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Variations in Stable Isotope Ratios and Anion Concentrations of In-Flight Water

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Sampling of the water used for hand washing in aeroplane lavatories (in-flight water) was conducted on passenger flights between Narita International Airport in the suburbs of Tokyo, Japan and Changi International Airport in Singapore from August 22, 2009 to July 29, 2010. These samples were analyzed for anion concentrations using ion chromatography (IC) and for stable nitrogen isotope ratios in the nitrate ion (NO_3^-) using GC-mass spectrometry (GC-MS). The results of these analyses indicate that in-flight water exhibits variations in stable isotope ratios and anion concentrations during flights. A very low isotopic ratio of δ(delta) $^{15}N/^{14}N$ = -368.5 [per mil] was measured for the in-flight water on an aircraft flying over thunder clouds on November 15, 2009, at 10º North offshore of Luzon Island in the Philippines. If the extremely low stable nitrogen Isotope ratio at -368.5 [per mil] measured on November 15, 2009, at 10º North is excluded, a rough trend consisting of the highest stable nitrogen isotope ratios at nearly the same altitude was observed at neighboring positions of declination. The concentration of the NO_3^- ion was highly variable in the sampled in-flight water during flight. The following nuclear chemical reaction is well known.

$$^{1}_{0}n + ^{14}_{7}N \longrightarrow ^{14}_{6}C + ^{1}_{1}H$$

If this nuclear chemical reaction occurred, the nitrate ion (NO_3^-) was converted to carbonate ion (CO_3^{2-}). Hence, the carbon in the product CO_3^{2-} would be carbon-14, a radioisotope. The passengers and crew members on flights may use in-flight water for hand washing, gargling with mouth wash and as drinking water. Internal exposure to radiation in the form of carbon-14 for these individuals is more likely.

Key Words: In-flight water, Passenger flights, Stable isotope ratios, Anion concentrations, δ(delta) $^{15}N/^{14}N$, thunder cloud, Declination.

INTRODUCTION

Latitude and altitude are known to effect the stable isotope ratios present in aerosols, in the atmosphere and in water. Anthropogenic changes may also have an influence on the observed stable isotope ratios. Since March 2007, international scheduled passenger flights have placed restrictions on passengers carrying liquids on board the aircraft. Consequently, collecting water normally used for hand washing in the airplane lavatory (in-flight water) is the best way to perform experiments that investigate the effects of latitude and altitude on stable isotope ratios on international scheduled passenger flights. To date, there have been a considerable number of reports concerning radioisotopes in the water. However, it is difficult to find published data regarding variation in the stable isotope ratios of actual in-flight water during flights. Therefore, sampling of the water in aeroplane lavatories (in-flight water) was conducted on passenger flights between Narita International Airport in the suburbs of Tokyo, Japan and Changi International Airport in Singapore from August 22, 2009 to 29 July 2010. In-flight water samples were analyzed for anion concentrations using ion chromatography and for nitrogen stable isotope ratios using gas chromatography-mass spectrometry.

EXPERIMENTAL

In-flight water samples were collected on AUG 22, 2009 United Airlines flight UA891 Narita International Airport to Changi International Airport (Sampling duration: 1818 Japan Standard Time (JST = 9 h + UTC) AUG 22 to 0128 JST AUG 23), on the SEP 13, 2009 flight UA804 Changi International Airport to Narita International Airport (Sampling duration: 0700 Singapore standard time (SST = 8 h + UTC) to 1413 SST), on the NOV 15, 2009 flight UA875 Narita International Airport to Changi International Airport (Sampling duration: 1805 JST NOV 15 to 0110 JST NOV 16), on the DEC 01, 2009 Northwest Airlines flight NW320 Changi International Airport to Narita International Airport (Sampling duration: 0545 SST to 1248 SST), on the FEB 07, 2010 Delta Airlines flight DL619 Narita International Airport to Changi International Airport (Sampling duration: 1735 JST FEB 07 to 0155 JST FEB 08), on the FEB 21, 2010 Singapore Airlines flight SQ368 Changi International Airport to Narita International Airport (Sampling duration: 2331 SST FEB 20 to 0606 SST FEB21), on the July 14, 2010 flight DL281 Narita International Airport to Changi International Airport (Sampling duration: 1814 JST JUL 14 to 0151 JST JUL 15) and on the July 29, 2010 flight UA804 Changi International Airport to Narita International Airport (Sampling duration: 0645 SST to 1428 SST).

The in-flight water samples were analyzed using ion chromatography (DX 120/AS, Dianex Inc.). The $\delta\ ^{15}N/^{14}N$ and $\delta\ ^{18}O/^{16}O$ isotope ratios in NO_3^- were measured using the denitrifier method[1,2]. The NO_3^- was converted to N_2O using a denitrifier (*Pseudomonas aureofaciens*; ATCC 13985) lacking N_2O reductase. The N_2O was then introduced into a Delta XP isotope ratio mass spectrometer coupled to a HP6890 gas chromatograph (Hewlett-Packard Co., Palo Alto, CA, U.S.A.) equipped with a Poraplot column and a GC interface III (Thermo Fisher Scientific). The anion concentrations and isotope ratios were measured at the Laboratory of Social Biogeochemistry (Laboratory of Professor Muneoki YOH & Associate Professor Keisuke KOBA), Tokyo University of Agriculture & Technology (TUAT), Building: #2, Room: 328 & 2N-101, 5-8, Saiwai-Cho 3-Chome, Fuchu-Shi, Tokyo 183-8509, Japan. The calibration curves for these isotopic analyses were constructed using the international standards USGS32, USGS34, USGS35 and IAEA. The stable isotope ratio δ (delta) was calculated with the following equation[3].

$$\left(\frac{R_{Sample} - R_{Standard}}{R_{Standard}}\right) \times 1000\ \% = \delta = \text{delta} \quad (1)$$

RESULTS AND DISCUSSION

During flights, the aeroplane cabin and water tank are exposed to the atmosphere. Occupants of the aeroplane, which is only pressurized and heated, are not completely isolated from the atmosphere. Therefore, the cabin air and water tank for in-flight water are affected by the environment outside of the airplane. Table-1 shows the latitude and corresponding nitrate ion (NO_3^-) concentration for all of the in-flight water samples obtained in this study; declination data are also included. Table-2 shows the latitude and corresponding $\delta\ ^{15}N/^{14}N$ isotope ratios in the NO_3^- for all of the in-flight water samples obtained in this study; declination data are also included. Tables 3-10 present the stable isotope ratios and anion concentrations in the in-flight water samples obtained for every flight. Fig. 1 shows the latitude *vs.* NO_3^- concentrations based on all of the in-flight water samples obtained in this study and Fig. 2 shows the latitude *vs.* $\delta\ ^{15}N/^{14}N$ isotope ratios in NO_3^- based on all of the in-flight water samples obtained in this study[4].

The United Airlines flight UA875 on November 15, 2009, from Narita to Singapore flew over a lightning cloud at 10° North of Luzon Inland, Philippines. The in-flight water sample collected on this flight indicated an extremely low stable nitrogen isotope ratio of -368.5 [per mil]. The top of a thunder cloud is known to possess an electric charge with a high positive voltage[5-7]. Thus, this high positive voltage may have a significant absorptive power for the heavier isotope of the nitrate ion in the in-flight water present in the aeroplane water tank. Because the absolute value of the electric potential or

TABLE-1
LATITUDE *vs.* NO_3^-

Latitude (North) [°]	22AUG2009 UA891 NRT-SIN; NO_3^- [μmol/L]	15NOV2009 UA875 NRT-SIN; NO_3^- [μmol/L]	07FEB2010 DL619 NRT-SIN; NO_3^- [μmol/L]	14JUL2010 DL281 NRT-SIN; NO_3^- [μmol/L]	13SEP2009 UA804 SIN-NRT; NO_3^- [μmol/L]	01DEC2009 NW320 SIN-NRT; NO_3^- [μmol/L]	21FEB2010 SQ368 SIN-NRT; NO_3^- [μmol/L]	29JUL2010 UA804 SIN-NRT; NO_3^- [μmol/L]
Declination [°]	11.92 N	18.35 S	15.52 S	21.77 N	3.97 N	21.72 S	10.80 S	18.09 N
NRT 35.8	20.5		487.6	34.5	6.0	74.7	74.8	11.2
32		80.4			6.4	132.3	58.3	
31	21.4							
30							57.5	
29.68				20.0				
26.7			449.7					
25					6.4			
22.98								2.4
20						92.6	71.3	
18				4.3				
15					6.3			
10		90.3				141.3		
9.8	22.9							
8.56				18.9				
7.5					5.8		63.6	
6.5	22.8							
4.95								67.8
3.45			273.2					
SIN 1.3	22.2	84.0	171.5	13.9	7.5	127.2	76.4	35.1

NRT = Narita International Airport; SIN = Changi International Airport.

TABLE-2
LATITUDE *vs.* $\delta\ ^{15}N/^{14}N$

Latitude (North) [°]	22AUG2009 UA891 NRT-SIN; $\delta^{15}N/^{14}N$ [per mil]	15NOV2009 UA875 NRT-SIN; $\delta\ ^{15}N/^{14}N$ [per mil]	07FEB2010 DL619 NRT-SIN; $\delta\ ^{15}N/^{14}N$ [per mil]	14JUL2010 DL281 NRT-SIN $\delta\ ^{15}N/^{14}N$ [per mil]	13SEP2009 UA804 SIN-NRT; $\delta\ ^{15}N/^{14}N$ [per mil]	01DEC2009 NW320 SIN-NRT; $\delta\ ^{15}N/^{14}N$ [per mil]	21FEB2010 SQ368 SIN-NRT; $\delta\ ^{15}N/^{14}N$ [per mil]	29JUL2010 UA804 SIN-NRT $\delta\ ^{15}N/^{14}N$ [per mil]
Declination [°]	11.92 N	18.35 S	15.52 S	21.77 N	3.97 N	21.72 S	10.80 S	18.09 N
NRT 35.8	11.7		1.2	10.1	6.2	20.9	-3.3	11.0
32		33.8			7.2	22.6	-3.3	
31	7.9							
29.7				7.4				
26.7			0.40					
25					6.0			
23								16.1
20						21.1	-3.2	
18				21				
15					7.1			
10		-368.5				16.5		
9.8	7.9							
8.6				19.1				
7.5					5.8			
6.5	5.9							
5								7.9
3.5			1.2					
SIN 1.4	6.5	25.9	1.0	17.7	6.4	22.1	-3.3	13.5

NRT = Narita International Airport; SIN = Changi International Airport.

TABLE-3
STABLE ISOTOPE RATIOS & ANION CONCENTRATIONS IN SAMPLES OF IN-FLIGHT WATER ON UNITED AIRLINES FLIGHT UA803 ON AUGUST 22, 2009, FROM NARITA (NRT) TO SINGAPORE (SIN)

Sampling date & time	Sampling place	Sampling altitude [meter]	Elapsed time from take-off [min]	Distance from take-off [km]	Latitude (North) [°]	$\delta\ ^{15}N/^{14}N$ [per mil]	$\delta\ ^{18}O/^{16}O$ [per mil]	NO_3^- [μmol/L]	F^- [μmol/L]	Cl^- [μmol/L]	SO_4^{2-} [μmol/L]
1818 JST (UTC+9) 22AUG2009	UA803 Before take-off at NARITA (NRT)	42	-43		35.8	11.7	7	20.5	13.6	141.9	41.9
19 01 36 JST 22AUG2009	UA803 Take-off at NRT on Boeing777	42	0	0	35.8						
2011 JST 22AUG2009	UA803 En- Route NRT=>SIN, Offshore south of Shikoku	11400	70	1066	31	7.9	-4.8	21.4	13.6	160.7	48.7
2307 JST 22AUG2009	UA803 En- Route NRT=>SIN, Offshore west of the Island of Palawa, west of Sulu Sea	11700	246	3774	9.8	7.9	-5.8	22.9	14.1	169.1	55.7
0027 JST 23AUG2009	UA803 En- Route NRT=>SIN, Offshore northwest of Borneo Island in the South China Sea	11700	326	5171	6.5	5.9	-0.7	22.8	14	169.6	54.4
0122 JST 23AUG2009	UA803 Landing at Singapore (SIN)		381	5318	1.3						
0128 JST 23AUG2009 UTC+9	UA803 After landing at Singapore	7	387	5318	1.3	6.5	-4.7	22.2	14.2	168	53.6

NRT = Narita International Airport; SIN = Changi International Airport.

the electric field (E_H) of the heavier isotopic electrode is higher than that of the electric potential or the electric field (E_L) of the lighter isotopic electrode, the following relationship between the electric potential or the electric field (E) and the electrostatic force (F) is known.

$$\vec{F} = q\vec{E} \qquad (2)$$

In this equation, q is the electric charge. Therefore, the electrostatic force (F_H) of the heavier isotopic electrode is stronger than the electrostatic force (F_L) of the lighter isotopic electrode[8]. Consequently, if the top of the thunder cloud had a positive electric charge and the base of the thunder cloud had a negative electric charge, then the top of the thunder cloud would have a stronger absorption force for heavier isotopes

TABLE-4
STABLE ISOTOPE RATIOS & ANION CONCENTRATIONS IN SAMPLES OF IN-FLIGHT WATER ON UNITED AIRLINES FLIGHT UA804 ON SEPTEMBER 13, 2009 FROM SINGAPORE (SIN) TO NARITA (NRT)

Sampling date & time	Sampling place	Sampling altitude [meter]	Ealapsed time from take-off [min]	Distance from take-off [km]	Latitude (North) [°]	δ $^{15}N/^{14}N$ [per mil]	δ $^{18}O/^{16}O$ [per mil]	NO_3^- [μmol/L]	F^- [μmol/L]	Cl^- [μmol/L]	SO_4^{2-} [μmol/L]
0800 JST (UTC+9) 13SEP2009	UA804 Before take-off at SIN on Boeing777	7	-30	0	1.3	6.4	-7.4	7.5	1.8	92.4	20.3
083026 JST 13SEP2009	UA804 Take-off at SIN	7	0	0	1.3						
1033 JST 13SEP2009	UA804 En-Route SIN=>NRT, Flying over between Vietnam and the Philippines in South China Sea	10800	123	1658	7.5	5.8	-7.1	5.8	1.7	76.5	19.5
1103 JST 13SEP2009	UA804 En- Route SIN=>NRT, Flying over near Typhoone on Luzon Island	10800	153	2182	15	7.1	-9.7	6.3	1.4	72.8	21.8
1317 JST 13SEP2009	UA804 En-Route SIN=>NRT, Offshore west of Okinawa Island	11100	287	4180	25	6	-7.7	6.4	1.5	71.7	22.7
1431 JST 13SEP2009	UA804 En-Route SIN=>NRT, Near Hachijo-Jima	38500	361	5394	32	7.2	-7.8	6.4	1.4	73.3	22.6
1507 JST 13SEP2009	UA804 Landing at NRT		397	5350	35.8						
1513 JST 13SEP2009	UA804 After landing at NRT	42	403	5350	35.8	6.2	-7.7	6	1.6	73.6	21

NRT = Narita International Airport; SIN = Changi International Airport.

TABLE-5
STABLE ISOTOPE RATIOS & ANION CONCENTRATIONS IN SAMPLES OF IN-FLIGHT WATER ON UNITED AIRLINES FLIGHT UA875 ON NOVEMBER 15, 2010 FROM NARITA (NRT) TO SINGAPORE (SIN)

Sampling date & time	Sampling place	Sampling altitude [meter]	Ealapsed time from take-off [min]	Distance from take-off [km]	Latitude (North) [°]	δ $^{15}N/^{14}N$ [per mil]	δ $^{18}O/^{16}O$ [per mil]	NO_3^- [μmol /L]	NO_2^- [μmol /L]	F^- [μmol /L]	Cl^- [μmol /L]	SO_4^{2-} [μmol/L]
1805 JST (UTC+9) 15NOV2009	UA875 NRT=>SIN, Take-off at NRT(35°45'50"N, 140° 23'30"E) on Boeing777	42	0	0	35.75							
1853 JST 15NOV2009	UA875 NRT=>SIN, En-route	10800	48	577	32	33.8	3	80.4	3.2	40.7	747	235.3
2235 JST 15NOV2009	UA875 NRT=>SIN, En-route flying over a thunder cloud offshore of the Philippines	11700	270	3641	10	-368.5	-879.9	90.3	0	34.7	802	223.7
0059 JST 16NOV2009	UA875 Landing at SIN		413	5350	1.35							
0110 JST 16NOV2009	UA875 After landing at SIN (1°21'28"N, 103°59'27"E)	7	425	5350	1.35	25.9	0.8	84	1.6	30.8	719	195.2

NRT = Narita International Airport; SIN = Changi International Airport.

TABLE-6
STABLE ISOTOPE RATIOS & ANION CONCENTRATIONS IN SAMPLES OF IN-FLIGHT WATER ON NORTHWEST AIRLINES FLIGHT NW320 ON DECEMBER 1, 2009 FROM SINGAPORE (SIN) TO NARITA (NRT)

Sampling date & time	Sampling place	Sampling altitude [meter]	Ealapsed time from take-off [min]	Distance from take-off [km]	Latitude [°]	δ $^{15}N/^{14}N$ [per mil]	δ $^{18}O/^{16}O$ [per mil]	NO_3^- [μmol /L]	NO_2^- [μmol /L]	F^- [μmol /L]	Cl^- [μmol /L]	SO_4^{2-} [μmol /L]
0645 JST (UTC+9) 01DEC2009	NW320 SIN=>NRT, Airbus330 Before take-off	7	-24		1.3	22.1	0.96	127.2	28.3	67.2	550.5	218.3
070901 JST 01DEC2009	NW320 SIN=>NRT, Take-off at NRT		0	0	1.3							
0843 JST 01DEC2009	NW320 En-Route SIN=>NRT, Flying over between Vietnam & Philippines in South China Sea	10770	94	1424	10	16.5	-5.5	141.3	24	58	573.1	229.5
1020 JST 01DEC2009	NW320 En-Route SIN=>NRT, Flying over between Luzon Island and Taiwan	11668	191	2918	20	21.1	0.97	92.6	27	76.6	441.6	170.7
1226 JST 01DEC2009	NW320 En-Route SIN=>NRT, Flying offshore of KII Peninsula	11668	317	5011	32	22.6	0.62	132.3	10.4	47.1	519.6	211.2
1308 JST 01DEC2009	NW320 Landing at NRT		360	5541	35.8							
1348 JST 01DEC2009	NW320 After landing at NRT	42	399	5541	35.8	20.9	0.37	74.7	24.9	68.5	364.1	140.5

NRT = Narita International Airport; SIN = Changi International Airport.

TABLE-7
STABLE ISOTOPE RATIOS & ANION CONCENTRATIONS IN SAMPLES OF IN-FLIGHT WATER ON DELTA AIRLINES FLIGHT DL619 ON FEBRUARY 7, 2010 FROM NARITA (NRT) TO SINGAPORE (SIN)

Sampling date & time	Sampling place	Sampling altitude [meter]	Elapsed time from take-off [min]	Distance from take-off [km]	Latitude (north) [°]	δ $^{15}N/^{14}N$ [per mil]	δ $^{18}O/^{16}O$ [per mil]	NO_3^- [μmol /L]	F^- [μmol /L]	Cl^- [μmol /L]	SO_4^{2-} [μmol /L]
1735 JST (UTC+9) 07FEB2010	DL619 Before take-off at NRT	42	-37	0	35.75	1.2	-12.4	487.6	27.8	1245.6	562.4
1812 JST 07FEB2010	DL619 Take-off at NRT		0	0	35.75						
2013 JST 07FEB2010	DL619 En-route NRT=>SIN	11472	121		26.68	0.35	-8.7	449.7	25.4	952.2	479.4
0036 JST 08FEB2010	DL619 En-route NRT=>SIN	12070	384	5194	3.45	1.2	-13.3	273.2	14.7	620.4	304.5
0146 JST 08FEB2010	DL619 Landing at SIN		394	5350	1.35						
0155 JST 08FEB2010	DL619 After landing at SIN	7	403	5350	1.35	0.98	-12.5	171.5	8.7	345.8	184.9

NRT = Narita International Airport; SIN = Changi International Airport.

than for lighter isotopes and the base of the thunder cloud would have a stronger repulsive force for heavier isotopes than for lighter isotopes. Thus, aqueous nitrate ions in the water tank could be affected by the difference in absorption power and a greater number of the heavier isotopes were transferred to positive charged part of the water tank of the aeroplane *i.e.* the water tank was a kind of cell or electrolysis tank. Lighter isotopes would then move to near of the water tap at the lavatory in the aeroplane.

If the extremely low stable nitrogen isotope ratio of -368.5 [per mil] measured on November 15, 2009 (at 10° North) is excluded, an approximate trend consisting of the highest stable nitrogen isotope ratios at nearly the same altitude was observed at neighboring positions of declination. The neighboring position of declination receives significant cosmic ray radiation, including neutron bombardment, from the sun. The nuclear chemical reaction involving ^{14}N and a neutron (n) to produce the ^{14}C radioisotope is well known to

TABLE-8
STABLE ISOTOPE RATIOS & ANION CONCENTRATIONS IN SAMPLES OF IN-FLIGHT WATER ON SINGAPORE AIRLINES SQ368 ON FEBRUARY 21, 2009 FROM SINGAPORE (SIN) TO NARITA (NRT)

Sampling date & time	Sampling place	Sampling altitude [meter]	Ealapsed time from take-off [min]	Distance from take-off [km]	Latitude (north) [°]	δ $^{15}N/^{14}N$ [per mil]	δ $^{18}O/^{16}O$ [per mil]	NO_3^- [μmol /L]	F^- [μmol /L]	Cl^- [μmol /L]	SO_4^{2-} [μmol /L]
2331 Singapore Standard Time (SST) 21FEB2010 = 0031 JST (UTC+9) 22FEB2010	SQ368 Before take-off at SIN	7	-35	0	1.35	-3.3	-9.8	76.4	64.7	2792.3	324.9
0106 JST 22FEB2010	SQ368 SIN=>NRT Airbus380, Take-off at SIN	7	0	0	1.35						
0136 JST 22FEB2010	SQ368 En-route SIN=>NRT	11895	90	446		-3.3	-10.1	63.6	53.7	2266.4	268.3
0414 JST 22FEB2010	SQ368 En-route SIN=>NRT, East of Bashi Channel	11894	188	3110	20	-3.2	-8.7	71.3	60	2571.9	300.4
0522 JST 22FEB2010	SQ368 En-route SIN=>NRT, Offshore south of Yaku-Shima Island	11893	256	4239	30	N/A	N/A	57.5	48	2041.7	242.8
0601 JST 22FEB2010	SQ368 En-route SIN=>NRT, Offshore of KII Peninsula	11980	295	4954	32	-3.3	-9.9	58.3	48.3	2068.1	245.3
0655 JST 22FEB2010	SQ368 Landing at NRT	42	348	5541	35.75						
0706 JST 22FEB2010	SQ368 After landing at NRT	42	359	5541	35.75	-3.3	-9.7	74.8	62.2	2707.5	314.9

NRT = Narita International Airport; SIN = Changi International Airport.

TABLE-9
STABLE ISOTOPE RATIOS & ANION CONCENTRATIONS IN SAMPLES OF IN-FLIGHT WATER ON DELTA AIRLINES FLIGHT DL281 ON JULY 14, 2009 FROM NARITA (NRT) TO SINGAPORE (SIN)

Sampling date & time	Sampling place	Sampling altitude [meter]	Ealapsed time from take-off [min]	Distance from take-off [km]	Latitude (north) [°]	δ $^{15}N/^{14}N$ [per mil]	δ $^{18}O/^{16}O$ [per mil]	NO_3^- [μmol /L]	NO_2^- [μmol /L]	F^- [μmol /L]	Cl^- [μmol /L]	SO_4^{2-} [μmol /L]	PO_4^{3-} [μmol /L]
1814 JST 14JUL2010	DL281 Before take-off at NRT (140° 23.044"E)	37	-60		35.75	10.1	3.2	34.5	2.4	0	375.6	118.7	1.5
191441 JST 14JUL2010	DL281 Take-off at NRT	37	0	0	35.75								
2008 JST 14JUL2010	DL281 En-route NRT=>SIN, Flying offshore, south of KII Peninsula	10799	54	846	29.68	7.4	4.7	20	0	0	159.2	56	0
2158 JST 14JUL2010	DL281 En-Route NRT=>SIN, Flying offshore, northeast of Luzon Island	11401	124	2545	18	21	14.1	4.3	0	0.043	118.8	41.8	0
2337 JST 14JUL2010	DL281 En-route NRT=>SIN, Flying offshore between the north of Borneo and west of Puetro Princesa	11700	263	4041	8.56	19.1	9.6	18.9	2.8	0	568.7	183.7	0
013933 JST 15JUL 2010	Landing at SIN	7	385										0
0151 JST 15JUL2010	DL281 After landing at SIN	7	397	5541	1.35	17.7	8.1	13.9	2.2	0	349.2	116.9	0

NRT = Narita International Airport; SIN = Changi International Airport.

TABLE-10
STABLE ISOTOPE RATIOS & ANION CONCENTRATIONS IN SAMPLES OF IN-FLIGHT WATER ON UNITED AIRLINES FLIGHT UA804 ON JULY 29, 2009 FROM SINGAPORE (SIN) TO NARITA (NRT)

Sampling date & time	Sampling place	Sampling altitude [meter]	Ealapsed time from take-off [min]	Distance from taking off [km]	Latitude (north) [°]	δ $^{15}N/^{14}N$ [per mil]	δ $^{18}O/^{16}O$ [per mil]	NO_3^- [μmol /L]	NO_2^- [μmol /L]	Cl^- [μmol /L]	SO_4^{2-} [μmol /L]	PO_4^{3-} [μmol /L]
0645 Singapore Standard Time (SST) 29JUL2010	UA804 Before take-off at SIN, Boeing 777	7	-41	0	1.35	13.5	3.6	35.1	10.2	1222.1	350.4	0
072650 SST 29JUL2010	Take-off at SIN, Boeing 777	7	0	0	1.35							
0805 SST 29JUL2010	UA804 En-route SIN=>NRT, Flying offshore between the south of Vietnam and east of West Malaysia	10800	39	601	4.95	7.9	-4.4	67.8	0	1046.3	282.6	3.1
1106 SST 29JUL2010	UA804 En-route SIN=>NRT, Flying offshore between the southeast of Taiwan and northeast of Luzon Island	11100	220	1989	22.98	16.1	20.3	2.4	0	1189.6	303.8	0
1514 48 JST = 1414 SST on 29JUL2010	Landing at NRT		408	5541	35.75							
1528 JST = 1428 SST 29JUL2010	UA804 After landing at NRT	42	422	5541	35.75	11	10.4	11.2	3.7	730.5	192.1	0

NRT = Narita International Airport; SIN = Changi International Airport.

occur in the atmosphere[9], especially at altitudes between 30000 feet and 50000 feet (9000-15000 m)[10], neutron is known to be a highly penetrating particle.

$$ {}^{1}_{0}n + {}^{14}_{7}N \longrightarrow {}^{14}_{6}C + {}^{1}_{1}H \qquad (3) $$

Approximately 30000 feet is the level flight altitude for international flights between Tokyo and Singapore. At nearly the same altitude, the highest stable nitrogen isotope ratios $^{15}N/^{14}N$ were observed at the neighboring position of declination. To explain this result, nuclear chemical reaction (3) is considered. If nuclear chemical reaction (3) occured frequently by cosmic ray radiation, lots of ^{14}N were convered to ^{14}C. Hence stable nitrogen isotope ratios $^{15}N/^{14}N$ could be increased.

The concentration of nitrate ions (NO_3^-) was quite variable in the in-flight water samples obtained during flights. On February 07, 2010, the NO_3^- concentration decreased substantially from 487.6 mmol/L to 171.5 mmol/L during flight DL619 from Tokyo to Singapore. However, this flight occurred at night and thus, this phenomenon could not be attributed to photochemical reactions. To explain this result, nuclear chemical reactions (4) and (5) involving ^{14}N in addition to nuclear reaction (3) are considered[11-13].

$$ {}^{14}_{7}N + {}^{1}_{0}n \longrightarrow {}^{11}_{5}B + {}^{4}_{2}He^{2+} \qquad (4) $$

$$ {}^{14}_{7}N + {}^{4}_{2}He^{2+} \longrightarrow {}^{17}_{8}O + {}^{1}_{1}H \qquad (5) $$

${}^{4}_{2}He^{2+}$ is an α particle. The nuclear chemical reactions (3-5) contributed to the observed decease in the NO_3^- concentration in the in-flight water during flight. If nuclear reaction (3) occurred, NO_3^- was converted to CO_3^{2-} and if nuclear reactions (4) and (5) occurred, NO_3^- might be converted to O_4^-. Consequently, NO_3^- concentrations in the in-flight water were decreased. Neutrons for the nuclear chemical reactions (3) and (4) are supplied by radiation from the sun and ${}^{4}_{2}He^{2+}$ particles for nuclear chemical reaction (5) are supplied by nuclear chemical reaction (4).

During flight, NO_3^- in the in-flight water was converted to CO_3^{2-} due to nuclear chemical reaction (3). Thus, the carbon in CO_3^{2-} is the carbon-14 radioisotope. The passengers and crew members on flights use this water for purposes including hand washing, gargling with mouth wash and drinking water and internal exposure to radiation by the carbon-14 radioisotope is more likely for these individuals.

The results summarized in Tables 1 and 2 and presented in Figs. 1 and 2 indicate that, in some cases, certain anion concentrations were observed to increase. One possible reason for this phenomena is that the in-flight water absorbed some gases or aerosols from outside of the airplane during flight because the airplane cabin and water tank are exposed to the atmosphere during flight. Another possible reason for this phenomenon is that other nuclear chemical reactions initiated by radiation from the sun occurred[14].

Conclusion

To date, limited information has been reported regarding the quality of water and food items present on international passenger flights and the effects of radiation and the outside flying environment on water and foodstuff during flights have not yet been considered. This study indicated that in-flight

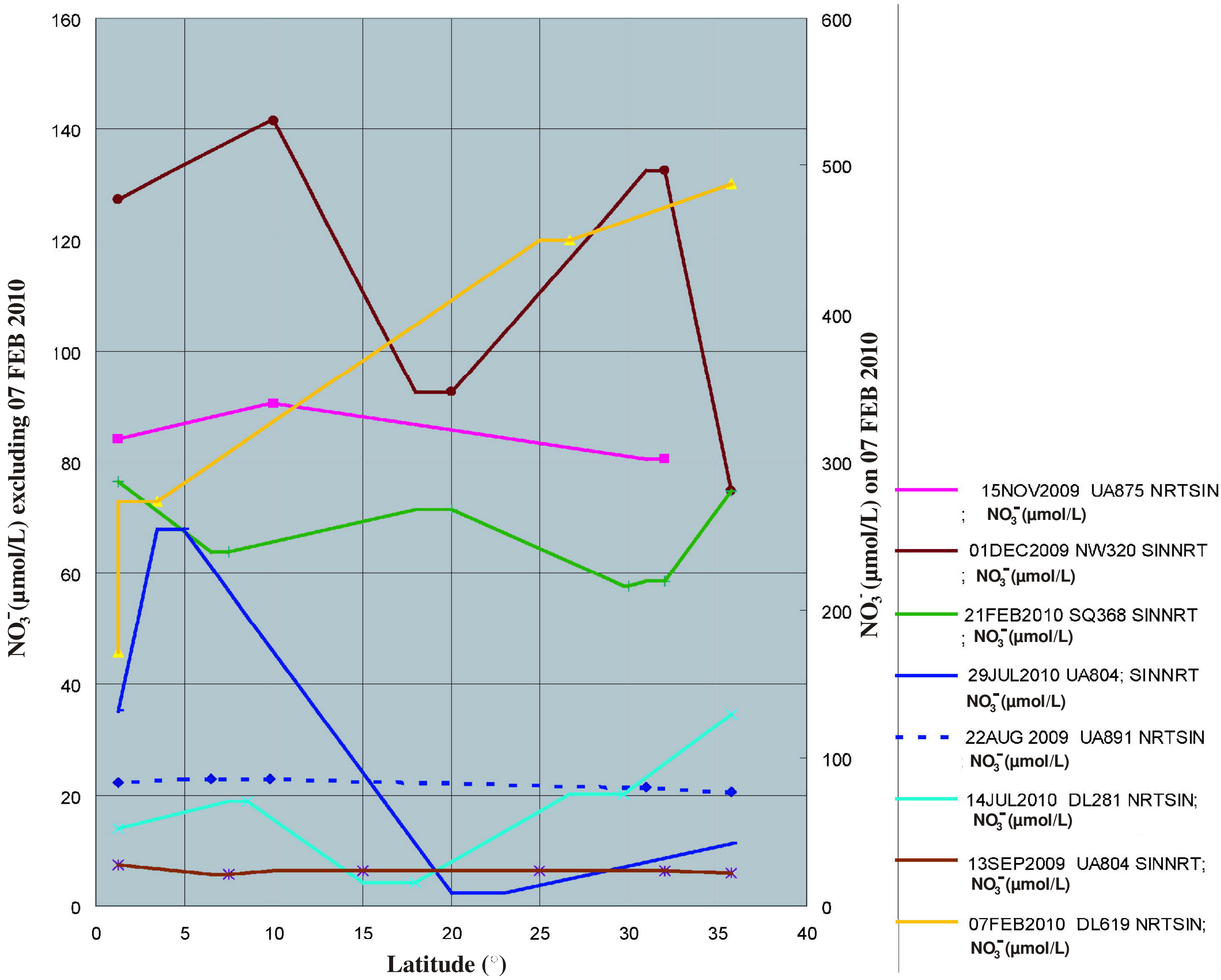

Fig. 1. Latitude *vs.* NO_3^- Narita <=> Singapore

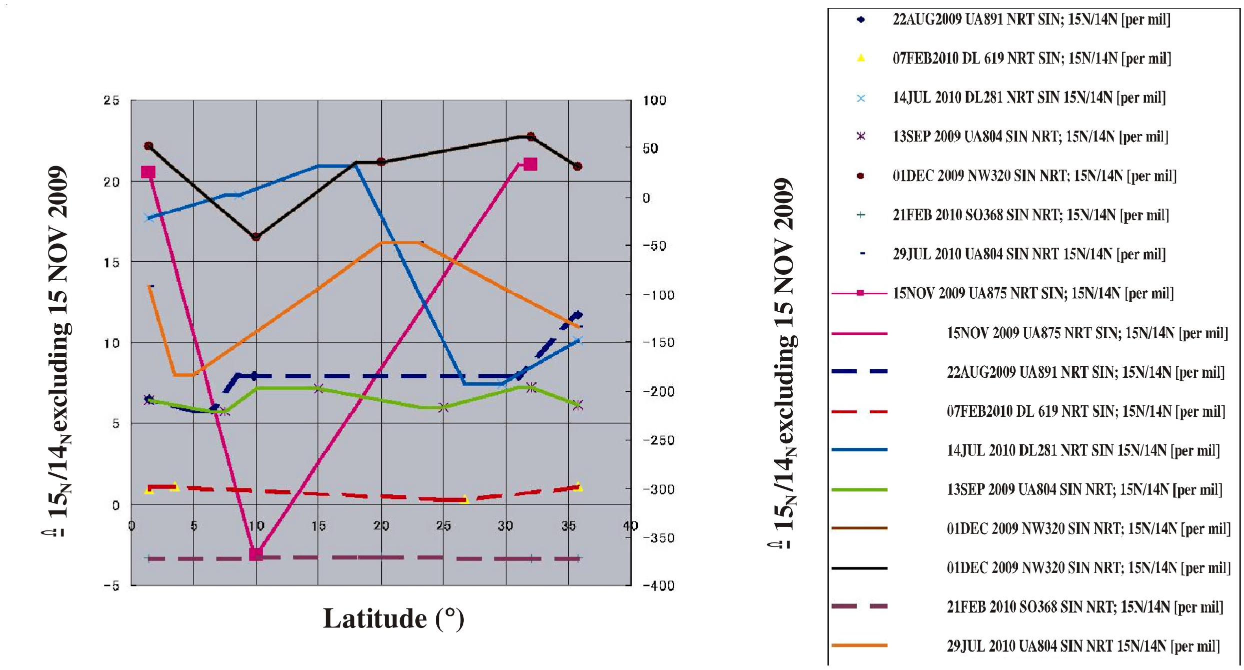

Fig. 2. Latitude *vs.* $\delta\ ^{15/14}N$

water was affected by these factors, especially neutron-activated nuclear chemical reactions and internal exposure to radiation in the form of radioisotope carbon-14 was more likely to occur for passengers and crew members. Because neutrons have significant penetrating power with regard to metal and plastic airplane materials[15], air transportation authorities should investigate to collect more detailed information concerning this issue. Huge amounts of foodstuffs are transported by airplane worldwide; thus, not only passengers and crew members but also foodstuff transported *via* air may be affected by neutron-activated nuclear chemical reactions during flights.

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REFERENCES

1. K.L. Casciotti, D.M. Sigman, M.G. Hastings, J.K. Böhlke and A. Hilkert, *Anal. Chem.*, **74**, 4905 (2002).
2. Y. Takebayashi, K. Koba, Y. Sasaki, Y.T. Fang and M. Yoh, *Rapid Commun. Mass Spectrom.*, **24**, 1001 (2010).
3. P. Richet, Y. Bottinga and M. Javoy, *Ann. Rev. Earth Planet. Sci.*, **5**, 65 (1977).
4. H. Katsura, Study on Lightning Effect on In-Flight Water in Nitrogen Stable Isotope Ratio, Abstract, 241st American Chemical Society National Meeting Anaheim California, Division of Environmental Chemistry (ENVR), p. 113 (2011).
5. F. Galembeck, J.S. Bernardes, T. Ducati, L. Santos and T. Burgo, Atmosphere is a Reservoir of Electric Charge, Mediated by Water Ion Partition, Abstract, 240th American Chemical Society National Meeting, Boston, MA, Division of Physical Chemistry, p. 501 (2010).
6. I.M. Imyanitov, *Soviet Physics Uspekhi*, **5**, 292 (1962).
7. W.P. Winn, C.B. Moore, C.R. Holmeset and L.G. Byerley III, *J. Geophys. Res.*, **83**, 3079 (1978).
8. H. Katsura, Investigation Report for the Trial Study of Chemistry, Electric Concentration of D Isotope of Hydrogen by Hydrogen Absorbing Alloy Electrodes, Tokai University, Japan (1979).
9. E. Fermi, *Nature*, **133**, 757 (1934).
10. C.B. Ramsey, *Archaeometry*, **50**, 249 (2008).
11. N. Feather, *Proc. Royal Soc. London. Series A*, **136**, 830 (1932).
12. W. Harkins, *Phys. Rev.*, **44**, 529 (1933).
13. E. Rutherford, Bakerian Lecture. Nuclear Constitution of Atoms, Proceedings of the Royal Society of London. Series A (1920).
14. E. Fermi, Artifical Radioactivity Produced by Neutron Bombardment, Nobel Lecture, December 12 (1938).
15. G. Kistiakovsky, *Bull. Atom. Sci.*, **34**, 27 (1978).