

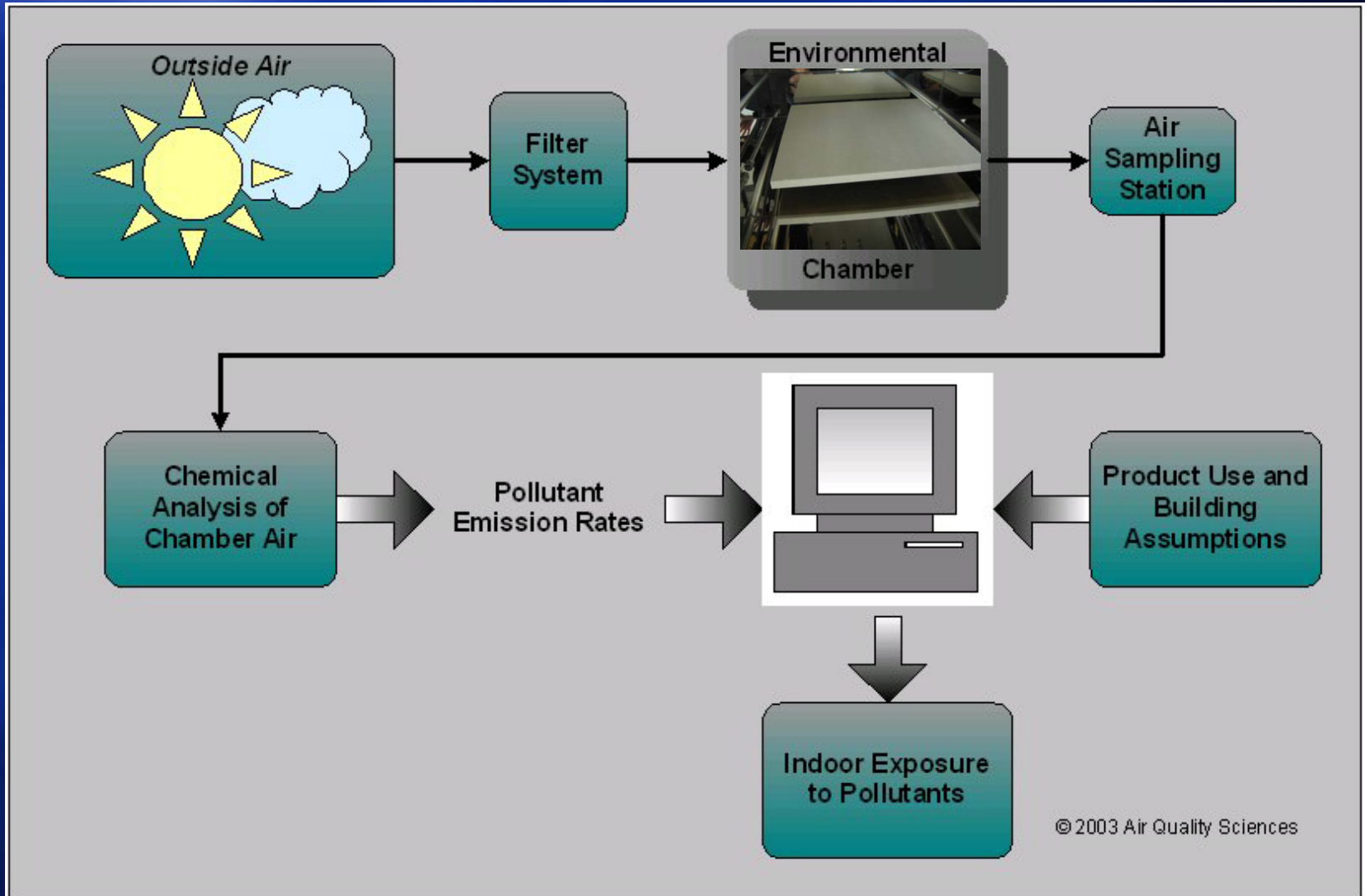
Chemical Emissions, Including Sulfur Compounds, from Chinese Produced Drywall

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- Drywall produced from China implicated in health complaints and corrosion of metal components in homes
- Sulfur compounds identified as a potential source
- Private, State and Federal efforts underway to fully characterize impacts
- Emissions of gaseous sulfur compounds from drywall a key component

- Sulfurs are very difficult to measure and analyze
- AQS developed an environmental chamber protocol to characterize chemical emissions, including sulfur compounds
- Goal was to simulate product performance in residential settings, including hot and humid climates

- Original technology developed in the early 1980's
- Significant improvements over the last 20 years allow for reproducible, trace measurements for a wide range of emissions
- Overall goal is to simulate product exposure to accurately characterize emissions
- In turn, emissions data can be modeled to predict human exposure
- Product failure studies are a common application for environmental chamber testing

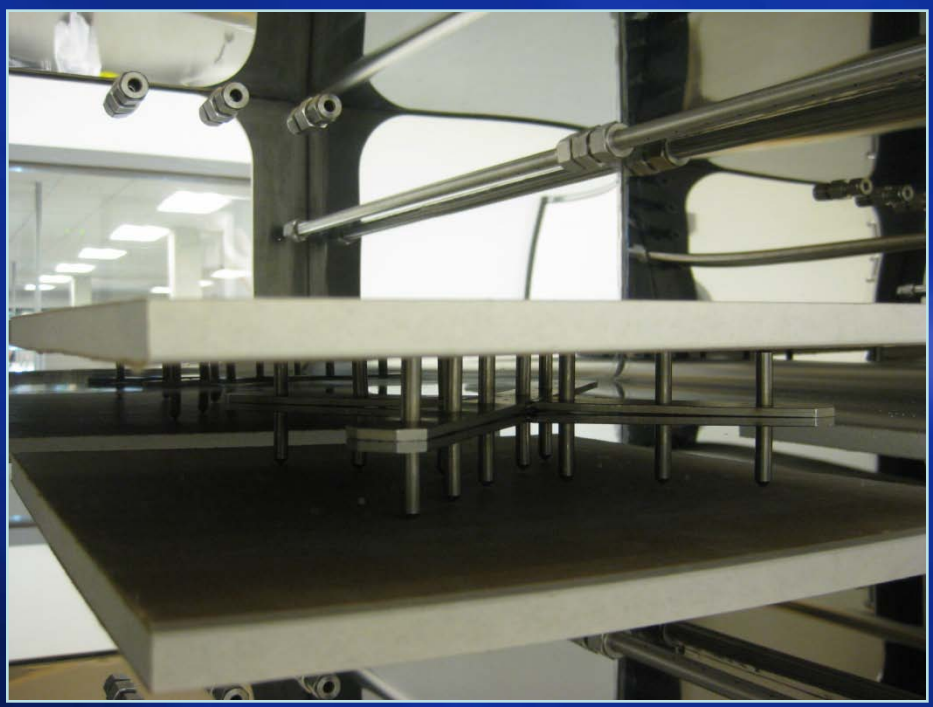








- 9 China-produced drywall samples evaluated
- Each sample evaluated at:
 - 73°F and 50% RH (Standard Conditions)
 - 98°F and >50% RH (Elevated Conditions)
- Environmental chamber operation and control measured followed the guidance of ASTM Standard D 5116 “Standard Guide for Small-Scale Environmental Chamber Determinations of Organic Emissions from indoor Materials/Products”



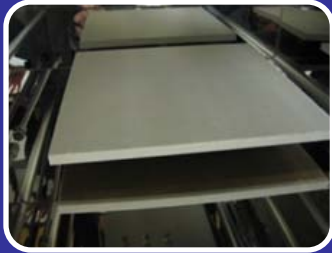
Analysis of Sulfur Compounds by Thermal Desorption GC/MS (ASTM D 6196)

- Performed on all 9 samples
- Chamber air collected onto a solid sorbent
- Thermal Desorption/GC/MS
- US EPA IP-1B and ASTM D 6196
- Generally C₆ – C₁₆ (BP 35°C – 250°C)
- Trace level detection (0.1 ug/m³)



Sulfur Compounds by GC with Chemiluminescence Detector (ASTM D 5504)

- Performed on a subset of 3 samples
- Chamber air collected in Tedlar bag
- GC with Sulfur Chemiluminescence Detector
- Target list of 20 sulfur compounds including hydrogen sulfide, carbon disulfide, and carbonyl sulfide among others
- ASTM D 5504



Products

- Suspect Chinese-produced Drywall
- 9 Samples Evaluated



Environmental Chamber Conditions

- 73°F and 50% RH (Standard)
- 98°F and >50% RH (Elevated)



Analytical Methodologies

- Solid Sorbent - Thermal Desorption/GC/MS
- Tedlar Bag - GC with Sulfur Chemiluminescence Detector

Tedlar Bag – GC Analysis (ASTM D 5504) 73°F and 50% RH

CAS Number	Chemical Name	Sample 1	Sample 6	Sample 8
		Measured Concentration (ppbV)		
7783-06-4	Hydrogen Sulfide	nd	nd	nd
463-58-1	Carbonyl Sulfide	nd	nd	nd
74-93-1	Methyl Mercaptan	nd	nd	nd
75-08-1	Ethyl Mercaptan	nd	nd	nd
75-18-3	Dimethyl Sulfide	nd	nd	nd
75-15-0	Carbon Disulfide	nd	nd	nd
75-33-2	Isopropyl Mercaptan	nd	nd	nd
75-66-1	tert-Butyl Mercaptan	nd	nd	nd
107-03-9	n-Propyl Mercaptan	nd	nd	nd
624-89-5	Ethyl Methyl Sulfide	nd	nd	nd
110-02-1	Thiophene	nd	nd	nd
513-44-0	Isobutyl Mercaptan	nd	nd	nd
352-93-2	Diethyl Sulfide	nd	nd	nd
109-79-5	n-Butyl Mercaptan	nd	nd	nd
624-92-0	Dimethyl Disulfide	nd	nd	nd
616-44-4	3-Methylthiophene	nd	nd	nd
110-01-0	Tetrahydrothiophene	nd	nd	nd
638-02-8	2,5-Dimethylthiophene	nd	nd	nd
872-55-9	2-Ethylthiophene	nd	nd	nd
110-81-6	Diethyl Disulfide	nd	nd	nd

Tedlar Bag – GC Analysis (ASTM D 5504) 98°F and >50% RH

CAS Number	Chemical Name	Sample 1	Sample 6	Sample 8
		Measured Concentration (ppbV)		
7783-06-4	Hydrogen Sulfide	38	36	7.4
463-58-1	Carbonyl Sulfide	nd	nd	nd
74-93-1	Methyl Mercaptan	nd	nd	nd
75-08-1	Ethyl Mercaptan	nd	nd	nd
75-18-3	Dimethyl Sulfide	nd	nd	nd
75-15-0	Carbon Disulfide	6.6	6.9	nd
75-33-2	Isopropyl Mercaptan	7.8	nd	nd
75-66-1	tert-Butyl Mercaptan	nd	nd	nd
107-03-9	n-Propyl Mercaptan	nd	nd	nd
624-89-5	Ethyl Methyl Sulfide	nd	nd	nd
110-02-1	Thiophene	6.6	nd	nd
513-44-0	Isobutyl Mercaptan	nd	nd	nd
352-93-2	Diethyl Sulfide	nd	nd	nd
109-79-5	n-Butyl Mercaptan	nd	nd	nd
624-92-0	Dimethyl Disulfide	nd	nd	nd
616-44-4	3-Methylthiophene	nd	nd	nd
110-01-0	Tetrahydrothiophene	nd	nd	nd
638-02-8	2,5-Dimethylthiophene	nd	nd	nd
872-55-9	2-Ethylthiophene	nd	nd	nd
110-81-6	Diethyl Disulfide	nd	3.1	nd

Solid Sorbent – Thermal Desorption GC/MS (ASTM D 6196) 73°F and 50% RH

CAS Number	Chemical Name	Sample	Sample	Sample	Sample	Sample	Sample	Sample	Sample	Sample
		1	2	3	4	5	6	7	8	9
		Measured Concentration (ug/m ³)								
75-33-2	2-Propanethiol			0.1			0.1			
2432-54-4	Butyric acid, thio-, S-hexyl ester								0.2	0.2
110-81-6	Diethyl disulfide				2.5	1.1				
4253-89-8	Disulfide, bis(1-methylethyl)	3.4	1.1	3.1	1.6	0.8	1.8			
5943-30-6	Disulfide, bis(1-methylpropyl)	2.9	1.3	2.4	1.8	1.3	2			
67421-86-7	Disulfide, ethyl hexyl	6.5		6			4.7			
67727-99-5	Disulfide, pentyl propyl	1.7	0.7	1.4	1.1	0.8	1.3			
17374-18-4	Tetrahydro-1,3-oxazine-2-thione									0.2
6028-61-1	Trisulfide, dipropyl	3.9	1.8	2.6	3.2	2.5	3			

Solid Sorbent – Thermal Desorption GC/MS (ASTM D 6196) 98°F and >50% RH (Page 1 of 3)

CAS Number	Chemical Name	Sample ID								
		1	2	3	4	5	6	7	8	9
		Measured Concentration (ug/m ³)								
505-20-4	1,2-Dithiane				1.4	0.5	2.6			
109-79-5	1-Butanethiol			0.1						
541-31-1	1-Butanethiol, 3-methyl-			0.1			0.6			
111-31-9	1-Hexanethiol						1.1			
110-66-7	1-Pentanethiol			0.1						
52195-40-1	1-Propene, 1-(methylthio)-, (Z)-						0.1			
513-53-1	2-Butanethiol	1.2	0.2	1.3	0.8	0.3	7.6			
1679-09-0	2-Butanethiol, 2-methyl-				24.3	10.8	33.1			
1679-06-7	2-Hexanethiol			0.4						
52326-10-0	2-Methyl-3-(methylthio)-1-propene						0.8			
2084-19-7	2-Pentanethiol	0.5	0.2	0.7	0.2	0.2	4			
75-33-2	2-Propanethiol			0.7			2.9		0.1	
632-15-5	3,4-Dimethylthiophene			0.1						
33959-26-1	3-Methyl-3-hydroxybutane-1-thiol						1.2			
616-31-9	3-Pentanethiol	0.4	0.1	0.4		0.2	2			
108-98-5	Benzenethiol						6.8			
54789-20-7	Benzo[b]thiophene, 2,3-diethyl-				1.1	0.7				
16587-45-4	Benzo[b]thiophene, 2,7-diethyl-						1.3			
16587-51-2	Benzo[b]thiophene, 2-ethyl-5-methyl-					1.2	2.2			
16587-43-2	Benzo[b]thiophene, 2-ethyl-7-methyl-	2.3	1	0.9	4.6	5.4	5.8			
16587-32-9	Benzo[b]thiophene, 2-propyl-						1.8			
16587-46-5	Benzo[b]thiophene, 7-ethyl-2-propyl-				4.4	2.7				

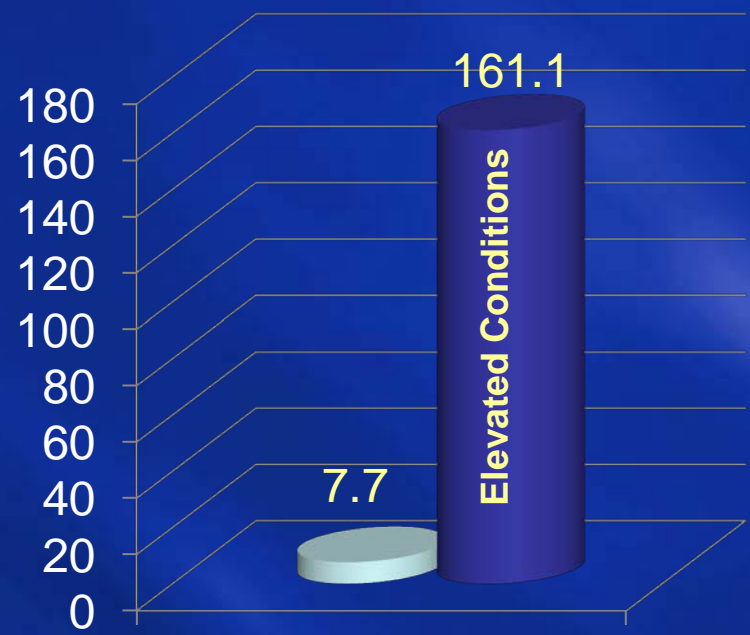
Solid Sorbent – Thermal Desorption GC/MS (ASTM D 6196) 98°F and >50% RH (Page 2 of 3)

CAS Number	Chemical Name	Sample ID								
		1	2	3	4	5	6	7	8	9
		Measured Concentration (ug/m ³)								
75-15-0	Carbon disulfide								0.2	
1679-07-8	Cyclopentanethiol			0.1				1.1		
132-65-0	Dibenzothiophene					0.3				
110-81-6	Diethyl disulfide		0.7	2.1	15.8	4.8	28			
597-35-3	Diethyl sulfone					0.2	3.6			
72437-50-4	Disulfide, 1-methylethyl isopentyl					1.7	2.1			
4253-89-8	Disulfide, bis(1-methylethyl)	14.6	8.1	13.8	42.8	21.5	57.3			
5943-30-6	Disulfide, bis(1-methylpropyl)	14.5	7.8	10.4	38.3	16	61.1			
10008-38-5	Disulfide, bis(2-sulphydrylethyl)-	3.1	1.6	2.3	38.8	16.2	60.7			
624-92-0	Disulfide, dimethyl				0.2					
629-19-6	Disulfide, dipropyl	3.9	1.4	3.3	16.2	6.4	29.5			
53966-36-2	Disulfide, ethyl 1-methylethyl	6.1	3.5	6.3	62	22.9	64.3			
67421-86-7	Disulfide, ethyl hexyl	21.4	13.3	16.7	53.9	26.7	52.4			
2179-60-4	Disulfide, methyl propyl						4.7			
67727-99-5	Disulfide, pentyl propyl	7.7	4	5.7	14.1	7.9	24.7			
72437-66-2	Disulfide, propyl isopentyl	1.8	0.7		5.8	1.8				
63986-03-8	Ethyl n-butyl disulphide				8.7	3.2	17			
30453-31-7	Ethyl n-propyl disulfide	0.9			0.6					
67421-82-3	Isopropyl isobutyl disulfide				39.1	53.5	17.1			
20333-39-5	Methyl ethyl disulphide	0.3	0.1	0.4	2.4	0.5	3.9			
40136-65-0	Methyl isopropyl disulphide	2	0.8	1.6	5.2	1.6	9			
67421-87-8	Methyl sec-butyl disulphide	1.3	0.7	1.3	3	1.2	5.4			
5008-73-1	Propane, 1-[(1-methylethyl)thio]	0.2	0.2		0.2	0.2	3.1			

Solid Sorbent – Thermal Desorption GC/MS (ASTM D 6196) 98°F and >50% RH (Page 3 of 3)

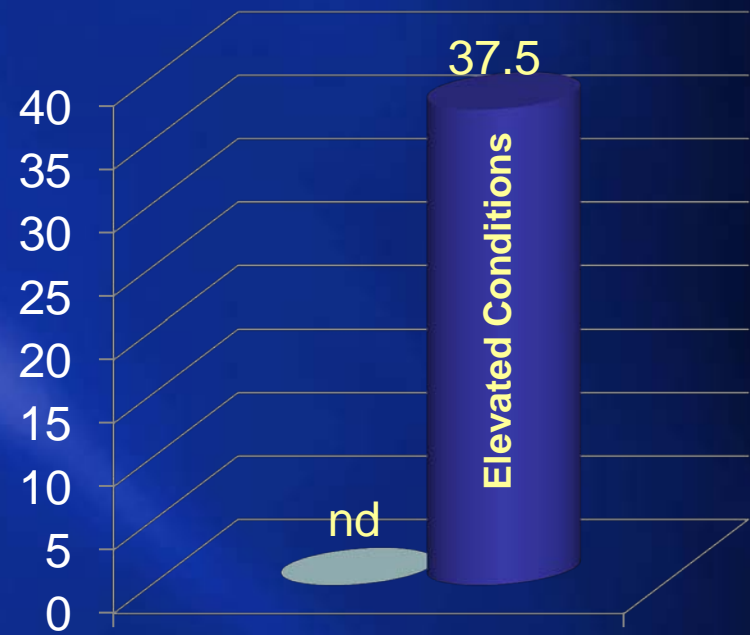
CAS Number	Chemical Name	Sample ID								
		1	2	3	4	5	6	7	8	9
		Measured Concentration (ug/m ³)								
7446-09-5	Sulfur dioxide						1.8			
5955-98-6	Thiirane, 2,3-dimethyl-, trans-						0.4			
1072-43-1	Thiirane, methyl-						0.4		0.1	
632-16-6	Thiophene, 2,3-dimethyl-				0.2	0.1	0.6			
638-00-6	Thiophene, 2,4-dimethyl-	0.8	0.3	0.4						
638-02-8	Thiophene, 2,5-dimethyl						2.5			
1689-79-8	Thiophene, 3-(1,1-dimethylethyl)-	0.8	0.3	0.6						
35686-14-7	Thiophene, 3,4-diethyl-				1.7	0.6	3.1			
6028-61-1	Trisulfide, dipropyl	11.1	5.7	8.7	36.4	15.8	48.8		1.3	0.3

**Comparison of Sum Sulfur Compounds Based on
Environmental Test Conditions**



Sorbent - GC/MS
(ASTM D 6196)

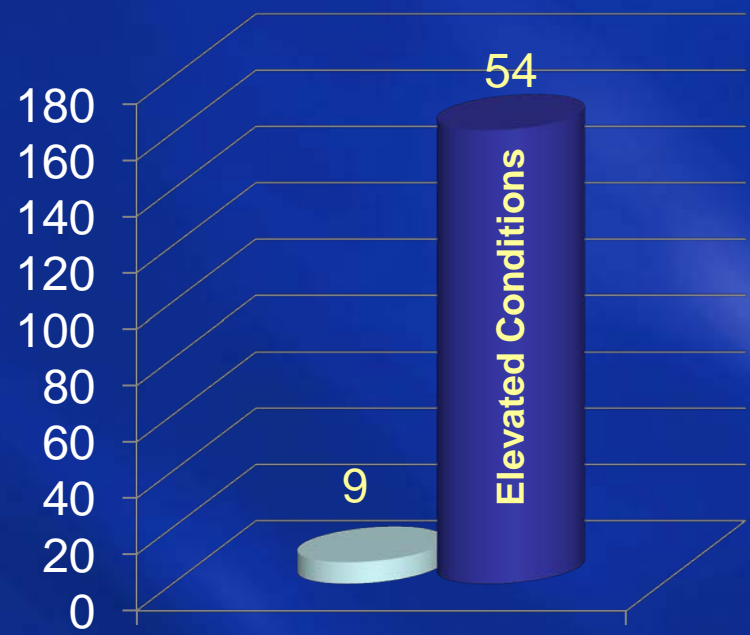
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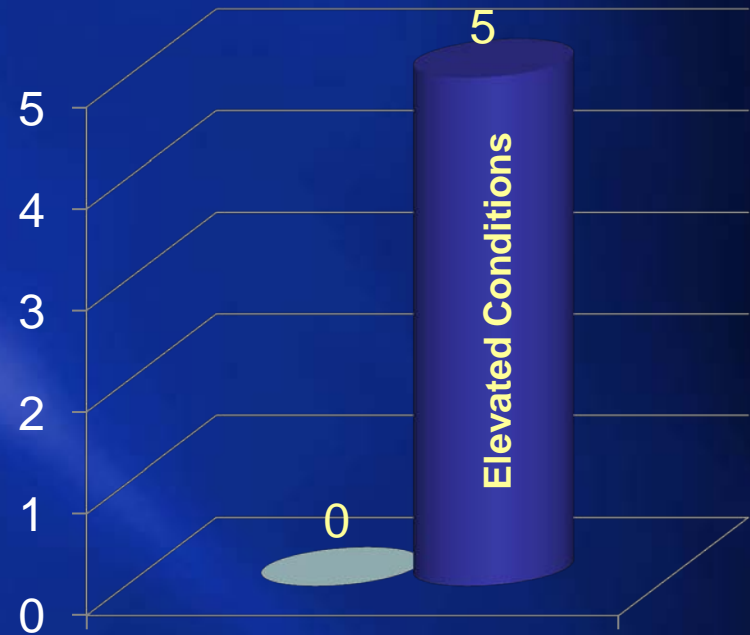
Tedlar - GC
(ASTM D 5504)

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**Comparison of The Total Number of Unique Sulfur Compounds
Detected Based on Environmental Test Conditions**



Sorbent - GC/MS
(ASTM D6196)



Tedlar - GC
(ASTM D5504)

- Emissions of sulfur compounds were detected from Chinese-produced drywall at both standard and elevated environmental conditions using sorbent collection coupled with TD/GC/MS analysis
- Emissions of sulfur compounds were detected at elevated conditions only using Tedlar bag collection coupled with GC/sulfur chemiluminescence detector analysis
- The number of sulfur compounds detected were significantly greater in elevated condition testing

- 222 non-sulfur VOCs were also identified as emitting from the products including alcohols, ketones, alkanes, alkenes, aromatics, carboxylic acids, amines and furans
- Specific examples include:
 - *Butyric acid*
 - *Acetic acid*
 - *Isobutyric acid*
 - Ethyl acetate
 - Naphthalene
 - Hexanal
 - Furfural
 - Tridecane
 - Undecane

- Sorbent collection followed by thermal desorption/GC/MS proved an effective measurement tool providing broad chemical range and trace level detection
- Further exploration of the impact of environmental conditions needed
- Better understanding emissions profiles over time (source type, decay rates)
- Knowledge of product manufacturing, shipping, storage and installation critical
- Full characterization of non-Chinese produced drywall using comparable analytical procedures needed as controls

- Additional analysis necessary to model emissions data for potential human exposure and resultant health risks
- Assessment of non-sulfur VOCs is necessary and should not be overlooked (over 200 detected)
 - Relationships between sulfur and non-sulfur compounds
 - Potential health risks
- Source identification is the key to future prevention

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