SUPPORTING INFORMATION

Impact of road salt on drinking water quality and infrastructure corrosion in private wells

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DESCRIPTION OF SUPPORTING INFORMATION

Section SI-1. Household questionnaire distributed in citizen science sampling kits

HOMEOWNER QUESTIONNAIRE
Please clearly print your contact information and answer the following questions.

Name: ________________________ Telephone: (_____) _____-________________

Mailing Address: ____
Street address City State Zip

Sample Location Address (if different from mailing address):

____
Street address City State Zip

WATER SOURCE:

1. What household water supply source was drawn for sample? Check one:
❑ well ❑ spring ❑ cistern ❑ other → specify: _______________

If well is checked above: (a) is it a: ❑ dug or bored well ❑ drilled well ❑ don't know;
(b) what is the well's depth? ________ ft ❑ don't know
(c) what year was well constructed? ________ ❑ don't know

2. What water treatment devices are currently installed? Check all that apply:
❑ none
❑ ultraviolet (UV) light
❑ sediment filter
❑ iron removal
❑ chlorinator
❑ acid neutralizer
❑ water softener (conditioner)
❑ reverse osmosis
❑ activated carbon (charcoal) filter
❑ other → specify: ________________

3. What pipe material(s) is/are used in your house for plumbing?
❑ copper ❑ lead ❑ galvanized steel ❑ plastic (PVC, PE, etc.) ❑ brass fittings
❑ plastic fittings ❑ don't know ❑ other → specify: _____________

WATER CHARACTERISTICS:

4. Do you have problems with corrosion, pitting or pinhole leaks in pipes or plumbing fixtures? ❑yes ❑no
If yes, please explain:

5. Does your water have an unpleasant taste? ❑ yes ❑ no
→ **If YES**, how would you describe the taste? Check **all** that apply:
❑bitter ❑sulfur ❑salty ❑metallic ❑oily ❑soapy ❑other → specify: ________

6. Does your water have an unpleasant odor? ❑ yes ❑ no
→ **If YES**, how would you describe the odor? Check **all** that apply:
❑rotten egg/sulfur ❑kerosene or gas ❑musty ❑chemical ❑other → specify:____

7. Does your water have an unnatural color or appearance? ❑ yes ❑ no
   → **If YES**, how would you describe the color or appearance? Check **<u>all</u>** that apply:
   ❑muddy ❑milky ❑black/gray tint ❑yellow tint ❑oily film ❑other →specify: ___

8. Does your water stain plumbing, cooking appliances, utensils, or laundry?
   ❑ yes ❑ no
   → **If YES**, how would you describe the stains? Check **<u>all</u>** that apply:
   ❑blue-green ❑rusty/orange/brown ❑black/gray ❑white/chalk
   ❑other → specify: ______

9. In a standing glass of water, do you notice floating or settled particles? ❑ yes ❑ no
   → **If YES**, how would you describe them? Check **<u>all</u>** that apply:
   ❑white flakes ❑black specks ❑red-orange slime ❑brown sediment
   ❑other → specify: _____

<u>WATER USEAGE:</u>

10. What are your primary sources of drinking water? Check <u>all</u> that apply:
    ❑Kitchen ❑Bathroom ❑Bottled water ❑ Filtered water from refrigerator
    ❑Other:_____
    If you <u>do not drink your tap water</u>, (a) when did you stop?: ____________________
    (b) why did you stop?: _____________________

11. What are your primary sources of water for cooking? Check <u>all</u> that apply:
    ❑Kitchen ❑Bottled water ❑Other:_____
    If you <u>do not cook your tap water</u>, (a) when did you stop?: ____________________
    (b) why did you stop?: _____________________

12. How many people live in the house on a regular basis? _____________________
    a. Is anyone pregnant? ❑yes ❑no ❑ Prefer not to answer
    b. Is anyone under the age of 6? ❑yes ❑no ❑ Prefer not to answer

Section SI-2. System characteristics of private wells sampled in the Town of Orleans area.

Most private wells sampled during this study were drilled (74%, n=66), 2 were dug or bored wells (2%), and almost a quarter of the residents (24%, n=21) did not know their well type. In keeping, 49% of residents did not know the depth of their well and 55% did not know when their well was constructed. Reported well depths (n=45) ranged from 25-240 ft., with 87% less than 100 ft (n=39). Wells also tended to be older, as the median year of construction reported (n=40) was 1988/1990 but ranged 1940-2015. This study did not evaluate microbial contamination, but testing conducted by Fourth Coast Inc. in 2013 reported that 58% of the 49 well sampled in their campaign tested positive for total coliform bacteria and 17% tested for *E. coli* bacteria.[1] These microbial rates are consistent with other well water surveys that suggest widespread microbial concerns among private wells.[2]

Section SI-3. R code to quantify well communities potentially impacted by road salt.

<u>Point Source Function</u>

This function is used to estimate the number of wells affected by NYSDOT Salt Storage facilities. Input variables include NHD+ contributing area catchments (catchments), USGS estimated well location raster (wells), and NHD+ flow accumulation raster (fac), and NYSDOT salt barn locations (salt_barn).

```
#Create function to estimate the number of wells affect by salt barns by catchment
ps_fun<-function(ID){

  #Isolate county
  catchment<-catchments[catchments$ID==ID,]

  #clip roads, watersheds, wells, and sb's to county
  fac<-crop(fac, catchment)
  fac<-mask(fac, catchment)
  wells<-crop(wells, catchment)
  wells<-mask(wells, catchment)
  salt_barn<-salt_barn[catchment,]

  #Estimate number of households affected by salt barn
  if(length(salt_barn)>0){
    #Determine salt barn fac value
    salt_barn$fac<-extract(fac, salt_barn)

    #Determine "potential" extent of plume (values with > fac values)
    plume_sb<-fac
    plume_sb[plume_sb<salt_barn$fac]<-NA
    plume_sb<-plume_sb*0+1
    plume_sb<-resample(plume_sb, wells)

    #Calculate number of households in plume
    wells_sb<-wells*plume_sb
    sb_households<-cellStats(wells_sb, sum)
  }else{
    sb_households<-0
  }

  #Export Results
  c(ID, sb_households)
}
```

Nonpoint Source Function

This function is used to estimate the number of wells potentially affected by nonpoint source pollution from roads. Input variables include roads from the USGS National Transportation Dataset (roads) and USGS estimated well location raster (wells).

```
#Create function to estimate the number of wells affect by roads in each county
nps_fun<-function(ID){

   #Isolate county of interest
   county<-counties[ID,]

   #Mask well raster
   wells<-crop(wells, county)
   wells<-mask(wells, county)

   #Mask roads
   roads<-roads[county,]

   #dissaggregate raster
   wells<-disaggregate(wells, fact=10)/100

   #Add buffer to roads
   roads<-gBuffer(roads, width=30, byid=T)
   roads<-rasterize(roads, wells)
   roads<-roads*0+1

   #Estimate number of wells within 30 m buffer of roads
   result<-cellStats(roads*wells, "sum")
   c(paste(county$GNIS_ID),result)

}
```

Figure SI-1. Brass wire, iron wire, zinc wire, stainless steel wire, and copper coupon with lead solder test apparatuses.

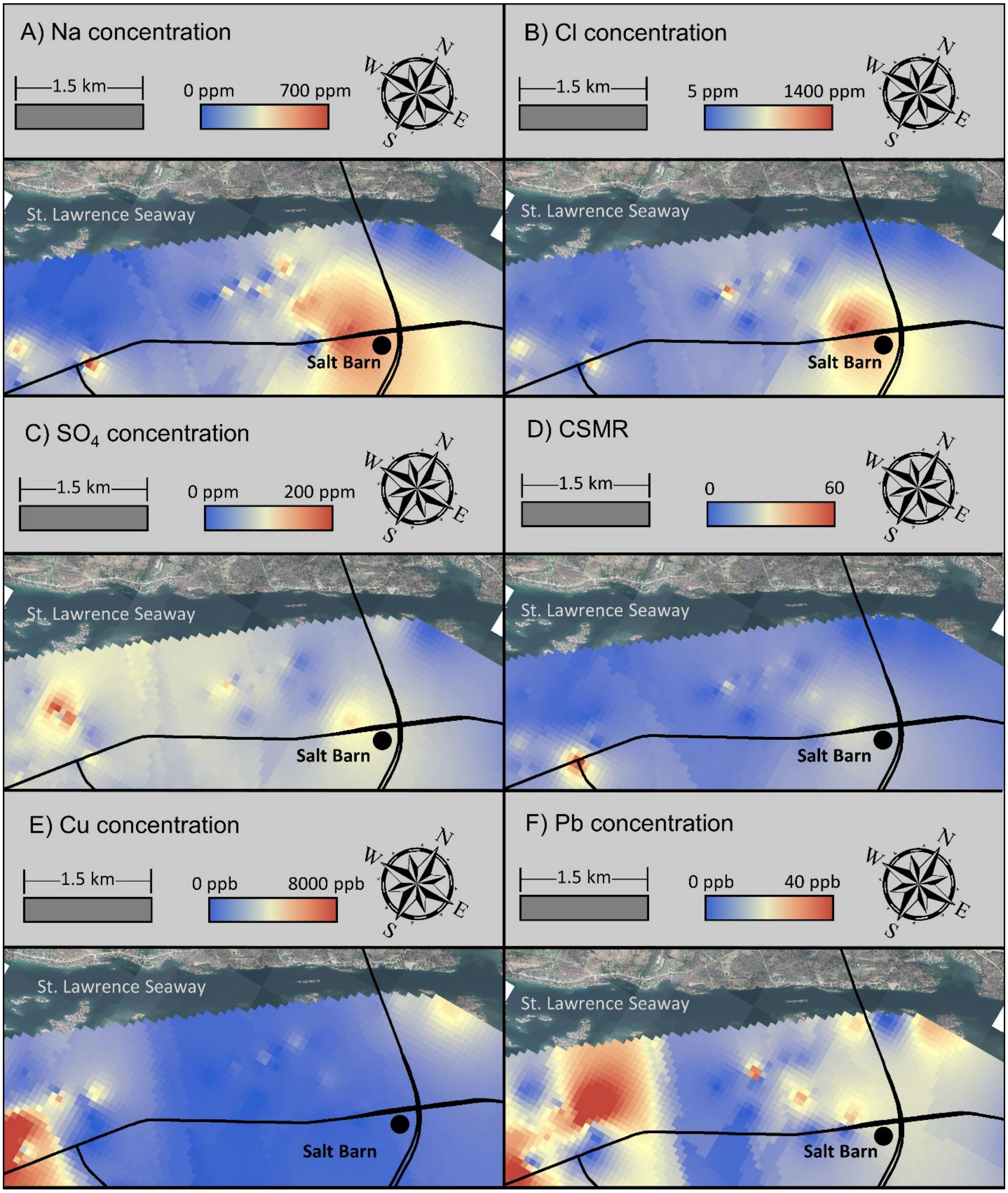

Figure SI-2. Spatial trends of (a) chloride concentrations, (b) sodium concentrations, (c) sulfate concentrations, (d) lead concentrations, (e) copper concentrations and (e) CSMR values in the Town of Orleans area. Cl = chloride; Na = sodium; SO4 = sulfate; CSMR = chloride-to-sulfate mass ratio; Cu = copper; Pb = lead.

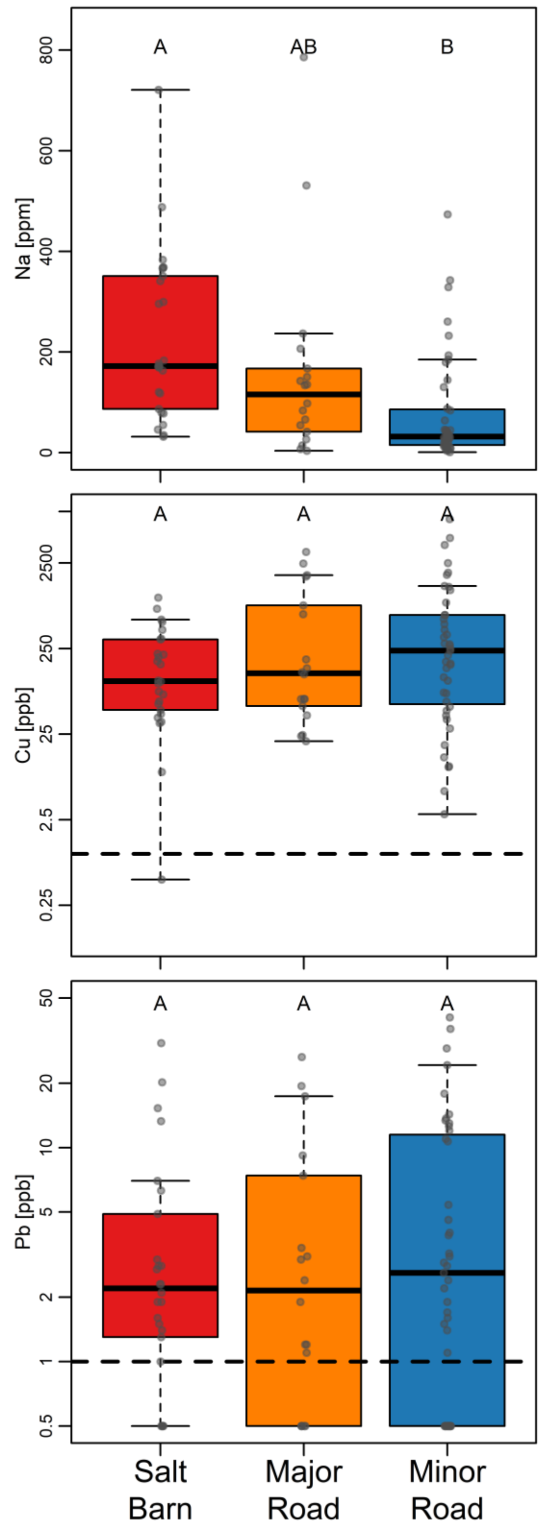

Figure SI-3. Sodium, lead, and copper concentrations based on groups: (1) downgradient of the salt barn and intersection of Interstate 81 and State Route 12; (2) within 30 m of a major roadway; and (3) not in proximity to the salt barn or major roadways. Pb: lead concentrations. Cu: copper concentrations. Na: sodium concentrations. A and B are used to denoted significant differences between groups (Kruskal-Wallis, $p<0.05$). Dashed lines indicated reporting limits of 1 ppb.

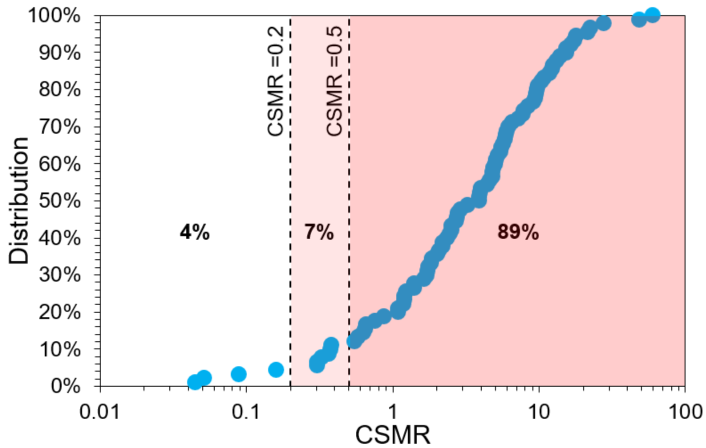

Figure SI-4. Chloride-to-sulfate mass ratio (CSMR) values among 90 wells in the Town of Orleans area

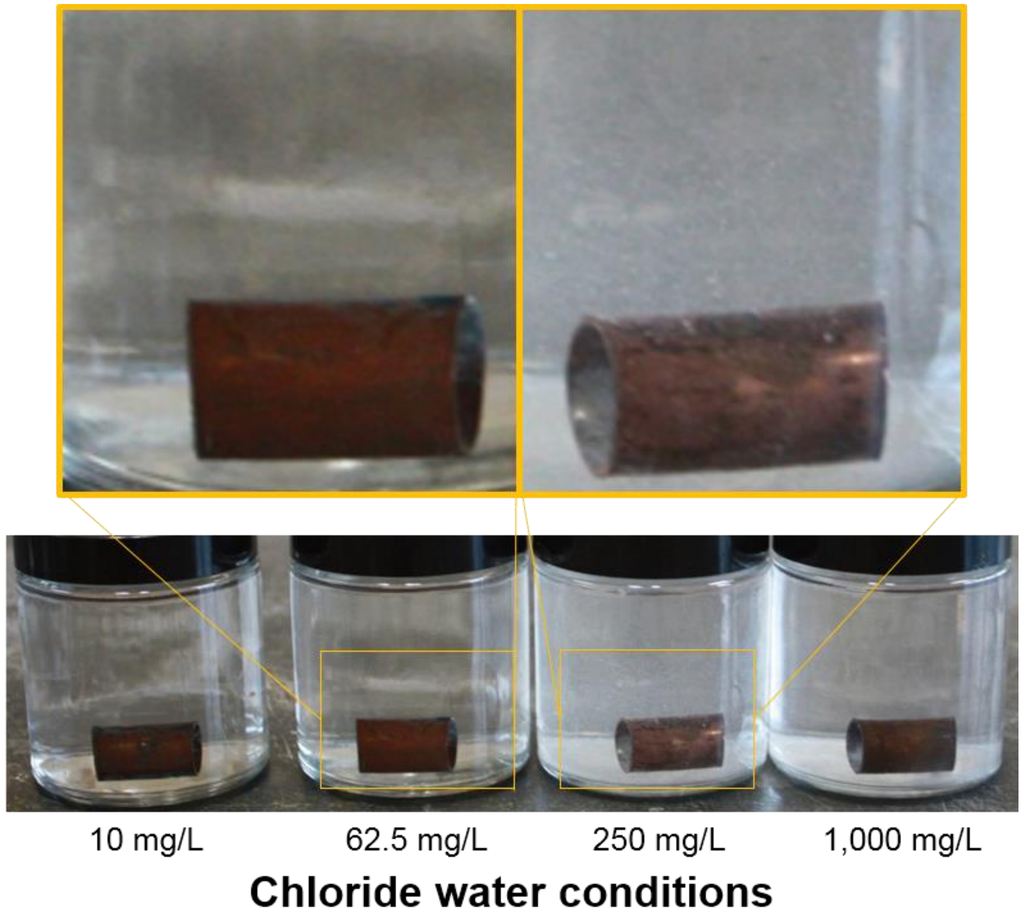

Figure SI-5. Lead leaching from lead solder joints exposed to 10-1,000 mg/L chloride waters.

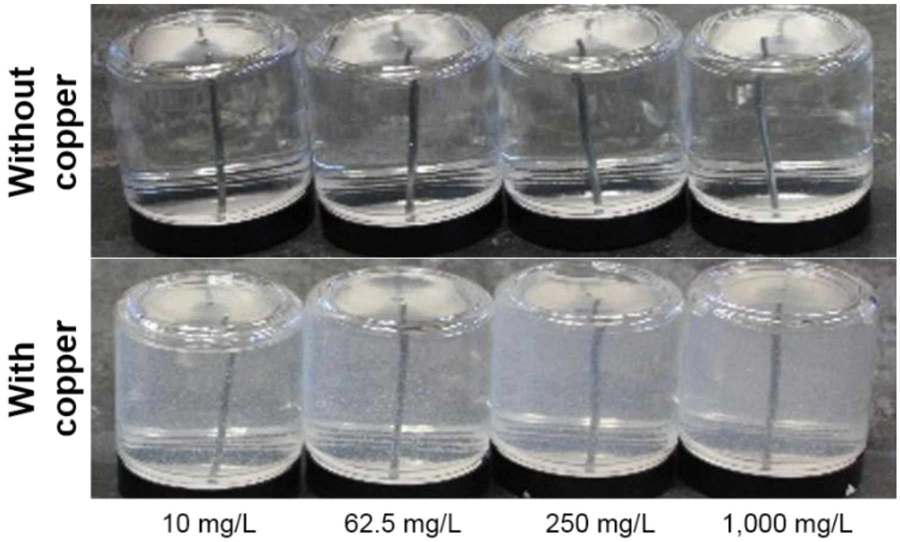

Figure SI-6. Zinc release from zinc wires when exposure to 10-1,000 mg/L chloride waters with and without 3 mg/L CuCl as copper.

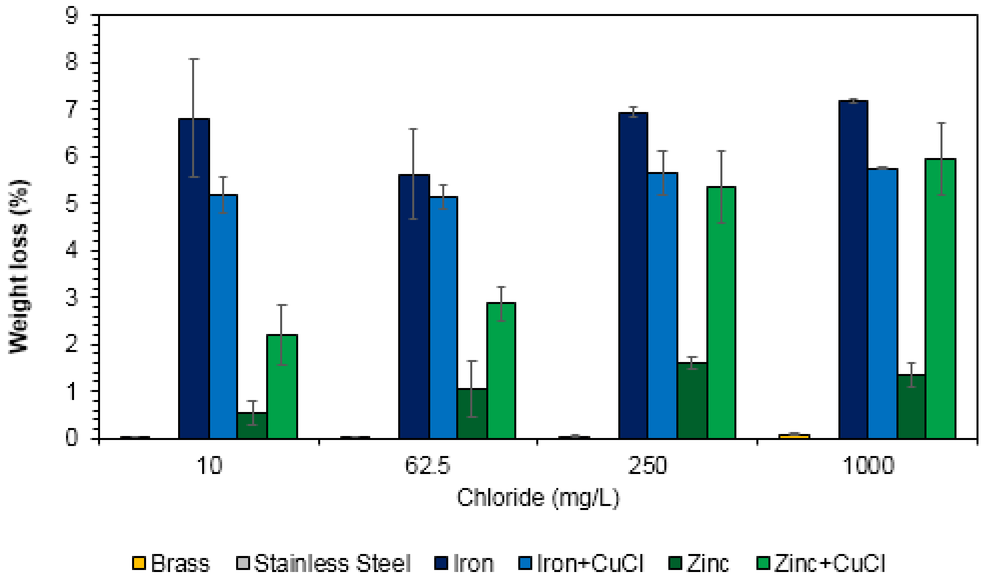

Figure SI-7. Weight loss of brass, stainless steel, iron, and zinc wires after 47-day exposure to 10-1,000 mg/L chloride. Error bars denote the standard deviation.

Figure SI-8. Brass wires exposed to 10-1,000 mg/L chloride waters on day 47.

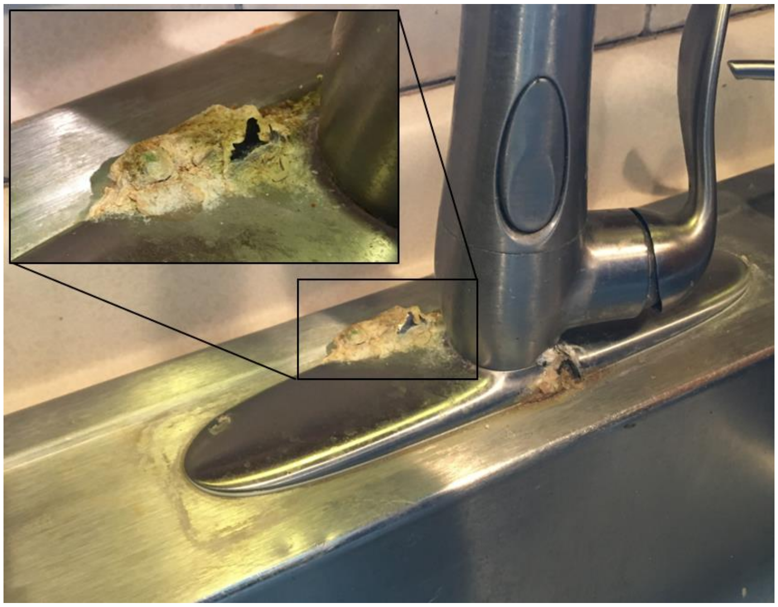

Figure SI-9. Corrosion and salt build up at kitchen faucet in a home in the Town of Orleans area

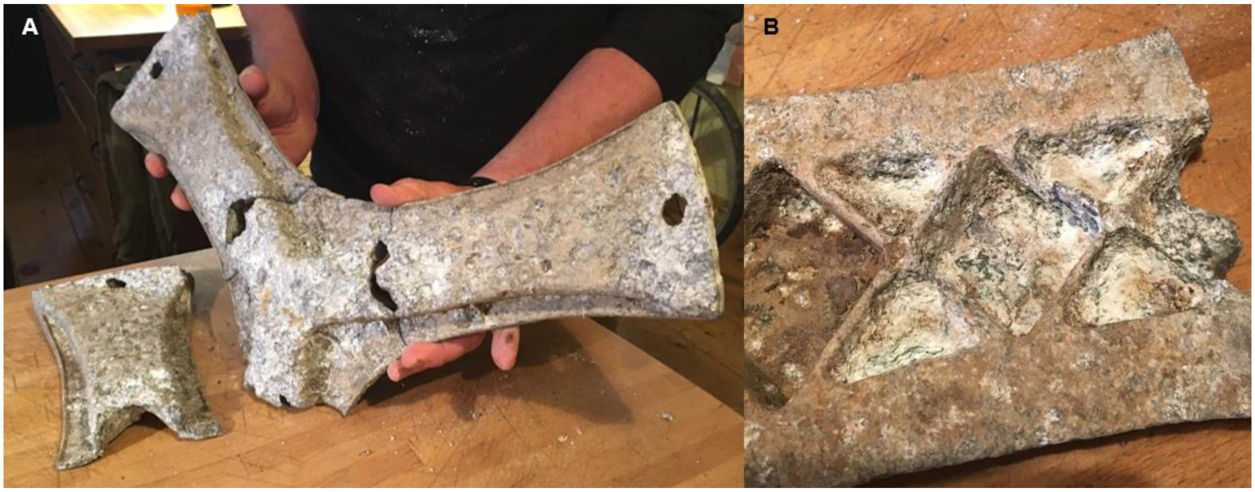

Figure SI-10. Corrosion of aluminum rear drum of washing machine in a home in the Town of Orleans area.

Table SI-1. Water quality in a Town of Orleans area well and synthesized well water.

Parameter	Measured parameters in well water	Target parameters for synthetic water
pH	7.4	7.4
Alkalinity as mg/L $CaCO_3$	390 (very hard)	122 (soft)
Sodium, mg/L	118	Varied (50, 90, 220, 630)
Magnesium, mg/L	69.3	8.1
Silicon, mg/L	10.4	11.9
Potassium, mg/L	1.5	1.4
Calcium, mg/L	132	8.2
Sulfate, mg/L	30.5	32.9
Chloride, mg/L	295	Varied (10, 62.5, 250, 1,000)
CSMR	9.7	0.3-30.4

Table SI-2. Water quality in private wells sampled in Town of Orleans area

Target water quality constituent	**Standard**		**Mean**	**Median**	**90^{th} Percentile**	**Percent Exceeding**
Exceeded at least one Action Level						20%
Exceeded at least one SMCL						56%
[‡]Arsenic, in mg/L	MCL	0.010 mg/L	<MRL	<MRL	<MRL	0.0%
[†]Cadmium, in mg/L		0.005 mg/L	<MRL	<MRL	<MRL	0.0%
[†]Chromium, in mg/L		0.1 mg/L	<MRL	<MRL	0.001	0.0%
[‡]Uranium, in mg/L		0.03 mg/L	0.005	0.003	0.009	1.1%
[†]Copper, in mg/L	Action Level	1.3 mg/L	0.58	0.17	1.74	13%
[†]Lead, in mg/L		0.015 mg/L	0.006	0.002	0.017	12%
[‡]Chloride, in mg/L	SMCL	250 mg/L	179.3	89.5	381.4	21%
[‡]Copper, in mg/L		1.0 mg/L	0.58	0.17	1.74	14%
[‡]Iron, in mg/L		0.3 mg/L	0.26	0.04	0.94	24%
[‡]Manganese, in mg/L		0.05 mg/L	0.029	0.003	0.089	16%
[‡]Sulfate, in mg/L		250 mg/L	30.7	27.0	45.0	0.0%
[†]Zinc, in mg/L		5 mg/L	1.46	0.54	4.74	10%
[‡]Sodium, in mg/L	DWEL	20 mg/L	144.5	81.7	366.3	82%

MCL: Maximum Contaminant Levels – associated with risk to human health
SMCL: Secondary Maximum Contaminant Levels – associated with aesthetic considerations
DWEL: Drinking Water Equivalency Level (or guidance level)
MRL: Maximum reporting level; 1 ppb for arsenic, cadmium, and chromium
[†]Measured in the first draw
[‡]Measured in the flushed sample

Table SI-3. Estimated number of potentially impacted private wells by road salt in New York

County Name	Wells affected by salt barn	Wells affected by roads	Total number of wells
Albany	461	5314	25168
Allegany	409	5115	21873
Bronx	0	999	1287
Broome	1217	11557	54295
Cattaraugus	1046	6132	32966
Cayuga	485	5069	26441
Chautauqua	905	8876	44298
Chemung	67	7057	28093
Chenango	115	5149	27008
Clinton	896	6064	33541
Columbia	753	8608	38000
Cortland	30	3325	17619
Delaware	1180	4134	20126
Dutchess	1019	26952	105357
Erie	400	7288	45751
Essex	109	2064	8859
Franklin	835	3305	19282
Fulton	362	3975	21721
Genesee	353	3593	26115
Greene	883	5181	25681
Hamilton	14	500	2445
Herkimer	43	3792	21345
Jefferson	1071	7278	34679
Kings	0	3170	3899
Lewis	123	2071	12871
Livingston	127	3671	19960
Monroe	144	4691	20395
Montgomery	165	4177	18274
Nassau	381	2214	4119
New York	0	564	684
Niagara	2	747	6047
Onondaga	234	6775	34805
Ontario	66	4683	24686
Orange	437	26303	97297
Orleans	223	3614	20437
Oswego	756	10754	61206
Otsego	428	4768	27328
Putnam	543	20578	55516
Queens	0	2335	2956
Rensselaer	580	13706	56108
Richmond	0	363	512
Rockland	435	8584	20130
Saratoga	4112	15651	62290
Schenectady	280	2259	11948
Schoharie	321	3405	19335

Schuyler	47	2251	11896
Seneca	16	2622	12886
St Lawrence	439	9692	52092
Steuben	579	9997	43299
Suffolk	4016	59698	130735
Sullivan	1097	8526	37892
Tioga	58	6129	31248
Tompkins	86	6064	29823
Ulster	1154	20906	89944
Warren	193	3896	15668
Washington	1011	6101	30573
Wayne	324	4643	25248
Westchester	928	15259	54953
Wyoming	226	3528	20571
Yates	42	2123	10895
Madison	1970	5604	26670
Oneida	683	10634	54975

Work Cited:

1. Fourth Coast Inc. (2014) *Town of Orleans Route 12 Water Testing Summary Results* [database].
2. Allevi, R.P.; Krometis, L.H.; Hagedorn, C.; Benham, B.; Lawrence, A.H.; Ling, E. J.; Ziegler, P.E. Quantitative analysis of microbial contamination in private drinking water supply systems. *J. Water Health* **2013**, *11* (2), 244.