Photodegradation and weathering effects on timber surface moisture profiles as studied using Dynamic Vapour Sorption

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Abstract

The moisture sorption profiles of Scots pine (*Pinus sylvestris*) early and late woods were studied using a Dynamic Vapour Sorption apparatus and analysed using the Parallel Exponential Kinetics model. The samples were chosen to give insight to the effects that photodegradation and weathering have on the moisture behaviour of surface layers of timber. Samples were subjected to indoor and outdoor exposure regimes. Significant differences were found between the sorption isotherms of exposed and unexposed wood, as well as with the sorption kinetics profiles. The isotherm differences are reported here. The reasons for these differences are discussed.

1 Introduction

As weathering includes the effects of moisture as well as photodegradation it is important to understand moisture behaviour in timber. While the behaviour on macroscale full soaking/saturation and uniform drying of timbers is well understood (Dinwoodie 2000), this type of moisture environment is rarely seen in weathering. Instead, the rapid fluctuations in atmospheric moisture levels and moisture events such as rainfall, snow or dew formation mean that timber outdoors is rarely uniformly saturated (being able to reach equilibrium moisture content (EMC)) but instead exists in a fluctuating state. The fluctuating state will be most severe at and near the surface as this is where the timber is exposed to and undergoes the majority of moisture changes. The moisture timber relationship is complicated by the changing character of the surface layers due to photodegradation (Kalnins and Feist 1993) or the presence of a surface coating which acts as a permeable barrier to moisture vapour. In order to begin to understand what happens in the surface layers of the wood beneath a coating, a dynamic vapour sorption study was undertaken. The experimentally obtained isotherms are discussed here along with an example of the Parallel Exponential Kinetics (PEK) model used for curve analysis for one RH step (Hill and Xie 2010).

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2 Earlywood and Latewood Isotherms

The following sample sets (earlywood and latewood) were studied in the DVS:

• Unexposed Scots pine.

• Outdoor exposed (OE) – Samples obtained from the surface layer of uncoated Scots pine panels which had been exposed for 18 months.

• Indoor exposed (500h) (dry) – Samples obtained from microtomed Scots pine strips which had been exposed in a Q-Sun Xe-1 for 500 hours.

• Indoor exposed (Wet exposed) (water spray) – Samples were exposed in a Q-Sun Xe-1 for 98 hours and subjected to a 10 minute water spray every hour.

The experimental sorption isotherms for both earlywood and latewood after exposures described above are included as Figure 1 and 2 respectively.

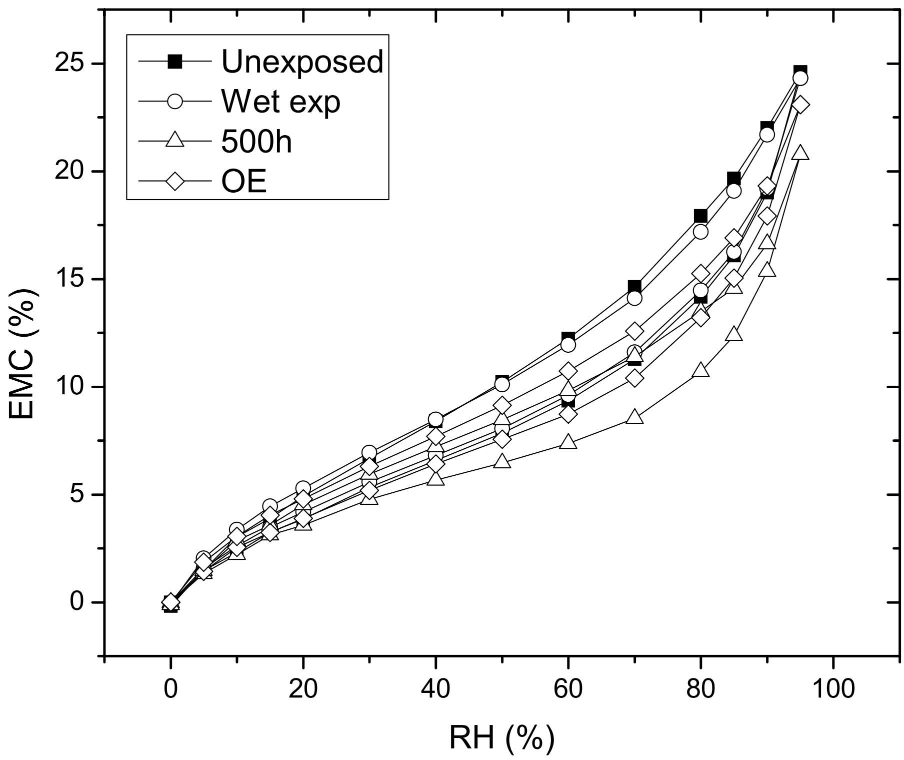

Figure 1: Sorption Isotherms for earlywood samples post exposure

Figure 1 shows the isotherms as obtained experimentally using the DVS for the earlywood samples. The hysteresis between the adsorption and desorption isotherms is visible in all samples the upper lines being the adsorption curves and the lower lines being desorption curves. The adsorption and desorption curves for the unexposed and wet exposed samples are similar throughout the entire isotherm. This is probably due to the time for exposure of this type being too short. The outdoor exposed sample has a lower adsorption level through the central RH (%) range (30-90%). At the upper and lower RH levels the outdoor exposed sample has similar moisture uptake levels to the unexposed and wet exposed samples. The greatest difference in the isotherms dependant on exposure is seen between the unexposed and 500h exposed sample. The 500 hour sample shows lower overall moisture content with a smaller hysteresis in the central region of the RH’s. This is counter intuitive to what was expected where a breaking down of lignin due to photodegradation was expected to increase (not decrease) the accessibility and uptake of water. This is discussed further below.

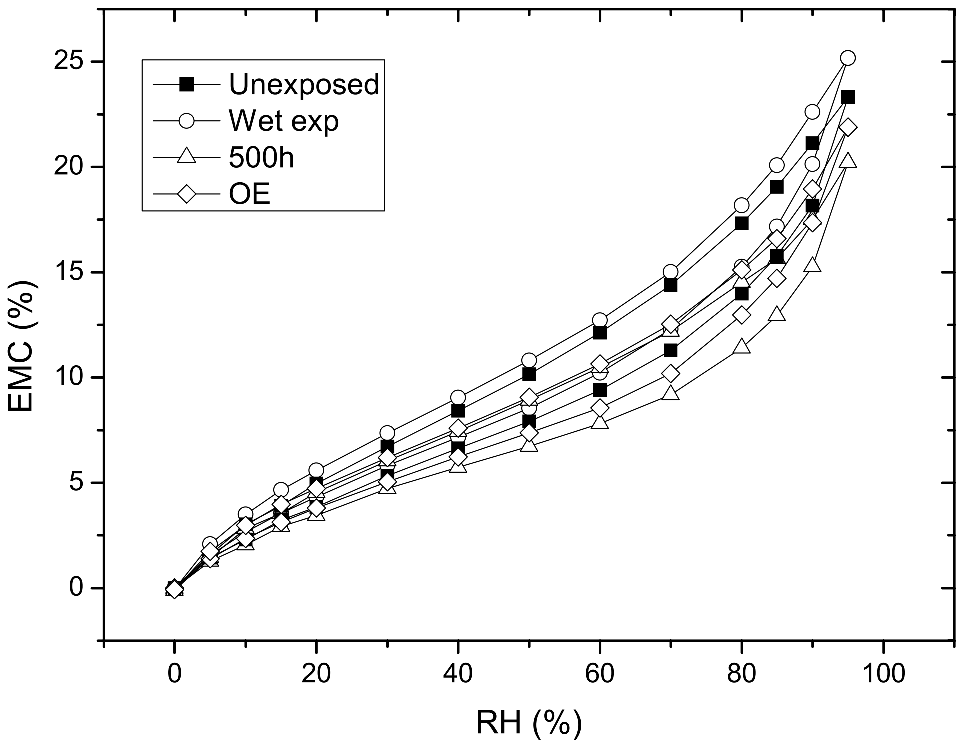

Figure 2: Sorption Isotherms for latewood samples post exposure

Figure 2 shows the isotherms for the latewood samples which are comparable to the earlywood data shown in Figure 1. The latewood samples do not behave the same as the earlywood samples. The notable differences are the wet exposed sample has a higher adsorption and desorption than the unexposed sample; the outdoor exposed and 500h adsorption up to 70% RH are the same differing after that point; the desorption for the outdoor exposed and 500h samples are different throughout. The lowest overall moisture content is once more the 500h sample. The moisture resistance seen in both 500h samples is believe dot be due to cross polymerisation of lignin blocking sites accessible to moisture ingress. If this is true then the PEK analysis method should show differences in the values found for the times and moisture contents associated with the curves.

3 An example of exposure effects on step curves using the PEK analysis

Below is an example of an individual step curve for earlywood Scots pine which has been exposed or unexposed as mentioned above. A definition of the PEK model is given in the proceedings (Hill and Xie 2010).

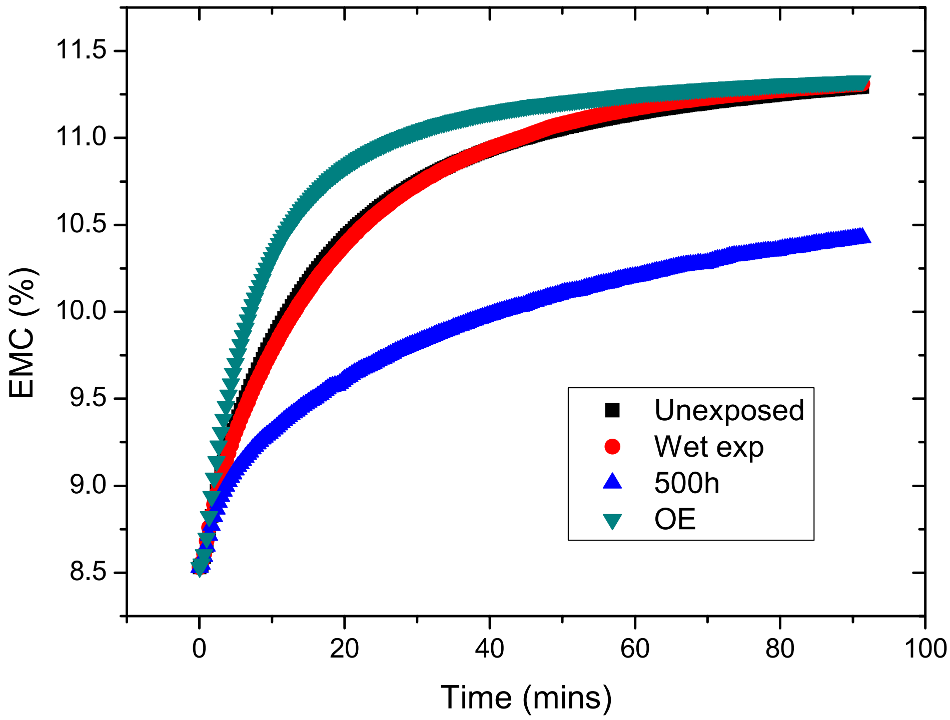

Figure 3: 70-80% RH sorption step for earlywood showing exposure differences

Table 1: Values obtained for times and moisture contents using PEK model for analysis of step curves shown in Figure 3

Exposure type	t_1 (fast process)	t_2 (slow process)	MC_0	MC_1	MC_2
Unexposed	10.49569	43.62648	11.43386	8.34794	5.20833
Wet exposed	10.87989	34.45708	11.62765	8.37887	6.22136
500h	5.45717	58.20325	8.55298	5.65199	4.91891
OE	6.18846	26.19716	10.30156	8.25946	4.64608

All curves have been analysed using the PEK model prior to normalisation to the lowest initial moisture content (MC_0) value for the step. The normalisation allows the curves to be compared as shown in Figure 3. The lowest initial moisture content was found in the 500h exposed sample. As can be seen on Figure 3 this sample continues to have the lowest moisture content throughout the entire RH step change. The unexposed and wet exposed samples have similar curves showing little difference between the samples. This is seen in the similar values given using the PEK model. This follows the findings on the isotherms as discussed above. The 500h curve is a dominated by a slower process (as seen in the shallower curve) than the other samples. This is shown by the smaller difference between the fast and slow moisture contents, $MC_1 \approx MC_2$, while the characteristic times (t_1 and t_2) show the greatest difference out of all samples $t_2>10t_1$. This compares to the outdoor exposed sample which is a fast process curve with $MC_1=1.77MC_2$ while the characteristic times $t_2>4t_1$ show the difference in moisture content combined with the smaller differences in characteristic times are due to the outdoor exposed sample being dominated by a fast process.

Two possible explanations for the fast and slow processes have been suggested; the fast process is due to fast moisture sorption at ‘external’ surfaces and amorphous regions, while the slow process is due to sorption onto ‘inner’ surfaces and ‘crystallites’ (Morton and Hearle 1997); or the fast process is connected with readily accessible sorption sites within the cell wall and the slow process with new sites made accessible by expansion due to moisture uptake (Hill, Norton *et al*. 2010). The outdoor exposed sample when compared to the unexposed sample gives evidence for the second definition. As the outdoor exposed sample has more exposed fast sites due to the loss of lignin (caused by weathering processes) than the unexposed the curve should be dominated more by the fast process. This is seen in the curve comparison and PEK analysis. This contrasts to what would be predicted if the 1st definition were correct whereby the curve should be dominated by the slow process. The 500h exposed sample was expected to behave the same as the outdoor exposed sample due to the lignin being photodegraded, however, as mentioned before this has not happened. Instead the overall moisture content is lower and the kinetics are dominated by the slow process as seen on the curve and the values from the PEK analysis. This indicates that instead of opening up the timber photodegradation causes a blocking of readily accessible sites. Two possible reasons for this are lignin fragments physically block accessible sites, or the lignin cross polymerised creating more slow process sites as the easily accessible fast process sites were changed. Cross linking is more likely the factor as the lignin fragments are water soluble and would be expected to dissolve and move leading to a change in the amount of hysteresis seen in the isotherms. As the size of the hysteresis remained unchanged it supports a cross linking rather than fragmentary blocking mechanism. The 500h exposed sample data therefore supports the second definition.

4 Conclusions

This study has shown that differences in the moisture-timber behaviour exist depending on type of exposure. The effects seen show a lower moisture affinity for moisture on photodegraded samples when there has been no leaching due to prior changes in moisture. This is believed to be due to cross polymerisation of lignin blocking fast process sites accessible to moisture ingress. This study shows the difficulties in interpreting the data and furthering the understanding of the physical processes which underlie the moisture-timber behaviour as modelled by the PEK model.

5 Acknowledgements

This research is part of a project funded by Akzo Nobel Decorative Paints. The authors would like to thank Akzo Nobel for their assistance in this research.

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