Product Update

GreenSuite®

Automated Hazard & Risk Assessments

*for* Chemicals, Products, Manufacturing Processes & Lifecycle Stages

2018 PDA Annual Conference

*Presented by*

George R. Thompson, Ph.D.

CCS

Chemical Compliance Systems, Inc.

“Anticipating the Unanticipatable”
Chemical and Product Inventory Management Capabilities

Green Chemistry Student Tutorial Module

Green Supply Chain Assurance System

Green Chemical and Product Compliance System

Chemical Inventory and Product Tracking System

Relational Chemical, Product and Regulatory Database

What Is The Purpose of Your Inventory?
Continuous Data Compilation Since 1985

≥ 80,000,000 Data Elements
280,000 Chemicals
>29,000 Chemicals with 44 EHS Endpoints

1,250 Fracking Chemicals
1,100 Munition Chemicals
1,000 Cosmetic Chemicals
200 PU & SPF Chemicals

1,500,000+ Product MSDSs
> 10,000 Manufacturers
1,000 Public Data Sources
> 800 Chemical Regulatory Lists
Hazard Characteristic Ranking and Normalization Process

- Each chemical criteria value, with unique units of measure (e.g., mg/kg, hours, ppm, etc.), were individually ranked from highest to lowest (i.e., “a” to “p”).

- The worst value was assigned 0% and the best value was assigned 100%. Values between were assigned a proportionate %, depending upon their value ranking/position.

- Approximately 27,000 chemicals were randomly selected for the initial normalization.

- By normalization, disparate units of measure are converted to an equivalent scale that facilitates direct value comparisons and integrations.

<table>
<thead>
<tr>
<th>Ranked Chemical Values (Per Criteria)</th>
<th>Chemical Criteria Normalization Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>100%</td>
</tr>
<tr>
<td>b</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td></td>
</tr>
<tr>
<td>d</td>
<td>80%</td>
</tr>
<tr>
<td>e</td>
<td></td>
</tr>
<tr>
<td>f</td>
<td>60%</td>
</tr>
<tr>
<td>g</td>
<td></td>
</tr>
<tr>
<td>h</td>
<td>40%</td>
</tr>
<tr>
<td>i</td>
<td></td>
</tr>
<tr>
<td>j</td>
<td>20%</td>
</tr>
<tr>
<td>k</td>
<td></td>
</tr>
<tr>
<td>l</td>
<td>0%</td>
</tr>
<tr>
<td>m</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td></td>
</tr>
<tr>
<td>o</td>
<td></td>
</tr>
<tr>
<td>p</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Same process used historically by many agencies: FDA, EPA, NFPA, NPCA
"GREENER" CHEMICAL SCORING PROCESS

Chemicals – Products – Processes – Wastestreams

Significance of each sub-score can be individually weighted

FINAL GREENER CHEMICAL GRADE
(0 - 100%)

ECOLOGICAL SCORE
(0-100%) → Air Score

HEALTH SCORE
(0-100%) →Water Score → Acute Health Score → Chronic Health Score

SAFETY SCORE
(0-100%) →Fire Score → Special Score → Reactivity Score

Health Score

TOXICITY - AIR
(V.P. MDMA LC50) BCF

LONG-TERM EFFECTS - AIR
Global Warming Potential
Ozone-Depleting Potential
Smog
Acidification

TOXICITY - WATER
Fish LC50
Daphne LC50
Green Algae EC50
(Solubility W-LC50) BCF

LONG-TERM EFFECTS - WATER
Eutrophication
Theoretical Oxygen Demand

TOXICITY - SOIL
(Koc MDMA LD50) BCF
14-day Worm LC50

LONG-TERM EFFECTS - SOIL
Groundwater Mobility Factor
CERCLA RQ

FLAMMABILITY
Flash Point
Boiling Point

44 "Endpoint" Criteria

44 ENDPOINTS IN THE NSF/GCI/ANSI 355-2011 NATIONAL STANDARD
Enhanced GreenSuite®

“One tool cannot do it all!”

1. Product Stewards & Toxicologists
   - RCR Chemical (Exposure Scenario Options)

2. Process Engineering (G-PEAS)
   - (24 Criteria - Customer)

3. Research/Development
   - Procurement/Acquisitions
   - 11 Optional Hazard & Risk Assessments

[Enhanced GreenSuite® Data Entry Screen]

- Chemical (GC-DDS)
  - (44 Criteria - CCS)

- Green Supply Chain (GSC-ACS)
  - (44 Criteria – CCS)

- Process (G-PACS)
  - (44 Criteria - CCS)
  - [Design/Evaluate]

- Green Chemistry Student Tutorial (GC-STM)
  - (44 Criteria CCS)

- Waste Stream (G-WACS)
  - (44 Criteria - CCS)
  - [Evaluate/Design]

- Manufacturer & Supplier
  - “Family Tree”
  - (44 Criteria – CCS)

- RCR Product (Exposure Scenario Options)
  - Munitions (G-MACS)
    - 44 Criteria - CCS
Inside the GreenSuite® “Black Box” – Calculation Algorithm Factors

A. Chemical **Hazard** Green Grade

- Chemical Endpoint **Hazard** Score
- Weighting Factors (%): Endpoint Subcategory Category
- Subcategory **Hazard** Scores
- Category **Hazard** Scores
- Chemical **Hazard** Green Grade

B. **Product/Process/Wastestream Risk** Green Grade¹

- Chemical Endpoint **Hazard** Score
- Weighting Factors (%): Endpoint Subcategory Category
- Constituent Chemical Concentration (%)
- Subcategory **Risk** Scores
- Category **Risk** Scores
- Product, Process & Wastestream **Risk** Green Grade

¹This first order risk calculation accounts for the product/process/wastestream-specific exposure concentration constraint, but not for other usage exposure constraints (e.g., amount utilized, frequency, duration, ventilation rate, etc.).
## GreenSuite® Scoring Hierarchy Descriptors

<table>
<thead>
<tr>
<th>Green Score</th>
<th>Alpha Score</th>
<th>Text Descriptor</th>
<th>Global Harmonization System (GHS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>97 - 100</td>
<td>A+</td>
<td>Highly Probable Non-Risk</td>
<td>Category 1?</td>
</tr>
<tr>
<td>93 - 96</td>
<td>A</td>
<td>Very Probable Non-Risk</td>
<td>Category 1?</td>
</tr>
<tr>
<td>90 - 92</td>
<td>A-</td>
<td>Probable Non-Risk</td>
<td>Category 1?</td>
</tr>
<tr>
<td>87 - 89</td>
<td>B+</td>
<td>Reasonable Non-Risk</td>
<td>Category 1?</td>
</tr>
<tr>
<td>83 - 86</td>
<td>B</td>
<td>Possible Non-Risk</td>
<td>Category 2?</td>
</tr>
<tr>
<td>80 - 82</td>
<td>B-</td>
<td>Cautious Non-Risk</td>
<td>Category 2?</td>
</tr>
<tr>
<td>77 - 79</td>
<td>C+</td>
<td>Minimal Risk</td>
<td>Category 2?</td>
</tr>
<tr>
<td>73 - 76</td>
<td>C</td>
<td>Slight Risk</td>
<td>Category 3?</td>
</tr>
<tr>
<td>70 – 72</td>
<td>C-</td>
<td>Moderate Risk</td>
<td>Category 3?</td>
</tr>
<tr>
<td>65 – 69</td>
<td>D</td>
<td>Serious Risk</td>
<td>Category 3?</td>
</tr>
<tr>
<td>&lt; 65</td>
<td>F</td>
<td>Extreme Risk</td>
<td>Category 3?</td>
</tr>
</tbody>
</table>
GBI ANSI Green Globe® Building & Construction Standard

Risk Assessment Subsection - Science-Based Stipulations (Draft)

• Formulated Products and Articles
  • Add Pure Chemicals (?)

• Certified to ANSI 355 Greener Chemicals and Processes Information Standard
  • Human Health
  • Safety
  • Ecologic Impacts

• Based Upon Chemical Concentrations in the Product/Article – Full Formulation

• Includes Exposure Scenario Factors

<table>
<thead>
<tr>
<th>Interior</th>
<th>Exterior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>Frequency</td>
</tr>
<tr>
<td>Duration</td>
<td>Duration</td>
</tr>
<tr>
<td>Amount Utilized</td>
<td>Amount Utilized</td>
</tr>
<tr>
<td>Ventilation Rate</td>
<td>Wind Speed</td>
</tr>
<tr>
<td>Room Size</td>
<td>Unlimited</td>
</tr>
</tbody>
</table>

• Informative References Cited
  • GreenSuite®
  • Other 3rd Party Tools Referencing ANSI 355

• Risk Reporting Classifications: Green (least), Yellow, Orange, Red (most)
  • Document Risk Calculation Methodology
  • Underlying Assumptions
  • Conversion to Color Scheme Methodology
  • Exposure Routes and Scenarios
  • Worst Case Constituent Chemical Exposure RCR (I,D, O)
GreenSuite®
Lifecycle Alternative Assessments

Design

New Constituents
[Screening Test Data Requirements]

Manufacturing Precursor Materials

Finished Manufactured Product

Transport & Storage

Usage Emissions
[Product Specific]

Disposal
[Product Specific]

Chemical Module
Product Module (Design)
Supplier “Family Tree” System

Process Module/Chemicals
Process Module/Engineering

Product Module (Evaluate)
Waste Module
How to Avoid (or Win) An SPF/PU Lawsuit

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“Anticipating the Unanticipatable”
Toxicology – The Regulatory Science of Poisons

Risk Assessment

- Regulatory Impacts
- Exposure Evaluation
- Hazard Testing and Assessment
- Chemical Safety, Biochemistry, and Pharmacology
  - Chemistry
  - Physiology
  - Pharmacology
  - Anatomical and Pathological Science
  - Medicine and Ecology

CCS-14
SPF Chemistry Lawsuit Experiences

Case-Specific Toxicological Root Cause Analysis Elements

- 5 Expert Witness Cases - Defendants
- 1.5 Summary Judgment Wins
- 2.5 Settled Wins
- 1 In Progress
- All Based Upon Detailed Chemistry Risk Assessments
- All Cases Started by Installation Complaint
## SPF and PU General Chemistry Reactions

<table>
<thead>
<tr>
<th>Side A</th>
<th>+</th>
<th>Side B</th>
<th>(--\rightarrow)</th>
<th>SPF/PU</th>
<th>(--\rightarrow)</th>
<th>Cured SPF/PU &quot;Article&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isocyanate Blend</td>
<td>+</td>
<td>Polyol Blend</td>
<td>(--\rightarrow)</td>
<td>SPF</td>
<td>(--\rightarrow)</td>
<td>SPF</td>
</tr>
<tr>
<td>Reacts 100% Isocyanate chemicals (100%)</td>
<td>Polyols React 100% Polyols (20-70%) Amine/Metal Catalysts (0.1-5%) Flame Retardants, Reactive (5-8%) Flame Retardants, Nonreactive (10-30%) Surfactants (&lt;1%) Blowing Agent, Reactive – Water (17-20%) Blowing Agent, Nonreactive (8-14%) Antimicrobial (&lt;0.5%)</td>
<td>SPF (+ CO₂) SPF (Solid) – No Free Isocyanate Residual Glycols – V. Low VP Amine/Metal Catalysts (Intact) – Low VP Bound 100% to SPF Flame Retardants, Nonreactive (Intact) – V. Low VP Surfactants (Intact) – Extremely Low VP Blowing Agent Reacts 100% to Form CO₂ Blowing Agent, Nonreactive (Intact) High VP Antimicrobial (Intact) – V. Low VP Urea – Low VP</td>
<td>SPF (+ CO₂) SPF (Solid) – No Free Isocyanate Amine/Metal Catalysts (Intact) – Low VP Bound 100% to SPF Flame Retardants, Nonreactive (Intact) – V. Low VP Surfactants (Intact) – Extremely Low VP Blowing Agent Reacts 100% to Form CO₂ Blowing Agent, Nonreactive (Intact) High VP Antimicrobial (Intact) – V. Low VP</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Isocyanate Blend | + | Polyamine Blend | \(--\rightarrow\) | PU | \(--\rightarrow\) | PU |
| Requires no catalyst Reactivity temperature independent Reactivity humidity independent Chemical, solvent, impact ,temp resistance | | | | | |

**CCS -16**
“Safe” – Dictionary Definitions

1. “free from harm or risk” – different?

2. “secure from threat or danger, harm, or loss”

3. “affording safety or security from danger, risk, or difficulty”

4. “not likely to take risks; cautious”

5. “successful in reaching base in baseball without being put out”
**HAZARD** – estimated/measured adverse effect from a chemical under specific conditions

**TOXIC** – deleterious to man &/or other organisms

**POISON** – any agent capable of producing a deleterious biological response (every known chemical)

**RISK** – probability an adverse effect will occur under specified conditions, influenced by

- Exposure amount, frequency, duration
- Exposure route (inhalation, ingestion, dermal)
- Effect severity/usage conditions

\[ \text{RISK} = f(\text{Hazard} \cdot \text{Exposure}) \]

**HAZARD ASSESSMENT** (Chemical) – experimentally identify deleterious effects: Health, Environmental, Safety

**RISK ASSESSMENT** – characterization of potential adverse effects under specified usage and exposure conditions

- Identify hazards
- Evaluate exposure elements & conditions
- Eliminate or control the hazards
“Alle Ding sind Gift, und nichts ohn Gift, allein die Dosis macht, das ein Ding kein Gift ist”

All things are poisons, and nothing is without poison; only the dose permits something not to be poisonous

“Substances considered toxic are harmless in small doses, and conversely, an ordinarily harmless substance can be deadly if over-consumed”

“’Poisons’ were not necessarily something negative...poisons could have beneficial medical effects”

[toxicology vs. pharmacology]
# Hazard Assessments vs. Risk Assessments

<table>
<thead>
<tr>
<th>HAZARD of CONCERN</th>
<th>RISK MODIFICATION STRATEGIES</th>
<th>RESULTANT BENEFITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Medicines/Vaccines</td>
<td>Dosages, Frequency, Duration</td>
<td>Prevent/Cure Diseases</td>
</tr>
<tr>
<td>• Food Constituents</td>
<td>Small concentrations, Vary Diet</td>
<td>Nutrition/Health</td>
</tr>
<tr>
<td>Potatoes – Arsenic/Bromine/Nickel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mushrooms, Duck,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pears, Cauliflower - Formaldehyde</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea – Fluoride</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Vehicle Fuel Flammability</td>
<td>Engineering Controls</td>
<td>Efficient Transportation</td>
</tr>
<tr>
<td>Product/Process Chemicals</td>
<td>Exposure Minimization Engineering Controls</td>
<td>Diverse Product Availability</td>
</tr>
</tbody>
</table>

All chemicals are hazardous, but prudent management & use can eliminate the risks
GreenScreen vs. GreenSuite

What is the GreenScreen?
- Identifies hazard of substance only
- Evaluates chemicals ranked on 18 hazard endpoints (human health, ecological, physical)
- Rankings are consolidated into a single benchmark score from 1-4 (1 = ”Do not use” to 4= ”Preferred”)
- Cannot be used for an overall assessment of a mixture (hazard score for any ingredient is applied to the whole product)
- Cannot be used to determine risk
- Resins typically have limited data and generally receive a relatively low score
- Evaluations are subjective

What is the GreenSuite?
- Tool developed in 2003 for the U.S Department of Defense munition analyses - hazard and risk
- In 2011, the logic used in the tool was accepted as an ANSI standard (ANSI-355: “Greener Chemicals and Processes Information Standard)
- Evaluates chemicals on 44 hazard endpoints (ecological, health, and safety) utilizing chemical database with over 80 million data elements
- Green score classification follows an easy to understand report card grading system (90-100% = A, 80-89%=B, etc.)
- Can be utilized for single chemicals or mixtures of chemicals (e.g., a coating) – objective evaluations
- Takes into account the amount of a chemical in the mixture - risk of the product can be assessed

<table>
<thead>
<tr>
<th>Tool</th>
<th>Hazard Assessment</th>
<th>Overall Product Score</th>
<th>Risk Assessment</th>
<th>Resins Evaluated Accurately</th>
<th>Full Automated</th>
</tr>
</thead>
<tbody>
<tr>
<td>GreenScreen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GreenSuite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</table>
“GREENER” CHEMICAL SCORING PROCESS

Chemicals – Products – Processes – Wastestreams

Significance of each sub-score can be individually weighted

**FINAL GREENER CHEMICAL GRADE**

(0 - 100%)

**ECOLOGICAL SCORE**

(0-100%)

**HEALTH SCORE**

(0-100%)

**SAFETY SCORE**

(0-100%)

**Water Score**

**Air Score**

**Soil Score**

**Acute Health Score**

**Chronic Health Score**

**Fire Score**

**Special Score**

**Reactivity Score**

**44 “Endpoint” Criteria**

Persistence
Partition
Toxicity
Long-Term Effects

Persistence
Partition
Toxicity
Long-Term Effects

Persistence
Partition
Toxicity
Long-Term Effects

Persistence
Partition
Toxicity
Long-Term Effects

TOXICITY - AIR
(V.P. \( \bullet \) LC50 \( \bullet \) BCF)

LONG-TERM EFFECTS - AIR
Global Warming Potential
Ozone-Depleting Potential
Smog
Acidification

TOXICITY - WATER
Fish LC50
Daphnia LC50
Green Algae EC50
(Solubility \( \bullet \) W-LC50 \( \bullet \) BCF)

LONG-TERM EFFECTS - WATER
Eutrophication
Theoretical Oxygen Demand

TOXICITY - SOIL
(K\(\text{oc}\) \( \bullet \) O-LD50 \( \bullet \) BCF
14-day Worm LC50

LONG-TERM EFFECTS - SOIL
Groundwater Mobility Factor
CERCLA RQ

FLAMMABILITY
Flash Point
Boiling Point

44 ENDPOINTS IN THE NSF/GCI/ANSI 355-2011 NATIONAL STANDARD
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<td>D</td>
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</tr>
<tr>
<td>&lt; 65</td>
<td>F</td>
<td>Extreme Risk</td>
</tr>
</tbody>
</table>
## Isocyanate GreenSuite® Hazard Assessment Comparisons

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>CAS #</th>
<th>Green Grade</th>
<th>Ecological</th>
<th>Health</th>
<th>Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hexamethylene diisocyanate</td>
<td>28182-81-2</td>
<td>89</td>
<td>84</td>
<td>87</td>
<td>97</td>
</tr>
<tr>
<td>P-Toluenesulfonyl isocyanate</td>
<td>4083-64-1</td>
<td>74</td>
<td>77</td>
<td>83</td>
<td>63</td>
</tr>
<tr>
<td>Polymethylene polyphenylisocyanate</td>
<td>9016-87-9</td>
<td>72</td>
<td>70</td>
<td>59</td>
<td>85</td>
</tr>
<tr>
<td>Methylene bisphenyl isocyanate</td>
<td>26447-40-5</td>
<td>68</td>
<td>59</td>
<td>60</td>
<td>85</td>
</tr>
<tr>
<td>Methylene diphenyl diisocyanate</td>
<td>101-68-8</td>
<td>65</td>
<td>59</td>
<td>51</td>
<td>85</td>
</tr>
<tr>
<td>Toluene-2-diisocyanate</td>
<td>584-84-9</td>
<td>64</td>
<td>69</td>
<td>47</td>
<td>77</td>
</tr>
<tr>
<td>Isophorone diisocyanate</td>
<td>4098-71-9</td>
<td>63</td>
<td>65</td>
<td>54</td>
<td>72</td>
</tr>
</tbody>
</table>
Primary Isocyanate Health Hazards
(Two Lowest Health Scores: TDI = 47 & MDI = 51)

• **Acute Health Hazards** *(Scores = 30 & 30)*
  - IDLH = 0 & 0
  - STEL/Ceiling = 0 & 5
  - Inhal LC5O = 2 & 7
  - Skin Irrit. = 25 & 80
  - Eye Irrit. = 0 & 25

• **Chronic Health Hazards** *(Scores = 64 & 73)*
  - Carcinogenicity = 50 & 90
  - Sensitizer = 0 & 0
  - TLV = 0 & 9

Scores < 65 in Red

CPI recommends full personal protective equipment to prevent skin, eye & inhalation exposure
<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>CAS #</th>
<th>Green Grade</th>
<th>Ecological</th>
<th>Health</th>
<th>Safety</th>
<th>Vapor Press. (mmHg)</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water/Air</td>
<td>7732-18-5/-</td>
<td>100/---</td>
<td>100/---</td>
<td>100/---</td>
<td>100/---</td>
<td>23.8</td>
<td>1.225 E-3</td>
</tr>
<tr>
<td>Hexamethylene diisocyanate</td>
<td>28182-81-2</td>
<td>89</td>
<td>84</td>
<td>87</td>
<td>97</td>
<td>1 E-3</td>
<td>1.14</td>
</tr>
<tr>
<td>P-Toluenesulfonyl isocyanate</td>
<td>4083-64-1</td>
<td>74</td>
<td>77</td>
<td>83</td>
<td>63</td>
<td>9.44 E-5</td>
<td>1.29</td>
</tr>
<tr>
<td>Polymethylene polyphenylisocyanate</td>
<td>9016-87-9</td>
<td>72</td>
<td>70</td>
<td>59</td>
<td>85</td>
<td>5.4 E-13</td>
<td>1.23</td>
</tr>
<tr>
<td>Methylene bisphenyl isocyanate</td>
<td>26447-40-5</td>
<td>68</td>
<td>59</td>
<td>60</td>
<td>85</td>
<td>4.8 E-5</td>
<td>1.24</td>
</tr>
<tr>
<td>Methylenediphenyl diisocyanate</td>
<td>101-68-8</td>
<td>65</td>
<td>59</td>
<td>51</td>
<td>85</td>
<td>1.89 E-4</td>
<td>1.23</td>
</tr>
<tr>
<td>Toluene-2-diisocyanate</td>
<td>584-84-9</td>
<td>64</td>
<td>69</td>
<td>47</td>
<td>77</td>
<td>2.38 E-2</td>
<td>1.22</td>
</tr>
<tr>
<td>Isophorone diisocyanate</td>
<td>4098-71-9</td>
<td>63</td>
<td>65</td>
<td>54</td>
<td>72</td>
<td>3.0 E-4</td>
<td>1.06</td>
</tr>
</tbody>
</table>
Isocyanate Chemical Reactions in Polyurethanes

\[
\begin{align*}
\text{R-NCO} \quad & \quad \text{RNHCONHR} \quad \text{UREA} \\
\text{R-NCO} \quad & \quad \text{R-NCO} \quad \text{OCN-R-N=C=N-RNCO} \quad \text{CARBODIIMIDE} \\
\text{R-NCO} \quad & \quad \text{R'-OH} \quad \text{RNHCOOR'} \quad \text{ALOPHANATE} \\
\text{R-NCO} \quad & \quad \text{RNHCONHR'} \quad \text{UREONAMINES} \\
\text{R-NCO} \quad & \quad \text{R'-COOH} \quad \text{RNHCOOH} \\
\text{R-NCO} \quad & \quad \text{R-NCO} \quad \text{RNHCONHR} \quad \text{UREA} \\
\text{R-NCO} \quad & \quad \text{RNHCONHR} \quad \text{R'-HN2} \\
\text{RNH2} + \text{CO2} \quad & \quad \text{R-NCO} \\
\text{RNHCONHR} \quad & \quad \text{R-NCO} \\
\text{R-NCO} \quad & \quad \text{RNCO} \\
\text{OCN-R} \quad & \quad \text{DIMER} \\
\text{R-NCO} \quad & \quad \text{RNCO} \\
\text{R-NCO} \quad & \quad \text{RNCO} \\
\text{R-NCO} \quad & \quad \text{RNCO} \\
\text{R-NCO} \quad & \quad \text{RNCO} \\
\text{OCN-R} \quad & \quad \text{TRIMER} \\
\text{R-NCO} \quad & \quad \text{RNCO} \\
\text{R-NCO} \quad & \quad \text{RNCO} \\
\text{R-NCO} \quad & \quad \text{RNCO} \\
\text{OCN-R} \quad & \quad \text{URETHANE} \\
\text{RHHCOR'} + \text{CO2} \quad & \quad \text{AMIDE} \\
\end{align*}
\]
## Side B – Polyol Blend GreenSuite® Hazard Assessment Comparisons (15-30 CAS #s)

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>Conc. (%)</th>
<th>Green Grade</th>
<th>Ecological</th>
<th>Health</th>
<th>Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blowing, Reactive (1)</td>
<td>1</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Blowing, Nonreactive (1)</td>
<td>9</td>
<td>86</td>
<td>77</td>
<td>91</td>
<td>92</td>
</tr>
<tr>
<td>Polyether Polyols (3)</td>
<td>0.8-15.2</td>
<td>85-88</td>
<td>75-84</td>
<td>78-90</td>
<td>92</td>
</tr>
<tr>
<td>Polyol, Sucrose (1)</td>
<td>6</td>
<td>85</td>
<td>74</td>
<td>89</td>
<td>92</td>
</tr>
<tr>
<td>Polyol, Aromatic (1)</td>
<td>39</td>
<td>86</td>
<td>78</td>
<td>89</td>
<td>92</td>
</tr>
<tr>
<td>Flame Retardant (2)</td>
<td>6-17</td>
<td>87</td>
<td>77</td>
<td>91</td>
<td>92</td>
</tr>
<tr>
<td>Surfactant (3)</td>
<td>0.03-4.8</td>
<td>79-86</td>
<td>74-81</td>
<td>70-86</td>
<td>92</td>
</tr>
<tr>
<td>Catalyst, Metal (6)</td>
<td>0.002-5.6</td>
<td>37,77-86</td>
<td>53, 62, 76-78</td>
<td>26, 61, 84-89</td>
<td>30, 83-92</td>
</tr>
<tr>
<td>Catalyst, Amine (7)</td>
<td>0.2-0.8</td>
<td>71-83</td>
<td>68-73</td>
<td>50, 55, 81-88</td>
<td>83-92</td>
</tr>
</tbody>
</table>
## Curing/Cured SPF Constituent Risk Assessments

(11/9 CAS #s)

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Conc. (%)</th>
<th>Ranking</th>
<th>Green Grade</th>
<th>Ecological</th>
<th>Health</th>
<th>Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyurethane Foam (SPF)</td>
<td>78</td>
<td>1</td>
<td>95</td>
<td>95</td>
<td>92</td>
<td>97</td>
</tr>
<tr>
<td>Polyol-1</td>
<td>0.04</td>
<td>2</td>
<td>89</td>
<td>83</td>
<td>86</td>
<td>97</td>
</tr>
<tr>
<td>Surfactant</td>
<td>0.36</td>
<td>3</td>
<td>88</td>
<td>78</td>
<td>89</td>
<td>97</td>
</tr>
<tr>
<td>Catalyst, Metal</td>
<td>5</td>
<td>4</td>
<td>88</td>
<td>77</td>
<td>91</td>
<td>97</td>
</tr>
<tr>
<td>Flame Retardant, NR</td>
<td>4</td>
<td>5</td>
<td>88</td>
<td>76</td>
<td>91</td>
<td>97</td>
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<tr>
<td>Blowing Agent</td>
<td>3.1</td>
<td>6</td>
<td>86</td>
<td>73</td>
<td>85</td>
<td>100</td>
</tr>
<tr>
<td>Catalyst, Amine-1</td>
<td>1</td>
<td>7</td>
<td>83</td>
<td>78</td>
<td>74</td>
<td>97</td>
</tr>
<tr>
<td>Reaction Product-1</td>
<td>7.3</td>
<td>8</td>
<td>82</td>
<td>69</td>
<td>77</td>
<td>100</td>
</tr>
<tr>
<td>Catalyst, Amine-2</td>
<td>1</td>
<td>9</td>
<td>81</td>
<td>68</td>
<td>86</td>
<td>88</td>
</tr>
<tr>
<td>Catalyst, Amine-3</td>
<td>0.05</td>
<td>10</td>
<td>77</td>
<td>66</td>
<td>84</td>
<td>82</td>
</tr>
<tr>
<td>Catalyst, Amine-4</td>
<td>0.2</td>
<td>11</td>
<td>72</td>
<td>74</td>
<td></td>
<td>90</td>
</tr>
</tbody>
</table>
Decreasing SPF Systems Relative Risk

Inverted GreenSuite® Rating

A Side
- Ecological
- Health
- Safety
- Overall Hazard

B Side
- Ecological
- Health
- Safety
- Overall Hazard

Cured SPF
- Ecological
- Health
- Safety
- Overall Hazard

SPF Article
- Ecological
- Health
- Safety
- Overall Hazard
# Spray Polyurethane Foam (SPF) Chemistry

## Side A + Side B

<table>
<thead>
<tr>
<th>Isocyanate Blend</th>
<th>Polyol Blend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reacts 100%</td>
<td>Polyols React 100%</td>
</tr>
<tr>
<td></td>
<td>Amine/Metal Catalysts 50% Dilution</td>
</tr>
<tr>
<td></td>
<td>Flame Retard., Nonreactive 50% Dilution</td>
</tr>
<tr>
<td></td>
<td>Blowing Agent, Nonreactive 50% Dilution</td>
</tr>
<tr>
<td></td>
<td>Antimicrobial 50% Dilution</td>
</tr>
</tbody>
</table>

## Curing SPF

- SPF (+ CO₂)
- SPF (Solid) – **No Free Isocyanate**
- Residual Glycols – **V. Low VP**
- Amine/Metal Catalysts (Intact) – **Low VP**
- Bound 100% to SPF
- Flame Retard., Nonreactive – **V. Low VP**
- Surfactants (Intact) – **Extremely Low VP**
- Blowing Agent, Nonreactive (Intact) – **High VP**
- Antimicrobial (Intact) – **V. Low VP**
- Urea – **Low VP**

## Cured SPF “Article”

- SPF (+ CO₂)
- SPF (Solid) – **No Free Isocyanate**
- Amine/Metal Catalysts (Intact) – **Low VP**
- Bound 100% to SPF
- Flame Retard., Nonreactive (Intact) – **V. Low VP**
- Surfactants (Intact) – **Extremely Low VP**
- Blowing Agent, Nonreactive (Intact) – **High VP**
- Antimicrobial (Intact) – **V. Low VP**

---

- **Full PPE required during installation**
- **All occupants vacated during & 24-48 hours after**
- **Ventilate to outside during installation**

- **Maintain vacancy for 24-48 hours after install**
- **Aggressively ventilate to outside during curing**

- **Document thorough final project inspection**
- **Walk through with customer**

---

*CCS-31*
OSHA Hazard Communication Standard (HazCom)

• Aligned with UN Global Harmonization System (GHS) 2012

• Classified Potential Chemical Hazards, including A & B Side constituents

• Employee Communication of Potential Chemical Hazards & Protections
  - Written Hazard Communication Plan (WHCP)
  - List of Chemical Hazards Present
  - Container Labeling – Workplace & Shipped
  - Safety Data Sheets (SDSs)
  - Employee Training Program
OSHA Safety Data Sheet (SDS) Elements

1. Product Identification – Chemical/Mixture
2. Hazard(s) Identification
3. Product Hazardous Composition
4. First Aid Measures
5. Fire Fighting Procedures
6. Accident Release Measures
7. Handling and Storage
8. Exposure Controls/PPE

9. Physical/Chemical Properties
10. Stability/Reactivity
11. Toxicological Information
12. Ecological
13. Disposal Consideration
14. Transportation Information
15. Regulatory Information
16. Other Information (Prep Date/Last Revision)
Exposure Prevention Strategies

• **OSHA Hazard Communication required employee training**
  Written Hazard Communication Program
  Product & chemical Safety Data Sheet (SDS) review
  Product hazard awareness training
  Container labeling
  Exposure prevention strategies & equipment
  Personal Protective Equipment (PPE) requirements

• **Installer certification with SPF/PU manufacturer**

• **Worksite preparation procedures**
  Ventilation during & 24-48 hours after installation
  Airflow barriers & site protection coverings
  Restricted access placards – outside, inside

• **Building vacancy 24-48 hours post installation**
  Humans & pets
  Written & signed documentation of this requirement
Safe SPF - Conclusions

- **SPF is safe for consumers, but potentially hazardous for workers**
  - SPF chemistry protects the customer when properly installed
  - PPE and best business practices keep workers safe from SPF constituents

- **A Side is very hazardous (Health Scores = 47-60) – Risk is controllable**
  - Full body PPE & air supply
  - Rapidly reactive – binds to anything/everything
  - Heavier than air – settles quickly
  - Isocyanates undetectable within < 1 hour; don’t evaporate
  - Isocyanates not in cured SPF

- **B Side is much less hazardous (Health Scores mostly 70-100)**
  - Protected by full body PPE & air supply
  - Zero to minimal residues in cured SPF – diluted 50%
  - Predominant polyols minimal hazards, mostly/entirely reacted

- **SPF system initial hazards essentially gone in properly cured SPF**
  - Isocyanate 100% reacted
  - B Side constituents diluted 50%
  - Proper chemistry during installation & curing is key
Safe SPF/PU - Recommendations

Manufacturers develop SPF/PU complete system risk assessments
- Evaluate A Side, B Side, Curing SPF/PU, & Cured SPF/PU
- Use proprietary reports for internal constituent alternative assessments & sales literature
- Provide nonproprietary reports to distributors & installers
- Train product development chemists regarding “green” chemistry, i.e., hazards & risks
- Add “green” chemistry SPF system awareness to installer certification program
- Distribute SDSs for entire SPF/PU system – A & B Sides, Curing & Cured SPF/PU – to customers
- Maintain liability insurance in case of lawsuits

Installers request mfr nonproprietary SPF/PU system risk assessment reports & SDSs
- Reject potential customers with asthma, known chemical sensitivities, or COPD
- Train & test installers & sales staff regarding constituent hazards & formulation risks
- Maintain SDSs for all SPF/PU system components
- Inspect/grade/evaluate completed SPF projects - with pictures
- Maintain detailed records for each SPF/PU project – specific process, issues, equipment
- Annually monitor installer health
- Maintain liability insurance in case of lawsuits
How to Avoid (or Win) An SPF/PU Lawsuit

Questions?

2018 PDA Annual Conference

Presented by

George R. Thompson, Ph.D.

CCS

Chemical Compliance Systems, Inc.

“Anticipating the Unanticipatable”