International Biodeterioration & Biodegradation 116 (2017) 219–226

Contents lists available at ScienceDirect

International Biodeterioration & Biodegradation

journal homepage: www.elsevier.com/locate/ibiod

Performance of copper treated utility poles and posts used in service for several years

Miha Humar*, Nejc Thaler

University of Ljubljana, Biotechnical Faculty, Department of Wood Science and Technology, Jamnikarjeva 101, SI-1000 Ljubljana, Slovenia

ARTICLE INFO

Article history:
Received 6 March 2016
Received in revised form
2 November 2016
Accepted 2 November 2016

Keywords:
Norway spruce
Copper
Wood preservatives
Performance
Mechanical properties
Decay
Shell treatment
Premature failures

ABSTRACT

Copper based wood preservatives are among the most important wood preservatives for heavy-duty applications. Wood treated with copper-based preservatives performs excellently if applied according to preservative specifications. If used improperly, premature failures can appear. In order to elucidate the properties of copper treated wood in use, utility poles and posts treated with copper-based preservatives were investigated. Poles were cut into smaller specimens, and copper and chromium penetration, retention, mechanical properties, extractive content, short-term water uptake and fungicidal properties were then determined. The results clearly showed that wood retains its properties if treated with sufficient amounts of copper-based wood preservatives. Insufficient amounts of preservatives applied result in premature failures of wood commodities. Regardless of the type of wood preservative used, the central part of spruce wood poles and piles is the weakest point, where the majority of the failures occurs.

1. Introduction

Copper-based preservatives are the most important solutions for impregnation of wood in heavy-duty applications (Schilling and Inda, 2011). The majority of alternatives in the European Union have been removed from the market (Pohleven, 1998; Humar et al., 2006). Copper compounds are usually leached from wood if not combined with fixatives. In the past, copper was mixed with chromium compounds (Richardson, 1997), which were later replaced by amines. The most recent generation of copper-based wood preservatives is based on nanotechnology – micronized copper. Although copper is very effective, there are a few drawbacks associated with copper-based wood preservatives: copper leaching (Tiruta-Barna and Schiopu, 2011) and the presence of copper tolerant fungi (Steenkjær Hastrup et al., 2005).

Copper-based preservatives are traditionally used for the protection of softwoods in infrastructural applications such as posts, bridges, vineyard poles, noise barriers, fences etc. In Northern Europe, predominately Scots pine (*Pinus sylvestris*) was utilised for impregnation. Due to the lack of available Scots pine, Norway spruce was used instead of pine in Central Europe (Humar et al., 2006). One of the most important drawbacks of Norway spruce is its insufficient permeability (CEN, 1994a). Since the retention and penetration requirements of pine cannot be met by spruce wood, some end users specify different retentions for Norway spruce and Scots pine (Willeitner, 2001).

Utility poles and piles are a good platform for service life prediction studies. Their design is fairly simple and the properties of utility poles have to follow standard or technical specifications. Service life prediction is nowadays important from various perspectives; for calculation of Life Cycle Assessment (LCA), Life Cycle Costs (LCC) and maintenance costs (Brischke and Thelandersson, 2014). These data are important in the decision making process, when materials for a particular application are selected. If data for a certain material are missing or they are inconsistent, it considerably reduces the possibility of suitable selection. In order to increase the use of wood, we have to provide as much information as possible. Current LCA studies indicates, that copper treated wood has lower environmental impact than alternative materials, like WPC (Bolin and Smith, 2011).

If wood preservatives are not applied correctly, premature failures are likely to occur. Morrell, (2008) reported that decay is the predominant reason for failure of utility poles in the region of the

* Corresponding author.
E-mail address: miha.humar@bf.uni-lj.si (M. Humar).

http://dx.doi.org/10.1016/j.ibiod.2016.11.004
0964-8305/

Pacific coast in the USA. Premature failures of wood can result in severe economic damage and negatively affect public perception of wood. Approaches for prevention of premature failures of copper treated wood have been well defined: selection of healthy, non-decayed wood, proper drying, proper retention and penetration, proper conditioning and quality control (Mcintyre and Freeman, 2002). If these recommendations are respected, premature failures can be avoided.

The aim of respective paper was to determine the link between premature failures and quality of impregnation (retention and penetration). It is hypothesized, that concentration of active ingredients in wood poles and their performance are tightly related. It is presumed, that concentration of copper is lower in the degraded parts either due to insufficient treatment and/or copper translocation. Properties of the wood will be assessed through visual inspection, analysis of mechanical properties and determination of extractives. It is believed that the mechanical properties and extractive contents changes in partly degraded wood, even if decay cannot be resolved by naked eye. Compression test are usually more indicative for changes in lignin, while bending test indicate potential cellulose degradation. Results of the mechanical analysis will be used in decision making process, if the material is suitable for reuse, considering the fact that part of the respective pole/post failed.

2. Material and methods

2.1. Material

Material for this investigation originated from three sources: a utility pole after 15 years of use (pole), a post that had been in use for 8 years (post 8y), and three posts (A, B and C), which had been in service for 3 years only (post 3y). All the poles and posts has been used in the same location during their service life. They have been installed shortly after treatment. Pole and posts were round shaped, made of Norway spruce (*Picea abies*), and treated with copper-based preservatives. Detailed description of the treatment is resolved from Table 1. They were all replaced due to ground contact failure. They were in contact with soil, reach with humus, covered with grass. Poles were divided into three sections: upper, middle and lower parts. The material was cut into smaller specimens as required by the various methods. Post and pole 8y were analysed in more detail, and post 3y was analysed to a lesser extent since there was less material available. The plan of the sample preparation is resolved from Fig. 1.

2.2. Retention and distribution of Cu and Cr compounds

The quality of the treatment is determined by the penetration and retention of active ingredients (CEN, 2007). In order to elucidate these parameters, the poles were cut to 3 cm thick cylinders. The cylinders were cut to thin layers (from 2 mm to 5 mm) for elemental XRF analysis. Dimensions of the layers were determined based on the visual assessment of penetration. Sections of each layer were milled together in a SM 2000 Retch mill (Retch GmbH; Haan, Germany) and five parallel tablets ($r = 16$ mm; $d = 5$ mm) were pressed with a Chemplex Sprectro pellet press (Chemplex Industries Inc., USA) from the milled material. The copper and chromium content in the tablets was determined with a Twin-X XRF spectrometer (XRF TwinX, Oxford instruments, UK). Measurements were performed with a PIN detector ($U = 26$ kV, $I = 112$ μA, $t = 360$ s). Profiles were determined for the utility pole and the post that had been in use for three years (post 3y), since there was not enough material with the 8-year-old post (post 8y). Two cylinders were analysed per specific value. From each position in respective cylinder 3 to 5 replicate tablets were prepared, depending on the amount of available material. Retention was determined with matched specimens, which were also used for determination of fungicidal properties.

2.3. Leaching of active ingredients from wood

Samples (1.5 × 2.5 × 5.0 cm^3) for leaching were made of pole (upper and lower part) and 8-year-old post only (post 8y). The (CEN, 1994b) procedure is based on leaching with water only. It was completed in only five days. Samples for leaching was made from the outer, impregnated part of the respective pole or post. For comparison, controls made of freshly cut wood was prepared. In relation to the standard, two modifications were made: (1) three specimens instead of five were positioned in the same vessel; and (2) water mixing was achieved by employing a non-rotary shaker (S-500 × 1100, Kambič d.o.o., Semič, Slovenia) instead of a magnetic stirrer. To perform three parallel leaching studies, nine specimens made of the specific pole were placed in three vessels (three specimens per vessel). Samples were secured with weights to prevent them from floating. Distilled water (300 g) was added, and the vessel with its contents was shaken with a frequency of 60 rpm. The water was replaced six times on five consecutive days, as described by the standard (CEN, 1994b). The copper concentration in the leachates was determined at the end of each leaching cycle. After each leaching cycle, the copper concentration in the leachates was determined by X-ray fluorescence spectrometry (XRF; Twin-X; Oxford Instruments, UK) ($U = 26$ kV, $I = 112$ μA, $t = 360$ s). Leachates with concentrations lower than 10 mg/kg, as analysed by XRF, were reanalysed by atomic absorption spectroscopy (Varian SpectrAA Duo FS240; Varian Inc.; Walnut Creek, CA, USA).

2.4. Decay test

The decay test was performed according to the modified EN 113 (CEN, 2006) standard on specimens from pole and 8 year old post. Disposable Petri dishes (Ø = 85 mm, h = 15 mm) containing 20 mL of 4% potato dextrose agar (PDA, Difco, NJ, USA) were inoculated with 5 different fungi: three white rot fungi (*Pleurotus ostreatus* (Jacq. ex Fr.) P.Kumm. (ZIM L030), *Hypoxylon fragiforme* (Pers.) J. Kickx f. (ZIM L108) and *Trametes versicolor* (L.) Lloyd (ZIM L057)) and two brown rot fungi (*Gloeophyllum trabeum* (Pers.) Murrill (ZIM L018) and *Fibroporia vaillantii* (DC.) Parmasto (ZIM L037)). The fungal isolates originate from the fungal collection of the Biotechnical Faculty, University of Ljubljana and are available to research institutions on demand (contact: miha.humar@bf.uni-lj.si) (Raspor et al., 1995). Information regarding the origin of the fungal isolates

Table 1
Description of the material used in respective experiment.

Name	Years in service	Wood species	Dimensions r × l (cm)	Wood preservative	Specified retention (kg/m^3)
Pole	15	Norway spruce	15 × 100	CCB	4–6
Post 8y	8	Norway spruce	4 × 80	Cu - amine	4
Post 3 y (A, B and C)	3	Norway spruce	6 × 60	Cu - amine	3–4