Oppdragsrapport 17/2010

fra Skog og landskap

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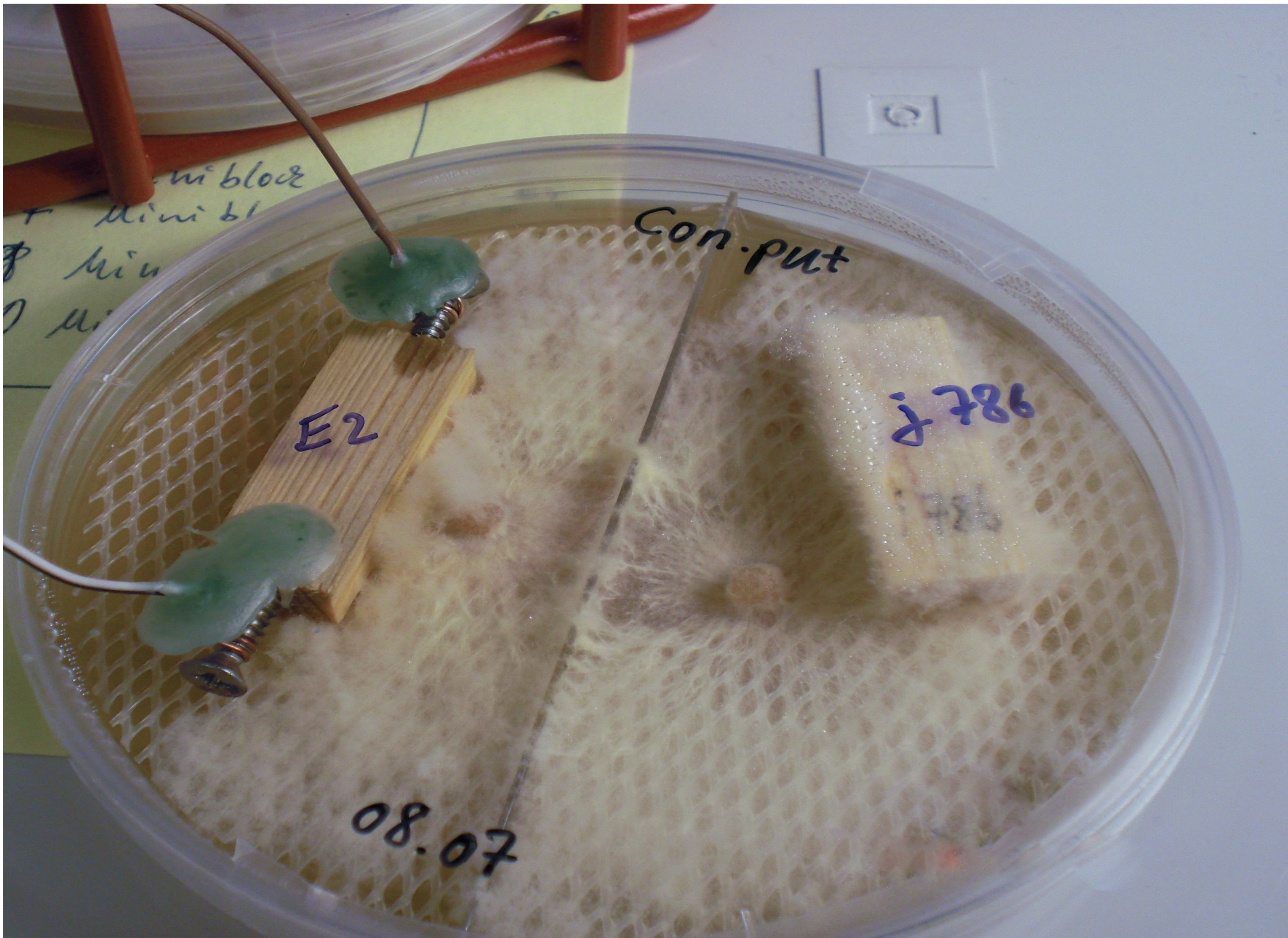

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INNOVASJON NORGE:
TREBASERT INNOVASJONSPROGRAM

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SUMMARY

Wood protection is mainly based on functional building design and on chemical protection of wood. The disposal of wood preservative treated material causes restrictions in its later use or by recirculation into the eco-cycle.

A new protective system, electro-osmotic pulsing technology on wood, called PLEOT, is tested in a fungi test and in soil contact. Mass loss and moisture content of Scots pine sapwood samples was calculated after testing and an element analysis was performed on the wood sample powder. Furthermore, studies on the exposure of wood samples to termites were performed using PLEOT protected wood samples.

Conductive material was tested in order to optimize the test setup and in order to have good documentation for future commercialization.

The results show that PLEOT-protected samples have nearly no mass loss after 4, 8 and 12 weeks of exposure to *Coniophora puteana* in laboratory trials. The samples protected with PLEOT showed lower moisture content and show trace elements of metals in the wood samples after basidiomycete test compared to untreated samples. It is concluded, that neither the lowered wood moisture content nor the transferred metal ions, but instead the PLEOT control of wood samples contribute to large amounts to the wood protection effect.

Conductive material and test setup are a crucial part of the tests. The conductive carbon fibers used in some tests were destroyed after several weeks while PLEOT was connected. A second test set-up, including conductive plastic, shows better results.

Furthermore, the PLEOT system might protect wood in soil contact. It is assumed that the PLEOT system also influenced the untreated wood samples since they were in the same surrounding.

The two choice and non-choice termite tests were carried out using a 4 weeks exposure to *Reticulitermes grassei* and different initial wood moisture content. The results show growth of mould fungi on untreated wood samples with high initial wood moisture content after 4 weeks of termite testing. Termite mortality was high on wet samples due to mould growth on untreated samples. PLEOT protection strongly reduced the development of moulds. Development of moulds was much less on samples with low initial wood moisture content. The mortality of termites was higher in test systems with PLEOT protected wood samples than unprotected wood samples. The loss of wood mass due to termite attack after 4 weeks was slightly reduced by using PLEOT.

Future trials should include different wood species and wood dimensions as well as various fungi species in lab trials. Furthermore, field tests have to be performed in order to evaluate the product performance of PLEOT- protected wood.

SAMMENDRAG

Trebeskyttelse er hovedsakelig basert på konstruktiv og kjemisk beskyttelse av tre. Avhending eller gjenbruk av treprodukter som inneholder trebeskyttelsesmidler, kan skade miljøet og skape problemer i økosystemet.

Et nytt beskyttelsessystem, pulserende elektro osmose teknologi (PLEOT), har blitt testet med hensyn på sopp, både muggsopp og råtesopp. Tørrstofftap og fuktighetsinnhold i prøver av furu yteved ble beregnet etter testing, og elementanalyse ble foretatt av trepulver fra prøvene. Treprøver som hadde PLEOT-systemet tilkoblet, er også blitt testet mot termitter.

Strømledende materiale ble testet for å optimere forsøksopplegget og som en dokumentasjon av produktet for senere kommersialisering.

Resultatene viser at PLEOT-beskyttede prøver tilnærmet ikke har noe tørrstofftap etter 4, 8 og 12 uker i råtenedbrytningstest (*Coniophora puteana*.) i laboratoriet. Sammenlignet med ubehandlede prøver, hadde prøvene med PLEOT-beskyttelse lavere fuktighetsinnhold, og kun spor av metallelementer etter råtenedbrytningsforsøk. Konklusjonen er at hverken lavere fuktighetsinnholdet eller de overførte metallionene i PLEOT-prøvene bidrar til trebeskyttelseseffekten.

Testing av strømledende materialer og utvikling av testoppsett er en vesentlig del av prosjektet. Strømledende karbonfibre som ble brukt i noen av forsøkene, ble ødelagt etter flere ukers PLEOT-tilkobling. Bruk av strømledende plast ga imidlertid bedre resultater.

PLEOT-systemet kan gi beskyttelse av tre i kontakt med jord. Sannsynligvis hadde PLEOT-systemet en beskyttende virkning også på de ubehandlede prøvene siden de var plassert i de samme omgivelsene.

I ”two-choice” og ”non-choice” termittforsøkene ble treprøver med forskjellig fuktighetsinnhold eksponert for Reticulitermes grassei over 4 uker. Tørrstofftap etter 4 ukers termittangrep ble redusert ved bruk av PLEOT. Dødeligheten av termitter var høyere i testoppsett med PLEOT-tilkobling enn i testoppsett med ubeskyttede prøver. Resultatene viste også at de ubehandlede prøvene med opprinnelig høyt fuktighetsinnhold hadde muggvekst etter 4 ukers termittangrep. Dødeligheten av termitter på grunn av muggsopp var høy på fuktige prøver på ubehandlede prøver. PLEOT-tilkobling reduserte i stor grad muggveksten.

Fremtidige laboratorieforsøk bør inkludere forskjellige treslag, dimensjoner på treprøver og forskjellige arter av sopp. Felttester bør utføres for å evaluere levetiden til produkter med PLEOT-beskyttelse i et bruksmiljø

Nøkkelord:	Pulserende elektro osmose teknologi, PLEOT, sopptest, trebeskyttelse
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CONTENT

1. INTRODUCTION

1.1 Hypothesis and aim of the project:

The hypothesis of the project is: electro osmotic pulsing technology (PLEOT) will protect wooden products against negative biological activity. The aim is to evaluate the influence of PLEOT on biological activity in and on wood, and we will focus on fungi and termites.

1.2 Research challenge and approach:

- Evaluation of the effect of several sources of electric current
- Further development of conductive materials and establishment of installation methods in laboratory tests
- Evaluation of ion transportation through wood samples during PLEOT protection
- Durability of wood samples in ground contact
- Evaluation of the effectiveness of PLEOT against termites

2. VARIOUS SOURCES OF ELECTRIC CURRENT AND THEIR EFFECTIVENESS AGAINST BIOLOGICAL ACTIVITY

2.1 Material and methods

Pre-trials have already showed the effectiveness of PLEOT. These results needed to be reproduced in order to verify the results and in order to determine that the pulsating of currency in a certain pattern is responsible for the effect. PLEOT is therefore compared to alternating current (AC) and direct current (DC).

Scots pine (*Pinus sylvestris*) sapwood samples with dimensions of 5 x 10 x 30 mm^3 (miniblocks) were used. The samples were connected to PLEOT, AC and DC by drilling 5 mm deep and 2.1 mm holes in diameter into the center of each cross section of the samples. Acid-resistant and rust-free screws with 15 mm in length were used on both sides of the samples. Isolated copper cables (0.5 mm), connected to the screws, transferred the electro-osmotic pulsing to the samples.

Non-leached wood samples were tested on *Coniophora puteana* for 4 and 12 weeks according to Bravery (1978) using 13 V/1 kOhm of PLEOT protection, 13 V/1 kOhm of DC from a battery and 13 V/1 kOhm of alternating current (AC) from a adjustable generator. Untreated Scots pine sapwood samples and samples connected to cables without connection to any electrical source were used as reference.

2.2 Results

After testing of different parameters such as voltage and resistance which lead to nearly the same results, the source of electricity was investigated. To verify that the anti-fungal effect is caused by the distinct electric pulsing and not by the electricity itself, 3 different electric sources were tested.

The results after 4 and 12 weeks (shown in figure 1) clearly indicate that only the PLEOT system gives sufficient protection against *Coniophora puteana* after both 4 and 12 weeks.

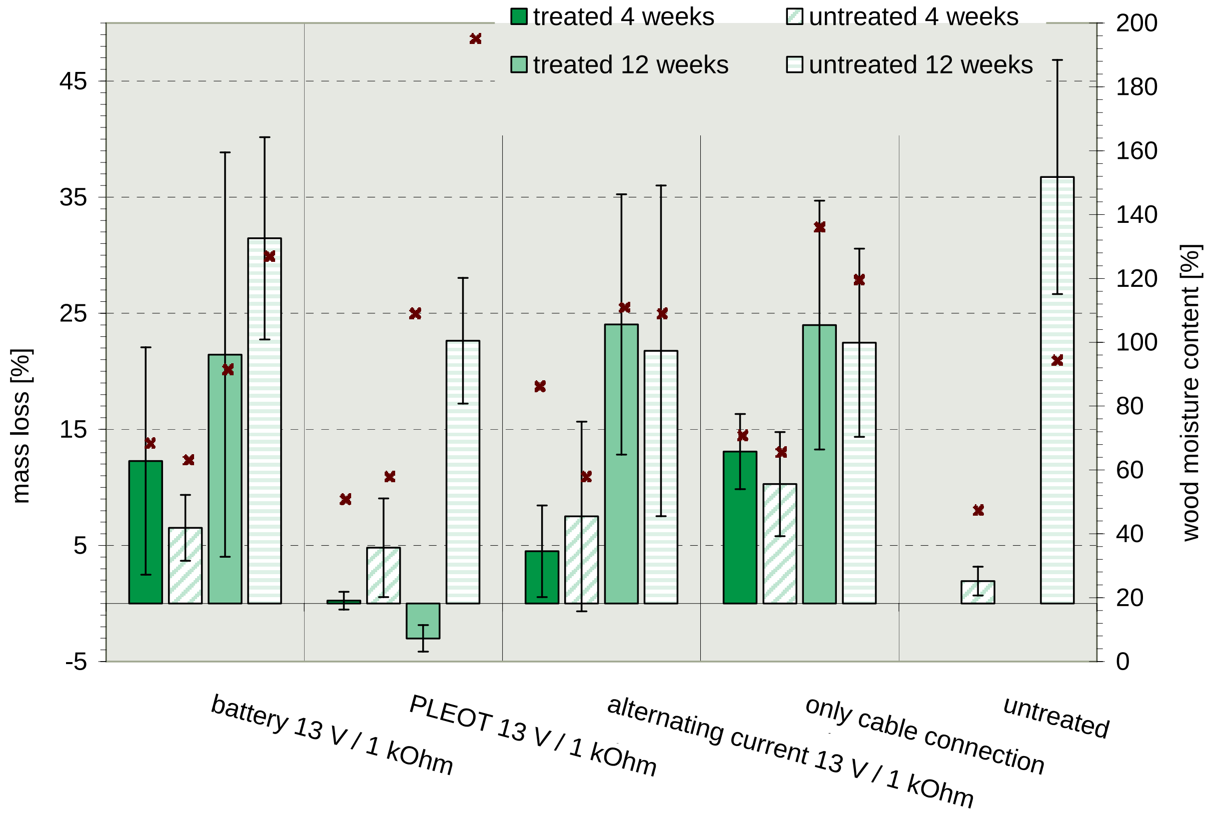

Figure 1: Average mass loss of different treated and untreated Scots pine samples *(Pinus sylvestris)* after 4 and 12 weeks of exposure to *Coniophora puteana.*

3. CONDUCTIVE MATERIAL AND INSTALLATION OF PLEOT

Two-component glue (S&P resin 220 epoksylim, S&P Clever Reinforcement Company AG) and conductive plastic electrode, which is used to connect the PLEOT system, was tested in a fungi test. The glue was applied on a glass plate and put on agar plates inoculated with respectively *Coniophora puteana* and *Trametes versicolor*. The conductive plastic electrode was tested using the same test setup.

The fungi showed no avoidance of the hardened glue or the plastic and it is likely that these materials have no antifungal properties. The glue was used in further tests to connect electrodes to the wood.

Conductive carbon fibers were used in a fungi test and in a termite test. In both cases the fibers lost strength after some weeks. High relative humidity in combination with the pulsating current and the connection to other conductive material (metals) is responsible for the weakening of the carbon fibers. Carbon fibers can only be used when the connection to other materials is water tight. In future trials, conductive plastic electrodes will therefore be used.

PLEOT has been installed into a test building in Porsgrunn. Indications of the performance of the test building are expected after 3 years.

Figure 2: Conductive plastic on agarplate inoculated with *Trametes versicolor*

Figure 3: Installation of PLEOT in a building

4. ION TRANSPORT THROUGH WOOD SAMPLES

4.1 Material and methods

Non-leached wood samples with dimensions of 5 x 10 x 30 mm³ (miniblocks) were tested on *Coniophora puteana* for 8 weeks according to Bravery (1978) using 40 V/1 kOhm, 40 V/10 kOhm, 10 V/1 kOhm as different parameters of PLEOT. Additionally, untreated samples and samples connected to cables but not to PLEOT were used as reference. A low frequency pulsed electrical direct current (DC) voltage was used in all tests. Petri dishes with a centre barrier were used in order to prevent the possible influence of PLEOT protection through the agar medium on the untreated sample.

The samples were dried at 103°C for 24 hours after 8 weeks of exposure and mass loss was calculated. Two of the protected samples respectively were ground, acid digested and analyzed using element analysis with ICP-AES. The determination of elements was performed by a simultaneous ICP-AES technique with axial or radial viewing of plasma (Skoog, Holler et al. 1998) on a Thermo Jarell Ash ICP-IRIS HR Duo. The following elements were determined in all leaching water samples: Al, As, B, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Se, Si and Zn.

Half of the samples collective was used to repeat the fungal test without any applied protection while testing. This was done in order to test the influence of a PLEOT pre-protection. The previously exposed samples (pre-protected by PLEOT) were compared to previously non-exposed and untreated Scots pine sapwood samples.

4.2 Results

As brown rot fungi are a hazard for above ground applications, the fungus *Coniophora puteana* was used for the test. The results presented in fig. 4 show the influence of applied voltage and applied resistance degradation by brown rot. Initial trials using Petri dishes gave not only no mass loss for the treated sample, but also very low mass loss for the untreated sample. It was assumed that the agar medium or the fungus itself conducted electricity. Petri dishes with a centre barrier were then provided. The samples did then not share agar medium, but shared the same atmosphere. The test setup has been optimized for the tests presented here.

The treated samples show nearly no mass loss and the untreated samples show higher mass loss (fig. 4). In figure 4 it is still apparent that the Petri dishes with two untreated samples (“untreated” bar) have higher mass loss than the untreated “neighbor” samples i.e. the “40V/1kOhm” bar. The bars labeled “cable connections” are untreated samples with cables connected, but no electricity was applied. The reason for the low mass loss in these samples is still unclear.

The moisture content of the PLEOT treated samples is in general lower compared to untreated control samples. However, the wood moisture content of all PLEOT treated samples is >40 % and should therefore still create a favorable environment for the fungus. Cardinal points on wood moisture content for *Coniophora puteana* of 30-70 % is given as optimum (Schmidt 2006) which supports the fact that the wood moisture content was favorable for the fungus. Wood with about 20 % moisture content can be considered as protected from basidiomycete decay (Dix and Webster 1995).

By changing the applied resistance from 1 to 10 kOhm, the antifungal effect of the PLEOT system does not change, but the untreated samples show much higher mass loss in the 10 kOhm Petri dishes. By reducing the voltage to 10V, some mass loss (<1%) is detected for the treated samples. An interesting artifact is the very low mass loss of the untreated control sample, but the reason for this is presently unclear. The results on mass loss of untreated wood samples show high standard deviations.

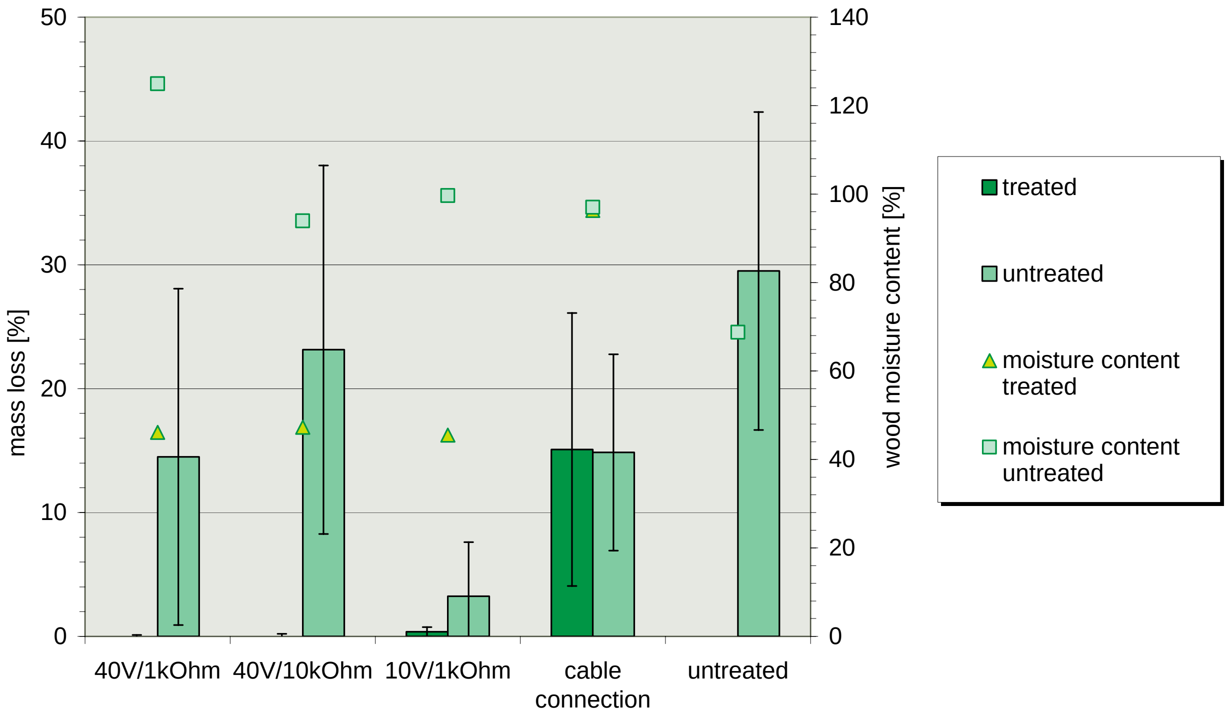

Figure 4: Average mass loss and wood moisture content of different PLEOT- treated and untreated Scots pine samples *(Pinus sylvestris)* after 8 weeks of exposure to *Coniophora puteana*.

Some of the samples protected by PLEOT showed some discoloration on the negative pole side. At this point the focus was drawn to the possibility that the effect of the protection solely was an effect of transferred ions into the wooden matrix. Copper from the wires and nickel and chromium from the screws, was the main concern. After the ICP element analysis of wood powder from the treated samples, trace amounts of elements were found (tab. 1). The distribution of these metal ions within the wood samples is not evaluated.

Table 1: Average amount of elements in µg/g (with STDV) of two ground wood samples per protection after 8 weeks of protection with PLEOT and exposure to *Coniophora puteana* analyzed by using ICP

Protection	Cr	Cu	Fe	Ni	S	P
40V/1kOhm	119 (9.4)	33 (23)	411 (78)	190 (33)	36 (9.2)	56 (5.7)
40V/10kOhm	149 (26)	51 (63)	516 (66)	324 (187)	28 (6.4)	37 (1.4)
10V/1kOhm	160 (162)	86 (95)	485 (517)	268 (311)	43 (26.9)	153 (154)
cable connection	2 (0.3)	3 (1.3)	13 (7.3)	1 (0)	224 (140)	1195 (830)
Untreated	1 (0)	1 (0.5)	6 (3.1)	1 (0)	226 (89)	1172 (427)

To verify if these elements had an influence on the protection of wood, the treated samples, which already had been exposed to the fungus *Coniophora puteana* for 8 weeks, were again exposed to a fungi test for 8 weeks, but now without PLEOT protection. The results from this trial are presented in figure 5.

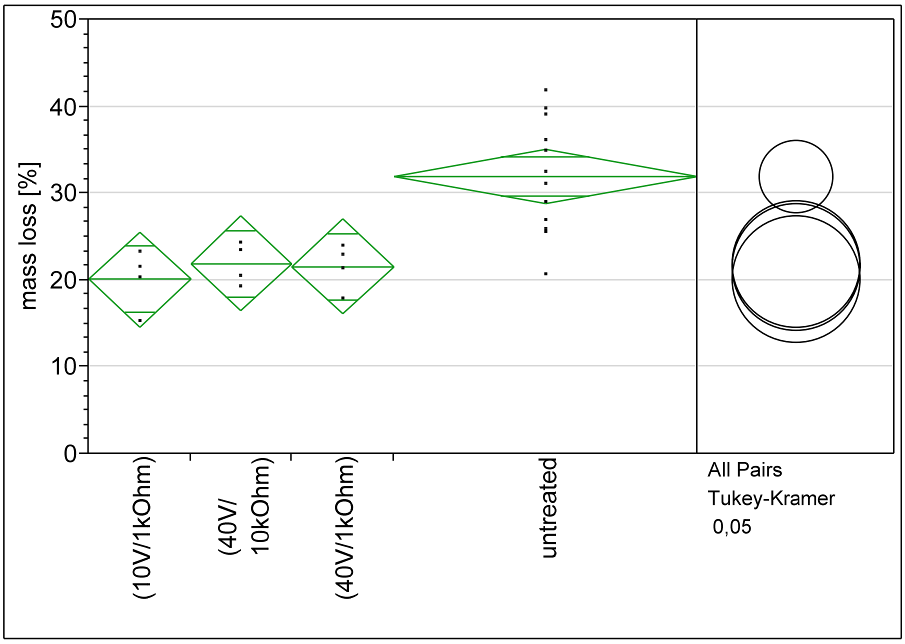

Figure 5: Mass loss of different previously protected (PLEOT) and untreated Scots pine samples *(Pinus sylvestris)* after 8 weeks of exposure to *Coniophora puteana;* none of the samples in this test had any PLEOT installation.

After 8 weeks of repeated exposure to *Coniophora puteana*, the mass loss of the previously protected samples is in average around 20%. This is a 10% lower mass loss than the mass loss of new untreated samples after the test. The difference of previously PLEOT protected samples compared to the untreated samples is an additional autoclaving, additional drying at 103°C, a previous exposure to *Coniophora puteana* and a previous protection by PLEOT during the preliminary fungi test. The difference in mass loss might be explained by these differences. Additionally, the trace elements that were found in the wood samples can also contribute to the differences in mass loss. However, as the samples that were previously protected and exposed to the fungus for a second time achieved around 20% mass loss, it is assumed that the trace elements have only a minor effect. One must also consider that the amount of trace elements has built up over 8 weeks, and the amount tested (as shown on samples in figure 4) was the maximum concentration over these 8 weeks.

The samples showed a wood moisture content (with STDV) after the test of 63 (16) % previously protected 10V/1kOhm, 58 (25) % previously protected 40V/10kOhm, 76 (18) % previously protected 40V/1kOhm and 82 (50) % untreated. A significant difference in moisture content can therefore not be seen.

5. DURABILITY IN GROUND CONTACT

5.1 Material and methods

Non-leached wood samples with dimensions of 5 x 10 x 100 mm³ were tested in soil contact according to ENV 807 (1999) for 32 weeks. A brown rot decay type dominated soil from Simlångsdalen (Sweden) was used.

The samples were PLEOT-treated with 40V/1kOhm and CCA-treated and untreated samples were used as reference.

5.2 Results

After concluding that the PLEOT system is protecting against attack from *Coniophora puteana* in miniblock lab trials, it was important to test PLEOT on wood samples in soil contact. The test results, shown in figure 6, show mass losses of untreated samples around 6% after 32 weeks.

The test is not valid according to ENV 807 (1999). However, the difference in mass loss between PLEOT-treated samples and the untreated control samples is significant.

The treated samples also showed severe degradation of the copper wire and were at several places broken.

It is likely to conclude that the PLEOT system was influencing not only the directly connected samples but also the untreated samples since the untreated samples were in the same soil and container as the treated ones. The PLEOT system could thereby lower the mass loss not only of the connected samples but also of the untreated samples. New test setup is necessary to verify these results.

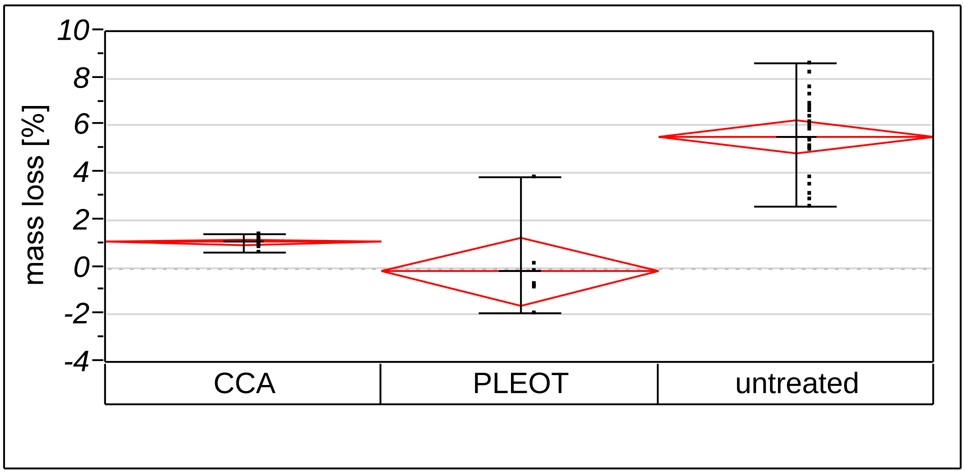

Figure 6: Average mass loss of CCA-treated, PLEOT-protected and untreated Scots pine samples *(Pinus sylvestris)* after 32 weeks in soil contact; the samples showed a wood moisture content (with STDV) after the test of 124 (11) % PLEOT, 100 (21) % and 165 (14) untreated.

6. EFFECTIVENESS AGAINST TERMITE ATTACK

Evaluation of PLEOT against subterranean termites (*Reticulitermes grassei*) was performed for 4 weeks on Scots pine sapwood samples (dimension 25 x 15 x 50 mm³) with different initial wood moisture content. A two choice and non-choice termite tests was performed.

Termite mortality was high on wet samples due to mould growth on untreated samples. The loss of wood mass due to termite attack after 4 weeks could be reduced by using PLEOT.The results show growth of mould fungi on untreated wood samples with high initial wood moisture content after 4 weeks of termite testing. PLEOT protection strongly reduced the development of moulds. The mortality of termites was higher in test systems with PLEOT protected wood samples than unprotected wood samples. This trend has to be confirmed in further lab tests and field tests.

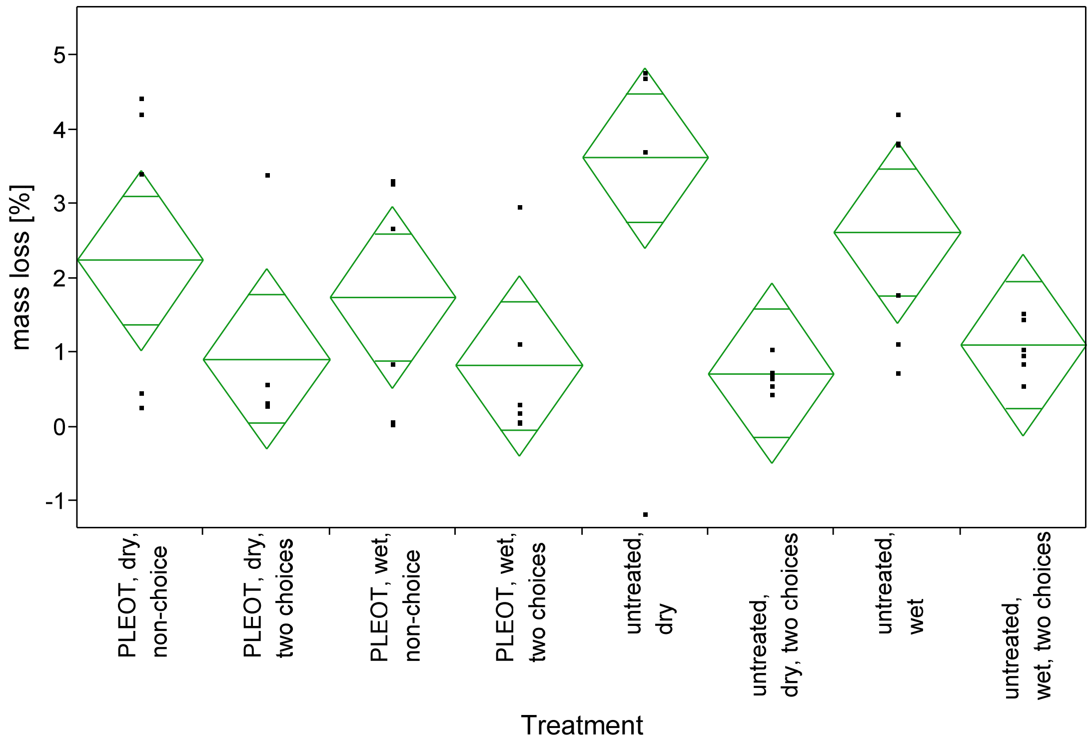

Figure 7: mass loss of Scots pine sapwood samples *(Pinus sylvestris)* exposed to subterranean termites *(Reticulitermes grassei)* for 4 weeks

Table 2: Termite mortality, attack degree, wood mass loss and wood moisture content after 4 weeks of exposure of Scots pine sapwood *(Pinus sylvestris)* onto subterranean termites *(Reticulitermes grassei).*

protection	termite mortality [%]	attack degree	mass loss [%]	wood moisture content [%]
PLEOT, wet, non-choice	70,27 (34,8)	2 (2.2)	1,74 (1.6)	69,13 (31)
PLEOT, dry, non-choice	60,67 (42,7)	2 (2.2)	2,24 (2)	49,91 (27.5)
PLEOT, wet, two choices	89,73 (24,8)	0,67 (1.6)	0,82 (1.1)	52,27 (28.9)
PLEOT, dry, two choices	87,27 (31,2)	0,67 (1.6)	0,91 (1.2)	29,98 (1.4)
untreated, wet, two choices	98,47 (2,5)	0,67 (1.6)	1,10 (0.4)	94,62 (20.7)
untreated, dry, two choices	100,00 (0)	0,0 (0)	0,72 (0.2)	29,90 (0.5)
untreated, wet	67,67 (36,1)	2 (2.2)	2,61 (1.5)	139,66 (21.2)
untreated, dry	32,67 (29,8)	3,43 (1.6)	4,56 (0.5)	45,10 (14.5)

7. CONCLUSIONS

- The PLEOT system protected Scots pine sapwood samples from attack by *Coniophora puteana* in laboratory trials.
- The samples treated with PLEOT had lower wood moisture content than untreated samples in the test against brown rot.
- The reduced wood moisture content of samples due to protection by means of PLEOT is not unfavorable for fungal attack.
- The PLEOT system transfers metal ions through the wood samples.
- The transferred metal ions are believed not to provide the wood protection effect.
- Conductive carbon fibers are not suitable for PLEOT setup.
- Other materials such as two component glue and conductive plastic is suitable to connect PLEOT to wood samples in lab trials.
- The PLEOT system may protect wood from decay in soil contact.
- PLEOT reduced mould growth on wet wood samples in a termite test.
- PLEOT reduced mass loss in wood samples exposed to termites for 4 weeks.

8. DISSEMINATION

Treu, A. & Larnøy, E. 2010. Wood protection by means of electro osmotic pulsing technology (PLEOT). *In:* International Research Group on Wood Protection, Biarritz, 9-13 May 2010, France. IRG/WP 10-40505: 10 pp.

9. LITERATURE

Bravery, A. F. (1978). A miniaturised wood-block test for rapid evaluation of wood preservative fungicides. The International Research Group on Wood Preservation, Peebles, Scotland.

Dix, N. J. and J. Webster (1995). Fungal ecology, Chapman & Hall.

Schmidt, O. (2006). Wood and Tree Fungi - Biology, Damage, Protection and Use, Springer Verlag.

Skoog, D. A., F. J. Holler, et al. (1998). Principles of Instrumental Analysis, Thomson Learning London.