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Speed of bacterial decay in waterlogged wood in soil and open water

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ABSTRACT

Whereas most studies on bacterial wood decay are focused on the micro level by assessing degradation patterns in wood, this study is done on macro level studying the temporal dynamics of the process of bacterial wood decay across the diameter of a wooden object. During the last 15 years information on wood quality and bacterial decay intensity from more than 5000 heads of wooden foundation piles under buildings and quay walls was collected in a database. This allowed a comparison of the performance of spruce ad pine piles under two different anoxic regimes, i.e. in organic peaty or clay soil and open water environment. Bacteria wood decay seems to be less active in an open water environment and this tendency is most clear in spruce. Bacterial infection and water dynamics in the wood are regarded as most important factors causing differences in the activity of wood degrading bacteria.

1. Introduction

Bacteria are able to degrade wood in almost all environmental circumstances. Under water in nearly anoxic conditions erosion bacteria are active (Blanchette et al., 1990, 1991) and in this environment they are a serious threat for wooden foundation piles. Especially in long- and well-populated estuarial areas (e.g. The Netherlands, Bangladesh) where wooden pile foundations are crucial for carrying houses, buildings and water building constructions (e.g. quay walls, locks). For a long time this type of decay has been neglected because of the assumption that wood will not degrade under water. But already in 1931 Wijnpersse (1931) mentioned that pine foundation piles are sensitive for decay under the ground water table and in 1949 Varossieau (1949) described the unknown pattern of decay in pine piles. Other anatomical morphological studies followed, and the unknown pattern of decay was finally linked to the activity of erosion bacteria (Liese, 1955, 1970; Schmidt and Dietrichs, 1976; Nilsson and Holt, 1983; Daniel and Nilsson, 1986; Kim and Singh, 2000). Also studies were published that described the conditions under which wood degrading bacteria were active and relations were seen with the availability of nutrients and oxygen and the water movement in the wood (Boutelje and Bravery, 1968; Boutelje and Göransson, 1975; Klaassen et al., 2008; Huisman et al., 2008a,b; Kretschmar et al., 2008a,b). Studies on isolations and identification of the erosion bacteria were done by Björdal and Nilsson (2008a), Björdal and Nilsson (2008b), Nilsson et al. (2008). Despite all these studies the identity of the wood degrading bacteria and the process of decay is until now not fully understood.

Erosion bacteria are regarded as the most common type of bacterial wood decay in anoxic soils. They are rod shaped and attached to the cell wall with their slime sheet in which they release their enzymes to dissolve the woody cell wall. As the lignin component stays more or less unattached, severely degraded wood consists of a skeleton of the highly lignified S_1 and S_3 cell wall layers, only.

Wood degrading bacteria do not have a real movement apparatus but it is believed that limited movement occurs by the circulation of their slime layer and therefore they are called gliding bacteria that motile. Their invasion in the wood relies on water movement to and through the wood, mainly. Also to secure an active bacterial wood degrading process, water movement is required while these bacteria live in consortia of about 10 species. Each link in this chain of erosion bacteria depends on its successor and predecessor with regard to useful and toxic cell wall derivatives and for an active decay process, the intermixing of derivatives and bacteria is necessary.

In order to protect the wooden elements in the anoxic soils, more information is needed on the interaction between erosion wood decay, the soil environment and the timber quality. As the process of bacterial decay is extremely slow, experiments that run over decades are needed but because of this time component difficult to establish. However, there is a unique situation in the Netherlands that can act as a *Field Trial*. In the period between the

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15th to 20th century millions of wooden piles were inserted in the Dutch soil to give all kinds of constructions a stable basis. In the last few decades, on a regular basis, piles were inspected in order to judge the stability of the foundation construction. These inspections were done because of a variety of reasons. The analysis of wood samples is part of a foundation inspection and yearly the wood of hundreds of piles is studied. Earlier studies on bacterial wood decay in this Dutch *Field Trial* were done by Klaassen (2008), and Klaassen and Overeem (2012). Klaassen and Creemers (2012) gave an overview of the wooden pilings under Dutch buildings and their actual problems. Two main aspects are related to decay. The first one is too low ground water table, causing fungal decay in the pile head. The second one is water movement in the pile causing bacterial decay. It is believed that the water dynamics in the wooden pile is related to those situations where the pile contacting soil layers have different water potentials, or to variations in ground water table including significance time periods with air contact around the pile heads. According to Hoogvliet et al. (2012) climate change could have a negative effect on the general water table in the Netherlands and they calculated that in the next few decades the ground water table in Dutch cities could decrease up to 10 cm. This process increases the threat of decay in wooden pile heads, not only by the increase fungal activity but also by an increase of bacterial activity while the water dynamics in the wood is stimulated.

In order to improve the knowledge on the dynamics of bacterial wood decay, this third study in row regarding the Dutch *Field Trial*, (Klaassen, 2008; Klaassen and Overeem, 2012) is done. This time the effect of a soil and a water environment is regarding. For the soil environment piles under buildings are chosen and for the water environment piles under quay walls (including bridge headings) are chosen. Quay walls are the boundary between canals and streets, and in the downtown area of many Dutch cities most of these quay walls are standing on wooden piles. The quay wall length varies within the cities e.g. 28 km in downtown Rotterdam (CURNET, 2013) and 70 km in downtown Amsterdam (Damen et al., 2011). The number of piles and the distance between the piles depends on the estimated load of the quay wall construction and the expected load of products stored on the quay wall. The piles at the front side of the quay stand with their upper part in open water or sediment and water. During foundation inspections on quay walls or bridge headings wood samples are always taken from the piles directly adjacent to the canal. In this situation less water movement in the wood is to be accepted because the water pathway with the lowest resistance lies outside the piles in the open water. In soil environments there is almost no water movement around the piles because of the water tight soil layers enclosing the piles. In this situation the water pathway with the lowest resistance is through the wood. As bacterial activity is stimulated by water movement in the wood, it is to be expected that piles in water will have a greater resistance against bacterial decay.

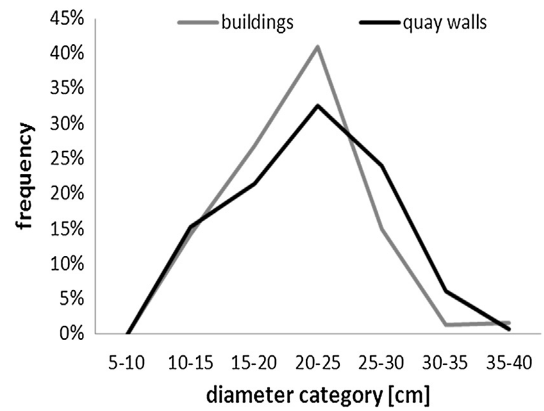

Fig. 2. Frequency diagram of the pile head diameter.

2. Method

From 1997 onwards, cores from wooden foundation pile heads were analysed with regard to timber species, sapwood amount (for pine and oak) and gradients of decay (type and degree), density and moisture content over the core (Klaassen, 2008). The cores were taken during foundation inspections carried out by 65 different companies. Immediately after sampling the cores with water are stored in a water tight tube and stored at a temperature of 4 °C before analysis. The core data were collected in a database together with information on the address and age of the building.

As the database is established on the basis of research which had a different aim than to learn more about the process of bacterial decay, the data are not randomly chosen over the country, over the serving time, over the timber species and over the type and size of the wooden constructions. It is realised that this causes restrictions to the statistical analyses and therefore the data are analysed in a descriptive way only.

3. Results

In Figs. 1 and 2 general aspects of the foundation construction under buildings and quay walls are compared. The number of piles

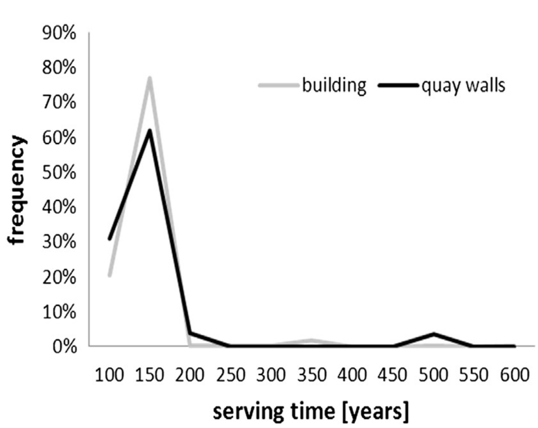

Fig. 1. Frequency diagram of the service time (0–100, 100–150, 150–200, 200–250, 250–300, 300–350, 350–400, 400–450, 450–500, 500–550, 550–600 years).

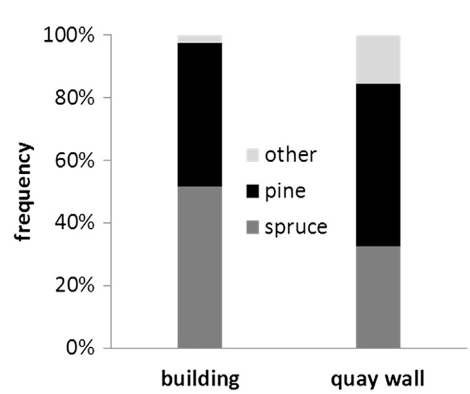

Fig. 3. Frequency diagram of the occurrence of timber species of piles under buildings or quay walls.