Strategies of subterranean termite control in buildings

Lina Nunes and Tânia Nobre
LNEC, Av. do Brasil, 101, 1700-066 Lisboa (linanunes@lnec.pt; tanianobre@lnec.pt)

ABSTRACT: Termites can cause damage to living trees and many crop plants, but the fact that they can use dead wood makes them a major pest for timber used both outdoors and inside buildings. In Portugal and in other termite-infested areas of Europe, considerable problems have already been reported and there is a clear trend of increasing infestations. In the past, organochloride insecticides were very effective for the control of termites but their persistence created potential problems to the environment and humans. The emphasis on termite control has thus changed from a massive use of pesticides to an integrated approach that involves the knowledge of the ecology and behaviour of the insect and the use of safer biological or chemical methods of control. Within the scope of this paper, different strategies of termite control will be discussed, from both preventive and curative points of view.

1 INTRODUCTION

Termites are social insects found in a wide range of terrestrial environments and are distributed throughout the warmer regions of the world. They are very important organisms ecologically as they significantly contribute to the organic decomposition process either by direct consumption of decomposing plant materials, by physical and chemical conditioning the soil they inhabit and by nitrogen fixation. They feed on a very wide variety of organic detritus like dry grass, decaying leaves, animal dung, humus and living or dead wood.

As termites forage on cellulosic resources they can cause damage to living trees and many crop plants, but the fact that they can use dead wood makes them a major pest for timber used for construction purposes both outdoors and inside buildings. They are known to cause damage to buildings throughout the tropics, sub-tropics and temperate regions and have an increasing economic impact when present.

There are now over 2 600 described species of termites in 281 genera (Kambhampati and Eggleton, 2000). From those, around 150 species have been recorded attacking buildings but only a few species can be the cause of major problems in constructions. Subterranean termites account for 80% of the economically important species (Su and Scheffrahn, 2000). This termite group requires contact with the soil at the site of the subterranean nest and become pests when foraging activity extends into man-made structures. They move above ground by building galleries that lead to wood.

Subterranean termites are a well-established pest to wood in service in Portugal namely to historical timber structures or structural elements, and the most destructive species are acknowledged to belong to the *Reticulitermes lucifugus* (Rossi) complex. The first known record of the presence of termites in Portugal goes back to the beginning of 20th century (Seabra, 1907). Since then many records have been reported, particularly in the last ten years and an attempt to access their exact distribution is presently being done (Nunes *et al*., 2000; Nobre and Nunes, 2001). However, with the data available so far, it is believed that they have a general distribution in mainland Portugal.

2 DETECTION

The first problem with the control of termites is their detection, as subterranean termites forage inside the wood, sometimes only allowing the detection by visual means in an advanced stage of infestation. The detection of foraging galleries made from soil and faecal particles and of wings or imagos during the dispersal flights, are ways to detect their presence. Naturally, the presence of typical termite damaged wood (figure 1) is one of the most effective way to detect it and it is usually associated with areas of high humidity.

In order to ease termite detection, non-destructive (non-invasive) methods of evaluation were and are still under development. These include, for instance, the use of acoustic emission detectors or heat detectors, both commercially available. Alternative options under development include the use of sound amplification and the measure of metabolic gases.

Indirect methods based on studies of the moisture profile of the applied timber can also be used as well as less conventional techniques like the use of canine olfaction, also applicable for the detection of fungal rot.

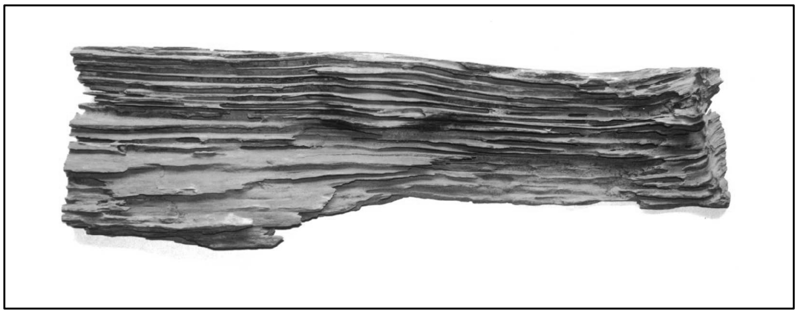

Figure 1: Aspect of typical termite damage to wood

3 CONTROL OPTIONS

The control of subterranean termites involves methods to prevent infestation of structures or curative strategies once prevention fails (Culliney and Grace, 2000). Once an infestation has begun, control of *R. lucifugus* is extremely difficult. On one hand, they form colonies and do not nest on or in the materials that are used as food, and on the other hand, a termite colony is generally made of several thousands individuals with an outstanding ability to develop from one caste to another if the need arises (Nunes, 1997). A preventive action, where termite presence is registered, is therefore highly recommended.

In the past, organochloride insecticides were very effective for the control of termites, but their persistence, stability in soil and relative stability to the ultraviolet of sunlight, created potential environmental problems and, in some cases, biomagnification in food chains causing wildlife and human health disturbances.

Research efforts have been launched towards more sophisticated chemical compounds and biological materials. The emphasis on termite control has thus changed from an extensive use of pesticides to an integrated approach that involves the knowledge of the ecology and behaviour of the termite population and the use of safer biological or chemical methods of control.

As summarised by Su and Scheffrahn (2000), current control options of subterranean termites include the use of a natural durable wood species, wood treatments (chemical or not), placement of chemicals and physical barriers, and population control using baits (with metabolic inhibitors or insect growth regulators) (Table 1).

The potential for biological control of subterranean termites need to be further evaluated (Culliney and Grace, 2000) but some studies have been performed focusing mainly on pathogenic agents, including nematodes and fungi (e.g. Smythe and Coppel, 1965; Epsky and Capinera, 1988; Mauldin and Beal, 1989; Zoberi and Grace, 1990; Jones *et al*., 1996; Le Bayon *et al*., 1999).

Table 1: Summary of preventive and curative measures to control subterranean termites (adapted from Su and Scheffrahn, 2000).

PREVENTION	NON-CHEMICAL	*Physical barrier* graded stone barriers, stainless steel barriers *Monitoring program* *Termite-resistant wood* *Construction practices* Removal of wood debris, correct moisture problem, termite shielding for suspended floor, avoid direct contact with the soil
	CHEMICAL TREATMENTS	*Soil insecticide barriers* Organophosphates, pyrethroids, nichotinoids, organochlorines *Pyrethroid-impregnated polymer barrier* *Wood Impregnation* e.g.: Chromated cooper arsenates (CCA), coal tar creosote, disodium octaborate tetrahydrate (DOT)
REMEDIAL CONTROL	BARRIER TREATMENTS	*Soil insecticide barriers* Trenching and drill-and sub-slab injection (organophosphates, pyrethroids, nichotinoids, organochlorines)
	LOCAL TREATMENTS	*Chemical* Wood surface (aqueous DOT) Wood injection Aerosol (chlorpyrifos), Dust (arsenical, silica gel, chlordane, carbamates), Liquids (organophosphates, pyrethroids, nichotinoids, organochlorines) *Non-Chemical* Wood surface (electrocution, microwave) Wood injection (nematodes, fungi) Infested wood replacement
	POPULATION CONTROL	*Biological control agents* Fungi, nematodes *Metabolic inhibitors* Mirex, hydramethylnon, sulfuramid *Insect growth regulators* Juvenoids (methoprene, hydroprene, fenoxycarb) Chitin synthesis inhibitors (hexaflumuron, diflubenzuron)

Note: The efficacy of some measures may not be supported by scientific data.

3.1 Wood treatments

Whenever the durability of the timber (construction wood) is considered not sufficient (EN350-2, 1994) for the hazard class of application (NP EN460, 1995), prevention measures should be specified, for example, the use of wood treated with an adequate preservative (EN599-1, 1996).

If the preventive measures are not applied or fail in practice, usually by errors of planning, curative strategies will have to come into action and this include not only the traditional treatments of wood surface and injection but also more recent non-chemical systems like electrocution, microwave and pathogens manipulation (Su and Scheffrahn, 2000). Some of these non-chemical procedures are still under evaluation, as for instance the ones involving the fungi and nematodes injection systems, as the potential of these pathogens to biological control of termites are not yet clearly understood (Logan *et al.*, 1990; Culliney and Grace, 2000).

3.2 Barrier treatments

The background of a barrier treatment considers that most subterranean termites invade buildings from the soil. These barriers, which aim to exclude termites from structures, can be either chemical or physical.

Chemical barriers consist on insecticide application along and/or beneath the building foundations. In addition, slab flooring may be drilled to inject insecticide. The chemicals to be applied in these soil barriers should remain effective for at least 5 years (ideally 10 or more) and should pose negligible risk to human health and the environment (Lenz *et al.*, 1990).

The increasing concern regarding the environmental impact of the use of insecticides have been turning the attention towards physical (instead of chemical) barriers. The evaluation of termites' dislodgement way allowed the discovery of a barrier composed of soil particles that are too large for termites to displace with their mandibles, thought too small for termites to pass between (Ebeling and Pence, 1957 *in* Su and Scheffrahn, 2000). Since then, research efforts in this area are being performed (*e.g.* Sornnuwat *et al.*, 1995; French and Ahmed, 1997; Lenz *et al.*, 1997; Peters and Fitzgerald, 1997a, 1997b) and commercial products are now available, not only using graded stone but also a stainless steel mesh.

A combination of physical and chemical barrier, that is, the use of polymer sheets impregnated with insecticides has also shown some promising results and is already commercially available.

3.3 Population management

Several management approaches can be undertaken aiming to supress colony populations. Slow-acting toxicants were introduced into baits (placed near foraging tubes) in order to be taken by the termites and delivered (through trophallaxis and grooming) to the colony members before they produce a killing effect.

This bait method, in contrast to the conventional barrier method, aims at eliminating a termite population in the ground and at the same time reducing the environmental hazard of the treatments because only a small amount of the insecticide is required (Nunes, 1997).

Studies using metabolic inhibitors introduced into baits matrix have been performed and a reduction of foraging activities and/or populations of target colonies were observed (*e.g.* Esenther and Beal, 1978; Su *et al.*, 1991; Forschler, 1996).

The identification and synthesis of chemicals that regulate or mediate growth and development of arthropod species has allowed the outgrowth of more selective chemical compounds, the insect growth regulators (IGRs). The target of these chemicals is a metabolic pathway that is missing in the other animals Orders and they cause disturbances in the normal activity of insect endocrine systems. Two classes of IGRs, juvenoids and chitin synthesis inhibitors, have been tested on termites (*e.g.* Howard and Haverty, 1979; Doki *et al.*, 1984; Tsunoda *et al.*, 1998; Sheets *et al.*, 2000; Kistner and Sbragia, 2001).

The lack of knowledge on the foraging populations of subterranean termites limited the assessment of the effects of baiting on colony populations (Su and Scheffrahn, 1996). The baiting approach demands much more refined information on the biology of specific termites, particularly at the population ecology level (Nutting and Jones, 1990).

Another approach to the management of termite populations is the biological control, where the pest numbers are reduced to an acceptable level from the human point of view, by means of management tactics involving natural enemies (predators/parasitoids or pathogens/parasites) manipulation (Pedigo, 1996).

Laboratory research demonstrates the pathogenicity of two endoparasitic fungi, *Beauveria bassiana* (Balsamo) and *Metarhizium anisopilae* Weiser towards termites (*e.g.* Bao and Yendol, 1971; Kramm and West, 1982; Grace and Zoberi, 1992; Milner *et al.*, 1996). Field trials, however, are span and their successful use into baiting schemes is compromised by a number of inherent biological limitations and logistical problems that need to be analysed (Culliney and Grace, 2000). Few studies have addressed the potential for nematodes to control termites and the field studies performed have been generally disappointing (Culliney and Grace, 2000; Su and Scheffrahn, 2000).

An integrated approach of termite management seems necessary for an effective termite control with long term protection. Accordingly, control systems involving more than one preventive and/or curative measure constitutes a better option (figure 2), and they must care for the specific situation and background of the infestation problem.

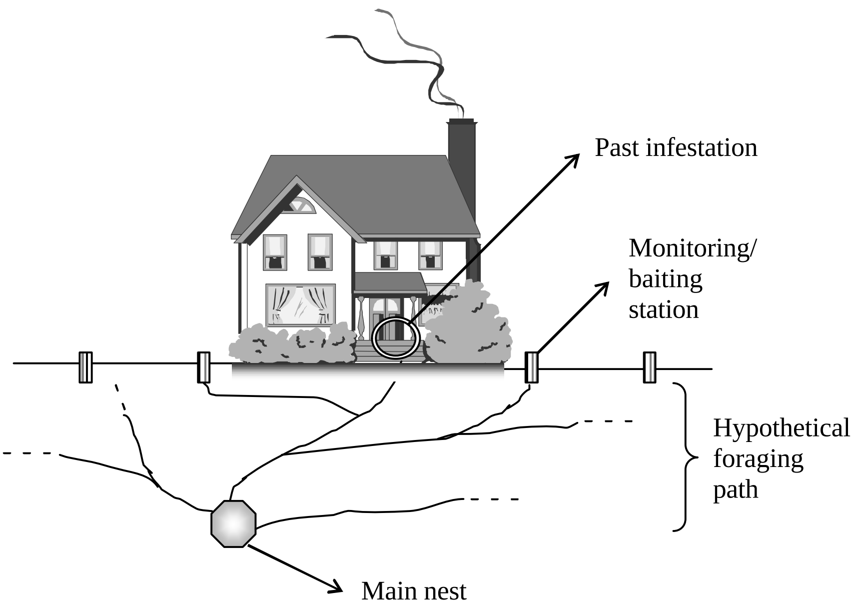

Figure 2: Diagrammatic representation of a control system combining soil barriers, monitoring/baiting stations and local treatments. An infestation problem inside the building was detected requiring a local treatment. The barrier treatment aimed to exclude soil-borne subterranean termites from structures. The monitoring/baiting approach should provide a population control. After the settlement of monitoring devices surrounding the structure, one must check for termites. When they are detected, baiting devices (with an insect growth regulator) replace the monitoring ones. Following bait application and when the termite activity ceases in the stations, bait tubes are again replaced by monitoring devices for continuing the monitoring program. (Adapted from Su and Scheffrahn, 2000).

4 FINAL CONSIDERATIONS

Human population is growing and an increase in the needs of wood products to construction demands is expected. This, in turn, will lead to a spreading of the pest species and can result into their establishment, partially due to the anthropogenic climate changes and the increased use of centrally heating systems. This has already been observed with the establishment of *Reticulitermes flavipes* (Kollar) in more northerly cities like Toronto or Hamburg or of *Reticulitermes lucifugus* (Rossi) in Saunton, North Devon, U.K. (Verkerk and Bravery, 2001), places not included in the natural distribution areas.

The continuously more demanding environmental-safety profile of pest management strategies is pushing the efforts towards a decrease in chemical use and an increase of their target specificity. Other systems, not relying on chemicals, are being refined but it is necessary, without any doubt, a better understanding of physical, chemical and biological factors affecting forage and food finding behaviours of subterranean termites (Logan *et al.* 1990; Su and Scheffrahn, 2000).

Finally, due to the large number of factors that have to be taken into account when addressing the specification of preventive strategies and/or the application of curative measures, it is recommended to have a specialist point of view as an important stage in the process.

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