Chapter 10
Sustainable Termite Management Using Physical Barriers

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Abstract Termites are highly socialized insects that caused serious damage to wood products and timber structures worldwide. Termite activity results in billions of dollars spent on control and replacement of damaged wooden members. Traditional termite control method involves injecting hundreds of liters of synthetic insecticides to the soil or use of termite bait products containing insect growth regulators. The former poses risk to both man and environment and the latter is relatively expensive. Slow-acting, non-repellent termiticides have also been developed recently for colony management. However, due to inherent problems and difficulties associated with these methods, their general use is considered non-sustainable.

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In recent years, the use of physical barriers for sustainable termite management gained popularity due to inherent risks with conventional termite control treatments and erratic performance of bait products in tropical climates. Physical barriers using sand and lahar aggregates are alternative, nonchemical control method that can be used to prevent tunneling and penetration of subterranean termites into wood structures. The installations of these barriers are relatively simple, requiring no expensive equipment with barrier remaining effective for an indefinite period of time against various species of temperate and tropical termites. Although these methods offer a sustainable and environmentally friendly alternative, limited commercial applications of these techniques have been developed to date.

Keywords Termites • Lahar • Physical barrier • Sustainable management

10.1 Introduction

Termites are widely distributed and cause significant damage in tropical and subtropical regions of the world. They are most abundant throughout the so-called termite belt, which is 40° north and south of the equator. This region includes South and Southeast Asia, northern Australia, most of Africa, and South America and the southern states of the USA. Their activities result in extensive damage to wood products and reduction of service life of timber structures. Building materials such as lumber, plywood, wood-based composites, paper, and textiles containing cotton are susceptible to their activity. In some cases, agricultural crops, seedlings, and living trees are attacked by termites (Edwards and Mill 1986; Logan et al. 1990). The damage in terms of worldwide annual control and repair cost is estimated to be about USD 40 billion (Rust and Su 2012).

There are over 3000 reported living and fossil termite species worldwide (Krishna et al. 2013). However, only 10% of the reported species are destructive and considered as pests (Edwards and Mill 1986). Most termites are beneficial because they contribute to the decomposition of organic materials lying on the ground, such as tree branches and twigs, grasses, leaf litter, etc. In addition, termites contribute to soil ecology by mixing soil nutrients through their burrowing and foraging (Holt and Lepage 2000). However, they are regarded as structural pest because of their natural appetite for wood.

Subterranean termites have large colonies that live in the soil and require constant source of moisture for survival. Drywood termites consist of small colonies that live inside wood, require little moisture, and never enter the ground. Several species belonging to the family Rhinotermitidae, Termitidae, and Kalotermitidae are considered serious structural pests. Genera belonging to *Coptotermes*, *Reticulitermes*, *Odontotermes*, *Nasutitermes*, *Macrotermes*, *Microcerotermes*, and *Cryptotermes* are regarded to have significant economic importance. Two species of subterranean termites belonging to the genus *Coptotermes*, viz., *C. formosanus* Shiraki and *C. gestroi* Wasmann, are most destructive and widely distributed. Majority of the drywood termites considered pests include *Cryptotermes brevis* Walker, *Cr. dudleyi* Banks, and *Incisitermes minor* Hagen.

10.2 Termite Control Methods

10.2.1 Chemical Barrier

The traditional control method to prevent subterranean termite infestation involves injection of hundreds of liters of liquid termiticide to the soil beneath structures before or after construction. The objective is to create a chemical barrier between the soil and the structure to be protected that is toxic or repellent to foraging termites in the ground. The toxicity or repellence of the chemical barrier prevents tunneling and penetration of termites into the structure, thus preventing infestation. Active ingredients of currently available termiticides are either contact or systemic poisons. Typical liquid termiticides contain organophosphates (e.g., chlorpyrifos) and synthetic pyrethroids (e.g., permethrin, cypermethrin, bifenthrin, etc.). However, the use of persistent synthetic insecticides associated with chemical barrier treatments poses risks to both health and environment.

A recent development in termite control is the use of slow-acting, non-repellent termiticides for colony management. Non-repellent termiticides (e.g., imidacloprid, fipronil, chlorfenapyr, and chlorantraniliprole) are metabolic inhibitors that affect nerve impulses and the normal functioning of the insect's nervous system. Due to the delayed toxicity of these chemicals, termites tunnel through treated soil contaminating their bodies and ingesting chemically laden soil. Social grooming and trophallaxis feeding facilitate transfer of chemical to unexposed members of the colony leading to convulsion, hyperactivity, or inability to move muscles and eventually death of the insect. However, due to its delayed toxicity, effective control could take several weeks to months after treatment.

10.2.2 Termite Baits

Termite baits contain insect growth regulators (e.g., chitin synthesis inhibitors, juvenile hormone analogues, etc.) impregnated into wood or cellulose-based material. The baits are placed in underground stations along the perimeter of the structure or above ground along natural pathways (mud tubes) of termites. The workers foraging randomly in the soil find the treated materials, feed on them, and carry it back to the nest. Social grooming and trophallaxis facilitate the transfer of toxicant to other members of the colony. By this process of food transfer from exposed colony member to another, termites in the colony eventually receive a lethal dose to cause death or colony suppression (Su 1994). Since the toxicants used for termite baiting (e.g., hexaflumuron, noviflumuron, chlorfluazuron, diflubenzuron, etc.) have very low mammalian toxicity and used in small amount, it is considered an environmentally friendly control method. However, the cost of treatment is relatively expensive. Consequently, only a small number of families and property owners were able to afford such treatments. In addition, poor or inconsistent performance of termite baits containing chitin synthesis inhibitors was reported in tropical countries, due primarily to the presence of other termite species belonging to the Termitidae, among others (Bajo and Acda 2016).

10.2.3 Biological Control

Concerns over effects of persistent insecticides on the environment and problems associated with current termite control treatments prompted demand for a safe and affordable alternative. Nonchemical, biological, and physical control methods were studied to response to the challenge to offer an alternative termite control method. The use of pathogens as biological control agents has been considered as an alternative technology for termite control (Grace 1997). Various virulent entomopathogenic organisms such as predatory nematodes (*Steinernema* sp.), fungi (*Metarhizium anisopliae*, *Beauveria bassiana*), and bacteria (*Bacillus thuringiensis*, etc.) were investigated against various species of termite worldwide (Connick et al. 2001; Osbrink et al. 2001; Chouvenc et al. 2008; Ibrahim and Abd El-Latif 2008; Husseneder et al. 2010; Shahina et al. 2011). However, laboratory results using inundative treatment were inconsistent, and field trials have been generally unsuccessful (Lai 1977; Mauldin and Beal 1989; Chouvenc et al. 2011). Factor that could have contributed to the poor performance of biological agents is the difficulty of introducing a pathogen or inoculating enough individuals to trigger an outbreak of disease or infection within the colony (Chouvenc et al. 2008).

10.2.4 Botanical Insecticides

Plant extracts have been studied as potential sources of botanical insecticides to control termites (Verma et al. 2009). Plant families belonging to Meliaceae, Rutaceae, and Annonaceae, among others, have been investigated for their termiticidal properties. Botanical insecticides are generally regarded as an alternative to chemical insecticides and considered safe, with little or no threat to man and environment (Isman 2006). Recent studies showed that plant derivatives such as pyrethrins, terpenoids, azadirachtin, saturated and unsaturated fatty acids, and flavanoids have excellent termiticidal activity (Grace and Yates 1992; Sharma et al. 1994; Cornelius et al. 1997; Ohmura et al. 1999, 2000; Maistrello et al. 2001; Zhu et al. 2001a, b; Chang et al. 2001; Doolittle et al. 2007; Acda 2014a, b). Botanical insecticides are reportedly toxic and repellent and have anti-feeding effects on termites. However, effective concentrations of plant extracts to cause mortality in termites are generally high, compared with synthetic insecticides. Apparently, isolation and use of the pure active component may offer a more effective termiticidal formulation.

10.2.5 Physical Barriers

Termite control using physical barrier uses inert particles to prevent tunneling and entry of termites into wood structures. To prevent termite penetration, the barrier size must be large enough to prevent them from moving with their mandibles but small enough so that spaces between particles are too small for termites to pass through. The effective particle size is dependent on the mandible and head capsule dimensions of the target termite species (Table 10.1). The barrier must be laid under slabs and foundation walls prior to the pouring of concrete during construction. Laboratory and field studies using particles of sand (Ebeling and Pence 1957; Tamashiro et al. 1987; Myles 1997), glass shards (Pallaske and Igarashi 1991), granite (Smith and Rust 1990; French 1991; French and Ahmed 1993), crushed basalt (Tamashiro et al. 1987, 1991), quartz and coral sand (Su et al. 1991), crushed cement-stabilized sludge (Yanase et al. 2000), lahar aggregates (Acda and Ong

Table 10.1 Effective size and materials reported for particle barriers against various species of subterranean termites

Species	Material	Effective particle size (mm)	References
Reticulitermes hesperus	Sand (silica)	1.2–2.7	Ebeling and Pence (1957)
	Granite	1.7–2.4	French et al. (2003)
	Granite	0.84–2.36	Smith and Rust (1990)
Reticulitermes flavipes	Sand (silica)	2.0–2.8	Su and Scheffrahn (1992)
	Sand (limestone)	1.4–2.8	Myles and Grace (1991)
	Sand (beach)	1.18–2.26	Myles (1997)
	Coral (crushed)	1.0–2.36	Su et al. (1991)
Coptotermes formosanus	Sand (silica)	1.7–2.4	Tamashiro et al. (1987)
	Sand (silica)	2.0–2.8	Su and Scheffrahn (1992)
	Coral (crushed)	1.7–2.36	Su et al. (1991)
	Polynite	1.7–2.0	Yanase et al. (2000)
C. lacteus	Granite	1.7–2.4	French et al. (2003)
C. acinaciformis	Granite	1.7–2.4	French et al. (2003)
	Glass (sintered)	1.7–2.4	Ahmed and French (2011)
C. gestroi (*C. vastator*)	Lahar aggregates	1.18–2.36	Acda and Ong (2005a)
Nasutitermes luzonicus	Lahar aggregates	1.18–2.36	Acda and Ong (2005b)
Microcerotermes losbanosensis	Lahar aggregates	1.18–2.36	Acda and Ong (2005b)
Macrotermes gilvus	Lahar aggregates	1.70–2.26	Acda and Ong (2005b)
M. beesoni	Marble chips	1.18–2.36	Singh and Rawat (1999)
Heterotermes indicola	Glass beads	0.5–3.0	Pallaske and Igarashi (1991)

2005a, b), etc. screened to specific particle sizes have proven to be effective in preventing termite penetration. However, the range of effective particle size differs from one termite species to another (Su and Scheffrahn 1992).

The success of laboratory and field trials of particle barriers resulted in commercial applications. For example, crushed basalt (Basaltic Termite Barrier®, Ameron HC&D, Honolulu) and granite aggregate (Granitgard®, Granitgard Pty. Ltd., Victoria) are already available as alternative method of termite control in the USA and Australia. However, installation issues including unstable or not compacted soil, irregular surfaces at the edges of the barrier, protection from contamination, or mixing with adjacent soil were reported (Grace et al. 1996). Other types of nontoxic physical barriers were also investigated. Concrete slabs (Lenz et al. 1997), solid sheet material (e.g., high-grade stainless steel, marine-grade aluminum), plastic sheets impregnated with insecticide (Su et al. 1994), kaolin-based particle film (Wiltz et al. 2010), and woven stainless steel mesh were reported to be effective in preventing termite penetration as those of particle barrier (Grace et al. 1996). A commercial stainless steel mesh barrier (Termi-Mesh®, Termi-Mesh Australia Pty. Ltd.) was also developed in Australia. However, the role of physical barriers in the future of subterranean termite control may depend on continuous ban on persistent organic insecticides and willingness of property owners to absorb the higher cost of treatment.

10.3 Sustainable Termite Management

Termite management as outlined above represents various termite control methods, but each has its own inherent shortcomings. It is in this context that the concept of integrated pest management (IPM) for termite control came about. As discussed by Su and Scheffrahn (1998), IPM originated in the 1990s as a philosophy to address agricultural crop problems such as pest resistance, pest outbreaks, environmental pollution, etc. It is essentially a knowledge-based decision-making process requiring an understanding of the pest biology, in order to take action or intervention aimed at reducing the economic impact of the pest (Forschler 2011). The type of intervention is dictated by available technologies and by its economics and capability to reduce pest population. The definition of IPM for termite control, however, is dependent on the point of view and priorities of various stakeholders (Su and Scheffrahn 1998). Home and property owners look at IPM as eliminating termite infestation at the shortest time and most possible cost-effective way. Researchers perceived IPM in terms of effective and safe control methods with limited risk to the environment (Robinson 1996). Chemical companies look at IPM as the use of its own product plus the use of all other control measures, to achieve acceptable performance and remedy shortcoming of its own product (Ballard 1997). For pest control operators, IPM is the use of their preferred method (i.e., chemical barrier, spot treatments, or baiting) plus all other cultural methods (e.g., removal of wood debris, drainage, leaks and excessive moisture problems, mounds, etc.) to solve client's termite problems. These concepts and programs are often used for marketing purposes (Robinson 1996).

In contrast to IPM, sustainable termite management is relatively a new concept. It originated from the concept of sustainable development used in ecology and environmental science. For termite control, sustainable termite management may generally be described as an effective control measure that is safe to man, with no ecological damage or loss of ecosystem benefits derived from termite activity, conservation of nontarget organisms, and the use of products and technology that do not contribute to the depletion of natural resources. No, or limited, threat to man and environments for the protection of wood products, timber structures, and other nontarget organisms is essential in any sustainable termite management program. The description is somewhat contradictory since the aim of an effective termite control measure is to eliminate or kill termite colonies. However, killing termites would deprive the environment of an efficient decomposer of organic materials lying on the ground. Apparently, a working compromise between these two objectives must be reached, to arrive at an acceptable definition. An acceptable solution is the modification of the original definition of sustainable termite management into eliminating or suppressing destructive termite colonies near wood structures or areas of economic activities, such as farms, around utility poles, golf courses, etc. In view of the above, termite control method such as chemical barrier using toxic or repellent termiticides would not meet sustainable termite management criteria. The use of termite baits and slow-acting termiticides may pass the requirements (Su 1994; Su et al. 1995, 2001; Evans 2010). However, the use of physical barriers such as sand and lahar aggregates would truly fit the requisites of sustainable termite management. Both sand and lahar aggregates have been shown to be effective in preventing tunneling and penetrating of various species of subterranean termites into structures (Tamashiro et al. 1987, Myles and Grace 1991; Myles 1997; Acda and Ong 2005a, b). These materials are also safe, widely available, and cost-effective barriers against subterranean termites. Assuming no break in the barrier is made during service due to remodeling or landscaping activity, the protection offered by physical barriers could last indefinitely.

10.3.1 Sand Barrier

Sand as barriers to prevent tunneling of termites was discovered by Ebeling and Pence (1957), and Tamashiro et al. (1987), and later confirmed by others (Smith and Rust 1990; Su et al. 1991; Su and Scheffrahn 1992; Lewis et al. 1996). Commercial sand barrier is available in Hawaii (Honolulu Construction & Draying Co., Ltd., Honolulu) and Australia. However, despite studies finding that sand barrier excludes termites from wood structures, its use by the pest management industry has been mostly overlooked for a number of reasons (Yates et al. 2002). These include consumer unawareness of the product, a slightly higher initial cost compared with chemical barrier treatments, resistance on the part of the pest control industry to accept and implement this nonchemical technology, and the absence of a performance warranty from the licensed manufacturer (Yates et al. 2002). In addition, architects and building contractors have little understanding of installation requirements for this barrier. Furthermore, termites can build over physical barriers, and regular inspections of the building are necessary. However, mud tubes over the barrier reveal evidence of their presence facilitating control during regular inspections. Recent study involving engineering analysis of sand aggregate particles indicated that angularity, fineness modulus, and weighted particle size were variables related to the success of particle barriers against subterranean termites (Keefer et al. 2013).

10.3.2 Lahar Barrier

Another material that can be used as physical barrier to prevent entry of subterranean termites into wood structures is lahar. Lahar is a saturated mixture of ash, solid rock particles, and other volcanic debris washed down by rainwater from the slope of recently erupted volcano. Once dried, lahar could be described as a sandy aggregate (Fig. 10.1) consisting mainly of feldspar, hornblende, quartz, mica, and magnetite (Cabillon et al. 1997). The northern part of the island of Luzon in the

Fig. 10.1 Lahar (10×) consists of sandy aggregates prescreened to 1.18–2.36 mm used as physical barrier to prevent tunneling and penetration of Philippine subterranean termites

Philippines has huge volume of lahar deposits in several provinces made during the eruption of Mt. Pinatubo in 1991. It is estimated that about 11 billion cubic meters of ash and volcanic debris ejected during the eruption could potentially be carried by monsoon rains downslope as lahar to clog streams and rivers in low-lying areas (Newhall and Punongbayan 1996). Twenty-five years after the eruption and after continuous quarrying, lahar still clogs major river systems in the northern provinces of the Philippines. Similar lahar deposits were made during volcanic eruptions in Nevado del Ruiz and Nevado del Huila volcanoes in Colombia, Mount St. Helens and Redoubt Volcano in the USA, Mount Ontake volcano in Japan, and other eruptions worldwide (Pierson et al. 1994).

Laboratory and field trials showed that the effective particle size of 1.18–2.36 mm would prevent tunneling and penetration of *C. gestroi*, *N. luzonicus*, and *Microcerotermes losbanosensis* (Acda and Ong 2005a, b). However, a slightly larger lahar particle size range of 1.7–2.36 mm would be required for *Macrotermes gilvus*, due to the large head capsule and mandibles of this species. The natural sharp edges of lahar particles also proved to be detrimental to the termites as they cut their appendages (i.e., antennae and legs) and die when they tunnel and burrow through the barrier.

A small wooden house was built in 1997 where a protective barrier consisting of prescreened lahar particles was installed beneath floor and concrete foundation walls (Fig. 10.2, Acda 2013). Regular inspections made over a 7-year period showed no signs of subterranean termite penetration inside and outside of the structure (Fig. 10.3). The study showed that lahar barrier could be used to protect wooden structures from entry of subterranean termites and offer a nonchemical alternative to

Fig. 10.2 Installation of lahar barrier underneath floor and foundation walls prior to the pouring of concrete

Fig. 10.3 A small wooden house protected underneath by lahar barrier remained free of subterranean termites 7 years after construction

commercially available termiticides. Promoting the use of lahar barrier against termites offers several economic and environmental benefits compared to commercially available termite control products.

The utilization of lahar from affected river systems could help improve the profile of streambeds and river channels, thus benefiting flood control, irrigation, and water quality. There would also be potential for a commercial bagged product that could be sold at garden shops and hardware stores for small-scale applications such as protection of utility poles, wooden posts and signs, under stacked firewood, etc. The technique is beneficial to property owners not only in the Philippines but also in other neighboring countries like Malaysia, Indonesia, Thailand, China, India, Australia, etc. with structural problems involving similar species of termites. Lahar barrier offers an alternative and affordable method of protecting properties against ongoing threat of subterranean termites. It is environment friendly and could greatly reduce the load of toxic chemicals in the urban environment. However, despite the availability of excellent performance in laboratory and field trials, the use of lahar has not seen commercial application. The exact reason for this is unclear. Various pest control operators hinted that the use of liquid termiticides or baits has better economic gains compared with physical barriers.

10.4 Conclusion

Termites are serious structural pests of wood products and timber structures worldwide. Financial damage to structures and agricultural crops results in billions of dollars spent in termite control and replacement of wooden members. Traditional control method injecting hundreds of liters of synthetic insecticides to the soil poses risk to both man and environment. Recent development in colony management resulted in the use of termite baiting technology and slow-acting, non-repellent termiticides. However, due to inherent problems and difficulties associated with these methods, the general use for sustainable management remains in doubt. A truly sustainable termite control method using physical barriers gained popularity and acceptance due to the ban on persistent inorganic termiticides. Sand and lahar aggregates are examples of alternative, nonchemical control method that can be used to prevent tunneling and penetration of subterranean termites into wood structures. Although they offer a sustainable and environmentally friendly alternative, limited commercial applications of these techniques have been developed to date.

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