180 DAY PRELIMINARY RESEARCH REPORT
Mir 24/NASA 6/STS 89
MSD053 Analysis of Mir Archival Water
(formerly Collecting Mir Source and Reclaimed Waters for Postflight Analysis)

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I. Introduction

A portion of the potable water supplied to the Russian cosmonauts, American astronauts, and other occupants of the current Russian Mir Space Station is produced by the direct recycle of water from humidity condensate. Additional supplies come from ground supplied potable water that is delivered on a Progress resupply spacecraft, or processed fuel cell water transferred from the Shuttle. This project is being conducted to determine the potability of the water supplied on Mir, to assess the reliability of the water reclamation and distribution systems and to aid in developing water quality monitoring standards for International Space Station.

A. Hypothesis

Detailed analysis of reclaimed and other Mir supplied potable waters will confirm that the design of the Mir purification and distribution systems are adequate to maintain water of potable quality.

B. Objectives of Experiment

1. Characterize the chemical composition of Mir humidity condensate to support development and testing of the water recycling and monitoring systems for the International Space Station (ISS)
2. Characterize the chemical composition of the ground-resupply water prior to launch and on orbit
3. Characterize the chemical composition of Mir recycled water to evaluate the efficiency of onboard water processors and aid in the development of ISS water processing and monitoring technology
4. Compare the chemical composition of Mir and Shuttle humidity condensate
5. Provide inflight testing of water collection hardware being developed to collect water samples on ISS

C. Background/History of Project

Historically, water provided for crew consumption during U.S. space missions has either been launched from the ground or produced as a byproduct of fuel cell operation. Reclamation and purification of spacecraft wastewaters as practiced on the Russian Space Station Mir, will be required for supplying crewmembers of the International Space Station with potable and hygiene water during Phase II.

This experiment has flown under the Human Life Sciences Discipline during the Mir 18/NASA 1, the Mir 19, the Mir 20/STS-74, and the Mir 21/NASA 2/STS-79 missions. In addition, this activity was performed under the Space Medicine Program during the Mir 22/NASA 3/STS-81, the Mir 23/NASA 4/STS-84 and the Mir 24/NASA5/STS-86 missions.

II. Methods/Research Operations

A. Discussion of Method/Protocol

The water experiment kit (WEK) contained the disinfectant wipes, potable water samplers, waste bags, chemical sample, postflight analysis bags, and storage bags needed for water sampling. During an inflight water sampling sessions, the WEK was unstowed. A prepackaged disinfectant wipe containing 1 ml of benzalkonium chloride in 250 ml of water, was retrieved from the kit and used to disinfect the Mir galley-hot, galley-cold, or SVO-ZV water port. Next, a potable water sampler was connected to the port. A waste bag was then connected to the potable water sampler. Using the waste bag, 50 ml of water was collected and discarded. Next, 700 ml of water was collected into the chemical sample, postflight analysis bag. The sample bag was placed in a self sealing storage bag and stowed for return on the Shuttle. These procedures were used to collect galley-hot, galley-cold, and SVO-ZV (ground-supplied) water for postflight chemical analysis for this investigation. Following the collection of the chemical samples, microbiological samples were obtained for a separate experiment. The procedures used for microbiological sample collection, analysis, and preliminary results are reported elsewhere in “Microbiological Investigations of the Mir Station and Flight Crew” [4].

Postflight chemical analysis of samples occurred at Johnson Space Center (JSC) and the Institute for Biomedical Problems (IBMP). Following recovery of the samples on the ground, the samples were allocated (See Table 2) for distribution to the water analysis laboratories at JSC and IBMP. Parameters tested at JSC included total carbon components (total inorganic carbon, purgeable organic carbon, nonpurgeable organic carbon and total organic carbon), specific organics (alcohols, organic acids, semivolatiles, volatiles, nonvolatiles, formaldehyde), and metals. Parameters tested by IBMP included conductivity, pH, color, chemical oxygen demand, total solids, calcium, magnesium, total hardness, and silver.

B. List & Description of All Functional Objectives

FO1. Preflight collection of ground-supplied water at RSC Energia, Korolov, Russia
FO2. Water Sampling Hardware Setup
FO3. Inflight collection of hot, cold, and SVO-ZV (stored) water
FO4. Inflight collection of humidity condensate
FO5. Inflight collection of partially processed humidity condensate
FO6. Postflight analysis of samples

C. List & Description of All Hardware Items Used

Major hardware items used inflight for this experiment:
HW1. Water Experiment Kit - NASA provided
HW2. Disinfectant/Antiseptic Wipes - NASA provided
HW3. Potable Water Samplers (with Mir port adapter interfaces) - NASA provided
HW4. Waste bags and Chemical Sample, Postflight Analysis Bags - NASA provided
HW5. Self Sealing Storage Bags - NASA provided
HW6. Atmospheric Condensate Sampler - RSA provided

Major hardware items used postflight for this experiment:
HW7. HP 5890 Gas Chromatograph (GC) with HP5971A Mass Spectrometer (MS)- NASA provided
HW8. Waters Quanta 4000 Capillary Electrophoresis System - NASA provided
HW9. OI 700 Carbon Analyzer - NASA provided
HW10. Sievers Model 800 Total Organic Carbon Analyzer - NASA and RSA provided
HW11. HP 7694 Headspace sampler with a HP 5890 GC and 5972 Mass Selective Detector - NASA provided
HW12. HP 5989 Mass Spectrometer (MS) with a 1090 Liquid Chromatograph with Particle beam & Thermospray interfaces - NASA provided
HW13. pH meter - RSA and NASA provided
HW14. Conductivity meter - RSA provided

D. Sessions/Functional Objectives (FO) Table

See Table 1.

III. Results

A. List of Pre-, In-, Post-flight Anomalies

Preflight Anomalies

None

Inflight Anomalies

Sampling for galley hot water and SVO-ZV were planned for the docked phase, but no samples were received. One condensate sample from CRS (dated 1/17/98 2200 to 1/18/98 2200) contained only 0.25 ml of sample and the other condensate collected in a Teflon sample bag dated 1/26/98 1700 to 1/28/98 1500 was received empty. It appears that the SRV-K system did not receive sufficient condensate during the docked phase because the Shuttle humidity control system was dominant.

Postflight Anomalies

Samples 98-0202-01 and 98-0202-04 are galley hot water samples collected in US supplied Teflon sample bags. These two samples leaked during transport from KSC to JSC after landing. The leakage from each sample was recovered in the outer Ziplock bags and were archived as samples 98-0202-02 and 98-0202-05, respectively. The leakage, however, did not adversely impact sample analysis.

B. Completeness/Quality of Data

Sample analyses are in progress.

C. Tables, Graphs, Figures Index

See attachments

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D. Photographs

No photographs of this investigation are available.

E. Status of Data Analysis

Chemical analyses of the recycled water sample are in progress. Analyses completed to date include conductivity, pH, turbidity, total organic carbon (TOC), trace metals, anions, cations, carboxylates, amines, volatile and semivolatile organics, glycols, urea, and alcohols. Analyses yet to be completed by IMBP include color, taste, odor, total hardness, total solids, and chemical oxygen demand (COD).

F. Preliminary Research Findings

Regenerated Water

Preliminary results show that the regenerated water samples collected met the Russian requirement of 25 mg/L, but exceeded the U.S. maximum contaminant level of 0.5 mg/L for total organic carbon (TOC) (See Table 3). The TOC for these samples ranged from 3.11 mg/L to 11.1 mg/L according to results analyzed by the U.S. In contrast, measurements from IBMP (Russia) for the samples ranged from 4.8 mg/L to 23.2 mg/L. Turbidity was the only other parameter analyzed that exceeded the U.S. specifications. Turbidity in the regenerated water samples ranged from 2.88 to 4.29 NTU, whereas the U.S. potable water specification is 1 NTU. The Russian specification is 1.5 mg/L. Overall, the results indicate the regenerated water is of potable quality.

Stored Water

One SVO-ZV sample was collected during this mission. This sample exceeded NASA water quality standards for TOC and turbidity. This sample, collected on 11/27/97 contained 20 mg/L TOC with a turbidity of 1.66 NTU. The U.S. specification for TOC is 0.5 mg/L; the specification for turbidity is 1 NTU.

Condensate

A variety of compounds have been identified in the humidity condensate samples. Samples collected during this mission had TOC levels of 9.86 - 192 mg/L. Ethylene glycol (1,2-ethanediol) was detected in condensate samples collected on 1/19/98 and 1/28/98 and were 342.5 mg/L and 270 mg/L respectively. Propylene glycol (1,2-propanediol) levels were 18.2 mg/L and 14 mg/L in these samples. During this mission two samples of partially processed humidity condensate, identified as filter reactor effluent in Table 6, were collected. The results of these samples indicate that the catalytic reactor subsystem of the SRV-K is very effective in removing ethylene glycol and propylene glycol. These compounds were not detected in the filter reactor effluent samples.

G. Conclusions

Initial findings from the analysis of the regenerated and stored water samples show that the water met the Joint U.S./Russian spacecraft water quality standards. It is noted, however, that the NASA requirements for TOC and turbidity were exceeded in the samples. The water is however of potable quality.

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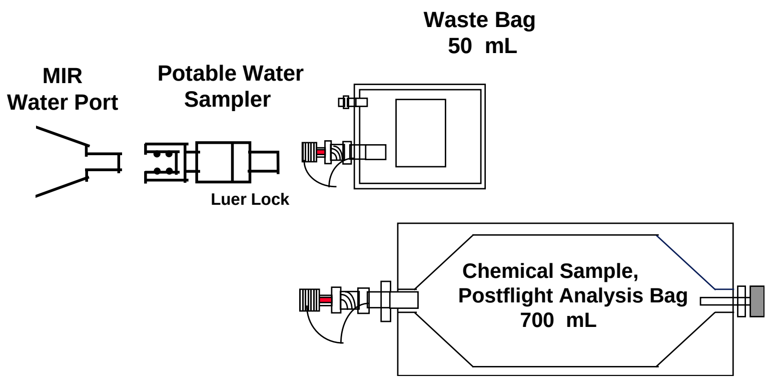

Figure 1. Sample Collection Methodology

Table 3: Joint U.S./Russian Potable Water Specifications for International Space Station

Water Parameter	U.S. Maximum Contaminant Level (MCL)	Russian Maximum Contaminant Level (MCL)
pH[1]	5.5-9.0 pH units	5.5-9.0 pH units
Color[2]	15 Pt-Co units	20 degrees
Taste[2]	3 TTN	2 points
Odor[2]	3 TON	2 points
Total Dissolved Solids[3]	100-1,000 mg/L	100-1,000 mg/L
Turbidity[2]	1 NTU	1.5 mg/L
Total Gas	5% volume @1 ATM, 20^{o}C	5% volume @1 ATM, 20^{o}C
Ammonia (NH3-N)	2 mg/L	2 mg/L
Arsenic	0.01 mg/L	0.01 mg/L
Barium	1 mg/L	1 mg/L
Cadium	0.005 mg/L	0.005 mg/L
Calcium	100 mg/L	100 mg/L
Chlorine-total (includes Cl-)	250 mg/L	250 mg/L
Chromium	0.1 mg/L	0.1 mg/L
Copper	1 mg/L	1 mg/L
Fluorine	1.5 mg/L	1.5 mg/L
Iodine-total (includes I-)	15 mg/L	15 mg/L
Iodine-residual[4]	1.0-4.0 mg/L	1.0-4.0 mg/L
Iron	0.3 mg/L	0.3 mg/L
Lead	0.05 mg/L	0.05 mg/L
Magnesium	50 mg/L	50 mg/L
Manganese	0.05 mg/L	0.05 mg/L
Mercury	0.002 mg/L	0.002 mg/L
Nickel	0.1 mg/L	0.1 mg/L
Nitrate (NO_3-N)	10 mg/L	10 mg/L
Selenium	0.01 mg/L	0.01 mg/L
Silver	0.5 mg/L	0.5 mg/L
Sulfate	250 mg/L	250 mg/L
Zinc	5 mg/L	5 mg/L
Total Hardness (Ca & Mg)	7 meq/L	7 meq/L
Total Bacteria[2]	100 CFU/100 ml	10,000 CFU/100 ml
Coliform Bacteria	<1 CFU/100 ml	<1 CFU/100 ml
Virus	<1 PFU/100 ml	<1 PFU/100 ml
Cyanide	200 µg/L	200 µg/L
Total Phenols	1 µg/L	1 µg/L
Total Organic Carbon (TOC)	500 µg/L	25,000 µg/L
Uncharacterized TOC	100 µg/L	no limit
Oxygen Consumption-COD	no limit	100 mg/L

[1]pH range applies only before iodination
[2]Parameters have different values for U.S. and Russian supplied water because of different analytical methods used
[3]The 100 mg/L limit applies to the water before mineralization. After mineralization, this parameter will not exceed 1,000 mg/L
[4]Range of required level if iodine is used as a biocide