JSC TOXICOLOGY AND ENVIRONMENTAL CHEMISTRY GROUP

E. Spencer Williams, PhD DABT

NASA JSC/SK4
Houston, TX 77058

Memorandum Number
TOX-SW-2023-01

Voice: (281) 483-8921
Fax: (281) 483-3058
edward.s.williams@nasa.gov

DATE: May 4, 2023

SUBJECT: Toxicological Assessment of ISS Air and Water Quality: October 17, 2021 – March 28, 2022 (Increment 66) Including SpX-24 and NG-17 Ingresses

SUMMARY: Based on these data, air quality was acceptable on ISS for this period, and potable water remains acceptable for crew consumption.

AIR QUALITY

Eight archive air samples were collected in mini grab sample containers (mGSCs) on ISS during Increment 66, including 5 routine samples, 2 ingress samples, and a contingency sample collected in Node 3 on March 7, 2022 in response to an odor that crew described as "like sulfur or rotten eggs". A summary of the results from the Increment 66 mGSC samples is provided in Table 1A. Additionally, four sets of formaldehyde badges were deployed in the US Lab and the Russian Service Module (SM) during Increment 66. All badges from the Increment were returned on SpX-25 (Table 1B).

Data tables containing measured concentrations and corresponding T-values based on appropriate Spacecraft Maximum Allowable Concentrations (SMACs) for compounds present at levels above the laboratory reporting limit are attached to this report. Complete data tables, which include compounds assessed but not detected, are available upon request. Pressure readings for the mGSCs indicate that all Increment 66 samples were acceptable. The mean relative recoveries of the three surrogate standards from the mGSC samples returned on SpX-24 and SpX-25 were all within acceptable limits.

On-orbit, the Air Quality Monitors (AQMs) automatically collect and analyze samples every 73 hours, which results in 2-3 sampling sessions per unit per week. Monthly average concentrations as well as the Increment average concentrations for compounds measured on the AQMs are presented in Table 2.

Toxicological Evaluation of ISS Air Quality

Routine air quality monitoring is performed in-flight using the AQMs. Archive air samples (mGSCs and formaldehyde badges) are collected during each Increment and returned for analysis in the Toxicology and Environmental Chemistry (TEC) Group's Air Quality Laboratory. Data from the ground analyses complement the in-flight data and provide a more complete understanding of air quality on the ISS. The routine mGSC samples that returned on SpX-24 and SpX-25 confirmed that air quality was acceptable during this Increment. **T-values calculated using data from the routine archive samples and the one contingency sample met the 180-d T-value guideline (T< 1), indicating no concern for crew health.**

Table 1A. Analytical summary of ISS air analyses from mGSCs (Increment 66)

Return Flight	Sample Location	Sample Date	Freon 218 (mg/m^3)	Alcohols[a] (mg/m^3)	T-Value[b] (units)
SpaceX-24	US Lab	10/20/2021	5.7	5.3	0.5
SpaceX-24	SpX-24 ingress	12/22/2021	<1.5	2.3	0.2 (0.1)
SpaceX-24	US Lab	1/10/2022	9.9	7.7	0.5
SpaceX-24	Columbus	1/10/2022	8.9	7.4	0.6
SpaceX-25	NG-17 ingress	2/21/2022	<1.5	2.9	0.3 (0.2)
SpaceX-25	US Lab	2/23/2022	13	7.8	0.4
SpaceX-25	SM	2/23/2022	20	8.2	0.4
SpaceX-25	Node 3 contingency	3/7/2022	8.0	7.8	0.4
Guideline			---	*<5*	*<1*[c]

[a] Includes acetone

[b] Sum of the ratios of the measured concentrations and the corresponding 180-day SMAC for each compound; parenthesis indicate value based on 7-day SMACs and applicable to first ingress.

[c] T-value <1 used to evaluate routine monthly sampling; <3 used to evaluate first ingress.

Table 1B: Analytical summary of formaldehyde samples from Increment 66

Return Flight	Sample Location	Sample Date	Formaldehyde ($\mu g/m^3$)
SpaceX-25	US Lab	10/20/2021	16
SpaceX-25	SM	10/20/2021	<11
SpaceX-25	US Lab	11/30/2021	16
SpaceX-25	SM	11/30/2021	14
SpaceX-25	US Lab	1/10/2022	17
SpaceX-25	SM	1/10/2022	<15
SpaceX-25	US Lab	2/23/2022	<11
SpaceX-25	SM	2/23/2022	<11
Guideline			*<120*

The reported concentrations for the individual compounds detected during Increment 66 are slightly elevated compared to previous Increments but remain below levels of concern for crew health. The average, rounded T-value calculated from the nominal Increment 66 mGSC samples was 0.5 (Figure 1), which is lower than the Increment 65 value (0.9). The increase in T-value during Increment 65 was primarily attributed to the level of heptafluoro-butanoyl fluoride measured in the sample collected from the US Lab on June 18, 2021. That compound was not detected in any samples during Increment 66. The T-value in Increment 66 is primarily driven by the presence of acrylonitrile, which has been intermittently present on ISS since early 2021. The source of acrylonitrile has not yet been identified. T-values calculated from GSC results (Figure 1) and AQM (Figure 2) were in reasonable agreement given the differences between the analytical techniques and the number of target compounds used in the calculation. AQMs do not detect acrylonitrile, the primary driver of T-value through the Increment.

Alcohol values for all five of the routine mGSC samples returned on SpX-24 and -25 exceeded the ECLS guideline of <5 mg/m^3. The level increased over the Increment, from 5.3 mg/m^3 in October 2021 to 8 mg/m^3 in February 22. The increase is attributable to ethanol, which remained above 6 mg/m^3 from January 2022 through the end of the Increment. Measured levels do not present a risk to crew health but are a potential concern for the water recovery system.

Table 2. Average monthly concentrations (mg/m^3) of AQM target compounds (Increment 66)

Compound	October 2021 Average	November 2021 Average	December 2021 Average	January 2022 Average	February 2022 Average	March 2022 Average	Increment Average
2-Butanone	ND	*	*	ND	ND	ND	**ND**
2-Propanol	0.26	0.22	0.28	0.26	0.2	0.24	0.25
Acetaldehyde	0.22	0.17	0.17	TRACE	TRACE	TRACE	TRACE
Acetone	0.28	0.32	0.30	0.38	0.25	0.35	0.31
Acrolein	ND	ND	ND	ND	ND	ND	ND
Benzene	MI	MI	MI	MI	MI	MI	MI
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND
Dichloromethane	ND	*	*	ND	ND	ND	ND
Decamethylcyclopentasiloxane#	ND	ND	ND	ND	ND	ND	ND
Ethanol	5.23	6.02	5.99	6.62	6.48	6.53	6.00
Ethyl Acetate	TRACE	*	*	TRACE	TRACE	0.11	TRACE
Hexanal	ND	ND	ND	ND	ND	ND	ND
Hexane	ND	ND	ND	ND	ND	ND	ND
Hexamethycyclotrisiloxane#	ND	ND	TRACE	TRACE	TRACE	TRACE	TRACE
Methanol	0.34	0.24	0.22	TRACE	0.14	TRACE	0.22
m,p-Xylenes#	ND	ND	ND	ND	ND	ND	ND
n-Butanol	ND	*	*	0.07	0.06	0.06	0.06
Octamethylcylcotetrasiloxane#	ND	ND	ND	ND	ND	ND	ND
o-Xylene#	ND	ND	ND	ND	ND	ND	ND
Toluene#	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Trimethylsilanol	ND	*	*	ND	ND	ND	ND

TRACE: >MDL, <MQL (Minimum Quantification Limit)
ND: Not detected; <MDL (Minimum Detection Limit)
MI: matrix interference
*: No data is available as AQM1 was not operational during this period.

Levels of octafluoropropane (Freon 218) dropped precipitously from the prior Increment. In Increment 65, levels of Freon 218 were on the order of 180-200 mg/m^3, but they dropped to <10 mg/m^3 in the October 2021 sample collected in the US Lab. Previously, NASA had not believed that Freon 218 could be scrubbed by any trace contaminant control system on board. However, the 4-Bed CO_2 scrubber, a technology demonstration unit which was activated in late September 2021, appears to effectively remove Freon 218 from the atmosphere.

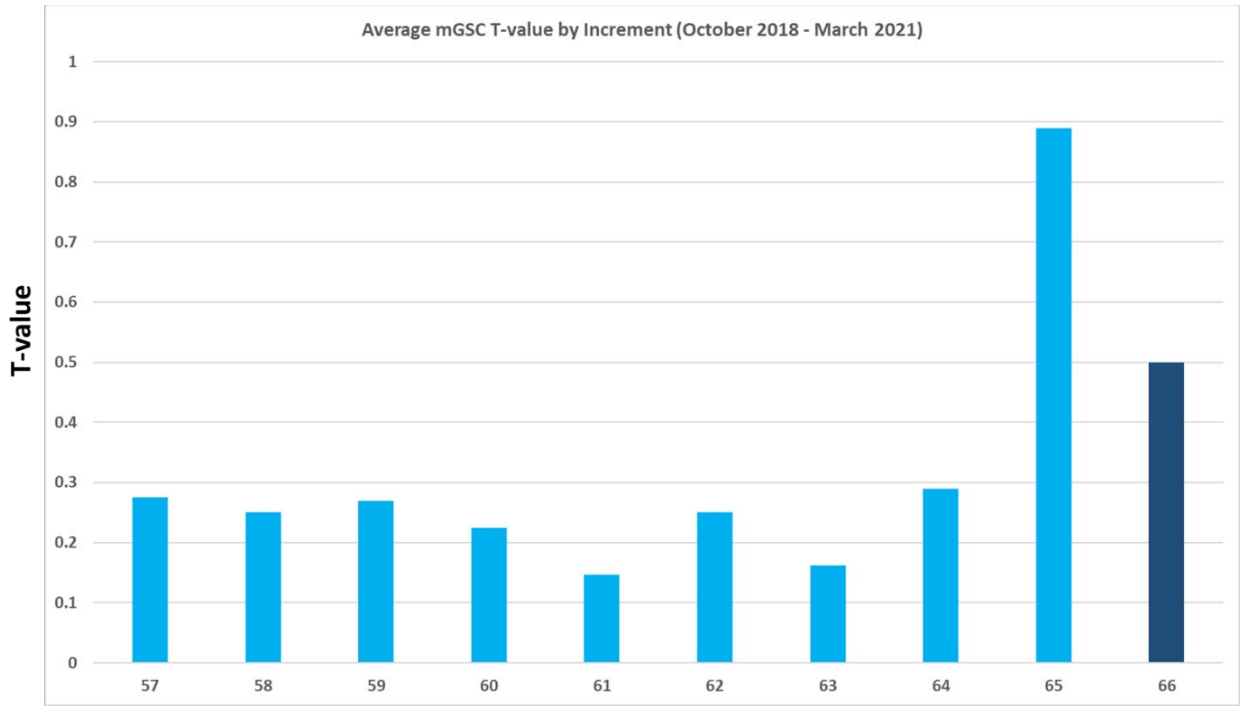

Figure 1. GSC-Derived T-values for Increments 57-66

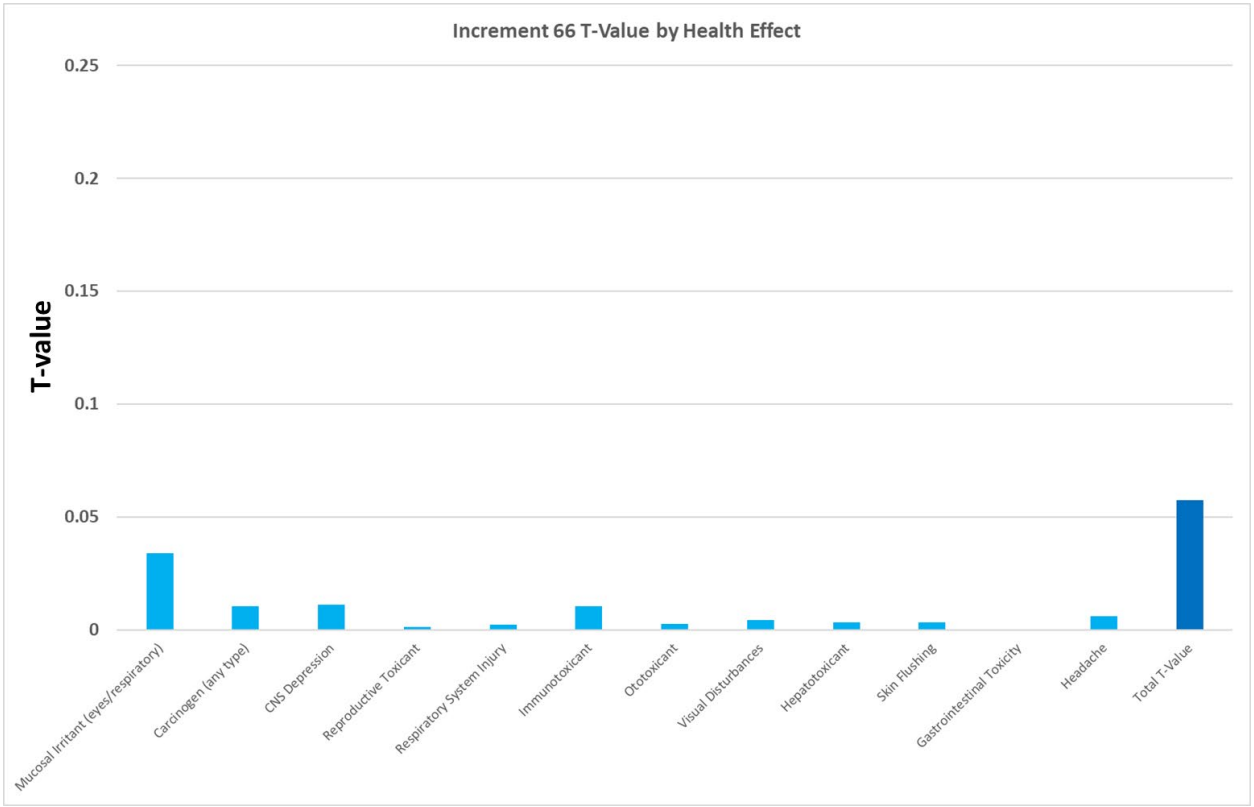

Figure 2. AQM-Derived T-Values by Health Effect for Increment 66

All 5 routine mGSC samples collected during Increment 66 contained a CO_2 concentration below the limit documented in Flight Note F091532D, which requests that the 24-hour average concentration not exceed a 24-hour average of 3.0 mmHg (7100 mg/m^3, 4000 ppm) on the US segment. However, the contingency sample collected in Node 3 on March 7, 2022, contained CO_2 at 3.67 mmHB (8700 mg/m^3, 4800 ppm).

While mGSC CO_2 sampling provides a snapshot of the CO_2 concentration, real-time CO_2 data are available from a sensor in the Columbus module, and intermittently from the Major Constituent Analyzer (MCA) (Figure 3). To preserve the longevity of the instrumentation, MCAs are only activated during EVA activities, crew metabolic characterization, tech demo analysis, anomaly resolution, and when requested by crew surgeons. Overall, CO_2 concentrations (per data from the Columbus sensor and Lab MCA) were well-controlled throughout the Increment (Figure 3). Excursions above 5 mmHg were noted in early December 2021 and in March 2022 in conjunction with EVA activities (i.e., rapid sampling of the airlock). The ISS crew was comprised of 7 crew from October 17 to November 8, 2021, 3 crew very briefly, 7 crew from 11 November, 2021 through 18 March, 2022, and 10 crew for 10 days at the end of the Increment.

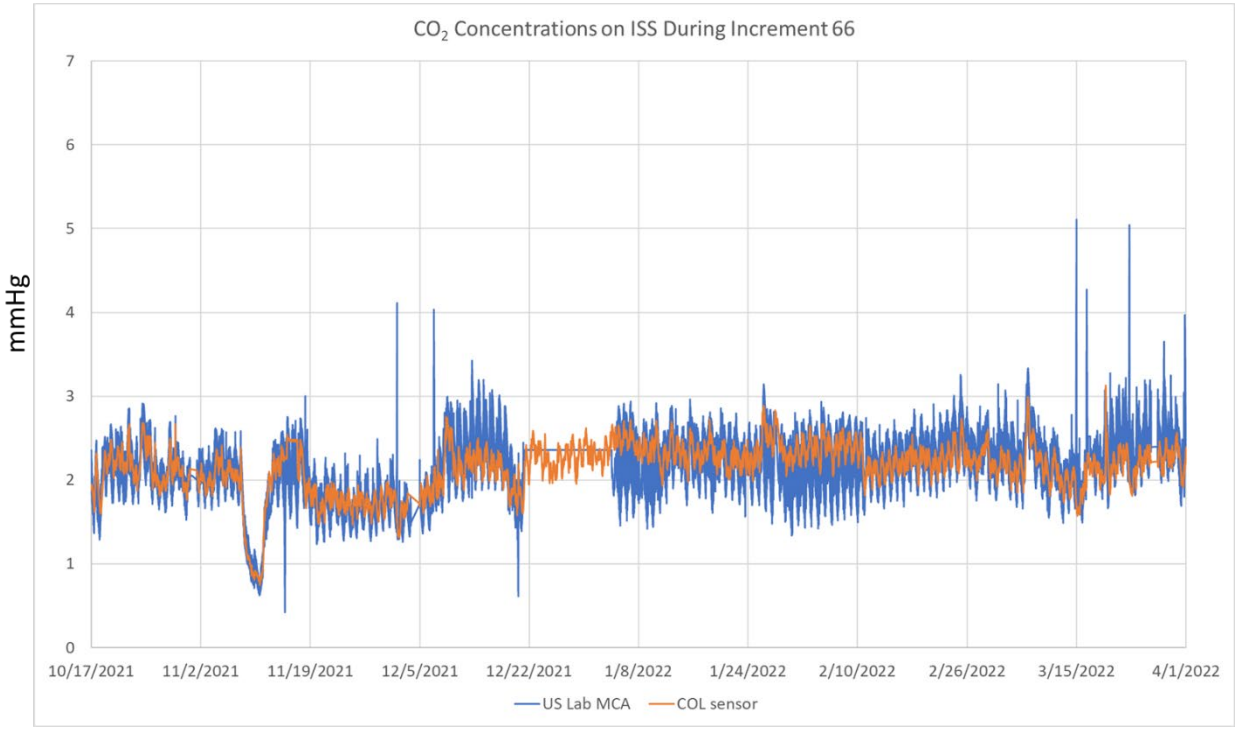

Figure 3. Environmental CO_2 Concentrations on ISS During Increment 66 (mmHg)

Four sets of passive formaldehyde badges were deployed on ISS during Increment 66. Results from analysis of these badges indicated that formaldehyde remains at or below the historical range observed on ISS, and concentrations are well below the SMAC of 120 µg/m^3 (Figure 4). By the end of the Increment formaldehyde was not detected in either the US Lab or the Russian SM.

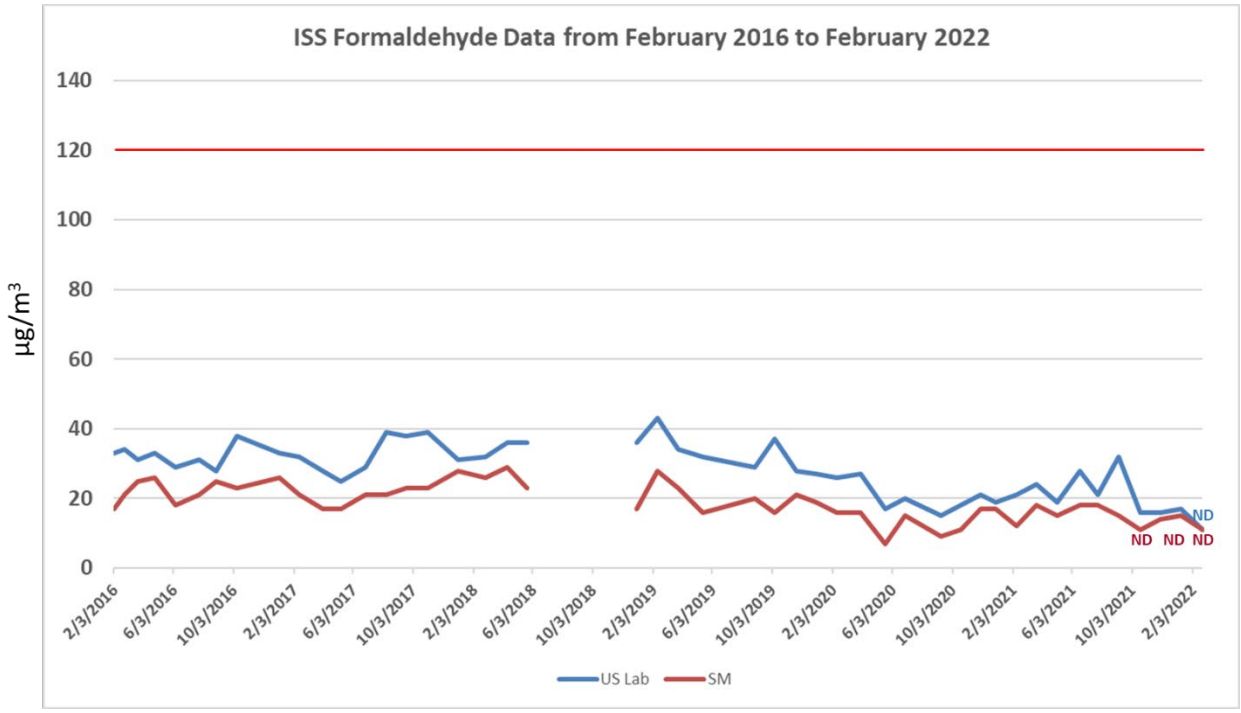

Figure 4: Formaldehyde Concentrations from February 2016 to February 2022

SpX-24 Ingress

An ingress sample was collected in SpX-24 on December 22, 2021, approximately 3 minutes after hatch opening. This sample contained 940 mg/m^3 CO_2 (0.4 mmHg, 500 ppm), much lower than typical for ISS and thus mixing with the stack was minimal. 2-Propanol was present at 1 mg/m^3, compared to levels on ISS on the order of 0.45 mg/m^3. **The T-value for SpX-24 ingress was 0.2, well below levels of concern for human health**.

NG-17 Ingress

An ingress sample was collected in NG-17 on February 21, 2022, at 17:20 GMT. Unfortunately, the time at which the hatch was opened was not recorded. The sample contained 2000 mg/m^3 CO_2 (0.8 mmHg, 1100 ppm), which is about half the level on ISS during this period. Octafluoropropane was not detected in the vehicle, though it was present at approximately 8 mg/m^3 in ISS air. **The T-value for NG-17 ingress was 0.2, well below levels of concern for human health**.

Node 3 Contingency Sample

In response to an odor described as "like sulfur or rotten eggs," crew collected a contingency mGSC in Node 3 on March 7, 2022 at 20:34 GMT. The only unusual readings in this sample were a higher-than-expected CO_2 level (8700 mg/m^3, 3.7 mmHg, 4800 ppm) and ethyl acetate at 0.11 mg/m^3, compared with readings <0.08 mg/m^3 for the rest of the Increment. Console personnel speculated that operation of the Urine Processor Assembly (UPA) might be the cause of the smell, and so UPA ops were terminated. The odor dissipated overnight, further suggesting the UPA was the likely source.

WATER QUALITY

In total, four samples were collected from the US Segment during Increment 66 and returned on SpX-24. Two of these were potable water samples collected from the US Potable Water Dispenser (PWD): one hot water sample and one ambient water sample. Samples of US condensate and wastewater were also

collected during Increment 66. Summaries of select analytical results from the Increment 66 samples are provided in Tables 3A and 3B.

Table 3A. Analytical Summary of ISS Water Analyses for CHeCS Samples (Increment 66)

Return Mission	Sample Location	Sample Date	TOC (mg/L)	DMSD (mg/L)	Methyl Sulfone (mg/L)	Conductivity (µS/cm)	Total Iodine (mg/L)
SpX-24	PWD Hot	12/29/2021	1.12	2.7	0.138	1	0.05
SpX-24	PWD Ambient	1/10/2022	0.964	1.8	0.287	1	<0.05

Table 3B. Analytical Summary of ISS Water Analyses for ECLS Samples (Increment 66)

Return Mission	Sample Location	Sample Date	TOC (mg/L)	DMSD (mg/L)	Methyl Sulfone (mg/L)	Conductivity (µS/cm)	Total Iodine (mg/L)
SpX-24	WPA Wastewater	1/11/2022	50.2	14.0	0.068	143	NA
SpX-24	US Condensate	1/11/2022	136	22.0	0.069	276	NA

NA: not analyzed

Toxicological Evaluation of ISS Water Quality

Routine water quality monitoring is performed in-flight using the total organic carbon analyzer (TOCA). Results from these analyses provide a general indication of overall water quality. Typically, archive water samples are also collected during each Increment and returned for comprehensive analysis in ground laboratories. Data from the ground analyses complement the in-flight data and provide a more complete understanding of water quality on the ISS.

Potable Water

Concentrations of all chemicals detected in the potable water samples met the requirements listed in SSP 41000, *System Specification for the International Space Station* and JSC 63414, *Spacecraft Water Exposure Guidelines (SWEGs)*. Total organic carbon (TOC) concentrations from in-flight (PWD TOC and WPA TOC) and ground analyses (Archive TOC) performed between April 2021 and March 2022 are shown in Figure 5. The TOC concentrations in the two potable samples continued to be low and were well below both the specification for the US segment (<3 mg/L) and the 100-day SWEG (5 mg/L).

The DMSD concentrations were above the 1 mg/L reporting limit in the two potable water samples (2.7 and 1.8 mg/L) from December 2021 and are slightly higher than those seen in Increment 65. Methyl sulfone was detected in all potable water samples at levels well below the SWEG of 1,500 mg/L. Silicon was detected in both samples (0.74 and 0.71 mg/L), above the historical averages. Based on these results, the water produced by the Water Processor Assembly (WPA) met all US potability requirements.

Iodine is a biocide used on the US Segment. It is added to the water produced by the WPA but removed prior to crew consumption to avoid potential thyroid dysfunction. The total iodine level in the potable samples collected from the PWD was at or below the reporting limit (0.05 mg/L), indicating effective removal of iodine in water intended for consumption. The main difference between potable water and WPA product water is the presence of iodine. For additional information regarding microbial analyses, see the Increment 66 post-flight report generated by the JSC Environmental Microbiology Laboratory.

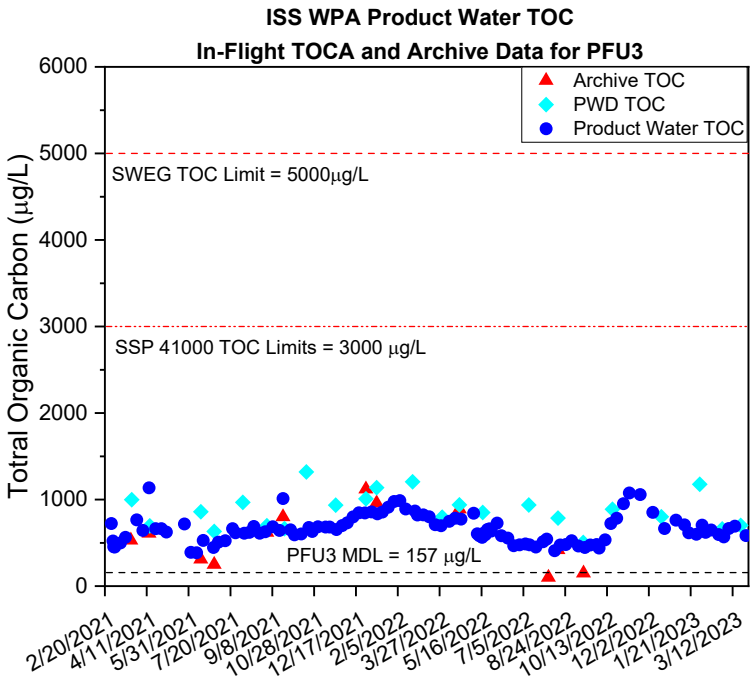

Figure 5. Total Organic Carbon (TOC) trending in US Potable Water from Archive Water Samples and On-Orbit TOCA (PFU3).

Condensate

The condensate sample collected on January 11, 2022 contained a TOC level of 136 mg/L, which is below the historical average (152 mg/L). Organic compounds detected at or above 1 mg/L are listed in Table 4. Several of them were markedly above historical averages. Silicon was present at 9.2 mg/L and can mostly be accounted for by the presence of DMSD (22 mg/L). Zinc and nickel were detected above 0.1 mg/L (8.34 and 0.464 mg/L, respectively). Trace amounts of aluminum, barium, boron, chromium, copper, manganese, and silver were also present. Trace amounts of calcium, magnesium, phosphate, sodium, and fluoride were detected in the sample. Ammonium was present at a concentration of 31.3 mg/L, below the historical average of 37 mg/L. All of these compounds were effectively removed by the WRS, as evidenced by the low or undetectable levels of these species in the potable samples.

Table 4: Organic Compounds Detected >1 mg/L in US Condensate (January 11, 2022)

Compound	Concentration (mg/L)	Historical average (mg/L)
Ethanol	90.8	46.7
Acetate	55.6	39.5
Dimethylsilanediol (DMSD)	22.0	37.0
1,2-propanediol (propylene glycol)	15.8	27.8
Benzyl alcohol	14.4	12.9
Methanol	7.82	4.64
Formate	4.55	7.77
Acetone	3.44	1.82
Benzoic acid	2.29	1.54
2-propanol (isopropanol)	1.83	1.36
Lactate	1.46	5.77
Caprolactam	1.42	4.60
Formaldehyde	1.19	1.08

Wastewater

The wastewater sample contained a TOC level of 50.2 mg/L (historical average of 41 mg/L). The DMSD concentration in the sample was 14 mg/L, slightly lower than the historic average of 15.3 mg/L (Table 5). Silicon was present in the sample at 4.8 mg/L, which can be mostly accounted for by the presence of DMSD. Zinc (3.7 mg/L) was the only metal detected above 0.1 mg/L. Traces of other metals were present in the sample, including aluminum, boron, chromium, copper, iron, manganese, nickel, and silver. Trace amounts of calcium, magnesium, phosphate, potassium, sodium and fluoride were also present. Ammonium was present at a concentration of 15.7 mg/L, lower than the historical average (17.4 mg/L). As with the condensate samples, all compounds of toxicological interest were effectively cleaned from the samples by the WRS.

Table 5: Organic Compounds Detected >1 mg/L in US Wastewater (January 11, 2022)

Compound	Concentration (mg/L)	Historical average (mg/L)
Ethanol	17.7	11.2
Dimethylsilanediol (DMSD)	14.0	15.2
1,2-propanediol (propylene glycol)	9.39	5.04
Acetone	6.71	3.67
Benzyl alcohol	5.74	2.88
Methanol	5.21	4.61
Acetate	3.35	2.41

Expanded summary tables containing organic carbon recoveries and results for all analytes present at concentrations above reporting limits are included as attachments to this report.

E. Spencer Williams, PhD DABT
NASA Toxicologist

Edward Williams
Digitally signed by Edward Williams
Date: 2023.05.04 13:32:03 -05'00'

Valerie E. Ryder, PhD DABT
NASA Toxicologist

Valerie Ryder
Digitally signed by Valerie Ryder
Date: 2023.05.04 14:10:33 -05'00'

Enclosures

- Table S-1: Analytical concentrations of compounds quantified in mGSCs collected in and returned on SpaceX-24 and -25
- Table S-2A: T-values corresponding to concentrations for routine and contingency archive mGSC samples returned on SpaceX-24 and -25, based on 180-day SMACs
- Table S-2B: T-values corresponding to concentrations for SpaceX-24 and NG-17 ingresses air samples returned on SpaceX-24 and -25, based on 7-day and 180-day SMACs
- Table S-3A: Analytical concentrations of compounds quantified in potable ambient and potable water samples returned on SpaceX-24
- Table S-3B: Analytical concentrations of compounds quantified in US wastewater and US condensate returned on SpaceX-24

TABLE S-1
CONCENTRATION RESULTS FOR SPACEX-24 and SPACEX-25 RETURN SAMPLES

Increment	**66**							
Mission	**SpaceX-24**			**SpaceX-25**			**SpaceX-24**	**SpaceX-25**
Sample Location	Lab	Lab	Columbus Module	Lab	Service Module	Node 3	Dragon	NG
Sample Description	Nominal air sample, S/N 2095	Nominal air sample, S/N 2069	Nominal air sample, S/N 2077	Nominal air sample, S/N 2071	Nominal air sample, S/N 2073	Contingency air sample, S/N 2076	Ingress air sample, SpX-24, S/N 2035	Ingress air sample, NG-17, S/N 2075
Sample Date	10/20/2021	1/10/2022	1/10/2022	2/23/2022	2/23/2022	3/7/2022	12/22/2021	2/21/2022
Sample Time	16:20	18:15	18:17	07:45	07:54	20:34	10:21	17:20
Analysis/Sample ID	**AQ220189**	**AQ220192**	**AQ220193**	**AQ220746**	**AQ220747**	**AQ220748**	**AQ220191**	**AQ220753**
Volatiles Targets GCMS (TO-15 mod)	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3
1,1,1,2-Tetrafluoroethane	0.12	0.16	0.16	0.13	0.15	0.13	0.33	0.11
1-Butanol	0.074	0.068	0.071	0.051	0.062	0.049	<0.031	0.034
1-Propanol	0.045	0.041	0.055	0.038	0.042	0.028	<0.025	0.024
2-Methyl-1-propene	0.016	0.018	0.018	<0.014	<0.014	<0.014	<0.023	0.060
2-Methyl-2-propanol	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.031	0.036
2-Methylhexane	<0.024	<0.024	<0.024	<0.024	<0.024	<0.024	<0.041	0.028
2-Propanol (Isopropanol)	0.41	0.45	0.46	0.35	0.38	0.43	0.97	1.0
3-Methylhexane	<0.024	<0.024	<0.024	<0.024	0.026	<0.024	<0.041	0.066
Acetaldehyde	0.23	0.24	0.23	0.23	0.24	0.29	0.082	0.18
Acetone	0.44	0.48	0.50	0.37	0.39	0.49	0.16	0.26
Acrylonitrile	0.020	0.021	0.023	0.015	0.014	0.013	<0.022	<0.013
Butane	0.017	<0.014	<0.014	<0.014	<0.014	<0.014	<0.024	0.062
Ethanol	See GC-FID	See GC-FID	See GC-FID	See GC-FID	See GC-FID	See GC-FID	0.72	See GC-FID
Ethyl acetate	0.029	0.022	<0.022	0.039	0.077	0.11	<0.037	0.11
Hexanal	<0.024	<0.024	<0.024	<0.024	<0.024	<0.024	<0.041	0.025
Isobutane	0.16	0.045	0.052	0.029	0.031	0.019	<0.024	2.9
Isoprene (2-Methyl-1,3-butadiene)	0.046	0.024	0.024	0.029	0.030	0.032	<0.029	<0.017
Methanol	See GC-FID	See GC-FID	See GC-FID	0.36	0.38	0.41	0.44	0.12
Methyl acetate	<0.018	<0.018	<0.018	0.021	0.030	0.051	<0.031	0.019
Methylene chloride (Dichloromethane)	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.034	0.19
o-Xylene	<0.026	<0.026	<0.026	<0.026	0.033	<0.026	<0.044	<0.026
Perfluoro(2-methylpentane)	<0.082	<0.082	<0.082	0.21	0.25	0.34	0.14	<0.082
Propanal (Propionaldehyde)	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.024	0.017
Propane	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	<0.018	0.017
Propene	<0.010	<0.010	<0.010	<0.010	<0.010	0.011	<0.018	<0.010
Toluene	<0.022	<0.022	<0.022	<0.022	0.025	<0.022	<0.037	0.025
Trimethylsilanol	0.068	0.060	0.097	0.056	0.055	0.058	0.040	0.30
Volatiles SICs GCMS (estimated conc.)								
Hexamethylcyclotrisiloxane (HMCTS)	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.31	0.21
Volatiles Non-Targets GCMS (estimated conc.)								
1,1-Difluoroethane	<0.032	<0.032	<0.032	not found	not found	not found	0.22	not found
2,2,6-Trimethyloctane	not found	not found	not found	<0.076	<0.076	<0.076	not found	0.11
C11-Alkanes	not found	not found	not found	<0.076	<0.076	<0.076	not found	0.68
Tetradecafluorohexane	not found	not found	not found	0.58	0.65	0.91	not found	<0.17
Volatiles Targets GCFID								
Ethanol	3.9	6.2	5.9	6.6	6.9	6.4	NR	1.5
Methanol	0.41	0.42	0.44	NR	NR	NR	NR	NR
Octafluoropropane (Perfluoropropane)	5.7	9.9	8.9	13	20	8.0	<1.5	<1.5
Volatiles Targets TGA								
Carbon dioxide	4,800	5,400	5,800	4,400	4,800	8,700	940	2,000
Carbon monoxide	0.91	0.87	0.92	0.92	0.92	1.0	1.6	1.5
Hydrogen	7.4	5.9	6.0	5.6	5.6	5.5	2.1	0.92
Methane	42	83	83	67	65	70	10	9.4
	GMT 293	GMT 10	GMT 10	GMT 54	GMT 54	GMT 66	GMT 356	GMT 52

Comments: NR= Not Reported
Not Found = No unknown peaks above the threshold limit.

TABLE S-2A
T-VALUES FOR SPACEX-24 and SPACEX-25 RETURN SAMPLES

Increment	**66**					
Mission	**SpaceX-24**			**SpaceX-25**		
	T-Value (180-day)					
Sample Location	Lab	Lab	Columbus Module	Lab	Service Module	Node 3
Sample Description	Nominal air sample, S/N 2095	Nominal air sample, S/N 2069	Nominal air sample, S/N 2077	Nominal air sample, S/N 2071	Nominal air sample, S/N 2073	Contingency air sample, S/N 2076
Sample Date	10/20/2021	1/10/2022	1/10/2022	2/23/2022	2/23/2022	3/7/2022
Sample Time	16:20	18:15	18:17	07:45	07:54	20:34
Analysis/Sample ID	**AQ220189**	**AQ220192**	**AQ220193**	**AQ220746**	**AQ220747**	**AQ220748**
Volatiles Targets GCMS (TO-15 mod)						
1,1,1,2-Tetrafluoroethane	0.000	0.000	0.000	0.000	0.000	0.000
1-Butanol	0.002	0.002	0.002	0.001	0.002	0.001
1-Propanol	0.001	0.001	0.001	0.001	0.001	0.000
2-Methyl-1-propene	0.001	0.001	0.001	ND	ND	ND
2-Propanol (Isopropanol)	0.003	0.003	0.003	0.002	0.003	0.003
3-Methylhexane	ND	ND	ND	ND	0.002	ND
Acetaldehyde	0.057	0.059	0.058	0.057	0.059	0.072
Acetone	0.008	0.009	0.010	0.007	0.007	0.009
Acrylonitrile	0.286	0.302	0.329	0.214	0.195	0.193
Butane	0.000	ND	ND	ND	ND	ND
Ethanol	See GC-FID	See GC-FID	See GC-FID	See GC-FID	See GC-FID	See GC-FID
Ethyl acetate	0.000	0.000	ND	0.000	0.000	0.000
Isobutane	0.001	0.000	0.000	0.000	0.000	0.000
Isoprene (2-Methyl-1,3-butadiene)	0.015	0.008	0.008	0.010	0.010	0.011
Methanol	See GC-FID	See GC-FID	See GC-FID	0.014	0.015	0.016
Methyl acetate	ND	ND	ND	0.000	0.000	0.000
o-Xylene	ND	ND	ND	ND	0.001	ND
Perfluoro(2-methylpentane)	ND	ND	ND	0.000	0.000	0.000
Propene	ND	ND	ND	ND	ND	0.000
Toluene	ND	ND	ND	ND	0.002	ND
Trimethylsilanol	0.017	0.015	0.024	0.014	0.014	0.014
Volatiles Non-Targets GCMS (estimated conc.)						
Tetradecafluorohexane	not found	not found	not found	0.000	0.000	0.000
Volatiles Targets GCFID						
Ethanol	0.002	0.003	0.003	0.003	0.003	0.003
Methanol	0.016	0.016	0.017	NR	NR	NR
Octafluoropropane (Perfluoropropane)	0.000	0.000	0.000	0.000	0.000	0.000
Volatiles Targets TGA						
Carbon monoxide	0.054	0.051	0.054	0.054	0.054	0.059
Hydrogen	0.022	0.017	0.018	0.017	0.016	0.016
Methane	0.012	0.024	0.024	0.019	0.019	0.020
Total T-Value	**0.5**	**0.5**	**0.6**	**0.4**	**0.4**	**0.4**

Comments: ND= Value is less than the laboratory reporting limit.
NR= Not Reported
Not Found = No unknown peaks above the threshold limit.

TABLE S-2B
T-VALUES FOR SPACEX-24 and SPACEX-25 RETURN INGRESS SAMPLES

Increment	**66**			
Mission	**SpaceX-24**		**SpaceX-25**	
	T-Value (7-day)	**T-Value (180-day)**	**T-Value (7-day)**	**T-Value (180-day)**
Sample Location	Dragon Module	Dragon Module	NG	NG
Sample Description	Ingress air sample, SpX-24, S/N 2035	Ingress air sample, SpX-24, S/N 2035	Ingress air sample, NG-17, S/N 2075	Ingress air sample, NG-17, S/N 2075
Sample Date	12/22/2021	12/22/2021	2/21/2022	2/21/2022
Sample Time	10:21	10:21	17:20	17:20
Analysis/Sample ID	**AQ220191**	**AQ220191**	**AQ220753**	**AQ220753**
Volatiles Targets GCMS (TO-15 mod)				
1,1,1,2-Tetrafluoroethane	0.000	0.000	0.000	0.000
1-Butanol	ND	ND	0.000	0.001
1-Propanol	ND	ND	0.000	0.000
2,3-Dimethylpentane	ND	ND	0.000	0.004
2-Butanone (Methyl ethyl ketone)	ND	ND	0.001	0.001
2-Methyl-1-propene	ND	ND	0.000	0.003
2-Methyl-2-propanol	ND	ND	0.000	0.000
2-Methylhexane	ND	ND	0.000	0.002
2-Propanol (Isopropanol)	0.006	0.006	0.007	0.007
3-Methylhexane	ND	ND	0.000	0.005
Acetaldehyde	0.021	0.021	0.044	0.044
Acetone	0.003	0.003	0.005	0.005
Butane	ND	ND	0.000	0.000
Ethanol	0.000	0.000	See GC-FID	See GC-FID
Ethyl acetate	ND	ND	0.000	0.000
Hexanal	ND	ND	0.001	0.001
Isobutane	ND	ND	0.015	0.015
Methanol	0.017	0.017	0.004	0.004
Methyl acetate	ND	ND	0.000	0.000
Methylene chloride (Dichloromethane)	ND	ND	0.004	0.019
Perfluoro(2-methylpentane)	0.000	0.000	ND	ND
Propanal (Propionaldehyde)	ND	ND	0.001	0.001
Propane	ND	ND	0.000	0.000
Toluene	ND	ND	0.002	0.002
Trimethylsilanol	0.010	0.010	0.075	0.075
Volatiles SICs GCMS (estimated conc.)				
Hexamethylcyclotrisiloxane (HMCTS)	ND	ND	0.002	0.023
Volatiles Non-Targets GCMS (estimated conc.)				
1,1-Difluoroethane	0.000	0.000	ND	ND
2,2,6-Trimethyloctane	not found	not found	0.000	0.006
C11-Alkanes	not found	not found	0.015	0.015
Volatiles Targets GCFID				
Ethanol	NR	NR	0.001	0.001
Volatiles Targets TGA				
Carbon monoxide	0.026	0.096	0.024	0.090
Hydrogen	0.006	0.006	0.003	0.003
Methane	0.003	0.003	0.003	0.003
Total T-Value	**0.1**	**0.2**	**0.2**	**0.3**

Comments: ND = Value is less than the laboratory reporting limit.
NR = Not Reported
Not Found = No unknown peaks above the threshold limit.

Project Specific SMACs: 1,1-Difluoroethane: 7 & 180-day: 2701 mg/m3

TABLE S-3A: ANALYTICAL CONCENTRATIONS OF COMPOUNDS QUANTIFIED IN POTABLE HOT AND AMBIENT WATER SAMPLES RETURNED ON SPACEX-24

Increment Mission Sample Location Sample Description Sample Date Analysis/Sample ID	Units	Test Conducted by	Potable Water Contaminant Level (MCL)	Contaminant Level Source	66 SpaceX-24 WPA PWD Hot Potable Water 12/29/2021 WQ220059	 WPA PWD Ambient Potable Water 1/10/2022 WQ220060
Physical Characteristics						
Conductivity	µS/cm	U.S.			1	1
pH	pH units	U.S.	4.5-8.5	41000	5.43	5.62
Iodine LCV						
Iodine	mg/L	U.S.	1.0-4.0	41000 (residual iodine in product water)	0.05	< 0.05
Total I	mg/L	U.S.	6/0.2	41000 (tl I max in product water/tl I at pt of consumption)	0.08	< 0.05
Minerals ICPMS						
Calcium	mg/L	U.S.	30	41000	0.02	0.02
Phosphate (as P)	mg/L	U.S.			< 0.01	0.01
Potassium	mg/L	U.S.	340	41000	0.02	0.02
Trace Metals ICPMS						
Aluminum	µg/L	U.S.			< 1	1
Barium	µg/L	U.S.	10,000	SWEG&41000	3	< 1
Nickel	µg/L	U.S.	300	SWEG&41000	6	2
Zinc	µg/L	U.S.	2,000	SWEG&41000	< 1	2
Silicon ICPMS						
Silicon	µg/L	U.S.			741	705
Total Organic Carbon-Sievers						
Total Inorganic Carbon (TIC)	mg/L	U.S.			0.688	0.784
Total Organic Carbon (TOC)	mg/L	U.S.	5 / 3	SWEG / 41000	1.12	0.964
Semi-volatile Organics-Targets						
Methyl sulfone	µg/L	U.S.	1,500,000	interim SWEG (06-2017)	138	287
Base and Neutral Extractables-EPA 625 List GCMS						
bis-(2-Ethylhexyl)phthalate	µg/L	U.S.	20,000/6	SWEG/EPA	38	< 20
Silanols LCRI (Semi-Quantitative-NIST traceable standard not available)						
Dimethylsilanediol (DMSD)	µg/L	U.S.	35,000	SWEG	2,700	1,800
Organic Carbon Recovery	percent	U.S.			68.33	56.22
Unaccounted Organic Carbon	mg/L	U.S.			0.36	0.42

NA=Not analyzed
MI=Matrix Interference
N/A=Not applicable
#previously identified as bis(2-Chloroisopropyl) ether

TABLE S-3B: ANALYTICAL CONCENTRATIONS of COMPOUNDS QUANTIFIED in US WASTEWATER AND US CONDENSATE RETURNED on SPACEX-24

Increment					66	
Mission					SpaceX-24	
Sample Location					WPA Wastewater ORU	WPA Condensate Sample Port
Sample Description					WPA Wastewater	US Condensate
Sample Date					1/11/2022	1/11/2022
Analysis/Sample ID	Units	Test Conducted by	Potable Water Maximum Contaminant Level (MCL)	Maximum Contaminant Level Source	WQ220061	WQ220062
Physical Characteristics						
Conductivity	µS/cm	U.S.			143	276
pH	pH units	U.S.	4.5-8.5	41000	7.18	7.54
Anions IC						
Fluoride	mg/L	U.S.			0.2	0.2
Cations IC						
Ammonium (as N)	mg/L	U.S.	1	SWEG&41000	15.7	31.3
Minerals ICPMS						
Calcium	mg/L	U.S.	30	41000	0.07	0.08
Phosphate (as P)	mg/L	U.S.			0.06	0.02
Potassium	mg/L	U.S.	340	41000	0.12	0.11
Sodium	mg/L	U.S.			0.10	0.01
Trace Metals ICPMS						
Aluminum	µg/L	U.S.			5	4
Barium	µg/L	U.S.	10,000	SWEG&41000	< 1	2
Boron	µg/L	U.S.			36	66
Chromium	µg/L	U.S.	230	41000	16	2
Copper	µg/L	U.S.	1,000	41000	1	2
Manganese	µg/L	U.S.	300	SWEG&41000	30	48
Nickel	µg/L	U.S.	300	SWEG&41000	248	464
Silver	µg/L	U.S.	400	SWEG&41000	8	18
Strontium	µg/L	U.S.			< 1	1
Zinc	µg/L	U.S.	2,000	SWEG&41000	3,710	8,340
Silicon ICPMS						
Silicon	µg/L	U.S.			4,770	9,180
Total Organic Carbon-Sievers						
Total Inorganic Carbon (TIC)	mg/L	U.S.			17.7	17.8
Total Organic Carbon (TOC)	mg/L	U.S.	5 / 3	SWEG / 41000	50.2	136
Volatile Organics-Targets						
2-Butanone (Methyl ethyl ketone)	µg/L	U.S.	54,000	SWEG	280	< 50
Volatile Organics-Special Interest Compounds (Semi-quantitative)						
Acetaldehyde	µg/L	U.S.			250	450
Trimethylsilanol	µg/L	U.S.			110	160
Semi-volatile Organics-Targets						
Benzothiazole	µg/L	U.S.			42	34
Decamethylcyclopentasiloxane (DMCPS)	µg/L	U.S.			20	50
Dodecamethylcyclohexasiloxane	µg/L	U.S.			22	27
Methyl sulfone	µg/L	U.S.	1,500,000	interim SWEG (06-2017)	68	69
Acid Extractables-EPA 625 List GCMS						
4-Chloro-3-methylphenol	µg/L	U.S.			58	88
4-Methylphenol (p-Cresol)	µg/L	U.S.			156	22
Benzoic acid	µg/L	U.S.			339	2,290
Phenol	µg/L	U.S.	4,000	SWEG	79	86
Base and Neutral Extractables-EPA 625 List GCMS						
Benzyl alcohol	µg/L	U.S.			5,740	14,400
bis-(2-Ethylhexyl)phthalate	µg/L	U.S.	20,000/6	SWEG/EPA	< 10	20
Diethylphthalate	µg/L	U.S.			177	359
Dimethylphthalate	µg/L	U.S.			11	14
Di-n-butylphthalate	µg/L	U.S.	40,000	SWEG	27	31
Semi-volatile Organics-Special Interest Compounds (Semi-quantitative)						
1-Methyl-2-pyrrolidinone	µg/L	U.S.			150	240
2-(2-Butoxyethoxy)ethanol	µg/L	U.S.			440	890
2-Butoxyethanol	µg/L	U.S.			92	160
2-Ethoxyethanol	µg/L	U.S.			180	260
2-Ethyl-1-hexanol	µg/L	U.S.			32	32
2-Ethylhexanoic acid	µg/L	U.S.			190	380
2-Phenoxyethanol	µg/L	U.S.			190	440
2-Phenyl-2-propanol	µg/L	U.S.			61	84
3-tert-Butylphenol	µg/L	U.S.			< 20	24
Benzaldehyde	µg/L	U.S.			41	42
Dipropylene glycol methyl ether	µg/L	U.S.			420	600
Heptanoic acid	µg/L	U.S.			not found	160
Hexanoic acid (Caprolate)	µg/L	U.S.			not found	340
Ibuprofen	µg/L	U.S.			280	not found
Monomethyl phthalate	µg/L	U.S.			13	16
N,N-Dimethyl acetamide	µg/L	U.S.			240	290
N,N-Dimethylformamide	µg/L	U.S.			240	260
Neomenthol	µg/L	U.S.			54	39
Nonanoic acid	µg/L	U.S.			not found	290
Phenethyl alcohol	µg/L	U.S.			18	26
p-Menth-1-en-8-ol (alpha-Terpineol)	µg/L	U.S.			21	not found
Alcohols & Acetone GCMS						
1-Butanol	µg/L	U.S.			< 400	474
2-Propanol (Isopropanol)	µg/L	U.S.			760	1,830
Acetone	µg/L	U.S.	15,000	SWEG	6,710	3,440
Ethanol	µg/L	U.S.			17,700	90,800
Methanol	µg/L	U.S.	40,000	SWEG	5,210	7,820
Glycols GCMS						
1,2-Propanediol (Propylene glycol)	µg/L	U.S.	1,700,000	SWEG	9,390	15,800
Silanols LCRI (Semi-Quantitative-NIST traceable standard not available)						
Dimethylsilanediol (DMSD)	µg/L	U.S.	35,000	SWEG	14,000	22,000
Carboxylates IC						
Acetate	µg/L	U.S.			3,350	55,600
Formate	µg/L	U.S.	2,500,000	SWEG	< 500	4,550
Lactate	µg/L	U.S.			< 500	1460
Propionate	µg/L	U.S.			< 500	817

NA=Not analyzed
MI=Matrix Interference
N/A=Not applicable
#previously identified as bis(2-Chloroisopropyl) ether

TABLE S-3B: ANALYTICAL CONCENTRATIONS of COMPOUNDS QUANTIFIED in US WASTEWATER AND US CONDENSATE RETURNED on SPACEX-24

Increment					66	
Mission					SpaceX-24	
Sample Location					WPA Wastewater ORU	WPA Condensate Sample Port
Sample Description					WPA Wastewater	US Condensate
Sample Date					1/11/2022	1/11/2022
Analysis/Sample ID	Units	Test Conducted by	Potable Water Maximum Contaminant Level (MCL)	Maximum Contaminant Level Source	WQ220061	WQ220062
Aldehydes GCMS						
Formaldehyde (Methanal)	µg/L	U.S.	12,000	SWEG	< 10	1190
Non-volatile Organics LC						
Caprolactam	µg/L	U.S.	100,000	SWEG	657	1420
Organic Carbon Recovery	percent	U.S.			65.38	80.83
Unaccounted Organic Carbon	mg/L	U.S.			17.36	25.98

NA=Not analyzed
MI=Matrix Interference
N/A=Not applicable
#previously identified as bis(2-Chloroisopropyl) ether