Spacecraft Maximum Allowable Concentrations for Airborne Contaminants

Toxicology Group
Environmental Factors Office
Habitability and Environmental Factors Division
Space Life Sciences Directorate

November 2008

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas
Errata

Correct CAS numbers are below:

Freon 11  75-69-4
Glutaraldehyde  111-30-8
Hydrogen chloride  7647-01-0
Limonene  5989-27-5
The enclosed table lists official spacecraft maximum allowable concentrations (SMACs), which are guideline values set by the NASA/JSC Toxicology Group in cooperation with the National Research Council Committee on Toxicology (NRCCOT). These values should not be used for situations other than human space flight without careful consideration of the criteria used to set each value. The SMACs take into account a number of unique factors such as the effect of space-flight stress on human physiology, the uniform good health of the astronauts, and the absence of pregnant or very young individuals. Documentation of the values is given in a 5 volume series of books entitled “Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants” published by the National Academy Press, Washington, D.C. These books can be viewed electronically at [http://books.nap.edu/openbook.php?record_id=9786&postpage=3](http://books.nap.edu/openbook.php?record_id=9786&postpage=3).

Short-term (1 and 24 hour) SMACs are set to manage accidental releases aboard a spacecraft and permit risk of minor, reversible effects such as mild mucosal irritation. In contrast, the long-term SMACs are set to fully protect healthy crewmembers from adverse effects resulting from continuous exposure to specific air pollutants for up to 1000 days. Crewmembers with allergies or unusual sensitivity to trace pollutants may not be afforded complete protection, even when long-term SMACs are not exceeded.

Crewmember exposures involve a mixture of contaminants, each at a specific concentration \(C_n\). These contaminants could interact to elicit symptoms of toxicity even though individual contaminants do not exceed their respective SMACs. The air quality is considered acceptable when the toxicity index \(T_{\text{grp}}\) for each toxicological group of compounds is less than 1, where \(T_{\text{grp}}\) is calculated as follows:

\[
T_{\text{grp}} = \frac{C_1}{\text{SMAC}_1} + \frac{C_2}{\text{SMAC}_2} + \ldots + \frac{C_n}{\text{SMAC}_n}
\]

Toxicological groups are defined according to the target organ and the nature of the toxic response from exposure to the compounds in the group. As shown in the table of SMACs, the target organ and toxic effect can change depending on the duration of exposure.

Early editions of this document contained many SMACs “developed” before 1990 when the cooperative effort between NASA and the NRCCOT began. These values had been considered official; however, an effort to determine how these values were set revealed that there was not an adequate document trail to continue to consider these old values as official SMACs. These old values will continue to be posted in the “MAPTIS” database, which is used to evaluate materials and hardware offgassing data, but they have been deleted from the present edition of this document. Many unofficial SMACs for groups of compounds with structural similarities (e.g. aliphatic ethers, aliphatic ketones) have been set with limited documentation and no review by the NRCCOT. These unofficial group SMACs can be obtained from the JSC Toxicology Group.
# SMACs (Spacecraft Maximum Allowable Concentrations)

## Chemicals

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Synonyms:</th>
<th>NRC Vol. #:</th>
<th>CAS #:</th>
<th>Year SMAC was Set/ Reviewed:</th>
<th>Remarks:</th>
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</thead>
<tbody>
<tr>
<td>Acetaldehyde</td>
<td></td>
<td>1</td>
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<tr>
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<tr>
<td>Acetone</td>
<td>2-Propanone</td>
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<td>67-64-1</td>
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<tr>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Acrolein</td>
<td>Propenal</td>
<td>5</td>
<td>107-02-0</td>
<td>2008</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2-C9 Aliphatic Alkanes</td>
<td></td>
<td>5</td>
<td>various</td>
<td>2005</td>
<td></td>
</tr>
</tbody>
</table>

## Potential Exposure Duration

<table>
<thead>
<tr>
<th>Potential Exposure Duration</th>
<th>1 hr ppm (mg/m³)</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>10 (18)</td>
<td>6 (10)</td>
<td>2 (4)</td>
<td>2 (4)</td>
<td>2 (4)</td>
<td>Not Set (Not Set)</td>
</tr>
<tr>
<td>Acetone</td>
<td>500 (1200)</td>
<td>200 (500)</td>
<td>22 (52)</td>
<td>22 (52)</td>
<td>22 (52)</td>
<td>Not Set (Not Set)</td>
</tr>
<tr>
<td>Acrolein</td>
<td>0.075 (0.2)</td>
<td>0.035 (0.08)</td>
<td>0.015 (0.03)</td>
<td>0.015 (0.03)</td>
<td>0.008 (0.02)</td>
<td>0.008 (0.02)</td>
</tr>
<tr>
<td>C2-C9 Aliphatic Alkanes</td>
<td>150 (varies)</td>
<td>80 (varies)</td>
<td>60 (varies)</td>
<td>20 (varies)</td>
<td>3 (varies)</td>
<td>Not Set (Not Set)</td>
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</tbody>
</table>

## Remarks:

- **CNS**: Central Nervous System
- **CDC**: Decreased Color Discrimination
- **GI**: Gastrointestinal tract
- **NRC**: National Research Council
- **PNS**: Peripheral Nervous System
- **CV**: Cardiovascular
- **RespSys**: Respiratory System
- **U.Blad**: Urinary bladder
- **Abbreviations:**

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jsc-txcology@mail.nasa.gov
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<th>1000 d ppm (mg/m³)</th>
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<tbody>
<tr>
<td><strong>C3-C8 Aliphatic Saturated Aldehydes</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>CAS #: various</td>
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<td></td>
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<td>Year SMAC was Set/Reviewed: 2008</td>
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</tr>
</tbody>
</table>

#### Ammonia

| Synonyms:                                    |                  |                   |                 |                  |                   |                    |
| NRC Vol. #: 5                                |                  |                   |                 |                  |                   |                    |
| CAS #: 7664-41-7                             |                  |                   |                 |                  |                   |                    |
| Year SMAC was Set/Reviewed: 2008             |                  |                   |                 |                  |                   |                    |
| Remarks: Ceiling values                      |                  |                   |                 |                  |                   |                    |

#### Benzene

| Synonyms:                                    |                  |                   |                 |                  |                   |                    |
| NRC Vol. #: 5                                |                  |                   |                 |                  |                   |                    |
| CAS #: 71-43-2                               |                  |                   |                 |                  |                   |                    |
| Year SMAC was Set/Reviewed: 2008             |                  |                   |                 |                  |                   |                    |
| Remarks: Leukemogen                          |                  |                   |                 |                  |                   |                    |

#### Bromotrifluoromethane

| Synonyms: Halon 1301                         |                  |                   |                 |                  |                   |                    |
| NRC Vol. #: 3                                |                  |                   |                 |                  |                   |                    |
| CAS #: 75-63-8                               |                  |                   |                 |                  |                   |                    |
| Year SMAC was Set/Reviewed: 1993             |                  |                   |                 |                  |                   |                    |
| Remarks:                                    |                  |                   |                 |                  |                   |                    |

### Abbreviations:

- CNS: Central Nervous System
- DCD: Decreased Color Discrimination
- GI: Gastrointestinal tract
- NRC: National Research Council
- PNS: Peripheral Nervous System
- RespSys: Respiratory System
- U.Blad: Urinary bladder
- CV: Cardiovascular
- RespSys: Respiratory System
- U.Blad: Urinary bladder
- CV: Cardiovascular
- RespSys: Respiratory System
- U.Blad: Urinary bladder

If you have any scientific or technical queries, contact jsc-txcoology@mail.nasa.gov
### Chemicals

#### 1-Butanol
**Synonyms:** n-butanol

<table>
<thead>
<tr>
<th>Potential Exposure Duration</th>
<th>1 hr</th>
<th>24 hr</th>
<th>7 d</th>
<th>30 d</th>
<th>180 d</th>
<th>1000 d</th>
</tr>
</thead>
<tbody>
<tr>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
</tr>
<tr>
<td>50 (150)</td>
<td>25 (80)</td>
<td>25 (80)</td>
<td>25 (80)</td>
<td>12 (40)</td>
<td>12 (40)</td>
<td></td>
</tr>
</tbody>
</table>

**Organ Effect:**
- Eye: Irritation
- CNS: Depression

**Year MAC was Set/Reviewed:** 2007

**Remarks:**

#### tert-Butanol
**Synonyms:** 2-Methyl-2-propanol

<table>
<thead>
<tr>
<th>Potential Exposure Duration</th>
<th>1 hr</th>
<th>24 hr</th>
<th>7 d</th>
<th>30 d</th>
<th>180 d</th>
<th>1000 d</th>
</tr>
</thead>
<tbody>
<tr>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
</tr>
<tr>
<td>50 (150)</td>
<td>50 (150)</td>
<td>50 (150)</td>
<td>50 (150)</td>
<td>40 (120)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Organ Effect:**
- Eye: Depression
- CNS: Depression

**Year MAC was Set/Reviewed:** 1995

**Remarks:**

#### Carbon dioxide
**Synonyms:** CO₂

<table>
<thead>
<tr>
<th>Potential Exposure Duration</th>
<th>1 hr</th>
<th>24 hr</th>
<th>7 d</th>
<th>30 d</th>
<th>180 d</th>
<th>1000 d</th>
</tr>
</thead>
<tbody>
<tr>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
</tr>
<tr>
<td>20000 (35000)</td>
<td>13000 (23000)</td>
<td>7000 (13000)</td>
<td>7000 (13000)</td>
<td>7000 (13000)</td>
<td>5000 (9000)</td>
<td></td>
</tr>
</tbody>
</table>

**Organ Effect:**
- CNS: Hyperventilation
- CNS: Headache
- CNS: Visual disturbance

**Year MAC was Set/Reviewed:** 2006

**Remarks:**

#### Carbon monoxide
**Synonyms:** CO

<table>
<thead>
<tr>
<th>Potential Exposure Duration</th>
<th>1 hr</th>
<th>24 hr</th>
<th>7 d</th>
<th>30 d</th>
<th>180 d</th>
<th>1000 d</th>
</tr>
</thead>
<tbody>
<tr>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
<td>ppm (mg/m³)</td>
</tr>
<tr>
<td>425 (485)</td>
<td>100 (114)</td>
<td>55 (63)</td>
<td>15 (17)</td>
<td>15 (17)</td>
<td>15 (17)</td>
<td></td>
</tr>
</tbody>
</table>

**Organ Effect:**
- CNS: Depression
- CV: Arrhythmia

**Year MAC was Set/Reviewed:** 2008

**Remarks:** Carboxyhemoglobin target

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**Abbreviations:**
- CNS: Central Nervous System
- CV: Cardiovascular
- RespSys: Respiratory System
- U.Blad: Urinary bladder
- NRC: National Research Council
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- sc-txcoology@mail.nasa.gov
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<th>CAS #:</th>
<th>Year SMAC was Set/Reviewed:</th>
<th>Remarks:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloroform</td>
<td>Trichloromethane</td>
<td>4</td>
<td>67-66-3</td>
<td>1999</td>
<td></td>
</tr>
<tr>
<td>Decamethylcyclopentasiloxane</td>
<td></td>
<td>4</td>
<td>541-02-6</td>
<td>1998</td>
<td>Documented as a polydimethylcyclosiloxane</td>
</tr>
<tr>
<td>Diacetone alcohol</td>
<td></td>
<td>3</td>
<td>123-42-2</td>
<td>1995</td>
<td></td>
</tr>
<tr>
<td>Dichloroacetylene</td>
<td></td>
<td>3</td>
<td>7572-29-4</td>
<td>1992</td>
<td></td>
</tr>
</tbody>
</table>

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<tr>
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<th>180 d ppm (mg/m³)</th>
<th>1000 d ppm (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloroform</td>
<td>2 (10)</td>
<td>2 (10)</td>
<td>2 (10)</td>
<td>1 (5)</td>
<td>1 (5)</td>
<td>Not Set (Not Set)</td>
</tr>
<tr>
<td>Decamethylcyclopentasiloxane</td>
<td>Not Set (Not Set)</td>
<td>Not Set (Not Set)</td>
<td>7 (100)</td>
<td>5 (75)</td>
<td>1 (15)</td>
<td>Not Set (Not Set)</td>
</tr>
<tr>
<td>Diacetone alcohol</td>
<td>50 (250)</td>
<td>50 (250)</td>
<td>20 (100)</td>
<td>6 (30)</td>
<td>4 (20)</td>
<td>Not Set (Not Set)</td>
</tr>
<tr>
<td>Dichloroacetylene</td>
<td>0.6 (2.4)</td>
<td>0.04 (0.16)</td>
<td>0.03 (0.12)</td>
<td>0.025 (0.10)</td>
<td>0.015 (0.06)</td>
<td>Not Set (Not Set)</td>
</tr>
</tbody>
</table>

#### Organ Effects

- **CNS**: Central Nervous System
- **PNS**: Peripheral Nervous System
- **GI**: Gastrointestinal tract
- **RespSys**: Respiratory System
- **CV**: Cardiovascular
- **U.Blad**: Urinary bladder
- **DCD**: Decreased Color Discrimination
- **NRC**: National Research Council
- **CNS**:  | Depression |
- **Liver**: Hepatotoxicity
- **Kidney**: Nephrotoxicity

#### Remarks

- Chloroform: Not Set
- Decamethylcyclopentasiloxane: Not Set
- Diacetone alcohol: Not Set
- Dichloroacetylene: Not Set

**Abbreviations:**

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</tr>
</thead>
<tbody>
<tr>
<td>1,2- Dichloroethane</td>
<td></td>
<td>5</td>
<td>107-06-2</td>
<td>2007</td>
<td>Impairs host defenses against bacteria.</td>
</tr>
<tr>
<td>Ethanol</td>
<td>Ethyl alcohol</td>
<td>5</td>
<td>64-17-5</td>
<td>2007</td>
<td></td>
</tr>
<tr>
<td>2- Ethoxyethanol</td>
<td></td>
<td>2</td>
<td>110-80-5</td>
<td>1992</td>
<td></td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td></td>
<td>3</td>
<td>100-41-4</td>
<td>1993</td>
<td></td>
</tr>
</tbody>
</table>

### Abbreviations:
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</tbody>
</table>

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<th>1000 d ppm (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,2- Dichloroethane</td>
<td>0.4 (1.6)</td>
<td>0.4 (1.6)</td>
<td>0.4 (1.6)</td>
<td>0.4 (1.6)</td>
<td>0.4 (1.6)</td>
<td>0.4 (1.6)</td>
</tr>
<tr>
<td>2- Ethoxyethanol</td>
<td>10 (40)</td>
<td>10 (40)</td>
<td>0.8 (3)</td>
<td>0.5 (2)</td>
<td>0.07 (0.3)</td>
<td>Not Set (Not Set)</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>180 (800)</td>
<td>60 (250)</td>
<td>30 (130)</td>
<td>30 (130)</td>
<td>12 (50)</td>
<td>Not Set (Not Set)</td>
</tr>
</tbody>
</table>

### Remarks:
- Ethanol: Eye Irritation, Mucosa Irritation, Skin Flushing, Liver Hepatotoxicity
- 2- Ethoxyethanol: Blood Hematotoxicity, Mucosa Irritation, Skin Flushing, Liver Hepatotoxicity
- Ethylbenzene: Mucosa Irritation, CNS Depression, Mucosa Irritation, Testes Necrosis

### Notes:
- 1992 Year SMAC was Set/Reviewed: 1992
- 1993 Year SMAC was Set/Reviewed: 1993

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</tr>
</thead>
<tbody>
<tr>
<td>Ethylene glycol</td>
<td>25 (60)</td>
<td>25 (60)</td>
<td>5 (13)</td>
<td>5 (13)</td>
<td>5 (13)</td>
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<tr>
<td>Mucosa Irritation</td>
<td>Organ Effect</td>
<td>Mucosa Irritation</td>
<td>Organ Effect</td>
<td>Mucosa Irritation</td>
<td>Organ Effect</td>
<td>Mucosa Irritation</td>
</tr>
<tr>
<td>CNS Depression</td>
<td></td>
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<tr>
<td>Kidney Nephrotoxicity</td>
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<tr>
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</tr>
<tr>
<td>Kidney Nephrotoxicity</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Ethylene glycol</td>
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### Remarks:

- **NRC Vol. #: 3**
- **CAS #: 107-21-1**
- **Year SMAC was Set/Reviewed:** 1993

## Formaldehyde

<table>
<thead>
<tr>
<th>Chemical</th>
<th>1 hr ppm (mg/m³)</th>
<th>24 hr ppm (mg/m³)</th>
<th>7 d ppm (mg/m³)</th>
<th>30 d ppm (mg/m³)</th>
<th>180 d ppm (mg/m³)</th>
<th>1000 d ppm (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formaldehyde</td>
<td>0.8 (1.0)</td>
<td>0.5 (0.6)</td>
<td>0.1 (0.12)</td>
<td>0.1 (0.12)</td>
<td>0.1 (0.12)</td>
<td>0.1 (0.12)</td>
</tr>
<tr>
<td>Mucosa Irritation</td>
<td>Organ Effect</td>
<td>Mucosa Irritation</td>
<td>Organ Effect</td>
<td>Mucosa Irritation</td>
<td>Organ Effect</td>
<td>Mucosa Irritation</td>
</tr>
<tr>
<td>CNS Depression</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Kidney Nephrotoxicity</td>
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<tr>
<td>Mucosa Irritation</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>CNS Depression</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Kidney Nephrotoxicity</td>
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</tr>
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### Remarks:

- **NRC Vol. #: 5**
- **CAS #: 50-00-0**
- **Year SMAC was Set/Reviewed:** 2005

## Freon 11

<table>
<thead>
<tr>
<th>Chemical</th>
<th>1 hr ppm (mg/m³)</th>
<th>24 hr ppm (mg/m³)</th>
<th>7 d ppm (mg/m³)</th>
<th>30 d ppm (mg/m³)</th>
<th>180 d ppm (mg/m³)</th>
<th>1000 d ppm (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freon 11</td>
<td>140 (790)</td>
<td>140 (790)</td>
<td>140 (790)</td>
<td>140 (790)</td>
<td>140 (790)</td>
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<tr>
<td>Heart Arrhythmia</td>
<td>Organ Effect</td>
<td>Heart Arrhythmia</td>
<td>Organ Effect</td>
<td>Heart Arrhythmia</td>
<td>Organ Effect</td>
<td>Heart Arrhythmia</td>
</tr>
<tr>
<td>CNS Heart Arrhythmia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CV Heart Arrhythmia</td>
<td></td>
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### Remarks:

- **NRC Vol. #: 4**
- **CAS #: 75-69-6**
- **Year SMAC was Set/Reviewed:** 1998

## Freon 113

<table>
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<th>1 hr ppm (mg/m³)</th>
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<th>7 d ppm (mg/m³)</th>
<th>30 d ppm (mg/m³)</th>
<th>180 d ppm (mg/m³)</th>
<th>1000 d ppm (mg/m³)</th>
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<tbody>
<tr>
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<td>50 (400)</td>
<td>50 (400)</td>
<td>50 (400)</td>
<td>50 (400)</td>
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<td>Heart Arrhythmia</td>
<td>Organ Effect</td>
<td>Heart Arrhythmia</td>
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<tr>
<td>CNS Heart Arrhythmia</td>
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<td></td>
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</tr>
<tr>
<td>CV Heart Arrhythmia</td>
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### Remarks:

- **NRC Vol. #: 1**
- **CAS #: 76-13-1**
- **Year SMAC was Set/Reviewed:** 1991

## Abbreviations:

- CNS: Central Nervous System
- DCD: Decreased Color Discrimination
- GI: Gastrointestinal tract
- NRC: National Research Council
- PNS: Peripheral Nervous System
- RespSys: Respiratory System
- U.Blad: Urinary bladder

---

{jsc-txcology@mail.nasa.gov}
### SMACs (Spacecraft Maximum Allowable Concentrations)

**Potential Exposure Duration**

<table>
<thead>
<tr>
<th>Chemical</th>
<th>1 hr ppm (mg/m³)</th>
<th>24 hr ppm (mg/m³)</th>
<th>7 d ppm (mg/m³)</th>
<th>30 d ppm (mg/m³)</th>
<th>180 d ppm (mg/m³)</th>
<th>1000 d ppm (mg/m³)</th>
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<tbody>
<tr>
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<td>NRC Vol. #: 4   CAS #: 75-71-8</td>
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<td>Remarks:</td>
<td></td>
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</tr>
<tr>
<td>540 (2600)</td>
<td>95 (470)</td>
<td>95 (470)</td>
<td>95 (470)</td>
<td>95 (470)</td>
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<td>Organ Effect</td>
<td>Organ Effect</td>
<td>Organ Effect</td>
<td>Organ Effect</td>
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</tr>
<tr>
<td>Heart Tachycardia</td>
<td>Heart Arrhythmia</td>
<td>Heart Arrhythmia</td>
<td>Heart Arrhythmia</td>
<td>Heart Arrhythmia</td>
<td></td>
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</tr>
<tr>
<td><strong>Freon 21</strong></td>
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<td>Remarks:</td>
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<tr>
<td>50 (210)</td>
<td>50 (210)</td>
<td>15 (63)</td>
<td>12 (50)</td>
<td>2 (8)</td>
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<tr>
<td>Heart Tachycardia</td>
<td>Heart Tachycardia</td>
<td>Liver Hepatotoxicity</td>
<td>Liver Hepatotoxicity</td>
<td>Liver Hepatotoxicity</td>
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<td><strong>Freon 22</strong></td>
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</tr>
<tr>
<td>Synonyms: Chlorodifluoromethane</td>
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<td>Remarks:</td>
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<td></td>
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<td>1000 (3500)</td>
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<td>1000 (3500)</td>
<td>1000 (3500)</td>
<td>1000 (3500)</td>
<td>Not Set (Not Set)</td>
<td></td>
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<td>Organ Effect</td>
<td>Organ Effect</td>
<td>Organ Effect</td>
<td>Organ Effect</td>
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</tr>
<tr>
<td>CNS Depression</td>
<td>CNS Depression</td>
<td>CNS Depression</td>
<td>CNS Depression</td>
<td>CNS Depression</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart Arrhythmia</td>
<td>Heart Arrhythmia</td>
<td>Heart Arrhythmia</td>
<td>Heart Arrhythmia</td>
<td>Heart Arrhythmia</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Furan</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Synonyms: 1,4-Epoxy-1,3-butadiene</td>
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<td></td>
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<td></td>
</tr>
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<td>NRC Vol. #: 4   CAS #: 110-00-9</td>
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<tr>
<td>Year SMAC was Set/Reviewed: 1998</td>
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<tr>
<td>Remarks:</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>4 (11)</td>
<td>0.36 (1)</td>
<td>0.025 (0.07)</td>
<td>0.025 (0.07)</td>
<td>0.025 (0.07)</td>
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<td>Organ Effect</td>
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<td>Organ Effect</td>
<td>Organ Effect</td>
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</tr>
<tr>
<td>Liver Hepatotoxicity</td>
<td>Liver Hepatotoxicity</td>
<td>Liver Cancer</td>
<td>Liver Cancer</td>
<td>Liver Cancer</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Abbreviations:**
- CNS: Central Nervous System
- DCD: Decreased Color Discrimination
- GI: Gastrointestinal tract
- NRC: National Research Council
- CV: Cardiovascular
- RespSys: Respiratory System
- U.Blad: Urinary bladder
- PNS: Peripheral Nervous System

jsc-txcology@mail.nasa.gov
### Glutaraldehyde

**Synonyms:** 1,5-Pentanediial  

<table>
<thead>
<tr>
<th>Chemical</th>
<th>1 hr ppm (mg/m³)</th>
<th>24 hr ppm (mg/m³)</th>
<th>7 d ppm (mg/m³)</th>
<th>30 d ppm (mg/m³)</th>
<th>180 d ppm (mg/m³)</th>
<th>1000 d ppm (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glutaraldehyde</td>
<td>0.12 (0.50)</td>
<td>0.04 (0.08)</td>
<td>0.006 (0.025)</td>
<td>0.003 (0.012)</td>
<td>0.0006 (0.002)</td>
<td>Not Set (Not Set)</td>
</tr>
</tbody>
</table>

**Organ Effects:**  
- Mucosa: Irritation  
- CNS: Headache  
- RspSys: Lesions

**Year SMAC was Set/Reviewed:** 1993

**Remarks:**

### Hexamethyldisiloxane

**Synonyms:**

<table>
<thead>
<tr>
<th>Chemical</th>
<th>1 hr ppm (mg/m³)</th>
<th>24 hr ppm (mg/m³)</th>
<th>7 d ppm (mg/m³)</th>
<th>30 d ppm (mg/m³)</th>
<th>180 d ppm (mg/m³)</th>
<th>1000 d ppm (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hexamethyldisiloxane</td>
<td>Not Set</td>
<td>Not Set</td>
<td>10 (90)</td>
<td>5 (45)</td>
<td>1 (9)</td>
<td>Not Set (Not Set)</td>
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</table>

**Organ Effects:**  
- Organ: Effect

**Year SMAC was Set/Reviewed:** 1998

**Remarks:** Documented as a polydimethylcylosiloxane

### Hydrazine

**Synonyms:** Diamine

<table>
<thead>
<tr>
<th>Chemical</th>
<th>1 hr ppm (mg/m³)</th>
<th>24 hr ppm (mg/m³)</th>
<th>7 d ppm (mg/m³)</th>
<th>30 d ppm (mg/m³)</th>
<th>180 d ppm (mg/m³)</th>
<th>1000 d ppm (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrazine</td>
<td>4 (5)</td>
<td>0.3 (0.4)</td>
<td>0.04 (0.05)</td>
<td>0.02 (0.03)</td>
<td>0.004 (0.005)</td>
<td>Not Set (Not Set)</td>
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</tbody>
</table>

**Organ Effects:**  
- Liver: Death  
- Liver: Hepatotoxicity  
- Liver: Hepatotoxicity  
- Liver: Hepatotoxicity  
- Liver: Hepatotoxicity  
- Liver: Hyperplasia  
- Liver: Cancer  
- Nose: Cancer

**Year SMAC was Set/Reviewed:** 1993

**Remarks:** Carcinogen.

### Hydrogen

**Synonyms:**

<table>
<thead>
<tr>
<th>Chemical</th>
<th>1 hr ppm (mg/m³)</th>
<th>24 hr ppm (mg/m³)</th>
<th>7 d ppm (mg/m³)</th>
<th>30 d ppm (mg/m³)</th>
<th>180 d ppm (mg/m³)</th>
<th>1000 d ppm (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>4100 (340)</td>
<td>4100 (340)</td>
<td>4100 (340)</td>
<td>4100 (340)</td>
<td>4100 (340)</td>
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</tbody>
</table>

**Organ Effects:**  
- Organ: Effect

**Year SMAC was Set/Reviewed:** 1990

**Remarks:** Ceiling values are 10% of the Lower Explosive Limit

---

**Abbreviations:**  
- CNS: Central Nervous System  
- DCD: Decreased Color Discrimination  
- GI: Gastrointestinal tract  
- NRC: National Research Council  
- PNS: Peripheral Nervous System  
- CV: Cardiovascular  
- RespSys: Respiratory System  
- U.Blad: Urinary bladder

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<table>
<thead>
<tr>
<th>Chemical</th>
<th>SMACs (Spacecraft Maximum Allowable Concentrations)</th>
<th>Potential Exposure Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hydrogen chloride</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Synonyms: HCl</td>
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</tr>
<tr>
<td>NRC Vol.: 4</td>
<td>CAS #: 7647-01-1</td>
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<tr>
<td>Year SMAC was Set/Reviewed: 1998</td>
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<tr>
<td>Remarks:</td>
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<td></td>
</tr>
<tr>
<td>ppm 1 hr</td>
<td>ppm 24 hr</td>
<td>ppm 7 d</td>
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<td>(mg/m³)</td>
<td>(mg/m³)</td>
<td>(mg/m³)</td>
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<tr>
<td>Eye Irritation</td>
<td>Eye Irritation</td>
<td>Eye Irritation</td>
</tr>
<tr>
<td>Mucosa Irritation</td>
<td>Mucosa Irritation</td>
<td>Mucosa Irritation</td>
</tr>
<tr>
<td>Not Set</td>
<td>(Not Set)</td>
<td>(Not Set)</td>
</tr>
</tbody>
</table>

| **Hydrogen cyanide**           |                                                    |                            |
| Synonyms: HCN                  |                                                    |                            |
| NRC Vol.: 4                   | CAS #: 74-90-8                                     |                            |
| Year SMAC was Set/Reviewed: 1998 |                                                    |                            |
| Remarks:                       |                                                    |                            |
| ppm 1 hr                       | ppm 24 hr                                          | ppm 7 d                    |
| (mg/m³)                        | (mg/m³)                                            | (mg/m³)                    |
| CNS Depression                 | CNS Depression                                     | CNS Depression             |
| CNS Headache                   | CNS Headache                                       | CNS Headache               |
| CNS Nausea                     | CNS Nausea                                         | CNS Nausea                 |
| Not Set                        | (Not Set)                                          | (Not Set)                  |

| **Indole**                     |                                                    |                            |
| Synonyms:                      |                                                    |                            |
| NRC Vol.: 2                   | CAS #: 120-72-9                                    |                            |
| Year SMAC was Set/Reviewed: 1992 |                                                    |                            |
| Remarks: Normal turnover of indole was used to establish a lower bound of 0.05 ppm. | | |
| ppm 1 hr                       | ppm 24 hr                                          | ppm 7 d                    |
| (mg/m³)                        | (mg/m³)                                            | (mg/m³)                    |
| CNS Nausea                     | CNS Nausea                                         | CNS Nausea                 |
| Blood Hematotoxicity           | Blood Hematotoxicity                               | Blood Hematotoxicity       |
| Not Set                        | (Not Set)                                          | (Not Set)                  |

| **Isoprene**                   |                                                    |                            |
| Synonyms: 2-Methyl-1,3-butadiene |                                                    |                            |
| NRC Vol.: 4                   | CAS #: 78-79-5                                     |                            |
| Year SMAC was Set/Reviewed: 1998 |                                                    |                            |
| Remarks:                       |                                                    |                            |
| ppm 1 hr                       | ppm 24 hr                                          | ppm 7 d                    |
| (mg/m³)                        | (mg/m³)                                            | (mg/m³)                    |
| Mucosa Irritation              | Mucosa Irritation                                  | Mucosa Irritation          |
| Blood Anemia                   | Blood Anemia                                       | Blood Anemia               |
| Lung Injury                    | Lung Injury                                        | Lung Injury                |
| CNS Neurotoxicity              | CNS Neurotoxicity                                  | CNS Neurotoxicity          |
| Not Set                        | (Not Set)                                          | (Not Set)                  |
## SMACs (Spacecraft Maximum Allowable Concentrations)

### Potential Exposure Duration

<table>
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<tr>
<th>Chemical</th>
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<th>24 hr ppm (mg/m³)</th>
<th>7 d ppm (mg/m³)</th>
<th>30 d ppm (mg/m³)</th>
<th>180 d ppm (mg/m³)</th>
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<tr>
<td>NRC Vol. #: 5</td>
<td>CAS #: 2008</td>
<td>Year SMAC was Set/Reviewed: 2008</td>
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<td>Lung</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.01 (0.1)</td>
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<td>0.001 (0.01)</td>
<td>0.001 (0.01)</td>
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<tr>
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<td>Organ</td>
<td>Effect</td>
<td>Organ</td>
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</tr>
<tr>
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<td>irritation</td>
<td>Lung</td>
<td>irritation</td>
<td>CNS</td>
<td>Neurotoxicity</td>
<td>Kidney</td>
</tr>
<tr>
<td>Methane</td>
<td>5300 (3500)</td>
<td>5300 (3500)</td>
<td>5300 (3500)</td>
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<tr>
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<td>Remarks: Ceiling values are 10% of the Lower Explosive Limit. Methane is a non-toxic simple asphyxiant.</td>
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<td>Methanol</td>
<td>200 (260)</td>
<td>70 (90)</td>
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<td>Synonyms:</td>
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<td>CAS #: 67-56-1</td>
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<td>Effect</td>
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<tr>
<td>Eye</td>
<td>Visual disturbance</td>
<td>Eye</td>
<td>Visual disturbance</td>
<td>Eye</td>
<td>Visual disturbance</td>
<td>Eye</td>
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</table>

### Abbreviations:
- CNS: Central Nervous System
- DCD: Decreased Color Discrimination
- GI: Gastrointestinal tract
- NRC: National Research Council
- PNS: Peripheral Nervous System
- CV: Cardiovascular
- RespSys: Respiratory System
- U.Blad: Urinary bladder
- jsc-txcoology@mail.nasa.gov
### SMACs (Spacecraft Maximum Allowable Concentrations)

#### Potential Exposure Duration

<table>
<thead>
<tr>
<th>Chemical</th>
<th>1 hr ppm (mg/m³)</th>
<th>24 hr ppm (mg/m³)</th>
<th>7 d ppm (mg/m³)</th>
<th>30 d ppm (mg/m³)</th>
<th>180 d ppm (mg/m³)</th>
<th>1000 d ppm (mg/m³)</th>
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</thead>
<tbody>
<tr>
<td><strong>Methyl Ethyl Ketone</strong></td>
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<tr>
<td>Synonyms: 2-Butanone</td>
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<td>50 (150)</td>
<td>10 (30)</td>
<td>10 (30)</td>
<td>10 (30)</td>
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<tr>
<td></td>
<td><strong>Organ</strong></td>
<td><strong>Effect</strong></td>
<td><strong>Organ</strong></td>
<td><strong>Effect</strong></td>
<td><strong>Organ</strong></td>
<td><strong>Effect</strong></td>
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<tr>
<td></td>
<td>Mucosa</td>
<td>Irritation</td>
<td>Mucosa</td>
<td>Irritation</td>
<td>Mucosa</td>
<td>Irritation</td>
</tr>
<tr>
<td>Year SMAC was Set/Reviewed: 1992</td>
<td>Remarks: Ceiling values</td>
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<tr>
<td><strong>Methyl hydrazine</strong></td>
<td>0.002 (0.004)</td>
<td>0.002 (0.004)</td>
<td>0.002 (0.004)</td>
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<td>0.002 (0.004)</td>
<td>Not Set (Not Set)</td>
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<td>Nose</td>
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<td>Year SMAC was Set/Reviewed: 1991</td>
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<td><strong>4-Methyl-2-pentanone</strong></td>
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<td>35 (140)</td>
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<td><strong>Organ</strong></td>
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<tr>
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<td>CNS</td>
<td>Depression</td>
<td>CNS</td>
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<tr>
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<tr>
<td>Year SMAC was Set/Reviewed: 1994</td>
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<tr>
<td><strong>Methylene chloride</strong></td>
<td>100 (350)</td>
<td>35 (120)</td>
<td>14 (49)</td>
<td>7 (24)</td>
<td>3 (10)</td>
<td>1 (3.5)</td>
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<td>Synonyms: Dichloromethane</td>
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<td><strong>Effect</strong></td>
<td><strong>Organ</strong></td>
<td><strong>Effect</strong></td>
<td><strong>Organ</strong></td>
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<td>Depression</td>
<td>CNS</td>
<td>Depression</td>
<td>Liver</td>
<td>Hepatotoxicity</td>
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<td>Kidney</td>
<td>Nephrotoxicity</td>
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<td>Remarks: CO formation, Carcinogen</td>
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</table>

**Abbreviations:**

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- PNS: Peripheral Nervous System
- RespSys: Respiratory System
- U.Blad: Urinary bladder
- CV: Cardiovascular

For more information, contact: jsc-txcology@mail.nasa.gov
<table>
<thead>
<tr>
<th>Chemical</th>
<th>Synonyms</th>
<th>1 hr ppm (mg/m³)</th>
<th>24 hr ppm (mg/m³)</th>
<th>7 d ppm (mg/m³)</th>
<th>30 d ppm (mg/m³)</th>
<th>180 d ppm (mg/m³)</th>
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<tbody>
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<td>Nitromethane</td>
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<td>15 (40)</td>
<td>7 (18)</td>
<td>7 (18)</td>
<td>5 (13)</td>
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<td>Not Set</td>
<td>23 (280)</td>
<td>5 (60)</td>
<td>1 (12)</td>
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<tr>
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<td>400 (4000)</td>
<td>200 (2000)</td>
<td>100 (1000)</td>
<td>20 (200)</td>
<td>4 (40)</td>
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</table>

**Abbreviations:**
### Chemical

#### Perfluoropropane
**(Aliphatic Perfluoroalkanes)**

**Synonyms:** Octafluoropropane  
**NRC Vol. #:** 4  
**CAS #:** 76-19-7  
**Year SMAC was Set/Reviewed:** 1998  
**Remarks:** This group SMAC is not applicable to perfluorocycloalkanes. SMACs in mg/m³ apply only to perfluoropropane.

<table>
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<th>Potential Exposure Duration</th>
<th>1 hr ppm (mg/m³)</th>
<th>24 hr ppm (mg/m³)</th>
<th>7 d ppm (mg/m³)</th>
<th>30 d ppm (mg/m³)</th>
<th>180 d ppm (mg/m³)</th>
<th>1000 d ppm (mg/m³)</th>
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</thead>
<tbody>
<tr>
<td>CNS Symptoms</td>
<td>11,000 (85,000)</td>
<td>11,000 (85,000)</td>
<td>11,000 (85,000)</td>
<td>11,000 (85,000)</td>
<td>11,000 (85,000)</td>
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<tr>
<td>Mucosa Irritation</td>
<td></td>
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<tr>
<td>Liver Hepatotoxicity</td>
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#### 2-Propanol
**(Isopropanol)**

**NRC Vol. #:** 2  
**CAS #:** 67-63-0  
**Year SMAC was Set/Reviewed:** 1992  
**Remarks:**

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<th>Potential Exposure Duration</th>
<th>400 ppm (1000)</th>
<th>100 ppm (240)</th>
<th>60 ppm (150)</th>
<th>60 ppm (150)</th>
<th>60 ppm (150)</th>
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<tbody>
<tr>
<td>CNS Depression</td>
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<td></td>
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</tr>
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<td>Mucosa Irritation</td>
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<tr>
<td>Mucosa Liver Hepatotoxicity</td>
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</table>

#### Propylene glycol
**(1,2-Propanediol; Methyl glycol)**

**NRC Vol. #:** 5  
**CAS #:** 57-55-6  
**Year SMAC was Set/Reviewed:** 2008  
**Remarks:**

<table>
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<th>Potential Exposure Duration</th>
<th>32 ppm (102)</th>
<th>17 ppm (54)</th>
<th>9 ppm (29)</th>
<th>3 ppm (9.6)</th>
<th>1.5 ppm (4.8)</th>
<th>1.5 ppm (4.8)</th>
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</thead>
<tbody>
<tr>
<td>Eye Discharge</td>
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<tr>
<td>Throat Hemorrhage</td>
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<tr>
<td>Lung Epithelium thickening</td>
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</tbody>
</table>

**Abbreviations:**  
- CNS: Central Nervous System  
- DCD: Decreased Color Discrimination  
- GI: Gastrointestinal tract  
- RespSys: Respiratory System  
- U.Blad: Urinary bladder  
- NRC: National Research Council  
- PNS: Peripheral Nervous System  
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- CV: Cardiovascular  
- RespSys: Respiratory System  
- U.Blad: Urinary bladder  
- NRC: National Research Council  
- PNS: Peripheral Nervous System  

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<table>
<thead>
<tr>
<th>Chemical</th>
<th>1 hr ppm (mg/m³)</th>
<th>24 hr ppm (mg/m³)</th>
<th>7 d ppm (mg/m³)</th>
<th>30 d ppm (mg/m³)</th>
<th>180 d ppm (mg/m³)</th>
<th>1000 d ppm (mg/m³)</th>
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</thead>
<tbody>
<tr>
<td>Toluene</td>
<td>16 (60)</td>
<td>16 (60)</td>
<td>4 (15)</td>
<td>4 (15)</td>
<td>4 (15)</td>
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<td>Synonyms: Methyl benzene</td>
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<td>Remarks:</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

| Trichloroethylene        | 50 (270)        | 11 (60)         | 9 (50)         | 4 (20)          | 2 (10)          | Not Set         |
| Synonyms:                |                 |                 |                |                 |                 |                 |
| NRC Vol.: 3 CAS #: 79-01-6 |                |                 |                |                 |                 |                 |
| Year SMAC was Set/Reviewed: 1992 |            |                |                |                 |                 |                 |
| Remarks: See dichloroacetylene if alkali scrubber is present. Possible carcinogen. | | | | | | |

| Trimethylsilanol         | 15 (55)         | 2 (7)           | 1 (4)          | 1 (4)           | 1 (4)           | 1 (4)           |
| Synonyms: Trimethylhydroxysilane |             |                 |                |                 |                 |                 |
| NRC Vol.: 5 CAS #: 1066-40-6 |                |                 |                |                 |                 |                 |
| Year SMAC was Set/Reviewed: 2008 |            |                |                |                 |                 |                 |
| Remarks:                 |                 |                 |                |                 |                 |                 |

| Unsymmetrical Dimethylhydrazine | 3 (7.5) | 0.12 (0.3) | 0.03 (0.075) | 0.017 (0.0425) | 0.003 (0.0075) | Not Set |
| Synonyms: 1,1-Dimethylhydrazine, UDMH |         |             |                |                 |                 |         |
| NRC Vol.: 5 CAS #: 57-14-7 |            |                |                |                 |                 |         |
| Year SMAC was Set/Reviewed: 2008 |            |                |                |                 |                 |         |
| Remarks: | | | | | | |

Abbreviations:
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- CV: Cardiovascular
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- NRC: National Research Council
- RespSys: Respiratory System
- PNS: Peripheral Nervous System
- U.Blad: Urinary bladder
- jsc-txcology@mail.nasa.gov
### Vinyl chloride

**Synonyms:** Chloroethene; chloroethylene  
**NRC Vol. #:** 1  
**CAS #:** 75-01-4  
**Year SMAC was Set/Reviewed:** 1992  
**Remarks:** Carcinogen  

<table>
<thead>
<tr>
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<th>24 hr ppm (mg/m³)</th>
<th>7 d ppm (mg/m³)</th>
<th>30 d ppm (mg/m³)</th>
<th>180 d ppm (mg/m³)</th>
<th>1000 d ppm (mg/m³)</th>
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</thead>
<tbody>
<tr>
<td>Liver Hepatotoxicity</td>
<td>130 (330)</td>
<td>30 (77)</td>
<td>1 (2.6)</td>
<td>1 (2.6)</td>
<td>1 (2.6)</td>
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</tr>
<tr>
<td>CNS Headache</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>CNS Depression</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

### Xylene

**Synonyms:** Dimethylbenzene, xylo  
**NRC Vol. #:** 5  
**CAS #:** 1330-20-7  
**Year SMAC was Set/Reviewed:** 2008  
**Remarks:** Applies to each individual xylene isomer and mixtures of xylene isomers.  

<table>
<thead>
<tr>
<th>Potential Exposure Duration</th>
<th>1 hr ppm (mg/m³)</th>
<th>24 hr ppm (mg/m³)</th>
<th>7 d ppm (mg/m³)</th>
<th>30 d ppm (mg/m³)</th>
<th>180 d ppm (mg/m³)</th>
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</thead>
<tbody>
<tr>
<td>Mucosa Irritation</td>
<td>50 (215)</td>
<td>17 (73)</td>
<td>17 (73)</td>
<td>17 (73)</td>
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<td>Eye Irritation</td>
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</table>

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RespSys: Respiratory System