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**Memorandum Number
TOX-SC-2022-01**

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DATE: May 16, 2022

SUBJECT: Toxicological Assessment of ISS Air and Water Quality: October 21, 2020 – April 17, 2021 (Increment 64) Including SpX-21 and NG-15 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

Eleven archive air samples were collected in mini grab sample containers (mGSCs) on ISS during Increment 64. Four sets of samples were collected for routine monitoring on November 29 and December 29, 2020, and February 10, and March 23, 2021. Two ingress samples were collected for SpX-21 (December 7, 2020) and NG-15 (February 22, 2021) and a single sample was collected during the ascent of SpX Crew-1 (Resilience) vehicle on November 16, 2020. Additionally, four sets of formaldehyde badges were deployed during Increment 64. The badges were deployed in the US Lab and the Russian Service Module (SM) on November 29, December 29, 2020, February 10, and March 23, 2021. The November 2020, December 2020, and February 2021 formaldehyde badges were returned on Soyuz 63. The badges from March 2021 were returned on SpX-23. A summary of the results from the Increment 64 samples is provided in Table 1.

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 64 samples were acceptable. The mean relative recoveries of the three surrogate standards from the mGSC samples returned on Soyuz 63, SpX-21, and SpX-22 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 for this Increment that returned on SpX-21 and SpX-22 confirmed air quality was acceptable. **T-values calculated using data from the routine archive samples (mGSC) met 180-d T-value guideline criteria ($T < 1$), indicating no concern for crew health.**

Table 1. Analytical summary of ISS air analyses (Increment 64)

Return Flight	Sample Location	Sample Date	Freon 218 (mg/m ³)	Alcohols ^a (mg/m ³)	T-Value ^b (units)	Formaldehyde ^c (µg/m ³)
Crew-1	Cabin (Ascent)	11/16/2020	<1.5	0.5	0.3	--
SpX-21	US Lab	11/29/2020	210	2.0	0.4	21
SpX-21	JPM	11/29/2020	200	6.1	0.2	17 ^e
SpX-21	SpX-21 Ingress	12/7/2020	29	2.3	0.2 (0.1)	--
SpX-21	US Lab	12/29/2020	190	3.5	0.4	19
SpX-21	Columbus	12/29/2020	190	3.4	0.4	17 ^e
SpX-22	US Lab	2/10/2021	140	3.8	0.3	21
SpX-22	SM	2/10/2021	170	3.3	0.2	12
SpX-22	NG-15 Ingress	2/22/2021	50	2.5	0.5 (0.3)	--
SpX-22	US Lab	3/23/2021	190	3.3	0.2	24
SpX-22	JPM	3/23/2021	180	3.4	0.2	18 ^e
<i>Guideline</i>			---	<5	<1 ^d	<120

^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 All formaldehyde badges were returned on Soyuz 63S, except for samples collected on March 23, 2021 that were returned on SpaceX-23.

^d T-value <1 used to evaluate routine monthly sampling; <3 used to evaluate first ingress.

^e These formaldehyde samples were collected in the Russian SM.

Table 2. Average monthly concentrations (mg/m³) of AQM target compounds (Increment 64)

Compound	October Average †	November Average †	December Average	January Average	February Average	March Average	April Average	Increment Average
2-Propanol	---	0.44	0.76	0.68	0.54	0.46	0.22	0.52
Acetone	---	0.23	0.32	0.39	0.28	0.32	0.43	0.33
Acrolein	---	ND	ND	ND	ND	ND	ND	ND
Benzene	---	MI	MI	MI	MI	ND	ND	MI
1,2-Dichloroethane	---	ND	ND	ND	ND	ND	ND	ND
Decamethylcyclotrisiloxane#	---	ND	ND	ND	ND	ND	ND	ND
Hexanal	---	ND	ND	ND	ND	ND	ND	ND
Hexane	---	ND	ND	ND	ND	ND	ND	ND
m,p-Xylenes#	---	ND	ND	ND	ND	ND	ND	ND
Methanol	---	0.36	0.44	0.32	0.22	0.4	0.62	0.39
o-Xylene#	---	ND	ND	ND	ND	ND	ND	ND
Octamethylcyclotetrasiloxane#	---	ND	ND	ND	ND	ND	ND	ND
Toluene#	---	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE
2-Butanone	ND	ND	ND	ND	ND	ND	ND	ND
Acetaldehyde	ND	TRACE	TRACE	TRACE	TRACE	0.23	0.23	TRACE
Dichloromethane	ND	ND	ND	ND	ND	ND	ND	ND
Ethanol	2.4	2.25	2.65	3.01	2.99	5.07	5.86	3.46
Ethyl Acetate	ND	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE
Hexamethylcyclotrisiloxane#	---	ND	ND	ND	ND	ND	ND	ND
n-Butanol	ND	0.04	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE
Trimethylsilanol	ND	ND	ND	ND	ND	ND	ND	ND

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

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

MI: matrix interference

--: Data is not available.

*: AQM1 began detecting benzene at trace levels on April 13, 2020. This signal was due to an interfering compound.

† AQM1 failed in late June 2020 and was replaced in November 2020.

The reported concentrations for the compounds detected during Increment 64 indicated an increase from the previous Increment 63 but remain well below levels of concern for crew health. The average, rounded T-value calculated from the nominal Increment 64 mGSC samples was 0.29 (Figure 1), nearly twice that of Increment 63 (0.16). This increase can be attributed to the rising levels of acrylonitrile in November and December nominal samples. The concentration of 1-propanol in the JPM on November 29 was 3.6 mg/m³, compared to levels on the order of 0.02-0.05 mg/m³ for the rest of the Increment. Trimethylsilanol was also elevated above normal levels in the February 10, 2021 sample collected in the US Lab (0.5 mg/m³). Both these results appear to be due to transient increases in the concentrations of these compounds, although no specific activity or source has been identified that explains these findings. Importantly, the measured levels of both compounds were well below levels of concern for crew health and neither concentration remained elevated. As AQM1 failed in June 2020 and was inoperative until November 2020, no T-values could be calculated from AQM data during this period.

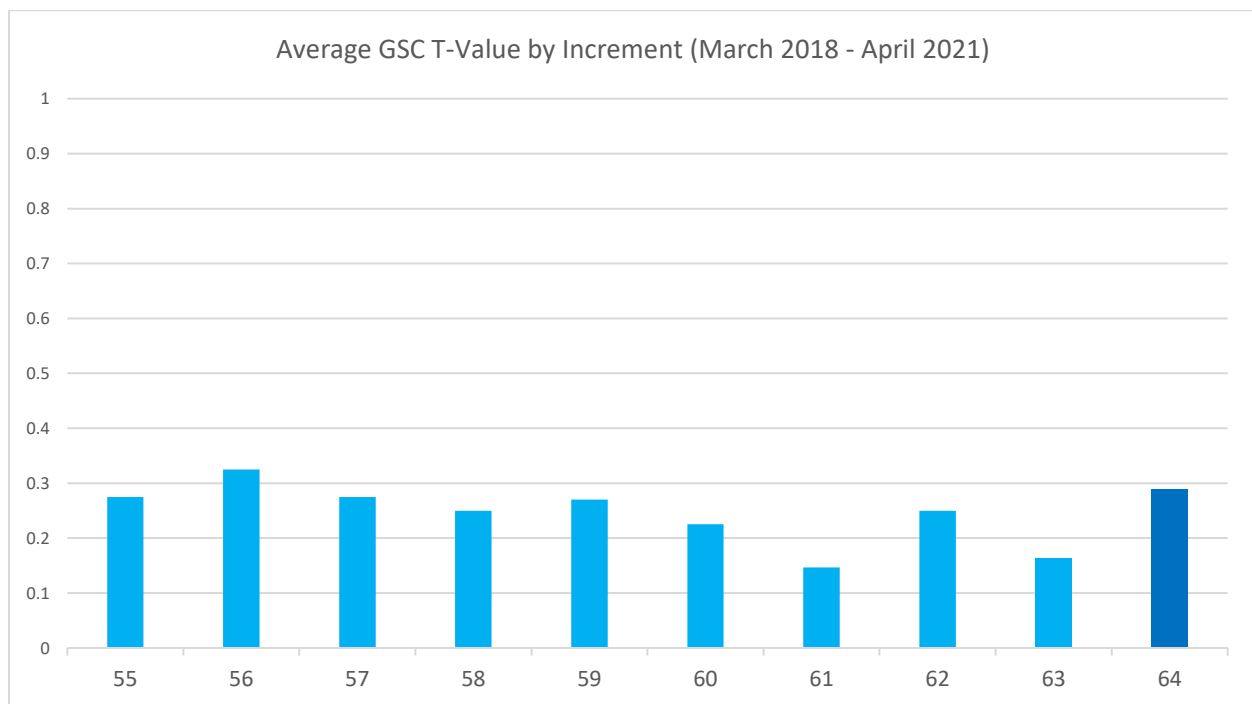


Figure 1. GSC-Derived T-values for Increments 55-64

All of the 8 routine mGSC samples collected during Increment 64 contained a CO₂ concentration below the limit documented in Flight Note F091532D, which requests that the 24-hour average concentration not exceed 3.2 mmHg (7600 mg/m³) on the US segment. While mGSC CO₂ sampling provides a snap-shot of the CO₂ concentration, real-time CO₂ data are available from sensors in the Columbus module and SM, and intermittently from the Major Constituent Analyzer (MCA) (Figure 2). Concentrations measured by these sensors and the MCA fluctuate as a result of multiple factors including the number of crew on ISS, current scrubbing capability, and processes and activities that generate CO₂. To preserve the longevity of the instrumentation, the MCAs were transitioned to intermittent operations starting in mid-February 2020. The MCAs are only activated during EVA activities, crew metabolic characterization, tech demo analysis, anomaly resolution, and when requested by crew surgeons.

CO₂ data were obtained from the Columbus sensor and Lab (MCA) sensor throughout the Increment. Overall, CO₂ concentrations were well-controlled throughout the Increment (Figure 2). The ISS crew was comprised of 7 crew for most of the Increment. Increment 64 started with 3 crew, with the addition of 4 crew members starting in mid-November with the docking of SpX Crew-1 mission. CO₂ levels exceeded 4

mmHg in mid and late January, early and mid-February, and early and mid-March as a result of EVA activity and MetOx regeneration activities.

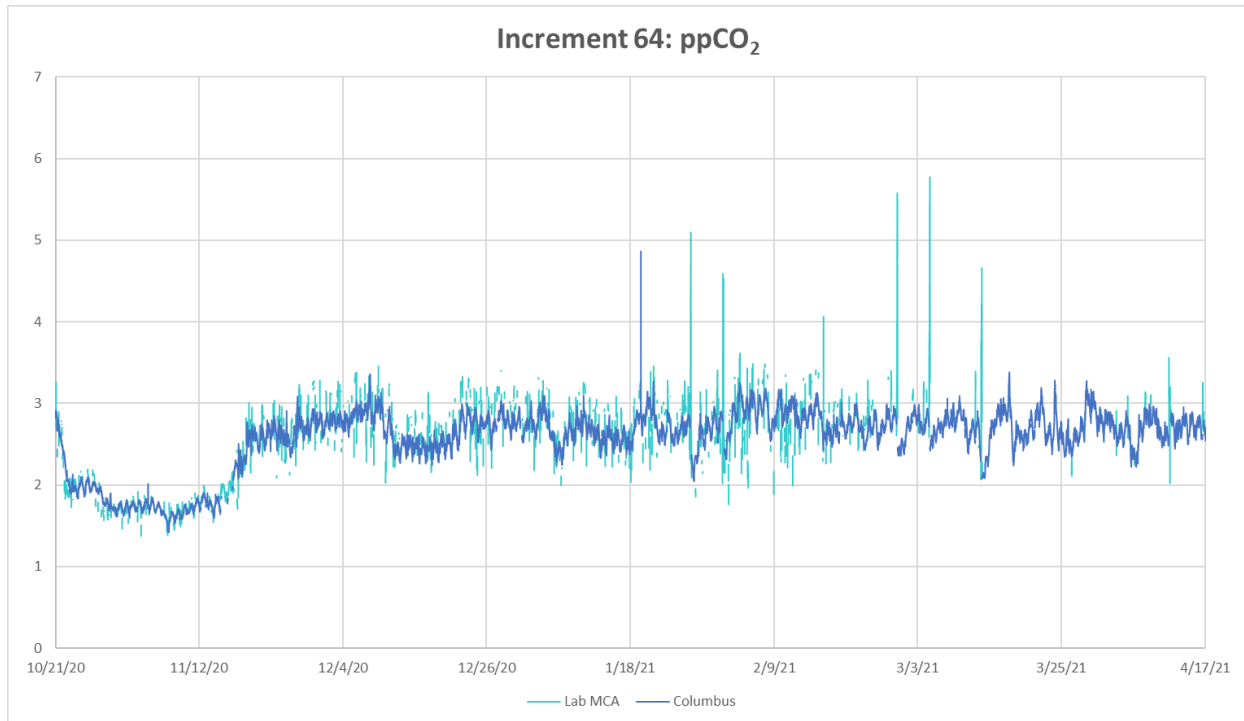


Figure 2. Environmental CO₂ Concentrations on ISS Increment 64 (mmHg)

Alcohol values for one of the routine mGSC samples returned on SpX-21 exceeded the ECLS guideline of <5 mg/m³, but all other samples were below. The sample collected on November 29, 2020 reported total alcohols at 6.1 mg/m³. The higher alcohol value for November is attributed to an increase in 1-propanol (3.6 mg/m³) within the JPM (source unknown). For the other samples collected, total alcohol levels generally ranged from 2.0-3.8 mg/m³, slightly lower than the previous increment. For most samples across the Increment, total alcohol levels were largely attributable to ethanol, with the exception of the aforementioned reading of 1-propanol in JPM in November 2020. Measured levels do not present a risk to crew health.

Levels of octafluoropropane (Freon 218) increased during the early part and near the end of the Increment (180-210 mg/m³), but a slight decrease was observed in the two February 2021 samples (140-170 mg/m³). Previous increases of octafluoropropane in ISS air have been associated with maintenance of CKB. However, no such activities are believed to have occurred during this Increment. These concentrations are well below levels of concern for crew health.

Four sets of passive formaldehyde badges were deployed on ISS during Increment 64 (November 29 and December 29, 2020, February 10 and March 23, 2021). Results from analysis of these badges indicated that formaldehyde remains in the historical range observed on ISS, and concentrations are well below the SMAC of 120 µg/m³ (Figure 3). The concentrations in the SM ranged from 12 to 18 µg/m³, and in the US Lab the concentration ranged from 19-24 µg/m³, slightly higher than levels observed in Increment 63.

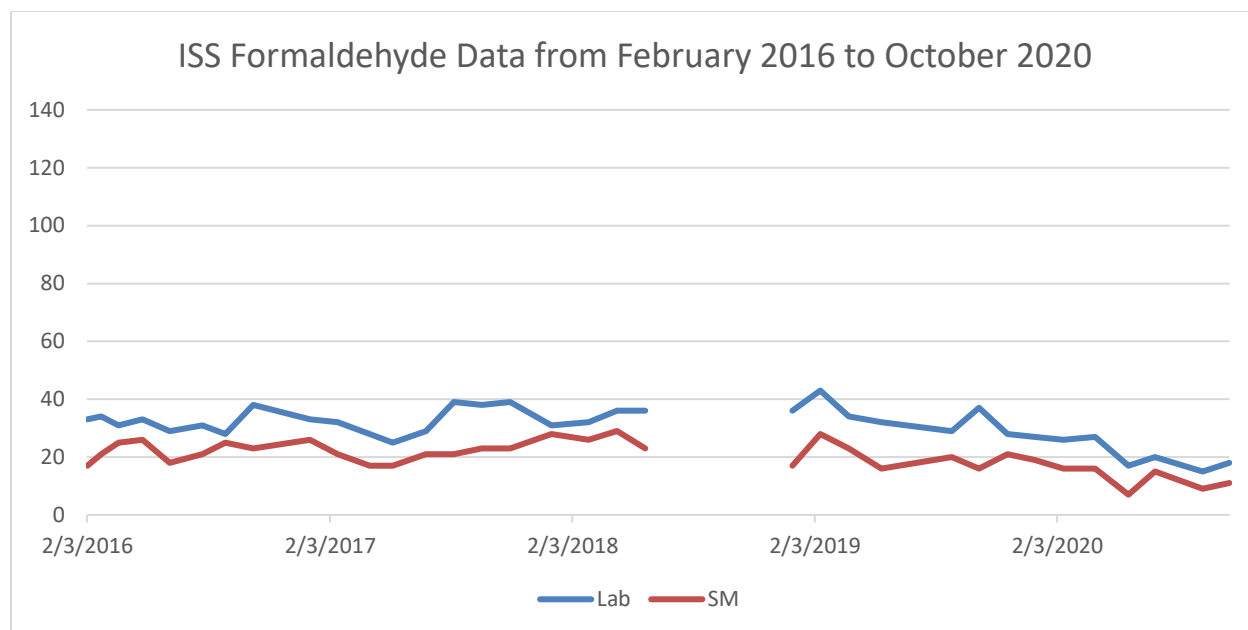


Figure 3: Formaldehyde Concentrations from February 2016 to March 2021

SpX-21 Ingress

An ingress sample was collected for SpX-21 on December 7, 2020, approximately 1 minute after hatch opening. The octafluoropropane (Freon 218) concentration was 29 mg/m³ for the ingress sample, much lower than the concentrations observed in the late-November and late-December archive samples suggesting limited atmospheric mixing occurred prior to sample collection. The measured T-value for the SpX-21 ingress sample was 0.1 (excluding CO₂); well below levels of concern for human health.

SpX Crew-1 Cabin Sample

One planned nominal mGSC sample was collected on ascent of the SpX Crew-1 (Dragon) *Resilience* vehicle on November 16, 2020. The sample was collected in the center of the vehicle cabin and the measured T-value was (0.3). This is well below levels of concern for crew health.

NG-15 Ingress

An ingress sample was collected for NG-15 on February 22, 2021, approximately 8 minutes after hatch opening. The octafluoropropane (Freon 218) and CO₂ concentrations in the ingress sample were ~1/3 – 1/2 those observed during nominal ISS sampling in mid-Feb and late March, indicating less than full mixing. The measured T-value for this ingress was 0.3 (excluding CO₂), which is well below levels of concern for crew health.

WATER QUALITY

Three samples were collected from the US Segment during Increment 64 and returned on Soyuz 63. Two of these were potable water samples collected from the US Potable Water Dispenser (PWD): a hot water sample on April 13 and an ambient water sample on March 23, 2021. The third sample was a product water sample collected from the PWD auxiliary port on March 11, 2021. Samples of US condensate and wastewater were also collected during Increment 64. These samples were returned to ground for analysis on SpX-21. A summary of select analytical results from the Increment 64 samples is provided in Table 3. 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.

Table 3. Analytical Summary of ISS Water Analyses (Increment 64)

Return Mission	Sample Location	Sample Date	TOC (mg/L)	DMSD (mg/L)	Methyl Sulfone (mg/L)	Conductivity (µS/cm)	Total Iodine (mg/L)
SpX-21	US Condensate	12/31/2020	71.5	18.0	0.078	290	NA
SpX-21	WPA Wastewater	1/4/2021	24.4	7.9	0.068	153	NA
Soyuz 63	WPA Product Water	3/11/2021	0.581	1.7	0.076	2	2.12
Soyuz 63	PWD Ambient	3/23/2021	0.531	1.1	0.082	1	<0.05
Soyuz 63	PWD Hot	4/13/2021	0.607	1.7	0.094	<1	<0.05

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 2019 and April 2021 are shown in Figure 4. In January 2021, inconsistencies between in-flight samples and archive results were noted and thought to be due to TOCA PFU2 approaching end of life. TOCA PFU3 was installed on February 22, 2021 to resolve the end of life issues with PFU2. Following activation of TOCA PFU3 in-flight readings have shown excellent agreement with archival samples. 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 (1.1 and 1.7 mg/L) and are similar to the average concentration seen in previous flights. 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 (0.38 and 0.44 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 the potable samples collected from the PWD was 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 64 post-flight report generated by the JSC Environmental Microbiology Laboratory.

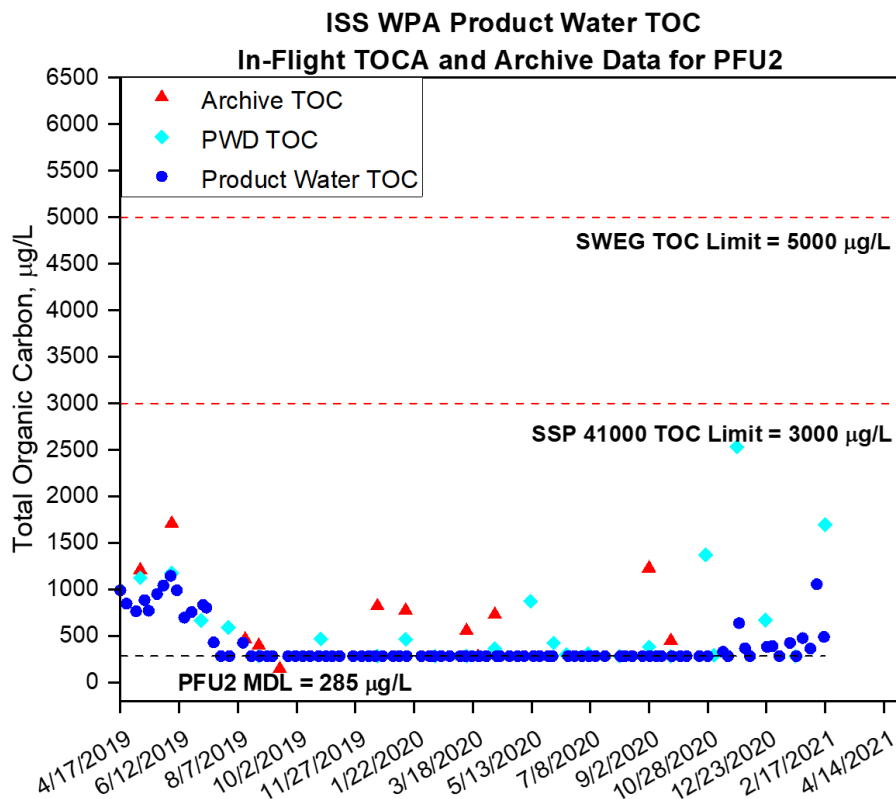


Figure 4. Total Organic Carbon (TOC) trending in US Potable Water for PFU2. The PFU2 was replaced with the PFU3 in February 2021.

Condensate

The condensate sample collected on December 31, 2020 contained a TOC level of 71.5 mg/L, which is below the historical average. Two organic compounds not seen since 2018, 1,3,5-triallyl-1,2,5-triazine-2,4,6(1H,3H,5H)-trione and neomenthol, were detected. Reported concentrations of these compounds were higher than historical averages, but well below historical maximums. Organic compounds detected at or above 1 mg/L include 2-propanol (1.5 mg/L), acetone (2.8 mg/L), ethanol (16.1 mg/L), methanol (7.3 mg/L), ethylene glycol (3.7 mg/L), propylene glycol (19.7 mg/L), dimethylsilanediol (DMSD, 18 mg/L), acetate (51.1 mg/L) and formate (1.7 mg/L). Acetaldehyde, which has not been detected in condensate since 2016, was measured at 0.23 mg/L. While this is above the average, it is below the historical high of 1.68 mg/L. Ibuprofen, not detected in condensate since 2006, was detected at 0.55mg/L. Silicon was present at 6.8 mg/L, which can mostly be accounted for by the presence of DMSD (5.4 mg/L Si). Zinc (14.2 mg/L) was the only metal detected above 0.1 mg/L in the sample. Trace amounts of aluminum, barium, boron, chromium, copper, manganese, nickel, selenium, silver, and strontium were also present. Ammonium was present at a concentration of 32.2 mg/L, which is 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 in the potable samples.

Wastewater

The wastewater sample, collected on January 4, 2021, contained a TOC level of 24.4 mg/L, which is well below the historical average of 41.9 mg/L. The DMSD concentration was 7.9 mg/L, which was similar to the previous wastewater sample (6.9 mg/L) collected during Increment 62 in April 2020. Silicon was present at 3.2 mg/L, which again can be mostly accounted for by the presence of DMSD (2.4 mg/L Si).

Zinc (11.1 mg/L) was the only metal detected above 0.1 mg/L in the sample. Traces of other metals were also present, including aluminum, barium, boron, chromium, copper, manganese, nickel, selenium, silver, and strontium. As with the condensate samples, all compounds of toxicological interest were effectively cleaned from the samples by the WRS.

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Enclosures	Table 1A: Analytical concentrations of compounds quantified in mGSCs collected in and returned on SpaceX Crew-1
	Table 1B: Analytical concentrations of compounds quantified in routine archive and SpaceX-21 ingress mGSCs returned on SpaceX-21
	Table 1C: Analytical concentrations of compounds quantified in routine archive and NG-15 ingress mGSCs returned on SpaceX-22
	Table 2A: T-values corresponding to concentrations for routine archive mGSC samples returned on SpaceX Crew-1, based on 180-day SMACs
	Table 2B: T-values corresponding to concentrations for routine archive mGSC samples returned on SpaceX-21, based on 180-day SMACs
	Table 2C: T-values corresponding to concentrations for SpaceX-21 ingress air sample returned on SpaceX-21, based on 7-day and 180-day SMACs
	Table 2D: T-values corresponding to concentrations for routine archive mGSC samples returned on SpaceX-22, based on 180-day SMACs
	Table 2E: T-values corresponding to concentrations for NG-15 ingress air sample returned on SpaceX-22, based on 7-day and 180-day SMACs
	Table 3A: Analytical concentrations of compounds quantified in potable ambient, potable hot, and product water samples returned on Soyuz 63
	Table 3B: Analytical concentrations of compounds quantified in US wastewater and US condensate returned on SpaceX-21

**TABLE 1A
ANALYTICAL RESULTS FOR SPACEX CREW-1 RETURN SAMPLE**

CHEMICAL CONTAMINANT	CONCENTRATION (mg/m ³)
	AQ210443 SN2011 SpaceX Resilience Cabin Center 11/16/2020 @ 20:36
TARGET COMPOUNDS (TO-15) *	
1,1,1,2-Tetrafluoroethane	0.56
Chloromethane	0.024
Isobutane	0.028
Methanol	0.061
Acetaldehyde	0.021
Ethanol	0.031
Acetone	0.13
2-Propanol (Isopropanol)	0.29
SPECIAL INTEREST COMPOUNDS #	
The Special Interest Compound was below its reporting limit	
NON-TARGET COMPOUNDS	
All non-target compounds were below their reporting limit	
TOTAL ALCOHOLS PLUS ACETONE	0.52
TARGET COMPOUNDS (GC) *	
Methane	<2.0
Carbon dioxide	2100
Hydrogen	9.5
Carbon monoxide	3.9

* Quantified using a multi-point calibration

< : Value is less than the laboratory reporting limit.

**TABLE 1B
ANALYTICAL RESULTS FOR SPACEX-21 RETURN AIR SAMPLES**

CHEMICAL CONTAMINANT	CONCENTRATION (mg/m3)				
	AQ210088 S/N 2006 LAB	AQ210089 S/N 2007 JPM	AQ210090 S/N 2008 SpaceX-21 Ingress	AQ210091 S/N 2009 LAB	AQ210092 S/N 2109 Columbus
	11/29/20 @ 12:58	11/29/20 @ 13:00	12/7/20 @ 20:52	12/29/20 @ 10:19	12/29/20 @ 09:34
TARGET COMPOUNDS (TO-15) *					
1,1,1,2-Tetrafluoroethane (Norflurane)	0.16	0.13	0.46	0.095	0.11
Isobutane	0.036	0.038	0.015	0.046	0.051
Methanol	0.50	0.32	0.56	0.41	0.45
Acetaldehyde	0.19	0.15	0.052	0.13	0.13
2-Methyl-1-propene	0.017	0.015	<0.014	<0.014	0.015
Ethanol	0.32	0.66	0.55	2.3	2.1
Acetone	0.44	0.91	0.20	0.31	0.34
2-Propanol (Isopropanol)	0.60	0.62	0.91	0.42	0.44
Isoprene (2-Methyl-1,3-butadiene)	0.043	0.045	<0.017	0.024	0.029
Acrylonitrile	0.013	<0.013	<0.013	0.014	0.015
Methylene chloride (Dichloromethane)	<0.021	<0.021	0.021	<0.021	<0.021
1-Propanol	0.050	3.6	0.018	0.030	0.034
Trimethylsilanol	0.076	0.099	0.033	0.031	0.078
Ethyl acetate	0.033	0.033	<0.022	<0.022	0.022
1-Butanol	0.048	0.038	0.021	0.028	0.039
Octafluoropropane (Perfluoropropane)	210	200	29	190	190
SPECIAL INTEREST COMPOUND #					
The Special Interest Compound was below its reporting limit.					
NON-TARGET COMPOUNDS **					
The Non-Target Compound was below its reporting limit.					
TOTAL ALCOHOLS PLUS ACETONE	2.0	6.1	2.3	3.5	3.4
TARGET COMPOUNDS (GC) *					
Methane	38	39	7.4	53	55
Carbon dioxide	6700	7100	5600	6900	7600
Hydrogen	6.3	6.3	2.4	6.0	6.1
Carbon monoxide	0.71	0.71	2.0	0.80	0.69

* Quantified using a multi-point calibration

** Quantified using "B" response factor except where noted; concentrations are estimates only.

Response factor generated from an internal study; concentrations are estimates only.

< : Value is less than the laboratory reporting limit.

TABLE 1C
ANALYTICAL RESULTS FOR SPACEX-22 RETURN NOMINAL SAMPLES

CHEMICAL CONTAMINANT	CONCENTRATION (mg/m ³)				
	AQ210609 SN2108	AQ210610 SN2027	AQ210611 SN2021	AQ210612 SN2024	AQ210613 SN2110
	Lab 02/10/21 14:53	SM 02/10/21 14:52	NG-15 Ingress 02/22/21 16:45	Lab 03/23/21 07:30	JPM 03/23/21 07:35
TARGET COMPOUNDS (TO-15) *					
1,1,1,2-Tetrafluoroethane	0.11	0.10	0.20	0.11	0.11
Propane	0.014	<0.011	<0.011	<0.011	<0.011
Carbonyl sulfide (Carbon oxide sulfide)	<0.015	<0.015	0.043	<0.015	<0.015
Isobutane	1.1	0.051	1.3	0.047	0.047
Methanol	0.41	0.38	0.31	0.38	0.39
Acetaldehyde	0.18	0.14	0.22	0.18	0.19
2-Methyl-1-propene	0.039	0.014	0.085	0.016	0.016
Butane	<0.014	<0.014	0.021	<0.014	<0.014
Ethanol	2.1	2.3	0.98	2.3	2.3
Acetone	0.36	0.31	0.32	0.34	0.35
Propanal (Propionaldehyde)	<0.014	<0.014	0.027	<0.014	<0.014
2-Propanol (Isopropanol)	0.86	0.32	0.84	0.30	0.32
Isoprene (2-Methyl-1,3-butadiene)	0.028	0.032	<0.017	0.035	0.039
Methylene chloride (Dichloromethane)	<0.021	<0.021	0.12	<0.021	<0.021
Carbon disulfide	<0.019	<0.019	0.039	<0.019	<0.019
1-Propanol	0.031	0.018	0.017	0.038	0.024
Trimethylsilanol	0.50	0.033	0.23	0.039	0.091
2-Butanone (Methyl ethyl ketone)	<0.018	<0.018	0.030	<0.018	<0.018
Ethyl acetate	<0.022	0.022	0.049	0.024	0.023
1-Butanol	0.051	0.030	0.045	0.031	0.034
2-Methylhexane	<0.025	<0.025	0.046	<0.025	<0.025
2,3-Dimethylpentane	<0.025	<0.025	0.053	<0.025	<0.025
3-Methylhexane	<0.025	<0.025	0.095	<0.025	<0.025
Toluene	<0.023	<0.023	0.023	<0.023	<0.023
Octafluoropropane (Perfluoropropane)	140	170	50	190	180
SPECIAL INTEREST COMPOUNDS #					
Hexamethylcyclotrisiloxane (HMCTS)	<0.18	<0.18	0.48	<0.18	<0.18
NON-TARGET COMPOUNDS **					
Fluorotrimethylsilane	<0.045	<0.045	0.13	<0.045	<0.045
C11-Alkane	<0.077	<0.077	0.093	<0.077	<0.077
C12-Alkane	0.11	<0.084	0.17	<0.084	<0.084
Undecane	0.11	<0.077	0.19	<0.077	<0.077
C12-Alkane	0.094	<0.084	0.19	<0.084	<0.084
C12-Alkane	0.087	<0.084	0.15	<0.084	<0.084
TOTAL ALCOHOLS PLUS ACETONE					
	3.8	3.3	2.5	3.3	3.4
TARGET COMPOUNDS (GC) *					
Methane	46	58	17	54	54
Carbon dioxide	5100	5900	3000	5500	6200
Hydrogen	5.9	6.6	2.0	7.7	7.7
Carbon monoxide	1.1	0.61	1.3	0.75	0.71

* Quantified using a multi-point calibration

** Quantified using "B" response factor except where noted; concentrations are estimates only.

Response factor generated from an internal study; concentrations are estimates only.

< : Value is less than the laboratory reporting limit.

**TABLE 2A
T-VALUES FOR SPACEX CREW-1 RETURN SAMPLE**

CHEMICAL CONTAMINANT	T-VALUE (180-d SMAC)
	AQ210443 SN2011 SpaceX Resilience Cabin Center 11/16/2020 @ 20:36
TARGET COMPOUNDS (TO-15)	
1,1,1,2-Tetrafluoroethane	0.000
Chloromethane	0.013
Isobutane	0.000
Methanol	0.002
Acetaldehyde	0.005
Ethanol	0.000
Acetone	0.002
2-Propanol (Isopropanol)	0.002
SPECIAL INTEREST COMPOUND	
The Special Interest Compound was below its reporting limit	
NON-TARGET COMPOUNDS	
All non-target compounds were below their reporting limit	
TARGET COMPOUNDS (GC) *	
Hydrogen	0.028
Carbon monoxide	0.229
TOTAL T-VALUE	0.3

ND : Value is less than the laboratory reporting limit.

Note: Number of decimal places in T-Values do not represent significant figures of measurements.

**TABLE 2B
T-VALUES FOR SPACEX-21 RETURN AIR SAMPLES**

CHEMICAL CONTAMINANT	T-VALUE (180-d SMAC)			
	AQ210088 S/N 2006 LAB 11/29/20 @ 12:58	AQ210089 S/N 2007 JPM 11/29/20 @ 13:00	AQ210091 S/N 2009 LAB 12/29/20 @ 10:19	AQ210092 S/N 2109 Columbus 12/29/20 @ 09:34
TARGET COMPOUNDS (TO-15)				
1,1,1,2-Tetrafluoroethane (Norflurane)	0.000	0.000	0.000	0.000
Isobutane	0.000	0.000	0.000	0.000
Methanol	0.019	0.012	0.016	0.017
Acetaldehyde	0.047	0.037	0.032	0.032
2-Methyl-1-propene	0.001	0.001	ND	0.001
Ethanol	0.000	0.000	0.001	0.001
Acetone	0.008	0.018	0.006	0.006
2-Propanol (Isopropanol)	0.004	0.004	0.003	0.003
Isoprene (2-Methyl-1,3-butadiene)	0.014	0.015	0.008	0.010
Acrylonitrile	0.187	ND	0.207	0.208
1-Propanol	0.001	0.048	0.000	0.000
Trimethylsilanol	0.019	0.025	0.008	0.019
Ethyl acetate	0.000	0.000	ND	0.000
1-Butanol	0.001	0.001	0.001	0.001
Octafluoropropane (Perfluoropropane)	0.003	0.002	0.002	0.002
SPECIAL INTEREST COMPOUND				
The Special Interest Compound was below its reporting limit.				
NON-TARGET COMPOUNDS				
The Non-Target Compound was its reporting limit.				
TARGET COMPOUNDS (GC)				
Methane	0.011	0.011	0.015	0.016
Hydrogen	0.019	0.019	0.018	0.018
Carbon monoxide	0.019	0.042	0.047	0.040
TOTAL T-VALUE	0.4	0.2	0.4	0.4

ND : Value is less than the laboratory reporting limit.

Note: Number of decimal places in T-Values do not represent significant figures of measurements.

**TABLE 2C
T-VALUES FOR SPACEX-21 RETURN INGRESS SAMPLE**

CHEMICAL CONTAMINANT	T-VALUE	
	7-day	180-day
	AQ210090 S/N 2008 SpaceX-21 Ingress 12/7/20 @ 20:52	AQ210090 S/N 2008 SpaceX-21 Ingress 12/7/20 @ 20:52
TARGET COMPOUNDS (TO-15)		
1,1,1,2-Tetrafluoroethane (Norflurane)	0.000	0.000
Isobutane	0.000	0.000
Methanol	0.022	0.022
Acetaldehyde	0.013	0.013
Ethanol	0.000	0.000
Acetone	0.004	0.004
2-Propanol (Isopropanol)	0.006	0.006
Methylene chloride (Dichloromethane)	0.000	0.002
1-Propanol	0.000	0.000
Trimethylsilanol	0.008	0.008
1-Butanol	0.000	0.001
Octafluoropropane (Perfluoropropane)	0.000	0.000
SPECIAL INTEREST COMPOUND		
The Special Interest Compound was below its reporting limit.		
NON-TARGET COMPOUNDS		
The Non-Target Compound was below its reporting limit.		
TARGET COMPOUNDS (GC)		
Methane	0.002	0.002
Hydrogen	0.007	0.007
Carbon monoxide	0.031	0.115
TOTAL T-VALUE	0.1	0.2

ND : Value is less than the laboratory reporting limit.

Note: Number of decimal places in T-Values do not represent significant figures of measurements.

TABLE 2D
T-VALUES FOR SPACEX-22 RETURN NOMINAL GSC SAMPLES

CHEMICAL CONTAMINANT	T-VALUE (180-d SMAC)			
	AQ210609	AQ210610	AQ210612	AQ210613
	SN2108	SN2027	SN2024	SN2110
	Lab	SM	Lab	JPM
	02/10/21	02/10/21	03/23/21	03/23/21
	14:53	14:52	07:30	07:35
TARGET COMPOUNDS (TO-15)				
1,1,1,2-Tetrafluoroethane	0.000	0.000	0.000	0.000
Propane	0.000	ND	ND	ND
Isobutane	0.006	0.000	0.000	0.000
Methanol	0.016	0.015	0.015	0.015
Acetaldehyde	0.046	0.036	0.046	0.046
2-Methyl-1-propene	0.002	0.001	0.001	0.001
Ethanol	0.001	0.001	0.001	0.001
Acetone	0.007	0.006	0.007	0.007
2-Propanol (Isopropanol)	0.006	0.002	0.002	0.002
Isoprene (2-Methyl-1,3-butadiene)	0.009	0.011	0.012	0.013
1-Propanol	0.000	0.000	0.001	0.000
Trimethylsilanol	0.124	0.008	0.010	0.023
Ethyl acetate	ND	0.000	0.000	0.000
1-Butanol	0.001	0.001	0.001	0.001
Octafluoropropane (Perfluoropropane)	0.002	0.002	0.002	0.002
SPECIAL INTEREST COMPOUNDS				
The Special Interest Compound was below its reporting limit				
NON-TARGET COMPOUNDS				
C12-Alkane	0.005	ND	ND	ND
Undecane	0.006	ND	ND	ND
C12-Alkane	0.004	ND	ND	ND
C12-Alkane	0.004	ND	ND	ND
TARGET COMPOUNDS (GC)				
Methane	0.013	0.016	0.015	0.015
Hydrogen	0.017	0.019	0.023	0.023
Carbon monoxide	0.066	0.036	0.044	0.042
TOTAL T-VALUE	0.3	0.2	0.2	0.2

ND : Value is less than the laboratory reporting limit.

Note: Number of decimal places in T-Values do not represent significant figures of measurements.

The following non-target compound interim 180-day SMAC was used in the T-value calculations for SpX-22 return only:

C12 Alkane: 19.2 mg/m³

**TABLE 2E
T-VALUES FOR SPACEX-22 RETURN NG-15 INGRESS**

CHEMICAL CONTAMINANT	T-VALUE	
	7-day	180-day
	AQ210611 SN2021 NG-15 Ingress 02/22/21 16:45	AQ210611 SN2021 NG-15 Ingress 02/22/21 16:45
TARGET COMPOUNDS (TO-15)		
1,1,1,2-Tetrafluoroethane	0.000	0.000
Carbonyl sulfide (Carbon oxide sulfide)	0.000	0.002
Isobutane	0.007	0.007
Methanol	0.012	0.012
Acetaldehyde	0.055	0.055
2-Methyl-1-propene	0.001	0.004
Butane	0.000	0.000
Ethanol	0.000	0.000
Acetone	0.006	0.006
Propanal (Propionaldehyde)	0.002	0.002
2-Propanol (Isopropanol)	0.006	0.006
Methylene chloride (Dichloromethane)	0.002	0.012
Carbon disulfide	0.035	0.035
1-Propanol	0.000	0.000
Trimethylsilanol	0.059	0.059
2-Butanone (Methyl ethyl ketone)	0.001	0.001
Ethyl acetate	0.000	0.000
1-Butanol	0.001	0.001
2-Methylhexane	0.000	0.004
2,3-Dimethylpentane	0.000	0.004
3-Methylhexane	0.000	0.008
Toluene	0.002	0.002
Octafluoropropane (Perfluoropropane)	0.001	0.001
SPECIAL INTEREST COMPOUNDS		
Hexamethylcyclotrisiloxane (HMCTS)	0.005	0.053
NON-TARGET COMPOUNDS		
Fluorotrimethylsilane	0.034	0.056
C11-Alkane	0.000	0.005
C12-Alkane	0.000	0.008
Undecane	0.001	0.010
C12-Alkane	0.000	0.009
C12-Alkane	0.000	0.007
TARGET COMPOUNDS (GC)		
Methane	0.005	0.005
Hydrogen	0.006	0.006
Carbon monoxide	0.021	0.076
TOTAL T-VALUE	0.3	0.5

Note: Number of decimal places in T-Values do not represent significant figures of measurements.

Table 3A: Analytical concentrations of compounds quantified in potable ambient, potable hot, and product water samples returned on Soyuz 63

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	64		
					Soyuz 63		
					WPA PWD Hot Potable water 4/13/2021 WQ210142	WPA PWD Ambient Potable water 3/23/2021 WQ210143	WPA PWD Aux Port WPA Product Water 3/11/2021 WQ210144
Physical Characteristics							
Conductivity	µS/cm	U.S.			< 1	1	2
pH	pH units	U.S.	4.5-8.5	41000	5.61	5.52	5.33
Iodine LCV							
Iodide	mg/L	U.S.			< 0.05	< 0.05	0.26
Iodine	mg/L	U.S.	1.0-4.0	41000 (residual iodine in product water)	< 0.05	< 0.05	1.85
Total I	mg/L	U.S.	6/0.2	41000 (tl I max in product water/tl I at pt of consumption)	< 0.05	< 0.05	2.12
Minerals ICPMS							
Calcium	mg/L	U.S.	30	41000	0.01	0.01	0.02
Trace Metals ICPMS							
Aluminum	µg/L	U.S.			6	5	7
Barium	µg/L	U.S.	10,000	SWEG&41000	1	< 1	< 1
Copper	µg/L	U.S.	1,000	41000	< 1	< 1	1
Nickel	µg/L	U.S.	300	SWEG&41000	1	10	56
Zinc	µg/L	U.S.	2,000	SWEG&41000	5	< 1	3
Silicon ICPMS							
Silicon	µg/L	U.S.			446	384	473
Total Organic Carbon-Sievers							
Total Inorganic Carbon (TIC)	mg/L	U.S.			0.929	1.24	1.03
Total Organic Carbon (TOC)	mg/L	U.S.	5 / 3	SWEG / 41000	0.607	0.531	0.581
Semi-volatile Organics-Targets							
Methyl sulfone	µg/L	U.S.	1,500,000	interim SWEG (06-2017)	94	82	76
Base and Neutral Extractables-EPA 625 List GCMS							
Diethylphthalate	µg/L	U.S.			24	25	< 20
Silanols LCRI (Semi-Quantitative-NIST traceable standard not available)							
Dimethylsilanediol (DMSD)	µg/L	U.S.	35,000	SWEG	1,700	1,100	1,700
Organic Carbon Recovery	percent	U.S.			79.4	61.0	79.5
Unaccounted Organic Carbon	mg/L	U.S.			0.13	0.21	0.12

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

Table 3B: Analytical concentrations of compounds quantified in US wastewater and US condensate returned on SpaceX-21

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	64 SpaceX-21	
									WPA Wastewater ORU	WPA Condensate Sample Port
									WPA Wastewater 1/4/2021 WQ210018	US Condensate 12/31/2020 WQ210019
Physical Characteristics										
					µS/cm	U.S.			153	290
					pH units	U.S.	4.5-8.5	41000	7.24	7.43
Anions IC										
					mg/L	U.S.			0.3	0.2
Cations IC										
					mg/L	U.S.	1	SWEG&41000	14.6	32.2
Minerals ICPMS										
					mg/L	U.S.	30	41000	0.05	0.16
					mg/L	U.S.	50	41000	< 0.01	0.05
					mg/L	U.S.	340	41000	0.06	0.08
					mg/L	U.S.			0.02	0.07
Trace Metals ICPMS										
					µg/L	U.S.			1	1
					µg/L	U.S.	10,000	SWEG&41000	2	3
					µg/L	U.S.			15	54
					µg/L	U.S.	230	41000	5	4
					µg/L	U.S.	1,000	41000	4	4
					µg/L	U.S.	300	SWEG&41000	8	22
					µg/L	U.S.			< 1	1
					µg/L	U.S.	300	SWEG&41000	330	130
					µg/L	U.S.	10	41000	1	2
					µg/L	U.S.	400	SWEG&41000	4	22
					µg/L	U.S.			2	5
					µg/L	U.S.	2,000	SWEG&41000	11,100	14,200
Silicon ICPMS										
					µg/L	U.S.			3,160	6,820
Total Organic Carbon-OI										
					mg/L	U.S.			16.8	19.7
					mg/L	U.S.	5 / 3	SWEG / 41000	24.4	71.5
Volatile Organics-Targets										
					µg/L	U.S.	54,000	SWEG	416	< 50
Volatile Organics-Special Interest Compounds (Semi-quantitative)										
					µg/L	U.S.			not found	230
					µg/L	U.S.			not found	98
Semi-volatile Organics-Targets										
					µg/L	U.S.			32	< 20
					µg/L	U.S.			< 20	25
					µg/L	U.S.			< 20	24
					µg/L	U.S.	1,500,000	Interim SWEG (08-2017)	68	78
					µg/L	U.S.			35	38
					µg/L	U.S.			< 20	62
Acid Extractables-EPA 625 List GCMS										
					µg/L	U.S.			289	< 20
					µg/L	U.S.			< 40	705
					µg/L	U.S.	4,000	SWEG	77	< 20
Base and Neutral Extractables-EPA 625 List GCMS										
					µg/L	U.S.			252	569
					µg/L	U.S.			100	174
					µg/L	U.S.	40,000	SWEG	52	53
Semi-volatile Organics-Special Interest Compounds (Semi-quantitative)										
					µg/L	U.S.			110	160
					µg/L	U.S.			not found	180
					µg/L	U.S.			100	170
					µg/L	U.S.			65	74
					µg/L	U.S.			not found	110
					µg/L	U.S.			69	130
					µg/L	U.S.			16	< 10
					µg/L	U.S.			40	47
					µg/L	U.S.			not found	< 40
					µg/L	U.S.			590	550
					µg/L	U.S.			not found	20
					µg/L	U.S.			21	29
					µg/L	U.S.			120	230
					µg/L	U.S.			200	300
					µg/L	U.S.			55	34
Alcohols & Acetone GCMS										
					µg/L	U.S.			463	1,500
					µg/L	U.S.	15,000	SWEG	10,100	2,800
					µg/L	U.S.			7,120	16,100
					µg/L	U.S.	40,000	SWEG	5,670	7,330
Glycols GCMS										
					µg/L	U.S.	4,000	SWEG	1,000	3,740
					µg/L	U.S.	1,700,000	SWEG	4,200	19,700
Silands LCRI (Semi-Quantitative-NIST traceable standard not available)										
					µg/L	U.S.	35,000	SWEG	7,900	18,000
Carboxylates IC										
					µg/L	U.S.			< 500	51,100
					µg/L	U.S.	2,500,000	SWEG	< 500	1,720
Aldehydes GCMS										
					µg/L	U.S.	12,000	SWEG	58	702
Non-volatile Organics LC										
					µg/L	U.S.	100,000	SWEG	< 500	514
Organic Carbon Recovery										
					percent	U.S.			76.59	75.06
Unaccounted Organic Carbon										
					mg/L	U.S.			5.71	17.84

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