Arsenic Abundance In Arugula And Kale

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Background

All About Arsenic (AAA)

The AAA project was started in 2015 as a collaboration between the Community Environmental Health Laboratory at Mount Desert Island Biological Laboratory and Dartmouth College's Toxic Metals Superfund Research Program.

- Aim of the project: Understand the prevalence of arsenic in well water throughout ME and NH with the aid of citizen-science based initiatives in secondary schools.

Sources of Arsenic

- Regional bedrock geology: metasedimentary and igneous rocks (Peters, 2008).
- Residuals of historical arsenical pesticide application from the early-mid twentieth century (Robinson and Ayotte, 2006).

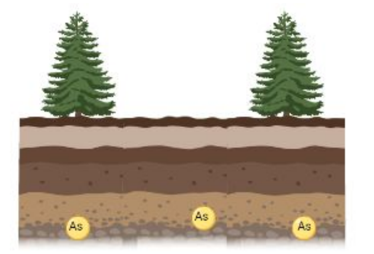


Figure 1 (left): Arsenic found within bedrock geology.

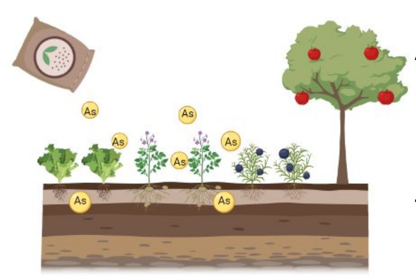


Figure 2 (left): Application of arsenical pesticides in early-mid twentieth century.

Arsenic in Plants

Arsenic levels in Brassica family plants exceeded guidance by prior research in former orchards where pesticides were likely applied (Lim and McBride, 2015).

Arsenic in Humans

Long-term arsenic exposure is linked to DNA damage and cancers (Normandin et al. 2014; Baris et al. 2016).

- The United States Food and Drug Administration (US FDA) does not have a maximum level of arsenic permissible in food products.
- US FDA has an action level guidance of 100 µg kg^{-1} on rice cereal products for infants (Food and Drug Administration, 2020).
- The World Health Organization (WHO) set an inorganic arsenic lower limit on the benchmark dose for a 0.5% increased incidence of lung cancer ($BMDL_{0.5}$) at 3.0 µg kg^{-1} (of bodyweight) day^{-1} based upon epidemiological studies (World Health Organization, 2011).

Hypothesis

Arugula and kale grown in areas with higher levels of arsenic in the water and/or soil will yield a higher arsenic concentration. The results of this study could suggest recommendations to farmers on appropriate crop selection or location to lessen the likelihood of arsenic uptake and subsequent human exposure.

Methods

Samples of arugula and kale were collected from various regions of Downeast Maine where arsenic levels were high in the groundwater and/or there was a high probability of arsenical pesticides being applied on the land (Maine CDC) (Robinson and Ayotte, 2006).

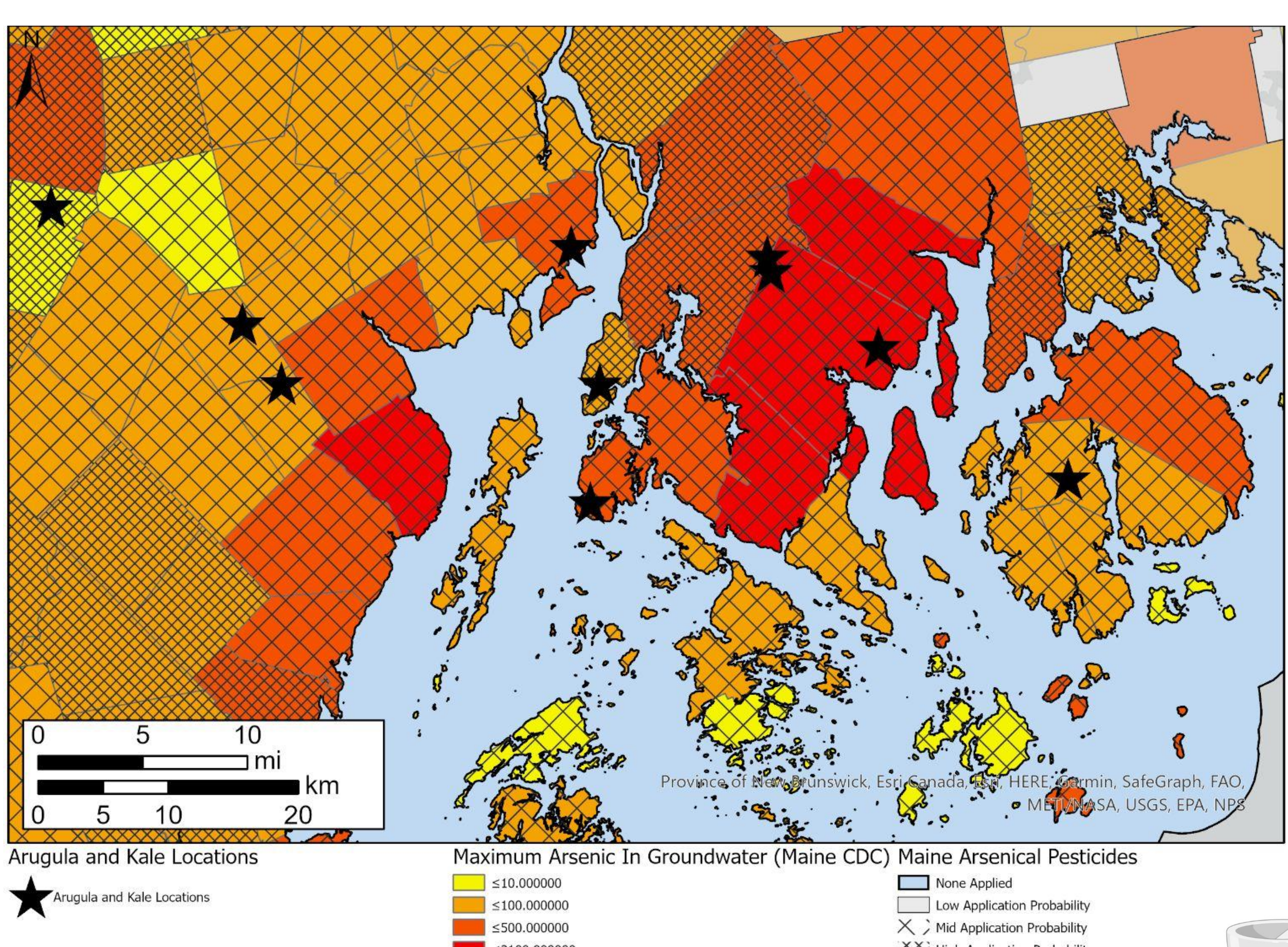


Figure 3 (left): The locations where each sample was grown. Map units show the maximum recorded arsenic levels in groundwater by town (Maine CDC) and the probability of arsenical pesticide application (Robinson and Ayotte, 2006).

Once collected, samples were individually:

- Dried at 70°C
- Homogenized into powder representative of each sample
- Sent to Dartmouth College's Trace Element Analysis Laboratory for trace metal analysis.

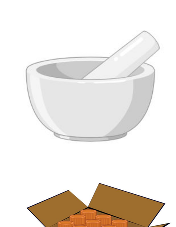


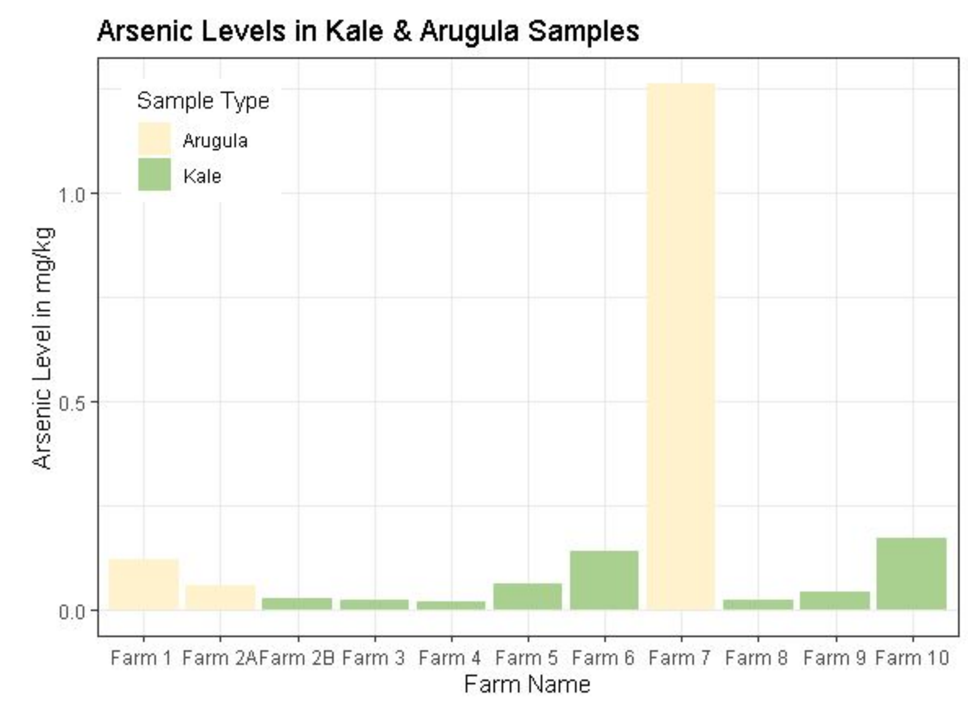
Figure 4 (left): Dried samples were homogenized using a mortar and pestle and then shipped in sample tubes to Dartmouth.

Results

Sample Name	Sample Type	As (mg/kg) Dry Weight	Arsenic (µg) in 1 US cup of Fresh (Wet) Sample	% Towards 3µg/kg/day Increased Cancer Risk for 50kg Individual
Farm 1	Arugula	0.12	0.21	0.14%
Farm 1	Arugula	0.11	0.19	0.13%
Farm 2A	Arugula	0.06	0.11	0.07%
Farm 2A	Arugula	0.05	0.09	0.06%
Farm 2B	Kale	0.03	0.32	0.21%
Farm 2B	Kale	0.03	0.30	0.20%
Farm 3	Kale	0.02	0.17	0.11%
Farm 3	Kale	0.02	0.25	0.17%
Farm 4	Kale	0.02	0.21	0.14%
Farm 4	Kale	0.02	0.22	0.14%
Farm 5	Kale	0.06	0.70	0.47%
Farm 5	Kale	0.04	0.41	0.27%
Farm 6	Kale	0.14	1.60	1.07%
Farm 6	Kale	0.08	0.92	0.61%
Farm 7	Arugula	1.26	2.27	1.51%
Farm 7	Arugula	1.16	2.08	1.39%
Farm 8	Kale	0.02	0.18	0.12%
Farm 8	Kale	0.02	0.26	0.18%
Farm 9	Kale	0.04	0.47	0.31%
Farm 9	Kale	0.03	0.35	0.24%
Farm 10	Kale	0.12	1.36	0.91%
Farm 10	Kale	0.17	1.95	1.30%
1 US Cup Fresh Kale = 67g, 1 US Cup Fresh Arugula = 20g.				

Table 1 (above): Individual sample results. Right columns shows the percent of the way towards the WHO $BMDL_{0.5}$ for a 50kg individual if they consumed 1 cup of the fresh produce.

As expected, arsenic was found within the samples of arugula and kale collected. Arsenic concentrations in arugula ranged from 0.05 to 1.26 mg kg^{-1} and in kale range from 0.02 to 0.17 mg kg^{-1}.



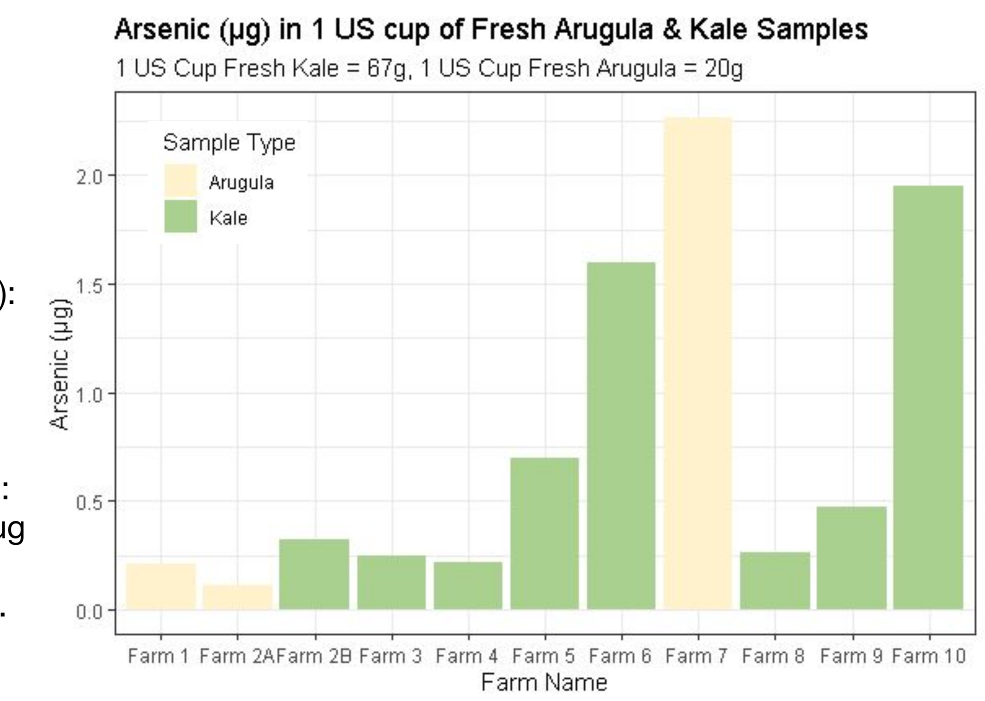


Figure 5 (upper right): Graph of arsenic in mg kg^{-1} of dried sample.

Figure 6 (lower right): Graph of arsenic in µg found within 1 US Cup of fresh sample.

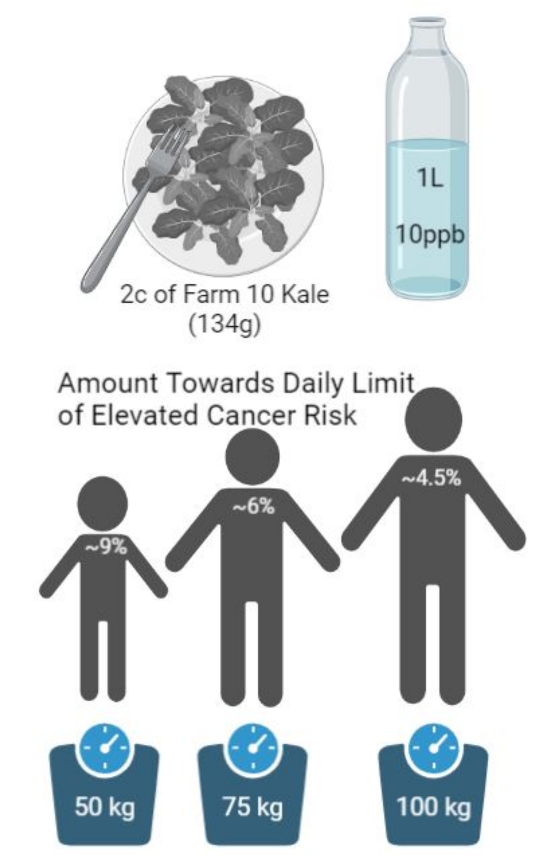


Figure 7 (above): The percentage towards the WHO $BMDL_{0.5}$ for individuals of three different weights if they consumed 2 cups of kale from Farm 10 and had 1 liter of water at 10 ppb of arsenic. 10 ppb is the limit for water in Maine (Maine CDC, 2012).

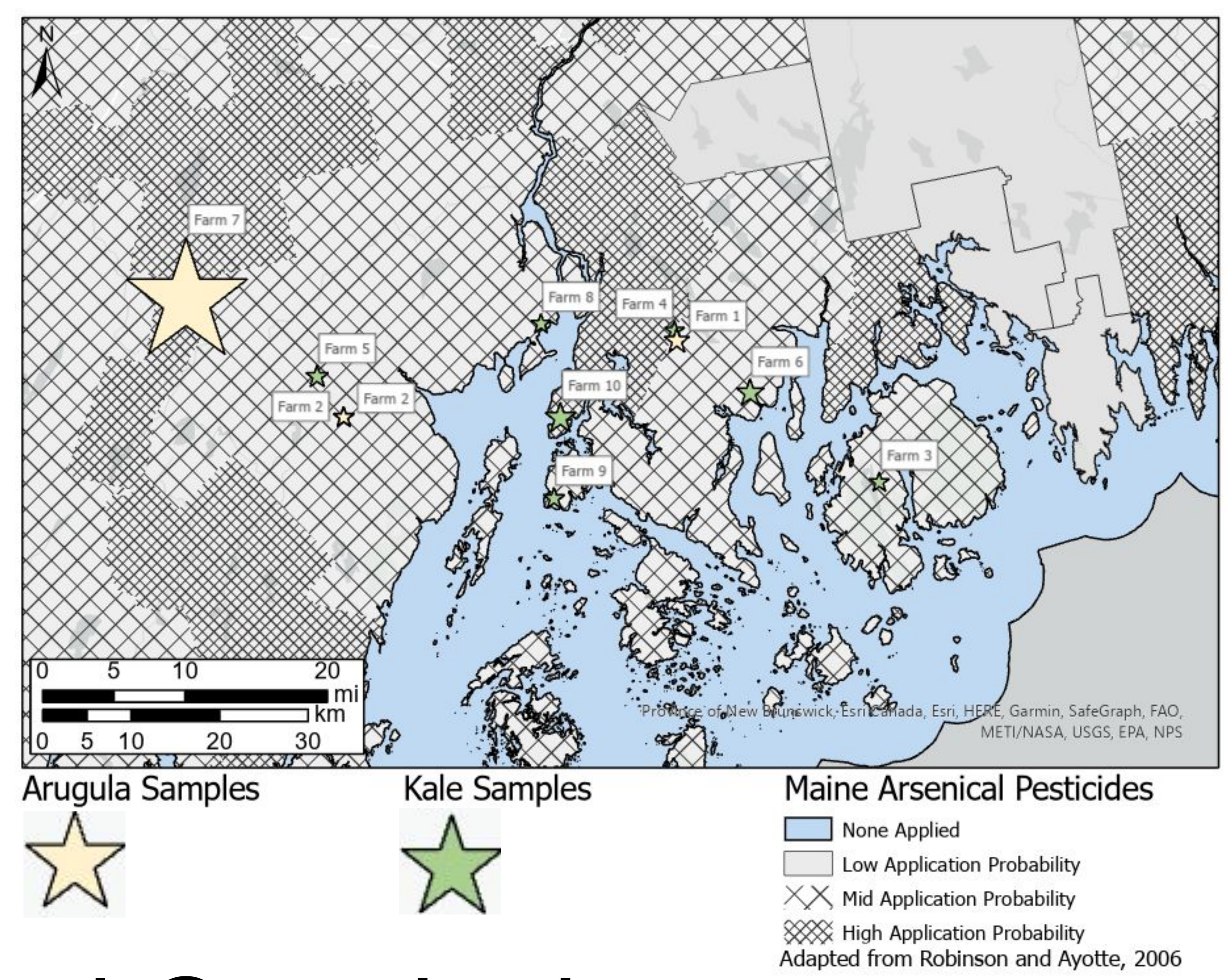


Figure 8 (right): Sites of sample locations, color coded based upon plant type: arugula (yellow) and kale (green). The size of the stars representing the location of each farm scaled with their arsenic concentration in mg kg^{-1} of dry sample. Notice that the most elevated arsenic levels comes from regions with a high probability of the historical application of arsenical pesticide (Robinson and Ayotte, 2006).

Discussion and Conclusion

These data indicate there is some arsenic uptake by arugula and kale, with arugula having a higher arsenic uptake than kale; consistent with past research (Lim and McBride, 2015).

All samples were grown in regions identified to have mid or high application probability of arsenical pesticides. Future work could include testing the soil and water used at these farms to determine the pathways of arsenic migration into the plants.

Arsenic ingestion should be kept as low as possible given its toxic nature (Normandin et al. 2014; Baris et al. 2016). Using the WHO $BMDL_{0.5}$ of 3.0 µg kg^{-1} day^{-1} as a maximum daily intake guideline, a moderate consumption of arugula and kale from all farms in this study does not pose a substantial risk to an individual assuming there are no other major contributing factors to arsenic exposure.

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