, few, if any, rats may die.

2. Bait transfer (hoarding) (d)

- Individual rats carry the bait away, grain by grain, block by block. Generally, the larger the bait particle, the more likely it will be carried off. Wax blocks and place packs secured inside a container may be broken up into smaller pieces or split open and then carried away piece by piece. Transferred bait may not be eaten, but simply cached somewhere. Refilling the container merely provides the stimulus for the particular rat(s) involved to carry bait away again. On inspection, the container seems relatively clean, with no fragments of bait remaining.

3. Other animals eating the bait (d)

- Mice typically leave plenty of droppings in a bait container that they visit and they also eat certain foods in ways distinct from rats. Thus individual grains of whole wheat eaten by mice have an 'apple-core' appearance, whereas grains eaten by rats look like 'banana ends'. Where wax-block baits have been partially eaten, the size of the incisor tooth marks distinguishes rats from mice.

- Small birds (e.g. chaffinches, sparrows) tend to scatter loose-grain bait over the bottom of the container and may also leave droppings. Larger birds, particularly those with long necks such as chickens and pheasants, may be able to reach inside boxes that do not have baffles to stop them. If the birds cannot reach all the bait, the bait remaining may show a characteristic 'V' shape (loose-grain bait only) indicating the limit to which they were able to stretch their necks.
- If bait points show signs of considerable disturbance, such as missing cover or upturned or crushed containers, then cattle, sheep, pigs or dogs may have been responsible. Where this happens, foxes and badgers may gain access to bait.

4. Reinvasion (c)

Recolonisation of cleared areas may be very rapid (i.e. within a few days) if rats are close (i.e. <200 m) to the site. Baiting records will show consecutive takes at specific points followed by 2-3 inspection visits when no takes are recorded. Then takes begin again from those same points.

Rats from more distant colonies (even a neighbouring farm) may move into a site during the course of a treatment. The rate of reinvasion from such places may be very low and difficult to

detect. The only indication will be that fresh signs suddenly appear in areas thought to be rat free.

5. Resistance (a, b, d, e)

- If none of above apply, then resistance should be suspected.
- Resistance to calciferol has never been recorded and therefore is most unlikely.
- During anticoagulant treatments, if the infestation is light, or the number of resistant animals is relatively small, the pattern of bait takes will show persistent takes of >25 g/day at specific points. Against heavy infestations with a large number of resistant rats, frequent 'doubling up' of bait may result in large quantities (>1 kg) at some points.
- Treatments with warfarin or other first-generation anticoagulants against populations containing mostly warfarin-resistant rats will kill very few rats. Similarly, very few will die if most are highly resistant to difenacoum/bromadiolone and difenacoum/bromadiolone formulations are being used. Effective control may be possible with difenacoum/bromadiolone if rats with only a lower degree of resistance are present, provided that the amounts of bait they consume are adequate.
- Populations containing high proportions of resistant rats seldom appear suddenly. More likely, a succession of partially

successful treatments leaves an increasing proportion of resistant individuals each time. At some point the number of resistant rats rises to a level where the reduced effectiveness of treatments becomes obvious. If good records of previous treatments are maintained, early detection of resistance may be possible before serious control problems emerge.

Remedies

- **Under-baiting** is easily rectified. Simply increase the density of bait points. The best baiting tactic is a relatively large number of bait points each with a relatively small amount of bait, rather than a small number of points each with a large amount. More bait stations increases the chance of intercepting rats as they move around their habitat, particularly if rats have many options on which way to go.
- **Bait transfer** (and hoarding) may be difficult to stop, especially if the rats that do it are not eating the bait they carry away, but merely leaving it somewhere. Securing wax blocks or place packs inside a container may partially solve the problem, but could result in no take at all or the bait broken up and then carried away piece by piece. Reducing the particle size of the bait may make transfer less likely. Thus, replace wax

blocks/place packs with whole wheat (i.e. split open place packs) and whole wheat with cut wheat or oatmeal.

- If **other animals are eating the bait**, immediate action is required, as most are susceptible to the rodenticides currently available. It will be difficult to exclude animals smaller than rats. Takes by small birds are more likely during prolonged cold spells (freezing conditions) when food is difficult to find and less likely during the breeding season. Changing the type of container may deter birds prone to enter one particular design. Wax-block formulations are less attractive to birds and, it appears, to rats also and can be used instead of loose-grain bait. Mice and voles may eat any type of bait at any time, although the latter may do so infrequently. Protection for baits disturbed by larger animals may need considerable reinforcing to prevent further interference. Ultimately, bait points may have to be removed rather than re-sited if other animals persist in visiting them.
- Rapid recolonisation (**reinvansion**) should be prevented by extending the treated area in any direction where rats are found. Thus, in addition to farm buildings, nearby infested hedgerows and ditches should be included. Bait to the limit of the visible rat

signs along the field margins. If some rats are coming from more distant places and are visiting a site for the first time or visit irregularly, visible signs of their travels may be difficult to spot. As farm rats may travel 500 m or more in one night, the source of these animals should be found and treated. Large numbers of rats are often found on rubbish tips between fields, around pheasant feeders and in any place where a food supply exists. If that supply is suddenly removed, the rats will move away. On a large scale, this is likely to happen in the post-harvest period when fields are ploughed up and any grain left by the combines is buried.

- A potential downside of treating a wider area to prevent reinvasion is that this could lead to an increase in selection pressure towards anticoagulant resistance. A control strategy that allows some susceptible individuals (i.e. those outside the treated area) to survive may prevent later infestations being entirely composed of resistant individuals. Thus, after a partially successful treatment, any invading susceptible rats could help dilute the resistant proportion of the residual population. By deliberately allowing some rats to survive, the potential benefit of reduced selection pressure should be weighed against the risk of disease transmission from immigrant rats.

- **Resistant rats** should be eliminated without applying further selection pressure. Preferably, such elimination should be attempted using non-anticoagulant rodenticides, gassing or physical control methods e.g. trapping. If anticoagulants have to be used, bromadiolone or difenacoum should kill rats resistant to warfarin and other first-generation anticoagulants. Both are available for outdoor use, but some warfarin-resistant rats are resistant to those also. However, few rat populations are completely resistant to difenacoum or bromadiolone treatment, thus some control will be possible. The key is to encourage rats to feed well on the bait by adopting baiting methods that maximise bait uptake. Nevertheless, the most resistant animals may survive and to prevent an even greater resistance problem developing in the future, all available control options should be utilised. This includes the use of brodifacoum and flocoumafen, but only inside buildings with limited access for rats to the outside.

8. LONG-TERM MANAGEMENT OF RAT PROBLEMS

The end of a treatment is the appropriate time to carry out or make recommendations about hygiene and proofing to prevent reinfestation. Poor hygiene practices often provide rats with essential food and shelter. Removing these vital resources is one of the most basic preventative measures. Proofing is the structural modification of buildings to prevent rats getting in or to limit their spread once inside. The DEFRA (formerly MAFF) Technical Bulletin No 12, '**Proofing of Buildings against Rats and Mice**' gives more details.

Some specific recommendations are:

- Fill holes with concrete or cement mortar (small rats can squeeze through a 10 mm crack).
- Fix kicking plates to doors.
- Repair defective drains.
- On farms, cap breeze-block walls to prevent rats getting inside them.
- Remove food at night put out for pets and birds during the day.
- Use dustbins with well-fitting lids and do not overfill them.
- Store food in rat-proof containers or in rat-proof storerooms.
- Prevent rubbish accumulating and cut back vegetation on rough ground to deny rats shelter.



Non-poisonous bait blocks can be used
to indicate the presence of rats

If after all practicable hygiene and proofing measures have been taken, a site still seems prone to reinfestation, permanent bait stations can be installed to intercept incoming rats. Such stations should preferably contain non-toxic indicator baits instead of anticoagulant formulations because of the risk of selecting for anticoagulant resistance and accidentally poisoning non-target animals. When rats are detected, the indicator bait can be replaced with a rodenticide product. [Section 5.5](#) gives advice on permanent baiting with a rodenticide.

Rodenticide treatments should be seen as short-term solutions for the control of rat infestations and for that purpose they are generally efficient, provided care is taken to minimise risks to other animals. However, should anticoagulant resistance (particularly to second-generation compounds) become more widespread, such treatments may quickly lose their cost-effectiveness. To delay, or perhaps prevent

that happening, it is essential to minimise the selection pressure for resistance. In practice, this means using non-anticoagulant methods (zinc phosphide/calCIFerol treatments, gassing burrows away from buildings, trapping, **physical exclusion**, **habitat modification**) as much as possible once resistance is detected or suspected. Even if resistance does not yet present a practical control problem in an area, it may be prudent to alternate non-anticoagulant methods with anticoagulant treatments. No new rodenticides are likely to be introduced for some considerable time. Moreover, it is important to eliminate by any legitimate means any surviving rats from an anticoagulant treatment. The ease with which rodenticides can be used should not deter occupiers from determining why infestations arose in the first place and then taking appropriate remedial action. Resistance and risks to non-targets mean that long-term solutions to keeping rat numbers down should rely less and less on rodenticides. Put simply, prevention is better than rodenticide cure.

GLOSSARY

Aluminium phosphide: see [Fumigation](#)

Anticoagulants: Discovered by chance during an investigation into a haemorrhagic disease in cattle in the 1930s. A synthetic derivative of the causative chemical agent was named warfarin and was introduced as a rodenticide in the UK around 1950. Anticoagulants prevent the manufacture of clotting agents inside the body, leading to a fatal haemorrhage in 4-10 days. Several other anticoagulants have been developed in the intervening years mainly in response to the development of resistance to warfarin, but all have the same mode of action.

Bait container: Available commercially as trays, tunnels, or boxes made of moulded plastic or metal, the latter material less preferred by rats. Boxes are frequently marketed with the description 'tamper-resistant' and have internal baffles to prevent animals larger than rats reaching the bait. Home-made containers (wooden boxes, drain pipes) can be just as effective as bait dispensers, but may need extra cover or more frequent inspections to minimise the risk of accidental poisoning.

Bait shyness: Typically results in little or no bait being eaten. The term is sometimes used to refer to avoidance of bait because of its novelty to rats and at other times to the avoidance of bait following an unpleasant experience (illness). The latter condition is more appropriately called a 'learned aversion'.

Bait transfer: The removal of bait particles by rats from a supply source to any other location. The supply source may be a protected container and such behaviour may circumvent attempts by pest controllers to prevent bait being eaten by other animals, particularly if the individuals that carry bait away then abandon particles in the open.

Brodifacoum: One of the most potent second-generation anticoagulants introduced commercially in 1979. Rats do not normally die quicker from brodifacoum poisoning than from warfarin poisoning, but a lethal dose can be ingested after one feed. Nevertheless, rats showing some degree of resistance to brodifacoum have been found, although this is not thought to be of practical importance.

Bromadiolone: A second-generation anticoagulant that became available commercially in the UK after 1980. One important attribute appears to be that it does not markedly reduce the palatability of baits in contrast to other anticoagulants that clearly do so. Rats highly resistant

to the compound have been discovered in Berkshire and Yorkshire to the extent that virtually no control of some populations has been possible.

Calciferol: A non-anticoagulant rodenticide used in the form ergocalciferol (vitamin D₂) and more recently cholecalciferol (vitamin D₃) to kill resistant rats and mice. The mode of action is to stimulate the absorption of calcium from the intestines and to mobilise calcium from bones causing calcification of soft tissue, particularly in the major arteries and kidneys. Calciferol is also toxic to other mammals and birds and there is some evidence that secondary poisoning may be possible.

Chlorophacinone: A first-generation anticoagulant, it belongs to a different chemical group, the indane-diones, to warfarin and coumatetralyl. No more or less effective than warfarin against susceptible rats and largely ineffective against warfarin-resistant animals.

Complete take: A commonly used term to indicate that all bait has been eaten by rats between two inspection visits. Can be denoted by 'C' on record sheets. Too many complete takes during the first week of an anticoagulant treatment almost certainly suggests that too few baits have been laid.

Concentrate: A rodenticide dissolved in an edible oil or mixed dry with a finely ground cereal that requires further dilution in order to obtain the most effective (and approved) concentration of poison. Concentrates are useful when rats cannot be attracted to ready-to-use formulations, allowing a bait base that they are already eating or one more attractive to be used instead. Damp baits are often very attractive to rats and whole wheat soaked in cold water for a few hours has proved very successful. A manufacturer's agreement is sometimes needed before users can be supplied with concentrates.

Coumatetralyl: A first-generation anticoagulant, introduced a few years after warfarin and appeared to be reasonably effective against warfarin-resistant rats. However, initial optimism was soon dispelled when rats resistant to both warfarin and coumatetralyl were discovered. One advantage of coumatetralyl over warfarin is that at concentrations over 0.025% it does not markedly reduce the palatability of bait.

Difenacoum: The first second-generation anticoagulant to be introduced (1974). It proved to be particularly effective against some warfarin-resistant rats, but not all of them. Almost immediately, rats resistant to it were discovered in Hampshire in populations where the average prevalence of warfarin resistance was 85%. Resistance to

second-generation compounds is not uniform within or between populations, with some individuals/populations succumbing after ingesting doses that are only slightly larger than that normally lethal to susceptible animals, while others can feed for several days on nothing but rodenticide bait and survive.

Doubling up: A term referring to the replenishment of bait following an inspection that finds no bait remaining and signs that it was all eaten by rats. For example, if 200g has been eaten, replenish the container with 400g, 500g with 1 kg.

Fast-acting: A description of the speed of the rodenticidal process often leading to death within 24 hours. Likely to cause rats to die on the surface rather than underground, so that a successful treatment will be immediately apparent. A disadvantage of fast-acting poisons is that unless they are species-specific, there may be no time to administer an antidote, even if one is available, if accidents occur.

First-generation (anticoagulant): A term used to describe the many compounds that were introduced before 1970, of which only warfarin, coumatetralyl and chlorophacinone currently remain registered for use in the UK. Chlorophacinone belongs to a different chemical

group (indane-diones) to all other anticoagulants (hydroxycoumarins), but the mode of action appears to be the same.

Flocoumafen: A highly potent second-generation anticoagulant, with the same restrictions on its use as brodifacoum (indoors only). The resistance to it that has been discovered appears, as with brodifacoum, to be of no practical importance. Thus, both brodifacoum and flocoumafen should be effective against rats that are resistant to other second-generation compounds, but it is difficult to see how they can be used effectively indoors to control rats that live mainly outdoors.

Formulation: The active ingredient mixed with an edible base attractive to rats. The base may be a cereal such as whole or cut wheat, either loose or ground and compressed into a pellet or moulded into a wax block. Many commercial formulations are ready to use, but occasionally rats ignore them preferring their normal food supply. In such cases, if a manufacturer sells a concentrate, then this can be mixed with the same food that the rats are eating.

Fumigation: An alternative means of controlling rats in situations where other rodenticides cannot be used. The technique covers ad hoc gassing of rat burrows to the highly specialised treatment of commodities stored in silos, ships and warehouses. To control rats in

burrows phosphine gas fills tunnel systems when a pellet or tablet of aluminium phosphide is placed well inside each entrance, which is then sealed. Moisture present in the atmosphere or soil causes the gas to evolve.

Habitat modification: Altering features of the environment to make them unattractive to rats. One technique is to keep cover, such as vegetation, cut short enough to increase the vulnerability of rats to predator attack. Removing discarded machinery/building materials/empty storage cases etc. can achieve the same effect. As rats often nest outdoors, but may find their food indoors, the aim is to make foraging trips more risky. The consequence should be that predators will take more rats or that rats will move away to find better cover. Either way population density is reduced. It is important that any modification of a habitat does not disadvantage other species.

Harbourage: Virtually anything that provides rats with shelter. Typically around farm buildings this can be dung heaps, junk piles, pallet stacks, straw bales as well as undisturbed ground between buildings where the soil is easy to excavate. Rats may also exploit hollows walls and false ceilings and often dig under buildings if the foundations are shallow. It will rarely be possible to remove all sources of harbourage.

Rats can find shelter in 'natural' features such as along hedgerows, ditches, streams and riverbanks or under tree roots.

Indicator bait: Non-toxic bait in the form of a block or pellet that can be laid at strategic points around a site to give early warning of rodent activity before an infestation becomes established. The blocks have central fixing holes so that if desired they can be secured in place to prevent rats carrying them away. In such cases, rat activity is likely to be revealed by incisor marks found on partially gnawed blocks.

Learned aversion: see [Bait shyness](#)

Loose-grain: Description of a formulation type, usually based in commercial products on cereals that are either whole or coarsely ground. Baits based on food types (especially in relation to particle size, texture and taste) that are 'natural' to rats should always be acceptable, so that failure to eat them is due to some other factor. A practical disadvantage of loose-grain baits is that they are easily dispersed into the environment if containers are disturbed and any spillage is consequently not easily retrieved.

Neophobia: Fear of new objects, even those that are completely harmless. It's been argued that intensive control of rats with baits and

traps over many decades has led to the selection of individuals in some areas that appear to be abnormally suspicious and are therefore particularly difficult to eliminate. However, this is more likely a misinterpretation of events in that rats apparently 'avoiding' baits do so because alternative food is more easily accessible. Extreme neophobia, as a heritable trait, would seem to be a poor survival strategy to cope with frequently changing conditions.

Partial take: A convenient description for a quantity of bait eaten by rats at a bait point. Often denoted by 'P' on record sheets to distinguish it from 'NT' (no take) or 'C' (complete take) or 'D' (disturbed). It may be useful to indicate how much bait has been eaten for each partial take with a fractional estimate e.g. $\frac{1}{3}$ or $\frac{2}{3}$.

Pellet: A type of formulation made by mixing finely divided cereals with a rodenticide concentrate and then forcing the resulting mixture through a die under pressure to bind the constituents together. Rodenticide in the extruded pellet should be evenly dispersed, which may improve the acceptability of baits containing an intrinsically unpalatable poison. Such a poison, when mixed with loose cereal grains, normally adheres to the surface of individual particles (vegetable oil is commonly used as a sticker) and thus might be more readily detected by rats.

Permanent baiting: Maintaining quantities of rodenticide bait (usually an anticoagulant formulation) at one or more locations around a site at all times whether or not rats are present. Permanent baiting may occur (by default) if uneaten bait is not retrieved at the end of a treatment, or if a treatment aim of total eradication is never achieved.

Physical exclusion: The simplest form of exclusion is often to keep the door shut! Barriers such as rodent-proof doors and fences have rarely been considered cost-effective. Makeshift barriers can be used to protect temporary stocks of small-volume commodities. Alternative means of excluding rodents have included chemical, ultrasonic and electromagnetic repellents, but none have so far proved to be reliably effective.

Place-pack: Essentially, loose-grain bait sealed inside a plastic bag (sachet). Like wax blocks, easy to use, but unless secured in place may be carried away by rats. Also, wild rats do not seem to readily open sealed sachets, which means the bait inside them may not be eaten for some time. In such circumstances it may be better to use a different formulation or empty the contents out.

Prebaiting: A technique introduced to encourage rats to eat lethal doses of fast-acting rodenticides. Prebaiting seeks to persuade individual rats to eat larger and larger quantities at each visit, as well as attracting increasing numbers of rats away from their usual food source. Against large populations these two processes can take at least 3 weeks to complete, which is indicated by approximately the same amount of bait (in total) being eaten by rats each day for 3 days.

Resistance: A trait found in rats (and other rodent pests) enabling them to survive doses of poison that would normally be expected to kill. An important aspect is that the characteristic can be passed to the next generation. Animals may develop an increased tolerance to a poison through repeated sub-lethal dosing, but such acquired tolerance would not be heritable. Resistance to the anticoagulant warfarin was first discovered within 10 years of its commercial introduction as a rodenticide and has been found in widely separated parts of the UK. This suggests that it has arisen independently and not by the movement of rats across the country. While resistance is an all-or-none characteristic, its detection in the animal is subject to errors of measurement. Consequently, claims about the practical significance of resistance, especially to second-generation anticoagulants, should be supported by more than one confirmatory

test. In the UK, resistance to the non-anticoagulant, calciferol, has never been found.

Secondary poisoning: A risk associated with rodenticide treatments, when predators, such as foxes, stoats and weasels, and scavengers, such as red kites, eat rats or other small animals that have eaten poison bait and then they become casualties as well. While primary poisoning (non-target animals eating the bait directly) can be prevented by adequate protection of bait points, the risk of secondary poisoning can be reduced by regularly searching for and disposing of dead or dying rats/mice/small birds.

Second-generation (anticoagulant): Introduced primarily to counter resistance to first-generation anticoagulants that appeared not only in the UK, but also in other European countries and the USA. They retain the same mode of action as the previous compounds and are considerably more toxic not only to rats, but also to other species.

Selection pressure: Increased by reliance on only one means to control rats, decreased by alternating the use of one method with another and removed entirely by using a different control method every time. In relation to anticoagulant resistance, repeated or permanent use of anticoagulants eliminates all susceptible rats leaving only resistant

animals to breed amongst themselves. To take advantage of the detrimental effects that some rats face by being resistant, anticoagulants should not be used again until the resistant strain has died out. Recent research suggests that for some resistant rats, this period may be several years long.

Single-feed: A feature of rodenticide formulations that are so toxic to the target species that a lethal dose can be ingested after one feed. The term has tended to replace 'acute' that was used to describe non-anticoagulant, fast-acting rodenticides. Poisons that have to be ingested over 2 or more days were described as 'chronic', a term now commonly replaced with 'multi-feed'. Even warfarin will kill some rats after one feed, but the majority of a population will only succumb after 2 or more feeds. Equally, resistant rats may need more than one feed to succumb to a 'single-feed' anticoagulant bait, as will susceptible rats that only eat very small amounts when visiting bait points.

Slow-acting: A description of the rodenticidal process, in which symptoms of poisoning appear a long time after a rat has fed on bait, so that it is unable to associate its illness with a particular food type or its taste. A characteristic of anticoagulants that has undoubtedly been responsible for their success, as it minimises the likelihood of learned aversions developing.

Vitamin K: The antidote to anticoagulant poisoning. Natural foods containing vitamin K₁ and manufactured animal feeds enriched with vitamin K₃ help resistant rats to thrive in the absence of anticoagulants. Some strains of resistant rat require additional vitamin K in order to maintain normal blood clotting activity. Vitamin K₃ may also protect resistant rats from small doses of second-generation anticoagulants.

Warfarin: One of the first hydroxycoumarin anticoagulants to be synthesised and marketed as a rodenticide to control commensal rodents. Its use has declined in recent years, as products containing second-generation anticoagulants are preferred by users. It is a feature of warfarin and other similar compounds that a single lethal dose is often several times greater than the sum of 4-5 daily doses that also cause death.

Warning dye: An additive in rodenticide formulations, often a food-grade colouring agent to discourage children, in particular, from eating poison bait by mistake. An additional technique used by manufacturers to increase safety is to add low concentrations of a bittering agent, such as denatonium benzoate, so that people eating bait accidentally will be repelled by the bitter taste.

Wax block: A type of formulation in which whole, finely- or coarsely- ground cereals are mixed with a quantity of paraffin wax and then cast or compressed to form a block that may weigh 15-225g depending on the manufacturer. Blocks are often brick-shaped with multiple gnawing edges and have a central hole for securing them in place, such as inside a box. An early use of block baits was to anchor them in manholes to control sewer rats, since coarse cereal baits could easily be washed away. However, the results were variable, not least because it was suspected that rats did not always recognise block baits as food. Nevertheless, block formulations are easy to use, relatively weather-resistant and seem to be less attractive to birds, thus offering added safety to rodenticide treatments.