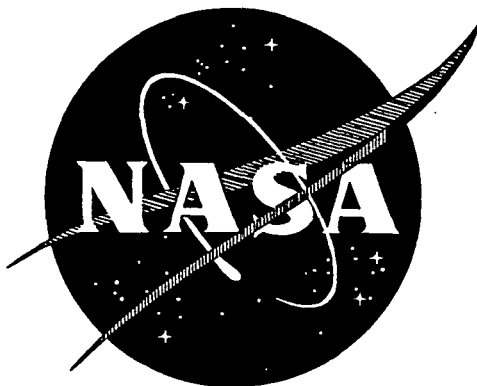


SPACECRAFT MAXIMUM ALLOWABLE CONCENTRATIONS FOR AIRBORNE CONTAMINANTS

**Toxicology Group
Biomedical Operations and Research Branch
Medical Sciences Division
Space and Life Sciences Directorate**

February 1995



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

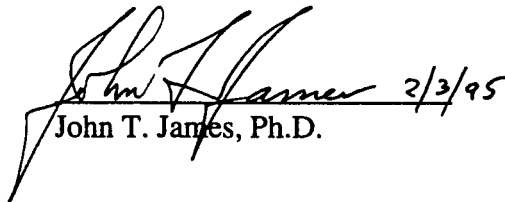
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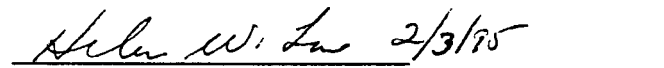
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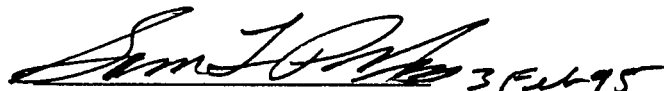
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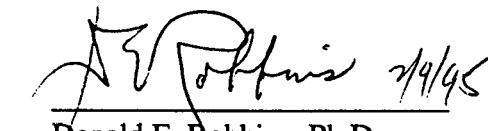
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SPACECRAFT MAXIMUM ALLOWABLE CONCENTRATIONS FOR AIRBORNE CONTAMINANTS

Long-term spacecraft maximum allowable concentrations (SMACs) are set for individual air pollutants as guidance concentrations that are believed to protect astronauts from adverse health effects if they were to be exposed continuously to the pollutant for a period ranging from 7 to 180 days. Short-term SMACs (1 and 24 hours) are guidance concentrations for protecting crewmembers from all adverse effects except mild irritation, mild headache, or other minor effects during an *accidental* exposure. Short-term SMACs are not set for engineering design purposes. Effects that could significantly degrade performance of the crew are not accepted for any SMAC. A risk of 0.01% of cancer from exposure to any airborne carcinogen is accepted for each mission.

Spacecraft air consists of a number (n) of pollutants at various concentrations (C) and the toxicological effect (T) of the mixture is assessed according to the equation below:

$$T = C_1/SMAC_1 + C_2/SMAC_2 + \dots C_n/SMAC_n$$

If $T < 1$ for all pollutants or for each toxicological group of pollutants, then the atmosphere is deemed safe to breathe for the length of the mission. Toxicological groups are defined according to the target organ and nature of the adverse effect, but individual chemicals often contribute to more than one group and the adverse effects change with exposure time. For example, many compounds are irritants or central nervous system depressants at relatively high concentrations, but may be hepatotoxicants or carcinogens at prolonged low-level exposures.

Table 1 lists all official SMACs available at the time of publication; however, new SMACs are being developed continuously. When a listed compound has only a 7-day SMAC, that SMAC was set many years ago by the National Research Council Committee on Toxicology (NRC-COT) without documentation. When a listed compound has a complete set of SMACs (1 hour to 180 days), the values were set recently by the JSC Toxicology Group and have been reviewed and approved by the NRC-COT. Documentation of these values is available from the JSC Toxicology Group and summaries of the toxic effects are given in table 2.

Many compounds are detected during hardware offgassing tests that have never been detected in spacecraft atmospheres. In order to interpret the concentrations of these compounds in toxicological terms, a computer database called "MAPTIS" is maintained at MSFC. This database contains many additional SMACs; however, the values were set quickly for the purpose of completing an offgas test and are not to be used for purposes other than interpreting offgas tests. Many of the values in MAPTIS are default SMACs (0.1 mg/m^3) that are automatically entered into the database with no toxicological review. The default SMAC is sufficiently low that almost no compound could pose a risk at this concentration; however, it is not applicable to highly toxic inorganic compounds or organometallic compounds.

TABLE 1
OFFICIAL SMAC LIMITS FOR TRACE GAS CONTAMINANTS
IN SPACECRAFT HABITABLE ATMOSPHERES

COMPOUNDS	MOL. WT.	SMACs (mg/m ³)				
		1 hr	24 hr	7 d	30 d	180 d
ALCOHOLS						
2-Propen-1-ol (Allyl alcohol)	58.08	-	-	1	-	-
1-Pentanol (n-Amyl alcohol)	88.15	-	-	130	-	-
2-Methyl-1-propanol (Isobutyl alcohol)	74.12	-	-	120	-	-
1-Butanol (n-Butyl alcohol)	74.12	150	80	80	80	40
2-Butanol (sec-Butyl alcohol)	74.12	-	-	120	-	-
2-Methyl-2-propanol (tert-Butyl alcohol)	74.12	-	-	120	-	-
Cyclohexanol	100.2	-	-	120	-	-
Ethanol (Ethyl alcohol)	46.07	4,000	4,000	2,000	2,000	2,000
1,2-Ethanediol (Ethylene glycol)	62.07	60	60	13	13	13
2-Hexanol (2-Hexyl alcohol)	102.2	-	-	170	-	-
Methanol (Methyl alcohol)	32.04	40	13	9	9	9
1-Octanol (Octyl alcohol)	130.2	-	-	210	-	-
Phenol	94.11	-	-	7.7	-	-
1-Propanol (n-Propyl alcohol)	60.09	-	-	98	-	-
2-Propanol (Isopropyl alcohol)	60.09	1,000	240	150	150	150
2-Ethoxyethanol	90.12	40	40	3	2	0.3
ALDEHYDES						
Ethanal (Acetaldehyde)	44.05	20	10	4	4	4
Propenal (Acrolein)	55.06	0.2	0.08	0.03	0.03	0.03
Benzaldehyde	106.1	-	-	173	-	-
Glutaraldehyde	100.13	0.5	0.08	0.025	0.012	0.002
Butanal (Butyraldehyde)	72.10	-	-	120	-	-
trans-2-Butenal (Crotonaldehyde)	70.09	-	-	120	-	-
Methanal (Formaldehyde)	30.03	0.5	0.12	0.05	0.05	0.05
2-Furancarboxal (Furfural)	96.08	-	-	7.9	-	-
Propanal (Propionaldehyde)	58.08	-	-	95	-	-
Pentanal (Valeraldehyde)	86.13	-	-	110	-	-
AROMATIC HYDROCARBONS						
Benzene	78.11	35	10	1.5	0.3	0.2

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COMPOUNDS	MOL. WT.	SMACs (mg/m ³)				
		1 hr	24 hr	7 d	30 d	180 d
Isopropylbenzene (Cumene)	120.2	-	-	74	-	-
Decahydronaphthalene (Decalin)	138.2	-	-	11	-	-
Ethylbenzene	106.2	800	250	130	130	130
1-Ethyl-2-methylbenzene	120.2	-	-	25	-	-
Indonaphthene (Indene)	116.1	-	-	9.5	-	-
1,3,5-Trimethylbenzene (Mesitylene)	120.2	-	-	15	-	-
2-Phenylpropene (Methyl styrene)	118.2	-	-	140	-	-
Napthalene	128.2	-	-	10	-	-
Propylbenzene	120.1	-	-	49	-	-
1,2,4-Trimethylbenzene (Pseudocumene)	120.2	-	-	15	-	-
Ethenylbenzene (Styrene)	104.1			43		
Toluene	92.13	60	60	60	60	60
1,2-Dimethylbenzene (o-Xylene)	106.2	430	430	220	220	220
1,3-Dimethylbenzene (m-Xylene)	106.2	430	430	220	220	220
1,4-Dimethylbenzene (p-Xylene)	106.2	430	430	220	220	220

CHLOROCARBONS

1-Chlorobutane (Butyl chloride)	92.57	-	-	150	-	-
Tetrachloromethane (Carbon Tetrachloride)	153.8	-	-	13	-	-
1-Chloro-2-propanone (Chloroacetone)	92.53	-	-	0.19	-	-
Chlorobenzene	112.6	-	-	46	-	-
Trichloromethane (Chloroform)	119.4	-	-	4.9	-	-
1,2-Dichlorobenzene (o-Dichlorobenzene)	147.0	-	-	30	-	-
Chloroethane (Ethylene chloride)	64.50	-	-	260	-	-
1,2-Dichloroethane (Ethylene chloride)	98.97	2	2	2	2	1
1,1-Dichloroethane (Ethylidene chloride)	98.97	-	-	100	-	-
2-Chloropropane (Isopropyl chloride)	78.54	-	-	270	-	-
Chloromethane (Methyl chloride)	50.49	-	-	41	-	-
1,1,1-Trichloroethane (Methyl chloroform)	133.4	-	-	160	-	-
Dichloromethane (Methylene chloride)	84.94	350	120	50	20	10
Tetrachloroethene (Perchloroethylene)	165.8	-	-	34	-	-


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COMPOUNDS	MOL. WT.	SMACs (mg/m ³)				
		1 hr	24 hr	7 d	30 d	180 d
1-Chloropropane (n-Propyl chloride)	78.54	-	-	96	-	-
1,2-Dichloropropane (Propylene dichloride)	113.0	-	-	42	-	-
1,1,2-Trichloroethane (beta-Trichloroethane)	133.4	-	-	5.5	-	-
Trichloroethene (Trichloroethylene)	131.4	270	60	50	20	10
Chloroethene (Vinyl chloride)	62.50	330	75	3	3	3
1,1-Dichloroethene (Vinylidene chloride)	96.95	-	-	7.9	-	-
Dichloroacetylene	94.9	2.4	0.16	0.12	0.10	0.06

ESTERS

n-Amyl acetate	130.2	-	-	160	-	-
n-Butyl acetate	116.2	-	-	190	-	-
2-Ethoxyethyl acetate	132.2	-	-	160	-	-
Ethyl acetate	88.10	-	-	(180)	-	-
Ethyl formate	74.08	-	-	91	-	-
Ethyl lactate	118.1	-	-	190	-	-
Isobutyl acetate	116.2	-	-	190	-	-
Isopropyl acetate	102.1	-	-	210	-	-
Methyl acetate	74.08	-	-	120	-	-
Methyl butyrate	102.1	-	-	84	-	-
Methyl methacrylate	100.1	-	-	100	-	-
n-Propyl acetate	102.1	-	-	170	-	-

ETHERS

2,5-Dimethylfuran	96.12	-	-	0.16	-	-
1,3-Dioxane	88.11	-	-	18	-	-
1-Ethoxybutane (Ethyl butyl ether)	102.2	-	-	330	-	-
Diethyl ether (Ethyl ether)	74.12	-	-	240	-	-
1,4-Epoxy-1,3-butadiene (furan)	68.07	-	-	0.11	-	-
2-Methylfuran	82.10	-	-	0.13	-	-
Methoxyethene (Methyl vinyl ether)	58.08	-	-	120	-	-
Diisopropyl ether	102.2	-	-	210	-	-
1,4-Epoxybutane (Tetrahydrofuran)	72.1	-	-	120	-	-