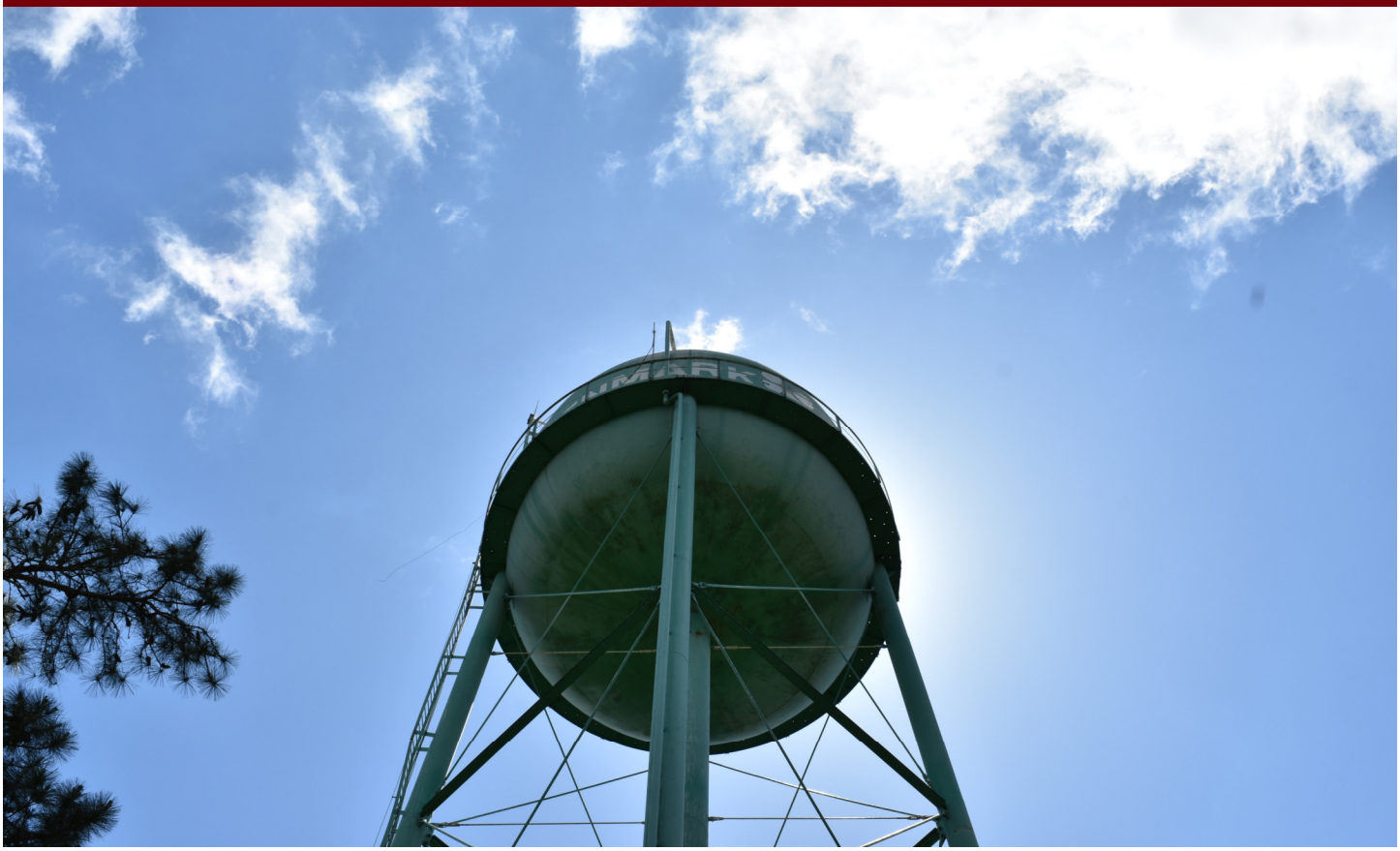
Dissolved metals in the town wells of Denmark, SC



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UNIVERSITY OF SOUTH CAROLINA

June 7th, 2018

UNIVERSITY OF
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College of Arts and Sciences

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An open letter to the city of Denmark, SC:

The primary mission of the University of South Carolina is the education of the state's citizens through teaching, research, creative activity, and community engagement. Faculty in the Department of Chemistry and Biochemistry and the Department of Environmental Health Sciences are committed to serving this mission and have done so through the analysis of Denmark's drinking water **sources**.

The South Carolina Department of Health and Environmental Control (DHEC) invited volunteers from USC and the Edisto Riverkeeper to a town meeting in Denmark, SC on April 5, 2018. The purpose of the meeting was to listen to the concerns of the residents about contaminants in their tap water and their possible health effects. The discussion focused on dissolved metals, particularly lead, iron, and manganese, and identified a need to find their sources. The quality of tap water is related to the quality of the water sources and the distribution system. This study focused on measuring metals in the source water only. We did **not** evaluate any tap water. This means the current study indicates the baseline for materials entering the distribution system but does not report how the system may affect water quality at the point of use. The data in this report is advisory but not actionable, since *USC is **not** a certified analytical laboratory.* Analyses performed for this study followed a modified version of USEPA method 200.8 (Determination of Trace Elements in Waters and Wastes by Inductively Coupled Plasma-Mass Spectrometry, www.epa.gov/homeland-security-research/epa-method-2008-determination-trace-elements-waters-and-wastes).

The city of Denmark currently uses four wells for its drinking water supply. The wells, ordered from east to west, are named after their street addresses: Acacia, Voorhees, Cox Mill, and West Voorhees. This report refers to water drawn directly from the wells before chlorination as "raw" water and disinfected water as "finished." Finished water is considered appropriate for distribution with no further treatment. Raw water is pumped

from each well, disinfected with chlorine and the finished water is distributed to the town. The publicly owned portions of the distribution system include the wells, holding tanks, distribution lines, and attachment points/meters. Privately owned portions include all piping and taps after the meter. The daily volume distributed from a given well is based on need of the system at a given time and can vary.

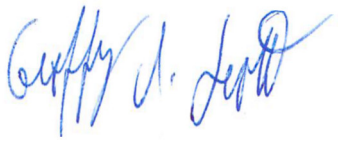
The group from USC and the Edisto Riverkeeper agreed to perform independent analyses from the same sites from samples drawn at the same time. The goal was to provide citizens with three **independent** measurements of lead, iron, and manganese to refer to going forward. The USC team measured an additional twenty metals that are included in our report.

The groups assembled in Denmark on April 16, 2018 and drew samples from raw and finished well water at the Acacia, Voorhees, Cox Mill, and West Voorhees well sites. Given the local reliance on Healing Springs as a supplemental water source, the USC team also sampled from that location. Detailed analyses follow, but the summary finding was that none of the tested wells exceeded USEPA limits for lead, iron, manganese, or any other of the suite of dissolved metals measured in the effort. Since the lead levels in the well water were low this finding implies that the distribution system was the source for higher levels that may have been measured at individual taps. However, iron and manganese were high enough in two of the wells that they could sometimes have aesthetic impacts on the quality of finished water drawn from those wells, particularly when influenced by seasonal changes in water consumption. There are several strategies to improve the aesthetic problems. The opinion of the USC team is that the addition of polyphosphate may suffice to sequester dissolved iron and manganese with an overall positive effect on water quality.

Analytical measurements are not perfect and are routinely repeated to determine their validity. When multiple measurements are made of the same sample, we report the average value measured and the “uncertainty” of that average. The term uncertainty refers to the statistical accuracy and precision of our methods. Results in this report are given in units of milligrams per liter (expressed with the symbol mg/L) with calculated uncertainty when relevant (for example, “the concentration of the analyte was 1.00 mg/L ± 0.1 mg/L”). Presenting our data in this format communicates that in the case of the example shown, 95% of the measurements would return results between 0.9 and 1.1 mg/L.

Our team appreciates you giving us the opportunity to help with this problem.

Sincerely,



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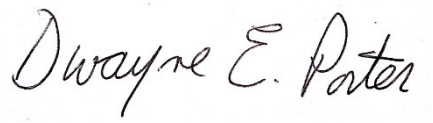

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EPA Maximum Contaminant Levels (MCL)

EPA Primary Contaminants	
Element	**MCL (in mg/L)**
Antimony	0.006
Arsenic	0.010
Barium	2.000
Beryllium	0.004
Cadmium	0.005
Chromium	0.100
Lead	0.015
Thallium	0.002

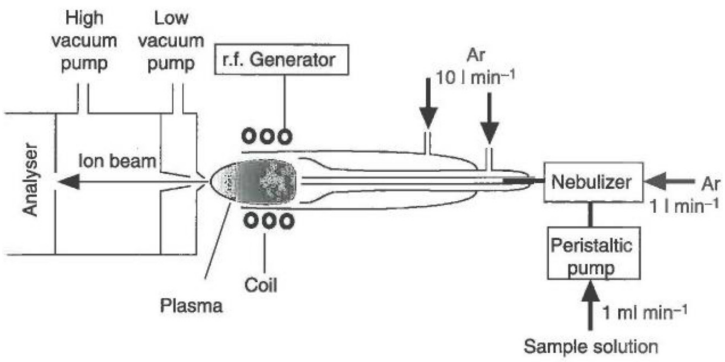
EPA Secondary Contaminants	
Element	**MCL (in mg/L)**
Aluminum	0.05 to 0.20
Iron	0.30
Manganese	0.05
Silver	0.10
Zinc	5.00

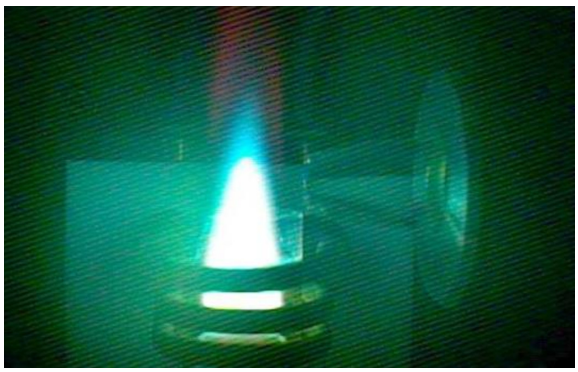
https://www.epa.gov/dwstandardsregulations

Elemental Analysis Method

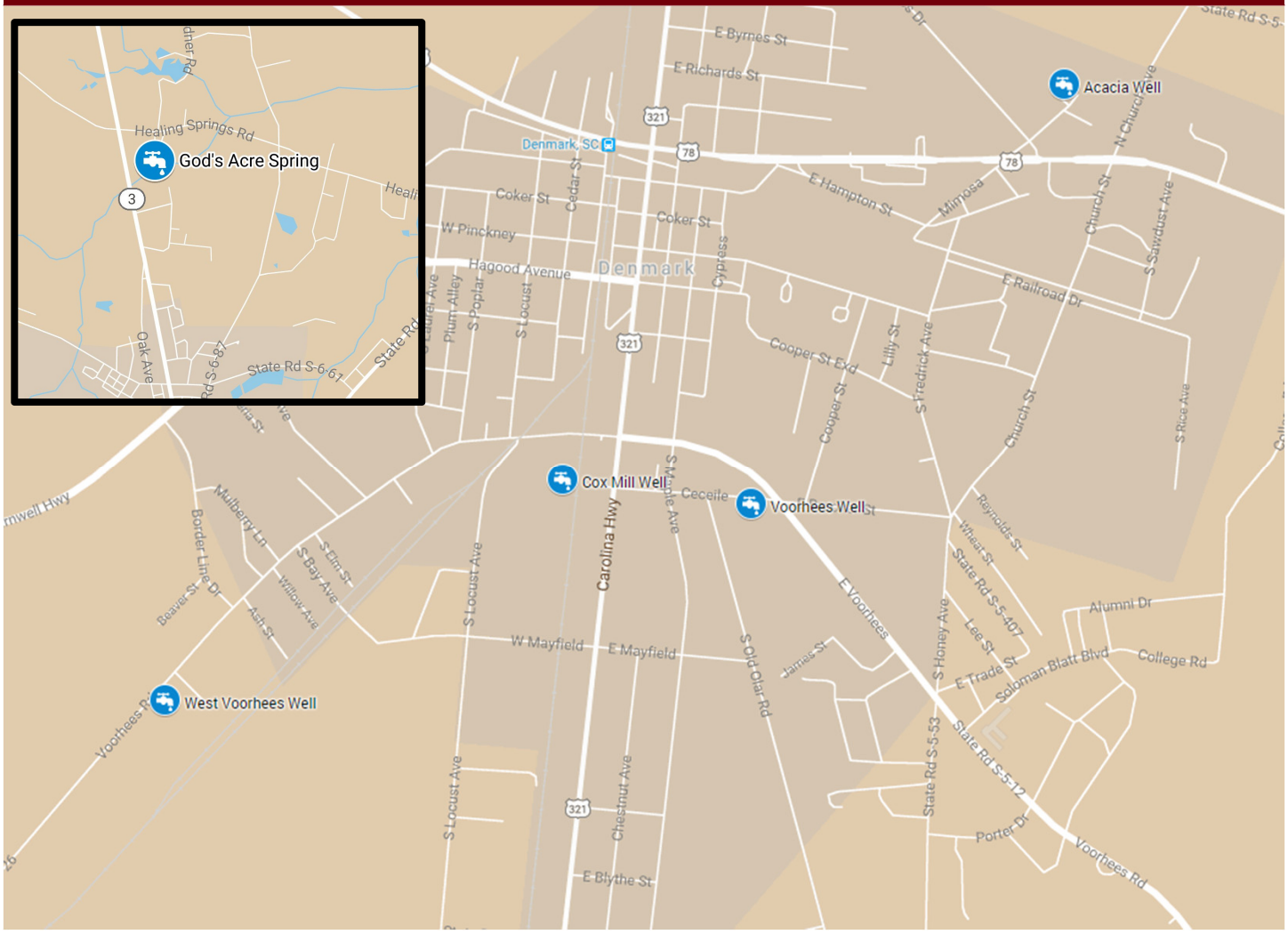
Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

The ICP-MS method used for calibration and analysis is based off the EPA method 200.8 for determination of trace elements in water. The University of South Carolina is not a certified laboratory and does not follow all of the precise certification steps in the EPA method; therefore all results presented in this report are not certified. However, USC is a research facility using modern analytical methods and we generally employ quality assurance/quality control measures that are equivalent to or in some cases exceed EPA certification requirements. Samples were collected from the town of Denmark, SC wells on April 16, 2018 and acidified for preservation. A mixture of known concentration containing 23 elements was diluted to make a five point calibration for each element. The concentrations of each element in the sample were calculated based on the instrument response to the known mixture. All samples were measured three times on the instrument and then averaged. Error presented in this report is at the 95% confidence level.





Well Locations and Sampling



All four active wells in Denmark, SC were sampled at the same time as DHEC and the Edisto Riverkeepers on April 16th, 2018. Each well has two types of samples:

Raw water – the water that comes straight out of the ground
Finished water – water after treatment

Also sampled was the God's Acre Healing Spring on Hwy 3 north of Blackville (shown in map inset).

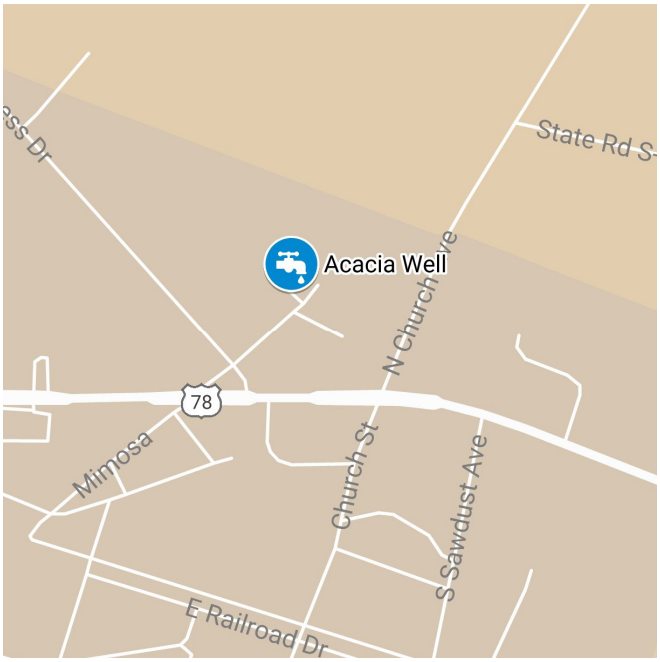
Acacia Well – Raw Water

Coordinates: 33.32804, -81.1277

April 16th, 2018

Results: None of the tested elements exceeded US EPA maximum contaminant level.

The USC team looked for twenty-three different elements that could have been in Denmark's well water. The three discussed at the town meeting on April 5th, 2018 (lead, iron, and manganese) are highlighted below and all are presented in the tables. Tables are organized according to USEPA classification of the elements as Primary Contaminants, Secondary Contaminants, or "Other" if unclassified. Elements reported with concentrations "less than" (<) a particular value were present at concentrations too low for our methods to reliably measure. These samples were NOT analyzed using Lead and Copper Rule protocols. The purpose of the study was to establish lead, iron, and manganese source baselines only.



Lead: <0.0002 mg/L

Iron: 0.1667 ± 0.0034 mg/L

Manganese: 0.0105 ± 0.0004 mg/L

All concentrations are reported in units of mg/L

EPA Primary Contaminants	
Antimony	<0.00055
Arsenic	0.0015 ± 0.0003
Barium	0.018 ± 0.001
Beryllium	<0.00015
Cadmium	<0.0001
Chromium	<0.0002
Lead	<0.0002
Thallium	<0.0001

EPA Secondary Contaminants	
Aluminum	<0.00125
Iron	0.1667 ± 0.0034
Manganese	0.0105 ± 0.0004
Silver	<0.00002
Zinc	0.00745 ± 0.00050

Other Elements	
Boron	0.011 ± 0.0020
Calcium	3.396 ± 0.282
Cobalt	<0.00025
Magnesium	1.647 ± 0.106
Molybdenum	0.0010 ± 0.0005
Nickel	<0.0006
Potassium	1.342 ± 0.081
Sodium	2.387 ± 0.263
Strontium	0.1830 ± 0.0063
Vanadium	0.0004 ± 0.0002

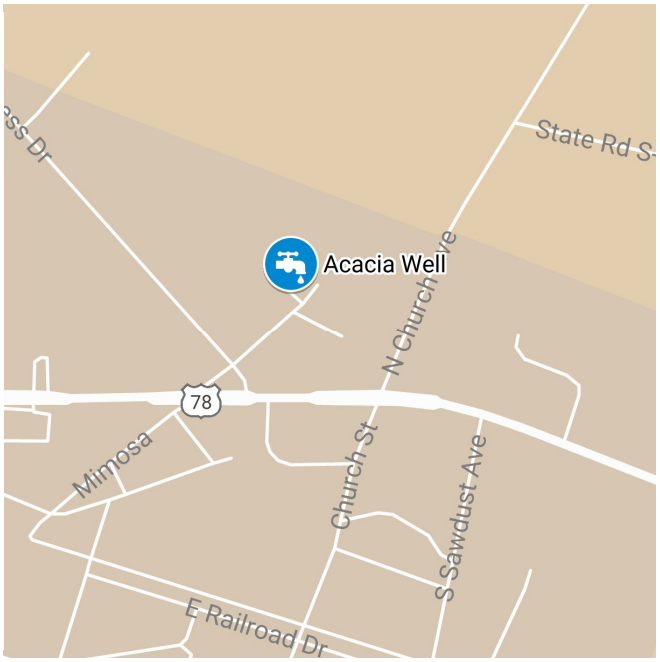
Acacia Well – Finished Water

Coordinates: 33.32804, -81.1277

April 16th, 2018

Results: None of the tested elements exceeded US EPA maximum contaminant level.

The USC team looked for twenty-three different elements that could have been in Denmark's well water. The three discussed at the town meeting on April 5th, 2018 (lead, iron, and manganese) are highlighted below and all are presented in the tables. Tables are organized according to USEPA classification of the elements as Primary Contaminants, Secondary Contaminants, or "Other" if unclassified. Elements reported with concentrations "less than" (<) a particular value were present at concentrations too low for our methods to reliably measure. These samples were NOT analyzed using Lead and Copper Rule protocols. The purpose of the study was to establish lead, iron, and manganese source baselines only.



Lead: 0.0003 ± 0.00003mg/L

Iron: 0.1800 ± 0.0119 mg/L

Manganese: 0.0107 ± 0.0005 mg/L

All concentrations are reported in units of mg/L

EPA Primary Contaminants	
Antimony	<0.00055
Arsenic	0.0021 ± 0.0003
Barium	0.020 ± 0.001
Beryllium	<0.00015
Cadmium	<0.0001
Chromium	<0.0002
Lead	0.0003 ± 0.00003
Thallium	<0.0001

EPA Secondary Contaminants	
Aluminum	<0.00125
Iron	0.1800 ± 0.0119
Manganese	0.0107 ± 0.0005
Silver	<0.00002
Zinc	0.00317 ± 0.00017

Other Elements	
Boron	0.012 ± 0.0007
Calcium	3.632 ± 0.145
Cobalt	<0.00025
Magnesium	1.771 ± 0.102
Molybdenum	0.0012 ± 0.0005
Nickel	<0.0006
Potassium	1.161 ± 0.066
Sodium	2.922 ± 0.097
Strontium	0.1950 ± 0.0139
Vanadium	0.0003 ± 0.0001

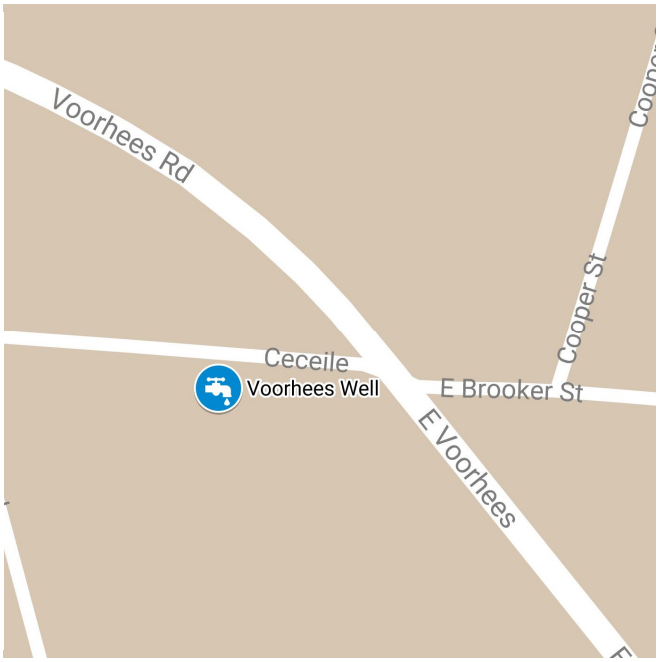
Voorhees Well – Raw Water

Coordinates: 33.31572, -81.13866

April 16th, 2018

Results: None of the tested elements exceeded US EPA maximum contaminant level.

The USC team looked for twenty-three different elements that could have been in Denmark's well water. The three discussed at the town meeting on April 5th, 2018 (lead, iron, and manganese) are highlighted below and all are presented in the tables. Tables are organized according to USEPA classification of the elements as Primary Contaminants, Secondary Contaminants, or "Other" if unclassified. Elements reported with concentrations "less than" (<) a particular value were present at concentrations too low for our methods to reliably measure. These samples were NOT analyzed using Lead and Copper Rule protocols. The purpose of the study was to establish lead, iron, and manganese source baselines only.



Lead: <0.0002 mg/L

Iron: 0.0175 ± 0.0006 mg/L

Manganese: 0.0094 ± 0.0004 mg/L

All concentrations are reported in units of mg/L

EPA Primary Contaminants	
Antimony	<0.00055
Arsenic	0.0005 ± 0.0009
Barium	0.023 ± 0.002
Beryllium	<0.00015
Cadmium	<0.0001
Chromium	0.0005 ± 0.00004
Lead	<0.0002
Thallium	<0.0001

EPA Secondary Contaminants	
Aluminum	<0.00125
Iron	0.0175 ± 0.0006
Manganese	0.0094 ± 0.0004
Silver	<0.00002
Zinc	0.00103 ± 0.00001

Other Elements	
Boron	0.010 ± 0.0015
Calcium	3.579 ± 0.092
Cobalt	<0.00025
Magnesium	1.718 ± 0.089
Molybdenum	<0.0011
Nickel	<0.0006
Potassium	0.680 ± 0.041
Sodium	2.023 ± 0.073
Strontium	0.1490 ± 0.0038
Vanadium	0.0005 ± 0.0002

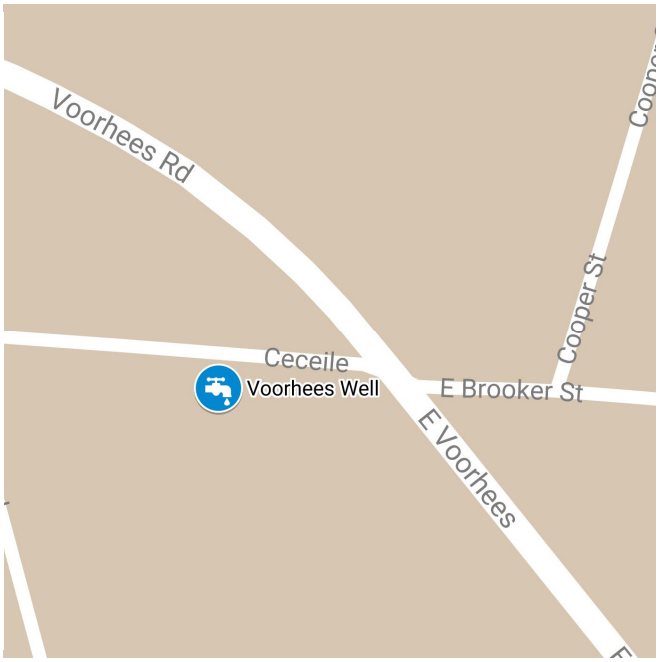
Voorhees Well – Finished Water

Coordinates: 33.31572, -81.13866

April 16th, 2018

Results: None of the tested elements exceeded US EPA maximum contaminant level.

The USC team looked for twenty-three different elements that could have been in Denmark's well water. The three discussed at the town meeting on April 5th, 2018 (lead, iron, and manganese) are highlighted below and all are presented in the tables. Tables are organized according to USEPA classification of the elements as Primary Contaminants, Secondary Contaminants, or "Other" if unclassified. Elements reported with concentrations "less than" (<) a particular value were present at concentrations too low for our methods to reliably measure. These samples were NOT analyzed using Lead and Copper Rule protocols. The purpose of the study was to establish lead, iron, and manganese source baselines only.



Lead: <0.0002 mg/L

Iron: 0.0148 ± 0.0009 mg/L

Manganese: 0.0090 ± 0.0011 mg/L

All concentrations are reported in units of mg/L

EPA Primary Contaminants	
Antimony	<0.00055
Arsenic	0.0007 ± 0.0002
Barium	0.023 ± 0.003
Beryllium	<0.00015
Cadmium	<0.0001
Chromium	0.0006 ± 0.0001
Lead	<0.0002
Thallium	<0.0001

EPA Secondary Contaminants	
Aluminum	<0.00125
Iron	0.0148 ± 0.0009
Manganese	0.0090 ± 0.0011
Silver	<0.00002
Zinc	0.00405 ± 0.00069

Other Elements	
Boron	0.011 ± 0.0025
Calcium	3.678 ± 0.075
Cobalt	<0.00025
Magnesium	1.750 ± 0.199
Molybdenum	<0.0011
Nickel	<0.0006
Potassium	0.703 ± 0.035
Sodium	2.292 ± 0.047
Strontium	0.1466 ± 0.0020
Vanadium	0.0004 ± 0.0001

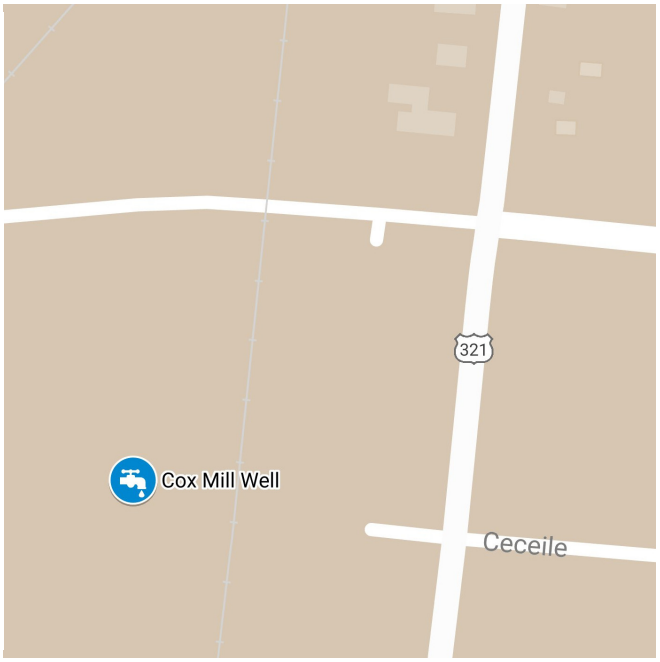
Cox Mill Well – Raw Water

Coordinates: 33.31646, -81.14527

April 16th, 2018

Results: None of the tested elements exceeded US EPA maximum contaminant level.

The USC team looked for twenty-three different elements that could have been in Denmark's well water. The three discussed at the town meeting on April 5th, 2018 (lead, iron, and manganese) are highlighted below and all are presented in the tables. Tables are organized according to USEPA classification of the elements as Primary Contaminants, Secondary Contaminants, or "Other" if unclassified. Elements reported with concentrations "less than" (<) a particular value were present at concentrations too low for our methods to reliably measure. These samples were NOT analyzed using Lead and Copper Rule protocols. The purpose of the study was to establish lead, iron, and manganese source baselines only.



Lead: <0.0002 mg/L

Iron: 0.0113 ± 0.0009 mg/L

Manganese: 0.0093 ± 0.0007 mg/L

All concentrations are reported in units of mg/L

EPA Primary Contaminants	
Antimony	<0.00055
Arsenic	0.0011 ± 0.0006
Barium	0.021 ± 0.001
Beryllium	<0.00015
Cadmium	<0.0001
Chromium	<0.0002
Lead	<0.0002
Thallium	<0.0001

EPA Secondary Contaminants	
Aluminum	<0.00125
Iron	0.0113 ± 0.0009
Manganese	0.0093 ± 0.0007
Silver	<0.00002
Zinc	0.00901 ± 0.00018

Other Elements	
Boron	0.011 ± 0.0004
Calcium	4.048 ± 0.197
Cobalt	<0.00025
Magnesium	1.060 ± 0.023
Molybdenum	0.0009 ± 0.0005
Nickel	<0.0006
Potassium	0.836 ± 0.025
Sodium	2.504 ± 0.155
Strontium	0.1137 ± 0.0019
Vanadium	<0.00035

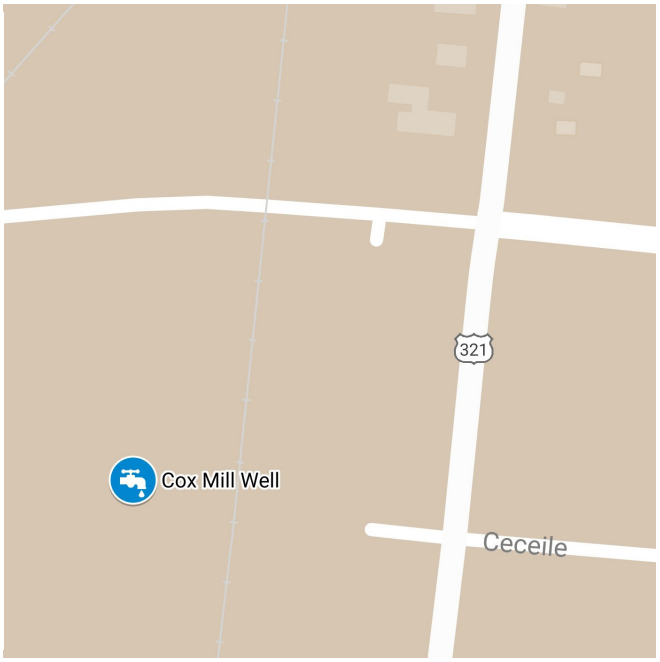
Cox Mill Well – Finished Water

Coordinates: 33.31646, -81.14527

April 16th, 2018

Results: None of the tested elements exceeded US EPA maximum contaminant level.

The USC team looked for twenty-three different elements that could have been in Denmark's well water. The three discussed at the town meeting on April 5th, 2018 (lead, iron, and manganese) are highlighted below and all are presented in the tables. Tables are organized according to USEPA classification of the elements as Primary Contaminants, Secondary Contaminants, or "Other" if unclassified. Elements reported with concentrations "less than" (<) a particular value were present at concentrations too low for our methods to reliably measure. These samples were NOT analyzed using Lead and Copper Rule protocols. The purpose of the study was to establish lead, iron, and manganese source baselines only.



Lead: <0.0002 mg/L

Iron: <0.0009 mg/L

Manganese: 0.0046 ± 0.0006 mg/L

All concentrations are reported in units of mg/L

EPA Primary Contaminants	
Antimony	<0.00055
Arsenic	0.0010 ± 0.0004
Barium	0.019 ± 0.001
Beryllium	<0.00015
Cadmium	0.0000 ± 0.0001
Chromium	<0.0002
Lead	<0.0002
Thallium	<0.0001

EPA Secondary Contaminants	
Aluminum	<0.00125
Iron	<0.0009
Manganese	0.0046 ± 0.0006
Silver	<0.00002
Zinc	0.01048 ± 0.00111

Other Elements	
Boron	0.010 ± 0.0007
Calcium	4.172 ± 0.182
Cobalt	<0.00025
Magnesium	1.100 ± 0.032
Molybdenum	0.0008 ± 0.0004
Nickel	<0.0006
Potassium	0.864 ± 0.014
Sodium	2.315 ± 0.362
Strontium	0.1174 ± 0.0090
Vanadium	0.0003 ± 0.0002

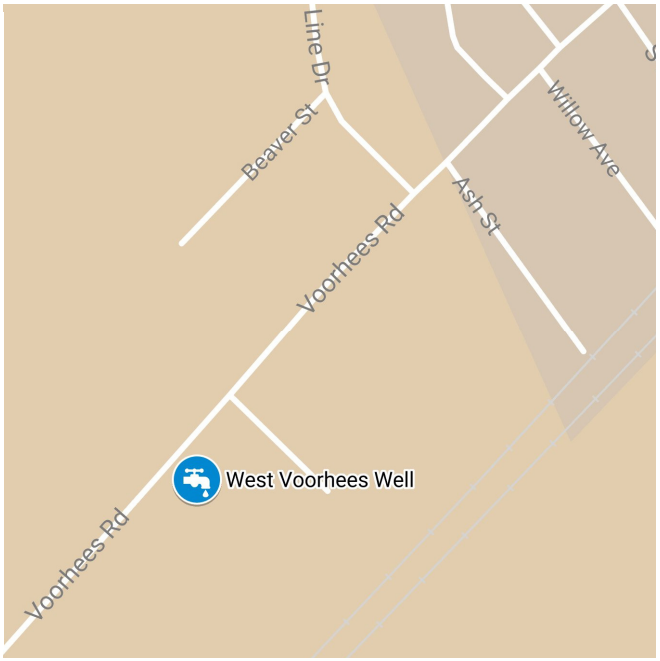
W. Voorhees – Raw Water

Coordinates: 33.31001, -81.1592

April 16th, 2018

Results: None of the tested elements exceeded US EPA maximum contaminant level.

The USC team looked for twenty-three different elements that could have been in Denmark's well water. The three discussed at the town meeting on April 5th, 2018 (lead, iron, and manganese) are highlighted below and all are presented in the tables. Tables are organized according to USEPA classification of the elements as Primary Contaminants, Secondary Contaminants, or "Other" if unclassified. Elements reported with concentrations "less than" (<) a particular value were present at concentrations too low for our methods to reliably measure. These samples were NOT analyzed using Lead and Copper Rule protocols. The purpose of the study was to establish lead, iron, and manganese source baselines only.



Lead: <0.0002 mg/L

Iron: 0.1319 ± 0.0060 mg/L

Manganese: 0.0285 ± 0.0018 mg/L

All concentrations are reported in units of mg/L

EPA Primary Contaminants	
Antimony	<0.00055
Arsenic	0.0013 ± 0.0006
Barium	0.008 ± 0.001
Beryllium	<0.00015
Cadmium	<0.0001
Chromium	0.0001 ± 0.0001
Lead	<0.0002
Thallium	<0.0001

EPA Secondary Contaminants	
Aluminum	<0.00125
Iron	0.1319 ± 0.0060
Manganese	0.0285 ± 0.0018
Silver	<0.00002
Zinc	0.00182 ± 0.00029

Other Elements	
Boron	0.011 ± 0.0018
Calcium	3.975 ± 0.195
Cobalt	<0.00025
Magnesium	1.386 ± 0.069
Molybdenum	<0.0011
Nickel	<0.0006
Potassium	0.715 ± 0.018
Sodium	2.066 ± 0.121
Strontium	0.1587 ± 0.0103
Vanadium	<0.00035

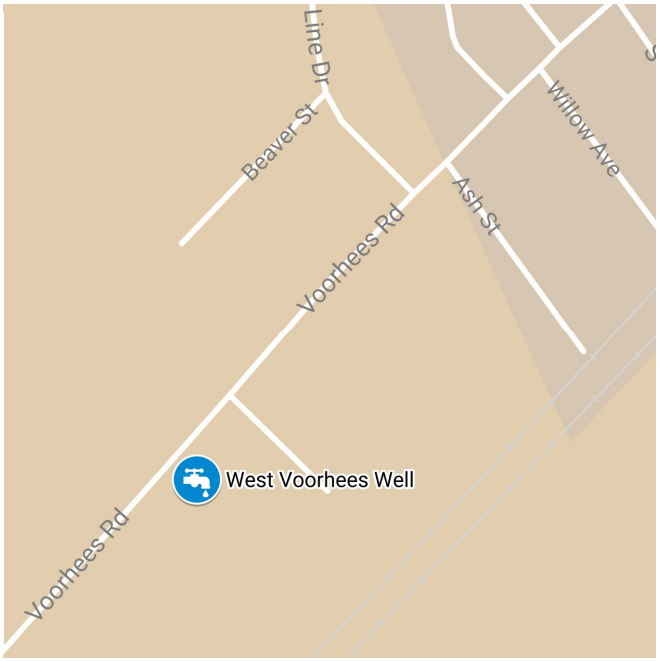
W. Voorhees – Finished Water

Coordinates: 33.31001, -81.1592

April 16th, 2018

Results: None of the tested elements exceeded US EPA maximum contaminant level.

The USC team looked for twenty-three different elements that could have been in Denmark's well water. The three discussed at the town meeting on April 5th, 2018 (lead, iron, and manganese) are highlighted below and all are presented in the tables. Tables are organized according to USEPA classification of the elements as Primary Contaminants, Secondary Contaminants, or "Other" if unclassified. Elements reported with concentrations "less than" (<) a particular value were present at concentrations too low for our methods to reliably measure. These samples were NOT analyzed using Lead and Copper Rule protocols. The purpose of the study was to establish lead, iron, and manganese source baselines only.



Lead: 0.0010 ± 0.00002 mg/L

Iron: 0.1398 ± 0.0095 mg/L

Manganese: 0.0291 ± 0.0007 mg/L

All concentrations are reported in units of mg/L

EPA Primary Contaminants	
Antimony	<0.00055
Arsenic	0.0018 ± 0.0008
Barium	0.008 ± 0.0004
Beryllium	<0.00015
Cadmium	<0.0001
Chromium	<0.0002
Lead	0.0010 ± 0.00002
Thallium	<0.0001

EPA Secondary Contaminants	
Aluminum	0.00739 ± 0.00046
Iron	0.1398 ± 0.0095
Manganese	0.0291 ± 0.0007
Silver	<0.00002
Zinc	0.00330 ± 0.00158

Other Elements	
Boron	0.010 ± 0.0006
Calcium	3.974 ± 0.338
Cobalt	<0.00025
Magnesium	1.300 ± 0.229
Molybdenum	0.0008 ± 0.0005
Nickel	<0.0006
Potassium	0.736 ± 0.024
Sodium	2.059 ± 0.091
Strontium	0.1567 ± 0.0093
Vanadium	<0.00035

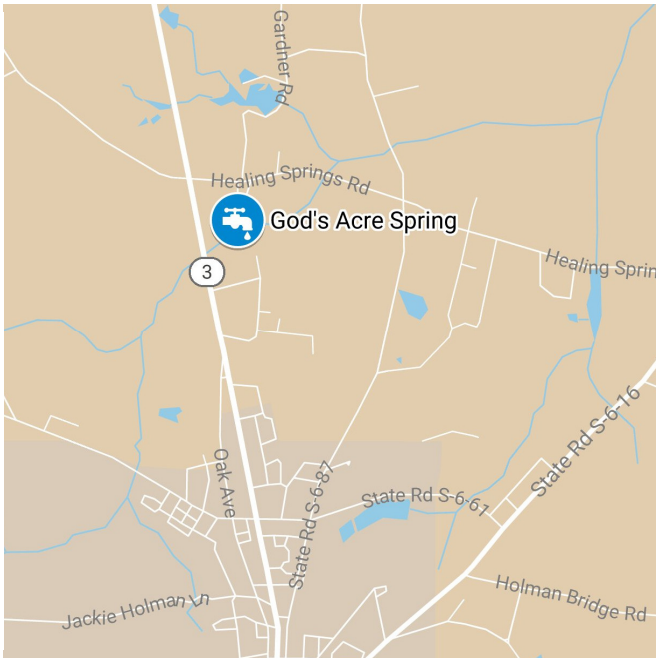
God's Acre Healing Spring

Coordinates: 33.39168, -81.27363

April 16th, 2018

Results: None of the tested elements exceeded US EPA maximum contaminant level.

The USC team looked for twenty-three different elements that could have been in Healing Springs' water. The three discussed at the town meeting on April 5th, 2018 (lead, iron, and manganese) are highlighted below and all are presented in the tables. Tables are organized according to USEPA classification of the elements as Primary Contaminants, Secondary Contaminants, or "Other" if unclassified. Elements reported with concentrations "less than" (<) a particular value were present at concentrations too low for our methods to reliably measure. These samples were NOT analyzed using Lead and Copper Rule protocols. The purpose of the study was to establish lead, iron, and manganese source baselines only.



Lead: <0.0002 mg/L

Iron: <0.0009 mg/L

Manganese: <0.0004 mg/L

All concentrations are reported in units of mg/L

EPA Primary Contaminants	
Antimony	<0.00055
Arsenic	<0.00055
Barium	0.030 ± 0.002
Beryllium	<0.00015
Cadmium	<0.0001
Chromium	0.0023 ± 0.0005
Lead	<0.0002
Thallium	<0.0001

EPA Secondary Contaminants	
Aluminum	<0.00125
Iron	<0.0009
Manganese	<0.0004
Silver	<0.00002
Zinc	<0.00075

Other Elements	
Boron	0.010 ± 0.0022
Calcium	3.122 ± 0.218
Cobalt	<0.00025
Magnesium	0.645 ± 0.009
Molybdenum	<0.0011
Nickel	<0.0006
Potassium	0.532 ± 0.008
Sodium	1.428 ± 0.070
Strontium	0.0389 ± 0.0017
Vanadium	0.0003 ± 0.0001

Inter-laboratory Quality Assurance

	Concentration in mg/L		
	Lead	Iron	Manganese
Actual Mixture	**0.015**	**0.200**	**0.150**
University of South Carolina	0.015 ± 0.0014	0.195 ± 0.0117	0.135 ± 0.009
DHEC	0.017	0.2	0.15
Edisto Riverkeepers	0.014	0.187	0.129

The different analytical laboratories were tested for the ability to measure the concentrations of lead, iron, and manganese in blind samples. Blind samples were prepared from solutions of the three metals and distributed to each laboratory. The concentrations of the metals were known to the preparer but not shared with the volunteers. Here we report the concentrations of each metal in the blind sample and the results reported by each laboratory as they shared them with USC. Although there is some minor variation between the laboratories, all the results are within 15% of the blind sample.

USC graduate students analyzing well samples (A), USC, DHEC, and the Riverkeepers sampling the water at the Voorhees well (B), using a field portable spectrometer for on-site analysis (C), water from the healing springs collected by local residents (D)