

Mould and decay resistance of wood treated with bio-friendly preservative systems

Waldemar Perdoch

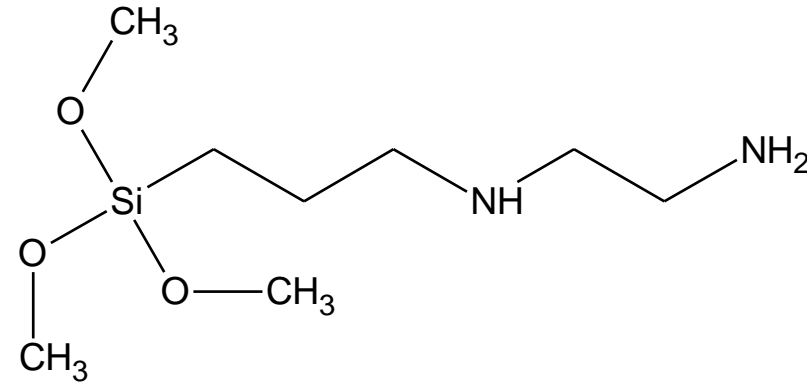
Bio-friendly preservative systems for enhanced wood durability - the DURAWOOD project

Anna Komasa, Anna Klementyna Przybył, Piotr Barczyński, Izabela Ratajczak, Kinga Szentner, Magdalena Woźniak, Paweł Kowalewski, Waldemar Perdoch, Grzegorz Cofta, Patrycja Kwaśniewska-Sip, Joanna Siuda, Wojciech Grześkowiak, Tomasz Krystofiak, Lone Ross Gobakken, Janka Dibdiakova, Magdalena Broda, Bartłomiej Mazela

Introduction

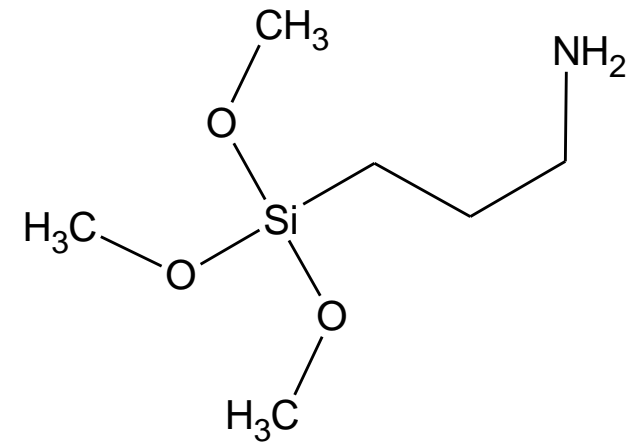
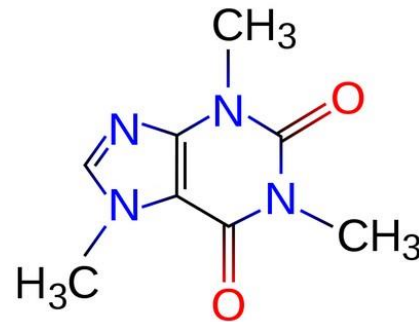
Silicons - Advantages:

1. Exceptional hydrophobic properties
2. Low toxicity
3. Resistant to fungi (aminosilanes)



Alkaloids – Advantages:

1. Natural substance
2. Low toxicity
3. Resistant to fungi



Aim of the study

**New biocide-free preservatives
for wood treatment**

Natural oils/
K₂CO₃/
Caffeine

+

Organosilicon
compounds



Limited fungi action of the treated wood

Experimental methods

Wood species

1. Pine - 540 kg/m³

Solvents

1. White spirit (Solvent-based SB)
2. Water (W)

Chemical compounds

1. Tung oil
2. Linseed Oil
3. Potassium carbamate (K₂CO₃)
4. Caffeine
5. Alkyd resin (AB)
6. Water alkyd resin (WAB)
7. Organosilicon compounds
 1. [3-(2-Aminoethylamino)propyl]trimethoxysilane (AATMOS),
 2. (Aminopropyl)triethoxysilane (APTEOS),
 3. (Aminopropyl)trimethoxysilane (APTAMOS)

Experimental methods

Vacuum impregnation:

15 minutes - vacuum conditions
(0.8MPa)

2 h - atmospheric pressure

Soaking method:

2.5 h - atmospheric pressure

Mycological examination

ASTM D 5590 (*A. niger*)

EN – 113 *C. puteana*

ASTM D 5590 (*A. niger*)

EN – 839

C. puteana – pine

Ageing method – EN 84

Impregnation methods

Soaking			
Chemical composition of examined formulations	Solvent	Number of samples	
		Unleached	Leached (EN-84)
14% Tung oil; 5%APT MOS;6%AB	Sb	5	5
6%AB	Sb	5	5
6%WAB	W	5	5
14%Linseed oil; 5%APT MOS;6%AB	Sb	5	5
5%AAT MOS;6%AB	Sb	5	5
5%AAT MOS;6%WAB	W	5	5
2%Caffeine;6%WAB	W	5	5
2%Caffeine;5%AAT MOS;6%WAB	W	5	5
2%Caffeine;5%APTEOS;6%WAB	W	5	5

Vacuum			
Chemical composition of examined formulations	Solvent	Number of samples	
		Unleached	Leached (EN-84)
20%Tung oil; 5%APT MOS	Sb	5	5
20%Linseed oil; 5%APT MOS	Sb	5	5
5%AAT MOS	Sb	5	5
5%APT MOS	W	5	5
5%AAT MOS	W	5	5
5%APTEOS	70% EtOH	5	5
2%Caffeine	W	5	5
10%K ₂ CO ₃ ;5%AAT MOS	W	5	5
10%K ₂ CO ₃ ;5%APTEOS	W	5	5
2%Caffeine;5%AAT MOS	W	5	5
2%Caffeine;5%APTEOS	W	5	5

The average value of *A. niger* overgrowing index after 3 weeks of exposure

Model protective system composition	Ratio of components	Concentration [%]	Medium	Treatment method	Without ageing	After ageing – EN84
AATMOS	-	5	SB	S	3,4	4,0
TO+APT MOS	4:1	25	SB	S	3,4	4,0
LO+AATMOS	4:1	25	SB	S	3,2	4,0
TO+APT MOS	4:1	25	SB	V	0,8	3,0
LO+AATMOS	4:1	25	SB	V	1,2	4,0
AATMOS	-	5	SB	V	1,0	2,0
AATMOS	-	5	WB	S	4,0	4,0
AATMOS	-	5	WB	V	2,0	3,0
APT MOS	-	5	Et-OH	S	4,0	4,0
APT MOS	-	5	Et-OH	V	4,0	4,0
APT EOS	-	5	Et-OH	S	4,0	4,0
APT EOS	-	5	Et-OH	V	4,0	2,2

The average value of *A. niger* overgrowing index after 4 weeks of exposure –
 formulation: Caffeine /AATMOS (W)

	week 1			week2			week3			week4		
	Treated	Inhibition zone	Control	Treated	inhibition zone	Control	Treated	inhibition zone	Control	Treated	inhibition zone	Control
Unleaching	index											
	0	z	4	0	-	4	0	-	4	0	-	4
	0	z	4	0	-	4	0	-	4	0	-	4
	0	z	4	0	-	4	0	-	4	1	-	4
	0	z	4	0	-	4	0	-	4	0	-	4
	0	z	4	0	-	4	0	-	4	2	-	4
Leaching	0	-	4	0	-	4	0	-	4	0,6	-	4
	0	-	4	0	-	4	0	-	4	1	-	4
	0	-	4	0	-	4	1	-	4	1	-	4
	0	-	4	1	-	4	2	-	4	2	-	4
	0	-	4	1	-	4	1	-	4	2	-	4
	0	-	4	2	-	4	2	-	4	2	-	4
	0	-	4	0,8	-	4	1,2	-	4	1,6	-	4

The results of mycological screening tests against *C. puteana* - vacuum impregnation

Model protective system composition	Solvent	Without leaching						After leaching (EN84)					
		Retention [kg/m ³]	RSD	WMC [%]	RSD	ML [%]	RSD	Retention [kg/m ³]	RSD	WMC [%]	RSD	ML [%]	RSD
MTMOS 5%	SB	21.2	1.01	78.0	15.2	16.30	5.1	21.2	1.3	65.6	22.4	11.23	2.84
	Et-OH	27.6	0.3	65.4	12.1	18.97	4.9	28.0	1.0	78.2	22.5	22.67	12.1
APT MOS 5%	SB	29.2	2.1	74.6	10.1	1.54	0.65	29.1	1.4	57.2	15.4	18.47	2.2
	Et-OH	29.7	1.0	101.5	10.3	1.45	1.7	22.8	2.0	48.6	13.4	0.63	0.9
	WB	47.9	1.3	62.4	12.5	2.39	0.7	50.3	1.7	47.7	19.5	10.89	9.7
AATMOS 5%	SB	21.1	1.1	103.9	7.1	1.59	0.7	22.0	1.1	52.7	15.5	2.76	0.5
	Et-OH	28.2	1.0	77.5	6.4	3.06	0.5	28.5	1.1	51.3	20.4	7.39	1.4
	WB	37.4	1.0	106.9	18.0	0.78	0.5	35.5	1.3	38.6	8.8	1.41	0.3
APTEOS 5%	WB	42.7	2.4	58.9	5.2	2.17	0.7	40.8	1.3	36.9	4.9	2.09	0.4
AATMOS 5% + K ₂ CO ₃ 10%	WB	40.2	0.6	78.7	6.9	2.68	0.3	43.1	2.0	55.2	5.9	8.52	0.4
APTEOS 5% + K ₂ CO ₃ 10%	WB	42.7	1.6	96.9	12.9	2.17	0.4	40.8	2.0	54.5	11.5	2.09	0.2
AATMOS 5% + Caffeine 2%	WB	67.0	2.5	115.5	7.8	2.81	0.4	63.4	1.9	39.6	6.7	2.27	0.3
APTEOS 5% + Caffeine 2%	WB	55.6	3.3	132.8	11.2	5.90	0.5	53.1	2.0	47.5	11.0	4.05	0.5
APTEOS 4% + MTMOS 1% + Caffeine 2%	WB	55.6	2.7	110.8	5.4	3.64	0.8	56.3	2.0	43.3	7.2	3.51	0.3
APTEOS 8% + MTMOS 2% + Caffeine 2%	WB	58.8	1.0	132.0	3.6	-	-	55.3	2.1	52.1	4.1	4.01	0.3
Propolis 30% + VT MOS 8% + MTMOS 2%	WB	281	14.1	23.6	1.8	3.73	2.9	-	-	-	-	-	-

The results of the mycological tests of pine against *C. puteana* – soaking impregnation

Model protective system composition			Test result											
Active ingredients	Concentration	Medium	Unleached						Leached (EN-84)					
			Retention	Weight loss treated samples (RSD ^{***})	Moisture treated samples (RSD)	Weight loss untreated sample (RSD)	Moisture untreated samples (RSD)	Durability class	Retention	Weight loss treated samples (RSD)	Moisture treated samples (RSD)	Weight loss untreated sample (RSD)	Moisture untreated samples (RSD)	Durability class
	[%]	[g/m ²]	[%]	[%]	[%]	[%]	[-]	[g/m ²]	[%]	[%]	[%]	[%]	[%]	[-]
Tung oil	14	Ws	14.7	4.0 (4.0)	27.1 (9.0)	48.6 (6.1)	43.3 (8.5)	1	15.2	39.8 (5.9)	40.9 (1.5)	42.2 (4.5)	41.3 (4.6)	5
APTAMOS	5		5.2						5.4					
AB	6		6.3						6.0					
AB	6	Ws	10.9	40.7 (9.2)	41.4 (2.1)	43.4 (4.8)	43.6 (1.9)	5	8.4	37.7 (1.5)	42.6 (3.6)	40 (2.5)	42.1 (3.5)	5
WAB	6	Ws	36.9	38.7 (6.7)	40.2 (2.8)	42.6 (6.6)	40.5 (2.5)	5	27.7	63.1 (6.5)	38.7 (1.5)	38.7 (3.0)	36.1 (6.5)	5
Linseed oil	14	Ws	16.4	35.2 (1.9)	41.1 (3.7)	39.4 (3.7)	46.9 (1.5)	5	15.3	40.3 (6.4)	41.5 (1.0)	43.8 (5.8)	40.4 (4.1)	5
APTAMOS	5		5.8						5.5					
AB	6		7						6.6					
AATMOS	5	Ws	9.3	44.8 (5.8)	42.5 (2.0)	40.8 (4.9)	41.0 (2.4)	5	7.3	40.6 (5.6)	41.5 (3.0)	41.7 (4.9)	41.2 (2.7)	5
AB	6		11.2						8.7					
AATMOS	5	W	19.7	43.5 (1.1)	39.1 (1.1)	43.4 (1.6)	41.5 (1.6)	5	24.7	45.6 (1.4)	38.9 (1.4)	40.7 (1.1)	45.6 (2.4)	5
WAB	6		23.6						29.7					
Caffeine	2	W	9.1	20.3 (7.7)	31.0 (2.4)	40.6 (6.0)	42.8 (2.1)	3	8.7	42.7 (3.9)	39.5 (0.9)	43.2 (4.3)	43.2 (1.2)	5
WAB	6		27.3						26.7					
Caffeine	2	W	10	8.0 (6.0)	28.6 (1.3)	43.4 (5.8)	43.0 (3.6)	2	12	35.7 (4.4)	34.1 (1.8)	37.1 (4.8)	35.7 (4.4)	5
AATMOS	5		24.9						29.9					
WAB	6		29.9						35.9					
Caffeine	2	W	19.2	1.8 (0.6)	38.1 (1.7)	42.7 (6.1)	43.1 (5.1)	1	14.7	31.6 (5.1)	33.6 (2.2)	33.3 (5.9)	40.7 (1.8)	5
APTEOS	5		48.1						36.7					
WAB	6		57.7						44.1					

The results of the mycological tests of pine wood against *C. puteana*-vacuum impregnation.

Model protective system composition			Test result											
Active ingredients	Concentration	Medium	Unleached						Leached (EN-84)					
			Retention	Weight loss treated samples (RSD)	Moisture treated samples (RSD)	Weight loss untreated sample (RSD)	Moisture untreated samples (RSD)	Durability class	Retention	Weight loss treated samples (RSD)	Moisture treated samples (RSD)	Weight loss untreated sample (RSD)	Moisture untreated samples (RSD)	Durability class
	[%]	[kg/m ²]	[%]	[%]	[%]	[%]	[-]	[kg/m ²]	[%]	[%]	[%]	[%]	[%]	[-]
Tung oil	20	Ws	48	0.7	52.0	35.5	71.2	1	58	18.1	53.4	41.9	74.9	3
APTAMOS	5		12	(1.5)	(4.7)	(5.2)	(5.6)		14.6	(7.4)	(16.2)	(6.7)	(4.4)	
Linseed oil	20	Ws	48.6	6.2	51.6	50.2	73.9	1	42.7	45.9	62.8	41.5	73.1	5
APTAMOS	5		12.2	(3.0)	(12.6)	(4.3)	(4.6)		10.7	(8.5)	(9.1)	(2.6)	(5.5)	
AATMOS	5	Ws	16.4	0.5	95.6	53.1	72.9	1	17.2	32.0	58.8	42.1	84.2	4
				(1.4)	(6.5)	(1.1)	(5.5)			(4.2)	(13.4)	(7.9)	(10.0)	
APTAMOS	5	W	31.2	3.4	101.1	54.5	70.7	1	31.2	41.8	71.2	36.6	75.3	5
				(0.6)	(11.1)	(3.8)	(2.3)			(5.8)	(5.8)	(3.3)	(6.2)	
AATMOS	5	W	29.4	1.5	76.3	57.5	70.6	1	30.1	22.7	52.7	45.1	78.5	3
				(0.9)	(12.3)	(8.9)	(4.5)			(4.2)	(17.1)	(5.3)	(11.5)	
APTEOS	5	70% EtOH	27.6	7.2	73.1	52.5	73.9	1	24.9	40.7	74.6	40.5	61.6	4
				(3.8)	(13.4)	(6.8)	(5.5)			(10.6)	(30.0)	(4.5)	(27.9)	
Caffeine	2	W	12.4	1.4	56.5	49.5	83.3	1	12.1	22.8	43.0	38.4	88.2	3
				(0.1)	(12.0)	(2.2)	(4.8)			(2.1)	(1.1)	(4.0)	(13.0)	
K ₂ CO ₃	10	W	69.1	6.9	148.1	41.5	58.9	1	70.6	55.4	95.9	38.3	75.3	5
AATMOS	5		34.5	(1.8)	(14.3)	(5.3)	(8.3)		35.3	(8.0)	(17.2)	(2.3)	(2.3)	
K ₂ CO ₃	5	W	67.0	4.8	148.7	44.9	122.0	1	70.6	62.6	122.0	48.4	91.9	5
APTEOS	10		33.5	(1.5)	(18.0)	(3.7)	(91.9)		35.3	(2.4)	(13.7)	(4.9)	(42.8)	
Caffeine	2	W	13.7	1.6	77.7	40.7	69.8	1	13.1	2.2	35.8	46.9	76.1	1
AATMOS	5		34.2	(0.1)	(7.1)	(3.4)	(3.3)		32.7	(0.6)	(4.3)	(3.9)	(2.2)	
Caffeine	2	W	13.7	1.6	91.9	48.4	81.3	1	13.5	5.8	46.3	36.8	70.9	2
APTEOS	5		34.2	(0.0)	(10.1)	(5.8)	(5.7)		33.7	(1.5)	(10.1)	(4.1)	(4.6)	

Summary

- 1) The model, bio-friendly wood protective systems based on: alkaloids, plant oils and organosilicon compounds have potential to protect wood against biological degradation (mould, decay)
- 2) More than 110 formulations have been tested so far against *A. niger*, *C. puteana*.
- 3) Aminosilanes formulated with natural oils or with caffeine are able to protect wood against microfungi and wood destroying fungi.

DURAWOOD

The work is supported by Norway Grants and the National Centre for Research and Development in Poland (NCBR) as part of Polish-Norwegian Research Program 11 within the framework of the project “Superior bio-friendly systems for enhanced wood durability” (No. Pol-Nor/203119/32, DURAWOOD).

Thank you for attention

