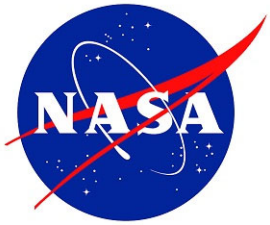
Spacecraft Maximum Allowable Concentrations for Airborne Contaminants

Human Health and Performance Directorate

Biomedical Research and Environmental Sciences Control Board (BRESCB) Controlled

Revision B

November 2022



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

PREPARED BY:

Valerie Ryder Digitally signed by Valerie Ryder Date: 2022.12.13 16:27:28 -06'00' — 12/13/22

Valerie E. Ryder, Ph.D., DABT — DATE
Toxicologist
Biomedical Research and Environmental Sciences Division

CONCURRED BY:

DANIEL GAZDA Digitally signed by DANIEL GAZDA Date: 2022.12.13 16:22:12 -06'00' — 12/13/22

Daniel B. Gazda — DATE
Chief, Environmental Sciences Branch
Biomedical Research and Environmental Sciences Division

JUDITH HAYES Digitally signed by JUDITH HAYES Date: 2022.12.13 16:16:23 -06'00' — 12/13/22

Judith C. Hayes — DATE
Chief, Biomedical Research and Environmental Sciences Division

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Lyndon B. Johnson Space Center
Houston, Texas

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

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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. 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) or through publication in the peer-reviewed scientific literature. Based on documented guidance (NRC, 1992; NRC, 2016), NASA has established SMACs for 60 chemical 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. 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 CAS #: 75-07-0 REFERENCE: Wong, King Lit, (1994), Acetaldehyde, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants Vol 1: 19-38, National Academy Press, Washington, DC REMARKS: Carcinogen	**10**	(18)	**6**	(10)	**2**	(4)	**2**	(4)	**2**	(4)	**Not Set**	(Not Set)
	Organ	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation		
									Throat	Cancer		
Acetone CAS #: 67-64-1 REFERENCE: Garcia, Hector D. (2000), Acetone, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:17-41, National Academy Press, Washington, DC REMARKS:	**500**	(1200)	**200**	(500)	**22**	(52)	**22**	(52)	**22**	(52)	**Not Set**	(Not Set)
	Organ	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
	CNS	Fatigue	CNS	Fatigue	CNS	Fatigue	CNS	Fatigue	CNS	Fatigue		
					CNS	Headache	CNS	Headache	CNS	Headache		
Acrolein CAS #: 107-02-8 REFERENCE: Langford, Shannon D. (2008), Acrolein, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:13-33, National Academy Press, Washington, DC REMARKS: Ceiling values	**0.075**	(0.17)	**0.035**	(0.08)	**0.015**	(0.03)	**0.015**	(0.03)	**0.008**	(0.02)	**0.008**	(0.02)
	Organ	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation
C3-C8 Aliphatic Saturated Aldehydes CAS #: various 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.	**45**	(varies)	**45**	(varies)	**5**	(varies)	**5**	(varies)	**5**	(varies)	**5**	(varies)
	Organ	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
	Mucosa	Irritation	Mucosa	Irritation	Nasal Cavity	Injury	Nasal Cavity	Injury	Nasal Cavity	Injury	Nasal Cavity	Injury

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)
C1-C4 Alkanes	10% LEL	(varies)	10% LEL	(varies)	10% LEL	(varies)	10% LEL	(varies)	10% LEL	(varies)	Not Set	(Not Set)
	Organ	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
CAS #: various		Explosion		Explosion		Explosion		Explosion		Explosion		
REFERENCE: McCoy, J. Torin. (2008), C2-C9 Alkanes and Garcia, Hector D. (1994), Methane, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:85-111 and Vol 1: 143-148, National Academy Press, Washington, DC												
REMARKS: Includes methane, ethane, propane, and butane Toxicity of these flammable gases occurs at much higher levels than the explosive hazard, so the ceiling limit is set at 10% of the lower explosive limit The mg/m3 value depends on the molecular weight of the particular alkane.												
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	CNS	Depression	CNS	Depression	CNS	Depression	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	Eye	Irritation	Eye	Irritation			CNS	Ototoxicity				
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.	Nose	Irritation	Nose	Irritation								
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	Eye	Irritation	Eye	Irritation	Eye	Irritation	Eye	Irritation	Eye	Irritation
REFERENCE: Garcia, Hector D. (2008), Ammonia, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:48-61, National Academy Press, Washington, DC	CNS	Headache	CNS	Headache	CNS	Headache	CNS	Headache	CNS	Headache	CNS	Headache
REMARKS:												
Benzene	10	(35)	3	(10)	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	Blood	Immunotoxicity	Blood	Immunotoxicity	Blood	Immunotoxicity	Blood	Immunotoxicity	Blood	Immunotoxicity	Blood	Hematological
REFERENCE: Kahn-Mayberry, Noreen N. (2008), Benzene, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:62-72, National Academy Press, Washington, DC	Blood	Anemia			Blood	Hematological			Blood	Leukemia		
REMARKS: Leukemogen	CNS	Grip/strength										

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)
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.												
tert- Butanol	**50**	(150)	**50**	(150)	**50**	(150)	**50**	(150)	**40**	(120)	**Not Set**	(Not Set)
	Organ	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
CAS #: 75-65-0	CNS	Depression	CNS	Depression	CNS	Depression	Kidney	Nephrotoxicity	Kidney	Nephrotoxicity		
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		
REMARKS:									U. Blad	Injury		
Carbon monoxide	**425**	(485)	**100**	(114)	**55**	(63)	**15**	(17)	**15**	(17)	**15**	(17)
	Organ	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
CAS #: 630-08-0	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression
REFERENCE: James, John T. (2008), Carbon Monoxide, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:125-143, National Academy Press, Washington, DC	CV	Arrhythmia	CV	Arrhythmia	CV	Arrhythmia	CV	Arrhythmia	CV	Arrhythmia	CV	Arrhythmia
REMARKS: Carboxyhemoglobin target												

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)
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		
REMARKS:	Kidney	Nephrotoxicity	Kidney	Nephrotoxicity	Liver	Hepatotoxicity	Liver	Hepatotoxicity	Liver	Hepatotoxicity		
					Kidney	Nephrotoxicity						
Decamethylcyclopentasiloxane	**Not Set**	(Not Set)	**Not Set**	(Not Set)	**7**	(100)	**5**	(75)	**1**	(15)	**Not Set**	(Not Set)
CAS #: 541-02-6	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: James, John T. (2000), Polydimethylcyclosiloxanes, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:151-174, National Academy Press, Washington, DC					RspSys	Injury	RspSys	Injury	RspSys	Injury		
REMARKS: Documented as a polydimethylcyclosiloxane					Gonad	Toxicity	Gonad	Toxicity	Gonad	Toxicity		
Diacetone alcohol	**50**	(250)	**50**	(250)	**20**	(100)	**6**	(30)	**4**	(20)	**Not Set**	(Not Set)
CAS #: 123-42-2	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: James, John T. (1996), Diacetone alcohol, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 3:105-116, National Academy Press, Washington, DC	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Liver	Hepatomegaly		
REMARKS:	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression		
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)
CAS #: 7572-29-4	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: James, John T. (1996), Dichloroacetylene, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 3:117-134, National Academy Press, Washington, DC	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression		
REMARKS:	Kidney	Nephrotoxicity	Kidney	Nephrotoxicity	Kidney	Nephrotoxicity	Kidney	Nephrotoxicity	Kidney	Nephrotoxicity		
	Liver	Hepatotoxicity	Liver	Hepatotoxicity								

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 REFERENCE: Ramanathan, Raghupathy (2008), 1,2-Dichloroethane, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:144-161, National Academy Press, Washington, DC REMARKS: Impairs host defenses against bacteria.	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
	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
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 REFERENCE: Khan-Mayberry, Noreen N. (2008), Dimethylhydrazine, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:162-189, National Academy Press, Washington, DC REMARKS:	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
	CNS		CNS		Blood	Anemia	Blood	Anemia	Liver	Anemia		
									Liver	Hepatotoxicity		
Ethanol	**5000**	(10000)	**5000**	(10000)	**1000**	(2000)	**1000**	(2000)	**1000**	(2000)	**1000**	(2000)
CAS #: 64-17-5 REFERENCE: McCoy, J. Torin (2008), Ethanol, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:190-205, National Academy Press, Washington, DC REMARKS:	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
	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
2- Ethoxyethanol	**10**	(40)	**10**	(40)	**0.8**	(3)	**0.5**	(2)	**0.07**	(0.3)	**Not Set**	(Not Set)
CAS #: 110-80-5 REFERENCE: Wong, King Lit (1996), 2-Ethoxyethanol, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 2:189-212, National Academy Press, Washington, DC REMARKS:	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
	Blood	Hematotoxicity	Blood	Hematotoxicity	Blood	Hematotoxicity	Blood	Hematotoxicity	Blood	Hematotoxicity		
	Mucosa	Irritation	Mucosa	Irritation	Testes	Toxicity	Testes	Toxicity	Testes	Toxicity		

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)
Ethyl acetate	**400**	(1440)	**400**	(1440)	**117**	(421)	**117**	(421)	**117**	(421)	**39**	(140)
CAS #: 141-78-6	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Williams, E.S. and Ryder, V.E. Spacecraft maximum allowable concentrations for ethyl acetate. Aerosp Med Hum Perform. 2023; 94(1):1–9.	Mucosa	Irritation	Mucosa	Irritation	Body Weight	Reduction	Body Weight	Reduction	Body Weight	Reduction	Body Weight	Reduction
REMARKS:												
Ethylbenzene	**180**	(780)	**60**	(260)	**30**	(130)	**30**	(130)	**12**	(50)	**Not Set**	(Not Set)
CAS #: 100-41-4	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Garcia, Hector D. (1996), Ethylbenzene, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 3:208-231, National Academy Press, Washington, DC	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Testes	Necrosis		
REMARKS:	CNS	Depression	CNS	Depression	Testes	Necrosis	Testes	Necrosis				
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	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation		
REMARKS:			CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression		
					Kidney	Nephrotoxicity	Kidney	Nephrotoxicity	Kidney	Nephrotoxicity		
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
REMARKS: Ceiling values, Carcinogen											Nose	Cancer

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 11 CAS #: 75-69-4 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 REMARKS:	140	(790)	140	(790)	140	(790)	140	(790)	140	(790)	Not Set	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
	Heart / Arrhythmia		Heart / Arrhythmia		Heart / Arrhythmia		Heart / Arrhythmia		Heart / Arrhythmia			
Freon 113 CAS #: 76-13-1 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:	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*	
	Heart / Arrhythmia		Heart / Arrhythmia		Heart / Arrhythmia		Heart / Arrhythmia		Heart / Arrhythmia			
Freon 12 CAS #: 75-71-8 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:	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*	
	Heart / Tachycardia		Heart / Arrhythmia		Heart / Arrhythmia		Heart / Arrhythmia		Heart / Arrhythmia			
Freon 21 CAS #: 75-43-4 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:	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*	
	Heart / Tachycardia		Heart / Tachycardia		Liver / Hepatotoxicity		Liver / Hepatotoxicity		Liver / Hepatotoxicity			

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		
REMARKS:	Heart	Arrhythmia	Heart	Arrhythmia	Heart	Arrhythmia	Heart	Arrhythmia	Heart	Arrhythmia		
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		
REMARKS:	CNS	Headache	CNS	Headache								
Hexamethylcyclotrisiloxane	**Not Set**		**Not Set**		**10**	(90)	**5**	(45)	**1**	(9)	**Not Set**	(Not Set)
CAS #: 541-05-9	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: James, John T. (2000), Polydimethylcyclosiloxanes, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:151-174, National Academy Press, Washington, DC					RspSys	Injury	RspSys	Injury	RspSys	Injury		
REMARKS: Documented as a polydimethylcyclosiloxane					CNS	Depression	CNS	Depression				

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)
n- Hexane	**200**	(703)	**30**	(106)	**2.4**	(8.4)	**2.4**	(8.4)	**2.4**	(8.4)	**2.4**	(8.4)
CAS #: 110-54-3	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Garcia, H.D. Acceptable Limits for n-Hexane in Spacecraft Atmospheres. Aerospace Medicine and Human Performance. 2021;92(12):956-961.	Mucosa	Irritation	Mucosa	Irritation	CNS	Neurotoxicity	CNS	Neurotoxicity	CNS	Neurotoxicity	CNS	Neurotoxicity
REMARKS:												
Hydrazine	**4**	(5)	**0.3**	(0.4)	**0.04**	(0.05)	**0.02**	(0.03)	**0.004**	(0.005)	**Not Set**	(Not Set)
CAS #: 302-01-2	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
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		Death	Liver	Hepatotoxicity	Liver	Hepatotoxicity	Liver	Hepatotoxicity	Liver	Hepatotoxicity		
REMARKS: Carcinogen							Liver	Hyperplasia	Liver	Hyperplasia		
							Nose	Cancer	Nose	Cancer		
Hydrogen	**4100**	(340)	**4100**	(340)	**4100**	(340)	**4100**	(340)	**4100**	(340)	**Not Set**	(Not Set)
CAS #: 1333-74-0	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Wong, King Lit (1994), Hydrogen, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 1:139-141, National Academy Press, Washington, DC		Explosion		Explosion		Explosion		Explosion		Explosion		
REMARKS: Ceiling values are 10% of the Lower Explosive Limit												
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		
REMARKS:	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation		

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 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		
REMARKS:	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		
							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:												
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	Nausea	CNS	Nausea	CNS	Nausea	CNS	Nausea		
REMARKS: Normal turnover of indole was used to establish a lower bound of 0.05 ppm.			Blood	Hematotoxicity	Blood	Hematotoxicity	Blood	Hematotoxicity	Blood	Hematotoxicity		
								Death		Death		
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	Irritation	Mucosa	Irritation	Lung	Injury		
REMARKS:					Blood	Anemia	Blood	Anemia	Blood	Anemia		
									CNS	Neurotoxicity		

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)
CAS #: 5989-27-5	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Lam, Chiu-Wing (2008), Limonene, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:250-274, National Academy Press, Washington, DC	Eye	Irritation	Eye	Irritation	Eye	Irritation	Eye	Irritation	Eye	Irritation	Eye	Irritation
REMARKS:	Lung	Irritation	Lung	Irritation	Lung	Irritation	Lung	Irritation	Lung	Irritation	Lung	Irritation
Linear Siloxanes	600	(varies)	100	(varies)	100	(varies)	50	(varies)	50	(varies)	50	(varies)
CAS #: various	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
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.	Lung	Neurotoxicity	Lung	Neurotoxicity	Liver	Hepatotoxicity	Liver	Hepatotoxicity	Liver	Hepatotoxicity	Liver	Hepatotoxicity
REMARKS: Includes hexamethyldisiloxane, octamethyltrisiloxane, decamethyltetrasiloxane, dodecamethylpentasiloxane. The mg/m3 value depends on the molecular weight of the particular linear siloxane.												
Manganese	3		1		0.3		0.3		0.008		0.008	
CAS #: 7439-96-5	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
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.	Lung	Lesions	Lung	Lesions	Lung	Irritation	Lung	Irritation	CNS	Neurotoxicity	CNS	Neurotoxicity
REMARKS:					Nasal Cavity	Irritation	Nasal Cavity	Irritation				
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	Neurotoxicity	CNS	Neurotoxicity	CNS	Neurotoxicity		
REMARKS:					Kidney	Nephrotoxicity	Kidney	Nephrotoxicity	Kidney	Nephrotoxicity		

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)
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												
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*	
REFERENCE: Garcia, Hector D. (2000), Methylhydrazine, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:119-136, National Academy Press, Washington, DC	Nose / Lesions		Nose / Lesions		Nose / Lesions		Nose / Lesions		Nose / Lesions			
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*	
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	CNS / Depression Mucosa / Irritation		CNS / Depression Mucosa / Irritation		CNS / Depression Mucosa / Irritation		CNS / Depression Mucosa / Irritation		CNS / Depression Mucosa / 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)
Methylene chloride CAS #: 75-09-2 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	100	(350)	35	(120)	14	(49)	7	(24)	3	(10)	1	(3.5)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
	CNS / Depression		CNS / Depression		CNS / Depression		Liver / Hepatotoxicity		Liver / Hepatotoxicity		Kidney / Nephrotoxicity	
Nitromethane CAS #: 75-52-5 REFERENCE: Wong, King Lit (1996), Nitromethane, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 2:331-350, National Academy Press, Washington, DC REMARKS:	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*	
	Blood / Anemia		Blood / Anemia		Blood / Anemia		Blood / Anemia		Blood / Anemia			
Octamethylcyclotetrasiloxane CAS #: 556-67-2 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	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*	
					Gonads / Toxicity CNS / Depression		Gonads / Toxicity		Gonad / Toxicity			
Perfluoropropane and Other Aliphatic Perfluoroalkanes CAS #: 76-19-7 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.	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*	
	CNS / Symptoms		CNS / Symptoms		CNS / Symptoms		CNS / Symptoms		CNS / Symptoms			

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)
CAS #: 67-63-0	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
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	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression		
REMARKS:	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation		
			Liver	Hepatotoxicity	Liver	Hepatotoxicity	PNS	DCV	PNS	DCV		
							Liver	Hepatotoxicity	Liver	Hepatotoxicity		
Propylene glycol	**64**	(200)	**32**	(100)	**32**	(100)	**32**	(100)	**32**	(1100)	**32**	(100)
CAS #: 57-55-6	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
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.	Mucosa	Irritation	Mucosa	Irritation	Blood	Elevated hemoglobin	Blood	Elevated hemoglobin	Blood	Elevated hemoglobin	Blood	Elevated hemoglobin
REMARKS: updated from 2008, NRC Vol 5	Eye	Irritation	Eye	Irritation		Body Weight Gain		Body Weight Gain		Body Weight Gain		Body Weight Gain
	CNS	Fatigue	CNS	Fatigue								
	CNS	Headache	CNS	Headache								
Toluene	**16**	(60)	**16**	(60)	**4**	(15)	**4**	(15)	**4**	(15)	**4**	(15)
CAS #: 108-88-3	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Garcia, Hector D. (2008), Toluene, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:329-347, National Academy Press, Washington, DC	CNS	Depression	CNS	Dizziness	Ear	Ototoxicity	Ear	Ototoxicity	Ear	Ototoxicity	Ear	Ototoxicity
REMARKS:									Gonads	Hormone	Gonads	Hormone
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		
REMARKS: See dichloroacetylene if alkali scrubber is present. Possible carcinogen.	Heart	Arrhythmia			Liver	Hepatotoxicity	Liver	Hepatotoxicity	Kidney	Nephrotoxicity		
									Liver	Hepatotoxicity		

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)
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		
REMARKS:	CNS	Headache	CNS	Depression								
	CNS	Depression										
Xylenes	50	(215)	17	(73)	17	(73)	17	(73)	8.5	(37)	1.5	(6.5)
CAS #: 1330-20-7 (mixed)	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Ramanathan, Raghupathy (2008), Xylenes, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:356-386, National Academy Press, Washington, DC	Mucosa	Irritation	Mucosa	Irritation	CNS	Neurotoxicity	CNS	Neurotoxicity	Ear	Ototoxicity	Ear	Ototoxicity
REMARKS: Applies to each individual xylene isomer and mixtures of xylene isomers.	CNS	Headache	CNS	Headache								
	Eye	Irritation	Eye	Irritation								

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

3.0 REFERENCES

NRC (1992) Guidelines for Developing Spacecraft Maximum Allowable Concentration for Space Station Contaminants, National Academy Press, Washington, D.C.

NRC (1994) Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Volume 1, National Academy Press, Washington, D.C.

NRC (1996) Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Volume 2, National Academy Press, Washington, D.C.

NRC (1996) Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Volume 3, National Academy Press, Washington, D.C.

NRC (2000) Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Volume 4, National Academy Press, Washington, D.C.

NRC (2008) Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Volume 5, National Academy Press, Washington, D.C.

Meyers VE, Garcia HD, James JT. Safe Human Exposure Limits for Airborne Linear Siloxanes during Spaceflight. Inhalation Toxicology 2013; 25(13):735-46.

NRC (2016) Refinements to the Methods for Developing Spacecraft Exposure Guidelines, National Academy Press, Washington, D.C

Romoser AA, Ryder VE, McCoy JT. Spacecraft Maximum Allowable Concentrations for Manganese Compounds in Mars Dust. Aerospace Medicine and Human Performance 2019; 90(8):709-719.

Scully RR, Garcia H, McCoy JT, Ryder VE. Revisions to Limits for Methanol in the Air of Spacecraft. Aerospace Medicine and Human Performance 2019; 90(9):807-812.

Garcia, H.D, Acceptable Limits for n-Hexane in Spacecraft Atmospheres. Aerospace Medicine and Human Performance. 2021;92(12);956-961.

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.Lam, C-W and Ryder, V.E. Spacecraft Maximum Allowable Concentrations for Hydrogen Fluoride. Aerospace Medicine and Human Performance. 2022; 93(5);467-469.

Williams, E.S. Spacecraft Maximum Allowable Concentrations for Ethyl Acetate. Aerospace Medicine and Human Performance. 2022; 93(5);467-469.

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