THE TREATABILITY OF THREE LESSER-USED GHANAIAN HARDWOOD TIMBER SPECIES

Joseph Ofori* & R.K. Bamfo, Jr**

***Forestry Research Institute of Ghana,
UST P. O. Box 63, Kumasi, Ghana.**

****Ghana Forestry Commission,
P. O. BOX M.434, Accra, Ghana.**

ABSTRACT - The treatability of three lesser-known timber species, namely, Kyenkyen (*Antiaris africana*), Esa (*Celtis mildbraedii*) and Otie (*Pycnanthus angolensis*) was investigated using a commercial copper-chrome-arsenate (CCA) preservative and treatment by the vacuum-pressure method at varying pressure magnitudes (690, 828, 966 or 1104 kPa) and treatment durations (0.5, 1, 2 and 4 hours). Net dry salt retentions and depths of penetration were determined, and a permeability assessment of the different wood species was made.

Preservative penetration increased significantly with increase in pressure in all three species, while preservative retention increased with pressure and time in *A. africana* and *C. mildbraedii.* There was no discernible effect of time on lateral penetration. Preservative distribution pattern in the tissues for all three species was either patchy or mottled.

A. africana sapwood and heartwood are moderately resistant to preservative treatment at a pressure of 1104 kPa for a period of one hour or more, or a pressure of 966 kPa for two hours or more. The sapwood and heartwood of *P. angolensis* and *C. mildbraedii* on the other hand, are resistant even if treated at 1104 kPa for 2 hours or more using CCA preservative.

Keywords - ***Antiaris africana, Celtis milbraedii, Pycnanthus angolensis,* treatability, vacuum-pressure**

INTRODUCTION

Kyenkyen (*Antiaris africana*), Esa (*Celtis mildbraedii*) and Otie (*Pycnanthus angolensis*) are indigenous species which are widely distributed in the high forest of Ghana. Danso (1975) reported that Celtis is the third most predominant wood species in Ghana after Wawa (*Triplochiton scleroxylon*), and Ofram (*Terminalia superba*); Antiaris is the seventh most frequent wood species, while Pycnanthus ties up with Odum (*Chlorophora excelsa*) at the tenth position. In a more recent study (Ghartey, 1989), Antiaris was found to constitute about 4.3% by volume of Forest Inventory Project (FIP) class I traditional species with diameter at breast height (dbh) greater than 70cm, while for trees with dbh greater than 30cm, Celtis is the second most abundant species by volume (12%), and Antiaris and Pycnanthus are the sixth most abundant (about 3% by volume each).

All the three species are susceptible to attack by termites, wood borers and staining fungi (Ofori, 1985). Biodeterioration of the three species may be minimized or eliminated if the species are suitable for complete or satisfactory treatment with wood preservatives. Treatment will increase service life and enhance the utilisation of these non-durable timbers which occur abundantly in our forests.

Irvine (1961) has indicated that the heartwood of Antiaris and Pycnanthus are fairly easy to impregnate with preservatives while Celtis heartwood is moderately resistant. Using coal-tar creosote (an oil-borne preservative) and treatment by the Hot-and-Cold Method, Redding (1971) rated the sapwood of the three species and the heartwood of Antiaris and Pycnanthus as permeable, and the heartwood of Celtis as moderately resistant. The Building Research Establishment (B.R.E.) (1979) has also used coal-tar creosote and full-cell treatment and rated the sapwood and hardwood of Antiaris and Pycnanthus as permeable, while the heartwood of Celtis is rated as moderately resistant.

However, with resistant timbers, differences in treatability (retention and penetration) have been found between creosote and CCA preservative applied under pressure (Farmer, 1972; Purslow & Redding, 1978). Therefore care should be taken when extrapolating from one type of fluid to another or from pressure treatments to other processes (B.R.E. 1979). Little is known about the permeability of the three wood species to CCA preservatives (the most widely used preservative in Ghana) using the most reliable treatment method, the vacuum-pressure impregnation. This study attempts to address this situation.

MATERIALS AND METHODS

Three trees each of Antiaris, Pycnanthus, and Celtis were obtained from the Bobiri Forest Reserve, about 30 km south-east of Kumasi in the moist semi deciduous forest type. Sapwood and heartwood billets of 35 mm x 35 mm x 700 mm were cut and dried to moisture contents of between 7.5 and 10.3%. The billets were cross-cut and planed into knot-free samples of dimensions 30 mm x 30 mm x 200 mm.

Basic Density

The basic densities of supplementary wood samples obtained from the billets after extracting samples earmarked for treatment were determined by the liquid displacement method on the oven dry weight and green volume basis. Fifteen replicates (5 from each tree) for each of sapwood and heartwood were used for each species.

Treatment

For each species, 96 sapwood and 96 heartwood samples (24 from each of three trees) were used for treatment. Dried test specimens were weighed, and one-third each of the samples sealed either at all four sides or at both ends and both radial faces, or at both ends and both tangential faces with two coats of an epoxy resin depending on whether penetration was being studied in the longitudinal, tangential or radial directions. The coated samples were dried and weighed prior to treatment.

The coated and dried samples were treated with a 1% (wt/vol) solution of Celcure A, a CCA Type II wood preservative conforming to the British Standard BS 4072 (British Standards Institution, 1974) using the full cell method and the schedules below:

Initial vacuum : 633 mm Hg maintained for 15 minutes.
Pressure magnitude : 690, 828, 966 or 1104 kPa (ie 100, 120, 140 or 160 lb/in^2).
Pressure duration : 0.5, 1, 2 or 4 hours.

After each treatment, excess preservative was blotted out with filter paper and the wood weighed to determine the preservative uptake. The treated wood samples were then conditioned by close piling for three weeks for fixation to take place and then left to air dry in the fourth week.

Measurement of Penetrability

The preservative treated samples were cut in half transversely. One-half was split longitudinally in the radial-longitudinal direction and the other half in the tangential-longitudinal direction. The exposed surfaces were then sprayed with chrome azurol S solution to indicate the presence of copper. The wood turned blue in the presence of copper where the CCA had penetrated, whereas the untreated zones were coloured red. The depth of penetration was measured in the longitudinal and transverse directions.

The method of Fougerousse (1976) was adopted in assessing the permeabilty of the three species to impregnation. The percent surface area penetrated were classified as follows:

% Area Penetrated	Classification
> 90	Permeable, P
50 - 90	Moderately resistant, MR
10 - 50	Resistant, R
< 10	Extremely resistant, ER.

RESULTS AND DISCUSSIONS

Basic Density and Theoretical Maximum Absorptions

The maximum absorption (litres of preservative per m^3 of wood) can be closely approximated by the following equation (McQuire, 1975) taking into account the basic density (BD, Kg/m^3) and the moisture content (m.c.%) of the wood:

Maximum Absorption ($litres/m^3$)
$= 1000 -[BD \times (m.c. \times 66.7)] / 100.$

The basic density and moisture content of the wood specimens before treatment, and the maximum theoretical absorption of preservatives are given in Table 1. The sapwood of Antiaris is significantly denser than its heartwood. However the sapwoods of celtis and pycnanthus are not significantly denser than their respective heartwoods.

Differences in Retention at Varying Times and Pressures

The uptake of preservative were calculated as volumetric retentions at different treatment durations and magnitudes of pressure. In addition, these absolute volumetric retentions (kg/m^3) were converted into relative volumetric retentions (%) using the calculated theoretical maximum absorptions as reported in Table 1.

The results of both the absolute and relative volumetric retentions have been summarized in Table 2. The influence of treatment duration and pressure magnitude on the relative volumetric retention are shown graphically in figs 1A and 1B respectively.

There were statistically significant differences in absolute retentions, with Antiaris recording the highest absolute volumetric retentions, and Celtis retaining the least amount of preservative per unit volume of wood. However, when the absolute volumetric retentions were converted into percent relative retentions based on the theoretically possible maximum absorptions due to the limitations of basic density and moisture content, a different trend is observed. It is found that Celtis rather retained the greatest percent of preservative based on the maximum theoretically obtainable. For schedule 4 hrs/1104 kPa, relative volumetric retentions of between 92 - 98 % were obtained. Retentions were not significantly different for the two other species.

Differences in treatability between sapwood and heartwood in all three species were generally not statistically significant, even though, sapwood retention appeared to be slightly greater than that of heartwood.

Figures 1A and 1B show that there was generally a sharp increase in retention up to one hour for the low pressure treatments, after which there was a slight increase in retention for the subsequent treating times.

The results of an analysis of variance carried out on the preservative retentions are shown in Table 3. The effect of treatment duration on retention was statistically significant in the sapwood and heartwood of both Antiaris and Celtis. Time influenced the retention of preservative in the sapwood of Antiaris and Celtis. In Pycnanthus, the effect of time on preservative retention was not significant in both the sapwood and heartwood.

The effect of pressure magnitude on preservative retention was significant for Antiaris and the sapwood of Celtis; it was however not significant the sapwood and heartwood of Pycnanthus.

Table 1: Basic Density, Moisture Content and Theoretical Maximum Absorption of the three species.

Wood Species		Moisture Content %		Basic density kg/m3		Max. Absorption
		Mean	S.D.	Mean	S.D.	l/m3
Antiaris	Sapwood	7.5	0.75	339	27	749
	Heartwood	8.1	0.17	296	9	778
Celtis	Sapwood	10.3	0.17	639	95	508
	Heartwood	10.0	0.60	641	89	511
Pycnanthus	Sapwood	7.8	0.10	489	68	636
	Heartwood	7.9	0.23	447	38	668

Table 2: The Influence of Treatment Duration and Pressure Magnitude on the Absolute and Percent Relative Volumetric Retention

Wood Species		Trt. Time (hr)	Absolute Volumetric Retn.(kg/m3) Treatment Pressure, kpa 690	828	966	1104	Relative Volumetric Retn.(%) Treatment Pressure, kpa 690	828	966	1104
Antiaris	Sap	0.5	199	337	423	475	26.6	45.0	56.5	63.4
		1	406	414	434	482	54.2	55.3	57.9	64.4
		2	415	421	443	560	55.4	56.2	59.1	74.1
		4	428	441	452	582	57.1	58.9	60.3	77.7
	Heart	0.5	190	377	425	501	24.4	48.5	54.6	64.4
		1	394	409	455	529	50.6	52.6	58.5	68.0
		2	452	456	550	579	58.1	58.6	70.7	74.4
		4	466	526	563	588	59.9	67.6	72.4	75.6
Celtis	Sap	0.5	201	372	384	395	39.6	73.2	75.6	77.8
		1	387	402	411	420	76.2	79.1	80.9	82.7
		2	394	400	435	484	77.6	78.7	85.6	95.3
		4	433	446	470	497	85.2	87.8	92.5	97.8
	Heart	0.5	229	288	372	391	44.8	56.4	72.8	76.5
		1	320	384	392	417	62.6	75.1	76.7	81.6
		2	404	415	435	464	79.1	81.2	85.1	90.8
		4	412	448	467	473	80.6	87.7	91.4	92.6
Pycnanthus	Sap	0.5	255	347	398	414	40.1	54.6	62.6	65.1
		1	281	362	408	434	44.2	56.9	64.2	68.2
		2	313	365	426	460	49.2	57.4	67.0	72.3
		4	355	411	446	470	55.8	64.6	70.1	73.9
	Heart	0.5	254	375	430	439	38.0	56.1	64.4	65.7
		1	346	399	432	446	51.8	59.7	64.7	66.8
		2	355	421	443	496	53.1	63.0	66.3	74.3
		4	404	428	454	515	60.5	64.1	68.0	77.1

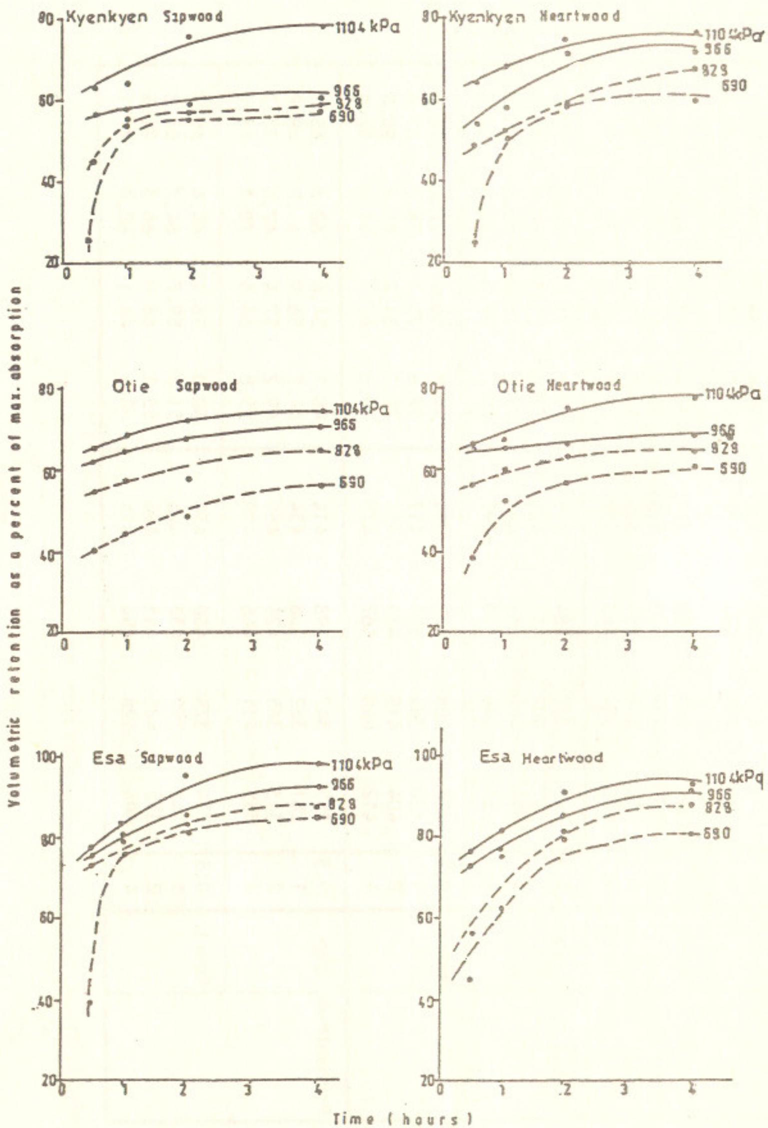

Fig. 1A: Influence of time on the volumetric retention of treating solution at constant pressure.

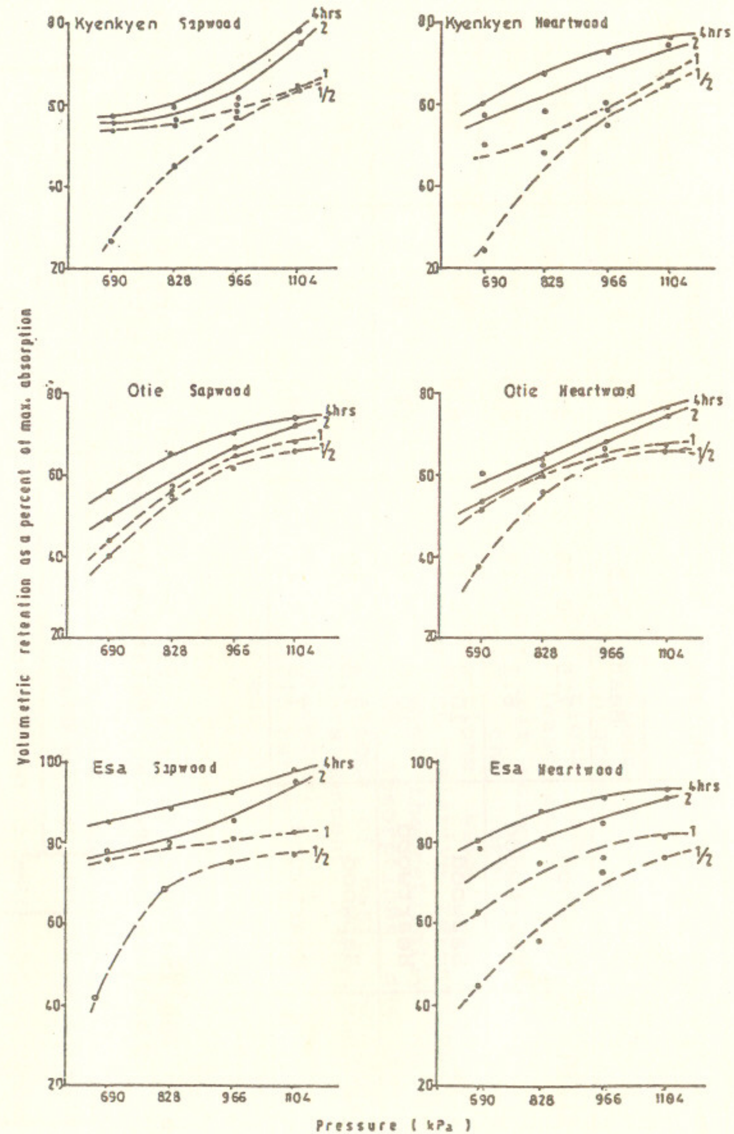

Fig. 1B: Influence of pressure on the volumetric retention of treating solution at constant time.

Table 3: Differences in Preservative Retentions in Antiaris, Celtis and Pycnanthus

Wood Species	Section of wood	Source of Variation		F
Antiaris	Sapwood	i. Pressure	a. Between Batches b. Within "	7.92*
		ii. Time	a. Between Batches b. Within "	11.40*
	Heartwood	i. Pressure	a. Between Batches b. Within "	12.96*
		ii. Time	a. Between Batches b. Within "	8.03*
Celtis	Sapwood	i. Pressure	a. Between Batches b. Within "	6.02*
		ii. Time	a. Between Batches b. Within "	11.35*
	Heartwood	i. Pressure	a. Between Batches b. Within "	1.60
		ii. Time	a. Between Batches b. Within "	3.24*
Pycnanthus	Sapwood	i. Pressure	a. Between Batches b. Within "	1.61
		ii. Time	a. Between Batches b. Within "	0.33
	Heartwood	i. Pressure	a. Between Batches b. Within "	2.70
		ii. Time	a. Between Batches b. Within "	0.41

* significant at P = 0.05.

Differences in Penetrability between and within species

Figures 2 and 3 show the influence of time at constant pressure on the depth of radial penetration, and longitudinal penetration of fibres and vessels.

Penetration varied significantly according to the direction of grain, with penetration in the longitudinal direction being about six times greater than penetration in either the radial or tangential direction. Differences between radial and tangential penetrations were neither consistent nor significant at low pressures and for short duration treatments. The depth of penetration in either the tangential or radial direction was not significantly affected by increase in treating time. At high pressure magnitudes, however, a significant increase in the depths of tangential and radial penetration were observed, with the radial depth being greater than the tangential depth.

Generally, the depth of longitudinal penetration increased significantly with increase in treating time. The depth of longitudinal penetration increased as the pressure increased in both sapwood and heartwood of all the species.

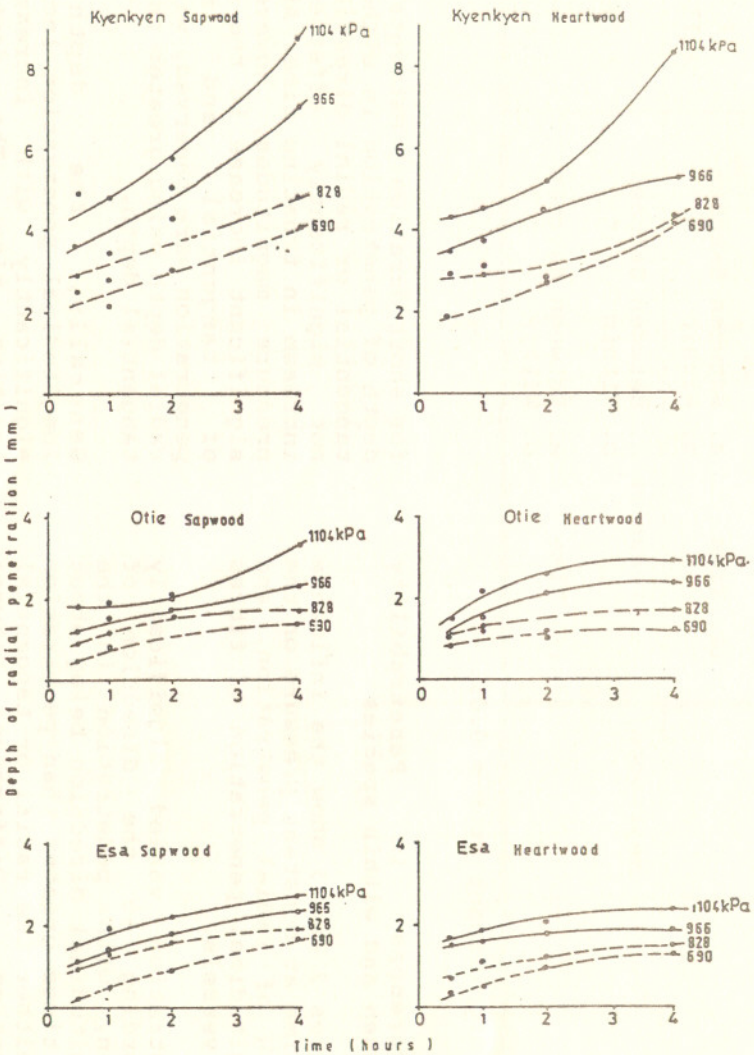

Fig. 2 Influence of time at constant pressure on depth of radial penetration.

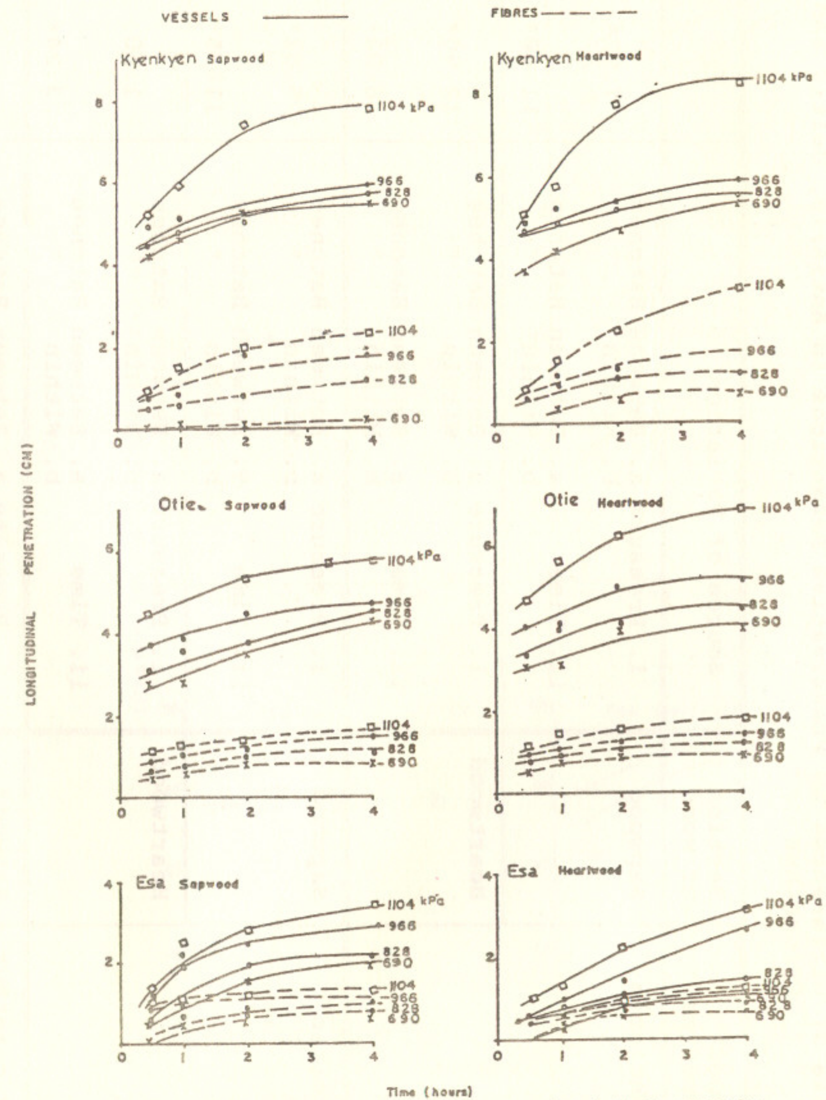

Fig. 3 Influence of time at constant pressure on longitudinal penetration of vessels and fibres.

Distribution of preservative

There were a number of characteristic types of penetration. In Antiaris, the vessels and fibres were penetrated throughout the timber with a large proportion of vessels completely impregnated. In Celtis, however, significantly less number of vessels were penetrated and fibre penetration was largely confined to those within 12mm of ends. Spotted penetration patterns were observed in fibres

Table 4: Mean Percent Surface Area Penetrated

Wood Species		Trt. Time (hr)	Surface Area Penetrated, %					
			Treatment Pressure, kPa					
				690	828	966	1104	
Antiaris	Sapwood	0.5		25	31	40	49	R
		1		27	34	41	52	MR
		2		31	44	50	61	
		4	R	39	49	61	70	
	Heartwood	0.5		26	32	39	46	R
		1		31	36	41	51	MR
		2		34	38	50	54	
		4	R	40	45	56	75	
Celtis	Sapwood	0.5		2	11	14	19	R
		1	ER	9	15	17	23	
		2		13	20	23	27	
		4	R	19	23	28	31	
	Heartwood	0.5		4	11	17	21	R
		1	ER	9	13	20	25	
		2		13	14	23	26	
		4	R	16	18	24	28	
Pycnanthus	Sapwood	0.5		6	12	13	20	R
		1	ER	9	12	19	23	
		2		15	20	23	26	
		4	R	18	22	28	36	
	Heartwood	0.5	ER	8	12	17	21	R
		1		12	15	20	26	
		2		13	15	23	31	
		4	R	15	21	27	33	

further from the end. In all the three species, the penetrated vessels were scattered at random throughout the timber or occurred in bands. Preservative macro-distribution patterns at the tissue level were, in a majority of cases, either patchy or mottled. The patchy pattern of penetration is, however expected since these species are vessel-porous (ie. the vessels are the major pathways for preservative penetration).

Assessment of Permeability

The percent surface areas penetrated in the three species when treated with CCA by the vacuum-pressure impregnation method using the various pressure magnitudes and durations are shown in Table 4.

The sapwood and heartwood of Antiaris are moderately resistant if treated at a pressure of 1104 kPa for one hour or more, or a pressure of 966 kPa for two hours or more. Pycnanthus and Celtis sapwood and heartwood, on the other hand, are resistant even if treated at 1104 kPa for 2 hours or more. However, the sapwood of these two species are slightly more permeable than their heartwoods. Generally, Pycnanthus is slightly more permeable than Celtis.

Permeability ratings on the basis of the classification by Redding (1971) and B.R.E. (1979) but using CCA and treatment by the vacuum-pressure method shows that Antiaris sapwood and heartwood are moderately resistant (ie, are fairly easy to treat, and it is usually possible to obtain penetration of a large proportion of the vessels) if treated at a pressure of 1104 kPa for a period of about 3 or 4 hours, whereas Pycnanthus and Celtis sapwood and heartwood are resistant (ie, are difficult to impregnate under pressure and require a long period of treatment, and often very difficult to obtain more than about 3 to 6 mm lateral penetration) if treated for the same period under the same pressure using CCA preservative.

CONCLUSIONS

It is concluded that Antiaris sapwood and heartwood are moderately resistant if treated at a pressure of 1104 kPa for a period of one hour or more. Pycnanthus and Celtis sapwood and heartwood, on the other hand, are resistant even if treated at 1104 kPa for two hours or more using the CCA preservative.

In view of the non-uniform distribution of preservative in the three species, it is suggested that in pressure treatments, pressures greater than 1104 kPa are essential to effect adequate treatment of Celtis since it is strong enough to withstand high treating pressures. Treating times can be sufficiently reduced at such high treating pressures.

The moisture content of 12 per cent at which the experiment was carried out was too low for vacuum-pressure treatments. To increase the permeability of the timbers and improve their treatability, drying to a moisture content of below their fibre saturation point (ie around 25 to 30 percent) is suggested.

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