SUITABILITY OF USING PLANTATION-GROWN *NAUCLEA DIDERRICHII* MERILL POLES FOR ELECTRICITY AND TELECOMMUNICATION OVERHEAD SUPPORT LINES IN GHANA – PART 2: TREATABILITY

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ABSTRACT

*One hundred and sixty four (164) poles of plantation-grown Kusia (**Nauclea diderrichii Merill**) of lengths 8 to 13m extracted from the Pra-Anum Forest Reserve in Ghana were kiln-dried and then treated by the full cell vacuum-pressure impregnation method until 'refusal' with a copper-chrome-arsenate wood preservative. The depths of penetration were measured and preservative retention analysed by X-ray fluorescence spectroscopy. Mean sapwood penetration was 91-103% of the sapwood width (30.9 – 52.9 mm). The total oxides retentions (23.75 to 24.81 kg/m^3) in an assay zone of 0-25 mm were higher than the recommended retention of 20 kg/m^3. The preservative oxides balance in the treated poles indicated some disproportionation, with slight differential fixation of the CrO_3 at the expense of the As_2O_5 components. It is recommended that the minimum sapwood width be limited to 25 mm; and that 85-100% sapwood penetration be achieved during treatment. An assay zone of 0-25 mm is recommended. The treatability properties of Kusia render it particularly suitable for use as 8-13 m long poles for high voltage electric transmission and distribution support lines.*

Keywords: **Copper-chrome-arsenate, vacuum-pressure impregnation, depth of penetration, preservative retention.**

INTRODUCTION

The Ghana National Electrification Scheme that aimed at extending the reach of electricity to all parts of the country over a 30-year period was instituted in 1990. The scheme requires at least 50,000 treated poles annually and also additional poles as replacements and reinforcements for existing systems. The treated poles had been traditionally manufactured from plantation-grown teak (*Tectona grandis)* trees. However, it is becoming difficult to obtain these teak pole trees (especially poles longer than 9 m) from the plantations. Currently, most of the 10 m to 12 m long poles are being imported to augment the quantities produced in the country. There is therefore the need to look beyond teak for additional local wood species, which could be used as distribution and transmission poles. Apart from teak, the only other local wood species that has been assessed (Ofori, 2001) and has been found suitable for use as poles for electric support lines is Afina (*Strombosia glaucescens*).

In addition to availability, straight form, adequate weight and good strength, adequate durability and/or amenability to treatment are also important considerations or requirements to be considered for the use of round timbers for overhead transmission and/or distribution poles (BSI, 1984; Aaron and Oakley, 1985; Wolfe and Moody, 1994; Wolfe, 1999).

Wood poles are exposed to harsh environments. Durability is directly related to the expected service life and is a function of natural decay, termite resistance, and treatability. Some species are noted for their natural decay resistance; however, even these may require preservative treatment, depending upon the environmental conditions under which the material is used and the required service life. The service life of poles can vary within wide limits, depending upon properties of the pole, preservative treatments, service conditions, and maintenance practices. In distribution or transmission line supports, however, service life of properly treated poles is often limited by obsolescence of the line rather than the physical life of the pole (Wolfe, 1999).

Treatability depends on penetration and distribution of preservative and adequate retention of preservative. Preservative can usually only be absorbed by sapwood. Wood species with high proportion of treatable sapwood are desirable since they ensure good penetration and retention of preservative. Early or premature failure of treated poles can generally be attributed to one or more of three factors: poor penetration and distribution of preservative, inadequate retention of preservative, and use of a substandard preservative. Properly treated poles can last 35 years or longer.

The availability, form and strength of Kusia (*Nauclea diderrichii* Merill) (a Ghanaian wood species) were discussed in the companion publication (Ofori *et al.,* 2008). The present paper considers factors such as sapwood width, preservative penetration and retention achievable in the Ghanaian Kusia. The natural resistance of the sapwood and heartwood to fungal decay and damage by termites and other insects are briefly mentioned.

The sapwood of Kusia is 25-50 cm wide. The whitish, pale, yellow, pink or grey sapwood is clearly distinguished from the yellow to pale or orange yellow heartwood (G.T.M.B., 1969; Bolza and Keating, 1972; BRE, 1975; ATIBT, 1990).

The sapwood is liable to attack by lyctus or powder-post beetles (Bolza and Keating, 1972; BRE, 1975; ATIBT, 1990). The heartwood is variously described as moderately resistant (BRE, 1975) or resistant (Bolza and Keating, 1972) or very resistant to termites (G. T. M. B., 1969), and resistant to *Anobium* and marine borers (Bolza and Keating, 1972) or very resistant to marine borers (G.T. M. B., 1969). The heartwood is naturally durable (ATIBT, 1990) or very durable (BRE, 1975) to fungal decay. The sapwood is permeable, and the heartwood is moderately resistant to treatment (Bolza and Keating, 1972; BRE, 1975; ATIBT, 1990).

In a previous study (Ofori *et al*, 2008), the circumference taper, the minimum and average sapwood width, and sapwood volume were determined. The basic density and the 'green' modulus of rupture were determined from small 'clear' defect-free specimens; and the fibre stress derived was used to determine the required dimensions of Kusia utility poles.

In the study reported here, the treatability of the sapwood by the standard full cell vacuum-pressure impregnation method using a copper-chrome-arsenate preservative was determined by measuring the depth of penetration, analysing the retention of preservative oxides components by X-ray fluorescence spectroscopy and the level of disproportionation or differential fixation of the preservative components. The minimum sapwood width, the sapwood penetration that may be achievable during treatment and an assay zone that could be used in the retention analysis **are** recommended.

MATERIALS AND METHODS

Pole Source

As part of a routine thinning exercise, 170 trees of plantation-grown Kusia of lengths 7 to 15 m were extracted from the Pra-Anum Forest Reserve [6° 12' - 6° 19' N; and 1° 9' - 1° 17' W] in the moist semi-deciduous forest zone of Ashanti Region of Ghana.

Pole Dimensions Measured

The poles' dimensions and classes, sapwood width and sapwood volume proportions had been previously determined (Ofori *et al.*, 2008).

Drying

One hundred and sixty six green poles (of lengths 8 to 13 m), which had initial moisture contents between 50-57 %, were kiln-dried. The kiln schedule used involved a gradual changing of the initial equilibrium moisture content (EMC), initial dry bulb temperature (DBT), and drying gradient from 14.8%, 50°C, and 2.8 respectively to final EMC, DBT and drying gradient of 2.9%, 65°C, and 2.0 respectively. The moisture contents of the loads were monitored using eight moisture probes, until the mean moisture content in the outer 40 mm of the poles at 1.8 m from the butt was below 25%.

Preservative Treatment

The preservative used was 'Wolman C', a copper-chrome-arsenate (CCA) type C oxide formulation wood preservative, conforming to the American Wood Preserver's Association (AWPA) Standard P5-96 (1996). Each charge or batch of poles was treated by the full cell vacuum-pressure impregnation method. An initial vacuum was applied, built up to -0.87 bar in about 15minutes, and maintained at -0.87 bar for about 10 minutes. After flooding with the preservative, a maximum pressure of magnitude 12.2 bar [12.2×10^5 N/mm^2] was applied and maintained. Treatment continued until 'refusal' and then the pressure was released. No final vacuum was applied.

Preservative Penetration and Retention

The treated poles were then tested for penetration in accordance with procedures in AWPA Standard M2-96 (1996), and for retention using X-ray fluorescence spectroscopy (AWPA Standard A9-96, 1996).

Penetration of Preservative at 3m from Butt

All poles in a charge were sampled. Increment corings were taken within 300 mm above and 300 mm below the brand mark at 3 m from the butt by means of a calibrated increment borer 5 mm in diameter. Treated portions were clearly distinguishable from the untreated portions. There was thus no need to use colour indicators. The depths of preservative penetration were measured.

Retention

The wood density was determined on the increment corings by measuring their length and oven-dry weight. Each increment coring was put in a jig and sectioned at intervals of 5 mm to obtain sections of distances 0-5, 5-10,.., and 35-40 mm from the pole bark. All sections that were equidistant from the pole bark and were penetrated with preservative were grouped together as one sample. The treated samples were dried to achieve 0% moisture content, pelletized, compacted and mounted in a sample holder of the Asoma X-ray fluorescence analyser (AWPA Standard A9-96, 1996). The samples were then irradiated, and the characteristic X-rays of the Cu, Cr and As atoms that were emitted were measured by the sensitive detectors in the X-ray fluorescence analyser. The detector output was the preservative retention of each component (Cu, Cr and As) and were calculated by the analyser and displayed as CuO, CrO_3 and As_2O_5 respectively (AWPA Standard A9-96, 1996).

RESULTS AND DISCUSSION

The sapwood of plantation-grown Kusia is susceptible to lyctus, therefore, rapid extraction and treatment is necessary. Serious end splits occur during air-drying, as such, poles must be cross-cut at least 30 cm longer than the required pole length, and trimmed to the final length after drying.

Drying

The green poles had initial moisture contents between 50.5 and 56.4%. The poles were kiln-dried using the schedule in Table 1 until the mean moisture content in the outer 40 mm of the poles at 1.8 m from the butt was below 25%. It took about 13 days to achieve this moisture level.

Table 1: Kiln schedule used for drying the Kusia poles

Drying days	0	1	2	3	4	5	6	7	9	10	11	12	13	14
Dry Bulb Temperature, °C	50	50	50	55	55	60	60	65	65	65	65	65	65	65
Drying Gradient	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.0	2.0	2.0	2.0
Equilibrium Moisture Content, %	14.8	14.2	11.9	9.9	7.0	6.7	5.4	4.5	3.6	3.4	2.8	2.9	3.1	2.9
Approximate Relative Humidity, %	82	80	72	64	46	46	35	29	22	20	15	16	17	16
Mean Moisture Content, %	54.2	50.4	45.5	42.9	40.2	40.6	38.3	36.4	32.2	29.6	26.6	25.3	23.4	21.3

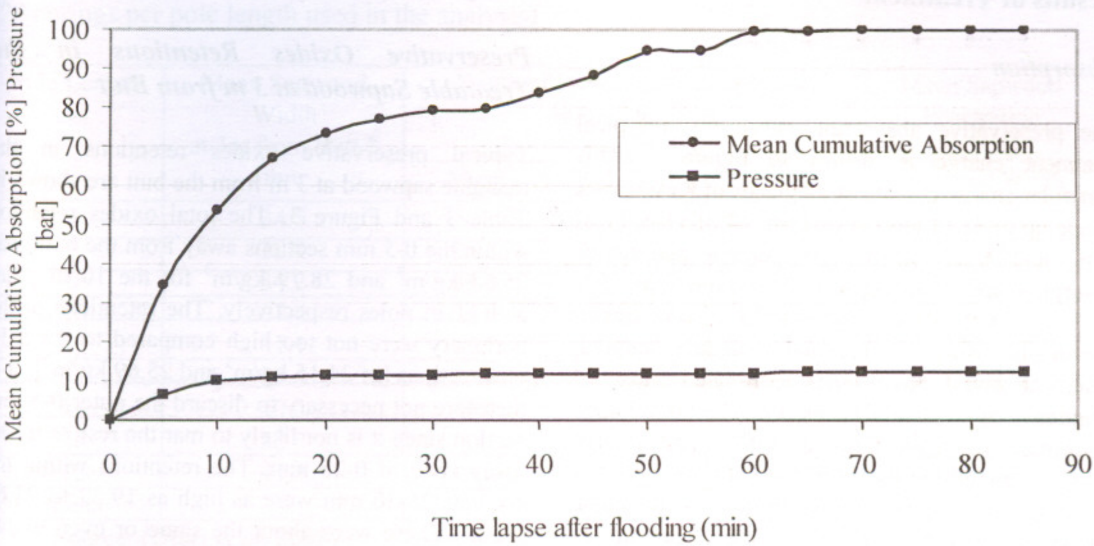

Figure 1: Absorption and pressure build-up in treatment of Kusia poles

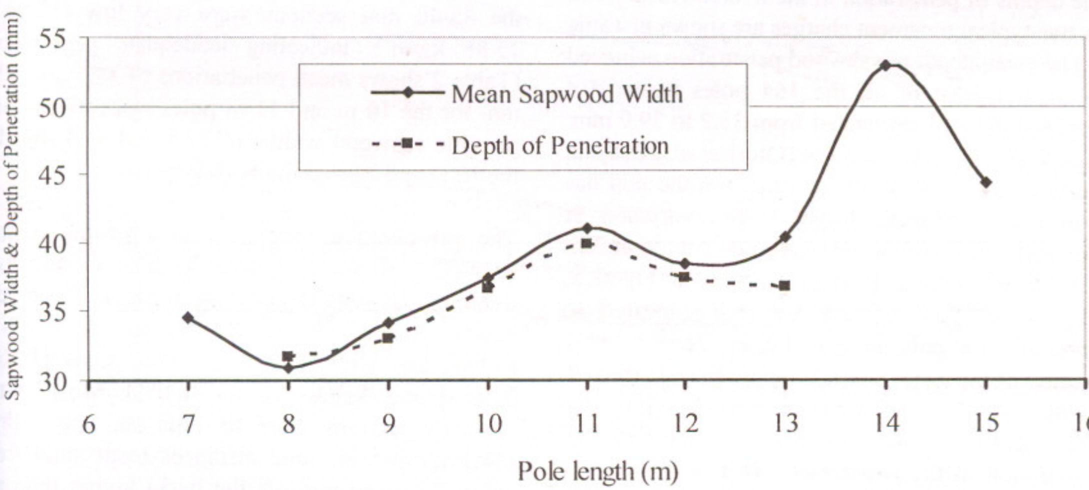

Figure 2: Variation of sapwood width and preservative penetration at 3m from butt with pole length

Results of Treatment

Absorption

The preservative absorption curve for a typical treatment charge is shown in Figure 1. This particular charge contained 76 pieces of Kusia poles (made up of 31 of 8m, 14 of 10m, 14 of 11m, 11 of 12m, and 6 of 13m). The percent cumulative absorption after flooding was 67% within ¼ hr, 88% in ¾ hr and 99% within 1 hr of treatment. Practically, using the treatment schedule adopted, treatment could have been terminated after 70 minutes of application of pressure. The gross gauge absorption was 5,690 litres (of 4.92 % preservative solution strength) in the 26.991 m^3 of poles or 8.394 m^3 of treatable sapwood in the poles. The net gauge absorption was thus 33.35 kg CCA per m^3 of treatable sapwood in the poles.

Preservative Penetration in the Treatable Sapwood at 3 m from Butt

The depths of penetration in the treated Kusia poles for two typical treatment charges are shown in Table 2. The mean depth of sapwood penetration achieved during treatment of all the 164 poles treated (of lengths 8 m to 13 m) ranged from 31.7 to 39.9 mm. Data from the previous study (Ofori *et al*, 2008) on the mean sapwood width at 3 m from the butt has been incorporated in Table 2. The variation of sapwood width and preservative penetration at 3 m from the butt with pole length is shown in Figure 2. Penetration at 3 m from the butt appeared to increase with pole length (Figure 2) apparently because of the increased pole diameter and sapwood width. Analysis of variance (ANOVA) of the differences in the depths of preservative penetration in the Kusia poles (8 m - 13 m) was highly significant ($F_{(5,114)} = 2.294$, $P < 0.001$). Sapwood penetration as a percent of sapwood width ranged from 91 to 103% of the sapwood width, and averaged 97%.

Preservative Oxides Retentions in the Treatable Sapwood at 3 m from Butt

Typical preservative oxides retentions in the treatable sapwood at 3 m from the butt are shown in Table 3 and Figure 3. The total oxides retention within the 0-5 mm sections away from the bark was 25.64 kg/m^3 and 28.79 kg/m^3 for the 10 m poles and 11 m poles respectively. The retentions at the periphery were not too high compared to the 5-10 mm sections [of 24.15 kg/m^3 and 25.69 kg/m^3]. It is therefore not necessary to discard the outer 0-5 mm section since it is not likely to mar the results for an assay zone of 0-25 mm. The retentions within the sections 25-30 mm were as high as 19.57 to 21.65 kg/m^3. These were about the same or even higher than the retention of 20 kg/m^3 recommended in the Ghana Standard GS 145 (Ghana Standards Board, 1992) for high hazard ground contact. The composite retention for all the 5-mm sections from 0 to 25 mm away from the bark averaged 23.75 to 24.81 kg/m^3 for all the charges. The retentions in the 35-40 mm sections were very low (11.98 – 13.85 kg/m^3), indicating inadequate penetration. (Table 2 shows mean penetrations of 36.6 and 39.9 mm for the 10 m and 11 m poles respectively, and possible sapwood widths of 37.4 and 41.1 mm for the 10 m and 11 m poles respectively).

The preservative oxides balance of the treated Kusia poles for the two lengths in the two treatment charges is shown in Table 4. The oxides balance ranges set in AWPA Standard P5-96 (1996) are: CrO_3 [44.5 - 50.5%], CuO [17.0 - 21.0%] and As_2O_5 [30.0 - 38.0%]. Most of the CrO_3 proportions were towards the upper limit (50.5%), and in some instances (especially from about 25 to 40 mm off the bark) higher than the upper limit.

Table 2: Depth of preservative penetration in sapwood of Kusia poles in treatment charges (20 corings per pole length used in the analysis)

Pole Length m	Mean Sapwood Width at 3m from Butt * mm	Depth of Preservative Penetration at 3m from Butt mm			Mean Sapwood Penetration as % of Sapwood Width
		Mean	Std. Dev.	Range	
7	34.5	-	-	-	-
8	30.9	31.7	4.4	25 - 34	102.6
9	34.2	33.0	3.9	27 - 39	96.5
10	37.4	36.6	3.8	29 - 45	97.9
11	41.1	39.9	4.9	30 - 50	97.1
12	38.4	37.4	7.1	31 - 55	97.4
13	40.4	36.8	2.5	30 - 49	91.1
14	52.9	-		-	-
15	44.4	-		-	-
Mean	-	-	-	25 - 55	97.1

* Source: (Ofori *et al*, 2008)

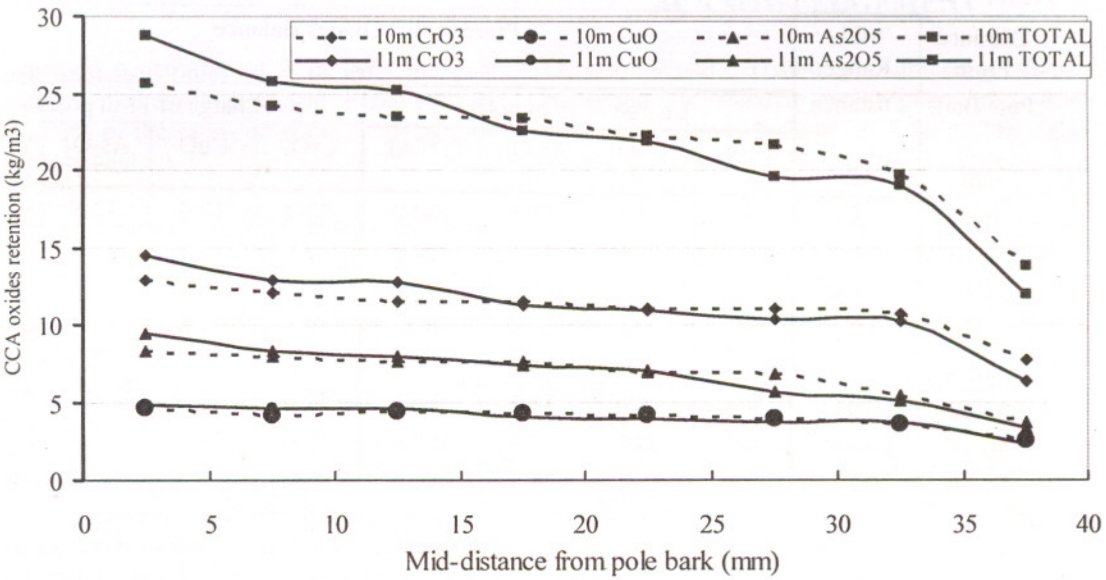

Figure 3: CCA Retention in treated Kusia poles

Table 3: Typical incremental preservative oxides retentions of 10 m & 11 m treated Kusia poles

Distance from pole bark mm	Mid-Range Distance mm	Preservative Oxides Retention kg/m^3							
		10 m				11 m			
		CrO_3	CuO	As_2O_5	Total	CrO_3	CuO	As_2O_5	Total
0 - 5	2.5	12.85	4.56	8.23	25.64	14.47	4.88	9.44	28.79
5 – 10	7.5	12.03	4.19	7.93	24.15	12.87	4.55	8.27	25.69
10 – 15	12.5	11.50	4.36	7.61	23.47	12.72	4.56	7.92	25.20
15 – 20	17.5	11.49	4.24	7.59	23.32	11.21	4.01	7.30	22.52
20 – 25	22.5	11.07	4.60	6.94	22.17	10.97	3.89	7.00	21.86
25 – 30	27.5	11.00	3.90	6.75	21.65	10.30	3.67	5.60	19.57
30 – 35	32.5	10.67	3.60	5.40	19.67	10.25	3.65	5.09	18.99
35 – 40	37.5	7.68	2.51	3.66	13.85	5.80	2.34	3.84	11.98

Table 4: Incremental preservative oxides balance of treated 10 m and 11 m Kusia poles

Distance From Pole Bark mm	Mid-Range Distance mm	Preservative Oxides Balance %							
		Charge of 10 m poles				Charge of 11 m poles			
		CrO_3	CuO	As_2O_5	TOTAL	CrO_3	CuO	As_2O_5	TOTAL
0-5	2.5	50.1	17.8	32.1	100.0	50.2	17.0	32.8	100.0
5-10	7.5	49.8	17.4	32.8	100.0	50.1	17.7	32.2	100.0
10-15	12.5	49.0	18.6	32.4	100.0	50.5	18.1	31.4	100.0
15-20	17.5	49.3	18.2	32.5	100.0	49.8	17.8	32.4	100.0
20-25	22.5	49.9	20.8	31.3	100.0	50.2	17.8	32.0	100.0
25-30	27.5	50.8	18.0	31.2	100.0	52.6	18.8	28.6	100.0
30-35	32.5	54.2	18.3	27.5	100.0	54.0	19.2	26.8	100.0
35-40	37.5	55.5	18.1	26.4	100.0	48.4	19.5	32.1	100.0

There was some disproportionation, as the CrO_3 oxides range in the treated wood was not entirely within the range set in the standard.

There seems to be some slight differential screening of the CrO_3 components at the expense of the fixation of the As_2O_5 components (especially from about 30 to 40 mm off the bark) that were lower than the lower limit (30.0%). The differential screening could possibly be due to the under drying (i.e. moisture content above 25%) within the 30 to 40 mm zone off the bark, which also resulted in the lower retention within the same zone (Table 3).

CONCLUSIONS

- Rapid extraction and prophylactic treatment of plantation-grown Kusia poles during drying and storage is necessary because the sapwood is susceptible to lyctus. Serious end splits occur during air-drying.

- Sapwood penetration at 3 m from the pole butt achieved during treatment ranged from 91 to 103% of the sapwood width of all the 164 poles treated.

- The preservative retention analysis by X-ray fluorescence spectroscopy indicated total oxides retentions within the assay zone of 0-25 mm away from the bark (23.75 to 24.81 kg/m^3) were higher than the retention of 20 kg/m^3 normally recommended for high hazard ground contact loadings in the hot humid tropics.

- The preservative oxides balance of the treated Kusia poles indicated some disproportionation, as the CrO_3 oxides range in the treated wood was not entirely within the range set in AWPA Standard P5-96 (1996). There seems to be some slight differential fixation of the CrO_3 components at the expense of the As_2O_5 components.

- It is recommended that the minimum sapwood width taken at the thinnest section of a Kusia pole be limited to 25 mm.

- Since a Kusia pole has about 31% proportion of sapwood volume, and the sapwood is not durable, but fairly permeable to treatment, it is recommended that full sapwood penetration be achieved during treatment. At worst, penetration of 25 mm or 85% of sapwood whichever is greater must be realized to enhance the efficacy of preservative treated pole in service.

- The treatability properties of Kusia as shown in this study render it suitable for use as wood poles for electric and telecommunication support lines.

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REFERENCES

Aaron, J. R. and Oakley, J. S. (1985) The production of poles for electricity supply and telecommunications. Forestry Commission Forest Record 128. HMSO, London. 11pp.

ATIBT (1990) Tropical timber atlas. Volume One

– Africa. Association Internationale Technique des Bois Tropicaux, Centre Technique Forestier Tropical, Paris. p.48-49.

AWPA Standard A9-96 (1996) Standard method for analysis of treated wood and treating solutions by X-ray spectroscopy. American Wood-Preservers' Association. Woodstock, Maryland, USA. 4pp.

AWPA Standard M2-96 (1996) Standard for inspection of wood products treated with preservatives. American Wood-Preservers' Association. Woodstock, Maryland, USA. 11pp.

AWPA Standard P5-96 (1996) Standard for waterborne preservatives. American Wood-Preservers' Association. Woodstock, Maryland, USA. 5pp.

Bolza, E. and Keating, W. G. (1972) African Timbers – The properties, uses and characteristics of 700 species. CSIRO, Melbourne, Australia. 1972. p.9 and 465.

BRE (1975) Handbook of hardwoods. Building Research Establishment. 2nd edition, HMSO, London. p.160-161.

BSI (1984) British Standard 1990 – Part 1: Wood poles for overhead power and telecommunication lines. Part 1. Specifications for softwood poles. British Standards Institution, London. 17pp.

Ghana Standards Board (1992) Ghana Standard GS 145: 1992 - 'Specification for wood poles for overhead power and telecommunication lines'. 1992. 20pp.

G. T. M. B (1969) Ghana Hardwoods, Ghana Timber Marketing Board, Takoradi, Ghana. p. 94-95.

Ofori, J. (2001) Suitability of using Afina, *Strombosia glaucescens* var lucida, poles for electric overhead transmission or distribution support lines in Ghana. *Ghana Journal of Forestry.* Vol.10. 43-52.

Ofori, J., Annan, M. & Amoako, K. A. (2008) Suitability of using plantation-grown Kusia (N*auclea diderrichii* Merill) wood poles for electricity and telecommunication overhead support lines in Ghana – Part 1: Sapwood Width, Sapwood Volume and Dimension Table. *Ghana Journal of Forestry*, Vol. 23 and 24, 1-14.

Wolfe, R. W. and Moody, R. C. (1994) ANSI pole standards – development and maintenance. Proc. of the 1st Southeastern pole conference. Forest Products Society, Madison, USA. p.143-149.

Wolfe, R. W. (1999) Round Timbers and Ties. In 'Wood handbook - Wood as an engineering material'. Gen. Tech. Rep. FPL-GTR-113. U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI., USA. p.18-1–18-10.