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**Termites on old timber structures: diagnosis, identification
and control methods**

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LNEC, Departamento de Estruturas, Lisbon, Portugal

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Host: Dr. Lina Nunes, LNEC (Portugal)

SCIENTIFIC REPORT

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1. Purpose of the visit

The Biodegradation and Preservation Laboratory of the Trees and Timber Institute, CNR, Italy, carries out researches focused on the evaluation and development of low environmental impact wood treatments. It is also interested on the natural and conferred durability of wood species against insects and fungal decay. The laboratory is equipped to perform efficacy tests of wood preservatives against insect wood borers and fungi causing brown rot and white rot according to European standards and accelerated methods. Part of the laboratory equipment are cultures of some important wood pests: *Hylotrupes bajulus* and *Trichoferus holosericeus* (= *Hesperophanes cinereus*), two longhorn beetles, and *Lyctus brunneus*.

The ability to perform efficacy tests of wood preservatives against termites would provide the Biodegradation and Preservation Laboratory the opportunity to give a complete and a broad-spectrum characterization of an experimental formulation. Therefore, one of the purposes of the visit was to learn how to set up and maintain a termite culture in order to envisage investments on the laboratory equipment and extent the potentialities of investigation of the Research Unit.

The cultural heritage may benefit of such an improvement of the Laboratory equipment, considering the threat represented by termites inside old timber structures and wooden elements. Attacks in old churches and monasteries occurred in Italy in the past, for example in the Duomo di Monreale, Palermo (Liotta, 2003) and Certosa del Galluzzo, Firenze (Zocchi, 1953), with conspicuous damages and expenses for the recovery.

In order to prevent these calamities on cultural heritage, when the risk of attack by termites is high, a treatment based on non-toxic for humans, eco-friendly, non coloured formulations may be very useful, especially if a consolidation action is associated with the repellent action.

One of the ongoing works at the Laboratory is just focused on experimental formulations based on silica gel and some biocides, such as boric acid and amines, incorporated within the silica gel through an innovative process (Palanti *et al.*, 2008). This research originates from a collaboration with Prof. Giovanni Predieri, Department of

Inorganic Chemistry of the University of Parma. The characteristics of silica nanosol applications seems very suitable for the wooden cultural heritage: tetraethoxysilane (TEOS) treatments were proved to confer the wood resistance against termites (Mai and Militz, 2004), while silica sol-gel coatings show consolidating and antimicrobial properties (Mahltig *et al.* 2008). The characterization of penetration and retention and the leaching tests are still in progress, while preliminary screening tests about efficacy against fungi have given positive results; next steps of the project are tests against termites and, later on, mechanical tests.

The second purpose of the visit was therefore to perform efficacy tests of these sol-gel formulations against termites, with the supervision and collaboration of Dr. Lina Nunes, who has a long and wide experience on this subject (Nunes and Dickinson, 1995; Nunes and Nobre, 2001; Nunes *et al.*, 2006).

The results obtained from all tests will provide useful information about the products based on silica sol-gel and will enable to assess the suitability of their application on cultural heritage.

Before execution of the Short Mission, three formulations were selected for efficacy test against termites (Table 1). In addition, a silicic acid and boric acid experimental formulation, whose efficacy against termites is reported in literature (Yamaguchi, 2003), was selected for comparison with the previous ones. All products were then used for the treatment of two sets of samples (Table 1) derived from *Pinus sylvestris* L. wood, differing by number and dimensions. The two sets were then carried to the Laboratory of Dr. Nunes for testing. The small samples would have been used for an accelerated test while the bigger samples were suitable for tests according to European standards.

Treatment	N of samples series 1	N of samples series 2
	1 cm _{rad} x 1 cm _{tang} x 3 cm _{long}	1,5 cm _{rad} x 2,5 cm _{tang} x 5 cm _{long}
1. sol-gel (TEOS - APTES - EtOH)	8	4
2. sol-gel + 0,1 M CuSO ₄	8	4
3. sol-gel + 0,1 M H ₃ BO ₃	8	4
4. silicic acid - H ₃ BO ₃	8	4
5. None (controls)	8	4

Table 1 – Characteristics of the samples series prepared for efficacy test against termites. Rad = radial direction, tang = tangential direction, long = longitudinal direction. TEOS = tetraethoxysilane, APTES = aminopropyltriethoxysilane, EtOH = ethanol. CuSO₄ = copper sulphate, H₃BO₃ = boric acid.

The standard references for efficacy tests against termites are EN 118: 2005 and EN 117: 2005. Different existing tests are adaptations or modification of these reference ones. The EN 117 describes a laboratory method to determine the toxic values of a preservative against *Reticulitermes* species, when this is applied by impregnation. Although we had only one concentration for each formulation, as the sol-gel results from an impregnation process, the EN 117 principles were decided to follow.

2. Description of the work carried out during the visit

The work plan was articulated as follows:

- Collection of wood material attacked by termites in the forest

Termites of the species *Reticulitermes grassei* Clément were collected in a mixed forest of eucalyptus and maritime pine located in Moitas, about 200 km North-East of Lisbon. The forest had a shady understory and the day temperature was mild. The presence of termites was detected by the signs of attacks and by the findings of the colonies inside wood (Figure 1). Colonies were located preferably on logs and branches on the ground decayed by brown rot fungi; about 20 units of this kind of material were taken out from the forest and carried to the laboratory.

- Extraction and labelling of termites colonies from the wood

In laboratory termites were extracted by gently opening and bating wood logs and stakes, then they were separated from the residues of wood and collected in Petri dishes (Figure 2), taking care not to mix the colonies (the workers might start fighting). Each colony was labelled and placed in the climatic cell at 24 °C and 80 % R.H., before the preparation of the test.



Figure 1 – a stake with visible signs of termite attack



Figure 2 – workers of termites extracted from wood

- Preparation of the accelerated test

The procedure of the accelerated test, developed by Dr. Nunes, is the same as the one indicated in EN 117, but the wood samples are smaller, a lower number of termites per wood sample is required (150 workers instead of 250 and some soldier, if present), and the duration of the test is shorter (4 weeks instead of 8 weeks). The small set of samples were used for this test, 7 of them for the test and one to calculate the preservative retention. For each sample, a small glass jar was filled in about $\frac{1}{4}$ of its volume with a fine white quartz sand (Fontainebleau sand) and water (4/1 vol/vol), previously mixed together. It is very important to leave some holes in the sand, in order to let the small insects move inside and air circulate. A small piece of the original wood was placed in the middle of the sand, while the test sample was laid on the sand surface, at one side of the container. Finally, a group of 150 workers picked up from the same colony, together with 1-3 soldiers and 1-2 nymphs if present in the original colony, was inserted in the container (Figures 3 and 4). Wounded, young, and motionless specimens were discharged. Each container was labelled and closed, leaving a small opening for air circulation. The containers were then kept in the climatic cell (24 °C and 80 % R.H.) for the whole duration of the test.



Figure 3 – preparation of the containers for the accelerated efficacy test



Figure 4 – a completed test container with visible the humid sand, the wood sample, and the workers

- Visit and description of the termites breeding.

Colonies are cultivated in moulded fibre glass containers about 60 cm x 60 cm x 60 cm, left in the dark and stored in the climatic cell. The matrix is constituted by soil, sand, vermiculite in different proportions, wood of the original nest and water. Fresh wood blocks (*Pinus sylvestris* and other susceptible wood species) and sawdust are added as a new food source for termites. The substrate has to be maintained damp but not flooded (Pearce, 1997). For this reason, about once a week some water is added by spraying it inside the container.

3. Description of the main results obtained

- Termites ecology, culturing techniques, identification of damage

The field activity has been very helpful in order to observe termites in their natural habitat and to understand their habits. Collection of natural colonies is in fact the starting point of a laboratory culture, thus it has been important to know the environmental conditions at which termites preferably live and how to detect their presence. With the laboratory activity I have learnt to handle termites and how to prepare a test. The visiting of cultures have made me understand how to replicate a termites culture.

- Efficacy tests

The results of these tests will be available 4 weeks after the short mission. According to the methods of evaluation of EN 117, they will be expressed as grade of attack (scale 0-4 based on visual examination) and percentage of survivors. The test is considered valid if there is the maximum grade of attack and at least 50 % of survivors in the non treated wood samples; this condition means that virulence of termites used in the test is good. As there was no time to set up a test with the standard samples, we decided to wait for the results of the accelerated test, that gives the same kind of information as the EN 117, before considering how to use those specimens: either to perform a EN 117 or a different test (for example the choice test, Nunes *et al.*, 2006).

This visit gave me also the opportunity to discuss about identification and diagnosis of damages caused by subterranean termites, the ecology of the species *Reticulitermes grassei*, the one present in Portugal and very similar to the species recorded in Italy, *Reticulitermes lucifugus* Rossi.

4. Future collaboration with host institution

As the activities started out during the Short Term Scientific Mission are currently running and a new termite culture in the Italian laboratory will be probably set up, collaboration with Dr. Nunes will keep on being very active. We have also discussed about the possibility to apply for some international project, for example about termite species distributions in Europe, if considered that similarities on climate between Portugal and some regions of Italy should create the same risks of termite spreading, even though the endemic species are different.

5. Projected publications/articles resulting or to result from the STSM

The Biodegradation and Preservation team I am part of and Dr. Nunes expect to present results on silica sol-gel formulations next year at the IRG meeting. I would like to report the results of the mission in the next COST IE0601 meeting.

6. Confirmation by the host institute of the successful execution of the mission

The document produced by Dr. Nunes who confirms the correct execution of this mission is produced separately from this scientific report.

7. Other comments

During the stay, a presentation have been given by the beneficiary to the personnel of the Timber Structure Division of LNEC to introduce the Trees and Timber Institute and the activities of the Biodegradation and Preservation Laboratory.

I would like to express my appreciation to the MC COST IE0601 and the COST Administrative Secretariat for granting this mission that made my professional experience increase.

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