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Water Tank Sampling, 2022-2023

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- The chemical water quality in rainwater-harvested water tanks was assessed at 17 residential properties, two government offices, and a government water depot in Bermuda in November 2022 in accordance with the requirements of Belco's Operating License.
- Sample locations were determined by input from Belco and DENR in response to concerns from residents over the potential for drinking water contamination resulting from atmospheric deposition of exhaust emissions on roof surfaces.
- Following preliminary results from the analytical laboratory that identified potential poor water quality at one residential location, a second round of sampling of nearby properties was undertaken in February 2023.
- Water samples were analysed for total dissolved solids (TDS), total suspended solids (TSS), pH, a suite of 31 metals, and a suite of 21 polycyclic aromatic hydrocarbons (PAHs – also called polyaromatic hydrocarbons).
- The results were compared with Primary and Secondary Drinking Water Standards in effect in Bermuda and the USA.
- The Secondary Drinking Water Standard for aluminium (Al) was exceeded at three locations. The water at one of these locations also exceeded the Secondary Drinking Water Standards for iron (Fe) and for manganese (Mn). Exceedance of Secondary Drinking Water Standards generally results in aesthetic and cosmetic effects (i.e. appearance, odour, and taste).
- No other Primary or Secondary Drinking Water Standards were exceeded.
- The analysis of a nearby residence to the location initially showing exceedance of 3 Secondary Drinking Water Standards showed that the tank water was compliant with respect to all drinking water standards.

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1 - Sampling

Water sampling was conducted by BIOS personnel on 24 and 25 November 2022, witnessed by representatives from BELCO and DENR. All water samples were collected from a spigot or faucet located as close to the foot valve as possible, prior to any filtration system. Samples can thus be considered to be representative of tank water supplied to the residence without any effects from plumbing and any subsequent water treatment processes. Water from the government water depot at Frog Lane was sampled directly from the outflow valve of a water truck immediately after it had been filled.

Samples were collected in pre-cleaned bottles supplied by the analytical laboratory. At each location, bottles were handled while wearing new nitrile gloves to avoid sample contamination.

Water was sampled from tanks at the following locations:

Site 1) Twin Lane Drive
Site 2) Mount Hill
Site 3) Twin Lane Place
Site 4) Bluff Lane
Site 5) Lismore Lane
Site 6) St John's Road
Site 7) Underhill Crescent
Site 8) Underhill Lane
Site 9) St John's Road
Site 10) Astwood Close
Site 11) Woodland Road
Site 12) Berkeley Road
Site 13) Ridgeway

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Site 14) Princess Estate

Site 15) Ingham's Vale

Site 16) Pembroke

Site 17) Sanz Close

Site 18) Paget Post Office

Site 19) Gov't Water Depot, Frog Lane

Site 20) Southlands (Dept. Cons. Services)

After filling, sample containers were immediately labelled and double-bagged in polyethylene "zip-lock" bags and kept in coolers with frozen freezer blocks. Samples were transported to the BIOS laboratory and stored in refrigerators at 4°C prior to shipping, for which sample containers were packed in insulated cooler boxes with bubble wrap and freezer blocks that had been frozen at -80°C. Chain of custody forms were completed by BIOS personnel to record all sample information and these were dispatched with the samples. The containers were shipped using FedEx Priority Alert service to ensure that they would be kept refrigerated in the event of any delay during shipping.

All chemical analyses were performed by Bureau Veritas Laboratories, Bedford, Nova Scotia, Canada. BV Labs are accredited by the Standards Council of Canada and conform with the requirements of ISO/IEC 17025:2005. All analytical results from BV Labs were sent in duplicate to BIOS and BELCO.

Water samples were analysed for total dissolved solids (TDS) and total suspended solids (TSS), a suite of 31 metals, and a suite of 21 polycyclic aromatic hydrocarbons (PAHs).

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Results

Analytical results for water from the 17 residences and 3 control sites are shown in Tables 2a and 2b (metals) and Tables 3a and 3b (PAHs). Note that PAHs were present below the detection limits in all samples.

These results were compared with the drinking water standards in effect in Bermuda, as legislated by the Department of Health, and also with the US Federal drinking water regulations established by the US Environmental Protection Agency (EPA). Both sets of standards are shown in Table 1, below.

		BERMUDA		USA	
	Units	**Primary Std**	**Secondary Std**	**Primary Std**	**Secondary Std**
Total Dissolved Solids	mg/L		500		500
Total Mercury (Hg)	µg/L	2.0		2.0	
Total Aluminum (Al)	µg/L		200		200
Total Antimony (Sb)	µg/L			6.0	
Total Arsenic (As)	µg/L	10		10	
Total Barium (Ba)	µg/L			2000	
Total Beryllium (Be)	µg/L			4.0	
Total Cadmium (Cd)	µg/L	5.0		5.0	
Total Chromium (Cr)	µg/L	100		100	
Total Copper (Cu)	µg/L		1000	1300*	1000
Total Iron (Fe)	µg/L		300		300
Total Lead (Pb)	µg/L			15*	
Total Manganese (Mn)	µg/L		50		50
Total Selenium (Se)	µg/L	50		50	
Total Silver (Ag)	µg/L		100		100
Total Thallium (Tl)	µg/L			2.0	
Total Uranium (U)	µg/L			30	
Total Zinc (Zn)	µg/L		5000		5000
Benzo(a)pyrene	µg/L			0.2	
2,3,7,8-Tetra CDD	pg/L			30	

Table 1: Drinking water standards in effect in Bermuda and USA. * denotes action level limit - see text for explanation.

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		1	2	3	4	5	6	7	8	9	10	RDL
Inorganics												
Total Dissolved Solids	mg/L	33	50	220	69	180	210	110	64	40	47	10
pH	pH	7.54	7.84	8.07	7.69	7.80	8.04	7.57	7.73	7.67	7.73	
Total Suspended Solids	mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.0
Metals												
Total Mercury (Hg)	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.013
Total Aluminum (Al)	µg/L	130	140	**200**	87	18	23	16	99	89	110	5.0
Total Antimony (Sb)	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.0
Total Arsenic (As)	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.0
Total Barium (Ba)	µg/L	2.0	2.5	5.3	3.0	17	4.4	9.5	2.2	5.1	4.1	1.0
Total Beryllium (Be)	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.10
Total Bismuth (Bi)	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.0
Total Boron (B)	µg/L	ND	ND	ND	ND	590	74	340	ND	ND	ND	50
Total Cadmium (Cd)	µg/L	ND	0.070	0.037	ND	ND	0.016	ND	ND	ND	ND	0.010
Total Calcium (Ca)	µg/L	5100	12000	17000	11000	13000	50000	6200	10000	10000	10000	100
Total Chromium (Cr)	µg/L	ND	ND	1.6	1.0	ND	1.1	ND	ND	ND	ND	1.0
Total Cobalt (Co)	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.40
Total Copper (Cu)	µg/L	16	39	8.8	73	13	11	8.3	29	10	15	0.50
Total Iron (Fe)	µg/L	ND	ND	150	170	75	ND	250	ND	ND	ND	50
Total Lead (Pb)	µg/L	2.7	1.5	0.56	2.1	0.65	ND	5.2	2.0	ND	ND	0.50
Total Magnesium (Mg)	µg/L	480	870	1300	740	1100	2000	880	430	650	830	100
Total Manganese (Mn)	µg/L	ND	ND	43	ND	ND	ND	3.3	ND	ND	ND	2.0
Total Molybdenum (Mo)	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.0
Total Nickel (Ni)	µg/L	ND	ND	ND	ND	ND	2.0	ND	ND	ND	ND	2.0
Total Phosphorus (P)	µg/L	ND	ND	ND	ND	ND	300	ND	ND	ND	ND	100
Total Potassium (K)	µg/L	340	310	1700	570	3100	2700	1900	700	150	350	100
Total Selenium (Se)	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.50
Total Silver (Ag)	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.10
Total Sodium (Na)	µg/L	6900	6900	12000	11000	53000	19000	33000	9500	4300	7000	100
Total Strontium (Sr)	µg/L	38	120	370	45	100	690	49	26	37	170	2.0
Total Thallium (Tl)	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.10
Total Tin (Sn)	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.0
Total Titanium (Ti)	µg/L	ND	ND	2.9	ND	ND	ND	ND	ND	ND	ND	2.0
Total Uranium (U)	µg/L	ND	ND	0.12	ND	ND	0.13	ND	ND	ND	ND	0.10
Total Vanadium (V)	µg/L	2.8	3.0	10	13	7.2	5.1	ND	19	7.8	5.2	2.0
Total Zinc (Zn)	µg/L	41	57	40	21	64	31	93	32	12	9.8	5.0

Table 2a: Total Dissolved Solids, Total Suspended Solids, pH and Total Metals in tank water at locations 1-10 in Bermuda, Nov 2022. ND = not detected; RDL = Reportable Detection Limit.

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		11	12	13	14	15	16	17	18	19	20	RDL
Inorganics												
Total Dissolved Solids	mg/L	62	80	42	54	74	300	150	62	350	41	10
pH	pH	7.68	7.66	7.58	7.81	8.08	8.19	7.78	7.85	7.49	7.73	
Total Suspended Solids	mg/L	ND	ND	ND	ND	110	ND	ND	ND	ND	ND	1.0
Metals												
Total Mercury (Hg)	µg/L	ND	ND	ND	ND	0.060	ND	ND	ND	ND	ND	0.013
Total Aluminum (Al)	µg/L	80	63	110	**260**	**4100**	20	140	64	31	40	5.0
Total Antimony (Sb)	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.0
Total Arsenic (As)	µg/L	ND	ND	ND	ND	1.2	ND	ND	ND	ND	ND	1.0
Total Barium (Ba)	µg/L	4.4	4.1	3.9	3.8	29	4.9	18	6.7	ND	4.1	1.0
Total Beryllium (Be)	µg/L	ND	ND	ND	ND	0.12	ND	ND	ND	ND	ND	0.10
Total Bismuth (Bi)	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.0
Total Boron (B)	µg/L	ND	200	ND	ND	ND	53	280	ND	1600	ND	50
Total Cadmium (Cd)	µg/L	ND	0.012	ND	ND	0.19	0.020	ND	0.047	0.023	0.019	0.010
Total Calcium (Ca)	µg/L	12000	8200	6800	12000	23000	60000	8100	14000	8500	8700	100
Total Chromium (Cr)	µg/L	1.4	1.7	ND	ND	7.7	1.5	ND	ND	ND	ND	1.0
Total Cobalt (Co)	µg/L	ND	ND	ND	ND	0.94	ND	ND	ND	ND	ND	0.40
Total Copper (Cu)	µg/L	19	26	1.6	14	26	42	7.0	1.5	0.62	9.2	0.50
Total Iron (Fe)	µg/L	ND	110	ND	ND	**1700**	ND	250	ND	78	ND	50
Total Lead (Pb)	µg/L	0.59	0.80	ND	1.4	11	3.6	0.60	ND	ND	1.7	0.50
Total Magnesium (Mg)	µg/L	450	830	860	660	3000	4100	1000	890	1700	800	100
Total Manganese (Mn)	µg/L	ND	2.3	ND	ND	**57**	ND	ND	ND	2.5	ND	2.0
Total Molybdenum (Mo)	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.0
Total Nickel (Ni)	µg/L	ND	2.5	ND	ND	12	3.1	ND	ND	ND	ND	2.0
Total Phosphorus (P)	µg/L	ND	ND	ND	ND	120	ND	ND	ND	ND	ND	100
Total Potassium (K)	µg/L	730	970	640	390	570	7500	2500	790	4800	310	100
Total Selenium (Se)	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.50
Total Silver (Ag)	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.10
Total Sodium (Na)	µg/L	9900	22000	7700	6400	10000	29000	40000	7800	120000	6600	100
Total Strontium (Sr)	µg/L	86	110	95	170	100	1900	88	80	33	53	2.0
Total Thallium (Tl)	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.10
Total Tin (Sn)	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.0
Total Titanium (Ti)	µg/L	ND	ND	ND	ND	270	ND	ND	ND	ND	ND	2.0
Total Uranium (U)	µg/L	ND	ND	ND	ND	0.30	0.60	ND	ND	ND	ND	0.10
Total Vanadium (V)	µg/L	13	4.2	ND	2.4	9.3	ND	4.4	ND	ND	ND	2.0
Total Zinc (Zn)	µg/L	16	28	66	19	130	250	13	89	16	95	5.0

Table 2b: Total Dissolved Solids, Total Suspended Solids, pH and Total Metals in tank water at locations 11-20 in Bermuda, Nov 2022. ND = not detected; RDL = Reportable Detection Limit; red shading indicates exceedance of a drinking water standard (see text).

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		1	2	3	4	5	6	7	8	9	10	RDL
Polyaromatic Hydrocarbons												
Benzo(b)fluoranthene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.007
Benzo(j)fluoranthene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.007
Perylene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Acenaphthene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Acenaphthylene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Anthracene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Benzo(a)anthracene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Benzo(a)pyrene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.009
Benzo(b/j)fluoranthene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Benzo(g,h,i)perylene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Benzo(k)fluoranthene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Chrysene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Dibenzo(a,h)anthracene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Fluoranthene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Fluorene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Indeno(1,2,3-cd)pyrene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
1-Methylnaphthalene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
2-Methylnaphthalene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Naphthalene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Phenanthrene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Pyrene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010

Table 3a: PAHs in tank water at locations 1-10 in Bermuda, Nov 2022. ND = not detected; RDL = Reportable Detection Limit (for PAHs).

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		11	12	13	14	15	16	17	18	19	RDL
Polyaromatic Hydrocarbons											
Benzo(b)fluoranthene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.007
Benzo(j)fluoranthene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.007
Perylene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Acenaphthene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Acenaphthylene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Anthracene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Benzo(a)anthracene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Benzo(a)pyrene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.009
Benzo(b/j)fluoranthene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Benzo(g,h,i)perylene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Benzo(k)fluoranthene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Chrysene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Dibenzo(a,h)anthracene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Fluoranthene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Fluorene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Indeno(1,2,3-cd)pyrene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
1-Methylnaphthalene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
2-Methylnaphthalene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Naphthalene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Phenanthrene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
Pyrene	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010

Table 3b: PAHs in tank water at locations 11-19 in Bermuda, Nov 2022. ND = not detected; RDL = Reportable Detection Limit (for PAHs). Note: PAH results not available for location 20.

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Primary Drinking Water Standards are established to be protective of human health. Exceedance of these values indicates a potential risk from consumption. Under US Federal law, levels of lead (Pb) and copper (Cu) in water are regulated by a Treatment Technique that requires water suppliers to control the corrosiveness of their water. If more than 10 percent of tap water samples exceed the action level, water suppliers must take additional corrective steps.

Secondary Drinking Water Standards are established for protection on aesthetic or taste grounds. Exceedance of these values may cause negative visual and/or taste and odour responses.

Comparison of the data in Tables 2 and 3 with the standards in Table 1 indicate that three Secondary Drinking Water Standards were exceeded. Tank water at three residences (locations 3, 14, and 15) exceeded the standard for aluminium (200 μg/L). Water from location 15 also exceeded the standard for iron (300 μg/L) and manganese (50 μg/L).

High concentrations of aluminium (Al) may arise from soil present in the water tank (Al is present at high concentrations in local soil), or from the corrosion of aluminium fittings located in or close to the roof-tank system. Consumption of water that exceeds the secondary DWS for Al may cause personal cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water.

High concentrations of iron (Fe) in tank water may be indicative of: i) dissolution of rust particles; ii) corrosion of plumbing, pipes, etc. or other fixtures; iii) input from soil (local soil has a high Fe content). Exceedance of the secondary DWS for Fe may result in the tank water developing a metallic taste when consumed and the presence of reddish-brown staining on water fixtures and laundry.

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Manganese (Mn) is a common, naturally-occurring mineral metal found in rocks, soil, groundwater, and surface water, often in combination with iron-bearing minerals. Elevated levels of Mn may result in water developing a metallic taste when consumed and can cause black staining on water fixtures.

Owing to the exceedance of 3 Secondary Drinking Water Standards and an elevated (but not excessive) Total Suspended Solids value (see Table 2b) at location 15, additional sampling of three neighboring residences was undertaken for the determination of metals (with the exception of mercury). Unfortunately, two of the three sample containers were broken in transit to the analytical laboratory and so some data are not available. The values for one of the additional locations (Ingham's Vale) are shown in Table 4, below.

The results from this residence show that no drinking water standards were exceeded, indicating that the initial sample from location 15 was possibly not representative of long-term tank water quality and/or was compromised in some way. Possible explanations include: 1) use of contaminated well water to fill the tank; or 2) initial sampling occurred shortly after tank/roof cleaning or after refilling by tanker trunk, both of which would increase resuspension of solid material in the water tank.

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		21	RDL
Metals			
Total Aluminum (Al)	µg/L	96	5.0
Total Antimony (Sb)	µg/L	ND	1.0
Total Arsenic (As)	µg/L	ND	1.0
Total Barium (Ba)	µg/L	4.0	1.0
Total Beryllium (Be)	µg/L	ND	0.10
Total Bismuth (Bi)	µg/L	ND	2.0
Total Boron (B)	µg/L	ND	50
Total Cadmium (Cd)	µg/L	ND	0.010
Total Calcium (Ca)	µg/L	13000	100
Total Chromium (Cr)	µg/L	1.5	1.0
Total Cobalt (Co)	µg/L	ND	0.40
Total Copper (Cu)	µg/L	4.3	0.50
Total Iron (Fe)	µg/L	ND	50
Total Lead (Pb)	µg/L	2.6	0.50
Total Magnesium (Mg)	µg/L	1500	100
Total Manganese (Mn)	µg/L	ND	2.0
Total Molybdenum (Mo)	µg/L	ND	2.0
Total Nickel (Ni)	µg/L	ND	2.0
Total Phosphorus (P)	µg/L	ND	100
Total Potassium (K)	µg/L	910	100
Total Selenium (Se)	µg/L	ND	0.50
Total Silver (Ag)	µg/L	ND	0.10
Total Sodium (Na)	µg/L	8800	100
Total Strontium (Sr)	µg/L	41	2.0
Total Thallium (Tl)	µg/L	ND	0.10
Total Tin (Sn)	µg/L	59	2.0
Total Titanium (Ti)	µg/L	ND	2.0
Total Uranium (U)	µg/L	ND	0.10
Total Vanadium (V)	µg/L	7.2	2.0
Total Zinc (Zn)	µg/L	11	5.0

Table 4: Total Metals in tank water at additional location (#21) in Bermuda, Feb 2023. ND = not detected; RDL = Reportable Detection Limit.