RESEARCH REVIEW
OF COAL TAR BASED WOOD PRESERVATIVES
The South African Experience

(PJ Rossouw, DW Hunter, July 2005)

ABSTRACT

This paper examines the performance of several creosotes and creosote coal tar solutions as a wood preservative. These are compared using data from existing studies. The relationship between efficacy, residual content and low-temperature carbonisation is demonstrated. The tar acid content of the different processes and their efficacy, as well as various findings over the past 50 years, are also discussed. Data to predict the loss of coal tar fractions from wood over time is extrapolated using existing South African research.

SUMMARY

The fact that bituminous coals produce a coal tar that is effective in wood preservation has been proved both in South Africa and internationally. Low-temperature processes are generally more effective than their high-temperature counterparts if combined with high-residue content, as tested in South Africa. It has been confirmed worldwide that high-residue content is generally more effective than low-residue content, especially in South Africa. High tar acid-containing wood preservatives are totally effective against fungi and termites providing that adequate retention is maintained with high-residue and/or wax components.

The authors recommend that a high-residue coal tar creosote solution specification be introduced as there is more than enough data to support its efficacy and superior properties as a long-term wood preservative.

INTRODUCTION

Studies in South Africa on the efficacy of creosotes and coal tar cresosote solutions started prior to 1927. Two test plots at Pienaarsrivier (near Pretoria) and Kruisfontein (near Knysna) were established and laid out by Krogh in 1948. Several creosotes, both from high and low-temperature processes, with high and low-tar acid content, creosotes and coal tar solutions, and creosotes and petroleum/waxy oil solutions were tested. Other studies measured the amount of creosote lost due to evaporation. The studies also examined the correlation between checking and residue content, general decay, termite and fungi repellancy. The general efficacy of coal tar derivatives produced from South African coal is also discussed.

LOW AND HIGH-TEMPERATURE PROCESSES

The low-temperature processes differ slightly in chemical composition in that low-temperature tar and its creosote fractions contain much higher levels of tar acids. Tar acids are toxic and good for fungi toxicity. However tar acids are also found to leach out more readily than material of the same boiling point from a high-temperature creosote. In the tests started in 1952, it was clearly demonstrated that the low-temperature, high-tar acid and high-residue (38,8%) creosote out-performed both medium and high-temperature processes with lower-distilled residue content.

Various blends were made from high and low-temperature creosotes and creosote solutions. The general rule of better efficacy with higher-residue material was confirmed. The creosote wax blends showed a notable improvement over pure creosote. The wax low-temperature creosote blends were found to be superior to the high-temperature creosote. The waxy blends also have a high-residue content. The wax oil on its own is not a good wood preservative, but with a high tar acid creosote it becomes effective due to retarding of water movement in the wood and a probable reduction in creosote losses due to evaporation.

All the coal tar creosote solutions out-performed their pure distilled creosote counterparts (both for Sasol and Iscor products). The best performer had a high tar acid and 38,8% residue (see table 3). Some notable comments from Coetzee, Vermaak and Quinn are extracted from their paper:

EFFECTIVENESS OF LOW AND HIGH TAR ACID CREOSOTES
AS DETERMINED BY STAKE TESTS
P.F. Coetzee, G.S. Vermaak and P. Quinn

> " High temperature creosotes have a low tar acid content while medium temperature, low-temperature and creosotes obtained from the Lurgi gasification, contain higher tar acid contents. "
>
> "High temperature (low tar acid) creosote … between 280°C and 320°C … are the most toxic to wood-destroying fungi."
>
> "The average loss of the different fractions was 3 times higher than the loss of pure creosote in treated blocks."
>
> "Field tests have generally shown that the high boiling oils are more effective than the low boiling oils. Colley, Henry, Leutritz & Stasse (1962) summarized the results of the 1948 co-operative creosote test on ¾-inch stakes exposed in the four test plots. …the effectiveness increased with distillation residue. The best performance was obtained by a 70/30 mixture of medium-residue creosote and a heavy residual petroleum. Later results on the co-operative creosote projects of 1948 and 1958 in the U.S.A reported by Harrford & Colley (1974), showed that distillation range and in particular the residue above 355°C '*correlate very strongly with performance'* ."

" ….. at comparable retentions the highest distilling oil generally gave a better performance"

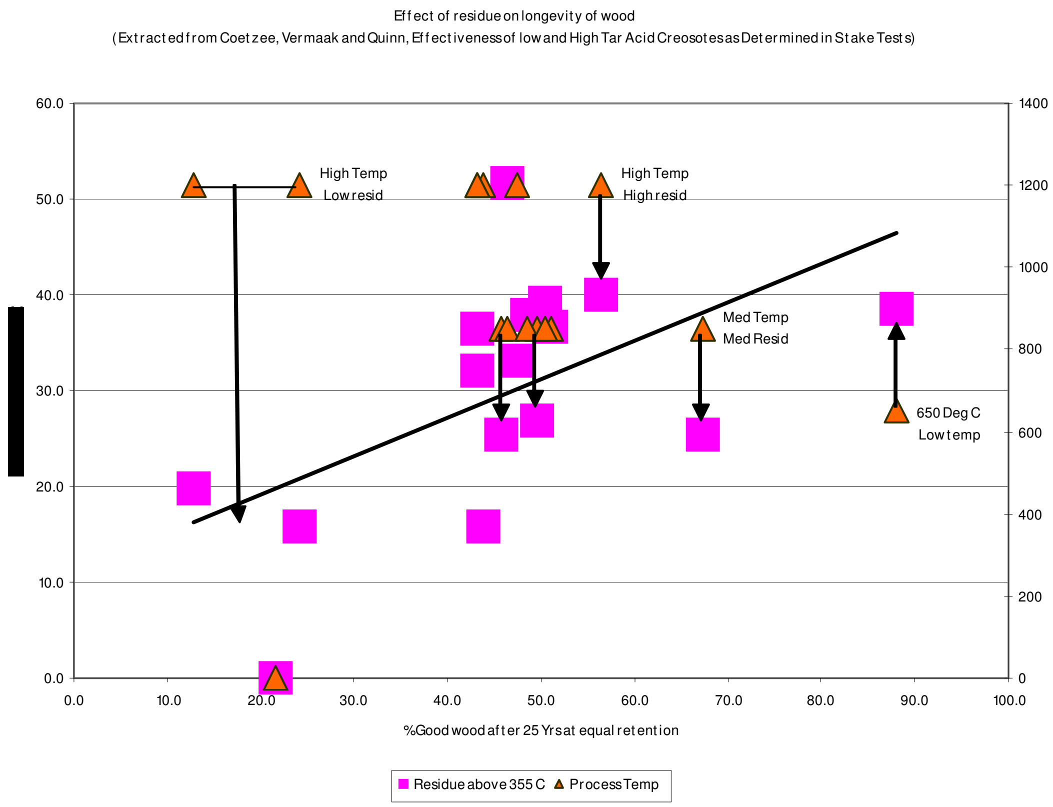
"In Britian, Smith (1970) showed that there is a ten-fold difference in the rate of soft rot decay in hardwoods treated with creosotes when the residues distilling above 315°C ranged from 11% to 55%. The effectiveness decreased as the high boiling fraction decreased. Contrary to the American results, no such correlation was found for treated softwoods."

"The addition of 30% Synthol waxy oil to creosote obtained from a Lurgi gasifier, retarded water absorption and creosote loss in laboratory tests"

"The high tar acid creosote (Sasol creosote) compares generally favourably with the low tar acid creosote obtained from Iscor, especially at the round stakes at Kruisfontein."

"The amount of the residue with boiling-temperature higher than 355°C is closely correlated with the performance of the pure creosotes, irrespective of the processes used in producing the creosotes."

The attached graph shows data from the Kruisfontein-Pienaarsrivier study. The scale on the right represents the temperature of the manufacturing process. It can be seen that the high-residue, high tar acid and low-temperature carbonisation process produced the best results with over 90% good wood left after 25 years. These tests were measured in both severe fungi and severe termite attack areas of South Africa.



SOUTH AFRICAN COAL TAR DERIVATIVES AND THEIR TOXICITY

A question arises as to the difference between South African coals and those in other countries. It has been reported that different coals produce different toxicity results when carbonised under the same conditions. Studies done in South Africa on brown coal at low-temperature carbonisation compared favourably to bituminous coal carbonisation. This is somewhat in contrast to findings in the USA and elswhere where the feeling is that carbonisation of bituminous coal produces a better wood preservative. In these studies the temperature of the process was not given and the residue and tar acid content was not recorded.

As we believe that these three elements are absolutely essential in any comparitive study, these studies are therefore of interest only. They do however indicate that a huge difference in coal quality is required to justify a debate regarding the toxicity and efficacy of coal tar and its derivatives.

In 1938 Van Wyk & Verwoerd published a study comparing the toxicity of high-temperature creosotes to American and German creosotes. High-temperature creosote was found to be equal or better in laboratory tests. It is not recorded what the residue content of these creosotes was. It is known that Iscor once marketed a coal tar creosote solution. Some quotes from Van Wyk & Verwoerd's paper as published in the SAF Association are given below.

THE TOXICITY OF SOUTH AFRICAN CREOSOTE
J.H Van Wyk and L. Verwoerd

> " Service tests…, extending back some seventeen years, give promise of a twenty year efficacy at least, for standard imported creosote, and, provided its toxicity is equally high, local creosote impregnated in the same proportionate volume, should be equally serviceable. "
>
> " In comparing the toxicity of South African creosote with that of the standard American and German product it is clear that the South African product is of a high standard and may be confidently used for the preservation of timber against rot-producing fungi. "
>
> " The product as produced at present has a toxic value somewhat higher than the imported creosote oils. "

COAL TAR FRACTIONS AND THEIR EFFICACY IN WOOD PRESERVE

It is quite obvious that if the quanitity of residual and high boiling fractions is increased in a wood preserve solution, there must be a reduction in the lower boiling fraction contents. These lower boiling, or lighter fractions, are internationally seen as the more toxic components with regard to fungi and, to a lesser degree, termites. The lower boiling fractions' toxicity is not in dispute and it is therefore of importance that these be retained in the wood over considerable time.

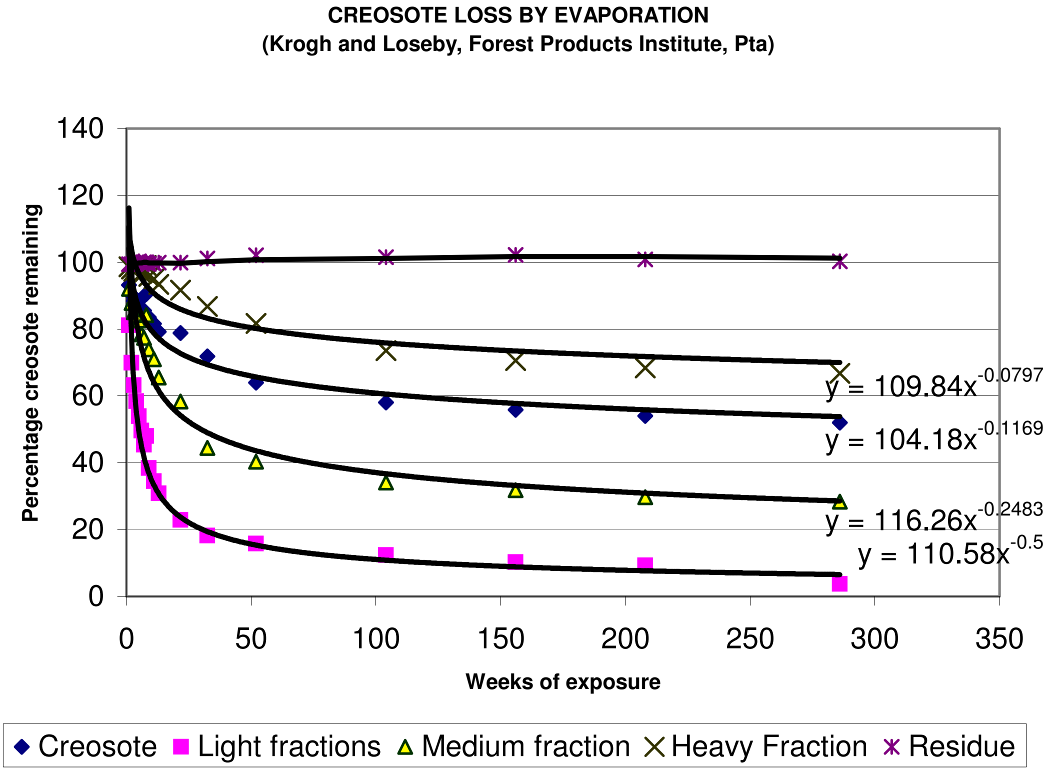
Dripping and leaching were most often considered to be the primary reason for the loss of creosote from poles. The evaporative losses of coal tar fractions were often discounted as not relevant. Evaporative losses have been quantified in several studies internationally and confirmed in South Africa by Loseby and Krogh and it has been found that the vast majority of losses are by evaporation. The relation is clear : the lower the boiling points of the constituents the faster the loss.

Several studies, including the South African one, confirmed that the only way to retard these losses is through increasing residual content of the solution. Over 90% of the boiling point fraction below 270°C will evaporate in average South African conditions within 5,5 years. (Loseby and Krogh)

It is of further interest to note that although the residue and high boiling fractions are considered to have a low toxicity, poles exist long after the vast majority of the low boiling fractions have been reduced to less than 5% of their original values (in high residue cases more than 20 years).

The South African study further noted that the resistance to termite attack is primarily in the residue and secondarily in the high boiling point coal tar fractions (fractions between 315 and 355°C boiling point). The residue-treated wood showed no termite attack, decay or checking whilst wood treated with other fractions showed checking and decay. The high boiling point fractions were fully resistant to termite attack in the study but all distilled fractions displayed some signs of decay.

The following graph was drawn up using data from their study:



The following are some of the more relevant quotes from the South African study:

THE PERSISTENCE AND TERMITE RESISTANCE OF CREOSOTE AND ITS CONSTITUENT FRACTIONS
P.J.A Loseby and P.M.D Krogh

" Our results tend to confirm those found by various American workers"

"It has been stated by Cislak that the presence of oils distilling above 355°C reduces *definitely* the actual loss of the lower boiling constituents of the creosote."

"It may be concluded that by the interaction of the various fractions constituting the creosote, a retarding influence is exerted on the evaporation and solution of the individual fractions."

"From laboratory toxicity tests, American workers have reached the almost unanimous conclusion that *it is in the higher than 355ºC boiling point fraction* more than in any other constituent part that the toxicity of the creosote to the fungi lies."

"The increase in weight of the test blocks treated in residue has also been observed by Snell and Shipley, who attribute it to oxidation and polymerisation."

"As time goes on, the unevaporated residue of the creosote which originally filled the lumen may be visualised as forming a non-volatile coating of the cell wall, materially retarding further loss."

"The fact must be stressed that the test blocks were exposed only to atmospheric conditions. Had they been placed in the ground, there would in all probability have been a greater loss of the water soluble constituents of the creosote, but we are of the opinion that this would have been more than offset by a reduction of losses due to evaporation."

"During the course of the experiments, observations were made on the checking of the test blocks. All the treated blocks were found to check less than the untreated controls, while the blocks treated in residue did not check at all."

Tests Blocks treated in	First sign of termite attack observed after	Percentage destroyed after 5½ years
Creosote (*Residue 19%)*	5 years	1
Fraction 1 *(Boiling up to 270 Deg C)*	1 year	100 (after 5 years)
Fraction 2 *(270-315 Deg C)*	2 years	30
Fraction 3 *(315-355 C)*	-	0
Residue *(Above 355 C)*	-	0
Untreated Controls	6 months (completely destroyed)	

"The significant results of these tests are the high termite deterrence of Fraction 3 and Residue, and it appears that it is in these two fractions that the principle termite repelling qualities of creosote lie. Whilst allowing for the probability of a high percentage loss of Fraction 1 probably lost by solution and evaporation during the period of the test, we nevertheless feel justified in concluding that this fraction, which is commonly supposed to possess the highest toxicity to fungi, has very little value as a termite repellent."

"Blocks treated in Fraction 2 showed the first signs of decay after 5 years, but neither in the creosoted blocks nor in those treated in the two highest fractions was any sign of decay noticed … these incidental observations are not without significance."

"The results of our tests justify the recommendation that, until further data becomes available, the creosote most suitable for South Africa, where termite attack is severe and losses from evaporation high, is one containing a high proportion of residue distilling above 355°C. A minimum residue content of 25% is suggested."

THE IMPORTANCE OF EVAPORATIVE LOSSES OF COAL TAR FRACTIONS

Calculations done using the tabulated data of Loseby and Koch show that the current low-residue specification in South African conditions will result in an evaporative loss of wood preserve solution of 40 kg/m^3 (of wood) within 5 months and 59 kg/m^3 in 5,5 years. This is in stark contrast to the 25 and 40 kg/m3 of the old high-residue specification (SABS 538 and 539, 1980) and the new FFS-proposed specification. The calculations in attached tables 1 and 2 show that, after 5 months, the high-fungi toxicity fraction of all specifications is similar in mass, but after 5,5 years wood treated with solutions conforming to the old SABS and FFS-proposed specifications will have retained almost twice the mass of this fraction.

It was found that for every 1% additional residue content in the wood preserve solution, evaporative losses will be retarded by approximately 0,35%. This retardation factor varies from 0,4% at 5 months to 0, 3 % at 5,5 years.

CHEMICAL COMPOSITION OF LOW-TEMPERATURE COAL TAR SOLUTION

The differences between low-temperature and high-temperature coal tar are generally that high-temperature coal tar is denser, has a lower tar acid content, a higher resin content (this is reduced by distillation) and contains more benzenes, tolueens, ethyl benzenes, xylenes (BTEX's), naphthalenes (moth poisons), anthracenes and benzo(a) pyrenes (BAP's).

BTEX's are removed as low boiling point material. They are carcinogenic and as such impact negatively on the the air pollution aspect of wood treatment. Low-temperature carbonisation (as done in the English vertical retort) normally has a BTEX content of less than 0,1% prior to water removal. BTEX's are further reduced if the water is removed by a distillation process.

Naphthalenes and anthracenes are mostly removed from high-temperature coal tar as they form crystals at room temperature and are high-value products in the chemical industry.

BAP's are an unfortunate by-product of the high-temperature carbonisation process but are naturally lower in the low-temperature coal tars. In the proposed FFS coal tar solution we have observed results of below 50 ppm (a coal tar solution is a solution of distilled coal tar and processed coal tar). This is in line with the most stringent European standards for human protection. A high-temperature creosote can contain as much as 3000ppm (0,3%) BAP.

The quantity of beta resins and solids is significantly greater in the high-temperature process, and distillation is required to reduce them. The lower quantities found in the low-temperature processes can be removed by high-speed centrifugation to within most international specifications.

A major difference between high and low-temperature coal tar is that tar acid level is far greater in low-temperature coal tars. Tar acids are extremely toxic to fungi and termites. They are slightly soluble in water and can be leached out by water over a period of time. Studies as quoted elsewhere in this paper show that these losses will still be minor when compared to the evaporation losses. It must be noted that the high tar acid creosote has to be contained in the wood to be effective and it is of some importance that the creosote solution includes water repellant properties.

The wax blend that Sasol uses will vastly improve the efficacy of a wood preservative as it essentially adds water repellancy and residue content to the solution (residue being defined as + 355ºC fraction). The high-residue level found after the wax blending improves the retardation of losses by evaporation.

It is therefore our opinion that the high-residue (old SABS 538/9 specification) with wax will produce a higher-efficacy wood preservative.

Comparing a compositional analysis of the low-temperature creosote and the Lurgi-based creosote shows they are similar in composition. There are thousands of components in a coal tar and to list them is an exercise in futility. An analysis of the FFS distillate fraction (associated with fungi toxicity) is attached in Table 4.

CONCLUSION

There is adequate South African field trial data to support the international research conclusions that:

1. Low-temperature coal tar based wood preservative is at least as effective as high-temperature material.

2. High-residual products perform better than low-residual creosote.

It is the authors' opinion that there is more than adequate data available from which conclusion can be drawn with a high degree of certainty and that further test work is of academic interest only.