JSC TOXICOLOGY AND ENVIRONMENTAL CHEMISTRY GROUP

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SUBJECT: Toxicological Assessment of Air Samples Collected During the SpaceX Dragon 2 Demo-1 Mission (March 3-7, 2019)

SUMMARY: Concentrations of all measured compounds at ingress, including R-134a, were well below levels of concern. Concentrations of 2-propanol (isopropanol or IPA) in ISS air during the SpaceX Dragon 2 Demo-1 mission were elevated but did not constitute a risk to the health of the crew and were of minimal risk to the water reclamation systems on board.

The first demonstration flight of SpaceX's Dragon 2 vehicle (Demo-1) launched on March 3, 2019. Prior to the launch, there were concerns about the potential for leakage of a refrigerant, R-134a (1,1,1,2-tetrafluoroethane or Norflurane), from the vehicle's cooling system. To address those concerns, NASA and international partners developed a first ingress plan that included monitoring R-134a in the vehicle atmosphere prior to initiation of intermodule ventilation (IMV). This was accomplished by having two crew members enter the vehicle while wearing ИПК masks to retrieve a hand-held COTS detector. Crew activated the detector and took multiple readings before initiating IMV. This plan of operations also included collection of a first ingress sample in a miniature Grab Sample Container (mGSC) and the Russian AK-1M inside the Dragon vehicle.

Due to reports of an odor in the SM on the afternoon of March 3, a contingency sample was collected in an mGSC and JSC Toxicology was asked to review data from the Air Quality Monitors (AQMs) collected shortly after Demo-1 ingress. During the evaluation of these data, a significant increase in 2-propanol was noted. The expected concentration was not a concern for crew health but was a potential concern for the water recovery systems. As a result, daily AQM runs were requested.

Due to crew reports of odors in Demo-1 during undocking preparations, a second contingency sample was collected on March 7. A planned egress sample was also collected a short time later just prior to hatch closure. A summary of analytical results from the samples collected in the mGSCs 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 also attached to this report. Complete data tables, which include compounds assessed but not detected, are available upon request.

Table 1: Summary of Analytical Results for mGSC Air Samples Collected During SpaceX Demo-1

Sample Location	Sample Date	Freon 218 (mg/m^3)	Alcohols[a] (mg/m^3)	T-Value[b] (units)	2-propanol (mg/m^3)	R-134a (mg/m^3)
Demo-1 ingress	3/3/2019	2.3	6.5	0.3 (0.2)	5.2	0.3
SM Contingency	3/3/2019	13	4.4	0.2	0.5	0.1
Demo-1 Contingency	3/7/2019	38	4.9	0.2	0.8	0.1
Demo-1 Egress	3/7/2019	33	6.3	0.1	2.3	0.1
Demo-1 Splashdown	3/9/2019	15	3.5	0.2	1.2	0.1
Guideline		---	*<5*	*<1*[c]	*150*	*33,000*

[a]Includes acetone

[b]Sum of the ratios of the measured concentration and the corresponding 180-day SMAC for each compound, excluding CO_2; parentheses 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

Toxicological Evaluation of ISS Air Quality

The COTS R-134a detector did not register a detectable level of this compound in the air of the vehicle at ingress (< 75 ppm). The mGSC ingress sample confirmed very low levels of R-134a at ingress. **These levels are far below levels of concern for crew health**; however, because elevated concentrations of this coolant are a potential crew health concern in the small vehicle volume, additional measures will be taken on future Dragon -2 missions to both reduce the likelihood of a leak and provide the capability to monitor and detect a leak if one does occur.

AQM data indicated that the 2-propanol levels were in excess of 5.9 mg/m^3 (the upper limit of the calibration range on the instrument) for the majority of docked operations. Interestingly, the trend in the 2-propanol peak area suggest a relationship between the concentration in the ISS atmosphere and Demo-1 cabin fan/ECLS operations. 2-propanol levels declined following Demo-1 undocking and returned to background levels within a few days. Analysis of the archive mGSC samples confirmed AQM trending but indicated that the AQM over predicted 2-propanol concentrations.

The ingress sample for Demo-1 was collected 3 minutes after hatch opening (13:10 GMT). **The measured T value of 0.2 was well below the acceptable value of 3 and did not present a concern for crew health.** The primary contributors to the T value were trans-1,2-dichloroethylene (0.05), carbon monoxide (0.04), 2-propanol (0.04), isobutane (0.02), and acetaldehyde (0.02). The 2-propanol concentration in this sample was 5.2 mg/m^3, which is above the zero risk level of 1.5 mg/m^3 but well below the acceptable risk level of 150 mg/m^3. As IMV was not connected to the Demo-1 vehicle, there should have been very little mixing of atmospheres between the vehicle and ISS at the time of sample collection. This was confirmed by low octafluoropropane and CO_2 levels in the sample.

In response to crew reports of an odor in the SM, a contingency sample was collected in the vicinity of the odor at approximately 21:00 GMT. There were no compounds detected in the sample that were notably elevated or expected to be associated with the reported odor. The concentration of 2-propanol was an order of magnitude lower (0.5 mg/m^3) than the Demo-1 ingress sample (5.2 mg/m^3) and well below both the zero risk and acceptable risk limits.

While preparing for undocking inside the Demo-1 vehicle on March 7, a crew member reported an odor and a contingency sample was collected inside the vehicle near the suspected source (08:00 GMT). The 2-propanol level in this sample was 0.8 mg/m^3. Another planned egress sample was taken inside the Demo-1 vehicle the same day just prior to hatch closure (17:15 GMT). The 2-propanol concentration in the egress sample was 2.2 mg/m^3. Both measured concentrations are below acceptable limits for crew health and the ISS Environmental Control and Life Support (ECLS) systems.

A post-flight sample was also taken from the Demo-1 vehicle on the recovery vessel following splashdown but prior to hatch opening. The 2-propanol concentration in this sample was 1.2 mg/m^3. During descent, a nitrox purge was conducted, and it is estimated that the purge resulted in a 50% dilution of cabin atmosphere based on comparison of the post-flight sample with the egress sample. Coupled with the changes in area counts for 2-propanol measured on the AQM, these results strongly suggest there was a persistent source of 2-propanol on the Demo-1 vehicle. Efforts to identify this source is ongoing. The inconsistencies between AQM and mGSC measurements for 2-propanol will also be closely evaluated.

In summary, concentrations of all compounds measured at ingress were acceptable and did not present a risk to crew health. The concentration of 2-propanol in the ISS atmosphere increased slightly during the Demo-1 mission; however, the highest measured concentrations were well below the 7-day SMAC value and thus are not anticipated to have had any implications for crew health. While the 2-propanol level did exceed the zero risk value and ECLS guideline for alcohols at ingress, the impact to ISS water systems is expected to be minimal.

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19 April 2019

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Enclosures

Table 1: Analytical concentrations of compounds quantified in the mGSC returned on SpX-Demo-1

Table 2A: T-values corresponding to concentrations for contingency, egress, and post-splashdown samples returned on SpX-Demo-1 in Table 1, based on 180-day SMACs

Table 2B: T-values corresponding to concentrations for ingress sample returned on SpX Demo-1 in Table 1, based on 7-day and 180-day SMACs

TABLE 1
ANALYTICAL RESULTS OF SPACEX-DEMO 1 RETURN

CHEMICAL CONTAMINANT	CONCENTRATION (mg/M^3)				
	AQ190080 SN 2021 DM1 Ingress 03/03/19 @ 13:10 GMT	**AQ190082 SN 2088 SM Near Panel 421 Contingency 03/03/19 @ 21:00 GMT**	**AQ190079 SN 2018 DM1 Egress 1 Contingency 03/07/19 @ 0:800 GMT**	**AQ190081 SN 2087 DM1 Egress 2 03/07/19 @ 17:15 GMT**	**AQ190078 SN 22525 After Splashdown 03/09/19**
TARGET COMPOUNDS (TO-15) **					
1,1,1,2-Tetrafluoroethane (Norflurane)	0.29	0.074	0.067	0.075	0.13
Perfluoro(2-methylpentane)	0.88	TRACE	<0.10	0.46	0.30
Propane	0.055	<0.025	<0.025	<0.025	TRACE
Isobutane	3.8	0.23	0.16	0.24	1.3
Methanol *	**0.82**	0.35	0.36	0.38	0.38
Acetaldehyde	0.070	0.20	0.17	0.17	0.19
Ethanol *	0.37	**3.3**	**3.5**	**3.5**	**1.8**
Acetone	0.11	0.22	0.20	0.18	0.078
2-Propanol (Isopropanol) *	**5.2**	0.48	0.81	**2.3**	**1.2**
Isoprene (2-Methyl-1,3-butadiene)	<0.025	0.027	<0.025	<0.025	<0.025
1-Propanol	<0.025	TRACE	TRACE	<0.025	<0.025
Trimethylsilanol	<0.025	0.084	0.13	<0.025	<0.025
Butanal (Butyraldehyde)	<0.025	<0.025	<0.025	<0.025	0.078
1-Butanol	<0.025	0.048	0.042	<0.025	<0.025
Pentanal	<0.025	<0.025	<0.025	<0.025	0.045
Hexanal	<0.025	<0.025	<0.025	<0.025	0.075
Heptanal	<0.050	<0.050	<0.050	<0.050	0.27
Decamethylcyclopentasiloxane	<0.175	0.34	0.42	<0.175	<0.175
Octafluoropropane (Perfluoropropane) *	**2.3**	**13**	**38**	**33**	**15**
SPECIAL INTEREST COMPOUND #					
Hexamethylcyclotrisiloxane	<0.20	<0.20	0.23	<0.20	<0.20
NON-TARGET COMPOUNDS ***					
C5- Fluorinated Aliphatic Hydrocarbon	0.86	<0.050	<0.050	0.25	0.19
C6- Fluorinated Aliphatic Hydrocarbon	<0.050	<0.050	<0.050	<0.050	0.37
Trans-1,2-dichloroethylene	0.42	<0.050	<0.050	0.17	0.11
Octanal	<0.050	<0.050	<0.050	<0.050	0.074
TOTAL ALCOHOLS PLUS ACETONE	6.5	4.4	4.9	6.3	3.5
TARGET COMPOUNDS (GC) **					
Methane	2.3	24	20	20	7.3
Carbon dioxide	360	6500	5900	3600	< 70
Hydrogen	0.20	2.0	1.9	1.9	0.60
Carbon monoxide	2.3	0.47	0.41	0.40	1.2
TOTAL CONCENTRATION (NON-METHANE HYDROCARBONS)	**15**	**18**	**44**	**41**	**22**
TOTAL CONCENTRATION - OFP (NON-METHANE HYDROCARBONS)	**13**	**5.4**	**6.1**	**7.6**	**6.6**

* GC/FID data results are in bold

** 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

< : Value is less than the laboratory reporting limit.

TRACE: Amount detected is sufficient for compound identification only. One-half of the reporting limit was used in the Total Concentration summation.

OFP - Octafluoropropane

TABLE 2A
T-VALUES FOR SPACEX-DEMO 1 RETURN

CHEMICAL CONTAMINANT	T-VALUE (180-d SMAC)			
	AQ190082 SN 2088 SM Near Panel 421 Contingency 03/03/19 @ 21:00 GMT	AQ190079 SN 2018 DM1 Egress 1 Contingency 03/07/19 @ 0:800 GMT	AQ190081 SN 2087 DM1 Egress 2 03/07/19 @ 17:15 GMT	AQ190078 SN 22525 After Splashdown 03/09/19
TARGET COMPOUNDS (TO-15)				
1,1,1,2-Tetrafluoroethane (Norflurane)	0.00001	0.00001	0.00001	0.00001
Perfluoro(2-methylpentane) &	0.00000	ND	0.00000	0.00000
Propane	ND	ND	ND	0.00000
Isobutane	0.00123	0.00084	0.00127	0.00674
Methanol	0.00391	0.00395	0.00424	0.00421
Acetaldehyde	0.05073	0.04153	0.04218	0.04655
Ethanol	0.00164	0.00175	0.00174	0.00089
Acetone	0.00431	0.00392	0.00350	0.00151
Propanal (Propionaldehyde)	ND	ND	ND	0.00462
2-Propanol (Isopropanol)	0.00319	0.00541	0.01502	0.00819
Isoprene (2-Methyl-1,3-butadiene)	0.00889	ND	ND	ND
1-Propanol	0.00017	0.00017	ND	ND
Trimethylsilanol	0.02102	0.03197	ND	ND
Butanal (Butyraldehyde)	ND	ND	ND	0.00521
1-Butanol	0.00119	0.00105	ND	ND
Pentanal	ND	ND	ND	0.00250
Hexanal	ND	ND	ND	0.00377
Heptanal	ND	ND	ND	0.01177
Decamethylcyclopentasiloxane	0.02264	0.02771	ND	ND
Octafluoropropane (Perfluoropropane)	0.00015	0.00045	0.00039	0.00018
SPECIAL INTEREST COMPOUNDS				
Hexamethylcyclotrisiloxane	ND	0.02585	ND	ND
NON-TARGET COMPOUNDS				
C5- Fluorinated Aliphatic Hydrocarbon	ND	ND	0.00104	0.00081
C6- Fluorinated Aliphatic Hydrocarbon	ND	ND	ND	0.00127
Trans-1,2-dichloroethylene	ND	ND	0.02105	0.01404
Octanal	ND	ND	ND	0.00284
TARGET COMPOUNDS (GC)				
Methane	0.00691	0.00565	0.00556	0.00208
Hydrogen	0.00600	0.00569	0.00562	0.00176
Carbon monoxide	0.02786	0.02434	0.02340	0.07088
TOTAL T-VALUE	**0.15984**	**0.18027**	**0.12502**	**0.18982**

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-DEMO 1 RETURN INGRESS

CHEMICAL CONTAMINANT	T-VALUE (7- & 180-d)	
	7-d SMAC	180-d SMAC
	AQ190080 SN 2021 DM1 Ingress 03/03/19 @ 13:10 GMT	AQ190080 SN 2021 DM1 Ingress 03/03/19 @ 13:10 GMT
TARGET COMPOUNDS (TO-15)		
1,1,1,2-Tetrafluoroethane (Norflurane)	0.00003	0.00003
Perfluoro(2-methylpentane)	0.00001	0.00001
Propane	0.00001	0.00001
Isobutane	0.02008	0.02008
Methanol	0.00908	0.00908
Acetaldehyde	0.01751	0.01751
Ethanol	0.00019	0.00019
Acetone	0.00209	0.00209
2-Propanol (Isopropanol)	0.03493	0.03493
Octafluoropropane (Perfluoropropane)	0.00003	0.00003
SPECIAL INTEREST COMPOUNDS		
No Special Interest Compounds were above their data reporting limit		
NON-TARGET COMPOUNDS		
C5- Fluorinated Aliphatic Hydrocarbon	0.00363	0.00363
Trans-1,2-dichloroethylene	0.05335	0.05335
TARGET COMPOUNDS (GC)		
Methane	0.00067	0.00067
Hydrogen	0.00059	0.00059
Carbon monoxide	0.03667	0.13591
TOTAL T-VALUE	**0.17888**	**0.27812**

ND : Value is less than the laboratory reporting limit.
Note: Number of decimal places in T-Values do not represent significant figures of measurements.