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SUBJECT: Toxicological Assessment of ISS Air and Water Quality: March 28, 2022 – September 29, 2022 (Increment 67) Including Boeing OFT-2 and SpX-25 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

Nine archive air samples were collected in mini grab sample containers (mGSCs) on ISS during Increment 67. These consisted of 7 routine samples and 2 ingress samples. A summary of the key air quality indicators from the Increment 67 mGSC samples is provided in Table 1A. Additionally, three sets of formaldehyde badges were deployed in the US Lab and the Russian Service Module (SM) during Increment 67. Table 1B includes a summary of the formaldehyde levels measured on these badges.

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 67 samples were acceptable. The mean relative recoveries of the three surrogate standards were all within acceptable limits for all samples.

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 Environmental Chemistry Laboratory. Data from the ground analyses complement the in-flight data and provide a more complete understanding of air quality on the ISS. Despite results which required additional scrutiny, the routine mGSC samples that returned on Boeing OFT-2, SpX-25, and SpX-26 confirmed that air quality was acceptable during this Increment. **T-values calculated using data from four of the routine archive samples met the 180-d T-value guideline ($T < 1$), indicating no concern for crew health. T-values from 3 archive samples slightly exceeded 1 but are not regarded as a concern for human health (see below).**

Table 1A. Analytical summary of ISS air analyses from mGSCs during Increment 67

Return Flight	Sample Location	Sample Date	Freon 218 (mg/m ³)	Alcohols ^a (mg/m ³)	T-Value ^b (units)
Boeing OFT-2	US Lab	4/13/2022	5.9	8.9	0.8
SpaceX-25	JPM	4/13/2022	6.2	7.6	0.6
Boeing OFT-2	Boeing OFT-2 ingress	5/21/2022	<1.5	1.4	0.1 (0.0)
SpaceX-25	US Lab	6/22/2022	<1.5	6.7	0.4
SpaceX-25	SpaceX-25 ingress	7/16/2022	3.0	2.3	0.4 (0.1)
SpaceX-25	US Lab	8/1/2022	8.4	5.9	1.9
SpaceX-25	Columbus	8/1/2022	4.9	6.3	1.3
SpaceX-26	US Lab	9/14/2022	1.9	8.4	0.2
SpaceX-26	SM	9/14/2022	2.6	9.3	2.9
<i>Guideline</i>			---	<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 67

Return Flight	Sample Location	Sample Date	Formaldehyde (µg/m ³)
SpaceX-25	US Lab	4/13/2022	18
SpaceX-25	SM	4/13/2022	<15
SpaceX-25	US Lab	6/22/2022	<15
SpaceX-25	SM	6/22/2022	<15
SpaceX-25	US Lab	8/1/2022	40
SpaceX-25	SM	8/1/2022	18
<i>Guideline</i>			<120

The reported concentrations for several individual compounds detected during Increment 67 are elevated compared to previous Increments. The average, rounded T-value calculated from the nominal Increment 67 mGSC samples was 1.2 (Figure 1), which is markedly higher than the T-value from Increment 66 (0.5), but similar to the Increment 65 value (0.9). The T-value in Increment 67 is primarily driven by the presence of acrylonitrile, which has been intermittently present on ISS since early 2021. The T-value generated by AQM data was markedly lower, as acrylonitrile is not measured by AQMs (Figure 2). Three mGSC samples taken during Increment 67 contained acrylonitrile at concentrations above the 180-day interim SMAC (0.07 mg/m³): August 1, 2022, in the US Lab and Columbus, and in the Russian SM on September 14, 2022. Acrylonitrile levels in the September sample from the Russian SM were 0.19 mg/m³, which contributed 93% of the T-value on that date (Figure 3).

Table 2. Average monthly concentrations (mg/m³) of AQM target compounds (Increment 67)

Compound	March 2022	April 2022	May 2022	June 2022	July 2022	August 2022	September 2022	Increment Average
2-Butanone	ND	ND	ND	ND	ND	ND	ND	ND
2-Propanol	0.24	0.12	0.26	0.30	0.41	0.31	0.30	0.28
Acetaldehyde	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	0.20	TRACE
Acetone	0.35	0.36	0.30	0.22	0.24	0.17	0.28	0.27
Acrolein	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	TRACE	ND	ND	ND	TRACE	ND	TRACE	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND
Dichloromethane	ND	ND	ND	ND	ND	ND	ND	ND
Decamethylcyclopentasiloxane#	ND	ND	ND	ND	ND	ND	ND	ND
Ethanol	6.53	6.01	6.08	6.71	6.48	5.92	5.49	6.17
Ethyl Acetate	0.11	0.07	0.07	0.08	0.07	ND	0.05	0.08
Hexanal	ND	ND	ND	ND	ND	ND	ND	ND
Hexane	ND	ND	ND	ND	ND	ND	ND	ND
Hexamethylcyclotrisiloxane#	TRACE	ND	ND	ND	ND	ND	ND	ND
Methanol	TRACE	0.18	0.1	TRACE	TRACE	TRACE	ND	TRACE
m,p-Xylenes#	ND	ND	ND	ND	ND	ND	ND	ND
n-Butanol	0.06	0.06	0.05	0.10	0.06	TRACE	0.04	0.06
Octamethylcyclotetra-siloxane#	ND	ND	ND	ND	ND	ND	ND	ND
o-Xylene#	ND	ND	ND	ND	ND	ND	ND	ND
Toluene#	0.04	0.03	0.03	0.03	TRACE	TRACE	TRACE	0.03
Trimethylsilanol	ND	ND	ND	ND	ND	ND	ND	ND

TRACE: >MDL, <MQL (Minimum Quantification Limit)

ND: Not detected; <MDL (Minimum Detection Limit)

The source of acrylonitrile has not yet been identified. Several potential sources have been investigated, including technological demonstration hardware for the removal of CO₂ and a 3-D printing payload. However, no activities or anomalies with any potential source have been correlated with the observed increase in acrylonitrile concentration.

Despite the presence of acrylonitrile in the ISS atmosphere at levels above the 180-day SMAC, crew have not reported symptoms (i.e., irritation, dizziness, headache). As indicated in Figure 3, data from subsequent sampling in Increment 68 indicated that acrylonitrile was not present in any samples from October or December 2022. Levels did not approach the 7-d interim SMAC level of 0.4 mg/m³, and the duration of acrylonitrile in ISS air above the 180-d SMAC was at most on the order of 45-55 days (August 1 to September 14, 2022).

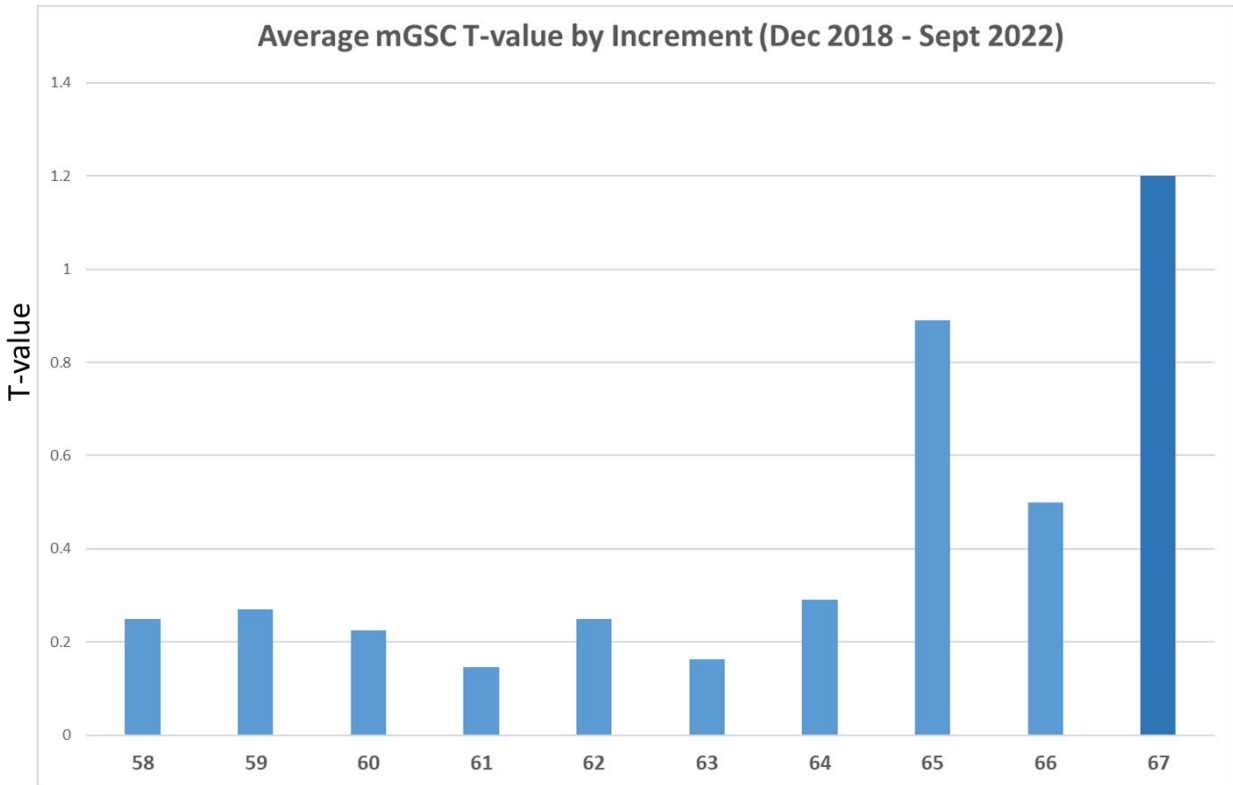


Figure 1. GSC-Derived T-values for Increments 58-67

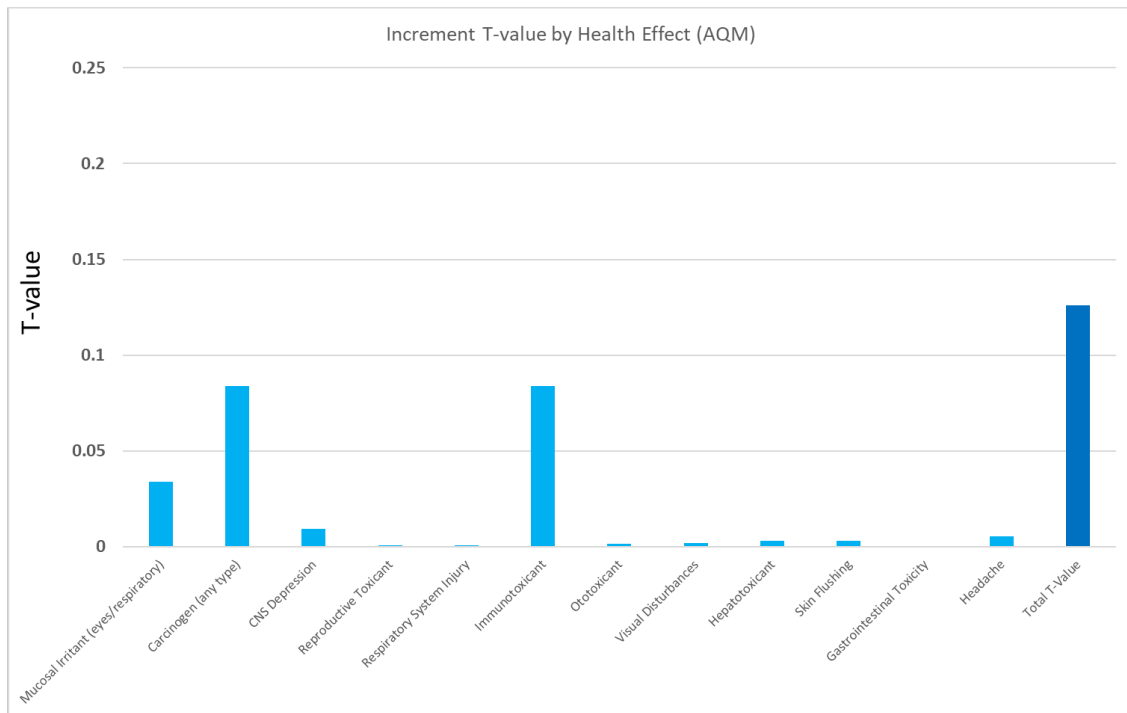


Figure 2. AQM-Derived T-Values by Health Effect for Increment 67

Alcohol values for all seven of the routine mGSC samples returned on SpX-25 exceeded the ECLS guideline of $<5 \text{ mg/m}^3$. The levels are mostly attributable to ethanol, which remained near or above 5 mg/m^3 throughout the Increment. Measured levels do not present a risk to crew health but are a potential concern for the water recovery system.

Levels of octafluoropropane (Freon 218) continue to be very low in ISS air compared with historical measurements.

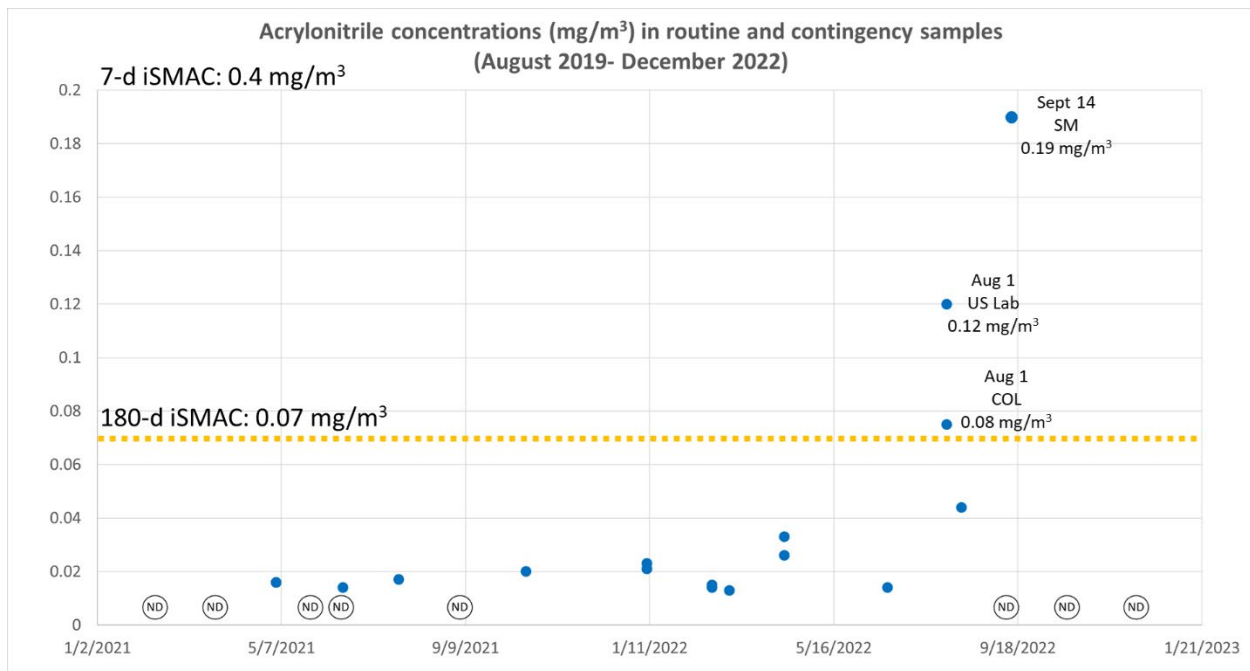


Figure 3: Acrylonitrile concentrations in ISS air from January 2021 through December 2022.
ND: not detected

All seven routine mGSC samples collected during Increment 67 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. 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 4). 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. Excursions above 5 mmHg were noted in mid-May 2022 in conjunction with EVA activities. Peaks were also observed in May and September but are associated with MCA startup; data from Columbus indicated markedly lower concentrations. The arrival of Axiom-1 (Ax-1), a private astronaut mission to ISS, resulted in an ISS crew complement of 11. Ax-1 departed on May 5, after which CO_2 concentrations stabilized below 2 mmHg .

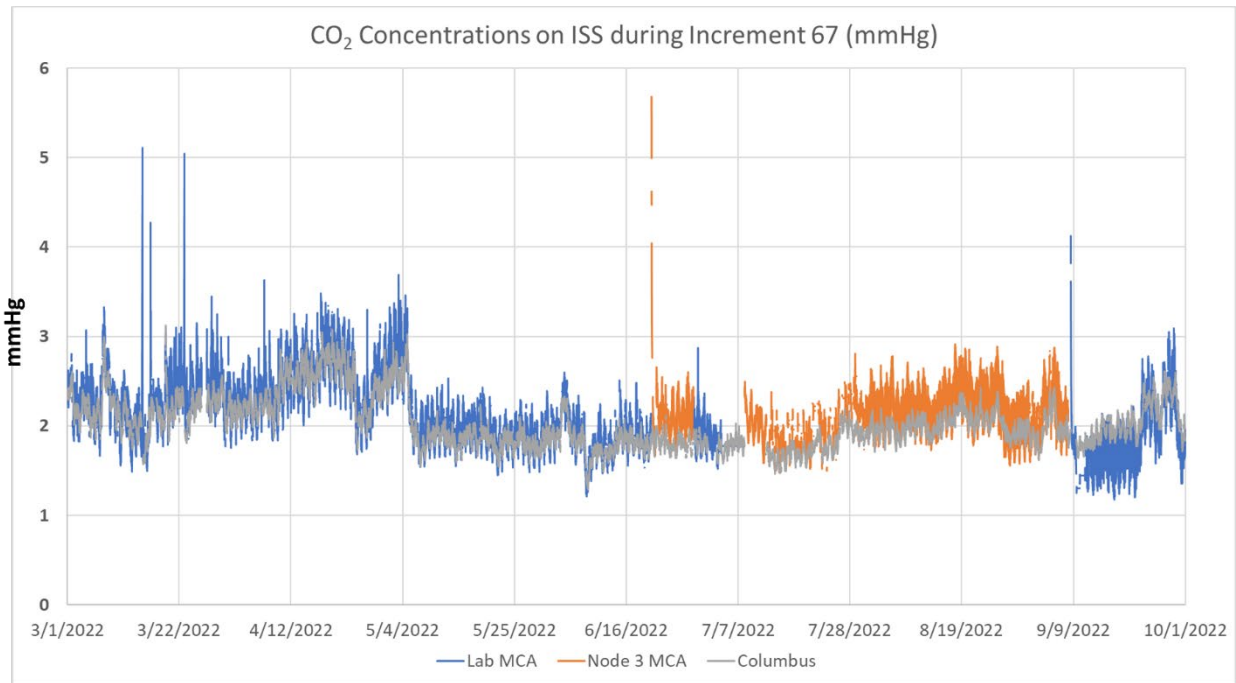


Figure 4. Environmental CO₂ Concentrations on ISS During Increment 67 (mmHg)

Three sets of passive formaldehyde badges were deployed on ISS during Increment 67. 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/m³ (Figure 5). For most of the Increment, formaldehyde was not detected in either the US Lab or the Russian SM but rose in the US Lab in the August sample.

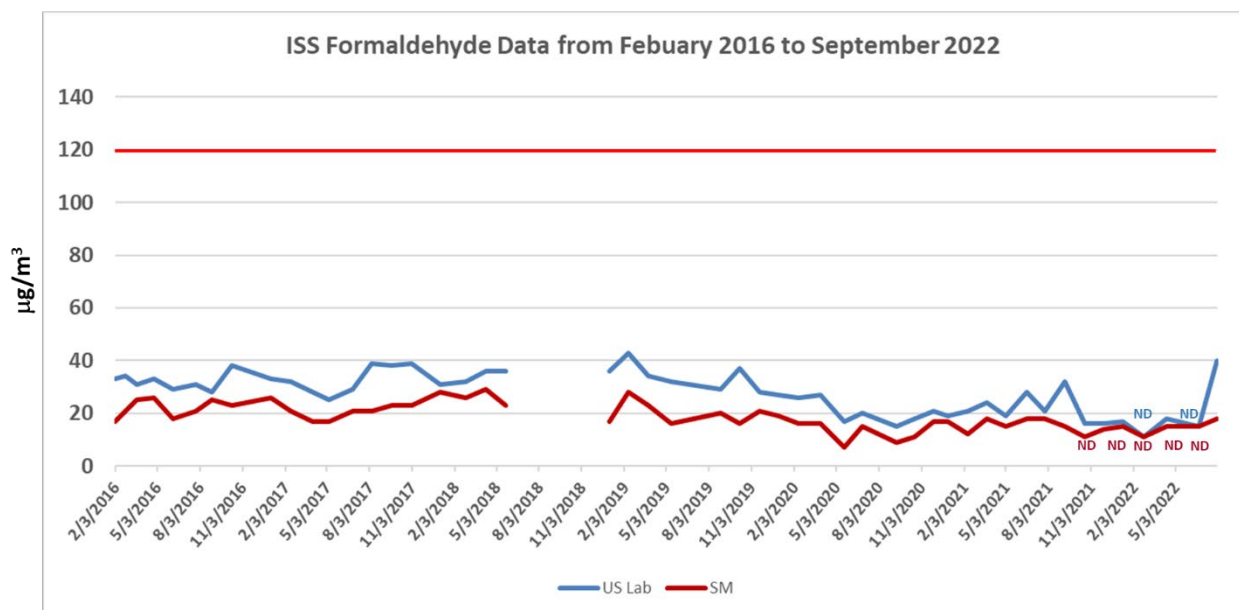


Figure 5: Formaldehyde Concentrations from February 2016 to February 2022

Boeing OFT-2 Ingress

An ingress sample was collected in Boeing's uncrewed Starliner Orbital Flight Test 2 (OFT-2) vehicle on May 21, 2022. The collection time for this sample was not recorded, so it is unclear how long after hatch opening it was collected. This sample contained 3300 mg/m³ CO₂ (1.4 mmHg, 1800 ppm), which is slightly lower than typical ISS atmosphere and could suggest equilibration with the ISS atmosphere prior to collection. However, ethanol levels in the vehicle (0.57 mg/m³) were significantly lower than ISS levels during this period (5.6-6.0 mg/m³). This makes interpretation of these results difficult as there should not have been any sources of CO₂ inside the vehicle. **Regardless, the T-value for OFT-2 ingress was 0.02, which is well below levels of concern for human health.**

SpX-25 Ingress

An ingress sample was collected in SpX-25 on July 16, 2022, at 16:44 GMT. Unfortunately, the time at which the hatch was opened was not recorded. The sample contained 6400 mg/m³ CO₂ (2.7 mmHg, 3600 ppm), markedly higher than the level on ISS during this period. These elevated levels may be a result of the presence of laboratory animals (Rodent Research-22) in the vehicle. Levels of ethanol and methanol were markedly lower inside the SpX-25 vehicle compared to the ISS level over the same period, indicating a low level of mixing. **The T-value for SpX-25 ingress was 0.1, well below levels of concern for human health.**

WATER QUALITY

In total, seven water samples were collected from the US Segment during Increment 67 and returned on Crew-3, Crew-4 and SpaceX-25. Four of these were potable water samples collected from the US Potable Water Dispenser (PWD): two hot water and two ambient water samples. The remaining samples were non-potable water, including a WPA product water sample collected from the PWD Aux Port and two samples each of US condensate and wastewater. Summaries of select analytical results from the Increment 67 samples are provided in Tables 3A and 3B.

Return Mission	Sample Location	Sample Date	TOC (mg/L)	DMSD (mg/L)	Methyl Sulfone (mg/L)	Conductivity (µS/cm)	Total Iodine (mg/L)
Crew-3	PWD Ambient	3/29/2022	0.78	1.6	0.24	1	0.06
Crew-3	PWD Hot	4/19/2022	0.89	1.9	0.21	1	<0.05
Crew-4	PWD Ambient	8/15/2022	0.42	<1	0.12	1	<0.05
Crew-4	PWD Hot	9/14/2022	0.15	<1	0.14	1	<0.05

Table 3A. Analytical Summary of ISS Water Analyses for CHCS Samples (Increment 67)

Return Mission	Sample Location	Sample Date	TOC (mg/L)	DMSD (mg/L)	Methyl Sulfone (mg/L)	Conductivity (µS/cm)	Total Iodine (mg/L)
SpaceX-25	WPA Wastewater	4/13/2022	13	7.7	0.09	102	NA
SpaceX-25	WPA Condensate	4/13/2022	131	16.0	0.11	230	NA
SpaceX-25	PWD Aux Port	8/4/2022	<0.1	<1	0.12	2	1.94
SpaceX-25	WPA Wastewater	8/5/2022	86.3	16.0	0.13	164	NA
SpaceX-25	WPA Condensate	8/5/2022	163	32.0	0.19	300	NA

NA: not analyzed

Table 3B. Analytical Summary of ISS Water Analyses for ECLS Samples (Increment 67)

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 6. The TOC concentrations in the four 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 PWD hot and ambient samples (1.6 and 1.9 mg/L) from March, April, August, and September 2022. Methyl sulfone was detected in two of the four potable water samples at levels well below the SWEG of 1,500 mg/L. Silicon was detected in three of four samples (0.5-0.6 mg/L). 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 one of four potable samples collected from the PWD was slightly above the reporting limit (0.05 mg/L) but below the potability limit, indicating effective removal of iodine in water intended for consumption. For additional information regarding microbial analyses, see the Increment 67 post-flight report generated by the JSC Environmental Microbiology Laboratory.

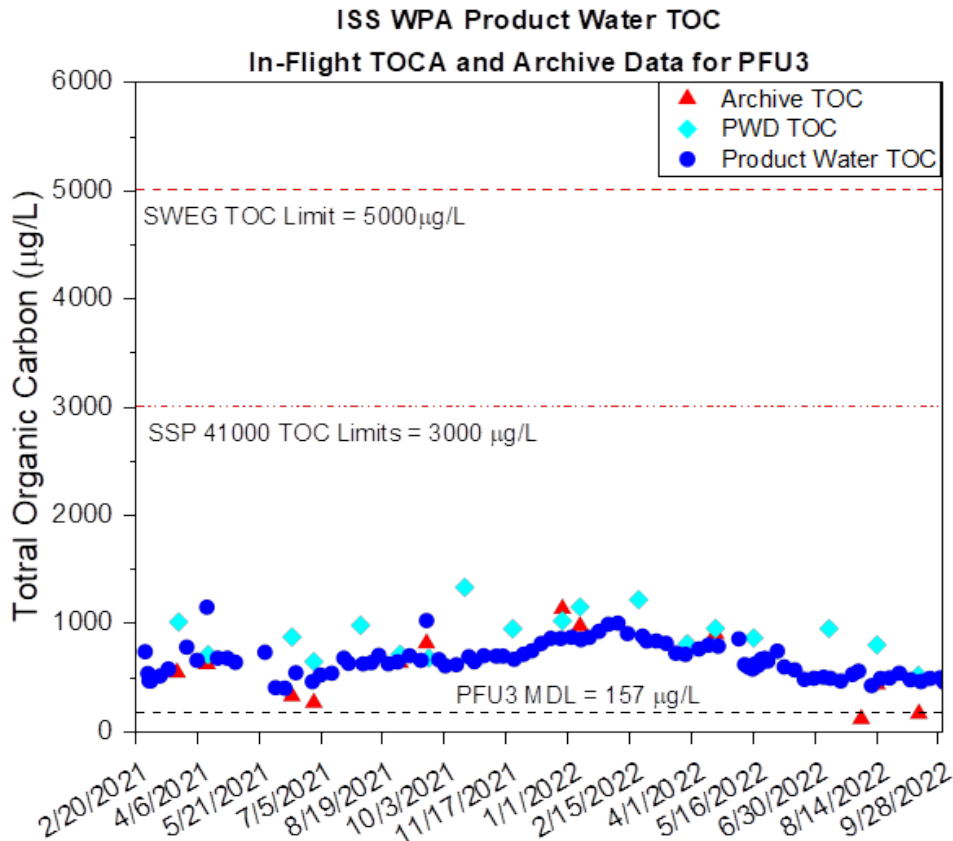


Figure 6. Total Organic Carbon (TOC) trending in US Potable Water from Archive Water Samples and On-Orbit TOCA (PFU3)

Condensate

The condensate sample collected on April 13 and August 5, 2022, contained TOC levels of 131 and 163 mg/L, respectively. Both of these concentrations are near the historical average of 150 mg/L. Organic compounds detected at or above 1 mg/L are listed in Table 4. Ethanol was markedly above historical average concentrations, consistent with the higher-than-historical levels of ethanol in ISS air. Silicon was present at 6.2-10.3 mg/L and can mostly be accounted for by the presence of DMSD. Zinc and nickel were detected above 0.1 mg/L. Ammonium was present at 31-39 mg/L, near 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

Compound	Condensate (mg/L)		Historical average (mg/L)
	April 13, 2022	August 5, 2022	
Benzoic acid	1.7	1.9	1.1
Benzyl alcohol	5.8	4.7	12.9
2-propanol (isopropanol)	3.1	2.3	1.4
Acetone	4.4	5.0	1.9
Ethanol	114.0	70.5	47.3
Methanol	9.1	6.7	4.7
1,2-ethanediol (ethylene glycol)	2.2	4.5	5.7
1,2-propanediol (propylene glycol)	15.1	23.6	27.6
Dimethylsilanediol (DMSD)	16.0	32.0	36.6
Acetate	34.8	76.7	39.7
Formate	2.6	3.5	7.7
Lactate	ND	11.9	5.7
Propionate	ND	1.7	1.0
Caprolactam	ND	1.2	4.6

ND: not detected

Wastewater

The wastewater samples from April 13 and August 5, 2022, contained TOC levels of 13 and 86 mg/L (historical average of 41 mg/L). Levels of several organic analytes present in these wastewater samples are shown in Table 5. Silicon was present in the sample at 3-6 mg/L, which can be mostly accounted for by the presence of DMSD. Zinc and nickel were the only metal detected above 0.1 mg/L. Traces of other metals were present in the samples, including aluminum, boron, chromium, copper, manganese, silver, and vanadium. Trace amounts of calcium, magnesium, phosphate, potassium, and sodium were also present. Ammonium ranged from 12.4-22.3 mg/L in the samples, which brackets the historical average (17.5 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

Compound	Wastewater (mg/L)		Historical average (mg/L)
	April 13, 2022	August 5, 2022	
Benzyl alcohol	ND	3.4	3.0
2-propanol (isopropanol)	ND	1.6	ND
Acetone	ND	5.7	3.8
Ethanol	ND	54.9	11.4
Methanol	0.62	5.1	4.6
1,2-ethanediol (ethylene glycol)	ND	1.6	1.6
1,2-propanediol (propylene glycol)	ND	10.5	5.2
Dimethylsilanediol (DMSD)	7.7	16.0	15.1
Acetate	ND	21.9	2.4

ND: not detected

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.

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Enclosures

- Table S-1: Analytical concentrations of compounds quantified in mGSCs collected in and returned on Boeing OFT-2, SpaceX-25, and SpaceX-26
- Table S-2A: T-values corresponding to concentrations for routine and contingency archive mGSC samples Boeing OFT-2, SpaceX-25, and SpaceX-26, based on 180-day SMACs
- Table S-2B: T-values corresponding to concentrations for Boeing OFT-2 and SpX-25 ingress air samples, based on 7-day and 180-day SMACs
- Table S-3A: Analytical concentrations of compounds quantified in potable hot and ambient water samples returned on Space-X Crew-3
- Table S-3B: Analytical concentrations of compounds quantified in US wastewater and US condensate returned on SpaceX-25

TABLE S-1: ANALYTICAL RESULTS FOR SAMPLES RETURNED ON BOEING OFT-2, SPACEX-25 AND SPACEX-26

Increment	67								
	Boeing OFT-2	SpaceX-25				SpaceX-26		Boeing OFT-2	SpaceX-25
Mission					Columbus Module				
Sample Location	Lab	JPM	Lab	Lab		Lab	Service Module	Boeing CST-100	Dragon Module
Sample Description	Nominal Air sample, S/N 2068	Nominal air sample, S/N 2085	Nominal air sample, S/N 2078	Nominal air sample, S/N 2044	Nominal air sample, S/N 2046	Nominal air sample, S/N 2019	Nominal air sample, S/N 2043	Ingress air sample, Boeing OFT-2, S/N 2072	Ingress air sample, SpX-25, S/N 2079
Sample Date	4/13/2022	4/13/2022	6/22/2022	8/1/2022	8/1/2022	9/14/2022	9/14/2022	5/21/2022	7/16/2022
Sample Time	14:35	14:39	14:52	17:00	17:00	11:13	11:17	16:22	16:50
Analysis/Sample ID	AQ220481	AQ220749	AQ220750	AQ220751	AQ220752	AQ230168	AQ230169	AQ220482	AQ220754
Volatiles Targets GCMS (TO-15 mod)					mg/m3			mg/m3	
1,1,1,2-Tetrafluoroethane	0.37	0.27	0.12	0.11	0.12	0.097	0.088	0.089	0.45
1-Butanol	0.098	0.057	0.063	0.047	0.047	0.064	0.069	0.038	<0.018
1-Propanol	0.056	0.048	0.037	0.033	0.031	0.054	0.061	<0.015	<0.015
2-Butanone (Methyl ethyl ketone)	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	0.023	<0.018
2-Methyl-1-propene	0.019	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014
2-Propanol (Isopropanol)	0.89	0.53	0.31	0.45	0.49	0.63	0.51	0.51	0.55
Acetaldehyde	0.27	0.18	0.14	0.14	0.15	0.27	0.24	0.047	0.062
Acetone	0.93	0.6	0.38	0.29	0.33	0.44	0.39	0.16	0.15
Acrylonitrile	0.033	0.026	0.014	0.120	0.075	<0.014	0.19	<0.013	<0.013
Carbon disulfide	0.019	<0.019	0.021	<0.019	<0.019	<0.020	<0.020	<0.019	<0.019
Ethanol	See GC-FID	See GC-FID	See GC-FID	See GC-FID	See GC-FID	See GC-FID	See GC-FID	0.57	See GC-FID
Ethyl acetate	0.055	0.057	0.046	0.023	0.023	0.040	0.039	<0.022	<0.022
Isobutane	0.045	0.034	<0.014	<0.014	<0.014	<0.015	<0.015	<0.014	<0.014
Isoprene (2-Methyl-1,3-butadiene)	0.065	0.057	0.049	0.023	0.028	0.054	0.051	0.026	<0.017
Methanol	0.74	0.4	0.28	0.26	0.28	See GC-FID	See GC-FID	0.089	0.19
Methyl acetate	0.033	0.027	0.019	<0.018	<0.018	<0.019	<0.019	<0.018	<0.018
o-Xylene	<0.026	<0.026	<0.026	<0.026	<0.026	<0.027	0.028	<0.026	<0.026
Perfluoro(2-methylpentane)	1.9	1.6	5.7	1.6	1.6	6.8	4.2	0.38	0.44
Propane	<0.011	0.031	0.019	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011
Propene	<0.010	<0.010	0.011	<0.010	<0.010	<0.011	<0.011	<0.010	<0.010
Toluene	0.030	0.025	0.024	0.024	<0.022	0.029	0.029	<0.022	<0.022
Trimethylsilanol	0.12	0.11	0.076	0.062	0.087	0.094	0.080	0.033	0.038
Volatiles Non-Targets GCMS (estimated conc.)									
Hexafluoropropene	not found	<0.074	<0.074	<0.074	<0.074	not found	not found	not found	0.16
Tetradecafluorohexane	6.8	4.2	13	4.4	4.3	21	13	1.4	1.2
Volatiles Targets GCFID									
Ethanol	6.2	6.0	5.6	4.8	5.1	6.7	7.8	NR	1.4
Methanol	NR	NR	NR	NR	NR	0.50	0.42	NR	NR
Octafluoropropane (Perfluoropropane)	5.9	6.2	<1.5	8.4	4.9	1.9	2.6	<1.5	3.0
Volatiles Targets TGA									
Carbon dioxide	5,200	5,500	3,900	4,200	4,400	3,800	5,000	3,300	6,400
Carbon monoxide	1.3	1.7	1.4	1.1	1.1	0.56	<0.48	<0.46	1.7
Hydrogen	7.2	6.6	5.0	5.9	6.0	5.1	5.3	2.2	2.1
Methane	77	81	110	120	120	130	130	30	29
	GMT 103	GMT 103	GMT 173	GMT 213	GMT 213	GMT 257	GMT 257	GMT 141	GMT 197

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

TABLE S-2A: T-VALUES FOR SAMPLES RETURNED ON BOEING OFT-2, SPACEX-25 AND SPACEX-26

Increment Mission Sample Location Sample Description Sample Date Sample Time Analysis/Sample ID	67						
	Boeing OFT-2	SpaceX-25				SpaceX-26	
	T-Value (180-day)						
	Lab	JPM	Lab	Lab	Columbus Module	Lab	Service Module
Nominal Air Sample, S/N 2068	Nominal air sample, S/N 2085	Nominal air sample, S/N 2078	Nominal air sample, S/N 2044	Nominal air sample, S/N 2046	Nominal air sample, S/N 2019	Nominal air sample, S/N 2043	
4/13/2022	4/13/2022	6/22/2022	8/1/2022	8/1/2022	9/14/2022	9/14/2022	
14:35	14:39	14:52	17:00	17:00	11:13	11:17	
AQ220481	AQ220749	AQ220750	AQ220751	AQ220752	AQ230168	AQ230169	
Volatiles Targets GCMS (TO-15 mod)							
1,1,1,2-Tetrafluoroethane	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1-Butanol	0.002	0.001	0.002	0.001	0.001	0.002	0.002
1-Propanol	0.001	0.001	0.000	0.000	0.000	0.001	0.001
2-Methyl-1-propene	0.001	ND	ND	ND	ND	ND	ND
2-Propanol (Isopropanol)	0.006	0.004	0.002	0.003	0.003	0.004	0.003
Acetaldehyde	0.067	0.046	0.034	0.036	0.038	0.068	0.061
Acetone	0.018	0.011	0.007	0.006	0.006	0.008	0.008
Acrylonitrile	0.474	0.365	0.200	1.664	1.075	ND	2.674
Carbon disulfide	0.017	ND	0.019	ND	ND	ND	ND
Ethyl acetate	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Isobutane	0.000	0.000	ND	ND	ND	ND	ND
Isoprene (2-Methyl-1,3-butadiene)	0.022	0.019	0.016	0.008	0.009	0.018	0.017
Methanol	0.028	0.015	0.011	0.010	0.011	See GC-FID	See GC-FID
Methyl acetate	0.000	0.000	0.000	ND	ND	ND	ND
o-Xylene	ND	ND	ND	ND	ND	ND	0.001
Perfluoro(2-methylpentane)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Propane	ND	0.000	0.000	ND	ND	ND	ND
Propene	ND	ND	0.000	ND	ND	ND	ND
Toluene	0.002	0.002	0.002	0.002	ND	0.002	0.002
Trimethylsilanol	0.030	0.028	0.019	0.016	0.022	0.023	0.020
Volatiles Non-Targets GCMS (estimated conc.)							
Tetradecafluorohexane	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Volatiles Targets GCFID							
Ethanol	0.003	0.003	0.003	0.002	0.003	0.003	0.004
Methanol	NR	NR	NR	NR	NR	0.019	0.016
Octafluoropropane (Perfluoropropane)	0.000	0.000	ND	0.000	0.000	0.000	0.000
Volatiles Targets TGA							
Carbon monoxide	0.076	0.100	0.080	0.065	0.067	0.033	ND
Hydrogen	0.021	0.019	0.015	0.017	0.018	0.015	0.015
Methane	0.022	0.023	0.031	0.033	0.034	0.037	0.038
Total T-Value	0.8	0.6	0.4	1.9	1.3	0.2	2.9

Comments: ND= Value is less than the laboratory reporting limit.
NR= Not Reported

TABLE S-2B: T-VALUES FOR BOEING OFT-2 AND SPACEX-25 INGRESS SAMPLES

Increment Mission Sample Location Sample Description Sample Date Sample Time Analysis/Sample ID	67			
	Boeing OFT-2		SpaceX-25	
	T-Value (7-day)	T-Value (180-day)	T-Value (7-day)	T-Value (180-day)
	Boeing CST-100	Boeing CST-100	Dragon Module	Dragon Module
Ingress air sample, Boeing OFT-2, S/N 2072	Ingress air sample, Boeing OFT-2, S/N 2072	Ingress air sample, SpX-25, S/N 2079	Ingress air sample, SpX-25, S/N 2079	
5/21/2022	5/21/2022	7/16/2022	7/16/2022	
16:22	16:22	16:50	16:50	
AQ220482	AQ220482	AQ220754	AQ220754	
Volatiles Targets GCMS (TO-15 mod)				
1,1,1,2-Tetrafluoroethane	0.000	0.000	0.000	0.000
1-Butanol	0.000	0.001	ND	ND
2-Butanone (Methyl ethyl ketone)	0.001	0.001	ND	ND
2-Propanol (Isopropanol)	0.003	0.003	0.004	0.004
Acetaldehyde	0.012	0.012	0.015	0.015
Acetone	0.003	0.003	0.003	0.003
Ethanol	0.000	0.000	See GC-FID	See GC-FID
Isoprene (2-Methyl-1,3-butadiene)	0.004	0.009	ND	ND
Methanol	0.003	0.003	0.007	0.007
Perfluoro(2-methylpentane)	0.000	0.000	0.000	0.000
Trimethylsilanol	0.008	0.008	0.009	0.009
Volatiles Non-Targets GCMS (estimated conc.)				
Hexafluoropropene	ND	ND	0.027	0.265
Tetradecafluorohexane	0.000	0.000	0.000	0.000
Volatiles Targets GCFID				
Ethanol	NR	NR	0.001	0.001
Octafluoropropane (Perfluoropropane)	ND	ND	0.000	0.000
Volatiles Targets TGA				
Carbon monoxide	ND	ND	0.027	0.101
Hydrogen	0.007	0.007	0.006	0.006
Methane	0.008	0.008	0.008	0.008
Total T-Value	0.0	0.1	0.1	0.4

Comments: ND= Value is less than the laboratory reporting limit.
NR= Not Reported

TABLE S-3A: ANALYTICAL CONCENTRATIONS OF COMPOUNDS QUANTIFIED IN POTABLE HOT AND AMBIENT WATER SAMPLES RETURNED ON CREW-3 and CREW-4

Increment Mission	Sample Location	Sample Description	Sample Date Analysis/Sample ID	Units	Test Conducted by	Potable Water Maximum Contaminant Level (MCL)	Maximum Contaminant Level Source	67			
								Crew-3		Crew-4	
								WPA PWD Ambient	WPA PWD Hot	WPA PWD Ambient	WPA PWD Hot
								Potable Water	Potable Water	Potable Water	Potable Water
								3/29/2022 WQ220149	4/19/2022 WQ220150	8/15/2022 WQ220293	9/14/2022 WQ220294
Physical Characteristics											
Conductivity				µS/cm	U.S.			1	1	1	1
pH				pH units	U.S.	4.5-8.5	41000	5.56	5.48	5.67	5.5
Turbidity				NTU	U.S.	1	41000	< 0.5	< 0.5	< 0.5	< 0.5
Iodine LCV											
Iodine				mg/L	U.S.	1.0-4.0	41000 (residual iodine in product water)	0.06	< 0.05	< 0.05	< 0.05
Total I				mg/L	U.S.	6/0.2	41000 (tl 1 max in product water/tl 1 at pt of consumption)	0.08	< 0.05	< 0.05	< 0.05
Minerals ICPMS											
Calcium				mg/L	U.S.	30	41000	0.02	0.02	< 0.01	< 0.01
Trace Metals ICPMS											
Aluminum				µg/L	U.S.			1	1	1	39
Barium				µg/L	U.S.	10,000	SWEG&41000	1	< 1	< 1	9
Boron				µg/L	U.S.			< 1	< 1	< 1	1
Nickel				µg/L	U.S.	300	SWEG&41000	2	2	8	9
Zinc				µg/L	U.S.	2,000	SWEG&41000	< 1	2	< 1	< 1
Silicon ICPMS											
Silicon				µg/L	U.S.			502	614	644	18
Total Organic Carbon-Sievers											
Total Inorganic Carbon (TIC)				mg/L	U.S.			0.678	0.766	1.06	1.04
Total Organic Carbon (TOC)				mg/L	U.S.	5 / 3	SWEG / 41000	0.780	0.893	0.419	0.146
Volatile Organics-Special Interest Compounds (Semi-quantitative)											
Acetaldehyde				µg/L	U.S.			11	not found	not found	not found
Semi-volatile Organics-Targets											
Methyl sulfone				µg/L	U.S.	1,500,000	interim SWEG (06-2017)	239	214	124	136
Base and Neutral Extractables-EPA 625 List GCMS											
bis-(2-Ethylhexyl)phthalate				µg/L	U.S.	20,000/6	SWEG/EPA	< 20	26	< 20	< 20
Silanols LCRI (Semi-Quantitative-NIST traceable standard not available)											
Dimethylsilanediol (DMSD)				µg/L	U.S.	35,000	SWEG	1,600	1,900	< 1,000	< 1,000
Organic Carbon Recovery				percent	U.S.			62.05	63.72	7.64	23.97
Unaccounted Organic Carbon				mg/L	U.S.			0.30	0.32	0.39	0.11

TABLE S-3B: ANALYTICAL CONCENTRATIONS OF COMPOUNDS QUANTIFIED IN WASTEWATER AND US CONDENSATE WATER SAMPLES RETURNED ON SPACEX-25

Increment Mission	Sample Location	Sample Description	Sample Date Analysis/Sample ID	Units	Test Conducted by	Potable Water Maximum Contaminant Level (MCL)	Maximum Contaminant Level Source	67 SpaceX-25				
								WPA Wastewater ORU WPA Wastewater 4/13/2022 WQ220261	WPA Condensate Sample Port US Condensate 4/13/2022 WQ220262	WPA PWD Aux Port WPA Product Water 8/4/2022 WQ220260	WPA Wastewater ORU WPA Wastewater 8/5/2022 WQ220263	WPA Condensate Sample Port US Condensate 8/5/2022 WQ220264
Physical Characteristics												
Conductivity				µS/cm	U.S.			102	230	2	164	300
pH				pH units	U.S.	4.5-8.5	41000	7.24	7.47	5.41	7.26	7.36
Iodine LCV												
Iodide				mg/L	U.S.			NA	NA	0.31	NA	NA
Iodine				mg/L	U.S.	1.0-4.0	41000 (residual iodine in product water)	NA	NA	1.94	NA	NA
Total I				mg/L	U.S.	6/0.2	41000 (tl 1 max in product water/tl 1 at pt of consumption)	NA	NA	2.25	NA	NA
Anions IC												
Fluoride				mg/L	U.S.			0.3	< 0.1	< 0.1	0.1	< 0.1
Cations IC												
Ammonium (as N)				mg/L	U.S.	1	SWEG&41000	12.4	30.9	< 0.25	22.3	38.9
Minerals ICPMS												
Calcium				mg/L	U.S.	30	41000	0.05	0.08	< 0.01	0.06	0.12
Phosphate (as P)				mg/L	U.S.			0.06	0.01	< 0.01	0.02	< 0.10
Potassium				mg/L	U.S.	340	41000	0.16	0.06	< 0.01	0.02	< 0.10
Sodium				mg/L	U.S.			0.08	0.01	< 0.01	0.01	< 0.10
Trace Metals ICPMS												
Aluminum				µg/L	U.S.			4	5	< 1	6	< 50
Boron				µg/L	U.S.			17	24	< 1	29	55
Chromium				µg/L	U.S.	230	41000	15	2	< 1	5	< 50
Copper				µg/L	U.S.	1,000	41000	1	2	1	1	< 50
Manganese				µg/L	U.S.	300	SWEG&41000	1	1	< 1	2	< 50
Nickel				µg/L	U.S.	300	SWEG&41000	260	84	36	154	165
Silver				µg/L	U.S.	400	SWEG&41000	23	42	< 1	14	< 50
Vanadium				µg/L	U.S.			2	< 1	1	< 1	< 50
Zinc				µg/L	U.S.	2,000	SWEG&41000	2,480	846	< 1	4,820	3,320
Silicon ICPMS												
Silicon				µg/L	U.S.			3,000	6,160	< 10	6,000	10,300
Total Organic Carbon-Sievers												
Total Inorganic Carbon (TIC)				mg/L	U.S.			13.1	19.0	0.958	17.4	17.4
Total Organic Carbon (TOC)				mg/L	U.S.	5 / 3	SWEG / 41000	13.0	131	< 0.100	86.3	163
Volatile Organics-Targets												
2-Butanone (Methyl ethyl ketone)				µg/L	U.S.	54,000	SWEG	< 50	< 50	< 5	205	< 50
Volatile Organics-Special Interest Compounds (Semi-quantitative)												
Acetaldehyde				µg/L	U.S.			not found	not found	not found	not found	140
Trimethylsilanol				µg/L	U.S.			62	150	not found	99	160
Semi-volatile Organics-Targets												
Benzothiazole				µg/L	U.S.			40	44	< 20	45	42
bis-(2-Ethylhexyl)adipate				µg/L	U.S.	400	EPA	< 20	55	< 20	57	56
Decamethylcyclopentasiloxane (DMCPS)				µg/L	U.S.			< 20	< 20	< 20	< 20	27
Dodecamethylcyclohexasiloxane				µg/L	U.S.			< 20	< 20	< 20	< 20	26
Methyl sulfone				µg/L	U.S.	1,500,000	interim SWEG (06-2017)	88	108	116	127	191
Acid Extractables-EPA 625 List GCMS												
4-Methylphenol (p-Cresol)				µg/L	U.S.			< 20	< 20	< 20	323	< 20
Benzoic acid				µg/L	U.S.			< 40	1,680	< 40	474	1,880
Phenol				µg/L	U.S.	4,000	SWEG	< 20	101	< 20	127	100
Base and Neutral Extractables-EPA 625 List GCMS												
Benzyl alcohol				µg/L	U.S.			< 20	5,820	< 20	3,420	4,650
bis-(2-Ethylhexyl)phthalate				µg/L	U.S.	20,000/6	SWEG/EPA	< 20	181	< 20	237	179
Diethylphthalate				µg/L	U.S.			111	302	< 20	252	264
Semi-volatile Organics-Special Interest Compounds (Semi-quantitative)												
1-Methyl-2-pyrrolidinone				µg/L	U.S.			89	150	not found	170	280
2-(2-Butoxyethoxy)ethanol				µg/L	U.S.			not found	160	not found	230	230
2-Butoxyethanol				µg/L	U.S.			not found	130	not found	99	120
2-Ethoxyethanol				µg/L	U.S.			not found	220	not found	210	220
2-Ethyl-1-hexanol				µg/L	U.S.			not found	60	not found	< 40	< 40
2-Ethylhexanoic acid				µg/L	U.S.			not found	98	not found	100	150
2-Methyl butyric acid				µg/L	U.S.			not found	not found	not found	71	53
2-Methyl-2,4-pentanediol				µg/L	U.S.			47	not found	not found	not found	not found
2-Phenoxyethanol				µg/L	U.S.			not found	69	not found	100	160
2-Phenyl-2-propanol				µg/L	U.S.			< 40	110	not found	< 40	54
2-Phenylacetic acid				µg/L	U.S.			not found	not found	not found	210	200
Acetophenone				µg/L	U.S.			not found	11	not found	< 10	< 10
Benzaldehyde				µg/L	U.S.			not found	29	not found	20	< 20
Dipropylene glycol methyl ether				µg/L	U.S.			30	not found	not found	not found	not found
Hexanoic acid (Caprolate)				µg/L	U.S.			not found	370	not found	180	380
Ibuprofen				µg/L	U.S.			290	270	not found	290	270
N,N-Diethylformamide				µg/L	U.S.			22	43	not found	42	53
N,N-Dimethyl acetamide				µg/L	U.S.			110	260	not found	210	340
N,N-Dimethylformamide				µg/L	U.S.			92	300	not found	310	430
Neomenthol				µg/L	U.S.			< 20	< 20	not found	< 20	< 20
Phenethyl alcohol				µg/L	U.S.			not found	18	not found	15	22
Alcohols & Acetone GCMS												
1-Butanol				µg/L	U.S.			< 400	788	< 400	401	529
1-Propanol				µg/L	U.S.			< 400	492	< 400	< 400	< 400
2-Propanol (Isopropanol)				µg/L	U.S.			< 400	3,140	< 400	1,620	2,340
Acetone				µg/L	U.S.	15,000	SWEG	< 400	4,370	See Volatiles	5,740	4,960
Ethanol				µg/L	U.S.			< 400	114,000	< 400	54,900	70,500
Methanol				µg/L	U.S.	40,000	SWEG	619	9,140	< 400	5,100	6,700
Glycols GCMS												
1,2-Ethanediol (Ethylene glycol)				µg/L	U.S.	4000	SWEG	< 1,000	2,190	< 1,000	1,580	4,490
1,2-Propanediol (Propylene glycol)				µg/L	U.S.	1,700,000	SWEG	< 1,000	15,100	< 1,000	10,500	23,600
Silanol LCRI (Semi-Quantitative-NIST traceable standard not available)												
Dimethylsilanediol (DMSD)				µg/L	U.S.	35,000	SWEG	7,700	16,000	< 1,000	16,000	32,000

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

Increment Mission	Sample Location	Sample Description	Sample Date Analysis/Sample ID	Units	Test Conducted by	Potable Water Maximum Contaminant Level (MCL)	Maximum Contaminant Level Source	67 SpaceX-25				
								WPA Wastewater ORU WPA Wastewater 4/13/2022 WQ220261	WPA Condensate Sample Port US Condensate 4/13/2022 WQ220262	WPA PWD Aux Port WPA Product Water 8/4/2022 WQ220260	WPA Wastewater ORU WPA Wastewater 8/5/2022 WQ220263	WPA Condensate Sample Port US Condensate 8/5/2022 WQ220264
								Carboxylates IC				
Acetate	µg/L	U.S.						< 500	34,800	< 500	21,900	76,700
Formate	µg/L	U.S.	2,500,000		SWEG			< 500	2,600	< 500	< 500	3,530
Isobutyrate (2-Methylpropanoic acid)	µg/L	U.S.						< 500	< 500	< 500	< 500	566
Lactate	µg/L	U.S.						< 500	< 500	< 500	< 500	11,900
Propionate	µg/L	U.S.						< 500	< 500	< 500	< 500	1,700
Aldehydes GCMS												
Formaldehyde (Methanal)	µg/L	U.S.	12,000		SWEG			< 10	520	< 10	36	464
Non-volatile Organics LC												
Caprolactam	µg/L	U.S.	100,000		SWEG			< 500	< 500	< 500	625	1,220
Organic Carbon Recovery	percent	U.S.						21.62	78.63	30.30	69.21	68.72
Unaccounted Organic Carbon	mg/L	U.S.						10.22	28.02	0.07	26.58	50.84

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