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DVS Application Note 64

Environmental Assessment of Formaldehyde Sorption by Dynamic Vapour Sorption Technique

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This study demonstrates the application of Dynamic Vapour Sorption (DVS) to study formaldehyde sorption by concrete materials.

Introduction

Formaldehyde has been reported as a pollutant in domestic and business environments due to the widespread applications in household and office furniture as well as building materials. The environmental impact of formaldehyde and its removal by wool fibres in a liquid phase have previously been reported. However, few studies into the formaldehyde vapour sorption have been performed due the difficulties in measuring the low uptake levels associated with volatile organic compounds (VOCs). The concern over formaldehyde has been focused on emissions from insulation, textile and wood materials. Methods of reducing the amount of formaldehyde include the application of adsorbents, where formaldehyde is removed either by physisorption through the pores or by forming a stable bond to the adsorbent i.e. chemisorption [1].

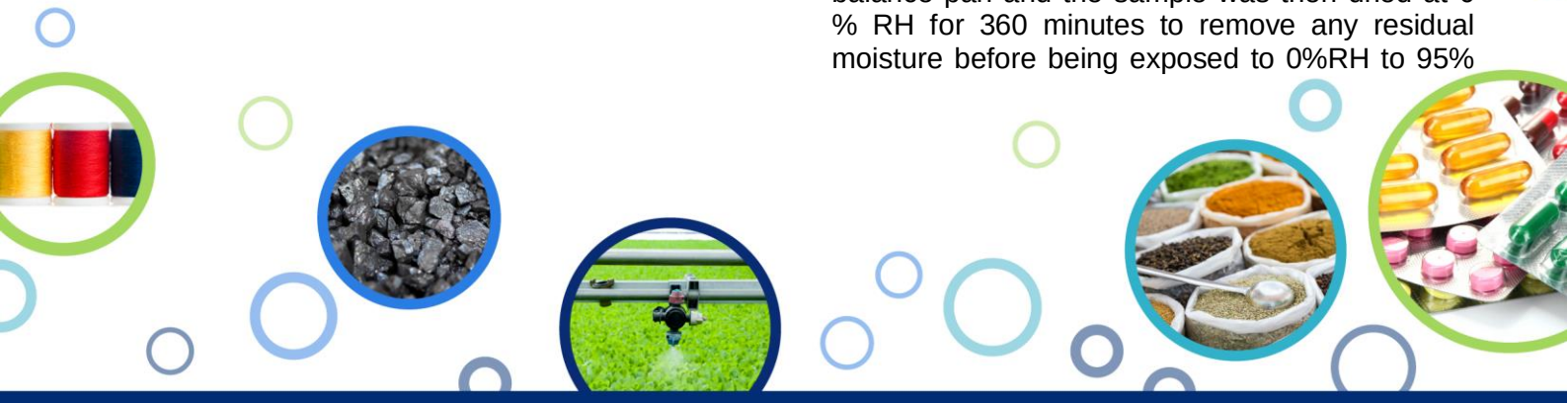
Traditional methods for measuring formaldehyde vapour uptake may not be effective as these methods do not directly measure the formaldehyde sorption and are time consuming [2]. This study demonstrates the application of Dynamic Vapour Sorption (DVS) to study formaldehyde sorption by concrete materials.

Method

Sorption experiments were performed on a small concrete sample using a DVS Advantage system. The DVS instrument measures changes in mass which is related to uptake or release of vapour by the sample at different concentrations and temperatures. The sample mass is monitored using an Ultrabalance with a resolution of ± 0.1 µg in a temperature controlled (±0.1°C) incubator. The concentration of the vapour is controlled by mixing saturated vapour and dry air using mass flow controllers at a standard total gas flow of 200 sccm.

The DVS system has two reservoirs which can be used for two different vapour generation. One reservoir was filled with deionised water and the second reservoir was filled with a 9.25% formaldehyde solution in water.

The experiments were carried out using counter weights. 1000mg of counterweights were used in the reference side of the balance. A concrete sample weighing approximately 1000mg was placed into a (large size aluminium) sampling balance pan and the sample was then dried at 0 % RH for 360 minutes to remove any residual moisture before being exposed to 0%RH to 95%



RH* (P/Po, whereby P = Partial pressure of water vapour and Po = Equilibrium vapour pressure of water) using 5% RH increments at 25°C. The sorption cycle was followed by desorption from 95% RH to 0% RH using 5% RH decrements maintaining the sample at the final 0%RH step at 25°C for 360 minutes. The weight change during the sorption cycle was then monitored, allowing for the hygroscopic nature of the sample to be determined. The %RH was maintained by the mixture of saturated water vapour and dry nitrogen (flow rate of 200 sccm). The percentage of mass change per minute (dm/dt) was set as 0.0002.

Chemisorption and physisorption processes were investigated by running the sample first with water and then the same sample with a 9.25% formaldehyde solution (in water) as a second method in a sequence. The change in mass would be expected to return to zero at the end of the desorption processes (physisorption), but if formaldehyde has been retained irreversibly then a difference in mass at the final 0%RH stage should be observed.

Results

Figure 1 shows the net percent change in mass (based on dry mass, m0) versus time plots for water (blue line) and formaldehyde (red line) sorption on the concrete sample at 25ºC.

There are differences in the water/formaldehyde capacities and sorption kinetics i.e. higher formaldehyde uptake over longer time, which indicates formaldehyde vapour sorption. The mass plot at the final 0%RH stage does not return to where it started from which indicates the retention of formaldehyde.

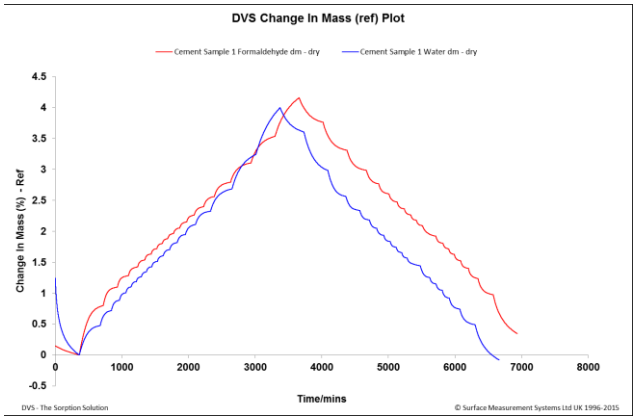


Figure 1: Sorption and desorption of formaldehyde (red) and water (blue) on the concrete sample.

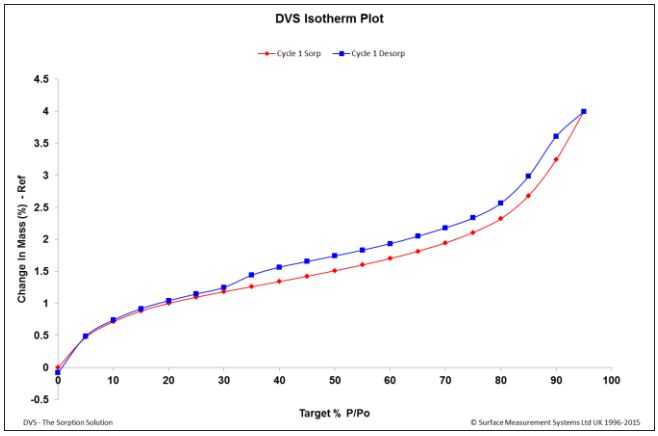


Fig. 2 Water sorption and desorption isotherms on the concrete sample.

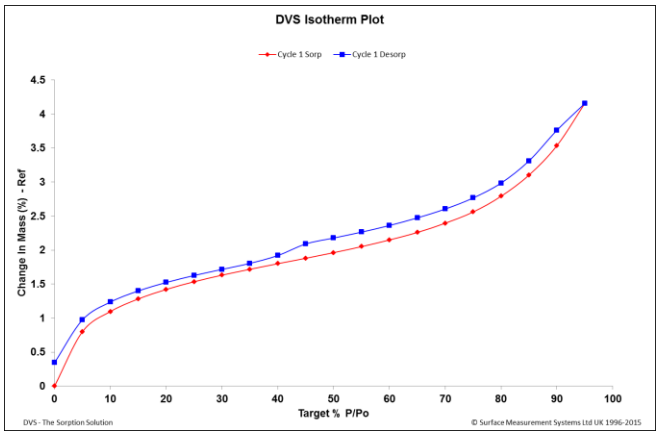


Fig. 3 Formaldehyde sorption and desorption isotherms on the concrete sample. Note that the hysteresis gap remains open due to the retention of formaldehyde by the sample.

The water and formaldehyde isotherm plots as shown in figures 2 and 3, respectively show a hysteresis gap over a wider range of P/P0 indicating bulk absorption. The isotherms for formaldehyde sorption (Figure 3) show an open hysteresis gap which indicates formaldehyde retention or an irreversible sorption process. Although some physisorbed formaldehyde may be released during the desorption process the open hysteresis and difference in mass at the start and end of the experiment indicates the retention of formaldehyde vapour molecules, which is absent in the water sorption isotherms.

Conclusion

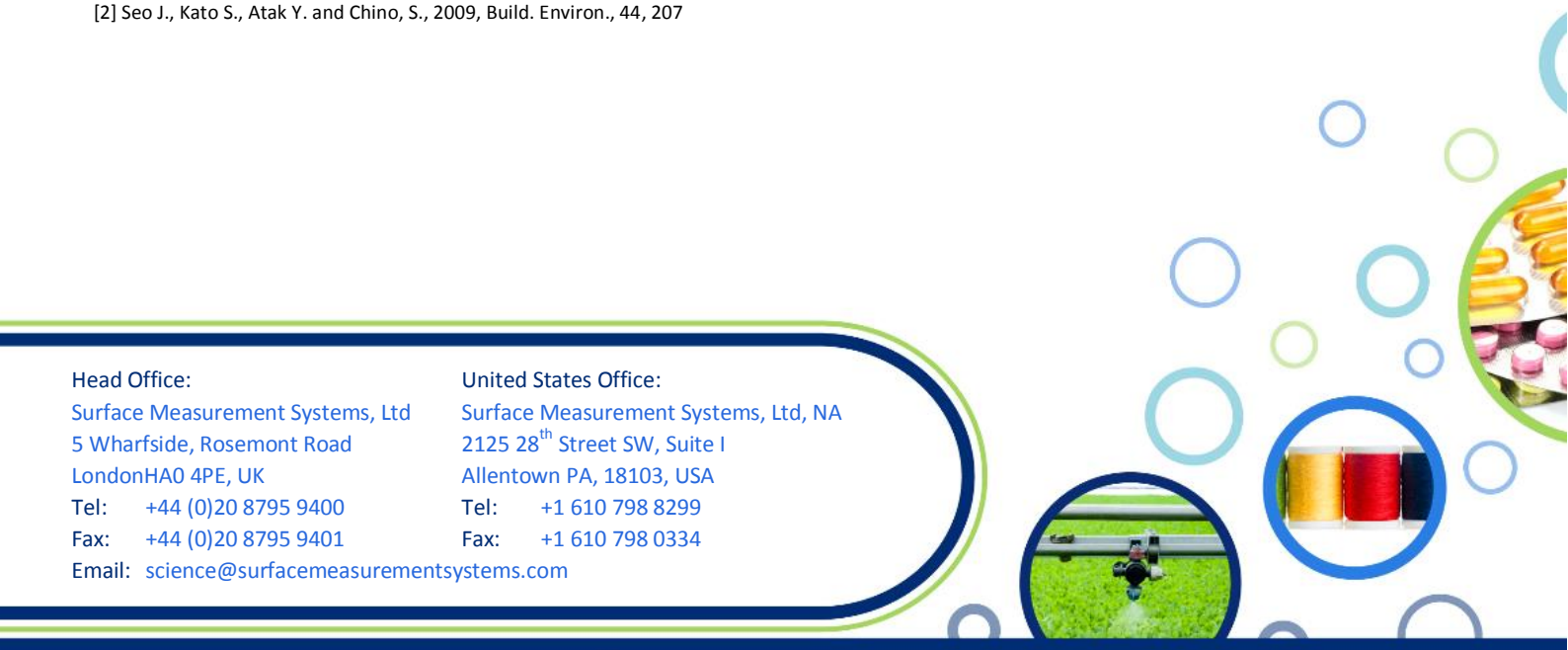
Chemisorption and physisorption studies of water and formaldehyde on a concrete sample were investigated by DVS. The open hysteresis and difference in mass at the start and end of the experiment indicated the retention of formaldehyde.

Further experiments including cumulative uptake measurements as a result of repeated sorption cycles would shed more light on the concrete/formaldehyde sorption mechanism.

References

[1] Curling, S.F., Loxton, C. and Ormondroyd, A., J. Mater. Sci., 2012, 47, 3248-3251.

[2] Seo J., Kato S., Atak Y. and Chino, S., 2009, Build. Environ., 44, 207



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