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Pick your poison: A comparative study on trace heavy metal concentrations in beverages

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Abstract

This study aims to determine trace heavy metal concentrations in beverages available for purchase by U.S. consumers using inductively coupled plasma mass spectrometry, ICP-MS. The main beverage types used in the study were beer, bottled water, and sports drinks. Beer categories were separated to compare among domestic, European, and microbrewery produced beers, and were further compared among common types of beer including pilsner, lager, pale ale, brown ale, stout, porter and wheat. The bottled water was separated between spring water, filtered water, and flavored sparkling water where three different brands of each type were tested. Similarly, three different brands of sports drinks were also tested. These samples were then tested for ten different metals including aluminum, arsenic, cadmium, chromium, copper, nickel, iron, lead, zinc, and magnesium. The results of the beverages is preliminary data to compare heavy metal concentration for each beverage type, and to further analyze heavy metal concentration among categories for each beverage type.

Background

Heavy metals are high density metals that can be toxic or harmful. The metals bioaccumulate in the body, and over time, can cause many health issues including cancer, kidney dysfunction, and nervous system disorders (3). Heavy metals can be found in beer and other beverages due to agricultural pesticides, irrigation water, soil composition, and air pollution (1). These metals can also be introduced via manufacturing and packaging processes (2) as well as from the raw materials used in the beverage production process (4).

References

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Methods

- A 0.5mL aliquot of each beverage (Figure 1, left) was digested in 0.3 mL of 70% trace metal free nitric acid (Figure 1, middle) and 9.2 mL of trace metal free water using a Multiwave GO microwave digester (Anton Paar).
- The digested samples were transferred into 15 mL centrifuge tubes, and analyzed using ICP-MS (Figure 1, right) with the following parameters; Analysis type: Water MiniTorch (collision), Radio Frequency Power: 1.20 kW, Sampling depth: 5.0 Plasma Gas: 9.0 L/min, Auxiliary Gas: 1.10 L/min, Carrier Gas: 0.70 L/min, Mixed Gas: 0.0 L/min, Cell Gas: 6.0 L/min, Cell voltage: -21 v, Energy Filter: 7.0 v, low and high pump rotation speed: 20 and 60 rpm respectively.
- Samples were analyzed in DBG mode (collision cell) in order to eliminate spectral interferences
- Standard curves were constructed for each metal based on the Environmental Protection Agency (EPA) maximum levels (ML). Al: 200 ppb, As: 25.0 ppb, Pb: 25.0 ppb, Cd: 5.00 ppb, Cu: 1300 ppb, Cr: 100 ppb, Mg: 25000 ppb, Ni: 100 ppb.[5]

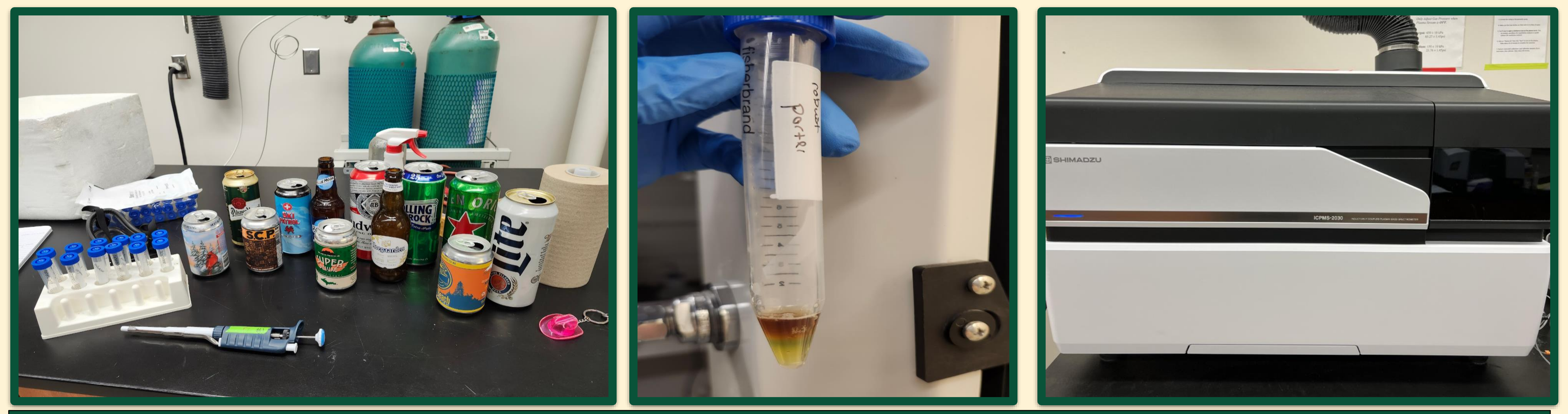

Figure 1: (Left) An overview of some of the samples tested. (Middle) A beer sample after sitting in 70% nitric acid for 1 hour before digestion. (Right) Shimadzu ICP-MS used for analysis of digested samples

Conclusions

ICP-MS analysis was performed to detect heavy metal concentrations in alcoholic beverages and sport drinks. We screened for nine heavy metals and magnesium. Of the ten metals, Iron and Zinc were not detected (or present in amounts below detection limit). Cadmium and Nickel were detected in all beverages but in trace amounts well below the EPA maximum limits. Aluminum was present at concentrations above the EPA maximum limit across all beverage types. Arsenic (As) levels were generally below the EPA maximum limits across all beverage types except in microbrewery where the As levels were above the EPA maximum limits across all beer types in the microbrewery category. Interestingly, different test batches showed different As levels across the same microbrewery beer types. Chromium and Copper levels were below the EPA limits in all beverage types except in EU (stout and wheat) beer types and sport drinks where Cr and Cu levels above the EPA limits were detected. Lead (Pb) levels were below the EPA limits in most beverage types except in sport drinks and spring water, with above the EPA limits. Higher levels of Pb was also detected in EU wheat, and USA Pale Ale beer types. Interestingly, Magnesium, an essential mineral, was detected across all beverage types all within the EPA maximum limits.

These results are a preliminary report on the ten metals detected in all the beverage types in two, six-month interval brewed batches. Future work will test more brewed batches to increase sample number and brands or beverage types. The goal of this research is to inform consumers on the quality and safety of common beverages and the importance of regular testing in the beverage industry.

Results

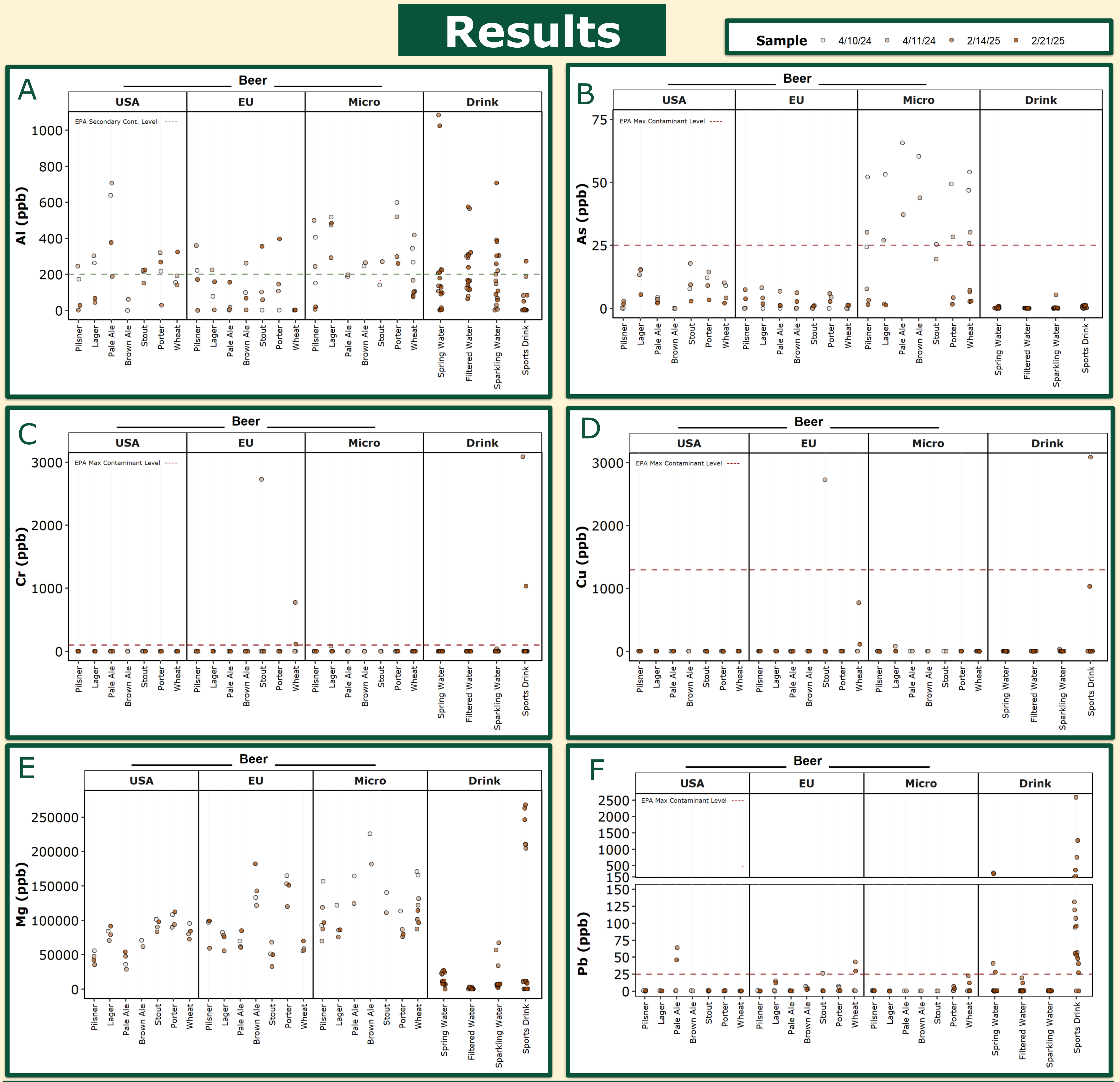

Figure 2: Plots of average heavy metal concentrations in each beverage type. For multi-isotope metals, only two or three of the most abundant isotopes concentrations were determined and averaged for (A) Aluminum (Al), (B) Arsenic (As), (C) Chromium (Cr), (D) Copper (Cu), (E) Magnesium (Mg) and (F) Lead (Pb). Dotted red line indicates the EPA acceptable limits. [6] The legend at the top (right) indicates dates the analysis were performed (sample batches).

Table 1: The number of observations (n), mean, and standard error (x±se) summarized for all beverage production types for aluminum (Al), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), magnesium (Mg), nickel (Ni), and lead (Pb) using ICP-MS methods.

Production	n	Al (ppb)	As (ppb)	Cd (ppb)	Cr (ppb)	Cu (ppb)	Mg (ppb)	Ni (ppb)	Pb (ppb)
USA	26	213.4±33.6	6.5±1.1	0.1±0.04	0.1±0.01	1.4±0.1	73629.5±4681.6	0.1±0.04	4.5±2.9
EU	28	106.9±23.2	2.2±0.5	0.2±0.2	129.2±100.2	129.9±100.1	90483.4±7602.9	0.2±0.2	5.8±2.0
Micro	28	272.9±31.2	25.5±21.1	0.03±0.01	2.9±2.9	3.9±2.8	117297.2±7213.8	0.04±0.01	1.8±0.9
Spring Water	19	209.2±70.7	0.2±0.1	0.04±0.01	0.1±0.01	1.3±0.1	13268.4±1865.7	0.04±0.01	31.2±18.7
Filtered Water	18	231.6±35.2	0.005±0.001	0.04±0.01	0.1±0.01	1.1±0.1	1027.6±1162.02	0.04±0.01	2.02±1.2
Sparkling Water	18	191.1±42.7	0.4±0.3	0.04±0.01	2.1±1.9	3.0±1.9	13605.8±4466.2	0.04±0.01	0.3±0.2
Sports Drink	18	38.3±18.0	0.5±0.1	0.04±0.01	228.8±177.5	229.8±177.4	81438.5±26395.1	0.04±0.01	332.3±152.5

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