Network Innovation Allowance (NIA) – Project APPEAL

*Environmentally Acceptable Wood Pole Pre-treatment Alternatives to Creosote: **Review of Potential Products and Initial Efficacy Tests***

Project Report 5 (of 6)

***[Note:** Report 5 of 6 (instead of 4 of 4) due to APPEAL extension from 4 to 6 years]*

Treated and Control Stake Samples after 60 Months Exposure to Conditions of Accelerated Decay:

Project Summary, Uplift Procedure, Sample Processing, Visual Examination, Mechanical Testing, Chemical Analyses and Statistical Analyses
(including changes due to project extension)

Author: Dr Derek Sinclair

Date: 23/02/2023

Table of Contents

1. Introduction/Summary page 3

1.1. Brief Summary of Trial Set Up and Changes to the Uplift Procedure due to Project Extension page 3

1.2. Changes to the Conditions of the Trial due to Earlier Results and Project Extension page 4

2. Stake Uplift, Visual Examinations and Sample Processing for MOR Tests page 5

2.1. Stake Uplift page 5

2.2. Visual Examination page 5

2.2.1. Bare (unsleeved) Stakes Condition page 6

2.3. Sample Processing for MOR Tests page 8

3. Modulus of Rupture (MOR) Test Process and Statistical Results page 9

3.1. MOR Test Process page 9

3.2. Statistical Analyses of MOR Results page 9

3.2.1. Introduction page 9

3.2.2. Analyses of Bare Stakes (BS Exposure) at 0, 12, 24, 36, 48 and 60 months page 10

3.2.3. Analyses of Captura Stakes at 0, 12, 24 and 48 months page 19

3.2.4. Analyses of Polesaver Stakes at 0, 12, 24 and 48 months page 22

3.2.5. Analyses of ALL Stakes (bare and sleeved) at 48 months page 25

4. Discussion of Results and Concluding Comments page 28

4.1. Visual Examination of Uplifted Stakes page 28

4.2. MOR Statistical Analysis page 29

4.3. General Comments/Points on findings in sections 4.1 and 4.2. page 31

4.4. Concluding Comments page 32

4.5. Calculating a Pole RSV (Residual Strength Value) from Stake Test Results page 33

Appendix 1: Uplift 5 - Stake Sampling Procedure

Appendix 2: Condition of Bare Untreated Stakes after 36, 48 and 60 Months of Soil Bed Exposure

1. Introduction/Summary

1.1. Brief Summary of Trial Set Up and Changes to the Uplift Procedure due to Project Extension

The trial comprises 4 timber stake treatments: 2 new copper based preservatives (Tanasote and RVP (Rundverke-PWR)) with creosote and untreated stakes included as treated and untreated controls respectively. In addition, a proportion of the preservative treated and untreated stakes are encapsulated in 2 ground-line sleeve types (CAPTURA and Polesaver). All stakes are of Scots Pine (**Pinus sylvestris**) and measure 1500 x 50 x 25 mm. The stakes are positioned to a depth of 500 mm at regular intervals in a microbially active sandy loam soil bed constructed in a 40' insulated Reefer container. To accelerate any preservative leaching processes, the soil bed and stakes are subjected to artificial rainfall equivalent to an average for 40 years field exposure in the UK. In addition to an elevated level of precipitation the soil bed is exposed to high temperature of 28-29^{o}C and high humidity of between 80-90% to accelerate timber decay. After given soil bed exposure periods the stakes are uplifted, visually examined, processed, dried and subjected to breaking tests to assess the impact of any decay on Modulus of Rupture (MOR). The determination of MOR was undertaken via a modification of the standard static bending test for small clear specimens of timber (BS 373 (1957)).

This document details the uplift and visual/physical analyses of the fifth set of timber stakes recovered from the soil bed and statistical analyses of all 5 sets recovered to date. The trial was originally planned to proceed for a total of 48 months (Oct. 2017 – Oct. 2021) and allow 4 sets of stake recoveries but has now been extended. The trial will now proceed for a total of 72 months (Oct. 2017 – Oct. 2023) and allow 6 sets of stake recoveries. **The extended stake uplift schedule is presented below (red highlighted stakes already uplifted and reported on in reports 1, 2, 3 and 4)**.

Treatment	Orig. Sampling Period 1: Test Stakes (1 YR)	Orig. Sampling Period 2: Test Stakes (2 YRS)	Orig. Sampling Period 3: Test Stakes (3 YRS)		Orig. Sampling Period 4: Test Stakes (4 YRS)		Total
			3 YRS	4YRS	5YRS	6YRS	
Creosote (**E**)	16	16	8	8	8	8	64
RV-PWR T (**E**)	16	16	8	8	8	8	64
Lonza T (**E**)	16	16	8	8	8	8	64
Untreated Control (**E**)	16	16	8	8	8	8	64
Creosote (**SE**)	16 (8/8)	16 (8P/8C)	16 (8P/8C)		16 (8P/8C)		64
RV-PWR T (**SE**)	16 (8/8)	16 (8P/8C)	16 (8P/8C)		16 (8P/8C)		64
Lonza T (**SE**)	16 (8/8)	16 (8P/8C)	16 (8P/8C)		16 (8P/8C)		64
Untreated Control (**SE**)	16 (8/8)	16 (8P/8C)	16 (8P/8C)		16 (8P/8C)		64
Creosote (**NE**)	16	**← Stakes (64) retained for test comparison – not exposed to the soil bed**					16
RV-PWR T (**NE**)	16						16
Lonza T (**NE**)	16						16
Untreated Control	16						16
Total Stakes in Test	192	128	32	96	32	96	**576**
Stakes in Soil Bed	128	128	32	96	32	96	**512**
Sub-Samples – BS 373	**384**	256	64	192	64	192	**1152**

Treatment (E):	Treated pole sections **exposed** to the soil bed
Treatment (SE):	Treated and **sleeved** pole sections **exposed** to the soil bed (2 sleeve types (P and C))

Treatment (NE):	Treated timbers **not exposed** to the soil bed but used for direct statistical comparison with respective **E** and **SE** samples across all sampling times
Untreated Control (E):	These pole sections also serve as the **Decay Tester** timbers

The original stake uplift schedule was as follows (48 months test exposure = 40 years field exposure):

Uplift 1 after 12 months: 192 stakes = 384 stakelets
Uplift 2 after 24 months: 128 stakes = 256 stakelets
Uplift 3 after 36 months: 128 stakes = 256 stakelets **Total Stakes = 576**
Uplift 4 after 48 months: 128 stakes = 256 stakelets **Total Stakelets = 1152**

The extended stake uplift schedule is as follows (72 months test exposure = 60 years field exposure):

Uplift 1 after 12 months: 192 stakes = 384 stakelets
Uplift 2 after 24 months: 128 stakes = 256 stakelets
Uplift 3 after 36 months: 32 stakes = 64 stakelets
Uplift 4 after 48 months: 96 stakes = 192 stakelets
Uplift 5 after 60 months: 32 stakes = 64 stakelets (results in this report*) **Total Stakes = 576**
Uplift 6 after 72 months: 96 stakes = 192 stakelets **Total Stakelets = 1152**

* The MOR results in this report include those uplifted at 48 months for stakelets processed from creosote, RVP, Tanasote and untreated stakes that had received Polesaver sleeves (64 stakelets). The tarry layer underlying the exterior sleeve had not dried sufficiently (after 6 weeks conditioning) for earlier testing. The MOR values for these Polesaver stakelets are therefore presented here (Report 5).

The extended schedule may seem to produce very unbalanced stake sample populations for testing and statistical analyses but this is not the case. At uplifts 3 and 5 no sleeved stakes are removed and the smaller numbers of unsleeved stakes removed (compared to uplifts 1 and 2) are still sufficient to provide meaningful statistical results. Therefore, the alteration of the sampling schedule allows the project to be extended to gain accurate results over a longer time period without addition of further samples. The only real difference in statistical comparisons is that sleeved sample results will be compared between 12, 24, 48 and 72 months instead of 12, 24, 36 and 48 months. This will provide an extended and therefore more robust evaluation of these sleeve types.

1.2. Changes to the Conditions of the Trial due to Earlier Results and Project Extension

Reduction in timber decay processes noted at the 2 year uplift was ascribed to the heavy “rainfall” schedule (of 3 hours per week) and consequent nutrient depletion from the soil bed (report 2, section 5.1, pages 20 and 21).

Alterations were therefore initiated one month after the second uplift (November 2019). “Rainfall” was reduced to 15 minutes every 2 weeks after it was determined that no adverse impact on decay would ensue. Moreover, a process of soil enrichment was begun with additions of nitrogen (and other elements) taking place every month. Enrichments were in the form of compost and slow release granules for the first few months with liquid fertiliser added thereafter. These additions were not excessive and provided a total of approximately 2.5 Kg of added nitrogen to the soil bed from October 2019 (second uplift) to October 2020 (third uplift) or about 100 g N/m^2. This is a correction from the N values given in section 5.1 of report 2.

Since the uplift of the fourth set of stakes (reported previously) the foregoing conditions have been maintained except for the period from May to July 2021 where soil enrichment was stopped and "rainfall" increased. "Rainfall" was increased to give, once more, the 40 year field equivalent originally planned for the trial. This was achieved in late July 2021 at which time "rainfall" was again reduced to 15 minutes every 2 weeks and soil enrichment started again. The extension of the stake trial from 4 to 6 uplifts ending in October 2023 provided the opportunity to undertake this action in the knowledge that its impact would be shown in later results.

To complement the extension of the stake trial from 4 to 6 years the foregoing rainfall ramp up was again undertaken in February/March of 2022 to achieve a 50 years field equivalent (before the new round trial timbers were erected in the soil bed). After this time, soil bed liquid enrichment with nitrogen was doubled by application every 2 weeks instead of every month. This increase was undertaken to further raise the decay potential of the soil bed to increase the likelihood of failure of one of the preservative types and therefore provide a more definitive "winner(s)" for the project partners.

2. Stake Uplift, Visual Examination and Sample Processing for MOR Tests

2.1. Stake Uplift

According to the new uplift schedule 32 stake samples were removed from the soil bed from random locations for the 5th uplift (see green boxes in table on page 3 of this report). The stake uplift is recorded in more detail in Appendix 1 of this report.

The total number and type of stakes for processing was as follows:

60 months Exposed Untreated Controls:	0 bare stakes (all lost due to disintegration)
60 months Exposed Creosote:	8 bare stakes
60 months Exposed RVP:	8 bare stakes
60 months Exposed Tanasote:	8 bare stakes
Total:	**24 stakes**

NOTE: **At uplift, 3 of the 8 untreated controls were retrieved "intact" but these disintegrated shortly thereafter**

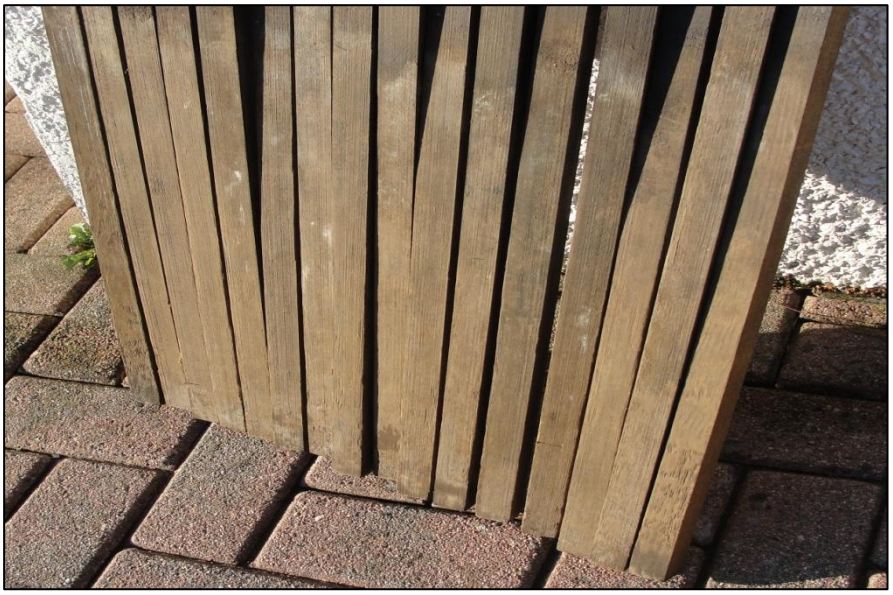
2.2. Visual Examinations

Visual examination of the below ground portion of all the stakes was undertaken. The stakes were cleaned of adherent soil then examined. It was evident that, in addition to the obvious complete deterioration of the untreated stakes, all the treated stakes had suffered degrees of decay. To permit better inspection, a full visual examination was not undertaken until the stakes had been dried and brushed and processed to stakelets (see section 2.3 for processing detail). Plates of the uplifted stakes and processed stakelets are shown together in this section.

2.2.1. Bare (unsleeved) Stakes Condition

Above is shown the **UNTREATED CONTROL STAKES**. These timbers are displaying almost complete disintegration below the ground line. The three stakes which were retrieved "intact" (see top far left and top far right) collapsed after further handling and no untreated control stakelets were available for MOR tests. These stakes are in much poorer condition than those uplifted after 48 months where 50% of uplifts were "intact". **The much poorer condition and disintegration of these 60 month control stakes compared to the 48 month control stakes is highlighted in Appendix 2.**

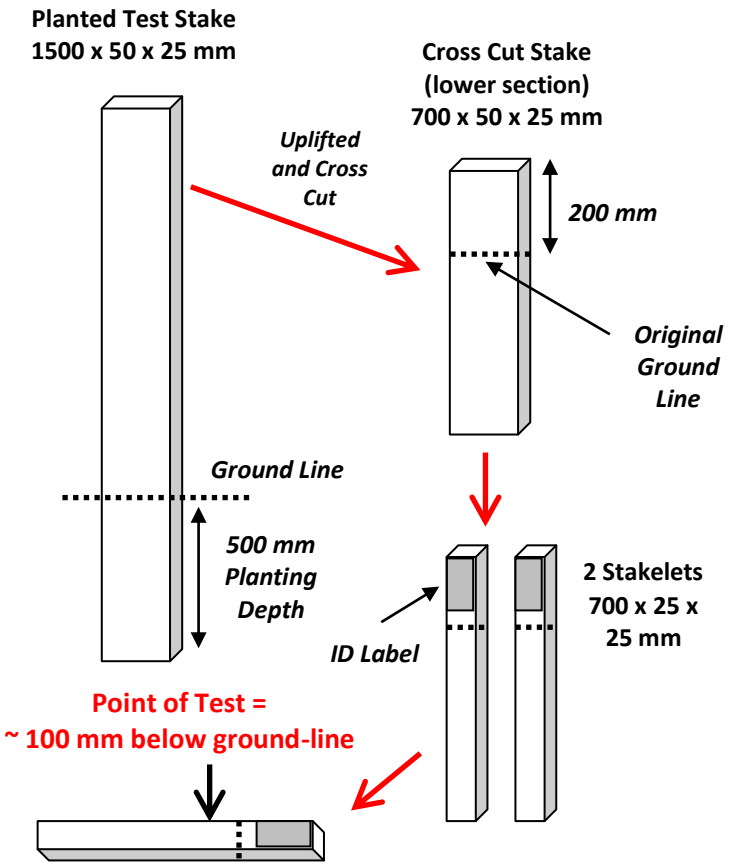
Above left is shown the **CREOSOTE TREATED STAKES** and the cleaned, brushed and processed stakelets are to the right. Though it is not immediately obvious, enlargement of the stakelet plate clearly shows widespread and very definite zones of surface decay below the ground line (note early wood loss (surface striations) and rounded edges)). There is not a single stake that is not affected to some degree. This differs greatly from the 48 month uplift when no overt indications of decay were found in any of the creosote stakes. Comparison of these 60 month stakelets with those of RVP and Tanasote (page 7) indicates that these are in better condition than the latter but much worse than the former.



Above left is shown the **RVP TREATED STAKES** and the cleaned, brushed and processed stakelets are to the right. The decay in the stakelets is much less obvious in the RVP stakelets (even with enlargement) because it is much less severe and less widespread. Note much sharper edges than for Creosote (page 6) and Tanasote stakes (below). Decay is there however, though it is not showing up clearly on the plate. **Nonetheless, RVP treated stakes appear to be displaying greater resistance to decay after 60 months exposure to the soil bed than are Creosote and Tanasote stakes**.

Above left is shown the **TANASOTE TREATED STAKES** and the cleaned, brushed and processed stakelets are to the right. The below ground line decay in these stakelets is more widespread than for the Creosote stakelets (page 6). Again, note early wood loss (surface striations) and rounded edges. Surface condition is certainly much poorer than the RVP stakelets (top of page). Like Creosote, the condition of these Tanasote stakes at 60 months differs greatly from the 48 month uplift when no decay was visually identified.

2.3. Sample Processing for MOR Tests



All 24 stakes were crosscut at 700 mm from the base. Note that "the base" is that end of each stake in contact with the base of the 500 mm deep soil bed.

Thus each crosscut stake consisted of the entire buried section (exposed to decay fungi) and 200 mm of the above ground portion. The full procedure is illustrated left.

All 24 crosscut stakes were then sawn longitudinally to provide a total of 48 twinned "stakelets" measuring 700 x 25 x 25 mm – giving a cross-section designed to better facilitate breaking to assess Modulus of Rupture (MOR) according to BS 373 (1957). The breakdown of the stakelets was as follows:

60 month stakelets (total = 32):

Exposed Controls (**U**ntreated and **E**xposed) – All Stakes lost = 0 Stakelets for test	
Exposed Creosote (**C**reosoted and **E**xposed)	
16 **B**are stakelets:	49A-CBE and 49B-CBE to 56A-CBE and 56B-CBE
Exposed RVP (**R**VP and **E**xposed)	
16 **B**are stakelets:	49A-RBE and 49B-RBE to 56A-RBE and 56B-RBE
Exposed Tanasote (**T**anasote and **E**xposed)	
16 **B**are stakelets:	49A-TBE and 49B-TBE to 56A-TBE and 56B-TBE

All the stakelets were retained for conditioning outside Abertay University (Dundee) to achieve a standard moisture content of approximately 12%. After conditioning, the stakelets were ready for testing.

3. Modulus of Rupture (MOR) Test Process and Statistical Results

3.1. MOR Test Process

Each stakelet was subjected to MOR determination according to a modification of the standard static bending test for small clear specimens of timber (BS 373 (1957)). Modulus of Rupture (MOR) is a determination of the strength of a timber specimen before rupture - a measure of its ultimate strength. This is also known as bending strength.

Each stakelet was positioned on the test bed such that the load was applied directly to that part of each stakelet which would have been positioned approximately 100 mm below the ground-line in the chamber soil bed (i.e. that part of each stake most susceptible to the activities of decay fungi). This positioning was copied for all test stakelets.

Load was applied in kN (kilonewtons) - 1 kilonewton is equal to 101.972 kilograms - and MOR was given in MPa (megapascals).

3.2. Statistical Analyses of MOR Results

3.2.1. Introduction

Statistical analyses were conducted to determine the effect of:

1) Wood treatment (with four levels: Treatments 1-4)
2) Effect of CAPTURA and Polesaver sleeve products
3) Effect of time exposure to soil bed (with four levels: Exposure periods 1-6 (0, 12, 24, 36, 48 and 60 months)).

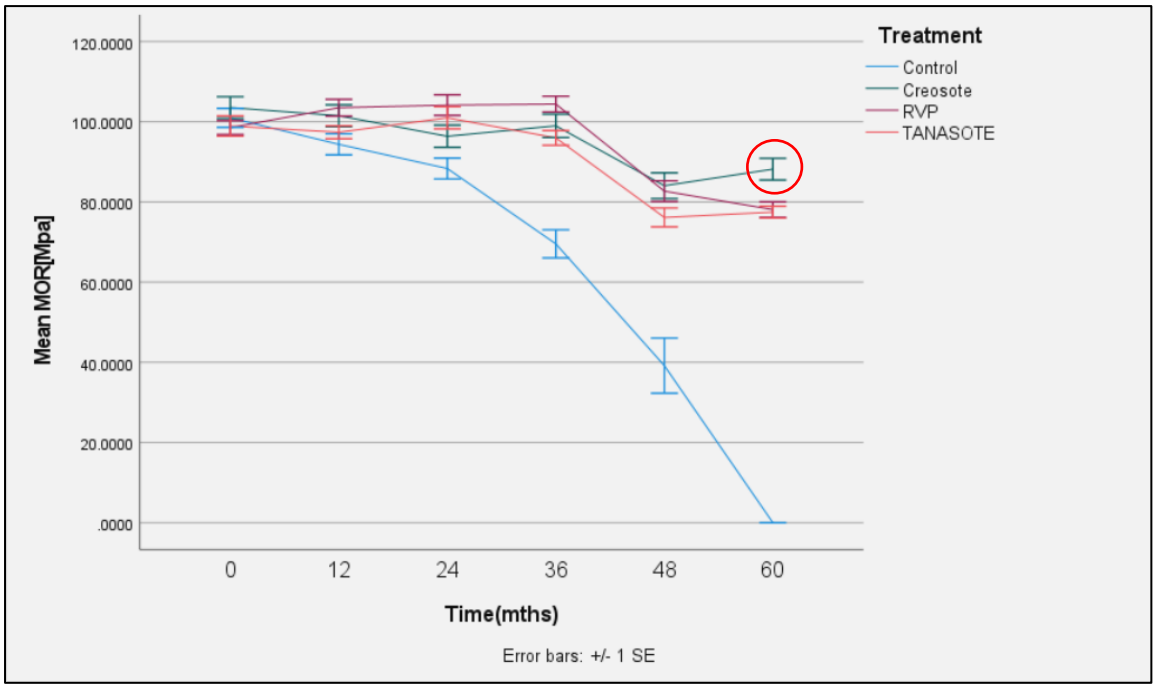
Pair-wise comparison tests were conducted to calculate differences in MOR among treatments, soil exposure and time and to identify statistically significant differences among treatments and between sleeved and unsleeved stakes. The main analysis was conducted on the full data and a sensitivity analysis was performed on the data after removing outliers. Please note that the statistical analysis steps are summarised here for clarity.

3.2.2. Analyses of Bare Stakes (BS Exposure) at 0, 12, 24, 36, 48 and 60 months

NOTE: All STATISTICAL STATEMENTS ARE SHOWN IN BOLD RED FOR CLARITY

3.2.2.1. General

Figure 1: Plotted means with standard error bars for the 4 treatment types at the 6 time intervals



Comparing means at the different time points (above) shows that the stand out effect is decay over time for control stakes. This reaches complete disintegration or a MOR of 0 at 60 months. Though there is decay in the other treatments after 48 months exposure, this does not appear to worsen after 60 months, with an uptick in mean MOR value for Creosote at this time (circled).

3.2.2.2. Comparing treatments regardless of time interval (i.e. exposure period)

Figure 2: **Plotted means with standard error bars for the 4 treatment types regardless of time interval (i.e. exposure period)**

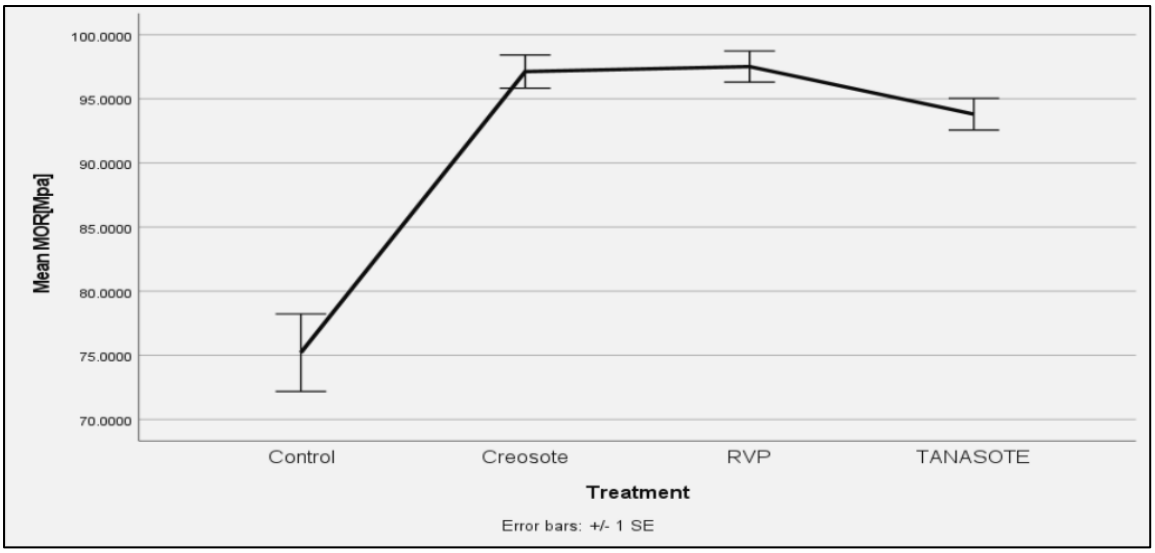


Table 1: **Pairwise comparisons of treatment means regardless of time interval (i.e. exposure period)**

Pairwise Comparisons

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	df	Sidak Sig.	95% Wald Confidence Interval for Difference	
						Lower	Upper
Control	Creosote	-21.9198[a]	2.60739	1	.000	-28.7799	-15.0596
	RVP	-22.3101[a]	2.60739	1	.000	-29.1702	-15.4500
	TANASOTE	-18.5984[a]	2.60739	1	.000	-25.4586	-11.7383
Creosote	Control	21.9198[a]	2.60739	1	.000	15.0596	28.7799
	RVP	-.3903	2.59826	1	1.000	-7.2264	6.4458
	TANASOTE	3.3213	2.59826	1	.740	-3.5148	10.1574
RVP	Control	22.3101[a]	2.60739	1	.000	15.4500	29.1702
	Creosote	.3903	2.59826	1	1.000	-6.4458	7.2264
	TANASOTE	3.7117	2.59826	1	.631	-3.1244	10.5478
TANASOTE	Control	18.5984[a]	2.60739	1	.000	11.7383	25.4586
	Creosote	-3.3213	2.59826	1	.740	-10.1574	3.5148
	RVP	-3.7117	2.59826	1	.631	-10.5478	3.1244

Pairwise comparisons of estimated marginal means based on the original scale of dependent variable MOR[Mpa]

a. The mean difference is significant at the .05 level.

Comparing means regardless of time (above) shows that stake populations treated with the 3 preservative types all have significantly higher MOR values than the control stakes. Though RVP stakes have the highest mean MOR, it is not significantly higher than Creosote and Tanasote stakes.

3.2.2.3. Comparing treatments taking time interval (i.e. exposure period) into consideration

Table 2: **Mean MOR values for each treatment type at each exposure period**

Estimates

Treatment	Time(mths)	Mean	Std. Error	95% Wald Confidence Interval Lower	Upper
Control	0	100.9800	2.68326	95.7209	106.2391
	12	94.3800	2.68326	89.1209	99.6391
	24	88.3500	2.68326	83.0909	93.6091
	36	69.5623	4.05671	61.6113	77.5133
	48	39.1890	3.79470	31.7515	46.6265
	60	.0000	3.79470	-7.4375	7.4375
Creosote	0	103.5600	2.48237	98.6946	108.4254
	12	101.5050	2.48237	96.6396	106.3704
	24	96.3900	2.48237	91.5246	101.2554
	36	98.9940	3.51061	92.1133	105.8747
	48	84.0600	3.51061	77.1793	90.9407
	60	88.1910	3.51061	81.3103	95.0717
RVP	0	98.5500	1.94289	94.7420	102.3580
	12	103.5150	1.94289	99.7070	107.3230
	24	104.1600	1.94289	100.3520	107.9680
	36	104.4210	2.74766	99.0357	109.8063
	48	82.7010	2.74766	77.3157	88.0863
	60	78.0960	2.74766	72.7107	83.4813
TANASOTE	0	98.9400	2.03446	94.9525	102.9275
	12	97.3950	2.03446	93.4075	101.3825
	24	100.9950	2.03446	97.0075	104.9825
	36	95.9940	2.87716	90.3549	101.6331
	48	76.1460	2.87716	70.5069	81.7851
	60	77.4630	2.87716	71.8239	83.1021

Table 3: **Pairwise comparisons of Control and Creosote means within each treatment type at each time interval (i.e. exposure period)**

Pairwise Comparisons

Treatment	(I) Time(mths)	(J) Time(mths)	Mean Difference (I-J)	Std. Error	df	Sidak Sig.	95% Wald Confidence Interval for Difference	
							Lower	Upper
Control	0	12	6.6000	3.79470	1	.723	-4.5101	17.7101
		24	12.6300[a]	3.79470	1	.013	1.5199	23.7401
		36	31.4177[a]	4.86382	1	.000	17.1774	45.6580
		48	61.7910[a]	4.64754	1	.000	48.1839	75.3981
		60	100.9800[a]	4.64754	1	.000	87.3729	114.5871
	12	0	-6.6000	3.79470	1	.723	-17.7101	4.5101
		24	6.0300	3.79470	1	.832	-5.0801	17.1401
		36	24.8177[a]	4.86382	1	.000	10.5774	39.0580
		48	55.1910[a]	4.64754	1	.000	41.5839	68.7981
		60	94.3800[a]	4.64754	1	.000	80.7729	107.9871
	24	0	-12.6300[a]	3.79470	1	.013	-23.7401	-1.5199
		12	-6.0300	3.79470	1	.832	-17.1401	5.0801
		36	18.7877[a]	4.86382	1	.002	4.5474	33.0280
		48	49.1610[a]	4.64754	1	.000	35.5539	62.7681
		60	88.3500[a]	4.64754	1	.000	74.7429	101.9571
	36	0	-31.4177[a]	4.86382	1	.000	-45.6580	-17.1774
		12	-24.8177[a]	4.86382	1	.000	-39.0580	-10.5774
		24	-18.7877[a]	4.86382	1	.002	-33.0280	-4.5474
		48	30.3733[a]	5.55488	1	.000	14.1097	46.6368
		60	69.5623[a]	5.55488	1	.000	53.2987	85.8258
	48	0	-61.7910[a]	4.64754	1	.000	-75.3981	-48.1839
		12	-55.1910[a]	4.64754	1	.000	-68.7981	-41.5839
		24	-49.1610[a]	4.64754	1	.000	-62.7681	-35.5539
		36	-30.3733[a]	5.55488	1	.000	-46.6368	-14.1097
		60	39.1890[a]	5.36652	1	.000	23.4769	54.9011
	60	0	-100.9800[a]	4.64754	1	.000	-114.5871	-87.3729
		12	-94.3800[a]	4.64754	1	.000	-107.9871	-80.7729
		24	-88.3500[a]	4.64754	1	.000	-101.9571	-74.7429
		36	-69.5623[a]	5.55488	1	.000	-85.8258	-53.2987
		48	-39.1890[a]	5.36652	1	.000	-54.9011	-23.4769
Creosote	0	12	2.0550	3.51061	1	1.000	-8.2233	12.3333
		24	7.1700	3.51061	1	.467	-3.1083	17.4483
		36	4.5660	4.29960	1	.994	-8.0224	17.1544
		48	19.5000[a]	4.29960	1	.000	6.9116	32.0884
		60	15.3690[a]	4.29960	1	.005	2.7806	27.9574
	12	0	-2.0550	3.51061	1	1.000	-12.3333	8.2233
		24	5.1150	3.51061	1	.905	-5.1633	15.3933
		36	2.5110	4.29960	1	1.000	-10.0774	15.0994
		48	17.4450[a]	4.29960	1	.001	4.8566	30.0334
		60	13.3140[a]	4.29960	1	.029	.7256	25.9024
	24	0	-7.1700	3.51061	1	.467	-17.4483	3.1083
		12	-5.1150	3.51061	1	.905	-15.3933	5.1633
		36	-2.6040	4.29960	1	1.000	-15.1924	9.9844
		48	12.3300	4.29960	1	.060	-.2584	24.9184
		60	8.1990	4.29960	1	.582	-4.3894	20.7874
	36	0	-4.5660	4.29960	1	.994	-17.1544	8.0224
		12	-2.5110	4.29960	1	1.000	-15.0994	10.0774
		24	2.6040	4.29960	1	1.000	-9.9844	15.1924
		48	14.9340[a]	4.96475	1	.039	.3982	29.4698
		60	10.8030	4.96475	1	.362	-3.7328	25.3388
	48	0	-19.5000[a]	4.29960	1	.000	-32.0884	-6.9116
		12	-17.4450[a]	4.29960	1	.001	-30.0334	-4.8566
		24	-12.3300	4.29960	1	.060	-24.9184	.2584
		36	-14.9340[a]	4.96475	1	.039	-29.4698	-.3982
		60	-4.1310	4.96475	1	1.000	-18.6668	10.4048
	60	0	-15.3690[a]	4.29960	1	.005	-27.9574	-2.7806
		12	-13.3140[a]	4.29960	1	.029	-25.9024	-.7256
		24	-8.1990	4.29960	1	.582	-20.7874	4.3894
		36	-10.8030	4.96475	1	.362	-25.3388	3.7328
		48	4.1310	4.96475	1	1.000	-10.4048	18.6668

Table 4: **Pairwise comparisons of RVP and Tanasote means within each treatment type at each time interval (i.e. exposure period)**

RVP	0	12	-4.9650	2.74766	1	.667	-13.0096	3.0796
		24	-5.6100	2.74766	1	.468	-13.6546	2.4346
		36	-5.8710	3.36518	1	.719	-15.7236	3.9816
		48	15.8490[a]	3.36518	1	.000	5.9964	25.7016
		60	20.4540[a]	3.36518	1	.000	10.6014	30.3066
	12	0	4.9650	2.74766	1	.667	-3.0796	13.0096
		24	-.6450	2.74766	1	1.000	-8.6896	7.3996
		36	-.9060	3.36518	1	1.000	-10.7586	8.9466
		48	20.8140[a]	3.36518	1	.000	10.9614	30.6666
		60	25.4190[a]	3.36518	1	.000	15.5664	35.2716
	24	0	5.6100	2.74766	1	.468	-2.4346	13.6546
		12	.6450	2.74766	1	1.000	-7.3996	8.6896
		36	-.2610	3.36518	1	1.000	-10.1136	9.5916
		48	21.4590[a]	3.36518	1	.000	11.6064	31.3116
		60	26.0640[a]	3.36518	1	.000	16.2114	35.9166
	36	0	5.8710	3.36518	1	.719	-3.9816	15.7236
		12	.9060	3.36518	1	1.000	-8.9466	10.7586
		24	.2610	3.36518	1	1.000	-9.5916	10.1136
		48	21.7200[a]	3.88577	1	.000	10.3432	33.0968
		60	26.3250[a]	3.88577	1	.000	14.9482	37.7018
	48	0	-15.8490[a]	3.36518	1	.000	-25.7016	-5.9964
		12	-20.8140[a]	3.36518	1	.000	-30.6666	-10.9614
		24	-21.4590[a]	3.36518	1	.000	-31.3116	-11.6064
		36	-21.7200[a]	3.88577	1	.000	-33.0968	-10.3432
		60	4.6050	3.88577	1	.982	-6.7718	15.9818
	60	0	-20.4540[a]	3.36518	1	.000	-30.3066	-10.6014
		12	-25.4190[a]	3.36518	1	.000	-35.2716	-15.5664
		24	-26.0640[a]	3.36518	1	.000	-35.9166	-16.2114
		36	-26.3250[a]	3.88577	1	.000	-37.7018	-14.9482
		48	-4.6050	3.88577	1	.982	-15.9818	6.7718
TANASOTE	0	12	1.5450	2.87716	1	1.000	-6.8787	9.9687
		24	-2.0550	2.87716	1	1.000	-10.4787	6.3687
		36	2.9460	3.52378	1	1.000	-7.3709	13.2629
		48	22.7940[a]	3.52378	1	.000	12.4771	33.1109
		60	21.4770[a]	3.52378	1	.000	11.1601	31.7939
	12	0	-1.5450	2.87716	1	1.000	-9.9687	6.8787
		24	-3.6000	2.87716	1	.971	-12.0237	4.8237
		36	1.4010	3.52378	1	1.000	-8.9159	11.7179
		48	21.2490[a]	3.52378	1	.000	10.9321	31.5659
		60	19.9320[a]	3.52378	1	.000	9.6151	30.2489
	24	0	2.0550	2.87716	1	1.000	-6.3687	10.4787
		12	3.6000	2.87716	1	.971	-4.8237	12.0237
		36	5.0010	3.52378	1	.921	-5.3159	15.3179
		48	24.8490[a]	3.52378	1	.000	14.5321	35.1659
		60	23.5320[a]	3.52378	1	.000	13.2151	33.8489
	36	0	-2.9460	3.52378	1	1.000	-13.2629	7.3709
		12	-1.4010	3.52378	1	1.000	-11.7179	8.9159
		24	-5.0010	3.52378	1	.921	-15.3179	5.3159
		48	19.8480[a]	4.06891	1	.000	7.9350	31.7610
		60	18.5310[a]	4.06891	1	.000	6.6180	30.4440
	48	0	-22.7940[a]	3.52378	1	.000	-33.1109	-12.4771
		12	-21.2490[a]	3.52378	1	.000	-31.5659	-10.9321
		24	-24.8490[a]	3.52378	1	.000	-35.1659	-14.5321
		36	-19.8480[a]	4.06891	1	.000	-31.7610	-7.9350
		60	-1.3170	4.06891	1	1.000	-13.2300	10.5960
	60	0	-21.4770[a]	3.52378	1	.000	-31.7939	-11.1601
		12	-19.9320[a]	3.52378	1	.000	-30.2489	-9.6151
		24	-23.5320[a]	3.52378	1	.000	-33.8489	-13.2151
		36	-18.5310[a]	4.06891	1	.000	-30.4440	-6.6180
		48	1.3170	4.06891	1	1.000	-10.5960	13.2300

Pairwise comparisons in tables 3 and 4 (within treatment differences) show the following:

- **For control treatment there is significant decay after 24 months exposure and, after 36 months exposure, at any time point compared to the previous time point.**

- **For both RVP and Tanasote treatments the decay becomes significant after 48 months (compared to 0, 12, 24 and 36 months), but decay does not become more significant at 60 months.**

- **Creosote treated stakes display significant decay at 48 months compared to 0, 12 and 36 months, and this stabilises at 60 months. Decay at 60 months is significant compared to 0 and 12 months but is not significant compared to 36 and 48 months.**

Table 5 (a): Pairwise comparisons of Control, Creosote, RVP and Tanasote means between each treatment type at each time interval (i.e. exposure period)

Pairwise Comparisons

Time(mths)	(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	df	Sidak Sig.	95% Wald Confidence Interval for Difference	
							Lower	Upper
0	Control	Creosote	-2.5800	3.27553	1	.966	-11.1981	6.0381
		RVP	2.4300	3.27553	1	.975	-6.1881	11.0481
		TANASOTE	2.0400	3.27553	1	.990	-6.5781	10.6581
	Creosote	Control	2.5800	3.27553	1	.966	-6.0381	11.1981
		RVP	5.0100	3.27553	1	.555	-3.6081	13.6281
		TANASOTE	4.6200	3.27553	1	.645	-3.9981	13.2381
	RVP	Control	-2.4300	3.27553	1	.975	-11.0481	6.1881
		Creosote	-5.0100	3.27553	1	.555	-13.6281	3.6081
		TANASOTE	-.3900	3.27553	1	1.000	-9.0081	8.2281
	TANASOTE	Control	-2.0400	3.27553	1	.990	-10.6581	6.5781
		Creosote	-4.6200	3.27553	1	.645	-13.2381	3.9981
		RVP	.3900	3.27553	1	1.000	-8.2281	9.0081
12	Control	Creosote	-7.1250	3.21542	1	.150	-15.5849	1.3349
		RVP	-9.1350[a]	3.21542	1	.027	-17.5949	-.6751
		TANASOTE	-3.0150	3.21542	1	.923	-11.4749	5.4449
	Creosote	Control	7.1250	3.21542	1	.150	-1.3349	15.5849
		RVP	-2.0100	3.21542	1	.989	-10.4699	6.4499
		TANASOTE	4.1100	3.21542	1	.740	-4.3499	12.5699
	RVP	Control	9.1350[a]	3.21542	1	.027	.6751	17.5949
		Creosote	2.0100	3.21542	1	.989	-6.4499	10.4699
		TANASOTE	6.1200	3.21542	1	.297	-2.3399	14.5799
	TANASOTE	Control	3.0150	3.21542	1	.923	-5.4449	11.4749
		Creosote	-4.1100	3.21542	1	.740	-12.5699	4.3499
		RVP	-6.1200	3.21542	1	.297	-14.5799	2.3399
24	Control	Creosote	-8.0400	3.72690	1	.172	-17.8456	1.7656
		RVP	-15.8100[a]	3.72690	1	.000	-25.6156	-6.0044
		TANASOTE	-12.6450[a]	3.72690	1	.004	-22.4506	-2.8394
	Creosote	Control	8.0400	3.72690	1	.172	-1.7656	17.8456
		RVP	-7.7700	3.72690	1	.203	-17.5756	2.0356
		TANASOTE	-4.6050	3.72690	1	.769	-14.4106	5.2006
	RVP	Control	15.8100[a]	3.72690	1	.000	6.0044	25.6156
		Creosote	7.7700	3.72690	1	.203	-2.0356	17.5756
		TANASOTE	3.1650	3.72690	1	.951	-6.6406	12.9706
	TANASOTE	Control	12.6450[a]	3.72690	1	.004	2.8394	22.4506
		Creosote	4.6050	3.72690	1	.769	-5.2006	14.4106
		RVP	-3.1650	3.72690	1	.951	-12.9706	6.6406
36	Control	Creosote	-29.4317[a]	3.60326	1	.000	-38.9120	-19.9514

Table 5 (b): Pairwise comparisons of Control, Creosote, RVP and Tanasote means between each treatment type at each time interval (i.e. exposure period)

		Creosote	4.6050	3.72690	1	.769	-5.2006	14.4106
		RVP	-3.1650	3.72690	1	.951	-12.9706	6.6406
36	Control	Creosote	-29.4317[a]	3.60326	1	.000	-38.9120	-19.9514
		RVP	-34.8587[a]	3.60326	1	.000	-44.3390	-25.3784
		TANASOTE	-26.4317[a]	3.60326	1	.000	-35.9120	-16.9514
	Creosote	Control	29.4317[a]	3.60326	1	.000	19.9514	38.9120
		RVP	-5.4270	3.48108	1	.532	-14.5858	3.7318
		TANASOTE	3.0000	3.48108	1	.948	-6.1588	12.1588
	RVP	Control	34.8587[a]	3.60326	1	.000	25.3784	44.3390
		Creosote	5.4270	3.48108	1	.532	-3.7318	14.5858
		TANASOTE	8.4270	3.48108	1	.089	-.7318	17.5858
	TANASOTE	Control	26.4317[a]	3.60326	1	.000	16.9514	35.9120
		Creosote	-3.0000	3.48108	1	.948	-12.1588	6.1588
		RVP	-8.4270	3.48108	1	.089	-17.5858	.7318
48	Control	Creosote	-44.8710[a]	5.72568	1	.000	-59.9355	-29.8065
		RVP	-43.5120[a]	5.72568	1	.000	-58.5765	-28.4475
		TANASOTE	-36.9570[a]	5.72568	1	.000	-52.0215	-21.8925
	Creosote	Control	44.8710[a]	5.72568	1	.000	29.8065	59.9355
		RVP	1.3590	5.72568	1	1.000	-13.7055	16.4235
		TANASOTE	7.9140	5.72568	1	.666	-7.1505	22.9785
	RVP	Control	43.5120[a]	5.72568	1	.000	28.4475	58.5765
		Creosote	-1.3590	5.72568	1	1.000	-16.4235	13.7055
		TANASOTE	6.5550	5.72568	1	.825	-8.5095	21.6195
	TANASOTE	Control	36.9570[a]	5.72568	1	.000	21.8925	52.0215
		Creosote	-7.9140	5.72568	1	.666	-22.9785	7.1505
		RVP	-6.5550	5.72568	1	.825	-21.6195	8.5095
60	Control	Creosote	-88.1910[a]	2.49584	1	.000	-94.7577	-81.6243
		RVP	-78.0960[a]	2.49584	1	.000	-84.6627	-71.5293
		TANASOTE	-77.4630[a]	2.49584	1	.000	-84.0297	-70.8963
	Creosote	Control	88.1910[a]	2.49584	1	.000	81.6243	94.7577
		RVP	10.0950[a]	2.49584	1	.000	3.5283	16.6617
		TANASOTE	10.7280[a]	2.49584	1	.000	4.1613	17.2947
	RVP	Control	78.0960[a]	2.49584	1	.000	71.5293	84.6627
		Creosote	-10.0950[a]	2.49584	1	.000	-16.6617	-3.5283
		TANASOTE	.6330	2.49584	1	1.000	-5.9337	7.1997
	TANASOTE	Control	77.4630[a]	2.49584	1	.000	70.8963	84.0297
		Creosote	-10.7280[a]	2.49584	1	.000	-17.2947	-4.1613
		RVP	-.6330	2.49584	1	1.000	-7.1997	5.9337

Pairwise comparisons in tables 5a and 5b (between treatment differences) show the following:

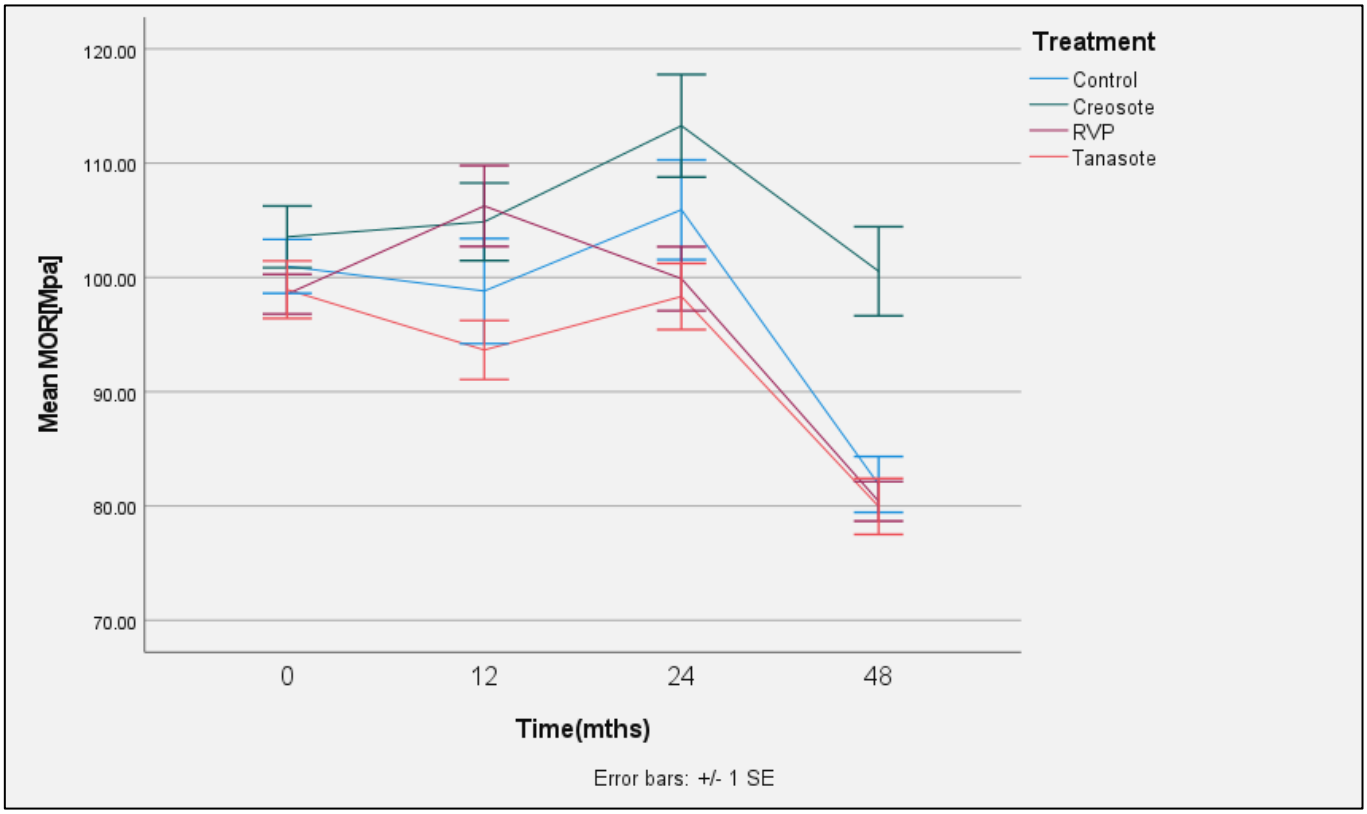
- **All treatments (Creosote, RVP and Tanasote) are superior to the controls at 36, 48 and 60 months**
- **RVP and Tanasote are superior to the control at 24 months**
- **RVP is superior to the control at 12 months.**
- **Up to and including 48 months, there is no significant difference between Creosote, RVP and Tanasote**
- **At 60 months, Creosote treatment is significantly superior to both RVP and Tanasote (due to an uptick in mean MOR value for Creosote at 60 months (see figure 1 and table 2).**

3.2.3. Analyses of Captura Stakes at 0, 12, 24, and 48 months

NOTE: All STATISTICAL STATEMENTS ARE SHOWN IN BOLD RED FOR CLARITY

3.2.3.1. General

Figure 3: **Plotted means with standard error bars for the 4 Captura sleeved treatment types at the 4 time intervals**



Comparison of means at 0, 12, 36 and 48 months indicates definite decay over 48 months for Control, RVP and Tanasote stakes and some variation for Creosote stakes.

3.2.3.2. Comparing Captura sleeved treatments regardless of time interval (i.e. exposure period)

Figure 4: **Plotted means with standard error bars for the 4 Captura sleeved treatment types regardless of time interval (i.e. exposure period)**

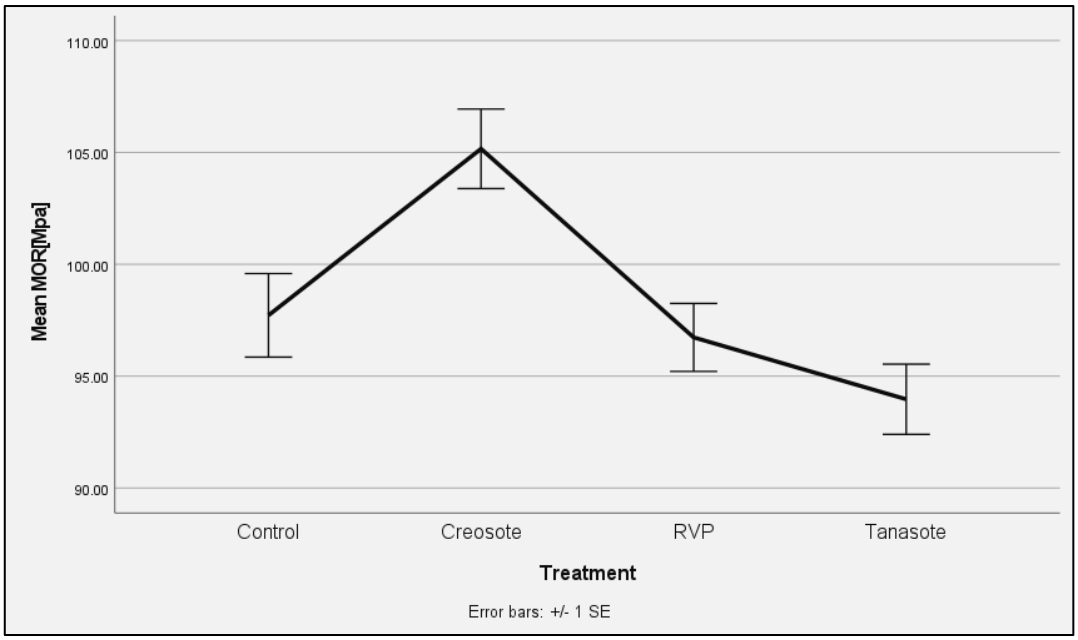


Table 6: **Pairwise comparisons of Captura sleeved treatment means regardless of time interval (i.e. exposure period)**

Pairwise Comparisons

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	df	Sidak Sig.	95% Wald Confidence Interval for Difference	
						Lower	Upper
Control	Creosote	-7.4448[a]	2.37376	1	.010	-13.6903	-1.1993
	RVP	.9858	2.37376	1	.999	-5.2597	7.2313
	Tanasote	3.7512	2.37376	1	.516	-2.4943	9.9967
Creosote	Control	7.4448[a]	2.37376	1	.010	1.1993	13.6903
	RVP	8.4306[a]	2.37376	1	.002	2.1851	14.6761
	Tanasote	11.1960[a]	2.37376	1	.000	4.9505	17.4415
RVP	Control	-.9858	2.37376	1	.999	-7.2313	5.2597
	Creosote	-8.4306[a]	2.37376	1	.002	-14.6761	-2.1851
	Tanasote	2.7654	2.37376	1	.813	-3.4801	9.0109
Tanasote	Control	-3.7512	2.37376	1	.516	-9.9967	2.4943
	Creosote	-11.1960[a]	2.37376	1	.000	-17.4415	-4.9505
	RVP	-2.7654	2.37376	1	.813	-9.0109	3.4801

Creosote stakes are significantly superior to all the other stake treatments, with RVP and Tanasote treatments showing no significant difference from Controls.

3.2.3.3. Comparing Captura sleeved treatments taking time interval (i.e. exposure period) into consideration

Table 7: Mean MOR values for each treatment type at each exposure period

Estimates

Treatment	Time(mths)	Mean	Std. Error	95% Wald Confidence Interval Lower	Upper
Control	0	100.9800	2.54582	95.9903	105.9697
	12	98.8200	3.60034	91.7635	105.8765
	24	105.9300	3.60034	98.8735	112.9865
	48	81.8940	3.60034	74.8375	88.9505
Creosote	0	103.5600	2.68559	98.2963	108.8237
	12	104.8800	3.79800	97.4361	112.3239
	24	113.2800	3.79800	105.8361	120.7239
	48	100.5480	3.79800	93.1041	107.9919
RVP	0	98.5500	1.83369	94.9560	102.1440
	12	106.2600	2.59323	101.1774	111.3426
	24	99.9000	2.59323	94.8174	104.9826
	48	80.4150	2.59323	75.3324	85.4976
Tanasote	0	98.9400	2.10324	94.8177	103.0623
	12	93.6600	2.97443	87.8302	99.4898
	24	98.3400	2.97443	92.5102	104.1698
	48	79.9680	2.97443	74.1382	85.7978

The pairwise comparison within treatments (not shown here) shows that there is significant decay at 48 months compared to 0, 12 and 24 months in the Control, RVP and Tanasote treatment, but not in the Creosote treatment.

For pairwise comparison of means between each treatment at each time point (not shown here) the following applies:

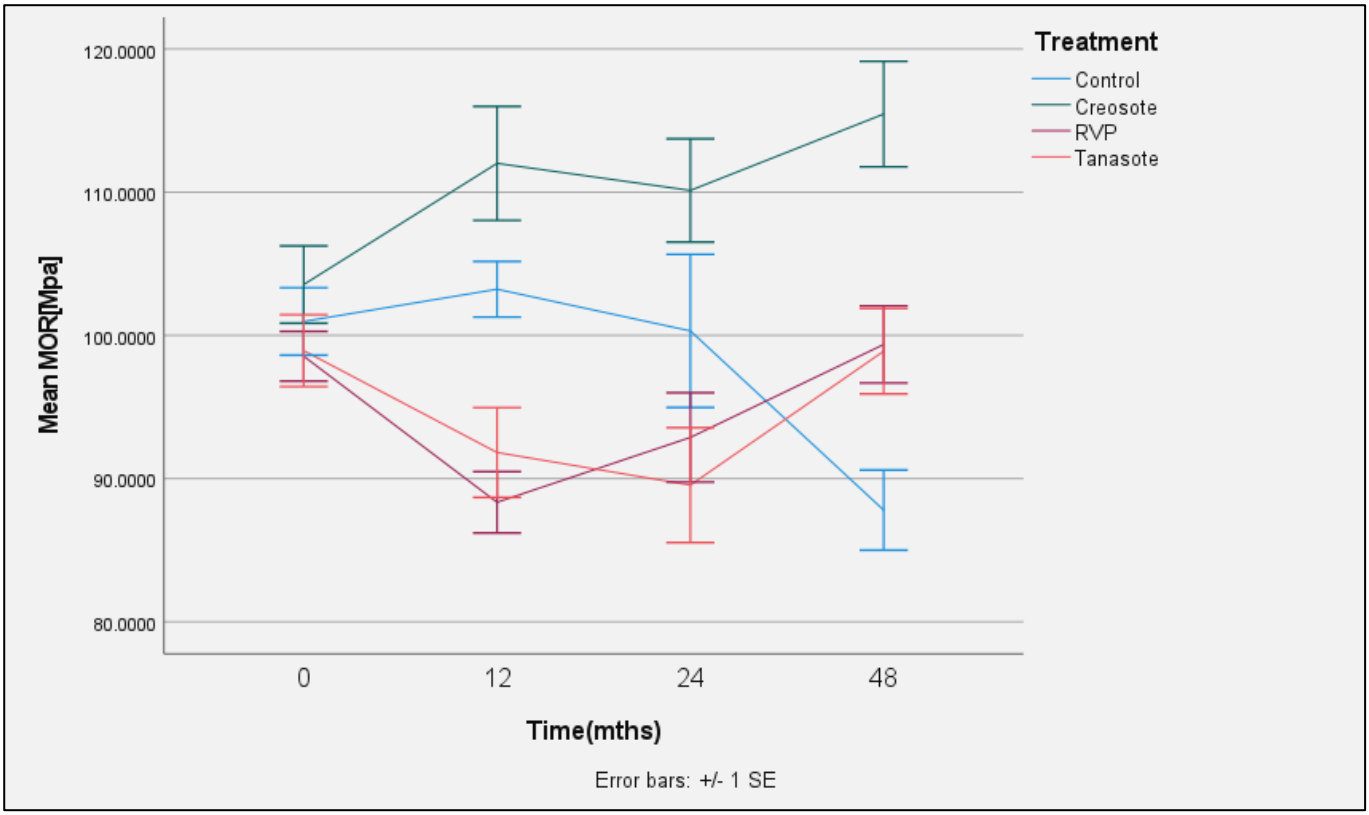
- **At 48 months Creosote is significantly superior to the other three treatments, and there are not significant differences at this time point among Control, RVP and Tanasote.**
- **Additionally, we see that at 24 months Creosote is significantly superior to Tanasote (p-value=0.02) and marginally significantly superior to RVP (p-value=0.051)**

3.2.4. Analyses of Polesaver Stakes at 0, 12, 24, and 48 months

NOTE: All STATISTICAL STATEMENTS ARE SHOWN IN BOLD RED FOR CLARITY

3.2.4.1. General

Figure 5: **Plotted means with standard error bars for the 4 Polesaver sleeved treatment types at each time interval (i.e. exposure period)**



Comparing treatment means at the different time periods (above) strongly indicates decay for control treated stakes at 48 months while stakes treated with creosote seem to display improvement.

3.2.4.2. Comparing Polesaver sleeved treatments regardless of time interval (i.e. exposure period)

Figure 6: **Plotted means with standard error bars for the 4 Polesaver sleeved treatment types regardless of time interval (i.e. exposure period)**

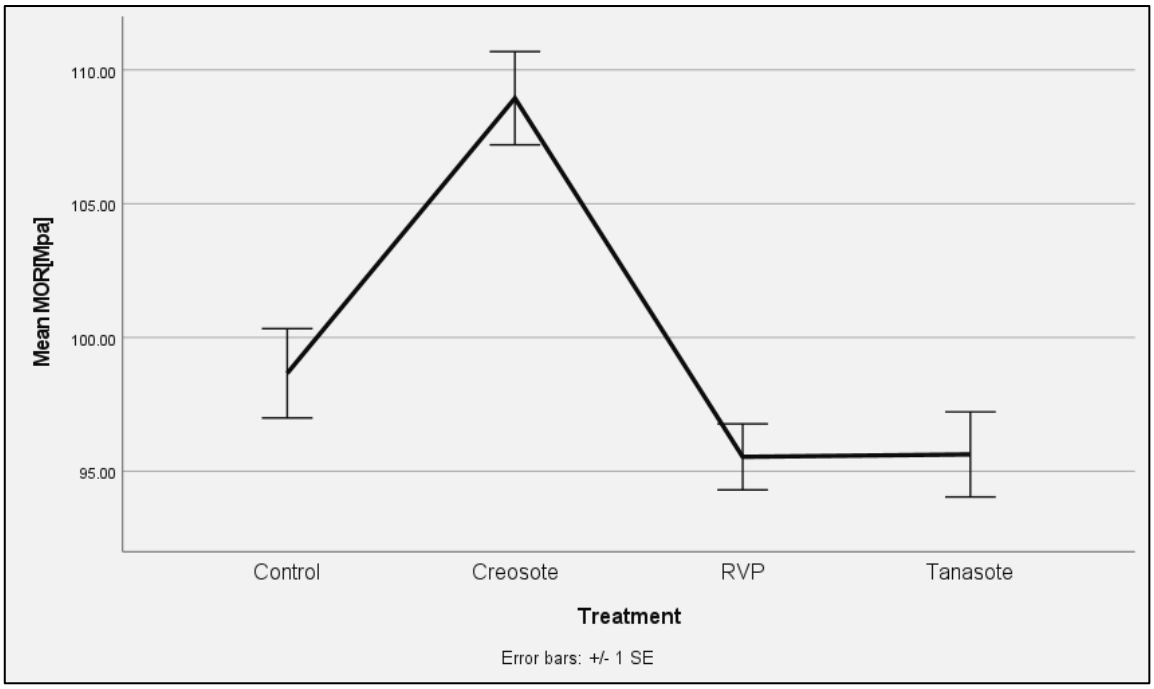


Table 8: **Pairwise comparisons of Polesaver sleeved treatment means regardless of time interval (i.e. exposure period)**

Pairwise Comparisons

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	df	Sidak Sig.	95% Wald Confidence Interval for Difference	
						Lower	Upper
Control	Creosote	-10.2828[a]	2.20712	1	.000	-16.0898	-4.4758
	RVP	3.1230	2.20712	1	.641	-2.6840	8.9300
	Tanasote	3.0306	2.20712	1	.672	-2.7764	8.8376
Creosote	Control	10.2828[a]	2.20712	1	.000	4.4758	16.0898
	RVP	13.4058[a]	2.20712	1	.000	7.5988	19.2128
	Tanasote	13.3134[a]	2.20712	1	.000	7.5064	19.1204
RVP	Control	-3.1230	2.20712	1	.641	-8.9300	2.6840
	Creosote	-13.4058[a]	2.20712	1	.000	-19.2128	-7.5988
	Tanasote	-.0924	2.20712	1	1.000	-5.8994	5.7146
Tanasote	Control	-3.0306	2.20712	1	.672	-8.8376	2.7764
	Creosote	-13.3134[a]	2.20712	1	.000	-19.1204	-7.5064
	RVP	.0924	2.20712	1	1.000	-5.7146	5.8994

Polesaver stakes treated with Creosote are significantly superior to all other treatments with RVP and Tanasote treated Polesaver stakes not significantly different to Polesaver Control stakes.

3.2.4.3. Comparing Polesaver sleeved treatments taking time interval (i.e. exposure period) into consideration

Table 9: Mean MOR values for each treatment type at each exposure period

Estimates

Treatment	Time(mths)	Mean	Std. Error	95% Wald Confidence Interval Lower	Upper
Control	0	100.9800	2.43321	96.2110	105.7490
	12	103.2300	3.44108	96.4856	109.9744
	24	100.3200	3.44108	93.5756	107.0644
	48	87.8070	3.44108	81.0626	94.5514
Creosote	0	103.5600	2.60628	98.4518	108.6682
	12	112.0200	3.68584	104.7959	119.2441
	24	110.1300	3.68584	102.9059	117.3541
	48	115.4610	3.68584	108.2369	122.6851
RVP	0	98.5500	1.78566	95.0502	102.0498
	12	88.3500	2.52531	83.4005	93.2995
	24	92.8800	2.52531	87.9305	97.8295
	48	99.3720	2.52531	94.4225	104.3215
Tanasote	0	98.9400	2.38969	94.2563	103.6237
	12	91.8300	3.37954	85.2062	98.4538
	24	89.5500	3.37954	82.9262	96.1738
	48	98.9040	3.37954	92.2802	105.5278

The pairwise comparison <u>within</u> treatments (not shown here) shows the following:

- **There is a significant decay at 48 months compared to 0, 12 and 24 months for the Control stakes.**
- **RVP treated stakes show significant decay at 12 months compared to 0 months, but no difference at 24 and 48 months compared to the baseline.**
- **Tanasote treated stakes show no significant change at any time points.**
- **Creosote treated stakes at 48 months show a significant improvement compared to those at 0 months.**

For pairwise comparison of means <u>between</u> each treatment at each time point (not shown here) the following applies:

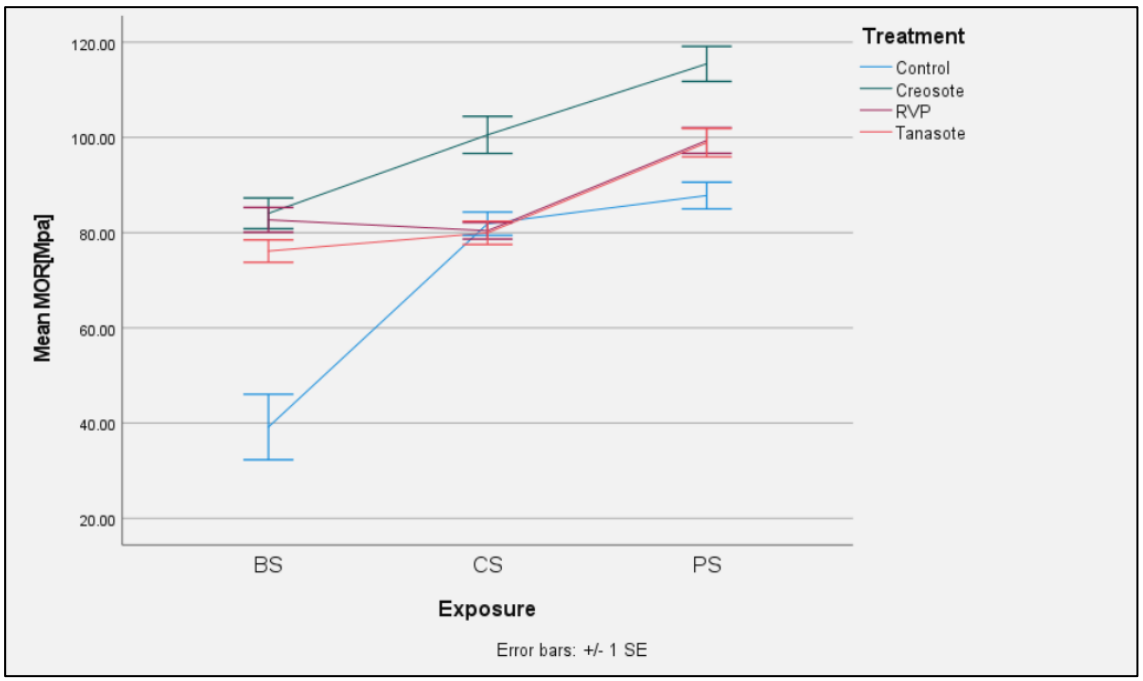
- **No significant difference between treatments at 0 months.**
- **After 12 months, RVP and Tanasote stakes are significantly decayed compared to Creosote and Control stakes (which are not significantly different).**
- **After 24 months, RVP, Tanasote and Control stakes display no significant differences but Creosote stakes are significantly superior to RVP and Tanasote stakes.**
- **After 48 months, Creosote stakes are significantly superior to Control, RVP and Tanasote stakes, and the latter stakes (which are not significantly different) are significantly superior to Control stakes.**

3.2.5. Analyses of ALL Stakes (bare and sleeved) at 48 months

NOTE: All STATISTICAL STATEMENTS ARE SHOWN IN BOLD RED FOR CLARITY

3.2.5.1. General

Figure 7: **Plotted means with standard error bars for the 4 treatment types and 3 barrier types (BS-Bare, CS-Captura and PS-Polesaver) at 48 months**



After 48 months there are larger MOR values on average for Creosote (with both Captura and Polesaver protection) compared to the other treatments. Polesaver protection seems to offer the most protection to the wood in all treatments.

Table 10: **Pairwise comparisons between all 4 treatments for each barrier (BS, CS and PS) at 48 months**

Pairwise Comparisons

Exposure	(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	df	Sidak Sig.	95% Wald Confidence Interval for Difference	
							Lower	Upper
BS	Control	Creosote	-44.8710[a]	5.72568	1	.000	-59.9355	-29.8065
		RVP	-43.5120[a]	5.72568	1	.000	-58.5765	-28.4475
		Tanasote	-36.9570[a]	5.72568	1	.000	-52.0215	-21.8925
	Creosote	Control	44.8710[a]	5.72568	1	.000	29.8065	59.9355
		RVP	1.3590	5.72568	1	1.000	-13.7055	16.4235
		Tanasote	7.9140	5.72568	1	.666	-7.1505	22.9785
	RVP	Control	43.5120[a]	5.72568	1	.000	28.4475	58.5765
		Creosote	-1.3590	5.72568	1	1.000	-16.4235	13.7055
		Tanasote	6.5550	5.72568	1	.825	-8.5095	21.6195
	Tanasote	Control	36.9570[a]	5.72568	1	.000	21.8925	52.0215
		Creosote	-7.9140	5.72568	1	.666	-22.9785	7.1505
		RVP	-6.5550	5.72568	1	.825	-21.6195	8.5095
CS	Control	Creosote	-18.6540[a]	3.75951	1	.000	-28.5454	-8.7626
		RVP	1.4790	3.75951	1	.999	-8.4124	11.3704
		Tanasote	1.9260	3.75951	1	.996	-7.9654	11.8174
	Creosote	Control	18.6540[a]	3.75951	1	.000	8.7626	28.5454
		RVP	20.1330[a]	3.75951	1	.000	10.2416	30.0244
		Tanasote	20.5800[a]	3.75951	1	.000	10.6886	30.4714
	RVP	Control	-1.4790	3.75951	1	.999	-11.3704	8.4124
		Creosote	-20.1330[a]	3.75951	1	.000	-30.0244	-10.2416
		Tanasote	.4470	3.75951	1	1.000	-9.4444	10.3384
	Tanasote	Control	-1.9260	3.75951	1	.996	-11.8174	7.9654
		Creosote	-20.5800[a]	3.75951	1	.000	-30.4714	-10.6886
		RVP	-.4470	3.75951	1	1.000	-10.3384	9.4444
PS	Control	Creosote	-27.6540[a]	4.19665	1	.000	-38.6955	-16.6125
		RVP	-11.5650[a]	4.19665	1	.035	-22.6065	-.5235
		Tanasote	-11.0970[a]	4.19665	1	.048	-22.1385	-.0555
	Creosote	Control	27.6540[a]	4.19665	1	.000	16.6125	38.6955
		RVP	16.0890[a]	4.19665	1	.001	5.0475	27.1305
		Tanasote	16.5570[a]	4.19665	1	.000	5.5155	27.5985
	RVP	Control	11.5650[a]	4.19665	1	.035	.5235	22.6065
		Creosote	-16.0890[a]	4.19665	1	.001	-27.1305	-5.0475
		Tanasote	.4680	4.19665	1	1.000	-10.5735	11.5095
	Tanasote	Control	11.0970[a]	4.19665	1	.048	.0555	22.1385
		Creosote	-16.5570[a]	4.19665	1	.000	-27.5985	-5.5155
		RVP	-.4680	4.19665	1	1.000	-11.5095	10.5735

Findings are as follows:

- **Bare Stakes: All treatments are significantly superior to the controls, and there are no differences among the three treatments.**
- **Captura Sleeves: Creosote treatment is significantly superior to the other three treatments and these are not significantly different.**
- **Polesaver Sleeves: All three treatments Creosote, Tanasote and RVP are significantly superior to the Control, and Creosote is significantly superior to Tanasote and RVP.**
- **The combination of Creosote and Polesaver sleeve appears to offer the greatest protection.**

Table 11: **Pairwise comparisons between all 3 barriers (BS, CS and PS) for each treatment at 48 months**

Pairwise Comparisons

Treatment	(I) Exposure	(J) Exposure	Mean Difference (I-J)	Std. Error	df	Sidak Sig.	95% Wald Confidence Interval for Difference	
							Lower	Upper
Control	BS	CS	-42.7050[a]	6.18142	1	.000	-57.4646	-27.9454
		PS	-48.6180[a]	6.18142	1	.000	-63.3776	-33.8584
	CS	BS	42.7050[a]	6.18142	1	.000	27.9454	57.4646
		PS	-5.9130	6.18142	1	.711	-20.6726	8.8466
	PS	BS	48.6180[a]	6.18142	1	.000	33.8584	63.3776
		CS	5.9130	6.18142	1	.711	-8.8466	20.6726
Creosote	BS	CS	-16.4880[a]	4.94132	1	.003	-28.2866	-4.6894
		PS	-31.4010[a]	4.94132	1	.000	-43.1996	-19.6024
	CS	BS	16.4880[a]	4.94132	1	.003	4.6894	28.2866
		PS	-14.9130[a]	4.94132	1	.008	-26.7116	-3.1144
	PS	BS	31.4010[a]	4.94132	1	.000	19.6024	43.1996
		CS	14.9130[a]	4.94132	1	.008	3.1144	26.7116
RVP	BS	CS	2.2860	3.25594	1	.862	-5.4883	10.0603
		PS	-16.6710[a]	3.25594	1	.000	-24.4453	-8.8967
	CS	BS	-2.2860	3.25594	1	.862	-10.0603	5.4883
		PS	-18.9570[a]	3.25594	1	.000	-26.7313	-11.1827
	PS	BS	16.6710[a]	3.25594	1	.000	8.8967	24.4453
		CS	18.9570[a]	3.25594	1	.000	11.1827	26.7313
Tanasote	BS	CS	-3.8220	3.57926	1	.635	-12.3683	4.7243
		PS	-22.7580[a]	3.57926	1	.000	-31.3043	-14.2117
	CS	BS	3.8220	3.57926	1	.635	-4.7243	12.3683
		PS	-18.9360[a]	3.57926	1	.000	-27.4823	-10.3897
	PS	BS	22.7580[a]	3.57926	1	.000	14.2117	31.3043
		CS	18.9360[a]	3.57926	1	.000	10.3897	27.4823

Findings are as follows:

- **Untreated Control: Captura and Polesaver sleeved stakes (which are not significantly different) show significant protection at 48 months compared to bare stakes.**
- **Creosote: Captura and Polesaver sleeved stakes show significant protection at 48 months compared to bare stakes, and Polesaver sleeves offer significantly increased protection compared to Captura sleeves.**
- **RVP and Tanasote: Polesaver offers significant additional protection compared to Bare and Captura stakes, with no significant difference between the latter.**
- **The Polesaver sleeve offers the greater protection for all treated stakes.**

4. Discussion of Results and Concluding Comments

4.1. Visual Examination of Uplifted Stakes (refer to section 2.2.1)

Bare Stakes: Visual examination of the uplifted bare (unsleeved) stakes indicates that, after 60 months exposure in the accelerated system:

- All the treated stakes (Creosote, RVP and Tanasote) are displaying definite indications of decay and deterioration, not visible previously. However, those stakes treated with RVP are displaying much less degrade so are demonstrating the greatest apparent resistance to decay. The Tanasote stakes appear to be worst affected by decay after 60 months.

- The ground line portions of all the untreated control timbers (+50mm to -300 mm) are effectively disintegrated disintegration (i.e. 100% strength loss) with no processing for MOR tests being possible.

- In the deteriorating stakes, decay was frequently found all the way to the base of each stake (i.e. 500 mm below the ground line). This demonstrates that the soil bed is better aerated than normal field soil where external decay would not typically be found deeper than ~ 350-400 mm due to increasing anaerobic conditions with depth. This underscores the strong decay potential of the soil bed.

The foregoing results represent a significant change after 60 months exposure for treated stakes compared to their condition after 48 months exposure (see Report 4) or earlier where no overt decay was noted. The condition of untreated control stakes at 60 months is significantly worse than at 48 months (see Appendix 2 and Report 4).

CAPTURA Stakes: Not included at this 5th (60 month) uplift.

Polesaver Stakes: Not included at this 5th (60 month) uplift.

The foregoing visual assessment results indicate that at this 5th stage of the trial (after 60 months exposure:

- **The accelerated decay chamber is serving its purpose in producing visible decay in both control and treated timbers. It therefore represents a very severe decay environment for both unprotected and protected timber**

- **Based on the condition of the untreated control stakes (disintegrating and disintegrated) after 60 months (5 years) exposure, the decay acceleration provided by the chamber is estimated to be 6-7x that of the normal field rate. This is less than the 10x which was hoped for. However, it does mean that the treated stakes have been subjected to decay conditions equivalent to 30-35 years in the field.**

- **The new preservative product Tanasote appears to be performing almost as well as Creosote but RVP, based on visual assessment only, is apparently performing better than both**

4.2. MOR Statistical Analyses (refer to section 3.2)

Statistical analyses of the MOR results after 60 months of stake exposure to the soil bed show the following:

Bare Stakes (Unsleeved) – 0, 12, 24, 36, 48 and 60 months:

- **When time is removed as a factor, stake populations treated with the 3 preservative types all have significantly higher MOR values than the control stakes and are not significantly different from each other.**

- **Untreated control timbers continue to show very highly significant strength loss, having now (at 60 months) completely failed with none of the retrieved samples surviving intact for MOR testing (i.e. all given a MOR of 0). So, for the control stakes, mean MOR values after 24, 36, 48 and 60 months exposure are 88%, 69%, 39% and 0% respectively of that at 0 time.**

- **For both RVP and Tanasote treatments the decay which was significant after 48 months (compared to 0, 12, 24 and 36 months), does not worsen after 60 months.**

- **Creosote treated stakes display significant decay at 48 months compared to 0, 12 and 36 months. This stabilises (actually has an uptick in mean MOR value) at 60 months as evidenced by decay at this stage being significant compared to 0 and 12 months but not significant compared to 36 and 48 months.**

- **All treatments (Creosote, RVP and Tanasote) are superior to the controls at 36, 48 and 60 months, RVP and Tanasote are superior to the control at 24 months and RVP is superior to the controls at 12 months.**

- **Up to and including 48 months, there is no significant difference between Creosote, RVP and Tanasote, however, after 60 months Creosote treatment is significantly superior to both RVP and Tanasote (due to an uptick in mean MOR value for Creosote at this stage).**

CAPTURA Stakes (sleeved) – 0, 12, 24, and 48 months (partially reprised from report 4):

- **When time is removed as a factor, Captura sleeved Creosote stakes are significantly superior to all the other stake treatments, with RVP and Tanasote treatments showing no significant difference from Controls.**

- **There is a significant reduction in mean MOR value for the CAPTURA sleeved Control, RVP and Tanasote stakes at 48 months compared to 0, 12 and 24 months, but there is no such difference for Creosote treated stakes.**

- **After 24 months exposure, Creosote is significantly superior to RVP and Tanasote and at 48 months Creosote is very highly significantly superior to Control, RVP and Tanasote.**

Polesaver Stakes (sleeved) – 0, 12, 24, and 48 months:

- **When time is removed as a factor, Polesaver stakes treated with Creosote are significantly superior to all other treatments with RVP and Tanasote treated Polesaver stakes not significantly different to Polesaver Control stakes.**

- **There is a significant decay at 48 months compared to 0, 12 and 24 months for the Control stakes, while RVP treated stakes show significant decay at 12 months compared to 0 months only, and Tanasote treated stakes show no significant change at any time points.**

- **Creosote treated stakes at 48 months show a significant improvement compared to those at 0 months.**

- **There are no significant differences between treatments at 0 months, but after 12 months RVP and Tanasote stakes are significantly decayed compared to Creosote and Control stakes (which are not significantly different).**

- **After 24 months, RVP, Tanasote and Control stakes display no significant differences but Creosote stakes are significantly superior to RVP and Tanasote stakes.**

- **After 48 months, Creosote stakes are significantly superior to Control, RVP and Tanasote stakes, and RVP and Tanasote stakes (which are not significantly different) are significantly superior to Control stakes.**

ALL Stakes (sleeved and unsleeved) at 48 months:

- **For untreated Controls both Captura and Polesaver sleeved stakes (which are not significantly different) show significant protection at 48 months compared to bare stakes.**

- **For Creosoted samples both Captura and Polesaver sleeved stakes show significant protection at 48 months compared to bare stakes, and Polesaver sleeves offer significantly increased protection compared to Captura sleeves.**

- **For RVP and Tanasote samples Polesaver offers significant additional protection compared to Bare and Captura stakes, with no significant difference between the latter.**

- **The Polesaver sleeve offers the greater protection for all treated stakes and the combination of Creosote and Polesaver sleeve appears to offer the greatest protection.**

4.3. General Comments/Points on findings in sections 4.1 and 4.2

Assessment of unsleeved preservative treated stakes after retrieval at 60 months showed for the first time that definite visible external decay was present. No decay was visible on treated stakes at the 48 month uplift. Despite this, statistical analyses of mean MOR values did not confer a significantly greater loss of strength on the 60 month stakes compared to those at 48 months. Significant strength loss that was found after 48 months in the treated groups generally stabilised up to the 60 month interval.

The foregoing highlights the following:

- External decay which was visible at 60 months was present but not easily visible at 48 months.
- External decay which was clearly present at 48 months had not appreciably worsened by 60 months (in terms of actual strength loss) indicating that **none of the new preservative types appear prone to a sudden loss of protective effectiveness (which is not uncommon).**
- As indicated in report 4, a subjective evaluation of timber deterioration (visible inspection) is no substitute for objective physical testing (MOR tests).

With regard to the broader statistical results for the unsleeved stakes, after 60 months soil bed exposure:

- **The ground line region of the untreated control stake population is effectively completely destroyed.**
- Creosote appears to be performing better than Tanasote and RVP, though this was due to an unusual uptick in mean MOR value for Creosote stakes at the 60 month stage - possibly due to the normal variability of timber allied to the relatively small population sizes compared. **It would probably be more accurate to say that though the performances of Creosote, RVP and Tanasote are largely indistinguishable after 60 months exposure, the indications are that Creosote is displaying an advantage over RVP which is displaying a slight advantage over Tanasote.** This result could be seen as unusual as Creosote does not usually perform well in stake tests. Poor performance is due typically to the loss of an upper Creosote reservoir (as found in poles) from which the ground line can be replenished with preservative via gravitational movement. It may be that the much greater length given to the stakes in this test (1500 mm) has provided enough of an upper reservoir to make the difference. Indeed, this was the reasoning for the 1500 mm length when the trial was designed.

It is not correct to take results from stake tests and extrapolate these to round timbers or poles to make definitive judgements on pole longevity and preservative efficacy. This is because rounds decay differently and poles always have untreated interiors which are also prone to decay. It is worth noting however that the loss of strength measured in treated stakes over the 60 month period represents some 15%, 20% and 20% for Creosote, RVP and Tanasote respectively. These values in terms of pole RSV (residual strength value) would give a pass for a creosoted pole and a pass or borderline pass (depending on the DNO) for an RVP or Tanasote treated pole.

Looking at results for all stakes (unsleeved and sleeved) at 48 months demonstrates that the Polesaver sleeve provides very significant additional decay protection to all treated stake types. Creosote treatment supported by a Polesaver provides much the best protection.

The relatively poor performance of the Captura sleeve was interesting given that this general design has shown good field results in the past. It may be that the greater decay potential of this soil bed to depth (compared to a field soil) as evidenced by the decay seen to the base of the treated stakes, has compromised the performance of this sleeve. The Captura sleeve was partial, not sheathing the stake below a depth ~ 350-400mm, whereas the Polesaver encompassed the entire below ground-line zone of the stakes.

4.4. Concluding Comments

As noted in all previous reports, this NIA project was developed to answer 3 main questions:

1. Will RVP and/or Tanasote provide a preservative effect efficacious enough to allow either or both to serve as a possible replacement for creosote for the treatment of OHL wood poles

2. Will the use of ground-line barrier products provide an additional protective effect which may extend the service life of an OHL pole treated with any replacement for creosote

3. Will the accelerated decay chamber developed for this project provide a challenging enough decay environment to permit the answers to the questions at 1 and 2 to be applicable to UK field conditions over a 40 year (now 60 year) period

Question 1:

At this stage of the project (5th year of 6) the answer to question 1 is yes. The similar loss of preservative effectiveness seen in all the treated stakes after 48 months exposure is shown again at 60 months but with no worsening of the effect. As indicated in section 4.3, this is important as it seems to demonstrate that **"none of the new preservative types appear prone to a sudden loss of protective effectiveness". At this stage of the trial, indications are that Creosote is showing an advantage over RVP and Tanasote (see section 4.3).**

Question 2:

It is clear from the results of this trial that the correct ground line barrier for the soil conditions will extend/improve the protective efficacy of all the treatment types. Possible reasons for the poor performance of the Captura sleeves are discussed in section 4.3. **The stand out result was for the Polesaver product which provided significant additional protection to all the treatment types to the extent that the mean MOR values for Polesaver stakes (all preservative treatments) after 48 months exposure was essentially identical to the mean MOR values for all treatment stakes at 0 time (i.e. before soil exposure).**

Question 3:

After 5 years of operation we can say with certainty (as was sad after 4 years) that the soil bed and environmental conditions are providing a very severe decay test for timbers. This is highlighted not only by the disintegrating condition of the untreated control stakes but also now by the fact that the preservative types are beginning to lose efficacy and are maintaining this loss.

As stated in section 4.1: Based on the condition of the untreated control stakes (disintegrating and disintegrated) after 60 months (5 years) exposure, the decay acceleration provided by the chamber is estimated to be 6-7x that of the normal field rate and **means that the treated stakes have been subjected to decay conditions equivalent to 30-35 years in the field.**

The trial length in terms of the decay accelerator effect has therefore reached that critical point beyond which the preservative manufacturers generally predict a loss of protective efficacy. The findings in this trial at this stage would seem to broadly agree with these predictions.

4.5. Calculating a Pole RSV (Residual Strength Value) from Stake Test Results

In section 4.3 it is stressed that stake test results should not be extrapolated to gauge the performance of similarly preservative treated poles in the field. As an exercise however, this was undertaken in a very basic way by equating whole stake strength loss to whole pole strength loss.

To give a better and much more accurate idea of a pole RSV based on the stake results at this 30-35 years stage (of decay acceleration) the stake test results are revisited here, and assessed in terms of depth of decay to the treated timber surface only (i.e. ignoring the MOR strength results entirely). This depth of decay is then applied to poles of different diameters and then an RSV calculated. The depth of decay was not measured precisely on any of the stakes but it is clear that it was never deeper than 5 mm for any treatment. Using this information the RSV calculation/prediction gives the following results for all the treatments after 30-35 years in the field:

- Pole Diameter 200 mm: RSV = 88.72%
- Pole Diameter 250 mm: RSV = 91%
- Pole Diameter 300 mm: RSV = 94%

Note 1: The above percentages are for external decay only and take no account of internal decay which can develop in poles as early as 20 years after installation (or earlier depending on treatment penetration (i.e. presence or absence of untreated sapwood)). The RSVs also take no account of physical damage to the pole at installation or after.

Note 2: The RSV will rise with increasing pole diameter as the proportion of pole strength residing in the outer 5 mm shell of the pole decreases.

Note 3: The method of RSV calculation used here is completely reliable as it will always tend to overestimate RSV to provide a margin of safety. This RSV calculation method is used in the PoleStat pole testing program (Freedom product) and is also used in assessing pole RSV via Resistograph. The method has been used on 1000s of field poles, has never permitted an unsafe pole to remain in service and was found to produce a more secure RSV than other methods when compared at the laboratories of EA Technology.

The foregoing Residual Strength Values for Tanasote and RVP treated poles are mainly predictive because there is no body of field data available for these pole types over a service life of 30-35 years. This is not the case for creosoted poles. Based on field evaluations of 1000s of such poles, the RSV results given above are entirely in keeping with values found for creosoted poles after 30-35 years' service life. Using the creosote results as a guide, the comparative performances of the treated stakes at this stage of the trial would indicate that the predictive values for Tanasote and RVP poles are likely fairly accurate.

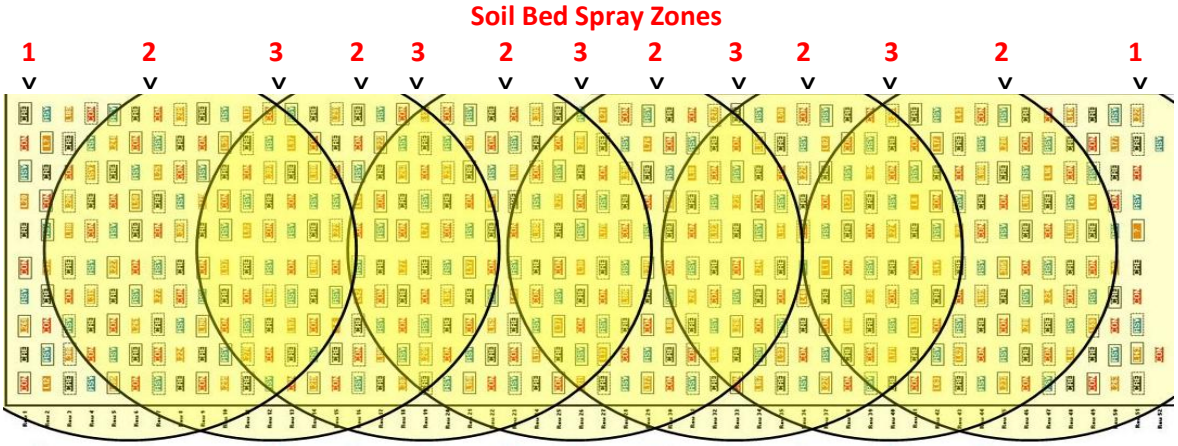
Appendix 1: Uplift 5 - Stake Sampling Procedure

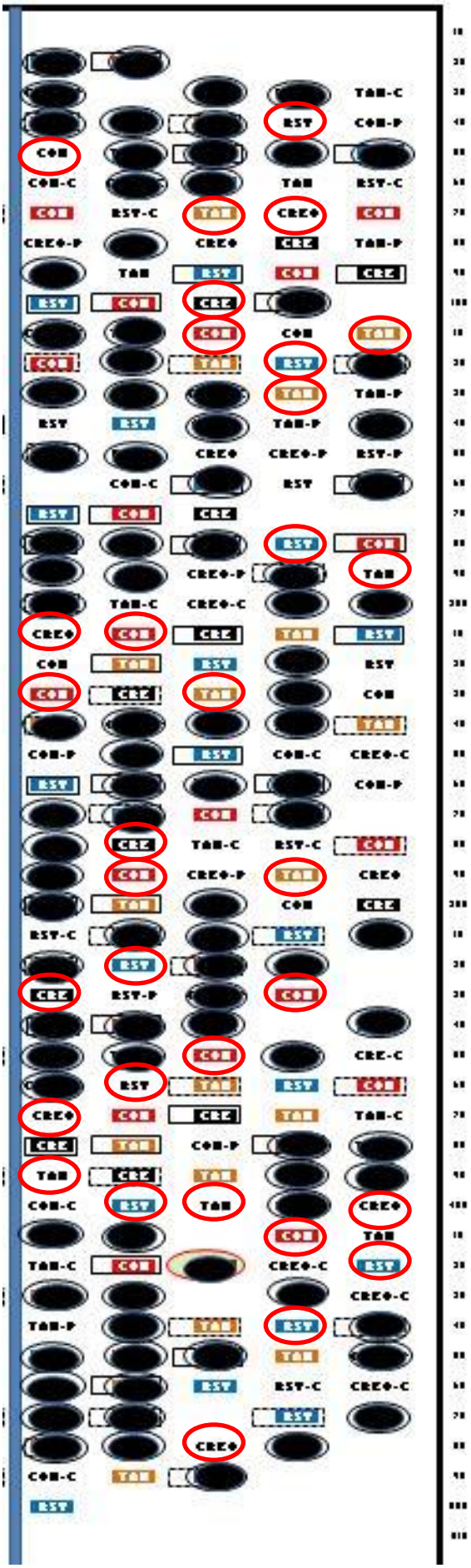
The total number of stakes in the trial is shown in the following table and the samples for recovery at the fifth uplift (60 months) are shown in the green boxes (1st, 2nd, 3rd and 4th uplifts in red):

Treatment	Orig. Sampling Period 1: Test Stakes (1 YR)	Orig. Sampling Period 2: Test Stakes (2 YRS)	Orig. Sampling Period 3: Test Stakes (3 YRS)		Orig. Sampling Period 4: Test Stakes (4 YRS)		Total
			3 YRS	4YRS	5YRS	6YRS	
Creosote (**E**)	16	16	8	8	8	8	64
RV-PWR T (**E**)	16	16	8	8	8	8	64
Lonza T (**E**)	16	16	8	8	8	8	64
Untreated Control (**E**)	16	16	8	8	8	8	64
Creosote (**SE**)	16 (8/8)	16 (8P/8C)	16 (8P/8C)		16 (8P/8C)		64
RV-PWR T (**SE**)	16 (8/8)	16 (8P/8C)	16 (8P/8C)		16 (8P/8C)		64
Lonza T (**SE**)	16 (8/8)	16 (8P/8C)	16 (8P/8C)		16 (8P/8C)		64
Untreated Control (**SE**)	16 (8/8)	16 (8P/8C)	16 (8P/8C)		16 (8P/8C)		64
Creosote (**NE**)	16	← Stakes (64) retained for test comparison – not exposed to the soil bed					16
RV-PWR T (**NE**)	16						16
Lonza T (**NE**)	16						16
Untreated Control	16						16
Total Stakes in Test	192	128	32	96	32	96	**576**
Stakes in Soil Bed	128	128	32	96	32	96	**512**
Sub-Samples – BS 373	**384**	256	64	192	64	192	**1152**

Treatment (E):	Treated pole sections **exposed** to the soil bed
Treatment (SE):	Treated and **sleeved** pole sections **exposed** to the soil bed (2 sleeve types (P and C))
Treatment (NE):	Treated timbers **not exposed** to the soil bed but used for direct statistical comparison with respective **E** and **SE** samples across all sampling times
Untreated Control (E):	These pole sections also serve as the **Decay Tester** timbers

As indicated below, the acceleration chamber spray pattern results in differential volumes being applied to different areas of the soil bed. This gives soil bed zones (and stakes) that are subjected to spray from 1, 2 or 3 spray heads (called **Zone 1**, **2** and **3**). All zone 1 samples were recovered at the first uplift leaving Zones 2 and 3 for all later uplifts



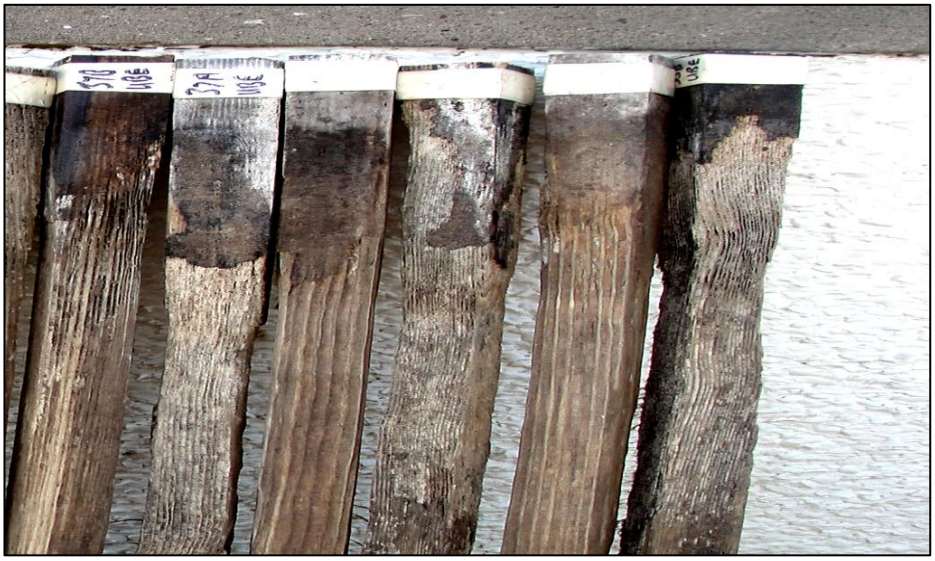


All uplift 5 stakes were therefore drawn randomly from the remaining zones 2 and 3. These sample stakes were drawn only from the right side of the soil bed – where all remaining stakes were repositioned at the time of uplift 3 (October 2020) to make space for the now positioned round timbers (APPEAL addition).

All uplift 5 stake samples are denoted by circles in the soil bed plan (left). Five (5) of the 8 untreated bare stakes broke at uplift due to decay and disintegration, and the remaining 3 collapsed shortly thereafter. This provided 24 complete stake samples to give 48 processed stakelets as follows:

8 Bare untreated Controls:	0 stakelets
8 Bare Creosote Treated:	16 stakelets
8 Bare RVP Treated:	16 stakelets
8 Bare Tanasote Treated:	16 stakelets

Appendix 2: Condition of Bare Untreated Stakes after 36, 48 and 60 Months of Soil Bed Exposure



36 months

48 months

60 months

The photographic plates above underline both the significant progression of decay processes over the 24 months between the third stake uplift (36 months) and the fifth uplift (60 months) and the success of the soil bed enrichment policy.