EFFECTS OF ORAL ADMINISTRATION OF A FUEL CELL PRODUCT WATER TO MACACA MULATTA

RALPH F. ZIEGLER, MAJOR, VC, USAF

Foreword

This work was performed under Project No. 6302, "Toxic Hazards of Propellants and Materials," Task No. 630201, "Toxicology," at the request of the Manned Spacecraft Center, National Aeronautics and Space Administration, Houston, Texas, under NASA-MSC Contract T-31248-G. Dr. Walter W. Kemmerer, Jr., served as contract monitor for NASA-MSC and Dr. Kenneth C. Back as technical consultant for the Aerospace Medical Research Laboratories. The work was accomplished during January and February 1965 in the Toxic Hazards Branch, Physiology Division, Biomedical Laboratory. The assistance rendered by members of the Veterinary Medicine Division, Aerospace Medical Research Laboratories, and the medical technologists of the Toxic Hazards Research Unit, Aerojet-General Corporation, is gratefully acknowledged.

This technical report has been reviewed and is approved.

WAYNE H. McCANDLESS
Technical Director
Biomedical Laboratory
Aerospace Medical Research Laboratories

Abstract

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A fuel cell product water, proposed as a supply of drinking water in space vehicles, was administered to *Macaca mulatta* at a rate of 35 ml per kg twice daily as the sole source of fluid intake for a 14-day period. Two of eight animals exhibited body weight and hematologic changes that were directly related to enteric disturbances. These, however, were apparently of a spontaneous nature since one of two control animals was also affected, although somewhat less severely. No apparent subacute oral toxicity of the fuel cell product water was demonstrated in monkeys. This indicates that product water having similar chemical and physical properties should present no serious hazard to humans when consumed as drinking water for short periods of time.

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SECTION I

Introduction

The water that is a by-product of the electrochemical reaction within fuel cells has been proposed as a supply of drinking water in space vehicles. Contaminants contributed by the cell materials, however, may show considerable variation in both quantity and quality depending on the accumulated time of operation and the load placed on the cell.

The Gemini fuel cell developed by the General Electric Co., West Lynn, Massachusetts, contains membranes of a polystyrene sulfonic acid polymer treated with an antioxident, tertiary butyl hydroquinone. These membranes separate the gaseous hydrogen and oxygen that react within the matrices of the polymer. In the early stages of operation, there is leaching of tertiary butyl hydroquinone and unpolymerized polystyrene sulfonic acid. This is followed by a period of minimum concentration of contaminants. With continued operation, there is an increase in amount due to breakdown of the membrane at the molecular level. Data received from the Manned Spacecraft Center revealed a total solids content of 65 mg per liter, of which 49 mg were volatile and considered primarily organic, in water produced after approximately 100 hours of operation of the same cell that was the source of the water used in this study. These amounts had risen to 412 mg per liter and 400 mg per liter, respectively, after about 680 hours.

Unpublished studies conducted for the General Electric Co. by the Dow Chemical Co., Midland, Michigan, revealed no evidence of subacute toxicity for mice when product water from a similar fuel cell was used as the sole source of drinking water for 30 days, even when concentrated to one-tenth the original volume. Soluble polystyrene sulfonic acid was identified as the major component of the soluble residue and cellulose as the major insoluble material in the water used.

The present study was undertaken using monkeys to determine any subacute toxic effects of the fuel cell product water.

SECTION II

Method

The product water was supplied by the Manned Spacecraft Center on 18 Jan 1965. Fifteen 2.5-liter samples of aliquots collected between 11 Oct and 4 Nov 1964 were furnished. The collection period covered a span of approximately 200 to 750 hours of operation of the cell.

The samples were pooled by mixing in two 5-gallon-capacity plastic carboys. The pooled specimen had a weakly acid taste and a faint greenish-yellow color. A small amount of suspended solids was present, either as white stringy material or light and dark colored particulate matter. Microbiological, chemical, and organoleptic analyses of the pooled product water were conducted by the Biospecialties Branch, Physiology Division, Biomedical Laboratory, and the results reported as follows:

Microbiological Analysis –
Total Plate Count (at dilutions from 10^{-1} to 10^{-5}): negative.
Chemical and Organoleptic Analysis –

pH	2.83
Conductivity	690.00 μmhos/cm
Nitrate N	2.1 ppm
Ammonia N	2.0 ppm
Chlorides	9.3 ppm
Sulfates	8.0 ppm
Phenols	<0.04 ppm
Barium	5.5 ppm
Iron	0.2 ppm
Manganese	0.2 ppm
Odor	acceptable
Color:	
Apparent	33 units (approximate)
True	10 units (approximate)
Turbidity	5 Jackson units (approximate)

Ten male *Macaca mulatta* monkeys weighing between 1.9 and 3.2 kg were used in this study. Two of these, A40 and A70, were randomly selected to serve as controls and were given tap water rather than fuel cell product water. The remaining eight animals, A44, A46, A48, A54, A60, A62, A68, and A74, were given the product water. The ten monkeys were selected by sex and weight from a group of approximately 35 animals recently released from a 90-day quarantine period following procurement. Their general condition was good, although there had been a high incidence of respiratory infections and enteritis during the quarantine period and sporadic cases of enteritis were still evident in other animals.

The animals were housed in individual hanging wire-mesh cages in the same room as the remainder of the group from which they were selected. Water was available ad libitum during the pre- and post-administration observation periods. During the period of administration of fuel cell product water or tap water, however, no other water source was available. A uniform diet was fed during the entire period of the study. The animals were given Purina Monkey Chow in the morning and an apple in the afternoon. The amount of chow given was based on the animal's appetite as determined by the caretaker. During the period of product water administration, the animals were fed shortly after the water was given.

The pooled product water, or tap water in the case of control animals, was administered for a 14-day period at a rate of 35 ml per kg twice daily. Animals were weighed on the first and eighth days of administration to determine the volume to be given. Administration was accomplished over a period of approximately 15 seconds by use of a size 8 French disposable plastic infant feeding tube passed via the nasal route and a 100-ml syringe.

Hematologic and body weight data were acquired on all animals 13 (6 Jan 1965) and 7 (12 Jan 1965) days prior to, and 1 (2 Feb 1965) and 10 (11 Feb 1965) days following administration of product water. Body weights were obtained by having a caretaker hold the animal while standing on a physician's office-type scale and subtracting the caretaker's weight from the gross weight obtained. Blood specimens were obtained by femoral vessel puncture. A portion of the specimen was placed in a tube containing a small amount of heparin and the remainder in a tube without anticoagulant. The following determinations were made: white cell count, white cell differential, red cell count, packed cell volume, hemoglobin concentration, sodium, potassium, calcium, inorganic phosphorus, alkaline phosphatase, lactic dehydrogenase (LDH), serum glutamic oxalacetic transaminase (SGOT), serum glutamic pyruvic transaminase (SGPT), serum protein, serum albumin, and serum globulin. Routine clinical methods were used in making these determinations. These are shown in the introduction to the individual animal data (Appendix).

Additional data were collected on several animals following the completion of the original protocol. Clinical observations were confined to those days when the additional blood specimens were collected. Following the collection of the 10-day postadministration data, however, the animals were moved to new quarters, placed in smaller cages, fed a variety of fruit and vegetables, and were exposed to subnormal room temperature for several days due to heating system failure.

SECTION III

Results

No difficulty was encountered in administering the water to the animals. One monkey regurgitated several ml during administration on one occasion and on another occasion an animal regurgitated while eating. In one instance, a control animal (A70) exhibited symptoms of gastric discomfort for several hours after eating.

Body weight and hematologic data acquired on the individual animals are given in the Appendix. Clinical observations are included.

Animal A48 in the product water group had a marked decrease in body weight during the administration period. A continued loss of weight was observed during the following 17 days. Two other animals, A62 in the product water group and A70 in the control group, also showed a decrease in body weight during the 14-day period. The loss was not as marked, however, and did not continue. A comparison of the trend of the body weights of the other animals failed to reveal any apparent differences.

Evaluation of the hematologic data revealed that animal A48 in the product water group was affected to the greatest degree. A shift to the left in the white cell differential, reduction in red cell count, packed cell volume, and hemoglobin concentration, and some electrolyte and enzyme changes are most apparent in the postadministration period. A reduction in serum sodium and potassium was evident in the first postadministration specimen and in inorganic phosphorous in the additional samples. The alkaline phosphatase level was significantly reduced for several weeks and a reduction in SGPT and possibly SGOT are noted in the second postadministration sample. A reduced SGPT level in A62 and possibly SGOT levels in A60 and A62 were observed in the first postadministration samples. Both these animals were in the product water group. A62 also showed an apparent reduction in red cell count, packed cell volume, and hemoglobin concentration in the postadministration period.

Three animals, A48 and A62 in the product water group and A70 in the control group, developed enteric disturbances during the administration period. The first symptom noted was a depressed appetite. This was first observed in A62 on the second day of the administration period, in A70 on the fifth day, and in A48 on the sixth day. Loose stools and/or diarrhea were then observed for several days after which the retarded appetite persisted. Animals A62 and A70 recovered clinically prior to the end of the 14-day period. A48, which was housed in a cage adjoining that of A62, was more severely affected. The enteritis lasted until several days after the end of the administration period and the retarded appetite persisted for at least 3 weeks. Dehydration was of little significance in the affected animals apparently due to the forced fluid intake. A moderate depression of activity was observed in animal A48, but A62 and A70 were only slightly affected.

Cultures of rectal swabs taken from the above animals during the acute stage revealed only bacteria of the coliform group. No *Salmonella* or *Shigella* species or other organisms of significance were isolated.

Loose stools were observed from Animal A74 on two occasions, and A60 exhibited a slightly depressed appetite on one occasion during the administration period. Although both these animals were in the product water group, the transient nature of these symptoms indicate they were of little significance.

No effects were observed on the activity, appetite, or digestive system of the other animals. Signs of generalized dehydration were not noted. Some dry lip lesions were observed in the majority of animals in both the product water and control groups near the end of the administration period. These were apparently due to lack of fluid intake by mouth since they healed rapidly when the animals were again given water ad libitum.

SECTION IV

Discussion

A comparison of the body weight and hematologic data with clinical observations reveals that the changes observed were associated primarily with animals that developed enteric disturbances. The magnitude of these changes was directly related to the severity of the condition.

The relationship of the fuel cell product water and the incidence of enteric disturbances is not established, however. The fact that one of the control animals was affected and sporadic incidents of enteritis were observed in other animals in the colony appears to indicate that this was a spontaneous condition not related to the product water. Since both animals in the product water group were more severely affected, one slightly and the other considerably, the response to the condition may have been modified. Due to the small number of animals involved, the current data do not substantiate or refute this possibility.

SECTION V

Summary and Conclusions

A fuel cell product water was administered to *Macaca mulatta* as the sole source of fluid intake for a 14-day period. Body weight and hematologic changes in 2 of 8 animals were directly related to enteric disturbances. These were apparently of a spontaneous nature since one of two control animals receiving tap water was also affected, although somewhat less severely.

The present study failed to reveal any apparent subacute oral toxicity of the fuel cell product water in monkeys and it should, therefore, present no serious hazard to humans when consumed as drinking water for short periods of time. Since the physical and chemical properties of product water vary with the accumulated time of operation of the fuel cell, however, this conclusion may not be applicable in all situations.

10 11 12 13 14 15 16 17 18 19

Appendix

INDIVIDUAL ANIMAL DATA

HEMATOLOGY

Column	*Test*	*Units*	*Method*
1	White cell count	per cubic mm	Coulter Counter, Model B
2-9	White cell differential: Neutrophiles, Blasts, Myelocytes, Bands, Lymphocytes, Monocytes, Eosinophiles, Basophiles	%	Wright's Stain
10	Red cell count	X 10^6 per cubic mm	Coulter Counter, Model B
11	Packed cell volume	%	Micro technique — International Micro-Capillary Centrifuge, Model MB and Reader
12	Hemoglobin concentration	gm per 100 ml	Cyanmethemoglobin — Hycel, Inc.
14-16	Sodium, Potassium, Calcium	mEq per liter serum	Flame photometry — Coleman Junior Spectrophotometer, Model 62 and Flame Photometer, Model 21
17	Inorganic phosphorous	mg per 100 ml serum	Air Force Manual 160-49, *Laboratory Procedures in Clinical Chemistry and Urinalysis*, pp 10-17 - 10-18, Department of the Air Force, Washington, D. C., 1962
18	Alkaline phosphatase	Klein-Babson-Read units	Phosphatabs-Alkaline Quantitative, Warner-Chilcott
19	Lactic dehydrogenase (LDH)	Units per ml serum	Cabaud-Wroblewski, Dade Reagents, Inc.
20	Serum glutamic oxalacetic transaminase (SGOT)	Units per ml serum	Reitman-Frankel, Modified, Dade Reagents, Inc.
21	Serum glutamic pyruvic transaminase (SGPT)	Units per ml serum	Reitman-Frankel, Modified, Dade Reagents, Inc.
22-23	Total protein, Albumin	gm per 100 ml serum	Gornall, A. G., C. J. Bardawill and M. M. David, *J Biol Chem*, 177:751-766, 1949, modified
24	Globulin	gm per 100 ml serum	Calculated from 22 and 23

ANIMAL: **Monkey** NUMBER: **A44** SEX: **Male** STUDY: **Fuel Cell Product Water**

Date	1 WBC	2 Ne	3 Bl	4 My	5 Ba	6 Ly	7 Mo	8 Eo	9 Bs	10 RBC	11 PCV	12 Hb	13 Remk*	14 Na	15 K	16 Ca	17 P	18 Alpts	19 LDH	20 SGOT	21 SGPT	22 Prot	23 Alb	24 Glo
6 Jan	12,265	22				67	2	9		4.48	39	11.7	a	148	4.2	5.7	5.9	17.0	480	50	31	7.7	4.0	3.7
12 Jan	10,219	24			1	67		8		3.93	36	11.3	a,c	149	4.4	5.7	5.2	19.0	500	45	35	6.8	4.6	2.2
2 Feb	9,865	17			1	80	1		1	3.98	36	11.0		150	5.1	5.6	5.8	26.5	520	35	28	6.6	4.9	1.7
11 Feb	8,171	17				73	2	7	1	3.84	36	11.0		147	5.0	5.5	6.2	17.0	480	26	18	7.3	4.4	2.9

* REMARKS: a. Hypochromia, b. Hyperchromia, c. Microcytosis, d. Macrocytosis, e. Anisocytosis, f. Target Cells, g. Nucleated RBC - Number

BODY WEIGHT:

Date	6 Jan	12 Jan	19 Jan	26 Jan	2 Feb	11 Feb						
kg	2.6	3.0	2.5	2.7	2.6	2.7						

EXPERIMENTAL PROTOCOL:

Controlled diet and environment 6 Jan to 11 Feb 1965.
Fuel cell product water 19 Jan thru 1 Feb 1965 - 35 ml per kg twice daily.

OBSERVATIONS:

ANIMAL DATA REPORT

ANIMAL: **Monkey** NUMBER: **A46** SEX: **Male** STUDY: **Fuel Cell Product Water**

Date	1 WBC	2 Ne	3 Bl	4 My	5 Ba	6 Ly	7 Mo	8 Eo	9 Bs	10 RBC	11 PCV	12 Hb	13 Remk*	14 Na	15 K	16 Ca	17 P	18 Alpts	19 LDH	20 SGOT	21 SGPT	22 Prot	23 Alb	24 Glo
6 Jan	9,840	18				70	5	7		4.24	38	11.0	a	146	4.5	5.2	5.7	26.5	390	40	31	6.4	3.4	3.0
12 Jan	8,931	13				74	4	7	2	3.74	38	11.0	a	142	4.4	5.4	6.1	21.0	390	45	31	6.4	3.8	2.6
2 Feb	10,374	28			1	59	6	6		4.15	39	11.3	e	145	4.7	5.2	5.8	20.5	390	45	22	6.2	4.2	2.0
11 Feb	11,309	35				57	1	7		4.07	37	10.6		146	4.5	5.3	6.4	18.5	280	26	22	6.7	4.2	2.5

* REMARKS: a. Hypochromia, b. Hyperchromia, c. Microcytosis, d. Macrocytosis, e. Anisocytosis, f. Target Cells, g. Nucleated RBC - Number

BODY WEIGHT:

Date	6 Jan	12 Jan	19 Jan	26 Jan	2 Feb	11 Feb
kg	2.3	2.4	2.2	2.4	2.3	2.4

EXPERIMENTAL PROTOCOL:

Controlled diet and environment 6 Jan to 11 Feb 1965.
Fuel cell product water 19 Jan thru 1 Feb 1965 - 35 ml per kg twice daily.

OBSERVATIONS:

ANIMAL DATA REPORT

ANIMAL: **Monkey** NUMBER: **A48** SEX: **Male** STUDY: **Fuel Cell Product Water**

Date	1 WBC	2 Ne	3 Bl	4 My	5 Ba	6 Ly	7 Mo	8 Eo	9 Bs	10 RBC	11 PCV	12 Hb	13 Remk*	14 Na	15 K	16 Ca	17 P	18 Alpts	19 LDH	20 SGOT	21 SGPT	22 Prot	23 Alb	24 Glo
6 Jan	12,519	58			2	34	4	2		4.44	39	11.0	a,f	149	4.3	5.5	6.2	25.0	780	50	39	7.5	3.9	3.6
12 Jan	15,197	53			2	41	2		2	4.39	40	11.0	a	150	5.1	5.8	6.9	20.0	520	50	35	7.7	4.6	3.1
2 Feb	13,327	33		4	37	17	9			4.08	44	11.3		136	2.8	5.1	6.4	8.5	390	50	25	6.2	4.6	1.6
11 Feb	11,914	72			8	17	3			3.80	34	10.3	a	142	5.0	5.2	5.5	4.5	720	31	10	6.2	4.0	2.2
18 Feb	15,607	58			7	35				3.23	34	9.3	a	144	5.4	5.3	2.8	7.0	440	64	35	6.0	3.4	2.6
25 Feb	13,695	66			1	32	2	1		3.81	40	10.0	a	140	4.3	5.3	3.2	13.5	180	35	25	6.4	3.9	2.5

* REMARKS: a. Hypochromia, b. Hyperchromia, c. Microcytosis, d. Macrocytosis, e. Anisocytosis, f. Target Cells, g. Nucleated RBC - Number

BODY WEIGHT:

Date	6 Jan	12 Jan	19 Jan	26 Jan	2 Feb	11 Feb	18 Feb	25 Feb				
kg	3.2	3.2	3.0	3.1	2.4	2.2	2.0	2.0				

EXPERIMENTAL PROTOCOL:

Controlled diet and environment 6 Jan to 11 Feb 1965.
Fuel cell product water 19 Jan thru 1 Feb 1965 - 35 ml per kg twice daily.

OBSERVATIONS:

24 Jan-5Feb Severe enteric disturbance - anorexia, blood tinged diarrhea.
8 Feb Appetite improved but not normal. Stool normal.
25 Feb Appetite still depressed. Diarrhea.

ANIMAL DATA REPORT

ANIMAL: **Monkey** NUMBER: **A54** SEX: **Male** STUDY: **Fuel Cell Product Water**

Date	1 WBC	2 Ne	3 Bl	4 My	5 Ba	6 Ly	7 Mo	8 Eo	9 Bs	10 RBC	11 PCV	12 Hb	13 Remk*	14 Na	15 K	16 Ca	17 P	18 Alpts	19 LDH	20 SGOT	21 SGPT	22 Prot	23 Alb	24 Glo
6 Jan	12,429	24				72	3	1		4.51	43	12.3		147	4.0	5.1	4.9	15.5	440	45	35	7.1	3.8	3.3
12 Jan	13,297	17				72	5	5	1	4.09	39	11.3	a	153	4.9	5.9	5.7	21.0	340	40	35	7.3	4.3	3.0
2 Feb	7,277	28			4	63	4	1		4.39	40	12.0	a	148	4.5	5.6	6.1	27.0	280	40	18	6.4	4.2	2.2
11 Feb	8,599	14				83	1	2		4.70	44	12.7		149	5.2	5.5	6.7	28.0	390	40	28	7.1	4.3	2.8

* REMARKS: a. Hypochromia, b. Hyperchromia, c. Microcytosis, d. Macrocytosis, e. Anisocytosis, f. Target Cells, g. Nucleated RBC - Number

BODY WEIGHT:

Date	6 Jan	12 Jan	19 Jan	26 Jan	2 Feb	11 Feb
kg	2.1	2.3	2.0	2.5	2.0	2.2

EXPERIMENTAL PROTOCOL:

Controlled diet and environment 6 Jan to 11 Feb 1965.
Fuel cell product water 19 Jan thru 1 Feb 1965 - 35 ml per kg twice daily.

OBSERVATIONS:

ANIMAL DATA REPORT

ANIMAL: **Monkey** NUMBER: **A60** SEX: **Male** STUDY: **Fuel Cell Product Water**

Date	1 WBC	2 Ne	3 Bl	4 My	5 Ba	6 Ly	7 Mo	8 Eo	9 Bs	10 RBC	11 PCV	12 Hb	13 Remk*	14 Na	15 K	16 Ca	17 P	18 Alpts	19 LDH	20 SGOT	21 SGPT	22 Prot	23 Alb	24 Glo
6 Jan	18,097	53				35	8	2	2	4.87	43	12.3		145	4.7	6.0	4.7	17.5	880	40	28	7.9	4.2	3.7
12 Jan	16,695	41		1	3	47	4	3	1	4.66	42	12.0	g-2	148	4.5	5.8	6.1	26.5	440	50	35	7.7	4.9	2.8
2 Feb	11,540	54			2	49	4			4.57	40	11.3	a	152	4.3	5.9	5.1	34.0	440	22	25	7.0	5.2	1.8
11 Feb	10,150	27				67	3	2	1	4.22	38	11.7		150	5.2	5.8	5.7	22.5	340	35	18	7.7	4.9	2.8
18 Feb																		21.0		31	22			

* REMARKS: a. Hypochromia, b. Hyperchromia, c. Microcytosis, d. Macrocytosis, e. Anisocytosis, f. Target Cells, g. Nucleated RBC - Number

BODY WEIGHT:

Date	6 Jan	12 Jan	19 Jan	26 Jan	2 Feb	11 Feb
kg	2.3	2.3	2.0	2.3	2.2	2.3

EXPERIMENTAL PROTOCOL:

Controlled diet and environment 6 Jan to 11 Feb 1965.
Fuel cell product water 19 Jan thru 1 Feb 1965 - 35 ml per kg twice daily.

OBSERVATIONS:

24 Jan Appetite slightly depressed.

ANIMAL DATA REPORT

ANIMAL: **Monkey** NUMBER: **462** SEX: **Male** STUDY: **Fuel Cell Product Water**

Date	1 WBC	2 Ne	3 Bl	4 My	5 Ba	6 Ly	7 Mo	8 Eo	9 Bs	10 RBC	11 PCV	12 Hb	13 Remk*	14 Na	15 K	16 Ca	17 P	18 Alpts	19 LDH	20 SGOT	21 SGPT	22 Prot	23 Alb	24 Glo
6 Jan	13,926	49				40	4	6	1	4.39	38	11.7	a	144	4.5	5.4	6.9	25.5	340	35	25	7.9	4.2	3.7
12 Jan	13,653	34			3	47		14	2	3.82	36	11.0	f	145	4.5	5.7	5.9	31.0	230	40	31	8.2	4.4	3.8
2 Feb	13,123	36				57	1	3	3	3.42	32	9.8	a,e	150	5.3	5.4	5.1	21.5	230	22	10	7.0	4.0	3.0
11 Feb	15,209	23				58	4	5		3.69	35	10.0	a	146	4.0	5.0	6.4	21.5	180	35	28	7.1	4.3	2.8
18 Feb																		27.0		45	25			

* REMARKS: a. Hypochromia, b. Hyperchromia, c. Microcytosis, d. Macrocytosis, e. Anisocytosis, f. Target Cells, g. Nucleated RBC - Number

BODY WEIGHT:

Date	6 Jan	12 Jan	19 Jan	26 Jan	2 Feb	11 Feb
kg	2.3	2.4	1.9	2.0	1.8	2.0

EXPERIMENTAL PROTOCOL:

Controlled diet and environment 6 Jan to 11 Feb 1965.
Fuel cell product water 19 Jan thru 1 Feb 1965 - 35 ml per kg twice daily.

OBSERVATIONS:

21 Jan-28 Jan Enteric disturbance - some ancrexia, loose stools with blood tinged mucus.
18 Feb Slight diarrhea.

ANIMAL DATA REPORT

ANIMAL: **Monkey** NUMBER: **A68** SEX: **Male** STUDY: **Fuel Cell Product Water**

Date	1 WBC	2 Ne	3 Bl	4 My	5 Ba	6 Ly	7 Mo	8 Eo	9 Bs	10 RBC	11 PCV	12 Hb	13 Remk*	14 Na	15 K	16 Ca	17 P	18 Alpts	19 LDH	20 SGOT	21 SGPT	22 Prot	23 Alb	24 Glo
6 Jan	13,018	22			1	75	1	1		4.66	42	12.3		150	4.4	5.7	6.6	24.5	880	64	50	7.7	4.0	3.7
12 Jan	12,628	24				70	3	3		4.32	42	12.3		152	5.2	6.1	6.4	30.0	520	45	39	7.7	4.7	3.0
2 Feb	7,925	37			2	55	4	1	1	4.53	41	11.3	e	145	4.4	5.8	5.6	27.0	440	35	31	7.1	4.2	2.9
11 Feb	8,128	21			1	71	5	1	1	4.50	40	12.0		150	4.7	5.6	6.4	25.0	280	31	35	7.1	4.9	2.2

* REMARKS: a. Hypochromia, b. Hyperchromia, c. Microcytosis, d. Macrocytosis, e. Anisocytosis, f. Target Cells, g. Nucleated RBC - Number

BODY WEIGHT:

Date	6 Jan	12 Jan	19 Jan	26 Jan	2 Feb	11 Feb						
kg	2.3	2.5	2.0	2.5	2.4	2.7						

EXPERIMENTAL PROTOCOL:
Controlled diet and environment 6 Jan to 11 Feb 1965.
Fuel cell product water 19 Jan thru 1 Feb - 35 ml per kg twice daily.

OBSERVATIONS:

ANIMAL DATA REPORT

ANIMAL: **Monkey** NUMBER: **A74** SEX: **Male** STUDY: **Fuel Cell Product Water**

Date	1 WBC	2 Ne	3 Bl	4 My	5 Ba	6 Ly	7 Mo	8 Eo	9 Bs	10 RBC	11 PCV	12 Hb	13 Remk*	14 Na	15 K	16 Ca	17 P	18 Alpts	19 LDH	20 SGOT	21 SGPT	22 Prot	23 Alb	24 Glo
6 Jan	8,993	28				66	3	2	1	4.91	44	13.3		148	4.1	5.5	7.2	25.0	230	50	42	7.9	4.4	3.5
12 Jan	10,297	50				42	4	3	1	4.06	36	10.6	a	144	3.8	5.4	4.1	31.0	360	45	35	7.0	4.6	2.4
2 Feb	12,937	42			1	44	4	8		3.79	38	11.0		144	3.4	5.3	5.6	34.0	180	40	25	6.8	4.3	2.5
11 Feb	10,619	36				52	2	9	1	3.98	38	11.3	a	144	4.3	5.1	6.9	34.0	280	31	22	7.0	4.2	2.8

* REMARKS: a. Hypochromia, b. Hyperchromia, c. Microcytosis, d. Macrocytosis, e. Anisocytosis, f. Target Cells, g. Nucleated RBC - Number

BODY WEIGHT:

Date	6 Jan	12 Jan	19 Jan	26 Jan	2 Feb	11 Feb						
kg	1.9	2.3	1.8	2.0	1.9	2.2						

EXPERIMENTAL PROTOCOL:
Controlled diet and environment 6 Jan to 11 Feb 1965.
Fuel cell product water 19 Jan thru 1 Feb 1965 - 35 ml per kg twice daily.

OBSERVATIONS:
22 Jan Semisolid stool.
24 Jan Loose stool.

ANIMAL DATA REPORT

ANIMAL: **Monkey** NUMBER: **A40** SEX: **Male** STUDY: **Fuel Cell Product Water - Control**

Date	1 WBC	2 Ne	3 Bl	4 My	5 Ba	6 Ly	7 Mo	8 Eo	9 Bs	10 RBC	11 PCV	12 Hb	13 Remk*	14 Na	15 K	16 Ca	17 P	18 Alpts	19 LDH	20 SGOT	21 SGPT	22 Prot	23 Alb	24 Glo
6 Jan														148	4.7	5.8	8.8	23.0	390	45	28	8.2	4.2	4.0
12 Jan	10,880	7				86	6		1	4.26	36	11.0	a	148	3.9	5.6	4.7	27.0	280	55	39	7.2	4.4	2.8
2 Feb	10,249	19			2	75	4			4.13	38	11.7		149	4.4	5.4	5.6	42.0	600	55	28	6.6	4.4	2.2
11 Feb	13,316	29			1	64	1	3	2	3.99	37	10.6		148	4.5	5.4	6.7	27.0	600	55	25	7.0	4.3	2.7

* REMARKS: a. Hypochromia, b. Hyperchromia, c. Microcytosis, d. Macrocytosis, e. Anisocytosis, f. Target Cells, g. Nucleated RBC - Number

BODY WEIGHT:

Date	6 Jan	12 Jan	19 Jan	26 Jan	2 Feb	11 Feb						
kg	2.4	2.7	2.4	2.5	2.6	2.7						

EXPERIMENTAL PROTOCOL:

Controlled diet and environment 6 Jan to 11 Feb 1965.
Tap water 19 Jan thru 1 Feb 1965 - 35 ml per kg twice daily.

OBSERVATIONS:

ANIMAL DATA REPORT

ANIMAL: **Monkey** NUMBER: **A70** SEX: **Male** STUDY: **Fuel Cell Product Water - Control**

Date	1 WBC	2 Ne	3 Bl	4 My	5 Ba	6 Ly	7 Mo	8 Eo	9 Bs	10 RBC	11 PCV	12 Hb	13 Remk*	14 Na	15 K	16 Ca	17 P	18 Alpts	19 LDH	20 SGOT	21 SGPT	22 Prot	23 Alb	24 Glo
6 Jan	5,862	30				66	1	3		4.40	41	12.3		144	4.2	5.0	6.9	30.0	280	35	31	7.1	3.7	3.4
12 Jan	9,141	31				55	13	1		4.20	39	12.0		148	3.8	5.6	5.9	23.5	440	55	39	7.2	4.2	3.0
2 Feb	9,816	56			1	35	5	3		4.19	39	11.7	e,g-1	148	4.4	5.3	4.8	34.0	390	40	25	6.2	4.0	2.2
11 Feb	6,558	27			1	69		2	2	4.00	36	10.6	a	146	4.4	5.2	7.4	35.0	600	55	28	7.3	4.0	3.3
19 Feb																		26.5		50	28			

* REMARKS: a. Hypochromia, b. Hyperchromia, c. Microcytosis, d. Macrocytosis, e. Anisocytosis, f. Target Cells, g. Nucleated RBC - Number

BODY WEIGHT:

Date	6 Jan	12 Jan	19 Jan	26 Jan	2 Feb	11 Feb
kg	2.1	3.0	2.4	2.4	2.3	2.5

EXPERIMENTAL PROTOCOL:

Controlled diet and environment 6 Jan to 11 Feb 1965.
Tap water 19 Jan thru 1 Feb 1965 - 35 ml per kg twice daily.

OBSERVATIONS:

23 Jan-30 Jan **Enteric disturbance - some anorexia, loose stools.**

ANIMAL DATA REPORT

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

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EFFECTS OF ORAL ADMINISTRATION OF A FUEL CELL PRODUCT WATER TO MACACA MULATTA

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Final report, January - February 1965

5. AUTHOR(S) *(Last name, first name, initial)*

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
Joint NASA/USAF Study	Aerospace Medical Research Laboratories, Aerospace Medical Div., Air Force Systems Command, Wright-Patterson AFB, Ohio

13. ABSTRACT

A fuel cell product water, proposed as a supply of drinking water in space vehicles, was administered to Macaca mulatta at a rate of 35 ml per kg twice daily as the sole source of fluid intake for a 14-day period. Two of eight animals exhibited body weight and hematologic changes that were directly related to enteric disturbances. These, however, were apparently of a spontaneous nature since one of two control animals was also affected, although somewhat less severely. No apparent subacute oral toxicity of the fuel cell product water was demonstrated in monkeys. This indicates that product water having similar chemical and physical properties should present no serious hazard to humans when consumed as drinking water for short periods of time.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Fuel cell product water						
Subacute toxic effects						
Enteric disturbances						
Drinking water						
Space vehicles						
Macaca mulatta						
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