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Spacecraft Maximum Allowable Concentrations for Airborne Contaminants

Human Health and Performance Directorate

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Biomedical Research and Environmental Sciences (BRESCB) Controlled

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Revision A

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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
Lyndon B. Johnson Space Center
Houston, Texas

CHANGE HISTORY

Requested changes shall be submitted on Change Request (CR) Form and approved by the BRES Configuration Control Board (CCB).

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	04/2020	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

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1.0 BACKGROUND

SPACECRAFT MAXIMUM ALLOWABLE CONCENTRATIONS FOR AIRBORNE CONTAMINANTS 2020

The enclosed table lists official Spacecraft Maximum Allowable Concentrations (SMACs) for selected airborne contaminants. 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), NASA has established SMACs for 56 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; RespSys: Respiratory System; DCV: Decreased Conduction Velocity; U.Blad: Urinary bladder; GI: Gastrointestinal tract; HA: Headache; PNS: Peripheral Nervous System

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; RespSys: Respiratory System; DCV: Decreased Conduction Velocity; U.Blad: Urinary bladder; GI: Gastrointestinal tract; HA: Headache; PNS: Peripheral Nervous System

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; RespSys: Respiratory System; DCV: Decreased Conduction Velocity; U.Blad: Urinary bladder; GI: Gastrointestinal tract; HA: Headache; PNS: Peripheral Nervous System

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)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
CAS #: 67-66-3	CNS / Depression		CNS / Depression		CNS / Depression		CNS / Depression		CNS / Depression			
REFERENCE: Garcia, Hector D. (2000), Chloroform, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:264-306, National Academy Press, Washington, DC	Kidney / Nephrotoxicity		Kidney / Nephrotoxicity		Liver / Hepatotoxicity		Liver / Hepatotoxicity		Liver / Hepatotoxicity			
REMARKS:					Kidney / Nephrotoxicity							
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			
REMARKS:	Liver / Hepatotoxicity		Liver / Hepatotoxicity									

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; RespSys: Respiratory System; DCV: Decreased Conduction Velocity; U.Blad: Urinary bladder; GI: Gastrointestinal tract; HA: Headache; PNS: Peripheral Nervous System

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
REMARKS: Impairs host defenses against bacteria.	.		.		.		.				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	*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		
REMARKS:									Liver	Hepatotoxicity		
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
REMARKS:	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	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
REFERENCE: Wong, King Lit (1996), 2-Ethoxyethanol, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 2:189-212, National Academy Press, Washington, DC	Blood	Hematotoxicity	Blood	Hematotoxicity	Blood	Hematotoxicity	Blood	Hematotoxicity	Blood	Hematotoxicity		
REMARKS:	Mucosa	Irritation	Mucosa	Irritation	Testes	Toxicity	Testes	Toxicity	Testes	Toxicity		

Abbreviations: CNS: Central Nervous System; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; PNS: Peripheral Nervous System; CV: Cardiovascular; 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)
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*	
	Mucosa / Irritation		Mucosa / Irritation		Mucosa / Irritation		Mucosa / Irritation		Testes / Necrosis			
	CNS / Depression		CNS / Depression		Testes / Necrosis		Testes / Necrosis					
CAS #: 100-41-4												
REFERENCE: Garcia, Hector D. (1996), Ethylbenzene, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 3:208-231, National Academy Press, Washington, DC												
REMARKS:												
Ethylene glycol	**25**	(64)	**25**	(64)	**5**	(13)	**5**	(13)	**5**	(13)	**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			
			CNS / Depression		CNS / Depression		CNS / Depression		CNS / Depression			
					Kidney / Nephrotoxicity		Kidney / Nephrotoxicity		Kidney / Nephrotoxicity			
CAS #: 107-21-1												
REFERENCE: Wong, King Lit (1996), Ethylene glycol, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 3:232-270, National Academy Press, Washington, DC												
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)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
	Mucosa / Irritation		Mucosa / Irritation		Mucosa / Irritation		Mucosa / Irritation		Mucosa / Irritation		Mucosa / Irritation	
											Nose / Cancer	
CAS #: 50-00-0												
REFERENCE: McCoy, J. Torin (2008), Formaldehyde, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:206-249, National Academy Press, Washington, DC												
REMARKS: Ceiling values, Carcinogen												
Freon 11	**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			
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:												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; RespSys: Respiratory System; DCV: Decreased Conduction Velocity; U.Blad: Urinary bladder; GI: Gastrointestinal tract; HA: Headache; PNS: Peripheral Nervous System

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)
CAS #: 76-13-1	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
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	Heart	Arrhythmia	Heart	Arrhythmia	Heart	Arrhythmia	Heart	Arrhythmia	Heart	Arrhythmia		
REMARKS:												
Freon 12	540	(2600)	95	(470)	95	(470)	95	(470)	95	(470)	Not Set	(Not Set)
CAS #: 75-71-8	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
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	Heart	Tachycardia	Heart	Arrhythmia	Heart	Arrhythmia	Heart	Arrhythmia	Heart	Arrhythmia		
REMARKS:												
Freon 21	50	(210)	50	(210)	15	(63)	12	(50)	2	(8)	Not Set	(Not Set)
CAS #: 75-43-4	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
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	Heart	Tachycardia	Heart	Tachycardia	Liver	Hepatotoxicity	Liver	Hepatotoxicity	Liver	Hepatotoxicity		
REMARKS:												
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		

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; RespSys: Respiratory System; DCV: Decreased Conduction Velocity; U.Blad: Urinary bladder; GI: Gastrointestinal tract; HA: Headache; PNS: Peripheral Nervous System

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)
Furan CAS #: 110-00-9 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 REMARKS: Carcinogen	**4**	(11)	**0.4**	(1)	**0.025**	(0.07)	**0.025**	(0.07)	**0.025**	(0.07)	**Not Set**	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
	Liver / Hepatotoxicity		Liver / Hepatotoxicity		Liver / Cancer		Liver / Cancer		Liver / Cancer			
Glutaraldehyde CAS #: 111-30-8 REFERENCE: Garcia, Hector D. (1996), Glutaraldehyde, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 3:271-291, National Academy Press, Washington, DC REMARKS:	**0.12**	(0.50)	**0.04**	(0.08)	**0.006**	(0.025)	**0.003**	(0.012)	**0.0006**	(0.002)	**Not Set**	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
	Mucosa / Irritation		Mucosa / Irritation		RspSys / Lesions		RspSys / Lesions		RspSys / Lesions			
	CNS / Headache		CNS / Headache									
Hexamethylcyclotrisiloxane CAS #: 541-05-9 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**		**10**	(90)	**5**	(45)	**1**	(9)	**Not Set**	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
					RspSys / Injury		RspSys / Injury		RspSys / Injury			
					CNS / Depression		CNS / Depression					
Hydrazine CAS #: 302-01-2 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 REMARKS: Carcinogen	**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*	
	Death		Liver / Hepatotoxicity		Liver / Hepatotoxicity		Liver / Hepatotoxicity		Liver / Hepatotoxicity			
							Liver / Hyperplasia		Liver / Hyperplasia			
							Nose / Cancer		Nose / Cancer			

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; RespSys: Respiratory System; DCV: Decreased Conduction Velocity; U.Blad: Urinary bladder; GI: Gastrointestinal tract; HA: Headache; PNS: Peripheral Nervous System

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 CAS #: 1333-74-0 REFERENCE: Wong, King Lit (1994), Hydrogen, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 1:139-141, National Academy Press, Washington, DC REMARKS: Ceiling values are 10% of the Lower Explosive Limit	**4100**	(340)	**4100**	(340)	**4100**	(340)	**4100**	(340)	**4100**	(340)	**Not Set**	(Not Set)
	Organ	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
		Explosion		Explosion		Explosion		Explosion		Explosion		
Hydrogen chloride CAS #: 7647-01-0 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 REMARKS:	**5**	(8)	**2**	(3)	**1**	(1.5)	**1**	(1.5)	**1**	(1.5)	**Not Set**	(Not Set)
	Organ	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
	Eye	Irritation	Eye	Irritation	Eye	Irritation	Eye	Irritation	Eye	Irritation		
	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation		
Hydrogen cyanide CAS #: 74-90-8 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 REMARKS:	**8**	(9)	**4**	(4.5)	**1**	(1.1)	**1**	(1.1)	**1**	(1.1)	**Not Set**	(Not Set)
	Organ	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
	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		
							Thyroid	Thyroid effects	Thyroid	Thyroid effects		
Indole CAS #: 120-72-9 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 REMARKS: Normal turnover of indole was used to establish a lower bound of 0.05 ppm.	**1.0**	(5)	**0.3**	(1.5)	**0.05**	(0.25)	**0.05**	(0.25)	**0.05**	(0.25)	**Not Set**	(Not Set)
	Organ	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
	CNS	Nausea	CNS	Nausea	CNS	Nausea	CNS	Nausea	CNS	Nausea		
			Blood	Hematotoxicity	Blood	Hematotoxicity	Blood	Hematotoxicity	Blood	Hematotoxicity		
								Death		Death		

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; RespSys: Respiratory System; DCV: Decreased Conduction Velocity; U.Blad: Urinary bladder; GI: Gastrointestinal tract; HA: Headache; PNS: Peripheral Nervous System

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)
Isoprene	50	(140)	25	(70)	2	(6)	2	(6)	1	(3)	Not Set	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
	Mucosa / Irritation		Mucosa / Irritation		Mucosa / Irritation Blood / Anemia		Mucosa / Irritation Blood / Anemia		Lung / Injury Blood / Anemia CNS / Neurotoxicity			
CAS #: 78-79-5 REFERENCE: James, John T. (2000), Isoprene, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 4:89-118, National Academy Press, Washington, DC REMARKS:												
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*	
	Eye / Irritation Lung / Irritation		Eye / Irritation Lung / Irritation		Eye / Irritation Lung / Irritation		Eye / Irritation Lung / Irritation		Eye / Irritation Lung / Irritation		Eye / Irritation Lung / Irritation	
CAS #: 5989-27-5 REFERENCE: Lam, Chiu-Wing (2008), Limonene, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:250-274, National Academy Press, Washington, DC 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*	
	Lung / Neurotoxicity		Lung / Neurotoxicity		Liver / Hepatotoxicity		Liver / Hepatotoxicity		Liver / Hepatotoxicity		Liver / Hepatotoxicity	
CAS #: various 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. 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	
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
	Lung / Lesions		Lung / Lesions		Lung / Irritation Nasal Cavity / Irritation		Lung / Irritation Nasal Cavity / Irritation		CNS / Neurotoxicity		CNS / Neurotoxicity	
CAS #: 7439-96-5 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. REMARKS:												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; RespSys: Respiratory System; DCV: Decreased Conduction Velocity; U.Blad: Urinary bladder; GI: Gastrointestinal tract; HA: Headache; PNS: Peripheral Nervous System

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	Neurotoxicity	CNS	Neurotoxicity	CNS	Neurotoxicity		
REMARKS:					Kidney	Nephrotoxicity	Kidney	Nephrotoxicity	Kidney	Nephrotoxicity		
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												

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; RespSys: Respiratory System; DCV: Decreased Conduction Velocity; U.Blad: Urinary bladder; GI: Gastrointestinal tract; HA: Headache; PNS: Peripheral Nervous System

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)
4- Methyl-2-pentanone CAS #: 108-10-1 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:	35	(140)	35	(140)	35	(140)	35	(140)	35	(140)	Not Set	(Not Set)
	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			
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		Gonads / Toxicity		Gonad / Toxicity			
					CNS / Depression							

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; RespSys: Respiratory System; DCV: Decreased Conduction Velocity; U.Blad: Urinary bladder; GI: Gastrointestinal tract; HA: Headache; PNS: Peripheral Nervous System

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)
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		
2- Propanol CAS #: 67-63-0 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 REMARKS:	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*
	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression	CNS	Depression		
	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation	Mucosa	Irritation		
			Liver	Hepatotoxicity	Liver	Hepatotoxicity	PNS	DCV	PNS	DCV		
							Liver	Hepatotoxicity	Liver	Hepatotoxicity		
Propylene glycol CAS #: 57-55-6 REFERENCE: Ramanathan, Raghupathy (2008), Propylene Glycol, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:314-328, National Academy Press, Washington, DC REMARKS:	32	(102)	17	(54)	9	(29)	3	(9.6)	1.5	(4.8)	1.5	(4.8)
	Organ	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
	Eye	Irritation	Eye	Discharge	Eye	Discharge	Eye	Discharge	Nose	Epithelial thickening	Nose	Epithelial thickening
	Throat	Irritation	Nose	Hemorrhage	Nose	Hemorrhage	Nose	Hemorrhage				
	Lung	Irritation										
Toluene CAS #: 108-88-3 REFERENCE: Garcia, Hector D. (2008), Toluene, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:329-347, National Academy Press, Washington, DC REMARKS:	16	(60)	16	(60)	4	(15)	4	(15)	4	(15)	4	(15)
	Organ	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
	CNS	Depression	CNS	Dizziness	Ear	Ototoxicity	Ear	Ototoxicity	Ear	Ototoxicity	Ear	Ototoxicity
									Gonads	Hormone	Gonads	Hormone

Abbreviations: CNS: Central Nervous System; CV: Cardiovascular; DCD: Decreased Color Discrimination; RespSys: Respiratory System; DCV: Decreased Conduction Velocity; U.Blad: Urinary bladder; GI: Gastrointestinal tract; HA: Headache; PNS: Peripheral Nervous System

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 CAS #: 79-01-6 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 REMARKS: See dichloroacetylene if alkali scrubber is present. Possible carcinogen.	**50**	(270)	**11**	(60)	**9**	(50)	**4**	(20)	**2**	(10)	**Not Set**	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
	CNS / Depression		CNS / Depression		Kidney / Nephrotoxicity		Kidney / Nephrotoxicity		Multi. / Cancer			
	Heart / Arrhythmia				Liver / Hepatotoxicity		Liver / Hepatotoxicity		Kidney / Nephrotoxicity			
									Liver / Hepatotoxicity			
Trimethylsilanol CAS #: 1066-40-6 REFERENCE: James, John T. (2008), Trimethylsilanol, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:348-355, National Academy Press, Washington, DC REMARKS:	**15**	(55)	**2**	(7)	**1**	(4)	**1**	(4)	**1**	(4)	**1**	(4)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
	CNS / Depression		CNS / Depression		CNS / Depression		CNS / Depression		CNS / Depression		CNS / Depression	
Vinyl chloride CAS #: 75-01-4 REFERENCE: Wong, King Lit (1994), Vinyl Chloride, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 1:185-219, National Academy Press, Washington, DC REMARKS:	**130**	(330)	**30**	(77)	**1**	(2.6)	**1**	(2.6)	**1**	(2.6)	**Not Set**	(Not Set)
	Organ / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*		*Organ* / *Effect*	
	Liver / Hepatotoxicity		Liver / Hepatotoxicity		Testes / Necrosis		Testes / Necrosis		Testes / Necrosis			
	CNS / Headache		CNS / Depression									
	CNS / Depression											
Xylenes CAS #: 1330-20-7 (mixed) REFERENCE: Ramanathan, Raghupathy (2008), Xylenes, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Vol 5:356-386, National Academy Press, Washington, DC REMARKS: Applies to each individual xylene isomer and mixtures of xylene isomers.	**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*	
	Mucosa / Irritation		Mucosa / Irritation		CNS / Neurotoxicity		CNS / Neurotoxicity		Ear / Ototoxicity		Ear / Ototoxicity	
	CNS / Headache		CNS / Headache									
	Eye / Irritation		Eye / Irritation									

Abbreviations: CNS: Central Nervous System; DCD: Decreased Color Discrimination; DCV: Decreased Conduction Velocity; GI: Gastrointestinal tract; HA: Headache; PNS: Peripheral Nervous System; CV: Cardiovascular; 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.

APPENDIX A ACRONYMS AND ABBREVIATIONS

C_n	Specific Concentration
ISS	International Space Station
NASA	National Aeronautics and Space Administration
NRC	National Research Council
NRCCOT	National Research Council Committee on Toxicology
SMACs	Spacecraft Maximum Allowable Concentrations
T_{grp}	Toxicity Index