



44th International Conference on
Environmental Systems



TEXAS TECH
UNIVERSITY.

Evaluating the Adsorptive Capacities of Chemsorb 1000 and Chemsorb 1425

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Marriott University Park, Tucson, AZ

July 13-17, 2014



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- On ISS, the Trace Contaminant Control Subassembly (TCCS) provides active control of trace contaminants from the cabin atmosphere utilizing physical adsorption, thermal catalytic oxidation, and chemical adsorption processes.
- High molecular weight contaminants and ammonia (NH_3) are removed by a granular activated carbon treated with ~ 10% by weight phosphoric acid (H_3PO_4) (B-S Type 3032 4×6 mesh), which is expendable and is periodically refurbished.
- The Type 3032 granular activated carbon bed is no longer commercially available.
- Need to characterize the efficiency and capacity of commercially available NH_3 sorbents.



Evaluating the Adsorptive Capacities of Chemsorb 1000 and Chemsorb 1425

- This study describes the characterization of two activated carbons from Molecular Products LTD : Chemsorb 1000 and Chemsorb 1425
- Untreated activated carbons (e.g. Chemsorb 1000) remove contaminants by physisorption.
- Low molecular weight or polar gases (e.g. HCl, SO₂, formaldehyde, and NH₃) require chemisorption for removal.
- Treated activated carbons (e.g. Chemsorb 1425) are impregnated with a chemical agent (e.g. phosphoric acid) that reacts with NH₃, converting it to a salt within the carbon and removes it from the air stream.
- Adsorption capacity is exhausted when the available impregnated chemicals are consumed.



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- Chemsorb 1000 and Chemsorb 1425 are coconut-shell activated carbon commercially available from Molecular Products, Inc.
- Chemsorb 1000 is a high grade activated carbon for organic vapor adsorption.
- Chemsorb 1425 is a high-grade impregnated activated carbon adsorption for ammonia and amines.



Chemsorb 1000



Chemsorb 1425



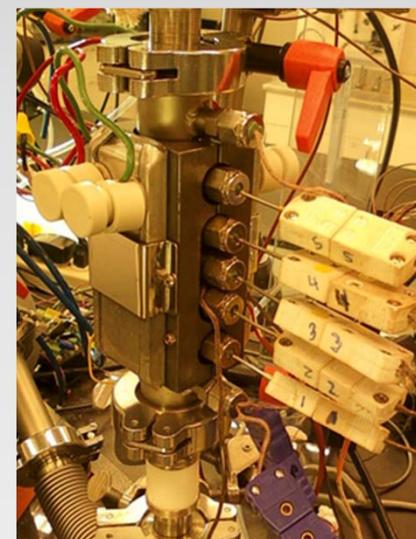
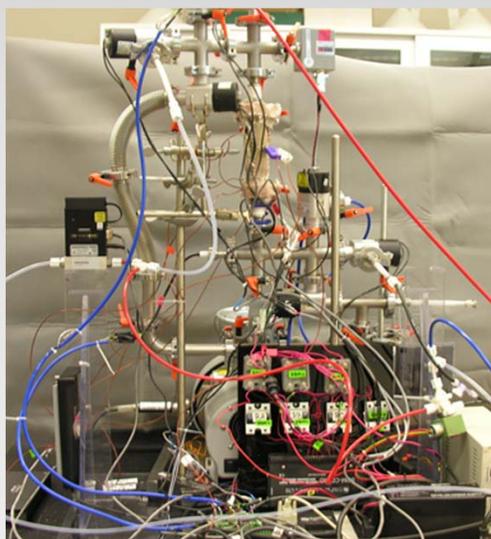
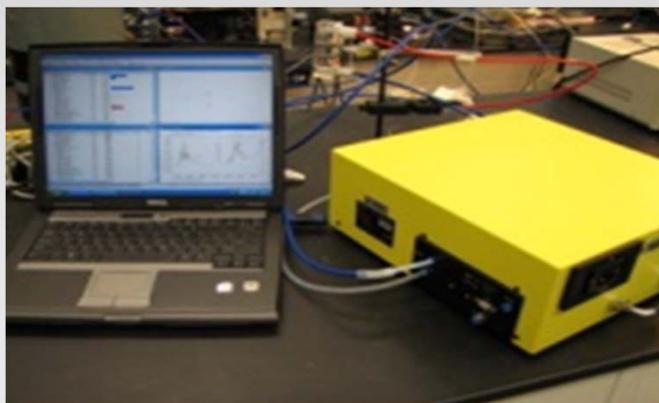
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- The adsorption capacity (mol/kg) of Chemsorb 1000 and Chemsorb 1425 was measured for gas mixtures with 40% relative humidity at 23 °C air temperature.
 - ✓ ethanol
 - ✓ acetone
 - ✓ toluene
 - ✓ acetaldehyde
 - ✓ dichloromethane
 - ✓ xylene

- The adsorption capacity (mol/kg) of Chemsorb 1425 was measured for for NH₃ gas streams.



Evaluating the Adsorptive Capacities of Chemsorb 1000 and Chemsorb 1425



- Adsorption studies were conducted in the Regenerable VOC Control System (RVCS) testbed using a Gaset (Model DX-4030) FTIR and instrumented regenerable sorbent beds.
- Simulated cabin air streams (humidified gas mixtures) were supplied at 1-2- SLPM to 3-5 g of Chemsorb 1000 or Chemsorb 1425.
- The VOC mixture was supplied using a Kintek gas generator
- Test were run for 10-16 hours to ensure maximum adsorption was reached.



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- A rapid screening test was developed to measure adsorptive capacity. The measure of adsorptive capacity used in this study is the cumulative amount of 5 ppm of VOC removed during the period of 1 hour.

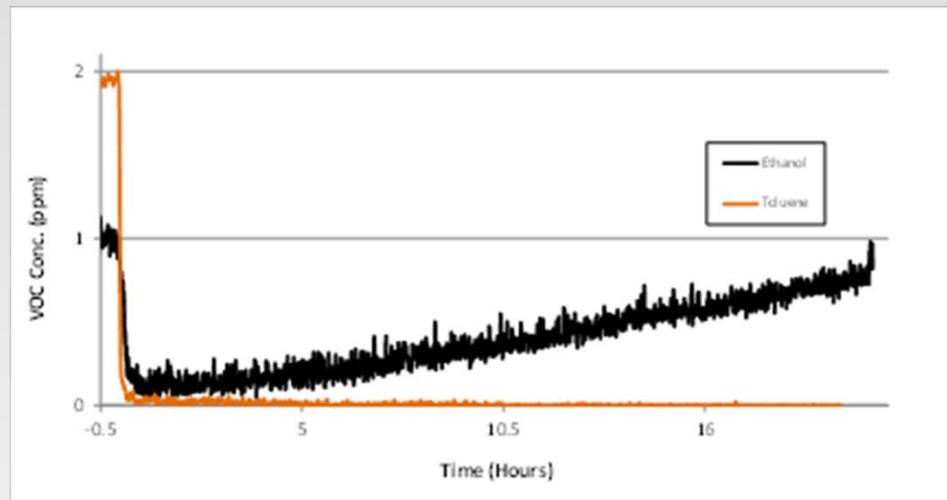


Figure 1. Breakthrough curves for the adsorption of ethanol and toluene by Chemsorb 1000. Ethanol breakthrough occurs after 3 hrs. The breakthrough time denotes the point at which the mass transfer zone reaches the end of the bed and contaminant is detected in the effluent gas stream



Results: Chemsorb 1000

- Chemsorb 1000 is a high grade activated carbon for organic vapor adsorption. Its adsorptive capacity for water is 0.27 mol/kg, and it is 0.0156 mol/kg for CO₂ when dry or wet.
- The 1-h adsorptive capacities for volatile organic compounds (VOCs) were determined by exposing Chemsorb 1000 to dry (0% RH) and wet (40-50% RH) gas mixtures (Fig 2).

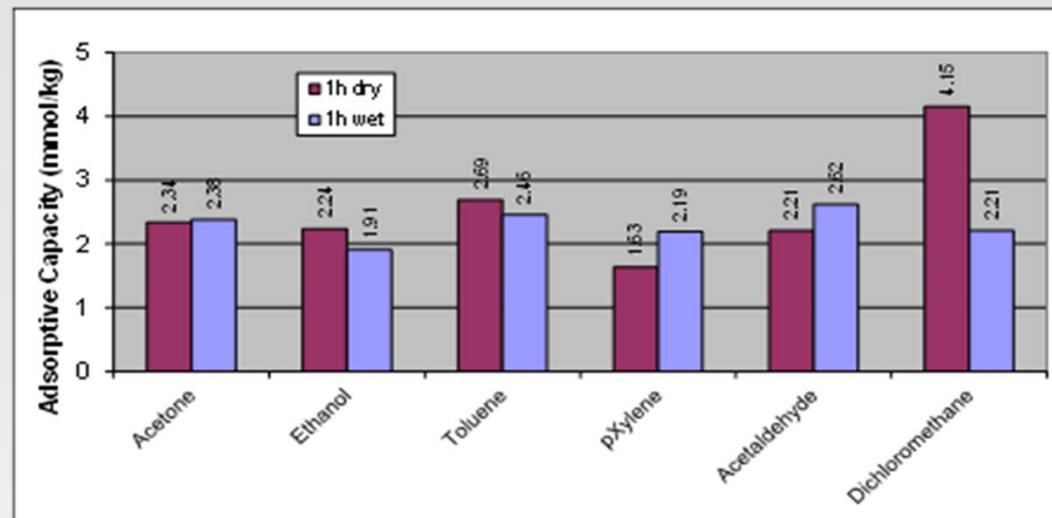


Figure 2. 1-h Adsorptive capacities of Chemsorb 1000 for several VOCs under dry and wet (40-50% RH) gas streams.



Comparison of Adsorptive capacities for Chemsorb 1000 and Barnebey Sutcliffe Type 3032

- The adsorptive capacity of Barnebey Sutcliffe Type 3032 activated carbon was determined in the RVCS using similar conditions used with Chemsorb 1000.

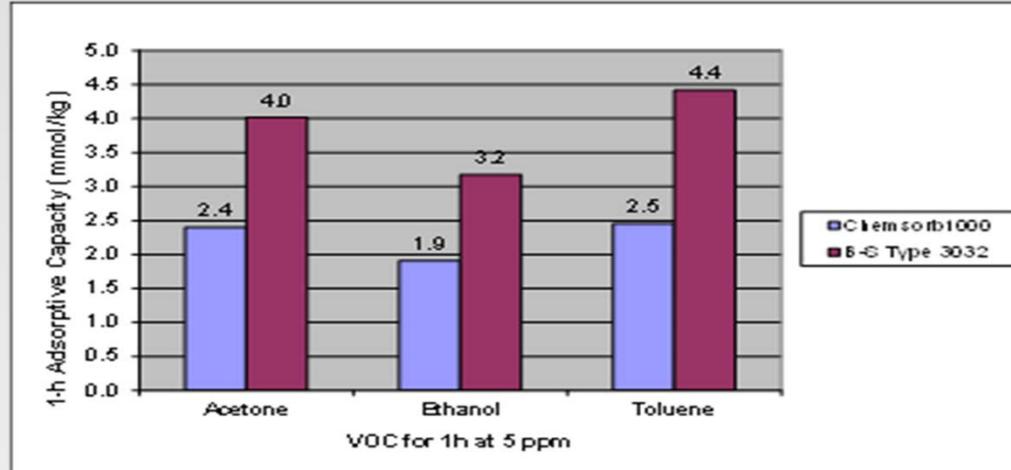


Figure 3. Comparison of 1-h Adsorptive capacities of moist Chemsorb 1000 vs B-S Type 3032 for acetone, ethanol, and toluene at 40-50 % RH. The B-S Type 3032 had significantly higher 1-h capacities than Chemsorb 1000.



Comparison of Adsorptive capacities for Chemsorb 1000 and Chemsorb 1425

The adsorptive capacities of moist Chemsorb 1425 and Chemsorb 1000 are compared in Fig 4. Generally, Chemsorb 1000 adsorbs more toluene, dichloromethane (DCM), xylene, and acetaldehyde than Chemsorb 1425.

These differences in adsorption may be influenced by chemical properties and by the different particle sizes between the two sorbents, as no attempt was made to compare equal mesh sizes in this study.

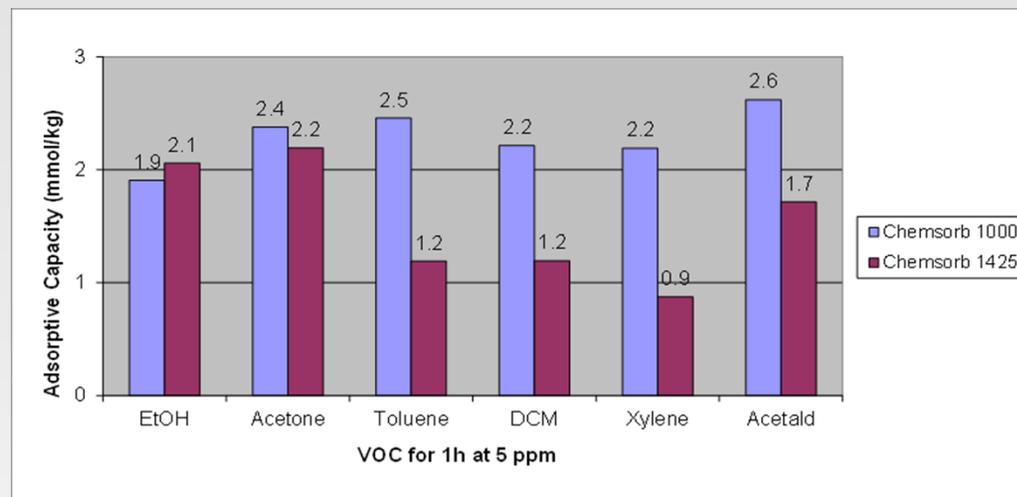


Figure 4. Comparison of 1-h Adsorptive capacities of moist (40-50% RH) Chemsorb 1425 and Chemsorb 1000 for ethanol, acetone, toluene, dichloromethane, xylene, and acetaldehyde.



Chemsorb 1425 – Adsorptive Capacity for Ammonia

Chemsorb 1425 was loaded at 2 L/min containing 345 ppm NH₃ at 40% RH for 15 hours. The 1-h adsorptive capacity for NH₃ was 0.21 mol/kg. At breakthrough, which occurred after 5 hrs, the adsorptive capacity for NH₃ was 1.05 mol/kg. The adsorptive capacity at 15 h for NH₃ was 2.4 mol/kg.

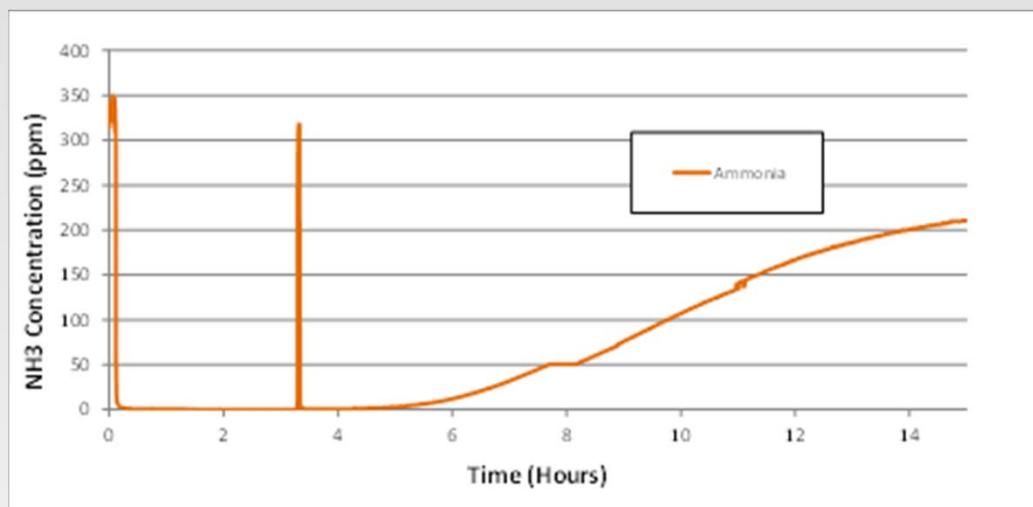


Figure 5. Breakthrough occurs at 5 hrs. The spike at 3.6 hrs shows when the bed was bypassed briefly to check the inlet NH₃ concentration. The adsorptive capacity of Chemsorb 1425 was not exhausted after 15 hrs of exposure to the inlet NH₃ gas stream.



Chemsorb 1425 – Adsorptive Capacity for Ammonia

The adsorptive capacity of Chemsorb 1425 for NH₃ grew nonlinearly with time up to a maximum of 2.4 mol/kg (Fig 6). The maximum adsorptive capacity was obtained from data in Fig 5 at 15 h.

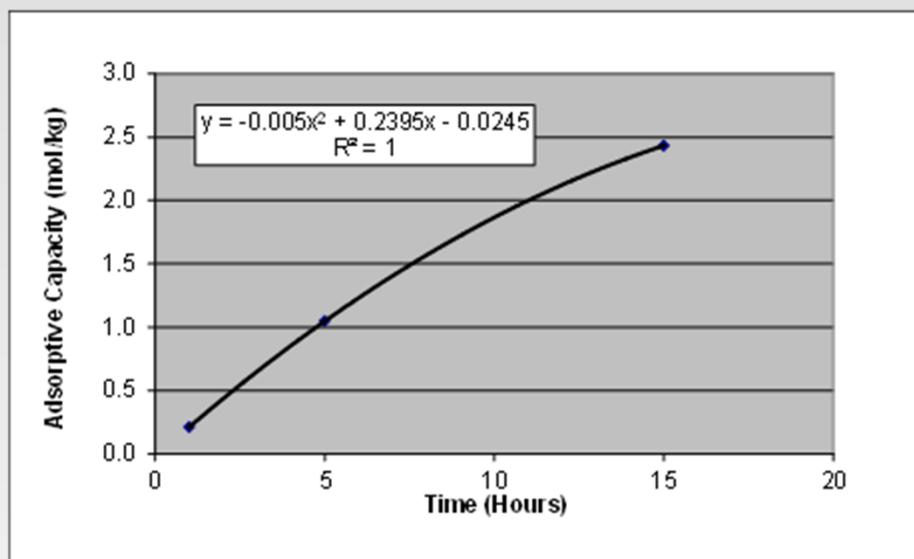


Figure 6. The adsorptive capacity of Chemsorb 1425 increased nonlinearly with time as the bed was being loaded with 345 ppm of NH₃ at 40% RH. The maximum capacity after 15 h for NH₃ was 2.4 mol/kg.



Conclusion

- The adsorptive characteristics of Chemsorb 1000 and Chemsorb 1425 were studied. These data are useful for designing future air revitalization systems that use adsorbent beds to remove VOCs and NH₃ from spacecraft atmospheres.
- The 1-h adsorptive capacity is a rapid screening method that was used to compare the effect of moisture on adsorption and to detect differences between the sorbents at low concentrations of contaminants typically found in spacecraft atmospheres.
- This measure of adsorptive capacity may not be representative of the true adsorption potential of the sorbents and an improved method needs to be developed.
- Further work should include examining the effect of particle size on adsorptive capacities, the effect of adsorption at lower NH₃ concentrations, as well as determining adsorptive properties at higher relative humidity.