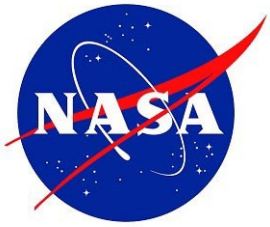
Spacecraft Maximum Allowable Concentrations for Airborne Contaminants

Human Health and Performance Directorate

Biomedical Research and Environmental Sciences Control Board (BRESCB) Controlled

Revision C

DATE 6/13/2024



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

NASA APPROVAL SHEET

Spacecraft Maximum Allowable Concentrations for Airborne Contaminants

Human Health and Performance Directorate

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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Houston, Texas

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CHANGE HISTORY

Revision/PCN	Date	Authorization/ Originator/Phone	Description
Baseline	09/2017	CR# SA-00308 Valerie E. Ryder 281-483-4989	**NOTE: Previous versions of the document were baselined through the STIC Library and not "BASELINED" through a Board. Therefore, the versioning of the document will start at BASELINE for Configuration Management purposes.** **PREVIOUS INFORMATION FROM STIC BASELINE:** ***Errata*** Correct CAS numbers are below: • 75-69-4 (Freon 11) • 111-30-8 (Glutaraldehyde) • 7647-01-0 (Hydrogen chloride) • 5989-27-5 (Limonene) **CURRENT UPDATES:** Introductory page revised CAS number for Acrolein corrected to 107-02-8 Compound names revised to match published NRC Vol. 5: 1-Butanol to n-Butanol; Unsymmetrical Dimethylhydrazine to Dimethylhydrazine C3-C8 Aliphatic Saturated Aldehydes 7-d, 30-d, 180-d, 1000-d values revised to match NRC Vol. 5 (5 ppm) **Carbon dioxide (CO_2) SMACs have been deleted** – CO_2 does not fit SMAC paradigm and is being managed based on expected performance and health decrements and the associated risks. NASA Standard 3001 is currently under revision to provide guidance on acceptable CO2 levels. Linear Siloxanes group SMACs added Octamethyltrisiloxane SMACs deleted (replaced by Linear Siloxanes)
Revision A	03/2020	CR# SA-02481 Valerie E. Ryder 281-483-4989	Clarification of SMACs for small chain alkanes (C2-C4) versus longer chain alkanes (C5-C9) Revised SMACs for methanol New SMACs for manganese Updated MAPTIS access information

Revision B	11/30/2022	CR # SA-05524 Valerie E. Ryder 281-483-4989	Revised SMACs for propylene glycol New SMACs for n-hexane, hydrogen fluoride, and ethyl acetate
Revision C	6/13/2024	CR# SA-07170 Shannon D. Langford 281-483-2137	Update to acute benzene SMACs Added new SMACs for hydrogen sulfide Added notation that SMACs are set based on and applicable to ambient conditions (14.7 psi/25˚C). Added clarification concerning the hierarchy of this document and specifying that this document is only a reprinting of data published and controlled in other sources.

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1.0 BACKGROUND

SPACECRAFT MAXIMUM ALLOWABLE CONCENTRATIONS FOR AIRBORNE CONTAMINANTS

The enclosed table lists official Spacecraft Maximum Allowable Concentrations (SMACs) for selected airborne contaminants. They are based upon experiments conducted at standard pressure and oxygen environments and may or may not be applicable to altered atmospheres. The values listed in this summery document are applicable only to ambient conditions at standard temperature and oxygen (14.7 psi and 21% O2 at 25°C). These are guideline values set by the National Aeronautics and Space Administration (NASA)/Johnson Space Center (JSC) Toxicology Group in cooperation with the National Research Council Committee on Toxicology (NRCCOT), through publication in the peer- reviewed scientific literature, or NASA Technical Memoranda. Based on documented guidance (NRC, 1992; NRC, 2016), NASA has established SMACs for 58chemical compounds that are particularly relevant to atmospheric contamination of the International Space Station (ISS) and targets of Exploration. Some long-term limits (1000-days) have also been established to support manned deep-space exploration. Summaries of these SMACs are presented in tabular form as part of this publication. This document provides a tabular summary of values that have been previously established based on guidelines established by NASA and the National Research Council's Committee on Toxicology and vetted and published through the NRCCOT and/or non-NASA scientific literature and NASA Technical Memoranda. Complete documentation of the rationale used to establish the values summarized here is provided in the reference section below.

Short-term (1- and 24-hour) SMACs apply to off-nominal situations, such as accidental releases aboard a spacecraft. These limits 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. Because allergic reactions or chemical idiosyncrasy to certain airborne pollutants are very difficult to predict, crewmembers with allergies or unusual sensitivity to trace pollutants may not be afforded complete protection, even when long-term SMACs are not exceeded.

Conversely, exceedance of a SMAC does not mean that health impairment is certain (there are many other factors that influence ultimate health outcomes), although it does indicate that the crew may be subject to increased risks that must be closely evaluated. Environmental pollutant control to mitigate exposure will likely be triggered.

These values have been specifically established for human spaceflight and are not intended to apply to other situations, such as ground operations. 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.

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. We assume that the effects of a toxicologically similar group of compounds are additive. The air quality is therefore considered

acceptable when the toxicity index (T_{grp}) for each toxicological group of compounds is less than 1, where T_{grp} is calculated as follows:

$$T_{grp} = C_1/SMAC_1 + C_2/SMAC_2 + \ldots + C_n/SMAC_n$$

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.

In addition to official SMACs used for the evaluation of spacecraft air, the JSC Toxicology Group sets interim 7-day SMAC values that are posted to the "MAPTIS" database, which is used to evaluate materials and hardware off-gassing data. Following registration, these values can be accessed at: https://maptis.nasa.gov/. For help with registration or using MAPTIS, contact MAPTIS support at maptissupport@mail.nasa.gov.

2.0 PUBLISHED SMACS

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
Acetaldehyde	**10**	(18)	**6**	(10)	**2**	(4)	**2**	(4)	**2**	(4)	**Not Set**	(Not Set)
CAS #: 75-07-0	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Wong, King Lit, (1994), Acetaldehyde, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants Vol 1: 19-38, National Academy Press, Washington, DC	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa Throat	Irritation Cancer		
REMARKS: Carcinogen												
Acetone	**500**	(1200)	**200**	(500)	**22**	(52)	**22**	(52)	**22**	(52)	**Not Set**	(Not Set)
CAS #: 67-64-1	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Garcia, Hector D. (2000), Acetone, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:17-41, National Academy Press, Washington, DC	CNS	Fatigue	CNS	Fatigue	CNS CNS	Fatigue Headache	CNS CNS	Fatigue Headache	CNS CNS	Fatigue Headache		
REMARKS:												
Acrolein	**0.075**	(0.17)	**0.035**	(0.08)	**0.015**	(0.03)	**0.015**	(0.03)	**0.008**	(0.02)	**0.008**	(0.02)
CAS #: 107-02-8	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Langford, Shannon D. (2008), Acrolein, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:13-33, National Academy Press, Washington, DC	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation
REMARKS: Ceiling values												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
C3-C8 Aliphatic Saturated Aldehydes	45	(varies)	45	(varies)	5	(varies)	5	(varies)	5	(varies)	5	(varies)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: various	Mucosa / Irritation		Mucosa / Irritation		Nasal Cavity / Injury		Nasal Cavity / Injury		Nasal Cavity / Injury		Nasal Cavity / Injury	
REFERENCE: Langford, Shannon D. (2008), C3-C8 Aliphatic Saturated Aldehydes, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:34-47, National Academy Press, Washington, DC												
REMARKS: Includes propanal, butanal, pentanal, hexanal, heptanal, octanal The mg/m3 value depends on the molecular weight of the particular aldehyde.												
C5-C9 Alkanes	150	(varies)	80	(varies)	60	(varies)	20	(varies)	3	(varies)	Not Set	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: various	CNS / Depression Eye / Irritation Nose / Irritation		CNS / Depression Eye / Irritation Nose / Irritation		CNS / Depression		CNS / Depression CNS / Ototoxicity		CNS / Ototoxicity			
REFERENCE: McCoy, J. Torin. (2008), C2-C9 Alkanes, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:85-111, National Academy Press, Washington, DC												
REMARKS: Includes pentane, heptane, octane, and nonane and branched isomers **EXCLUDES** n-hexane The mg/m3 value depends on the molecular weight of the particular alkane.												
Ammonia	30	(20)	20	(14)	3	(2)	3	(2)	3	(2)	3	(2)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 7664-41-7	Eye / Irritation CNS / Headache		Eye / Irritation CNS / Headache		Eye / Irritation CNS / Headache		Eye / Irritation CNS / Headache		Eye / Irritation CNS / Headache		Eye / Irritation CNS / Headache	
REFERENCE: Garcia, Hector D. (2008), Ammonia, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:48-61, National Academy Press, Washington, DC												
REMARKS:												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
Benzene	**40**	(120)	**6.7**	(20)	**0.5**	(1.5)	**0.1**	(0.3)	**0.07**	(0.2)	**0.013**	(0.04)
	Organ	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
CAS #: 71-43-2	CNS	Depression	CNS	Depression	Blood	Immunotoxicity	Blood	Immunotoxicity	Blood	Immunotoxicity	Blood	Hematological
REFERENCE: Ryder VE, Williams ES. Revisions to acute/off-nominal limits for benzene in spacecraft air. Aerosp Med Hum Perform. 2023; 94(7):544–545. Kahn-Mayberry, Noreen N. (2008), Benzene, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:62-72, National Academy Press, Washington, DC									Blood	Leukemia		
Remarks:												
REMARKS:												
Bromotrifluoromethane	**3500**	(21000)	**3500**	(21000)	**1800**	(11000)	**1800**	(11000)	**1800**	(11000)	**Not Set**	(Not Set)
	Organ	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
CAS #: 75-63-8	Heart	Arrhythmia	Heart	Arrhythmia	CNS	Depression	CNS	Depression	CNS	Depression		
REFERENCE: Lam, Chiu-Wing. (1996), Bromotrifluoromethane, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 3:21-52, National Academy Press, Washington, DC	CNS	Cognition	CNS	Cognition	Heart	Arrhythmia						
REMARKS:												
n- Butanol	**50**	(150)	**25**	(80)	**25**	(80)	**25**	(80)	**12**	(40)	**12**	(40)
	Organ	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
CAS #: 71-36-3	Eye	Irritation	Eye	Irritation	Eye	Irritation	Eye	Irritation	Eye	Irritation	Eye	Irritation
REFERENCE: James, John T. (2008), n-Butanol, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:73-84, National Academy Press, Washington, DC	CNS	Depression				Systemic Injury		Systemic Injury		Systemic injury		Systemic injury

REMARKS: The odor threshold and noxious odor concentrations are uncertain. These concentrations may not preclude odor detection by the crew.

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
tert- Butanol	**50**	(150)	**50**	(150)	**50**	(150)	**50**	(150)	**40**	(120)	**Not Set**	(Not Set)
CAS #: 75-65-0	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: James, John T. (1996), tert-Butanol, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 3:78-104, National Academy Press, Washington, DC	CNS	Depression	CNS	Depression	CNS	Depression	Kidney	Nephrotoxicity	Kidney	Nephrotoxicity		
							CNS	Depression	CNS	Depression		
									U. Blad	Injury		
REMARKS:												
Carbon monoxide	**425**	(485)	**100**	(114)	**55**	(63)	**15**	(17)	**15**	(17)	**15**	(17)
CAS #: 630-08-0	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: James, John T. (2008), Carbon Monoxide, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:125-143, National Academy Press, Washington, DC	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression
	CV	Arrhythmia	CV	Arrhythmia	CV	Arrhythmia	CV	Arrhythmia	CV	Arrhythmia	CV	Arrhythmia
REMARKS: Carboxyhemoglobin target												
Chloroform	**2**	(10)	**2**	(10)	**2**	(10)	**1**	(5)	**1**	(5)	**Not Set**	(Not Set)
CAS #: 67-66-3	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Garcia, Hector D. (2000), Chloroform, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:264-306, National Academy Press, Washington, DC	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression		
	Kidney	Nephrotoxicity	Kidney	Nephrotoxicity	Liver	Hepatotoxicity	Liver	Hepatotoxicity	Liver	Hepatotoxicity		
					Kidney	Nephrotoxicity						
REMARKS:												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
Decamethylcyclopentasiloxane	**Not Set**	(Not Set)	**Not Set**	(Not Set)	**7**	(100)	**5**	(75)	**1**	(15)	**Not Set**	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 541-02-6					RspSys / Injury		RspSys / Injury		RspSys / Injury			
REFERENCE: James, John T. (2000), Polydimethylcyclosiloxanes, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:151-174, National Academy Press, Washington, DC					Gonad / Toxicity		Gonad / Toxicity		Gonad / Toxicity			
REMARKS: Documented as a polydimethylcyclosiloxane												
Diacetone alcohol	**50**	(250)	**50**	(250)	**20**	(100)	**6**	(30)	**4**	(20)	**Not Set**	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 123-42-2	Mucosa / Irritation		Mucosa / Irritation		Mucosa / Irritation		Mucosa / Irritation		Liver / Hepatomegaly			
REFERENCE: James, John T. (1996), Diacetone alcohol, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 3:105-116, National Academy Press, Washington, DC	CNS / Depression		CNS / Depression		CNS / Depression		CNS / Depression		CNS / Depression			
REMARKS:												
Dichloroacetylene	**0.6**	(2.4)	**0.04**	(0.16)	**0.03**	(0.12)	**0.025**	(0.10)	**0.015**	(0.06)	**Not Set**	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 7572-29-4	CNS / Depression		CNS / Depression		CNS / Depression		CNS / Depression		CNS / Depression			
REFERENCE: James, John T. (1996), Dichloroacetylene, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 3:117-134, National Academy Press, Washington, DC	Kidney / Nephrotoxicity		Kidney / Nephrotoxicity		Kidney / Nephrotoxicity		Kidney / Nephrotoxicity		Kidney / Nephrotoxicity			
	Liver / Hepatotoxicity		Liver / Hepatotoxicity									
REMARKS:												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
1,2- Dichloroethane	**0.4**	(1.6)	**0.4**	(1.6)	**0.4**	(1.6)	**0.4**	(1.6)	**0.4**	(1.6)	**0.4**	(1.6)
CAS #: 107-06-2	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Ramanathan, Raghupathy (2008), 1,2-Dichloroethane, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:144-161, National Academy Press, Washington, DC	G.I.	GI Toxicity	G.I.	GI Toxicity	G.I.	GI Toxicity	G.I.	G.I. Toxicity	G.I.	G.I. Toxicity	G.I.	G.I. Toxicity
	.		.		.		.				Liver	Hepatotoxicity
REMARKS: Impairs host defenses against bacteria.												
Dimethylhydrazine	**3**	(7.5)	**0.12**	(0.3)	**0.03**	(0.075)	**0.017**	(0.0425)	**0.003**	(0.0075)	**Not Set**	(Not Set)
CAS #: 57-14-7	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Khan-Mayberry, Noreen N. (2008), Dimethylhydrazine, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:162-189, National Academy Press, Washington, DC	CNS		CNS		Blood	Anemia	Blood	Anemia	Liver	Anemia		
									Liver	Hepatotoxicity		
REMARKS:												
Ethanol	**5000**	(10000)	**5000**	(10000)	**1000**	(2000)	**1000**	(2000)	**1000**	(2000)	**1000**	(2000)
CAS #: 64-17-5	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: McCoy, J. Torin (2008), Ethanol, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:190-205, National Academy Press, Washington, DC	Eye	Irritation	Eye	Irritation	Eye	Irritation	Eye	Irritation	Eye	Irritation	Eye	Irritation
	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation
	Skin	Flushing	Skin	Flushing	Skin	Flushing	Skin	Flushing	Skin	Flushing	Skin	Flushing
	CNS	Depression	CNS	Depression	Liver	Hepatotoxicity	Liver	Hepatotoxicity	Liver	Hepatotoxicity	Liver	Hepatotoxicity
REMARKS:												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
2- Ethoxyethanol	**10**	(40)	**10**	(40)	**0.8**	(3)	**0.5**	(2)	**0.07**	(0.3)	**Not Set**	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 110-80-5	Blood / Hematotoxicity		Blood / Hematotoxicity		Blood / Hematotoxicity		Blood / Hematotoxicity		Blood / Hematotoxicity			
REFERENCE: Wong, King Lit (1996), 2-Ethoxyethanol, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 2:189-212, National Academy Press, Washington, DC	Mucosa / Irritation		Mucosa / Irritation		Testes / Toxicity		Testes / Toxicity		Testes / Toxicity			
REMARKS:												
Ethyl acetate	**400**	(1440)	**400**	(1440)	**117**	(421)	**117**	(421)	**117**	(421)	**39**	(140)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 141-78-6	Mucosa / Irritation		Mucosa / Irritation		Body Weight / Reduction		Body Weight / Reduction		Body Weight / Reduction		Body Weight / Reduction	
REFERENCE: Williams, E.S. and Ryder, V.E. Spacecraft maximum allowable concentrations for ethyl acetate. Aerosp Med Hum Perform. 2023; 94(1):1–9.												
REMARKS:												
Ethylbenzene	**180**	(780)	**60**	(260)	**30**	(130)	**30**	(130)	**12**	(50)	**Not Set**	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 100-41-4	Mucosa / Irritation		Mucosa / Irritation		Mucosa / Irritation		Mucosa / Irritation		Testes / Necrosis			
REFERENCE: Garcia, Hector D. (1996), Ethylbenzene, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 3:208-231, National Academy Press, Washington, DC	CNS / Depression		CNS / Depression		Testes / Necrosis		Testes / Necrosis					
REMARKS:												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
Ethylene glycol	**25**	(64)	**25**	(64)	**5**	(13)	**5**	(13)	**5**	(13)	**Not Set**	(Not Set)
CAS #: 107-21-1	*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
REFERENCE: Wong, King Lit (1996), Ethylene glycol, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 3:232-270, National Academy Press, Washington, DC	Mucosa / Irritation		Mucosa / Irritation CNS / Depression		Mucosa / Irritation CNS / Depression Kidney / Nephrotoxicity		Mucosa / Irritation CNS / Depression Kidney / Nephrotoxicity		Mucosa / Irritation CNS / Depression Kidney / Nephrotoxicity			
REMARKS:												
Formaldehyde	**0.8**	(1.0)	**0.5**	(0.6)	**0.1**	(0.12)	**0.1**	(0.12)	**0.1**	(0.12)	**0.1**	(0.12)
CAS #: 50-00-0	*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
REFERENCE: McCoy, J. Torin (2008), Formaldehyde, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:206-249, National Academy Press, Washington, DC	Mucosa / Irritation		Mucosa / Irritation		Mucosa / Irritation		Mucosa / Irritation		Mucosa / Irritation		Mucosa / Irritation Nose / Cancer	
REMARKS: Ceiling values, Carcinogen												
Freon 11	**140**	(790)	**140**	(790)	**140**	(790)	**140**	(790)	**140**	(790)	**Not Set**	(Not Set)
CAS #: 75-69-4	*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
REFERENCE: Garcia, Hector D. (2000), Trichlorofluoromethane (Freon 11), Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:211-226, National Academy Press, Washington, DC	Heart / Arrhythmia		Heart / Arrhythmia		Heart / Arrhythmia		Heart / Arrhythmia		Heart / Arrhythmia			
REMARKS:												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
Freon 113	50	(400)	50	(400)	50	(400)	50	(400)	50	(400)	Not Set	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 76-13-1	Heart / Arrhythmia		Heart / Arrhythmia		Heart / Arrhythmia		Heart / Arrhythmia		Heart / Arrhythmia			
REFERENCE: Garcia, Hector D. and James, John T. (1994), Freon 113, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 1:121-138, National Academy Press, Washington, DC												
REMARKS:												
Freon 12	540	(2600)	95	(470)	95	(470)	95	(470)	95	(470)	Not Set	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 75-71-8	Heart / Tachycardia		Heart / Arrhythmia		Heart / Arrhythmia		Heart / Arrhythmia		Heart / Arrhythmia			
REFERENCE: Garcia, Hector D. (2000), Dichlorodifluoromethane (Freon 12), Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:227-239, National Academy Press, Washington, DC												
REMARKS:												
Freon 21	50	(210)	50	(210)	15	(63)	12	(50)	2	(8)	Not Set	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 75-43-4	Heart / Tachycardia		Heart / Tachycardia		Liver / Hepatotoxicity		Liver / Hepatotoxicity		Liver / Hepatotoxicity			
REFERENCE: Garcia, Hector D. (2000), Dichlorofluoromethane (Freon 21), Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:175-189, National Academy Press, Washington, DC												
REMARKS:												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
Freon 22	**1000**	(3500)	**1000**	(3500)	**1000**	(3500)	**1000**	(3500)	**1000**	(3500)	**Not Set**	(Not Set)
CAS #: 75-45-6	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Garcia, Hector D. (2000), Chlorodifluoromethane (Freon 22), Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:190-210, National Academy Press, Washington, DC	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression		
	Heart	Arrhythmia	Heart	Arrhythmia	Heart	Arrhythmia	Heart	Arrhythmia	Heart	Arrhythmia		
REMARKS:												
Furan	**4**	(11)	**0.4**	(1)	**0.025**	(0.07)	**0.025**	(0.07)	**0.025**	(0.07)	**Not Set**	(Not Set)
CAS #: 110-00-9	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Garcia, Hector D. and James, John T. (2000), Furan, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:307-329, National Academy Press, Washington, DC	Liver	Hepatotoxicity	Liver	Hepatotoxicity	Liver	Cancer	Liver	Cancer	Liver	Cancer		
REMARKS: Carcinogen												
Glutaraldehyde	**0.12**	(0.50)	**0.04**	(0.08)	**0.006**	(0.025)	**0.003**	(0.012)	**0.0006**	(0.002)	**Not Set**	(Not Set)
CAS #: 111-30-8	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Garcia, Hector D. (1996), Glutaraldehyde, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 3:271-291, National Academy Press, Washington, DC	Mucosa	Irritation	Mucosa	Irritation	RspSys	Lesions	RspSys	Lesions	RspSys	Lesions		
	CNS	Headache	CNS	Headache								
REMARKS:												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
Hexamethylcyclotrisiloxane	**Not Set**		**Not Set**		**10**	(90)	**5**	(45)	**1**	(9)	**Not Set**	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 541-05-9					RspSys / Injury		RspSys / Injury		RspSys / Injury			
REFERENCE: James, John T. (2000), Polydimethylcyclosiloxanes, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:151-174, National Academy Press, Washington, DC					CNS / Depression		CNS / Depression					
REMARKS: Documented as a polydimethylcyclosiloxane												
n- Hexane	**200**	(703)	**30**	(106)	**2.4**	(8.4)	**2.4**	(8.4)	**2.4**	(8.4)	**2.4**	(8.4)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 110-54-3	Mucosa / Irritation		Mucosa / Irritation		CNS / Neurotoxicity		CNS / Neurotoxicity		CNS / Neurotoxicity		CNS / Neurotoxicity	
REFERENCE: Garcia, H.D, Acceptable Limits for n-Hexane in Spacecraft Atmospheres. Aerospace Medicine and Human Performance. 2021;92(12);956-961.												
REMARKS:												
Hydrazine	**4**	(5)	**0.3**	(0.4)	**0.04**	(0.05)	**0.02**	(0.03)	**0.004**	(0.005)	**Not Set**	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 302-01-2	/ Death		Liver / Hepatotoxicity		Liver / Hepatotoxicity		Liver / Hepatotoxicity		Liver / Hepatotoxicity			
REFERENCE: Garcia, Hector D. and James, John T. (1996), Hydrazine, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 2:213-233, National Academy Press, Washington, DC							Liver / Hyperplasia		Liver / Hyperplasia			
							Nose / Cancer		Nose / Cancer			
REMARKS: Carcinogen												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
Hydrogen chloride	**5**	(8)	**2**	(3)	**1**	(1.5)	**1**	(1.5)	**1**	(1.5)	**Not Set**	(Not Set)
CAS #: 7647-01-0	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Lam, Chiu-Wing and Wong, King Lit (2000), Hydrogen Chloride, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:60-88, National Academy Press, Washington, DC	Eye	Irritation	Eye	Irritation	Eye	Irritation	Eye	Irritation	Eye	Irritation		
	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation		
REMARKS:												
Hydrogen cyanide	**8**	(9)	**4**	(4.5)	**1**	(1.1)	**1**	(1.1)	**1**	(1.1)	**Not Set**	(Not Set)
CAS #: 74-90-8	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Lam, Chiu-Wing and Wong, King Lit (2000), Hydrogen Cyanide, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:330-365, National Academy Press, Washington, DC	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression		
	CNS	Headache	CNS	Headache	CNS	Headache	CNS	Headache	CNS	Headache		
	CNS	Nausea	CNS	Nausea	CNS	Nausea	CNS	Nausea	CNS	Nausea		
					Testes	Testicular toxicity	Testes	Testicular toxicity	Testes	Testicular toxicity		
REMARKS:							Thyroid	Thyroid effects	Thyroid	Thyroid effects		
Hydrogen fluoride	**3**	(2.5)	**3**	(2.5)	**0.3**	(0.25)	**0.3**	(0.25)	**0.3**	(0.25)	**0.3**	(0.25)
CAS #: 7664-39-3	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Lam, C-W and Ryder, V.E. Spacecraft Maximum Allowable Concentrations for Hydrogen Fluoride. Aerospace Medicine and Human Performance. 2022; 93(10):1–3.	RspSys	Irritation	RspSys	Irritation	RspSys	Irritation	RspSys	Irritation	RspSys	Irritation	RspSys	Irritation
REMARKS:												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
Hydrogen sulfide	**5**	(7)	**1.3**	(1.8)	**1.3**	(1.8)	**1.3**	(1.8)	**0.3**	(0.5)	**Not Set**	
CAS #: 7683-06-4	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Wimberly, AA and Ryder VE. Exposure Limits for Hydrogen Sulfide in Spaceflight. NASA/TM-20240000101, NASA Johnson Space Center, 2024.	Nasal Cavity	Odor Irritant*	Nasal Cavity	Lesions	Nasal Cavity	Injury	Nasal Cavity	Injury	Nasal Cavity	Injury		
REMARKS: *The endpoint includes increased anxiety directly related to odor irritation.												
Indole	**1.0**	(5)	**0.3**	(1.5)	**0.05**	(0.25)	**0.05**	(0.25)	**0.05**	(0.25)	**Not Set**	(Not Set)
CAS #: 120-72-9	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Lam, Chiu-Wing and James, John T. (1996), Indole, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 2:235-249, National Academy Press, Washington, DC	CNS	Nausea	CNS Blood	Nausea Hematotoxicity	CNS Blood	Nausea Hematotoxicity	CNS Blood	Nausea Hematotoxicity Death	CNS Blood	Nausea Hematotoxicity Death		
REMARKS: Normal turnover of indole was used to establish a lower bound of 0.05 ppm.												
Isoprene	**50**	(140)	**25**	(70)	**2**	(6)	**2**	(6)	**1**	(3)	**Not Set**	(Not Set)
CAS #: 78-79-5	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: James, John T. (2000), Isoprene, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:89-118, National Academy Press, Washington, DC	Mucosa	Irritation	Mucosa	Irritation	Mucosa Blood	Irritation Anemia	Mucosa Blood	Irritation Anemia	Lung Blood CNS	Injury Anemia Neurotoxicity		
REMARKS:												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
Limonene	80	(450)	80	(450)	20	(115)	20	(115)	20	(115)	20	(115)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 5989-27-5	Eye / Irritation		Eye / Irritation		Eye / Irritation		Eye / Irritation		Eye / Irritation		Eye / Irritation	
REFERENCE: Lam, Chiu-Wing (2008), Limonene, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:250-274, National Academy Press, Washington, DC	Lung / Irritation		Lung / Irritation		Lung / Irritation		Lung / Irritation		Lung / Irritation		Lung / Irritation	
REMARKS:												
Linear Siloxanes	600	(varies)	100	(varies)	100	(varies)	50	(varies)	50	(varies)	50	(varies)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: various	Lung / Hemorrhage		Lung / Hemorrhage		Liver / Hepatotoxicity		Liver / Hepatotoxicity		Liver / Hepatotoxicity		Liver / Hepatotoxicity	
REFERENCE: Meyers, Valerie E., Hector D. Garcia, Tami S. McMullin, Joseph M. Tobin, and John T. James. Safe human exposure limits for airborne linear siloxanes during spaceflight. *Inhal Toxicol*, 2013: 25(13): 735-746.	CNS / Neurotoxicity		CNS / Neurotoxicity									
REMARKS: Includes hexamethyldisiloxane, octamethyltrisiloxane, decamethyltetrasiloxane, dodecamethylpentasiloxane. The mg/m3 value depends on the molecular weight of the particular linear siloxane.												
Manganese	3		2		0.3		0.3		0.008		0.008	
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 7439-96-5	Lung / Lesions		Lung / Lesions		Lung / Irritation		Lung / Irritation		CNS / Neurotoxicity		CNS / Neurotoxicity	
REFERENCE: Romoser AA, Ryder VE, McCoy JT. Spacecraft Maximum Allowable Concentrations for Manganese Compounds in Mars Dust. Aerosp Med Hum Perform. 2019; 90(8):709-719.					Nasal Cavity / Irritation		Nasal Cavity / Irritation					
REMARKS:												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
Mercury	**0.01**	(0.08)	**0.002**	(0.02)	**0.001**	(0.01)	**0.001**	(0.01)	**0.001**	(0.01)	**Not Set**	(Not Set)
CAS #: 7439-97-6	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: James, John T. and Kaplan, Harold L. (1996), Mercury, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 2:251-276, National Academy Press, Washington, DC	Lung	Irritation	Lung	Irritation	CNS Kidney	Neurotoxicity Nephrotoxicity	CNS Kidney	Neurotoxicity Nephrotoxicity	CNS Kidney	Neurotoxicity Nephrotoxicity		
REMARKS:												
Methanol	**70**	(92)	**70**	(92)	**20**	(26)	**20**	(26)	**20**	(26)	**10**	(13)
CAS #: 67-56-1	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Scully RR, Garcia H, McCoy JT, Ryder VE. Revisions to Limits for Methanol in the Air of Spacecraft. Aerosp Med Hum Perform. 2019; 90(9):807-812.	CNS	Neurotoxicity	CNS	Neurotoxicity	CNS	Neurotoxicity	CNS	Neurotoxicity	CNS	Neurotoxicity	CNS	Neurotoxicity
REMARKS:												
Methyl ethyl ketone	**50**	(150)	**50**	(150)	**10**	(30)	**10**	(30)	**10**	(30)	**Not Set**	(Not Set)
CAS #: 78-93-3	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Wong, King Lit (1996), Methyl Ethyl Ketone, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 2:307-329, National Academy Press, Washington, DC	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation		
REMARKS: Ceiling values												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
Methyl hydrazine	**0.002**	(0.004)	**0.002**	(0.004)	**0.002**	(0.004)	**0.002**	(0.004)	**0.002**	(0.004)	**Not Set**	(Not Set)
CAS #: 60-34-4	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
	Nose	Lesions	Nose	Lesions	Nose	Lesions	Nose	Lesions	Nose	Lesions		
REFERENCE: Garcia, Hector D. (2000), Methylhydrazine, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:119-136, National Academy Press, Washington, DC												
REMARKS: Carcinogen												
4- Methyl-2-pentanone	**35**	(140)	**35**	(140)	**35**	(140)	**35**	(140)	**35**	(140)	**Not Set**	(Not Set)
CAS #: 108-10-1	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression		
	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation		
REFERENCE: Wong, King Lit (2000), 4-Methyl-2-Pentanone, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:240-263, National Academy Press, Washington, DC												
REMARKS:												
Methylene chloride	**100**	(350)	**35**	(120)	**14**	(49)	**7**	(24)	**3**	(10)	**1**	(3.5)
CAS #: 75-09-2	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
	CNS	Depression	CNS	Depression	CNS	Depression	Liver	Hepatotoxicity	Liver	Hepatotoxicity	Kidney	Nephrotoxicity
REFERENCE: Ramanathan, Raghupathy (2008), Methylene Chloride, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:289-313, National Academy Press, Washington, DC												
REMARKS: CO formation, carcinogen												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
Nitromethane	25	(65)	15	(40)	7	(18)	7	(18)	5	(13)	Not Set	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 75-52-5	Blood / Anemia		Blood / Anemia		Blood / Anemia		Blood / Anemia		Blood / Anemia			
REFERENCE: Wong, King Lit (1996), Nitromethane, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 2:331-350, National Academy Press, Washington, DC												
REMARKS:												
Octamethylcyclotetrasiloxane	Not Set		Not Set		23	(280)	5	(60)	1	(12)	Not Set	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 556-67-2					Gonads / Toxicity CNS / Depression		Gonads / Toxicity		Gonad / Toxicity			
REFERENCE: James, John T. (2000), Polydimethylcyclosiloxanes, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:151-174, National Academy Press, Washington, DC												
REMARKS: Documented as a polydimethylcyclosiloxane												
Perfluoropropane and Other Aliphatic Perfluoroalkanes	11,000	(varies)	11,000	(varies)	11,000	(varies)	11,000	(varies)	11,000	(varies)	Not Set	(varies)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 76-19-7	CNS / Symptoms		CNS / Symptoms		CNS / Symptoms		CNS / Symptoms		CNS / Symptoms			
REFERENCE: Lam, Chiu-Wing (2000), Perfluoropropane and Other Aliphatic Perfluoroalkanes, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:137-150, National Academy Press, Washington, DC												

REMARKS: EXCLUDES perfluorocycloalkanes.
The mg/m3 value depends on the molecular weight of the particular perfluoroalkane.

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
2- Propanol	**400**	(1000)	**100**	(240)	**60**	(150)	**60**	(150)	**60**	(150)	**Not Set**	(Not Set)
	Organ	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
CAS #: 67-63-0	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression		
REFERENCE: James, John T. and Kaplan, Harold L. (1996), 2-Propanol, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 2:351-371, National Academy Press, Washington, DC	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation		
			Liver	Hepatotoxicity	Liver	Hepatotoxicity	PNS	DCV	PNS	DCV		
							Liver	Hepatotoxicity	Liver	Hepatotoxicity		
REMARKS:												
Propylene glycol	**64**	(200)	**32**	(100)	**32**	(100)	**32**	(100)	**32**	(100)	**32**	(100)
	Organ	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
CAS #: 57-55-6	Mucosa	Irritation	Mucosa	Irritation	Blood	Elevated hemoglobin	Blood	Elevated hemoglobin	Blood	Elevated hemoglobin	Blood	Elevated hemoglobin
REFERENCE: Ryder, V.E. and Williams, E.S. Revisions to Limits for Propylene Glycol in Spacecraft Air. Aerospace Medicine and Human Performance. 2022; 93(5):467-469.	Eye	Irritation	Eye	Irritation		Body Weight Gain		Body Weight Gain		Body Weight Gain		Body Weight Gain
	CNS	Fatigue	CNS	Fatigue								
	CNS	Headache	CNS	Headache								
REMARKS: updated from 2008, NRC Vol 5												
Toluene	**40**	(151)	**40**	(151)	**40**	(151)	**40**	(151)	**4**	(15)	**4**	(15)
	Organ	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
CAS #: 108-88-3	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression	Gonads	Hormone	Gonads	Hormone
REFERENCE: Tapia CM, Langford SD, Ryder VE. Revisions to Limits for Toluene in Spacecraft Air. Aerosp Med Hum Perform. 2024.					Ear	Ototoxicity	Ear	Ototoxicity				
					Eye	Ocular toxicity	Eye	Ocular toxicity				
Garcia, Hector D. (2008), Toluene, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:329-347, National Academy Press, Washington, DC.												
REMARKS:												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
Trichloroethylene	**50**	(270)	**11**	(60)	**9**	(50)	**4**	(20)	**2**	(10)	**Not Set**	(Not Set)
CAS #: 79-01-6	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: James, John T., Kaplan, Harold L., and Coleman, Martin E. (1996), Trichloroethylene, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 3:292-320, National Academy Press, Washington, DC	CNS	Depression	CNS	Depression	Kidney	Nephrotoxicity	Kidney	Nephrotoxicity	Multi.	Cancer		
	Heart	Arrhythmia			Liver	Hepatotoxicity	Liver	Hepatotoxicity	Kidney	Nephrotoxicity		
									Liver	Hepatotoxicity		
REMARKS: See dichloroacetylene if alkali scrubber is present. Possible carcinogen.												
Trimethylsilanol	**15**	(55)	**2**	(7)	**1**	(4)	**1**	(4)	**1**	(4)	**1**	(4)
CAS #: 1066-40-6	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: James, John T. (2008), Trimethylsilanol, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:348-355, National Academy Press, Washington, DC	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression
REMARKS:												
Vinyl chloride	**130**	(330)	**30**	(77)	**1**	(2.6)	**1**	(2.6)	**1**	(2.6)	**Not Set**	(Not Set)
CAS #: 75-01-4	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Wong, King Lit (1994), Vinyl Chloride, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 1:185-219, National Academy Press, Washington, DC	Liver	Hepatotoxicity	Liver	Hepatotoxicity	Testes	Necrosis	Testes	Necrosis	Testes	Necrosis		
	CNS	Headache	CNS	Depression								
	CNS	Depression										
REMARKS:												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

SMACs (Spacecraft Maximum Allowable Concentrations)

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)	ppm	(mg/m^3)
Xylenes	**50**	(215)	**17**	(73)	**17**	(73)	**17**	(73)	**8.5**	(37)	**1.5**	(6.5)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 1330-20-7 (mixed)	Mucosa / Irritation		Mucosa / Irritation		CNS / Neurotoxicity		CNS / Neurotoxicity		Ear / Ototoxicity		Ear / Ototoxicity	
REFERENCE: Ramanathan, Raghupathy (2008), Xylenes, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:356-386, National Academy Press, Washington, DC	CNS / Headache		CNS / Headache									
	Eye / Irritation		Eye / Irritation									

REMARKS: Applies to each individual xylene isomer and mixtures of xylene isomers.

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; LEL: Lower Explosive Limit; PNS: Peripheral Nervous System; ppm: parts per million; RespSys: Respiratory System; U.Blad: Urinary bladder

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APPENDIX A ACRONYMS AND ABBREVIATIONS

CAS	Chemical Abstract Service
C_n	Specific Concentration
CNS	Central Nervous System
CV	Cardiovascular
DCD	Decreased Color Discrimination
DCV	Decreased Conduction Velocity
GI	Gastrointestinal
HA	Headache
ISS	International Space Station
JSC	Johnson Space Center
NASA	National Aeronautics and Space Administration
NRC	National Research Council
NRCCOT	National Research Council Committee on Toxicology
PNS	Peripheral Nervous System
ppm	Parts Per Million
RespSys	Respiratory System
SMACs	Spacecraft Maximum Allowable Concentrations
T_{grp}	Toxicity Index
U.Blad	Urinary Bladder