Evaluation of a Humidity Insensitive Sorbent-Based Air Sampling System

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Optimum plant growth in controlled environment chambers is

Introduction

Sampling of volatile organic compounds (VOCs) in spacecraft cabin air is needed for ensuring that crew health is not threatened when the concentrations of these VOCs exceed the Spacecraft Maximum Allowable Concentrations (SMACs). VOCs are produced by crew metabolism, in-flight operations, and off-gassing from hardware components (Limero et al., 2005). The SSAS and DST systems have made use of thermally regenerable adsorbers to trap VOCs in orbit, store them until return to Earth, and allow subsequent quantification using analytical methods. These adsorbers provide a time-integrated sample of cabin air because they are typically acquired over a 24-hour period (Limero et al., 2005). The adsorbents considered for use in DSTs include Tenax TA, Carbograph/Carboxen 569, Tenax TA/Carbosieve SIII, and Tenax TA/Carbograph 569 (Matney et al., 2000). The optimum adsorbent trap composition was chosen based on the highest overall recovery of a 10-component gas mixture in both dry and humid conditions.

Studies for sampling plant produced VOCs (e.g. ethylene, acetonitrile, and ethanol) from high humidity environments (60-80%) in plant growth chambers have found that water vapour can interfere with the trapping of VOCs by Carbosieve SIII, a thermally regenerable adsorbent (Monje et al., 2005). Unlike Tenax TA, C molecular sieves (e.g. Carbosieve SIII and Carboxen 569) were found to co-adsorb 15-25% by weight of water, which decreased their adsorptive capacity causing a decrease in recovery in breakthrough volume (Helming and Vierling, 1995; Monje et al., 2007). A technique for minimizing the effects of humidity is to heat the sorbent filter tube by several degrees above air temperature while sampling the atmosphere (Karbiwynk et al., 2002).

The goals of this study were:

• Develop the methodology to test sorbent-based sampling techniques.
• Evaluate the performance of a sorbent-based air sampling prototype that heats the adsorbent.
• Test the hypothesis that heating the tube will increase the adsorptive capacity of ethanol onto Carbosieve SIII when used in high humidity environments.

Materials & Methods

Chamber Sampling Procedure. The ethanol concentration of a sealed low mass Veggie chamber (Orbitec, Madison, WI) was increased by bubbling air through an impinger containing 15% EtOH (Fig. 1). Plant transportation and setup evaporation maintained a high relative humidity (70-75%) in the chamber. Temperature was measured to be 25°C±2°C. Chamber air was sampled through tubes using two air samplers. Chamber ethanol concentration was monitored periodically using a custom-made sampling apparatus (Fig. 2).

Commercial Adsorbent – Carbosieve SIII is a carbon molecular sieve with 60/80 mesh size, a packing density of 0.76 g/ml, and a surface area of 820 m²/g. Carbosieve SIII was found to be a very effective adsorbent for ethanol (Monje et al., 2007), which is a major functional class of spacecraft TCS. The adsorbent tubes (4mm diameter) were packed with 100 mg of Carbosieve SIII. It has been found that humid samples breakthrough sooner on Carbosieve SIII adsorbing less volume of VOC. When the humidity levels were lowered, or the tube was kept dry, the compound adsorbed VOC in larger amounts (Monje et al., 2007).

Sorption Tube System (STS) Sampler. The STS (Space Dynamics Lab, Logan, UT) is a programmable air sampler designed to sample a predetermined volume air (Fig. 3). The user interface (Sorpware) sets the desired sample volume, the number of pump intervals, and the sampling flow, as well as start and end times. As opposed to commercially available units, the STS controls the temperature of the sorbent tube during sampling. It achieves this through the sorbent-packed tube being fitted into a heater (Fig. 4), controlled by two sensors; one monitoring the ambient air temperature, the other the temperature of the sorbent tube. The unit also has a user-friendly interface system.

The Control Air Sampling Unit. An SKC Airechek Sampler, Model 244- PXR8, was used in this evaluation, as a representation of the commercially available air sampling units. It is possible with this unit, to pre-set a delayed start, as well as to control the pump flow, and duration of the sampling period. This unit applies no heat to the sorbent tube.

Results & Discussion

The unheated, control SKC Airechek adsorbent tubes needed to sample the same volume of air to increase the chamber concentration to >100% SMAC as did the heated STS tubes. The chamber ethanol concentration (Fig. 5). At lower volumes, the sampler underestimated the chamber concentration by up to 60%, while at volumes greater than 6L, the chamber concentration was also underestimated, probably because the sorbent began to elute VOC from the tube, comparable to when breakthrough volumes were exceeded in Carbosieve SIII at high humidities. The unheated STS gave similar results to the SKC Airechek sampler. When 3L of chamber air was sampled using 2OOC, the heated STS measured the actual VOC concentration, while the SKC measured 80% (Fig. 6). When the chamber volume was decreased from 6L to 1L, water co-adsorption is reduced, 2; thermal desorption of the VOCs adsorbed onto the sorbent bed may occur. Warmer air can hold more water, thus the heated tube prevents water vapor from condensing inside the adsorbent tube, reducing co-adsorption (Karbiewsky et al., 2002). Evidence of reduced water adsorption was observed after tubes were desorbed into Tedlar bags with the STS. The tubes that had been heated showed no water droplets, while the control, unheated tubes, had visible water droplets. The STS measured a chamber concentration of 100% when 1L of chamber air was sampled and when it was heated to >20°C above ambient air temperature. This loss of VOC may be due to thermal desorption of the tube during sampling.

Conclusion

It can be surmised from the findings of this evaluation, that the benefit of heating the adsorbent tube while sampling, reduces the sampling volume required to accurately measure the atmospheric VOC concentration.

References


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Figure 1. the schematic of the main components and set up of the experimental apparatus.