Overview / summary

Environmental residues of anticoagulants used for pest animal control

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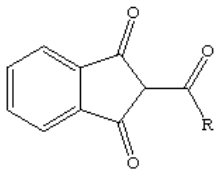
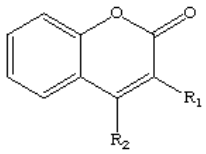
Background

Anticoagulants are a group of compounds used as rodenticides worldwide. They inhibit Vitamin K metabolism in the liver, which in turns prevents the formation of chemical factors essential to processes of blood coagulation (clotting). Toxicity occurs when enough anticoagulant is absorbed for these clotting factors become so depleted that blood can no longer clot. Death through anticoagulant poisoning generally occurs through massive internal haemorrhage after a number of days. Anticoagulant poisoning in humans and animals can be successfully treated through injections of Vitamin K_1, until blood clotting time returns to normal range.

As shown below, anticoagulants can be classified by their chemical structure (as indandione or coumarin compounds) or by when they were first developed (as first- or second-generation anticoagulant rodenticides –FGAR or SGAR)

First generation	1942: Pindone 1952: Diphacinone c.1962: Chlorophacinone	Indandione		R = alkyl, aryl
	1944: Warfarin 1962: Coumatetralyl			
Second generation	1975: Difethialone 1976: Brodifacoum 1978: Bromadiolone 1984: Flocoumafen 1986: Difenacoum	Coumarin		R_1 = complex substituent R_2 = OH

Toxicity and persistence

SGARs are the most toxic, so that targeted pests are likely to ingest a lethal amount in a single feed of bait. The lower toxicity of FGARs means that targeted pests need to consume small daily amounts of bait over a number of consecutive days for best efficacy. The carcasses of animals that have died of anticoagulant poisoning will contain residual concentrations and thus present potential secondary exposure to predators and scavengers.

SGARs are also more persistent than FGARs in animal tissues, and are eliminated very slowly from liver especially. Animals or birds that ingest sublethal amounts of an anticoagulant can carry residue burdens in tissue until they are eliminated, with the potential for SGAR residues to persist for months in liver. Repeated sublethal exposures within this time can result in accumulation of residues in liver, potentially to the point where harmful effects or mortality result.

Environmental transfer of anticoagulants

Environmental transfer of anticoagulant residues appears to largely trophic (rather than through exposure to residues in water, air or soil). While primary exposure can be managed to some extent by preventing non-target animals from accessing bait applied for pest animal control, it is typical for rodents or possums to move bait from stations into the wider environment. This includes the potential for exposure of grazing livestock to bait in areas where anticoagulants are used in field applications for pest animal control.

Invertebrates appear less sensitive than mammals or birds to anticoagulant toxicity. However invertebrates that feed on anticoagulant bait, or the carcasses of poisoned animals, can transfer residues in the wider environment.

Secondary exposure of predators, scavengers or insectivores through consumption of other animals or carcasses that contain anticoagulant residues is more problematic to manage. This includes the potential for some native wildlife and wild game animals, such as feral pigs, to incur anticoagulant residue burdens.

New Zealand uses of anticoagulants

Pindone: field applications for rabbit control in broadcast or bait station applications using carrot or pellet bait. Controlled Substances Licence required for aerial broadcast applications. Pindone pellet bait also used in bait stations for rat and possum control.

Diphacinone & Coumatetralyl: Bait station field applications (eg. by DOC) for rodent control, and also available 'over the counter' to general public for rodent control around houses, farms, factories etc.

Brodifacoum: Available 'over the counter' to general public for rodent control around houses, farms, factories etc. Bait station field application by Regional Councils, conservation groups etc for possum and rodent control although DOC currently limits field uses of brodifacoum in mainland conservation areas.

DOC or other unitary authorities can undertake broadcast (aerial) application of pellet baits for the eradication of rodents on uninhabited offshore islands or fenced sanctuaries. Recent examples of such 'one off' broadcast applications include Rangitoto/Motutapu Islands, Ulva Islands and Shakespear Park (Whangaparaora Peninsula). Such applications usually have environmental monitoring for brodifacoum residues as a condition, as it is acknowledged this method of bait distribution creates high potential for exposure of non-target animals.

Broadcast applications that aim for eradication should be clearly distinguished from ongoing / sustained ground-based applications of brodifacoum that aim for control of rodent or possum populations, but are not associated with formal monitoring for residues.

Bromadiolone & Flocoumafen: Available 'over the counter' to general public for rodent control around houses, farms, factories etc. Do not appear to currently have any field uses.

Note that warfarin is no longer registered as a rodenticide in NZ, but is a commonly used human therapeutic agent.

The use of anticoagulants, especially SGARs, in New Zealand is comparatively unrestricted compared to many other countries. In particular, over-the-counter availability, the absence of licensed user requirements and allowed field applications in New Zealand differ from other parts of the world. For example, in the European Union and the United States, sale and use of SGARs is generally restricted to licensed professional pest controllers and limited to bait station use in and around buildings.

Recent research and monitoring in New Zealand

- Research in the late 1990s identified concerns about the transfer of brodifacoum residues in NZ environments, and secondary poisoning of wildlife, as the result of field applications for pest control (eg. Eason, Milne et al. 1999).
- Subsequently, DOC implemented restrictions on their use of brodifacoum for conservation purposes on the mainland. However, field application of brodifacoum in bait stations for possum and rodent control by other agencies continues, with some programmes covering considerable areas (up to 300 000 ha) and may be sustained for a number of years.
- In 2004, MPI notified a restricted procurement area for feral pigs in Marlborough, due to the detection of brodifacoum residues in liver samples, which applies only to pigs killed from the specified area that are sold to game processors. It is unclear whether surveillance of feral pigs for brodifacoum residues in other areas has since been carried out.
- Spurr, Maitland et al. (2005) monitored brodifacoum residues in wildlife in and around the Rotoiti Nature Recovery Project area. The highest concentration of brodifacoum residues in mammalian livers was recorded during the period brodifacoum was used in the project area, but residues were still detected in some wildlife at least 24 months after brodifacoum use ceased. This study provided some of the first NZ evidence that anticoagulants used in household rodent control were also being transferred to the wider environment, as residues of flocoumafen, coumatetralyl, or warfarin, used only in a nearby village and on farms, were also detected in the livers of animals captured up to at least 8 km from the nearest source.
- Monitoring of hedgehogs and introduced birds as 'sentinel' wildlife species was undertaken in 2011, over sites in Hawke's Bay which had different histories of brodifacoum field use (Booth, Fisher et al. 2012). Brodifacoum exposure of some vertebrate wildlife was apparently ubiquitous, with c.50% incidence of brodifacoum-positive hedgehogs and birds across all sites, including one that had no history of brodifacoum use. Potential sources of brodifacoum were from both field bait station applications and its use for rodent control in and around farm and urban buildings.
- Other recent monitoring (Landcare Research, prepublication data) has included testing of liver tissue from road-killed harrier hawks (*Circus approximans*, n=27) for brodifacoum, bromadiolone, flocoumafen , coumatetralyl and warfarin. Results indicate wideapread exposure of this species to anticoagulants, including those

mostly used for household rodent control. Residues of at least one anticoagulant were detected in 22 out of the 27 harrier hawks. Three hawks had one anticoagulant only, and about half (13 of 27) had two anticoagulants present, most commonly brodifacoum and flocoumafen. Three anticoagulants were present in four of the 27 hawks, and four anticoagulants present in another two hawks.

- Findings of residual brodifacoum in liver sampled from three of nine little blue penguins (*Eudyptula minor*) found dead on beaches following aerial application of brodifacoum bait on Rangitoto/Motutapu islands in 2009 (Fisher, Griffiths et al. 2011) prompted wider testing. In 2010, liver samples were obtained from 'beach wrecked' penguin carcasses (n=26 from North Island, n=12 South Island) and tested for brodifacoum, bromadiolone, flocoumafen , coumatetralyl and warfarin. No anticoagulants were detectable in 50% (n=19) of the penguins, with 34.2% (n=13) having one anticoagulant detected, 7.9% (n=3) having two anticoagulants detected, 5.3% (n=2) having three anticoagulants and 2.6% (n=1) having four anticoagulants (Landcare Research, unpublished data). Of the total 38 penguins tested, 6 had brodifacoum concentrations, ranging from 0.001- 0.003mg/kg. This data further suggests that brodifacoum and other anticoagulant compounds used for domestic rodent control are reaching the wider environment through trophic transfer.
- Testing of liver and gut contents from two eels found dead in a Southland waterway (Tomoporakau Creek, Branxholme) in May 2012, measured 0.095 ppm brodifacoum in the gut contents of one eel (noting that other anticoagulants were not tested for). This suggests that the eel had recently ingested food containing brodifacoum, probably through scavenging the carcass of a poisoned possum. There was a bait station approximately 100 metres from the location where a possum and eels (n=13) were found dead in the water.
- Further samples of freshwater fish from Southland waterways were tested in May 2013, for the five coumarin anticoagulants brodifacoum, bromadiolone, flocoumafen, coumatetralyl and warfarin. Livers of yellow-eye mullet (*n*=2), trout (*n*=7), long finned eel (*n*=7) and short finned eel (*n*=6) were tested. No brodifacoum, flocoumafen or warfarin was detected in any liver sample. Bromadiolone was detected in one yellow-eye mullet, three trout and one long-finned eel. Coumatetralyl was detected in two trout and two long-finned eel. No anticoaguilant was detected in muscle samples from the five fish that had anticoagulant detected in liver.

Potential ecosystem and human health implications and anticoagulant residues

While the anticoagulants have an important role in pest animal management, there are currently few regulatory restrictions on their use in NZ. There is increasing evidence that uses of anticoagulants for both household rodent control and field pest management are resulting in widespread contamination of both terrestrial and aquatic wildlife. The latter is presumably through carcasses of poisoning animals entering waterways, rather than direct contamination of waterways by bait.

The occurrence of anticoagulant residues in meat-producing animals is of concern from a food safety perspective, as the Animal Products Act (Contaminant Specification) Notice 2008

sets maximum residue limit (MRL) for some of the anticoagulants, as the highest acceptable concentration of a residue in food. For the SGARs the MRL is 0.001 mg/kg, which is at or near the analytical limit of detection currently-available in New Zealand.

The implications of sublethal anticoagulant exposure for wildlife health are unclear. With the more persistent SGARs, there is potential for repeated sublethal exposure to accumulate residue burdens that eventually cause individual mortality – this is an important research question. Whether residues of multiple anticoagulant compounds in an individual animal have a cumulative effect is also not known.

The potential for sublethal exposure to affect reproductive success also requires investigation. Warfarin is widely recognised as a teratogen (ie. can cause birth defects), but the status of other anticoagulants in this regard is not well known. Warfarin residues in wildlife (eg. harrier hawks and penguins) may not originate from rodenticide uses but from human therapeutic use – excretion of warfarin in urine may be another environmental transfer pathway.

References

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