1. Environmental Health Standards for Human Spacecraft

1.1 Air Quality Standards

1.1.1 **Evidence-based Standards:** All standards shall be supported by the best data available in peer-reviewed literature or by direct experimentation on the compound. The database on each compound shall be used to create a document explaining how the data were used to develop standards for various times of exposure and that document shall include a summary and critique of all data available. Key toxicological studies from the database shall be identified and used as the basis for exposure standards for space-faring humans. Acceptable concentrations to avoid specific adverse effects shall be identified, and the final standard shall be based on the lowest of these acceptable concentrations, called the "critical effect." There may be more than one adverse effect caused by a single compound, and therefore more than one critical effect when acceptable concentrations for different adverse effects are quantitatively close.

1.1.2 **Factors Unique to Spaceflight:** During the process of setting air-quality standards from the key toxicological studies, factors unique to spaceflight must be considered and appropriate safety factors applied. Such factors shall include the known spaceflight-induced physiological effects on red blood cell volume, heart sensitization (arrhythmias), immune system, bone, and fluid shifts. Standards shall address a healthy, middle-aged population of crewmembers with wide ethnic and racial diversity. The additional carcinogenic effects of space radiation shall also be considered when standards are set.

1.1.3 **Effects from Exposures to Combinations of Compounds**: Crewmembers are never exposed to a single compound in their breathing atmosphere. Nevertheless, since the number of potential mixtures is unlimited, exposure standards must be set for individual compounds. To evaluate the potential adverse effects of mixtures, t he measured concentrations of individual compounds in relation to their individual standards are combined for those compounds whose effects could be presumed to be additive. The potential adverse effects of compounds shall be considered as grouped according to their common toxicological effects. For example, all compounds that irritate mucosal surfaces (e.g. eyes and upper airways) shall be considered as a group having additive effects in proportion to their air quality standard for the time of crew exposure. Non-additive effects of certain mixtures (e.g. liver enzyme inducers, promoters, competitive inhibitors) must be evaluated on a case-by-case basis.

1.1.4 **Contingency vs. Nominal Standards**: The capability exists to quantify many compounds using current on-board analyzers. Exposure standards are set to provide two different levels of protection, based on the exposure duration. To permit crew members to stop further releases, contain, and clean up a spilled toxicant, standards for brief exposures (up to 24 hr) are set to allow some mild effects, while standards for longer exposures should protect against all adverse effects. Standards are appropriate for short term, contingency exposures (1 and 24 hours) and for prolonged, nominal exposures (up to 1000 days).

1.1.5 Table of ISO Standards for Air Quality (ppm)

Compound	1 hr	24 hr	7 day	30 day	180 day	1000 day	Ref.
acetaldehyde	10	6	2	2	2	ns	1
acetone	500	200	22	22	22	ns	2
acrolein	0.075	0.035	0.015	0.015	0.008	0.008	3
aliphatic alkanes (C2-C9)	150	80	60	20	3	ns	5
aliphatic saturated aldehydes (C3-C8)	45	45	4.5	4.5	4.5	4.5	5
ammonia	30	20	3	3	3	3	5
benzene	10	3	0.5	0.1	0.07	0.013	5
1-butanol	50	25	25	25	12	12	5
t-butanol	50	50	50	50	40	ns	3
carbon dioxide	20000	13000	7000	7000	7000	5000	5
carbon monoxide	425	100	55	15	15	15	5
decamethylcyclopentasiloxane	ns	ns	7	5	1	Ns	4
1,2 dichloroethane	0.4	0.4	0.4	0.4	0.4	0.4	5
ethanol	5000	5000	1000	1000	1000	1000	5
2-ethoxyethanol	10	10	0.8	0.5	0.07	ns	2
ethylbenzene	180	60	30	30	12	ns	3
ethylene glycol	25	25	5	5	5	ns	3
formaldehyde	0.8	0.5	0.1	0.1	0.1	0.1	5
furan	4	0.36	0.025	0.025	0.025	ns	4
hexamethylcyclotrisiloxane	ns	ns	10	5	1	ns	4

hydrogen chloride	5	2	1	1	1	ns	4
Hydrogen cyanide	8	4	1	1	1	ns	4
Indole	1.0	0.3	0.05	0.05	0.05	ns	2
Isoprene	50	25	2	2	1	ns	4
Limonene	80	80	20	20	20	20	5
Mercury	0.01	0.002	0.001	0.001	0.001	ns	2
Methanol	200	70	70	70	70	23	5
Methyl ethyl ketone	50	50	10	10	10	ns	2
4-methyl-2-pentanone	35	35	35	35	35	ns	4
Methylene chloride	100	35	14	7	3	1	5
Octamethylcyclotetrasiloxane	ns	ns	23	5	1	ns	4
Perfluoropropane (Freon 218)	11000	11000	11000	11000	11000	ns	4
2-propanol	400	100	60	60	60	ns	2
Propylene glycol	32	17	9	3	1.5	1.5	5
Toluene	16	16	4	4	4	4	5
Trimethylsilanol	15	2	1	1	1	1	5
xylene	50	17	17	17	8.5	1.5	5

References to Table 1.1.5

1) National Research Council. Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Volume 1, National Academy Press, Washington, DC, 1994
2) National Research Council. Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Volume 2, National Academy Press, Washington, DC, 1996
3) National Research Council. Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Volume 3, National Academy Press, Washington, DC, 1996
4) National Research Council. Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Volume 4 , National Academy Press, Washington, DC, 2000
5) National Research Council. Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants, Volume 5, National Academy Press, Washington, DC, 2008

1.1.6 Updating of Standards

Air quality standards are developed by experts using the latest toxicological databases and risk assessment techniques. Databases on many compounds are constantly improving and toxicologists continue to refine the methods for setting standards from current data. Therefore, ISO standards must be reviewed and updated at least every 10 years to reflect any new data and new techniques. For example, Volume 5 of the above series, which was published in 2008, was an update to earlier air quality standards published in the 1990s.

1.2 Water Quality Standards

1.2.1 **Evidence-based Standards:** All standards shall be supported by the best data available in peer-reviewed literature or by direct experimentation on the compound. The database on each compound shall be used to create a document explaining how the data were used to develop standards for various times of exposure and that document shall include a summary and critique of all data available. Key toxicological studies from the database shall be identified and used as the basis for exposure standards for space-faring humans. Acceptable concentrations to avoid specific adverse effects shall be identified, and the final standard shall be based on the lowest of these acceptable concentrations, called the "critical effect." There may be more than one adverse effect caused by a single compound, and therefore more than one critical effect when acceptable concentrations for different adverse effects are quantitatively close.

1.2.2 **Factors Unique to Spaceflight:** During the process of setting water-quality standards from the key toxicological studies, factors unique to spaceflight must be considered and appropriate safety factors applied. Such factors shall include the known spaceflight-induced physiological effects on red blood cell volume, heart sensitization (arrhythmias), immune system, bone, and fluid shifts. Factors that might reduce the consumption of water must also be considered. Guidelines shall address a healthy, middle-aged population of crewmembers with wide ethnic and racial diversity. The additional carcinogenic effects of space radiation shall also be considered when guidelines are set.

1.2.3 **Effects from Exposures to Combinations of Compounds:** In contrast to air quality standards, standards for water quality do not require that compounds with similar effects be considered together.

1.2.4 **Contingency vs. Nominal Standards**: The capability may be developed to quantify many compounds using on-board analyzers. Exposure standards are set to provide two different levels of protection, based on the duration of water consumption. Contingency guidelines apply to situations where water has become contaminated and the crew must make an effort to identify the cause of contamination and control it within a defined period of time (1 or 10 days). During this time, as long as the guidelines are not exceeded, the crew can safely drink the water. Under nominal conditions, the longer-term limits must be met on a time-weighted-average basis.

1.2.5 **Table of ISO Standards for Water Quality (mg/L)**

Compound	1 day	10 days	100 days	1000 days	reference
Acetone	3500	3500	150	15	2
Di-alkylamines	0.3	0.3	0.3	0.3	2
Mono-alkylamines	2	2	2	2	2
Tri-alkylamines	0.4	0.4	0.4	0.4	2
Ammonia	5	1	1	1	2
Antimony	4	4	4	2	3
Barium	21	21	10	10	2
Benzene	21	2	0.7	0.07	3
Cadmium	1.6	0.7	0.6	0.02	2
Caprolactam	200	100	100	100	2
Chloroform	60	60	18	6	1
Di(2-ethylhexyl) phthalate	1800	1300	30	20	1
Di-n-butyl phthalate	1200	175	80	40	1
Dichloromethane	40	40	40	15	1
Ethylene glycol	2710	140	20	4	3
Formaldehyde	20	20	12	12	2
Formate	10,000	2500	2500	2500	2
Manganese	14	5	1.8	0.3	2
Mercaptobenzothiazole	200	30	30	30	1
Methanol	40	40	40	40	3
Methyl Ethyl Ketone	540	54	54	54	3
Nickel	1.7	1.7	1.7	0.3	1
Phenol	80	8	4	4	1

n-Phenyl-β-naphthylamine	1600	1600	500	260	1
Propylene glycol	25000	8000	8000	1700	3
Silver	5	5	0.6	0.4	1
Total organic carbon	Not set	Not set	3	Not set	2
Zinc	11	11	2	2	2

References to Table 1.2.5

1) National Research Council, Spacecraft Water Exposure Guidelines for Selected Contaminants, Volume 1, National Academy Press, Washington, DC, 2004
2) National Research Council, Spacecraft Water Exposure Guidelines for Selected Contaminants, Volume 2, National Academy Press, Washington, DC, 2007
3) National Research Council, Spacecraft Water Exposure Guidelines for Selected Contaminants, Volume 3, National Academy Press, Washington, DC, 2008

1.2.6 Updating of Standards

Water quality standards are developed by experts using the latest toxicological databases and risk assessment techniques. Databases on many compounds are constantly improving and toxicologists continue to refine the methods for setting standards from current data. Therefore, ISO standards must be reviewed and updated at least every 10 years to reflect any new data and new techniques.