

Baiting Techniques for Control of *Coptotermes* Species Within Existing Buildings in Australia¹

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Abstract: Baiting techniques have been developed over the years to control *Coptotermes* species, the most economically important termite species in Australia. Given the restrictions on organochlorines as termiticides in North America, this paper highlights research that has focussed on baiting programs against *Coptotermes* as alternatives to current control measures: drenching soil with pesticides or fumigation of entire structures. Details of the baiting procedures, toxins used, and their suitability for use in eradicating *Coptotermes* infestations in existing buildings are described. Suggestions are offered for the direction in which future baiting techniques may prove productive.

In Australia subterranean termites cause most of the termite damage to timber in service (French 1986). Of these termites, the most economically important are the *Coptotermes* species. Inarguably, protection from subterranean termites has come to depend almost entirely on soil barriers (Lenz and others 1988), with the use of toxic, persistent chemicals such as organochlorines and the organophosphate chlorpyrifos. Dusting termites in galleries and sheltertubes with arsenic trioxide is still permitted and is normally the first step in eradicating subterranean termites from existing buildings, followed by a soil treatment.

The risk to the public of these chemicals is underrated, and partially unknown. Yet for the last 20 years these treatments have been standardized and recommended for use by local governments and the pest control industry (see Australian Standard (AS) 2057-1986; AS-2178-1986). The application of these persistent organochlorines as chemical soil barriers has ecological and practical limitations, as was pointed out by Beard (1974). There are many situations within existing buildings that render their use and application impracticable. For instance, termites infesting timber in apartments above the ground floor level are difficult, if not impossible, to control with the conventional chemical barrier treatments.

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Many dusting treatments using arsenic trioxide fail to destroy the whole termite colony, because too few termites are "dusted," and these do not return to the nest. Thus, the damage continues. Furthermore, there is a lack of scientific data to indicate precisely how effective all these chemical treatments are in controlling subterranean termites in both the urban and rural environments. Alternative treatments are virtually unknown. The outcome is that the pest control industry in Australia (and the United States) has fewer and fewer options.

Apart from the physical nature of organochlorines, misuse of persistent termiticides by the pest control industry and increased public awareness of persistent home contamination and human exposure to organochlorine termiticides have contributed to these chemicals being severely restricted or banned in some countries around the world. In North America, the main manufacturers have voluntarily ceased production of organochlorines, whereas in Japan, organochlorines are banned, and only the organophosphate, chlorpyrifos (=Dursban), and several synthetic pyrethroids are registered for termite control. French and La Fage (1989) outlined the various treatments used around the world against the most economically important subterranean termite species.

Although I am aware of the need to refine effective and environmentally safer substitutes for organochlorines and arsenicals in termite control, this paper presents the results of some experiments carried out in southeastern Australia over the past decade, and offers some practical refinements regarding arsenic trioxide treatments, and alternatives (such as bait systems) to the pest control industry. I hope that some of these techniques may be adapted for North American conditions. In Australia, I have concentrated on the use of baits to aggregate termites (in this paper, the term 'termites' refers to subterranean termites' unless otherwise mentioned) in mounds and those that are infesting buildings, and the judicious use of small amounts of toxins to kill these colonies. The toxins referred to in this paper are arsenic trioxide and mirex.

The efficacy of mirex against termites in North America was demonstrated by Esenther and Gray (1968), Beard (1974), Esenther and Beat (1974, 1978, 1979) and Esenther (1979). In Australia, Paton and Miller (1980) found that less than 1 g of mirex was required to kill a colony of the Giant Northern termite (*Mastotermes darwiniensis* Froggatt), whereas French (unpubl. data) found that less than 0.25 g mirex was effective against a colony of *Coptotermes lacteus* (Froggatt). By way of contrast, an average 15 square building (1 square = 10 ft²) necessitates about 3 kg of active ingredient (i.e., organochlorine or organophosphate), using the Australian

Standard, whereas less than 1 g of mirex in wood-decay bait-blocks can suppress an active Coptotermes acinaciformis (Froggatt) colony in a building. Although mirex is considered a carcinogen by some and has been banned in North America, there has been no report of injury to a person by mirex, and the chemical has not been measured in persons with occupational exposure to the compound.

Mirex is currently registered under special permit to licenced pest control operators (PCOs) for controlling M. darwiniensis in north Queensland, the Northern Territory and northwest Western Australia. I am currently negotiating with the Victorian and New South Wales State Governments to allow the use of mirex under a special permit by licenced PCOs.

There are two main areas to apply baits against termites: (a) within and under buildings, and (b) around buildings, in termite mounds and in termite-infested trees. Prefabrication of the bait-containers is similar for both situations. However, whether inside or outside the building, location of active termites is the single most important factor. There is no substitute for a thorough and careful search in and around a building to locate active termite sheltertubes or galleries. Sometimes the termite nest may be located either in an above-ground mound or in a standing tree or stump.

Regardless of the location, the following procedures for aggregating Coptotermes species in bait-containers have been used. Although the application of the toxin may vary, the aim of this control technique is to destroy an active termite colony with a slow-acting stomach poison that will be distributed throughout the colony by foraging termites.

ARSENIC TRIOXIDE BAIT CONTAINERS

Box-Bait Container

Box-bait containers for use under a suspended floor may be made from 3-ply veneer, and measure 600 x 300 x 200 mm, with four slits (3 mm wide, 460 mm long) cut into the bottom board. The box is filled with layers of corrugated cardboard wetted with water, and the box sealed with a lid. The box is buried to half its depth into the soil alongside or near active termite sheltertubes on walls or stumps. Water is applied to the soil around the box. After seven days the box container should be inspected for termites. The cardboard should be doused again if no termites present after this period.

Pipe-Bait Container

The pipe-bait container consists of a plastic pipe (90 mm diameter, 300 mm long), into which two corrugated cardboard inserts (with corrugations inwards and measuring 60 and 240 mm wide respectively) are placed. A petri dish lid seals the end with the longest cardboard insert. The whole arrangement is buried upright into the soil alongside or near active termite sheltertubes on walls or stumps, to a depth of about 50 mm. The inserts and the ground around the pipe are soaked with water. Inspections for termite activity are made every week, and the system is rewatered if necessary.

Conduit-Box Bait Containers in Ground

Plastic conduit (25 mm diameter), with small holes (4 mm diameter) drilled every 100 mm, with a wetted corrugated cardboard insert is buried (ca. 100-150 mm depth) alongside or near sheltertubes, diagonally across the underhouse area, or around the outside of the building. Plastic tee-pieces are inserted about every meter with an upright piece of tubing (200 mm long) onto which is attached a small plastic box (200 x 130 x 100 mm) filled with layers of wetted corrugated cardboard. Before backfilling the conduit-box arrangement into the trench, water is poured the length of the trench. Inspections for termite activity in the plastic boxes may be made every week, and re-watered if necessary.

Conduit-Box Bait Container in Tree

In southeastern Australia, old, damaged eucalypt trees are a favored site for Coptotermes colonies. However, it is rarely possible to visually detect an active termite nest within a tree. So, a hole is drilled (ca. 18 mm diameter) into the base of the tree. If the tree is hollow at the center, indicating a possible nest, this is detected when drilling. On withdrawing the drill, wet mud and maybe parts of termites may be seen, indicating an active nest. Often, termite bodies are not found, and this necessitates placing a wood dowel into the drilled hole. Allow about 100 mm to extend beyond the tree trunk so that it may be withdrawn easily. Leave the dowel in position for 2 to 10 h, then remove the dowel. If the dowel cannot be withdrawn easily, and requires a sharp tug, this indicates an active nest. The termites will have "sealed in" the dowel. After the dowel is removed termites are usually found on its surface. At this point, a conduit-box bait-container may be inserted.

The conduit-box bait-container is designed as follows. A plastic conduit (400 mm long, 16 mm diameter) is glued into a plastic rectangular container (300 x 200 x 95 mm) so that it protrudes (200 mm) from one of the longest sides. Small holes (8 mm diameter) are drilled in the conduit within the container, giving termites passing into the conduit access to the interior of the container. A corrugated cardboard insert is arranged within the length of the conduit. Layers of corrugated cardboard completely occupy the interior of the container, and these are slightly wetted with water. A lid is then secured in position.

Termites enter the box-container via the conduit, and can be removed, treated outside the container with arsenic dust (see below for treatment details), and returned to the container. The lid is not replaced; this causes a mass exodus back into the tree. Usually, if a sufficient number of termites are treated, the colony will collapse within 6 to 10 days. Termite activity may be gauged by withdrawing the box-container, and inserting a wood dowel. If after 1 to 2 days the dowel has not been "mudded in," the nest can be considered to have been destroyed. Rarely is it necessary to use more than 3-5 g of arsenic trioxide to eradicate an entire colony.

Applying Arsenic Trioxide to Termites in Baits

Irrespective of the design of the bait-container, the general principle in applying arsenic trioxide onto the termites aggregated in the baits is similar. If, on inspecting inside the bait-container, you see several hundred termites walking on the corrugated paper, remove the paper, hold it vertically over a large tray (e.g., a film developing tray is ideal), then give the back of your hand holding the paper a sharp smack. The termites will drop off the paper into the tray. Transfer about 80 percent of the termites from the bait-container, using the papering method, and put them into a container with a tight-fitting lid. Dust them with arsenic trioxide. Take adequate safety precautions by wearing goggles, respirator, and gloves. Rotate the closed container, and ensure that the termites are well covered with arsenic trioxide. The dusted termites are deposited back into the bait-container and onto the untreated 20 percent that are rapidly moving back into the gallery systems. Given that several hundred termites can be dusted in this manner, I would expect a complete collapse of the colony within 6 to 10 days.

After about two weeks, inspect the building for signs of active termites. If none are seen, one can assume the destruction of the colony was successful, and the bait-containers may be withdrawn from the area.

"Trojan Termite" Technique

The "trojan termite" technique (coined by the author) refers to the technique of "dusting" several hundred *Coptotermes* individuals from one colony source with arsenic trioxide and placing them immediately into the gallery systems of *Coptotermes* termites infesting timbers in a building. The "trojan termites" do not have to be of the same species, but basically should be the same size. After the dusted termites are inserted into the galleries of the "host" colony, the sections that have been opened to allow their placement are left open, to speed up the dispersal of the dusted termites into the gallery systems. Efficacy of this technique ought to be equivalent to bait-container techniques.

MIREX-TREATED BAIT-BLOCKS

In the laboratory radiata pine (*Pinus radiata* D. Don) sapwood stakes (500 x 58 x 18 mm, with the grain running lengthwise) are buried to a depth of 450 mm in moist forest or woodland soil within large containers in the Artificial Fungal Simulator (AFS). Stakes are removed after 12-15 weeks when there is about 15-20 percent mass loss per stake due to wood-decay fungi activity. Adhering soil is removed, and the stakes are sterilized in an autoclave at 120°C for 1 h. After autoclaving, blocks measuring about 58 x 58 x 18 mm are cut from the sterilized stakes. They are impregnated by dip diffusion in a 0.4 percent solution of mirex in acetone for 30 seconds, and the solvent allowed to evaporate. The decayed-wood mirex-treated blocks are then ready for use, and should be kept in plastic bags until required.

Placement of Mirex-Treated Bait-Blocks

Mirex-treated wood-blocks are placed either in buildings, outside buildings, or in both locations.

In Buildings

Place in Active Galleries--When termites are detected infesting architraves, window frames, mouldings, skirting boards, in flooring, in structural timbers behind panelling, and other timber constructions, the mirex-treated blocks are placed directly in contact with feeding termites. This sometimes requires some "instant carpentry." Often *Coptotermes* will seal off treated blocks if not placed into active feeding galleries, so other manipulations are necessary. For example, when these termites are detected in skirting boards, breaking open the outer wood and taping the treated blocks to the outer surface do not solve the problem, because, invariably, the termites will seal off the blocks, and no feeding occurs. Rather, cut through and remove the sound skirting board just ahead of the feeding termites. Place the treated blocks in the space left, and cover them with corrugated cardboard and tape.

Assuming termite feeding occurs, allow about 3 to 4 weeks before inspection and retrieval of the partially eaten blocks when no further termite activity can be detected. The blocks are returned to the laboratory and mirex is chemically removed from the partially eaten blocks and used again to impregnate new, wood-decayed blocks. All treated blocks are sealed in suitable containers until used.

Place in Active Sheltertubes--When locating a termite sheltertube, break open a small portion (say about 25 mm) and verify the presence of active termites. If termite soldiers and workers are seen, remove a sufficient amount of sheltertube to allow treated blocks to be inserted between each of the broken ends of the sheltertube. Cover the blocks with corrugated cardboard, and tape in position. When placing several blocks in a sheltertube running vertically up a wall or stump (whether wood or brick construction), tape the blocks onto a suitable length of cardboard before placing between the broken ends of the active sheltertube. Allow 3 to 4 weeks for the termites to feed on the bait-blocks and distribute mirex throughout the colony.

Outside Buildings

Place in Active Galleries--When active galleries are found within infested trees, mirex-treated bait-blocks can be placed in conduit-box bait-containers and inserted into the trees (see section on conduit-box bait-container), and termite feeding can occur. Some of the most common places to find termite galleries are under timber structures, such as rail-sleepers and wood beams used in gardenscapes. On turning over these wood structures, the galleries may be seen running along the lengths of the timbers on the soil surface. Mirex-treated blocks can be laid along these galleries and the timber turned back in position. Again, allow up to 4 weeks before inspecting for termite activity. Assuming the blocks are attacked and partially eaten within this period, and no sign of live termites remains, one can assume a total eradication of that particular colony. The blocks may then be retrieved and reconstituted as mentioned previously.

Place in Active Sheltertubes--Careful inspection and digging around the building will often reveal active sheltertubes. Break into the tubes and place the mirex-treated bait-blocks between the broken tubes, and cover with corrugated cardboard and some soil to protect the termites from other insect predators, such as ants. Allow 3 to 4 weeks for termites to feed on the bait-blocks. The treatment period is similar to those suggested above.

MIREX-SAWDUST-AGAR IN HOLLOW WOOD DOWELS

M. darwiniensis and C. acinaciformis have been successfully controlled using mirex-sawdust-agar in hollow wood dowel baits in Queensland (Paton and Miller 1980) and New South Wales respectively. Small hollow wood dowels are manufactured, usually from hardwood dowelling. These are about 9 mm long, 10 mm in diameter with a 8-mm hole drilled out to a depth of 6 mm. Eucalypt sawdust is normally preferred, and this is impregnated with mirex. Up to 3 percent solutions are prepared for baits fed to M. darwiniensis. The mirex-treated dowels are easily inserted into active termite galleries and sheltertubes, and the contents eaten by the termites. This invariably leads to the death of the colony.

However, as often happens in natural systems, C. acinaciformis in the vicinity of Sydney in New South Wales behave differently than their conspecifics in and around Melbourne, which is about 890 km away. Coptotermes in the Melbourne area have never fed on these baits when applied in and around buildings which have active termite infestations, yet this technique has been very successful in Sydney (J.A. Easey, pers. comm.).

SUGGESTIONS FOR FUTURE RESEARCH IN BAIT TECHNIQUES

Physiological and Behavioral Studies

Given the differences in behavioral response to mirex-treated baits of similar composition by C. acinaciformis in different geographic locations, such as between Sydney and Melbourne, it would be useful to understand why there are such differences. This requires long-term studies into the physiology and behavior of this species, which I suggest would be greatly assisted with a strong microbiological emphasis. I cannot envisage the pest control or insecticide industry addressing this question. Rather this work will need to be done by Government agencies and universities. Financial funding could be sought from industry.

Attractancy Studies

The problem encountered in use of baiting techniques against Coptotermes species has been the inconsistency of bait acceptance. Often baits placed within galleries, and to a lesser extent within sheltertubes, are not eaten and are even bypassed. Thus, it would be advantageous for the pest control industry to acquire baits that are always eaten when contacted. This will require long-term studies on suitable bait substrates, coupled with "attractancy studies."

What is needed is a comprehensive monitoring of the termites' environment with respect to attractants from the wood substrates, attacked and unattacked substrate volatiles, leachates and chemical cues used by termites.

This will call for collaboration with such specialists as biochemists, microbiologists, organic chemists, physicists and statisticians.

Development of High-Technological Chemical Dusting Equipment

In Australia the pest control industry still uses simple technology, such as dental puffers, to dust arsenic trioxide onto termites in galleries and sheltertubes. (A dental puffer is a hollow rubber ball, that is filled with a toxin, and a steel tube fitted in place from which to discharge the toxic powder). Although there are few "termite dusts" on the market, the development of our own clathrated inclusion compounds and other forms of encapsulated systems could well indicate a viable option in the near future.

Refine the "Trojan Termite" Technique

Include not only other termite species, but other potential slow-acting stomach poisons, such as boron compounds, oxidative inhibitors, insect growth regulators, and so on.

Investigate the Gaseous Environment of Termites

Apply gases into termite gallery systems that may cause death or slow collapse. Or "herd" termites into bait containers, and administer a suitable toxin.

Use of Repellents

Repellents might be used to aggregate termites into bait containers, or to cause them to move past "pre-treated surfaces" in order to acquire a lethal dose.

SOME CONCLUDING REMARKS

The consequences of banning or voluntary withdrawal of organochlorines as termiticides in North America will have far-reaching implications, particularly in termite control measures. In Australia, the restrictions on these chemicals have been greeted with mixed feelings. There is considerable public concern about the use of organochlorines because of the potential for persistent environmental contamination and consequent human exposure. The public perception has been one of health and environmental problems associated with past agricultural use and with the only currently approved use, as termiticides.

The current administrative and legal systems (e.g., building regulations, Australian Standards) still specify organochlorine termiticides. However, events in North America and in Australia have helped to focus attention on pest control management systems that "target" termites more directly, such as baiting, rather than relying solely on chemical soil barriers. The reality of chemical barriers in Australia is that most pest control companies give only a one year warranty on chemical barriers. So it would seem that baiting is rapidly becoming a more acceptable control measure. The bait-block method of control using mirex (Beard 1974, and others) has proved successful in the past, the major drawback being that mirex is no longer registered for that use.

Personally, I prefer the judicious use of such chemicals as mirex rather than the proposed soil chemical treatments using organophosphates and synthetic pyrethroids to eradicate subterranean termites from an existing building. Baiting techniques are not only well-targeted control measures, but are more "user-friendly" than soil chemical barriers. Human and environmental contamination are kept to a minimum given the nature of persistent insecticides. Although no data have been published on the amount of mirex residue to be found in the environment following the death of a termite colony, I would consider it negligible. Our experiments in the field indicate that C. lacteus (Froggatt) mound colonies of between 700,000 and 1 million individuals die within 6 to 10 days after feeding on 10 mirex-treated wood blocks impregnated with a 0.4 percent mirex solution. This represents less than 2 g of active ingredient.

Although I am aware of the history of mirex, we already permit its use under strict situations in Australia (see McFadden 1989). The end-point of our termite control measures is to make sure we kill the insects, and not people! Baiting technology, forming part of an integrated termite pest management strategy, will hopefully ensure this outcome.

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