Solutions within.

# Adsorbents and Carbon Technology for Air Sampling & Thermal Desorption

PEFTEC
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sigma-aldrich.com/analytical

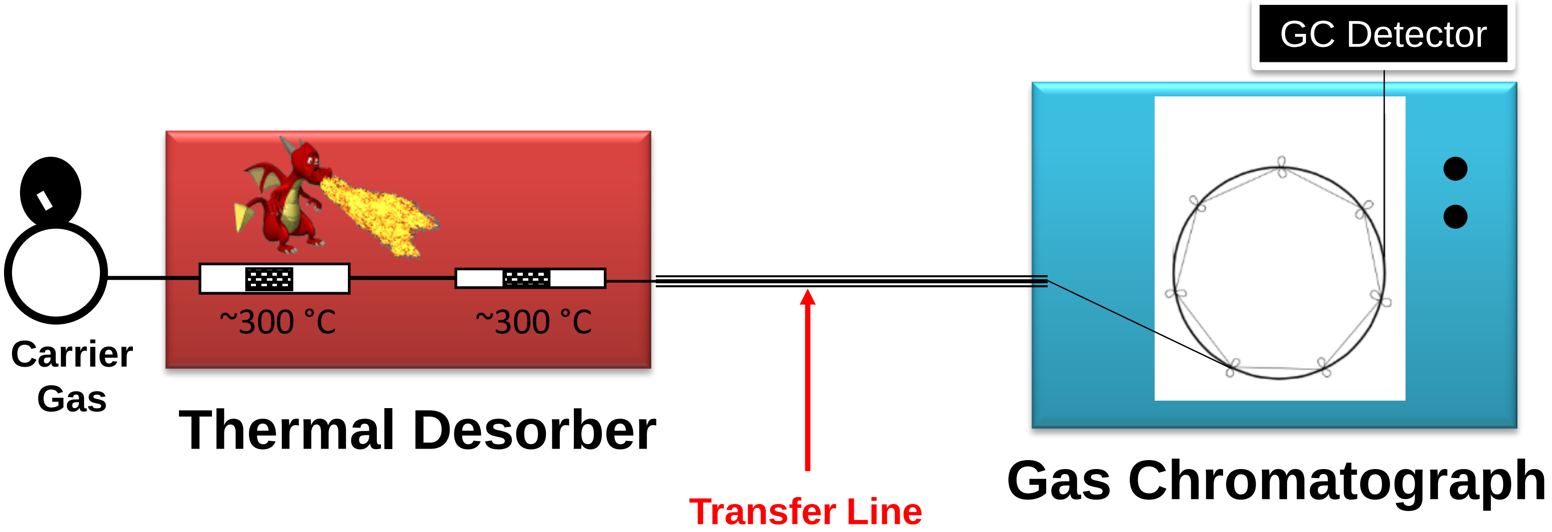
# Agenda

- Introduction
- Type of Adsorbents
- Selection Tool


# What is Thermal Desorption?

A Sample Preparation technique for Air & Gas Analysis and GC.

- The gas /air sample is collected onto an adsorbent packed glass or stainless steel tube. *The sample is concentrated on the adsorbents.*
- The packed tube is heated (Thermal) and the compounds are released into the carrier gas (Desorption) transfered onto GC column for Analysis



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# Adsorbent Characteristics for Thermal Desorption

- Able to retain & <u>release</u> the compounds of interest
- Able to withstand high temperatures ~ 300°C
- Low background levels
- Low metal content
- Hydrophobic

*Desirable*

- Consistent mesh/particle size
- Consistent density
- Low shrinkage
- Low amount of fines

# Terms Defined

**Surface Area:**

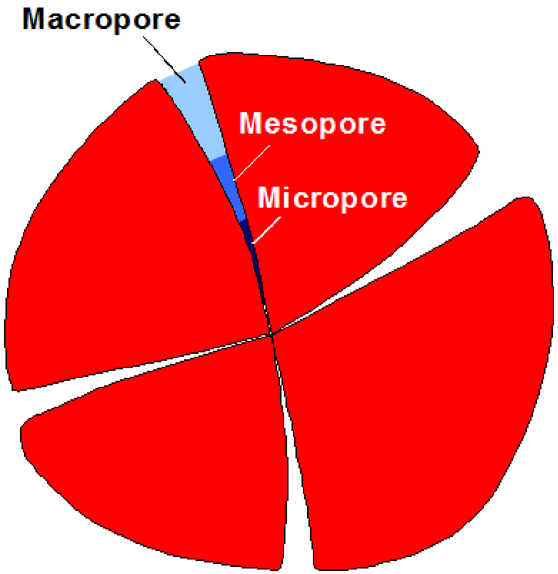
- provides a general idea of the adsorbent strength, but *it doesn't provide the whole picture*.
- Other characteristics such as pore size, pore shape, and porosity can also play a role in the adsorbent's ability to retain and release different compounds.

- *General Rule:*
  - *The higher the surface area value, the stronger the adsorbent.*
  - *For surface area >800 $m^2$/g, the size and shape of the pore becomes more important.*

# Terms Defined (cont.)

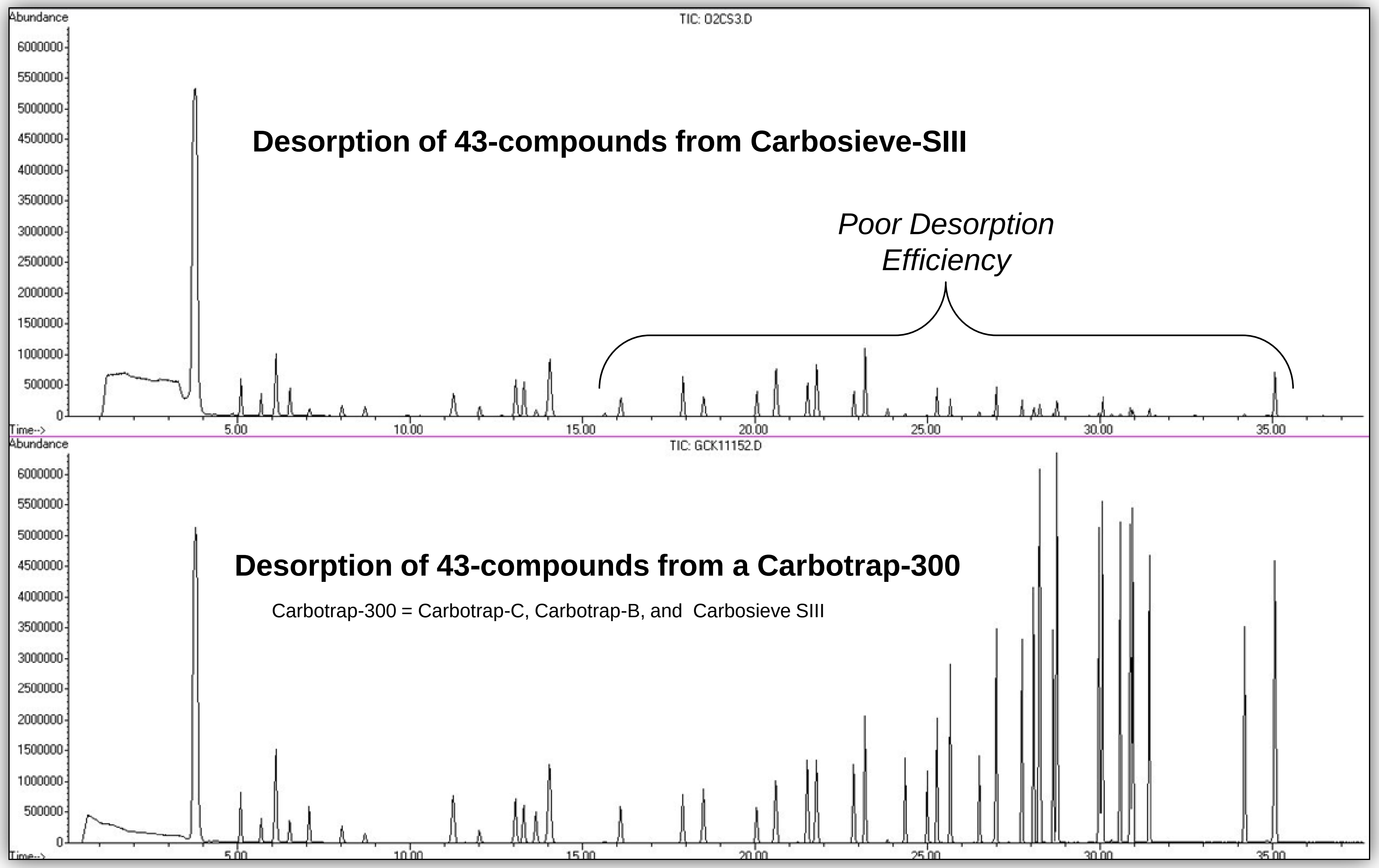
**Pore Size:**

- Macropores: > 50 nm diameter
- Mesopores: 2 - 50 nm diameter
- Micropores: < 2 nm diameter




**Molecules cannot access pores smaller than their size**

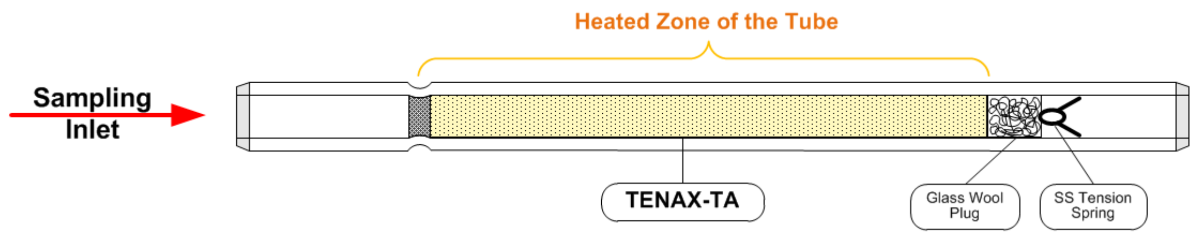
# Will the strongest adsorbent work for everything?

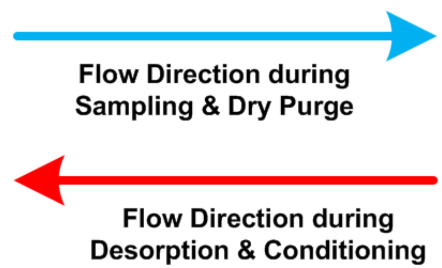


# Thermal Desorption Tube Adsorbent Beds

**Single-Bed Tube**

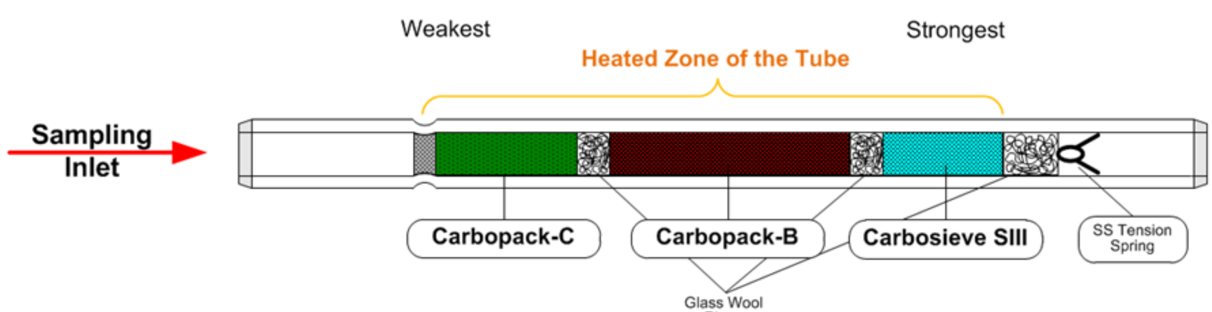
(e.g Tenax® TA)




**Multi-Bed Tube**

**Carbotrap® 300**



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# Adsorbent Types used in Thermal Desorption

# Typical Adsorbents for Thermal Desorption

- Polymers
  - Tenax® TA (2,6-diphenyl-p-phenylene oxide)
- Graphitized Carbon Blacks (GCB)
  - Non porous
  - Names: Carbopack™, Carbotrap™
  - Various types available
- Carbon Molecular Sieves (CMS)
  - Porous
  - Names: Carboxen™, Carbosieve™
  - Various types available
- Glass beads
  - Used to retain large molecular weight volatiles

**Key Expertise of Sigma-Aldrich / Supelco !!**

Materials used on the NASA missions Galileo (Jupiter) & Cassini-Huygens (Saturn-Titan)

# Carbon Adsorbents
# History in Supelco

## >20 year Experience in preparing Carbon Adsorbents

### Carbosieves

- First Family of Carbon molecular sieves (S-I, S-II, S-III)
- Carbosieve S-III one of strongest adsorbens
  - Micropoprus only
  - First CMS in air monitoring

### Carboxenes (Introduced 1987)

- Carboxene-1000 highly efficient adsorbent
  - Not as strong as S-III but far better kinetics
  - Materials on NASA Missions
    - *(e.g. Galileo, Cassini/Huygens to Titan)*

| Adsorbent | BET surface area (m2/g) | density (g/mL) | porosity micro- | meso- | macro- -pores (cc/g) | pore diameter (Å) |
|---|---|---|---|---|---|---|
| **Graphitized Carbons** | | | | | | |
| Carbopack X | 240 | 0.41 | ^ | 0.62 | ^ | 100 |
| Carbopack Z | 220 | 0.18 | ^ | 1.73 | ^ | 255 |
| Carbopack B | 100 | 0.35 | ^ | ^ | ^ | N/A |
| Carbopack Y | 24 | 0.42 | ^ | ^ | ^ | N/A |
| Carbopack C | 10 | 0.68 | ^ | ^ | ^ | N/A |
| Carbopack F | 5 | 0.64 | ^ | ^ | ^ | N/A |
| **Carbon Sieves** | | | | | | |
| Carboxen - 563 | 510 | 0.53 | 0.24 | 0.15 | 0.24 | 7 - 10 |
| Carboxen – 564 | 400 | 0.60 | 0.24 | 0.13 | 0.14 | 6 - 9 |
| Carboxen - 569 | 485 | 0.58 | 0.20 | 0.14 | 0.10 | 5 - 8 |
| Carboxen - 1000 | 1200 | 0.48 | 0.44 | 0.16 | 0.25 | 10 - 12 |
| Carboxen - 1001 | 500 | 0.61 | 0.22 | 0.13 | 0.11 | 5 - 8 |
| Carboxen - 1002 | 1100 | 0.43 | 0.36 | 0.28 | 0.30 | 10 - 12 |
| Carboxen - 1003 | 1000 | 0.46 | 0.38 | 0.26 | 0.28 | 5 - 8 |
| Carboxen - 1006 | 715 | ----- | 0.29 | 0.26 | 0.23 | 7 - 10 |
| Carboxen - 1010* | 675 | 0.60 | 0.35 | ^ | ^ | 6 - 8 |
| Carboxen - 1011 | 1100 | 0.48 | 0.41 | 0.19 | 0.24 | 10 - 12 |
| Carboxen - 1012 | 1500 | 0.50 | ^ | 0.66 | ^ | 19 - 21 |
| Carboxen - 1016 | 75 | 0.52 | ^ | 0.34 | ^ | ^ |
| Carboxen - 1018 | 700 | 0.60 | 0.31 | 0.04 | ^ | 6 - 8 |
| Carboxen - 1021 | 650 | 0.64 | 0.29 | 0.02 | ^ | 5 - 7 |
| Carbosieve S-III | 820 | 0.61 | 0.35 | 0.04 | ^ | 4 - 11 |
| Carbosieve S-II | 1059 | ----- | 0.45 | 0.01 | ^ | 6 - 15 |
| Carbosieve G | 1160 | ----- | 0.49 | 0.02 | ^ | 6 – 15 |
| NASA 20/45 (Carboxen - 1017) | 61 | 0.55 | ^ | 0.33 | ^ | ^ |
| Supelcarb | 1150 | 0.46 | 0.47 | 0.26 | 0.28 | 5 - 8 |

# Porous Polymers

**Tenax®-TA**

- The most popular adsorbent used in thermal desorption
- Maximum temperature: 350 °C
- Recommended desorption temp: 300 °C
- Recommended conditioning temp: 320 °C
- Methanol not retained  (Good for spiking tubes with liquid calibration standards)

## Typical Characteristics

- Granular - Tan in color
- Surface area: 35 $m^2/g$
- Hydrophobic

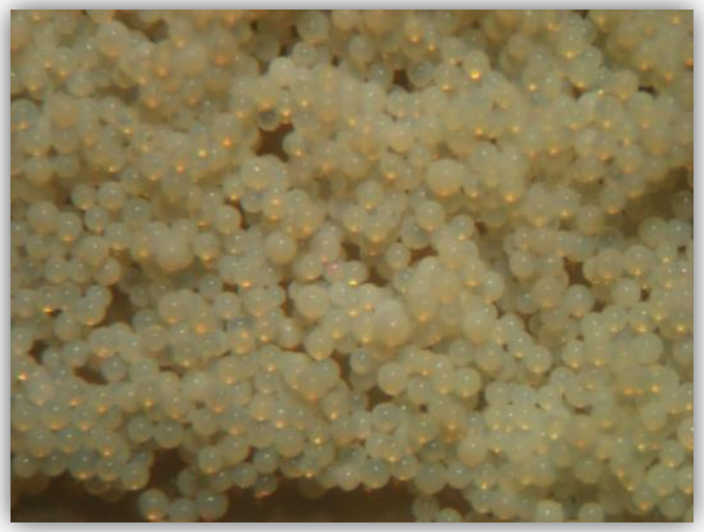
# Porous Polymers (cont.)

**PoraPak™-N, Chromosorb®-106, HayeSep®-D**

- Relatively low maximum temperatures: 225-290 °C
- Recommended desorption temp: 200 °C
- Recommended conditioning temp: 210 °C
- Typically has higher background levels than other adsorbents

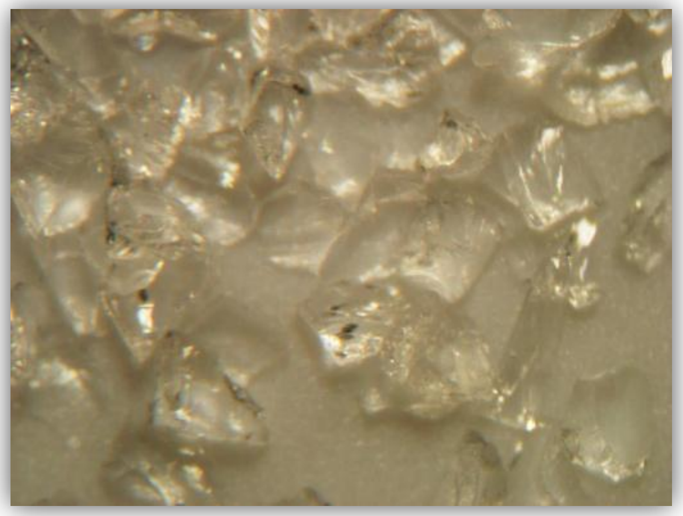
## Typical Characteristics

- Spherical - Light Yellow in color
- Surface area: 500 to 800 $m^2/g$
- Hydrophobic



# Other Adsorbents

**Glass Beads** 5 $m^2/g$ ("good pre-filter")



Rarely used for Thermal Desorption

- Petroleum Charcoal
- Coconut Charcoal
- Silica Gel
- Molecular Sieves (Zeolites)

# Graphitized Carbon Blacks

## Carbotrap® and Carbopack™

- Maximum temperature: 400 °C
- Recommended desorption temp: 330 °C
- Recommended conditioning temp: 350 °C
- Methanol not retained by most of them

**Carbotrap** = 20/40 mesh
**Carbopack** = 40/60, 60/80, 80/100, and 100/120 mesh

## Typical Characteristics

- Granular - Flat Grey/Black in color
- Surface area: 5 to 240 $m^2/g$
- Designed to retain and release mid to large molecular weight compounds
- Hydrophobic
- High Purity - Low Background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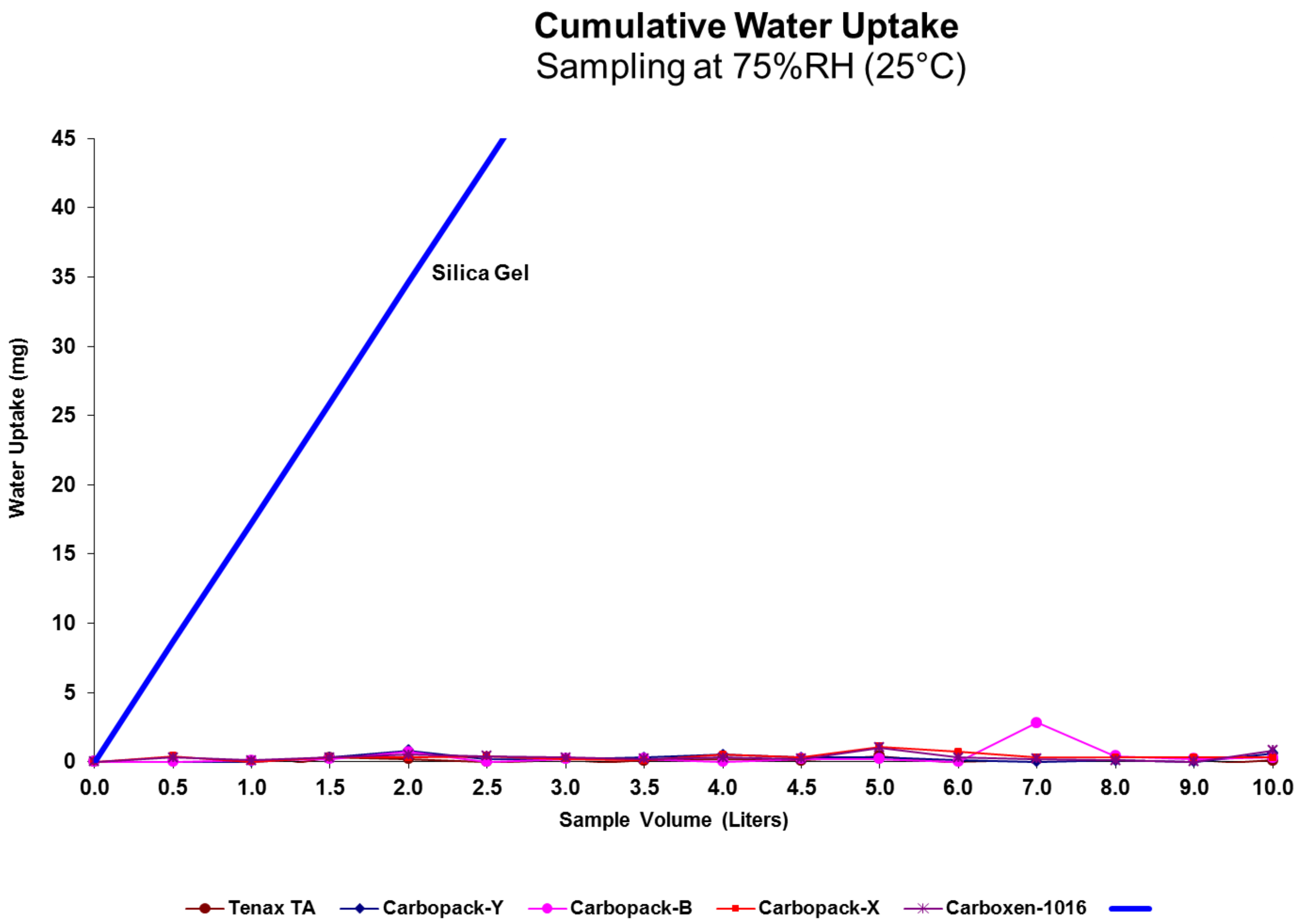
# Water vapor retained by Carbopack(s) & Tenax-TA



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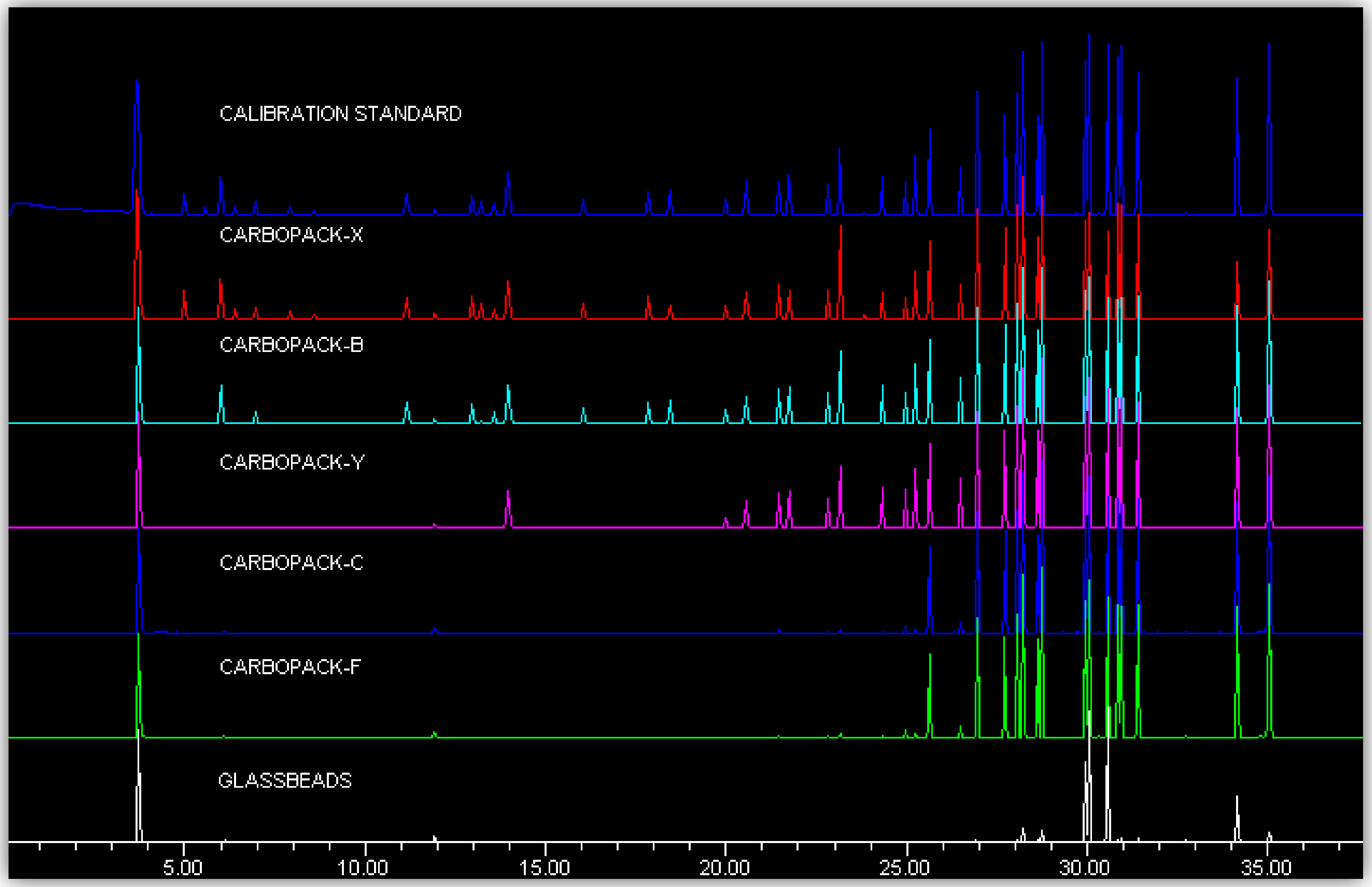
# Adsorptive Strength of Graphitized Carbon Blacks

| | | Relative Adsorption Strength |
|---|---|---|
| Carbopack X | 240 $m^2/g$ | Strongest |
| Carbopack Z | 220 $m^2/g$ | |
| Carbopack B | 100 $m^2/g$ | |
| Carbopack Y | 24 $m^2/g$ | |
| Carbopack C | 10 $m^2/g$ | |
| Carbopack F | 5 $m^2/g$ | Weakest |

# Graphitized Carbon Blacks



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# Fence line Monitoring  EPA325B (Draft)

On September 29, 2015, the U.S. EPA issued a final rule - requiring all U.S. Petroleum Refineries to conduct passive air sampling along the perimeter of their properties. (40 CFR Parts 60 and 63) Coming Method will be EPA325A/B.

EPA Method 325 uses passive (diffusive) samplers to collect air samples at specific intervals along the fence line of the petroleum refineries property[1]. The target compound is Benzene.

These passive air samplers are comprised of a inert-coated* stainless steel thermal desorption tube packed with a graphitized carbon adsorbent. **Carbopack™X** is listed as primary adsorbent.

The Carbopack X is also validated by the EPA and listed in the Method.

*The I.D. of the stainless steel tube are coated with a protective layer (Supelcoat™), which masks any active sites that could be present on the inside of the tube.





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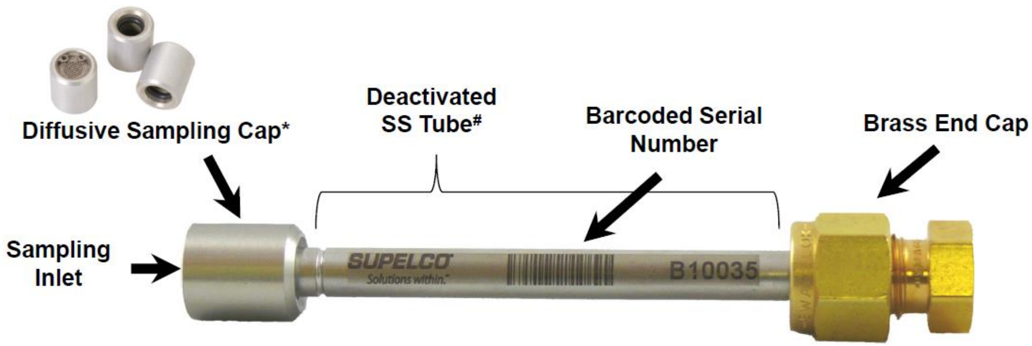
# EPA Method 325 (DRAFT) for Fenceline Monitoring (FLM)

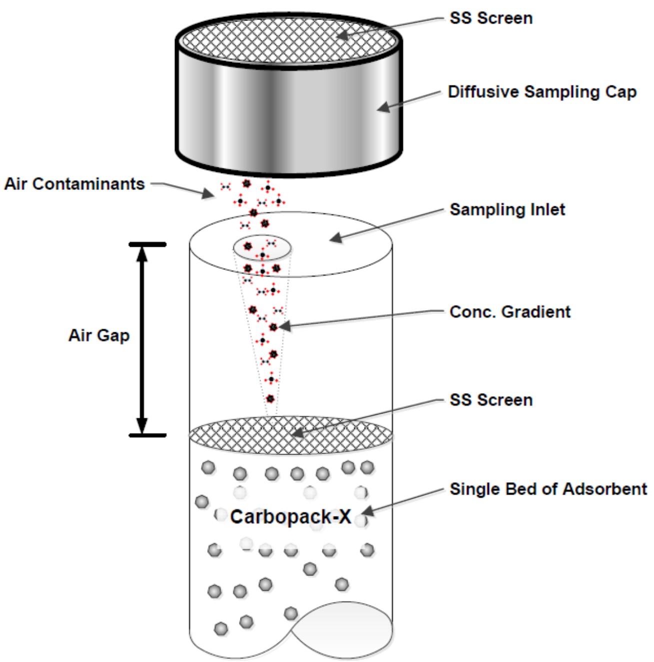
## Using **Carbopack X** in Specially Treated Thermal Desorption Tube

- Inert TD Tube with diffusion cap
- Carbopack X bed
  - retains wide range of analytes
    - *recovery of key analytes, 1,3-butadiene, benzene, toluene, remain at 100% when sampling large volumes*
  - is hydrophobic
    - *water will not be retained*




Tube Dimensions: 6.35 mm O.D. x 5 mm I.D. x 89 mm Long

**Cat# 28686-U** Stainless Steel w/SupelCoat Carbopack X (60/80) shown with diffusive sampling cap



Method 325B—Volatile Organic Compounds from Fugitive and Area Sources:

Sampler Preparation and Analysis

# EPA325B (Draft)

**Table 12.1**: Validated Sorbents and Uptake Rates (mL/min) for Selected Clean Air Act Compounds

| Compound | Carbopack™ X[a] |
|---|---|
| 1,1-Dichloroethene | 0.57±0.14 |
| 3-Chloropropene | 0.51±0.3 |
| 1,1-Dichloroethane | 0.57±0.1 |
| 1,2-Dichloroethane | 0.57±0.08 |
| 1,1,1-Trichloroethane | 0.51±0.1 |
| Benzene | 0.67±0.06 |
| Carbon tetrachloride | 0.51±0.06 |
| 1,2-Dichloropropane | 0.52±0.1 |
| Trichloroethene | 0.5±0.05 |
| 1,1,2-Trichloroethane | 0.49±0.13 |
| Toluene | 0.52±0.14 |
| Tetrachloroethene | 0.48±0.05 |
| Chlorobenzene | 0.51±0.06 |
| Ethylbenzene | 0.46±0.07 |
| m,p-Xylene | 0.46±0.09 |
| Styrene | 0.5±0.14 |
| o-Xylene | 0.46±0.12 |
| p-Dichlorobenzene | 0.45±0.05 |

[a] Reference 3, McClenny, J. Environ. Monit. 7:248-256. Based on 24-hour duration.

Carbopack X was validated for the broadest compound portfolio due to its broad suitability, not just Benzene (or BTEX).

# More Information

US EPA Method 325B Compliance Flyer (RNW)

Passive Fenceline Sampling Solution for Benzene and Other VOCs

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## US EPA Method 325B Compliance

Passive Fenceline Sampling Solution for Benzene and Other VOCs

### Compliance with US EPA Method 325B

The new US federal regulation 40 CFR Parts 60 and 63 – Petroleum Refinery Sector Risk and Technology Review and New Source Performance Standards, is an update to the previous version. It requires that the perimeter or fenceline of refineries are monitored for 14-day periods using passive sampling sorbent tubes at multiple locations for benzene and other volatile organic compounds (VOCs).

### The Complete Sampling and Analysis Solution

Our goal is to bring you the science and performance inside the tube and provide the quality on the outside to help you achieve compliance with the ruling. We make the carbon adsorbents and pack the adsorbent tubes in-house with our adsorbent manufacturing. Tube packing and QC are located in suites next to each other, no other supplier has the same capability. If you perform the laboratory analysis, our GC Capillary Columns are manufactured right next door in another suite. Our R&D facilities and experts are also located onsite.

**Proven quality and performance you can trust from the inside out with the Fenceline Monitor (FLM™) Carbopack™ X deactivated stainless steel TD tube.**

Carbopack X delivers trusted sampling performance from the inside while the easy to read tube markings and barcode delivers confidence and traceability on the outside.

### Features and Benefits

- Only sampling device available with Carbopack X adsorbent
- Only sampling device with sampling rates for Carbopack X validated by the US EPA
- Durable barcode to ensure traceability and minimize litigation risk
- Easy-to-read tube markings
- Certificate of Analysis included in every box
- Low-cost monitoring solution, tubes are reusable up to 100x

QC Testing
Carbon Adsorbent Manufacturing
Research and Development
Thermal Desorption Tube Manufacturing
Supelcoat TD Tube Treatment

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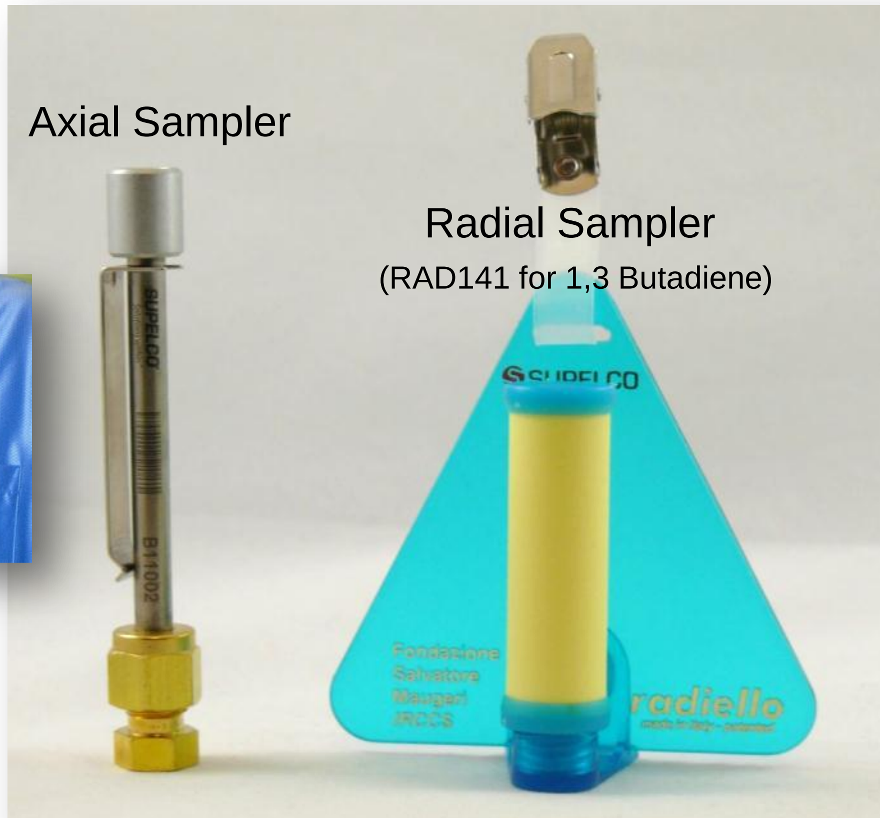
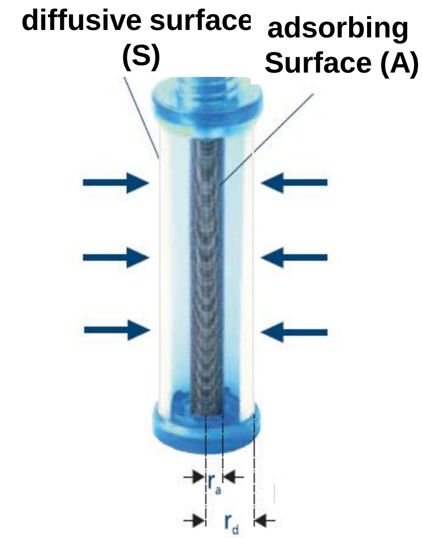
# Passive Sampling Options for Thermal Desorption Using Carbopack X



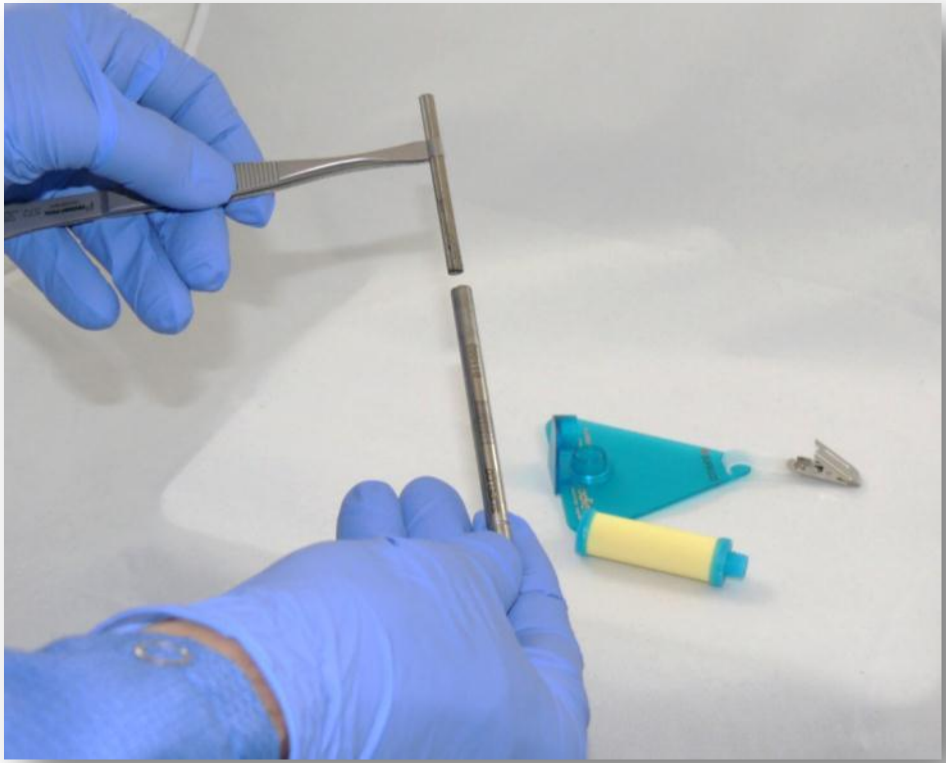




Radial Sampler (radiello®) due to design

- Higher Sampling rates
- Higher sensitivity

# Radiello (RAD141)
# Sampler for 1,3-Butadiene

After sampling, the RAD141 adsorbent cartridge is placed in an empty stainless steel thermal desorption tube for analysis.



# Carbon Molecular Sieves

## Carbosieve® and Carboxen®

- Maximum temperature: 400 °C
- Recommended desorption temp: 330 °C
- Recommended conditioning temp: 350 °C
- Methanol is retained

## Typical Characteristics

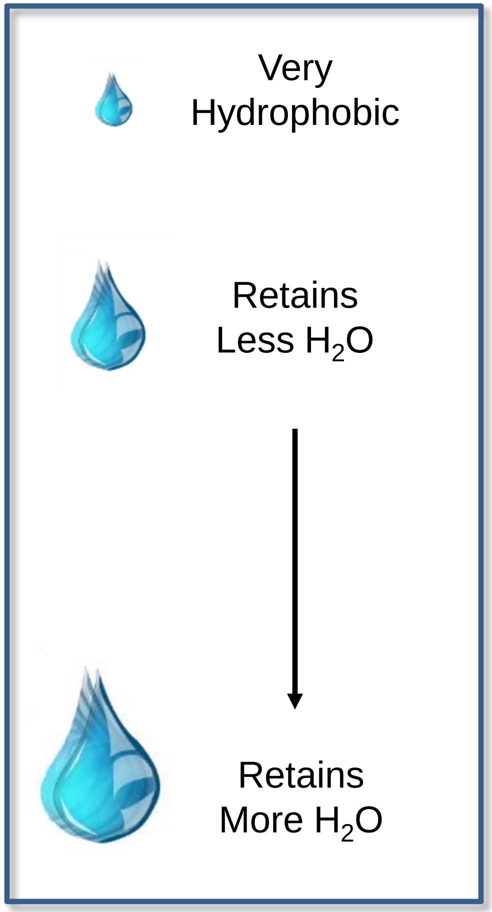
- Spherical (Carbosieve-G is granular)
- Shiny/Dull Black in color
- High surface area 400 to 1500 $m^2/g$
- Designed to retain and release small molecular weight compounds

# Adsorptive Strength of Carbon Molecular Sieves

**Relative Adsorption Strength**

| | | |
|---|---|---|
| Carboxen-1016 | *(75 m$^2$/g)* | **Weakest** |
| *Carbosieve-G* | *(1160 m$^2$/g)* | |
| *Carboxen-1012* | (1500 m$^2$/g) | |
| Carboxen-564 | (400 m$^2$/g) | |
| Carboxen-1000 | (1200 m$^2$/g) | |
| Carboxen-1001 | (500 m$^2$/g) | |
| Carboxen-569 | (485 m$^2$/g) | |
| Carboxen-1003 | (1000 m$^2$/g) | |
| Carboxen-1018 | (675 m$^2$/g) | |
| Carbosieve-SIII | (975 m$^2$/g) | |
| Carboxen-1021 | (1160 m$^2$/g) | **Strongest** |

# Relative Hydrophobicity




Glass Beads
Graphitized Carbon Blacks
Porous Polymers

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Carboxen-1016
Carboxen-569,1001,1003
Carboxen-563
Carboxen-564
Carboxen-1000
Carboxen-1012
Carboxen-1018,1021, Carbosieve G & SIII

Carbon Molecular Sieves

---

Silica Gel, Mole Sieve 5x, 13x


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# Information on Carbon Adsorbens

Wide Range of Properties

How to choose?

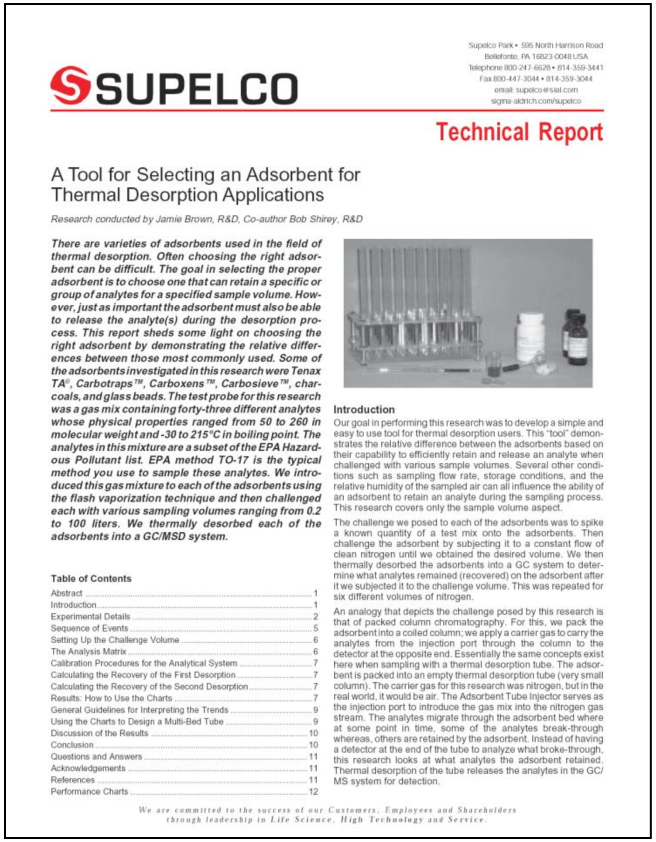
| Relative Analyte Size[1] | Adsorptive Strength | Recommended Adsorbents (listed highest to lowest surface area) |
|---|---|---|
| C20+ | Weakest | Carbotrap F, Carbopack F |
| C12-C20 | | Carbotrap C, Carbopack C |
| C9-C14 | | Carbotrap Y, Carbopack Y |
| C5-C12 | | Graphsphere 2027, Graphsphere 2029, Carbotrap B, Carbopack B, Graphsphere 2016, Graphsphere 2017 |
| C3-C9 | | Carbotrap X, Carbopack X, Carbopack Z |
| C2-C5 | Strongest | Carboxen 1012, Carboxen 1034, Carboxen 1000, Carboxen 1008, Carboxen 1026, Carbosieve G, Carboxen 1005, Carboxen 572, Carbosieve S-II, Carboxen 1003, Carbosieve S-III, Carboxen 1032, Carboxen 1030, Carboxen 1006, Carboxen 1018, Carboxen 1010, Carboxen 1021, Carboxen 563, Carboxen 1001, Carboxen 569, Carboxen 1033, Carboxen 564 |

| Carbon | Approx. Surface Area (m2/g) | Approx. Pore Volume (cc/g) Micro | Meso | Macro | Approx Pore Diam. (Å) |
|---|---|---|---|---|---|
| Carbotrap F / Carbopack F ▲ | 5 | – | – | – | – |
| Carbotrap C / Carbopack C ▲ | 10 | – | – | – | – |
| Carbotrap Y / Carbopack Y ▲ | 24 | – | – | – | – |
| Carboxen 1017 | 61 | – | 0.33 | – | – |
| Graphitized carbon black | 70 | 0.01 | 0.23 | – | 137 |
| Carboxen 1016 | 75 | – | 0.34 | – | – |
| Carbotrap B / Carbopack B ▲ | 100 | – | – | – | – |
| Mesoporous carbon | 203 | – | 0.49 | – | 96.3 |
| Purified carbon black | 214 | 0.06 | 0.28 | – | 63.9 |
| Carbopack Z ▲ | 220 | – | 1.73 | – | 255 |
| Carbotrap X / Carbopack X ▲ | 240 | – | 0.62 | – | 100 |
| Carboxen 564 | 400 | 0.24 | 0.13 | 0.14 | 6-9 |
| Carboxen 569 | 485 | 0.20 | 0.14 | 0.10 | 5-8 |
| Carboxen 1001 | 500 | 0.22 | 0.13 | 0.11 | 5-8 |
| Carboxen 563 | 510 | 0.24 | 0.15 | 0.24 | 7-10 |
| Carboxen 1021 | 600 | 0.30 | – | – | 5-8 |
| Carboxen 1010 | 675 | 0.35 | – | – | 6-8 |
| Carboxen 1018 | 675 | 0.35 | – | – | 6-8 |
| Carboxen 1006 | 715 | 0.29 | 0.26 | 0.23 | 7-10 |
| Carbosieve S-III | 975 | 0.35 | 0.04 | – | 4-11 |
| Carboxen 1003 | 1000 | 0.38 | 0.26 | 0.28 | 5-8 |
| Carbosieve S-II | 1059 | 0.45 | 0.01 | – | 6-15 |
| Carboxen 572 | 1100 | 0.41 | 0.19 | 0.24 | 10-12 |
| Supelcarb | 1150 | 0.47 | 0.26 | 0.28 | 5-8 |
| Carbosieve G | 1160 | 0.49 | 0.02 | – | 6-15 |
| Carboxen 1000 | 1200 | 0.44 | 0.16 | 0.25 | 10-12 |
| Carboxen 1012 | 1500 | – | 0.66 | – | 19-21 |

# Adsorbent / Thermal Desorption Literature

"A Tool for Selecting an Adsorbent for Thermal Desorption"

www.sigmaaldrich.com/air-monitoring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Technical Report

## A Tool for Selecting an Adsorbent for Thermal Desorption Applications

*Research conducted by Jamie Brown, R&D, Co-author Bob Shirey, R&D*

***There are varieties of adsorbents used in the field of thermal desorption. Often choosing the right adsorbent can be difficult. The goal in selecting the proper adsorbent is to choose one that can retain a specific or group of analytes for a specified sample volume. However, just as important the adsorbent must also be able to release the analyte(s) during the desorption process. This report sheds some light on choosing the right adsorbent by demonstrating the relative differences between those most commonly used. Some of the adsorbents investigated in this research were Tenax TA®, Carbotraps™, Carboxens™, Carbosieve™, charcoals, and glass beads. The test probe for this research was a gas mix containing forty-three different analytes whose physical properties ranged from 50 to 260 in molecular weight and -30 to 215°C in boiling point. The analytes in this mixture are a subset of the EPA Hazardous Pollutant list. EPA method TO-17 is the typical method you use to sample these analytes. We introduced this gas mixture to each of the adsorbents using the flash vaporization technique and then challenged each with various sampling volumes ranging from 0.2 to 100 liters. We thermally desorbed each of the adsorbents into a GC/MSD system.***

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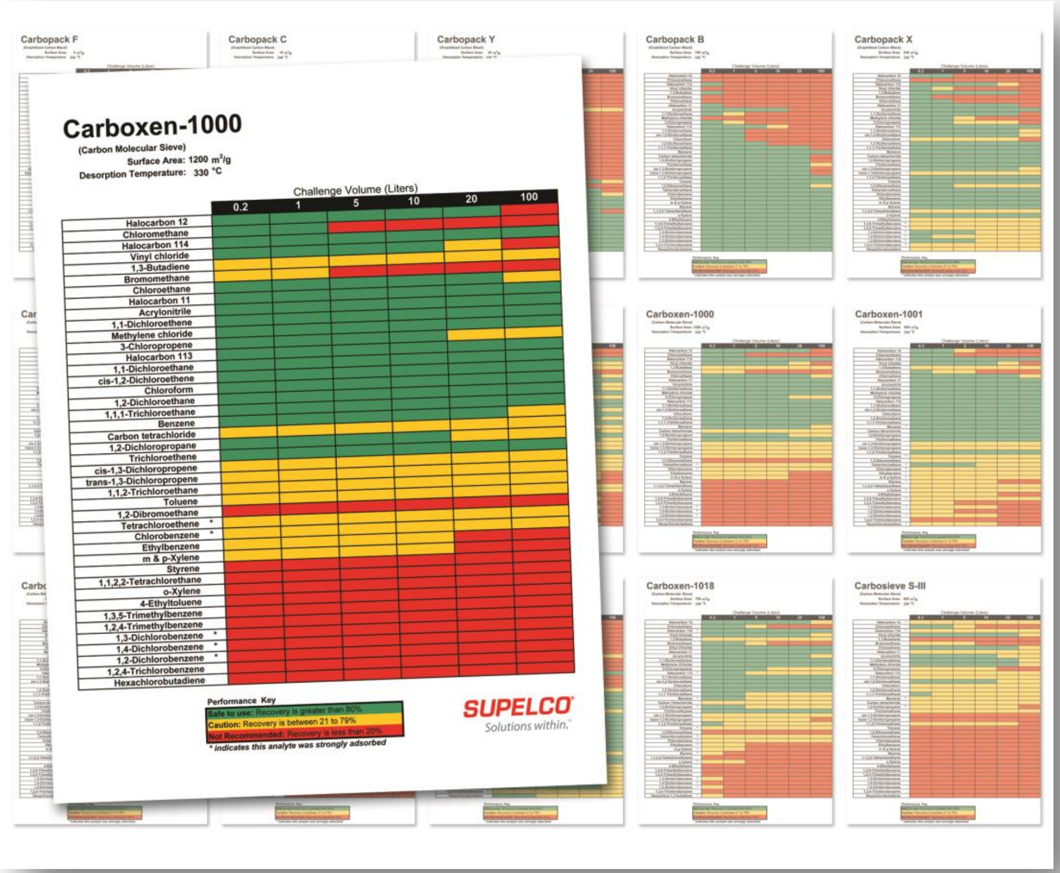
**Introduction**

Our goal in performing this research was to develop a simple and easy to use tool for thermal desorption users. This "tool" demonstrates the relative difference between the adsorbents based on their capability to efficiently retain and release an analyte when challenged with various sample volumes. Several other conditions such as sampling flow rate, storage conditions, and the relative humidity of the sampled air can all influence the ability of an adsorbent to retain an analyte during the sampling process. This research covers only the sample volume aspect.

The challenge we posed to each of the adsorbents was to spike a known quantity of a test mix onto the adsorbents. Then challenge the adsorbent by subjecting it to a constant flow of clean nitrogen until we obtained the desired volume. We then thermally desorbed the adsorbents into a GC system to determine what analytes remained (recovered) on the adsorbent after it we subjected it to the challenge volume. This was repeated for six different volumes of nitrogen.

An analogy that depicts the challenge posed by this research is that of packed column chromatography. For this, we pack the adsorbent into a coiled column; we apply a carrier gas to carry the analytes from the injection port through the column to the detector at the opposite end. Essentially the same concepts exist here when sampling with a thermal desorption tube. The adsorbent is packed into an empty thermal desorption tube (very small column). The carrier gas for this research was nitrogen, but in the real world, it would be air. The Adsorbent Tube Injector serves as the injection port to introduce the gas mix into the nitrogen gas stream. The analytes migrate through the adsorbent bed where at some point in time, some of the analytes break-through whereas, others are retained by the adsorbent. Instead of having a detector at the end of the tube to analyze what broke-through, this research looks at what analytes the adsorbent retained. Thermal desorption of the tube releases the analytes in the GC/MS system for detection.

*We are committed to the success of our Customers, Employees and Shareholders through leadership in Life Science, High Technology and Service.*



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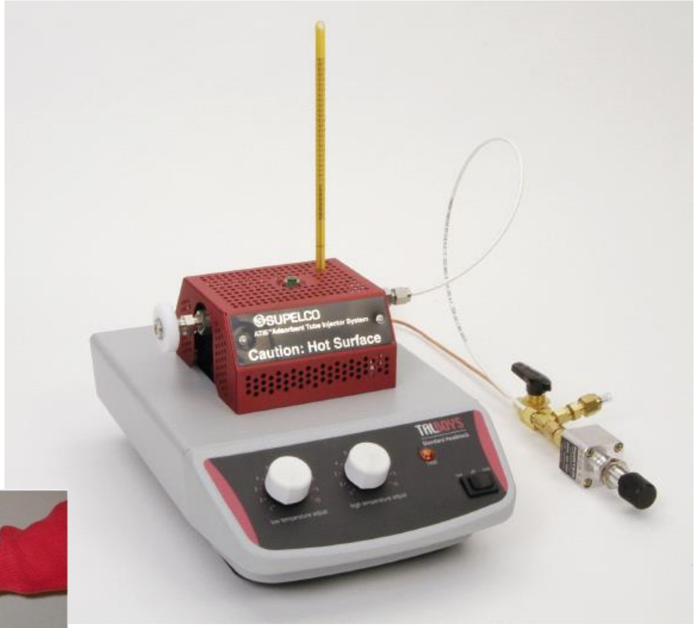
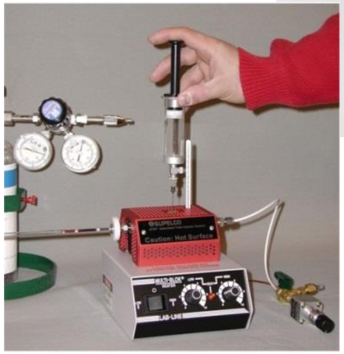
# Spiking the Tubes with the Gas Mix

**Adsorbent Tube Injector System (ATIS)**

used for spiking tubes

- 20 mL of gas mix
  - 43 Compounds: 50 to 260 in molecular weight,
    *-30 to 215°C in boiling point.*
  - Concentration : 1ppm of each compound
- Injected into a stream of $N_2$
- $N_2$ carried the compounds to the tube
  - Challenges volumes tested



sigma-aldrich.com/atis





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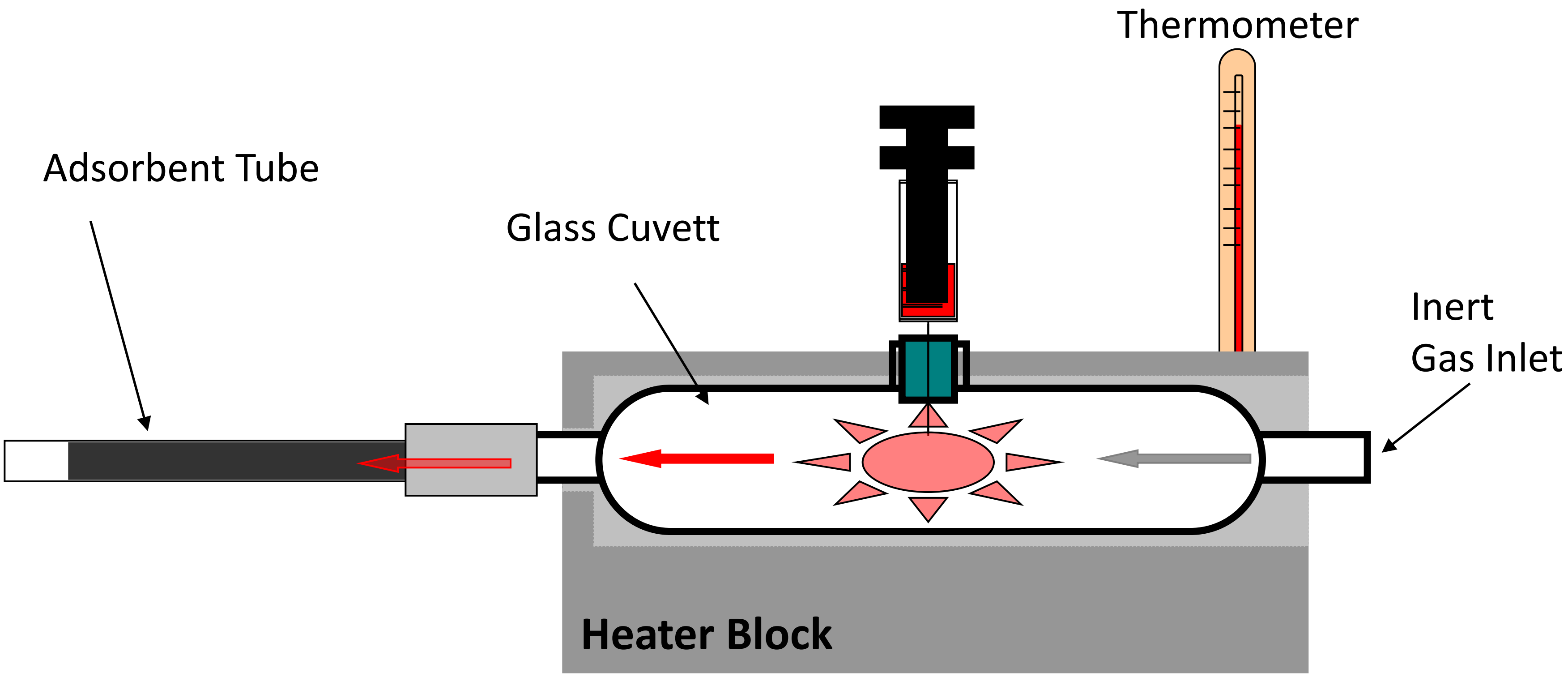
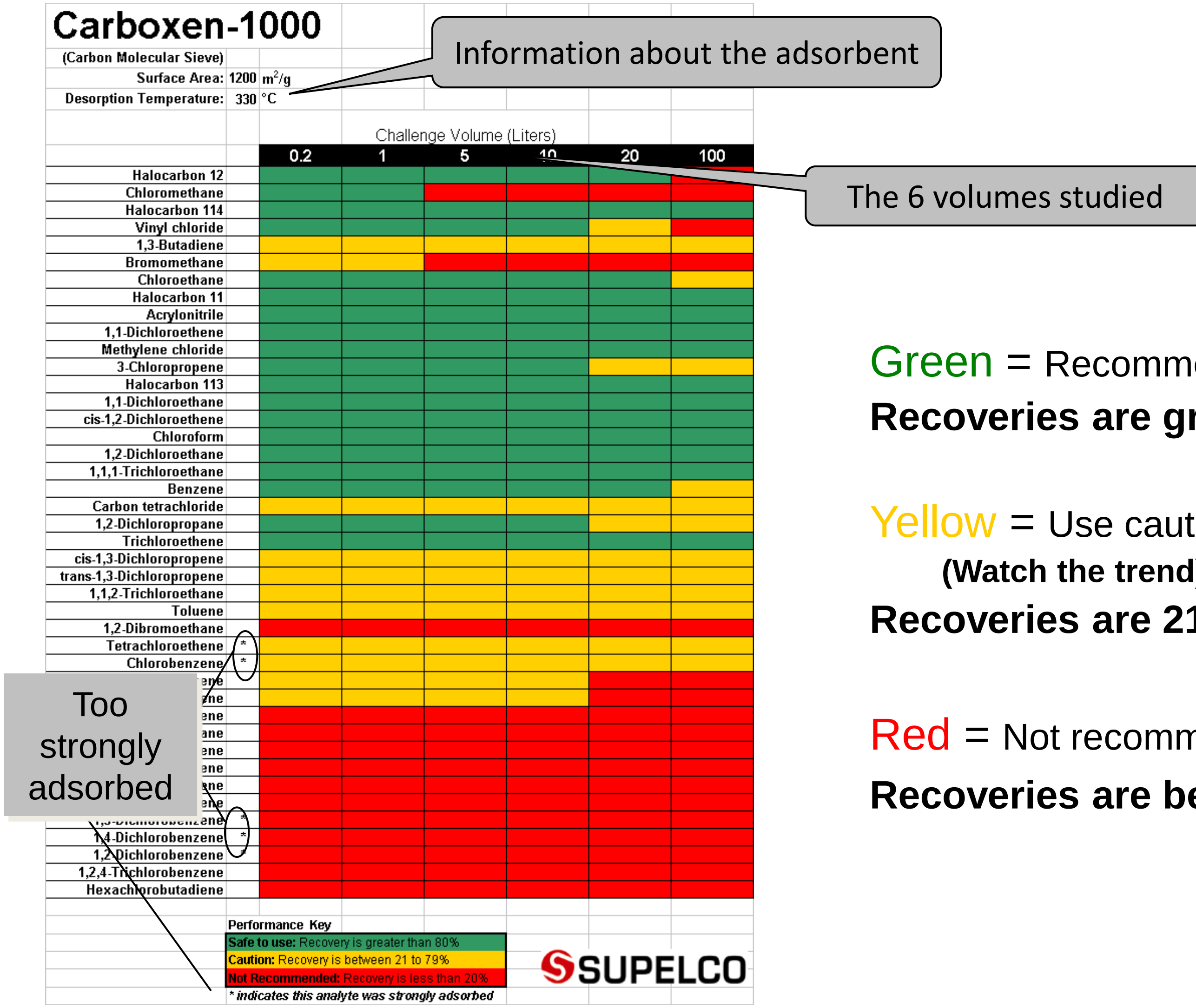
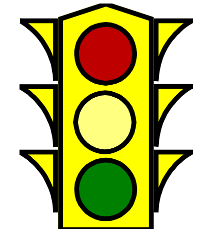
# ATIS - Principle



# How to use the performance charts



Green = Recommend for use

**Recoveries are greater then 80%**

Yellow = Use caution

**(Watch the trend)**

**Recoveries are 21 to 79%**

Red = Not recommend

**Recoveries are below 20%**





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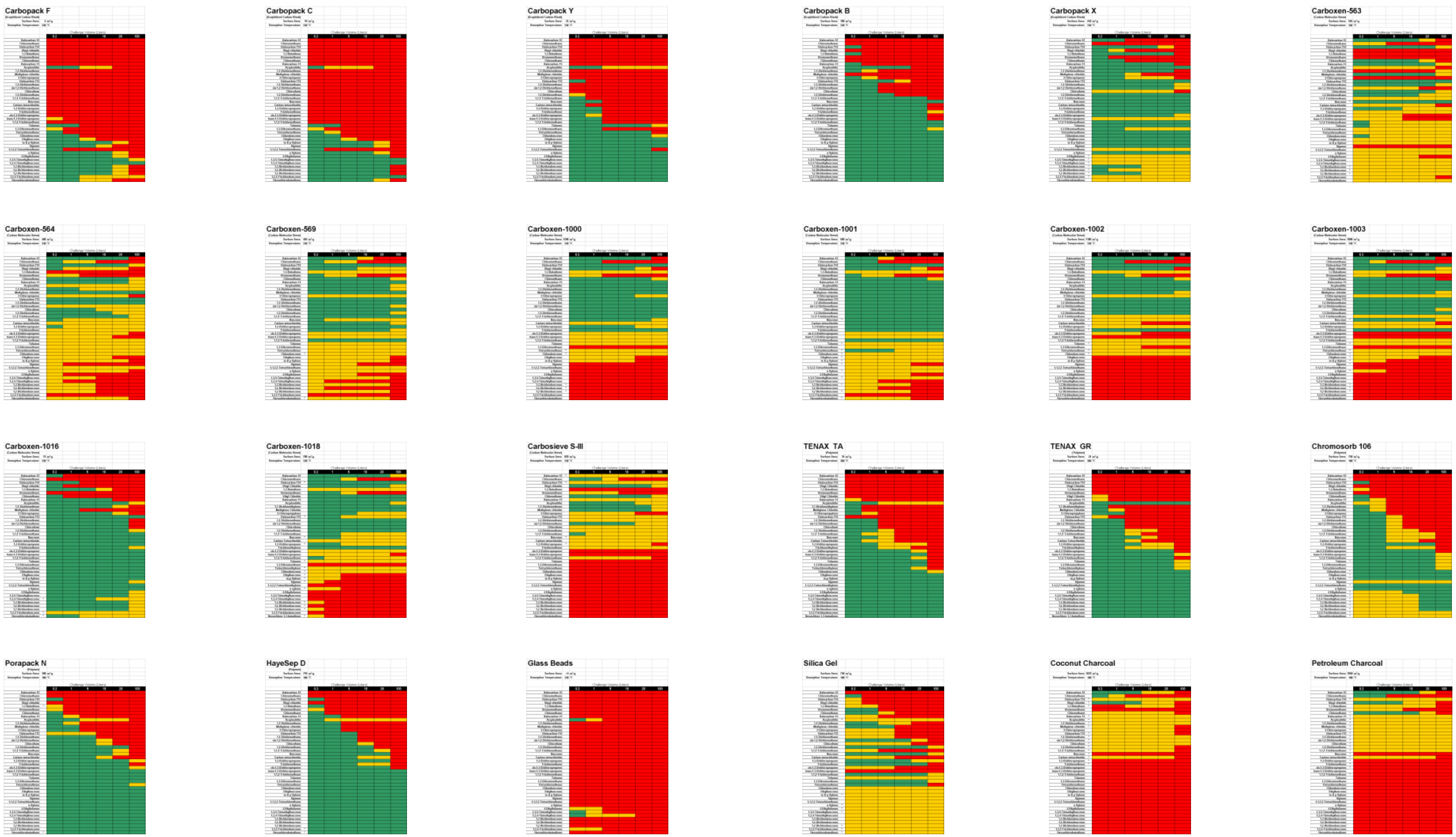
# The outcome of this research …





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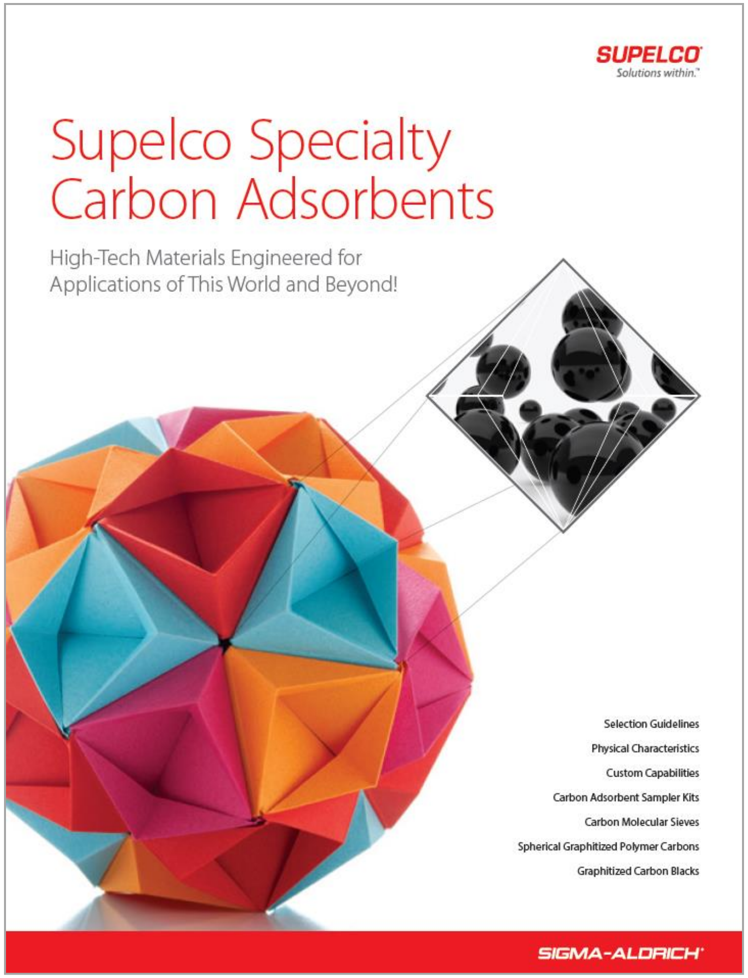
# “Inlet” First adsorbent bed

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Carbopack B** | | | | | | | |
| (Graphitized Carbon Black) | | | | | | | |
| Surface Area: | 100 | $m^2/g$ | | | | | |
| Desorption Temperature: | 330 | °C | | | | | |
| | | | Challenge Volume (Liters) | | | | |
| | | **0.2** | **1** | **5** | **10** | **20** | **100** |
| Vinyl chloride | | | Breaks through | | | | |
| Methylene chloride | | | | | | | |
| Toluene | | | Retained | | | | |
| 1,2,4-Trichlorobenzene | | | | | | | |

# Back-up adsorbent bed

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Carboxen-1003** | | | | | | | |
| (Carbon Molecular Sieve) | | | | | | | |
| Surface Area: | 1000 | $m^2/g$ | | | | | |
| Desorption Temperature: | 330 | °C | | | | | |
| | | | Challenge Volume (Liters) | | | | |
| | | **0.2** | **1** | **5** | **10** | **20** | **100** |
| Vinyl chloride | | | Retained | | | | |
| Methylene chloride | | | | | | | |
| Toluene | * | Carryover was observed (Too Strongly Adsorbed) | | | | | |
| 1,2,4-Trichlorobenzene | | Most likely irreversibly adsorbed | | | | | |

# Test different Carbon Adsobents?




(MQR)

| Adsorbent | Type[1] | S/G[2] | Sc[3] | Approximate | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Surface Area ($m^2/g$) | Pore Volume (cc/g) | | | Pore Diameter (Å) | Micropore Diameter (Å) | pH |
| | | | | | Macro | Meso | Micro | | | |
| Carboxen 1012 | CMS | S | | 1500 | — | 0.66 | — | — | 19–21 | — |
| Carboxen 1034 | CMS | S | Y | 1260 | 0.10 | 0.48 | 0.42 | 32 | 5–20 | 10.5 |
| Carboxen 1000 | CMS | S | | 1200 | 0.25 | 0.16 | 0.44 | — | 10–12 | — |
| Carboxen 1008 | CMS | S | | 1200 | 0.25 | 0.16 | 0.44 | — | 10–12 | — |
| Carboxen 1026 | CMS | S | | 1200 | — | 0.06 | 0.72 | — | 4–20 | — |
| Carbosieve G | CMS | G | | 1160 | — | 0.02 | 0.49 | — | 6–15 | — |
| Carboxen 1005 | CMS | S | Y | 1150 | 0.28 | 0.26 | 0.47 | — | 5–8 | 9.3 |
| Carboxen 572 | CMS | S | Y | 1100 | 0.24 | 0.19 | 0.41 | — | 10–12 | 9.5 |
| Carbosieve S-II | CMS | S | | 1059 | — | 0.01 | 0.45 | — | 6–15 | — |
| Carboxen 1003 | CMS | S | Y | 1000 | 0.28 | 0.26 | 0.38 | — | 5–8 | 9.2 |
| Carbosieve S-III | CMS | S | | 975 | — | 0.04 | 0.35 | — | 4–11 | — |
| Carboxen 1032 | CMS | S | Y | 820 | 0.10 | 0.38 | 0.29 | 37 | 4–20 | 3.0 |
| Carboxen 1030 | CMS | S | Y | 740 | 0.11 | 0.13 | 0.26 | 26 | 5–20 | 4.0 |
| Carboxen 1006 | CMS | S | | 715 | 0.23 | 0.26 | 0.29 | — | 7–10 | — |
| Carboxen 1018 | CMS | S | | 675 | — | — | 0.35 | — | 6–8 | — |
| Carboxen 1010 | CMS | S | | 675 | — | — | 0.35 | — | 6–8 | — |
| Carboxen 1021 | CMS | S | | 600 | — | — | 0.30 | — | 5–8 | — |
| Carboxen 563 | CMS | S | Y | 510 | 0.24 | 0.15 | 0.24 | — | 7–10 | 6.8 |
| Carboxen 1001 | CMS | S | | 500 | 0.11 | 0.13 | 0.22 | — | 5–8 | — |
| Carboxen 569 | CMS | S | Y | 485 | 0.10 | 0.14 | 0.20 | — | 5–8 | 8.6 |
| Carboxen 1033 | CMS | S | Y | 420 | 0.10 | 0.10 | 0.15 | 33 | 5–17 | 7.0 |
| Carboxen 564 | CMS | S | Y | 400 | 0.14 | 0.13 | 0.24 | — | 6–9 | 8.7 |
| Carbotrap X | GCB | G | Y | 240 | — | 0.62 | — | 100 | — | 9.5 |
| Carbopack X | GCB | G | | 240 | — | 0.62 | — | 100 | — | — |
| Carbopack Z | GCB | G | | 220 | — | 1.73 | — | 255 | — | — |
| Purified Carbon Black | CB | G | | 214 | — | 0.28 | 0.06 | 63.9 | — | — |
| Mesoporous Carbon | GCB | G | | 203 | — | 0.49 | — | 96.3 | — | — |
| Graphsphere 2027 | SGPC | S | | 126 | 0.20 | 0.35 | — | 173 | — | — |
| Graphsphere 2029 | SGPC | S | | 105 | 0.20 | 0.26 | 0.03 | 180 | — | — |
| Carbotrap B | GCB | G | Y | 100 | — | — | — | — | — | 9.7 |
| Carbopack B | GCB | G | | 100 | — | — | — | — | — | — |
| Graphsphere 2016 | SGPC | S | | 75 | — | 0.34 | — | — | — | — |
| Graphitized Carbon Black | GCB | G | | 70 | — | 0.23 | 0.01 | 137 | — | — |
| Graphsphere 2017 | SGPC | S | Y | 60 | — | 0.33 | | | | |
| Carbotrap Y | GCB | G | Y | 24 | — | — | | | | |
| Carbopack Y | GCB | G | | 24 | — | — | | | | |
| Carbotrap C | GCB | G | Y | 10 | — | — | | | | |
| Carbopack C | GCB | G | | 10 | — | — | | | | |
| Carbotrap F | GCB | G | Y | 5 | — | — | | | | |
| Carbopack F | GCB | G | | 5 | — | — | | | | |

Custom Tubes possible!

Sampler Kits

# Conclusion

- Thermal desorption covers a wide range of analytes
  - Available Adsorbents offer enables broad sampling scope
- Single bed tubes are often have limits for a wider analyte portfolio
  - Multibed tubes provide a wider range
- Synthetic carbon adorbents (Carbopack, Carboxen) are most suitable due to stability, reproducibility & purity
  - Sigma-Aldrich / Supelco has long year experience and wide selection
- Adsorbent selection can be done
  - by literature research (official methods, journal articles, vendor information)
  - using „A Tool for Selecting an Adsorbent for Thermal Desorption"
- Custom selected adsorbents for a multibed tube allow to achieve optimal retention & release characteristics for desired application

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Kristen Schultz - Air Monitoring Product Manager

*Bellefonte, Pennsylvania USA*

**Trademarks:**

Carbotrap®, Carbopack™, Carboxen®, Carbosieve® – Sigma Aldrich, USA

Chromosorb® - Imerys Minerals California, Inc. USA

HayeSep® - Hayes Separations, USA

PoraPak™ - Waters Associates, USA

Tenax® - Buchem B.V., Netherlands

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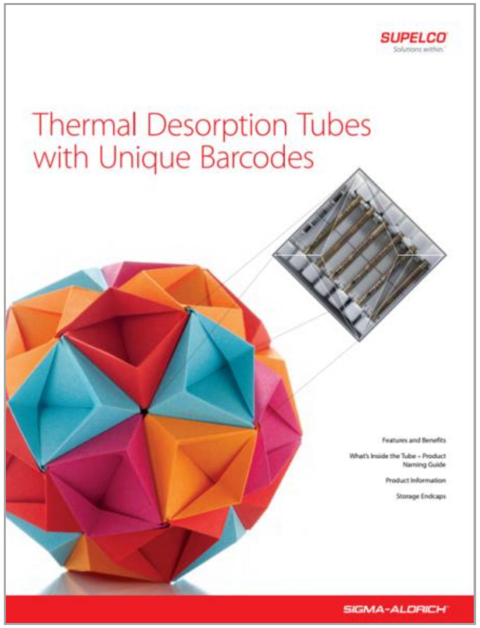
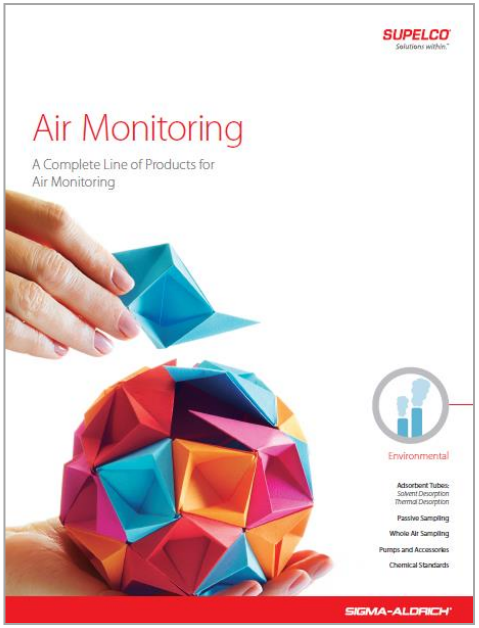
# Thank you!

(RKA)




(KQV)

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