UNIVERSITY of WASHINGTON

THE IMPACT OF NEARSHORE RECREATIONAL ACTIVITIES ON ARSENIC EXPOSURE IN CONTAMINATED LAKES: A STUDY OF SEDIMENT DISTURBANCE & WATER QUALITY

Kirsti Lipphardt, James E. Gawel, Environmental Science

Klipphar@outlook.com

INTRO

As summer temperatures rise due to **climate change**, more people in the **Pacific Northwest** are seeking relief from the heat in **recreational lakes**. However, many of these lakes in Western Washington are **contaminated** with **arsenic (As)** due to **legacy smelting** and **herbicide treatments**. **Arsenic exposure** can cause **cancer** and **neurological issues**, making it a significant **public health concern**. Previous studies have found that arsenic can **redistribute** in **deep lake sediments** after short-term stratification, resulting in high concentrations of **arsenic** in **near-shore sediments** of **shallow lakes** (Fung S.R. et al. 2022). Building upon this work, our study investigates the **potential risks** to **human health** associated with near-shore exposure to arsenic in recreational lakes, with a focus on **children** who may be particularly vulnerable during **recreational activities**.

We hypothesize that the resuspension of sediments caused by nearshore recreational play will result in the release of dissolved arsenic from pore water and ultimately increase the exposure of individuals to this potentially harmful element.

METHODS

- ❑ **I collected sediment and water samples at five near-shore sites** (approximate water depth 0.9 m) in selected recreational lakes in Western Washington (see Figure 1). Sample collections were carried out during **summer once monthly** (Aug-Sept). A metal hand core was used to extract the top 7.6 cm of **lakebed sediments**.
- ❑ **Total As (unfiltered: dissolved As and particle-bound As)** and **Dissolved As Fraction** (filtered through 0.45 µm) were collected 0.3 m below the water's surface. Water **samples were collected** from a boat **without sediment disturbance and again after simulated play**. To **simulate play**, I exited the boat and **stomped for 1 minute**.

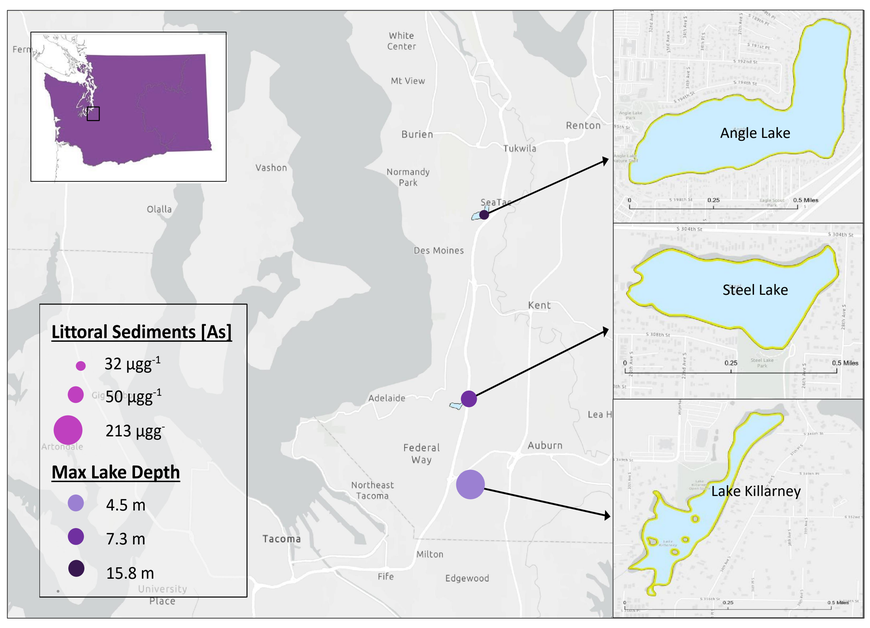

Image 1: Site selection based on average littoral sediment As concentrations and max depth (Hull E.A. et al. 2021). Nearshore sampling range (yellow). Map created in ArcGIS by Kirsti Lipphardt & Gibson Silagi.

- ❑ **Total As** and **Dissolved As** water samples were **acidified** with 1% HNO_3 (v/v). Total As sat for two weeks before As analysis.
- ❑ **Sediment samples** were dried at 60 °C for seven days, homogenized, sieved through a 0.2 mm screen, and **digested in a microwave with 100% HNO_3** (CEM MARS 5, modified EPA method 3015). The digested samples were analyzed for **Total As** using inductively coupled plasma mass spectrometry (**ICP-MS**) (Agilent 7900. University of Washington Tacoma).
- ❑ **Grain size analysis** was performed using a laser diffraction particle size analyzer (Beckman-Coulter LS 13 320 Laser Diffractometer. UWT).

Impact of Near-Shore Play on Arsenic Levels In Recreational Lakes

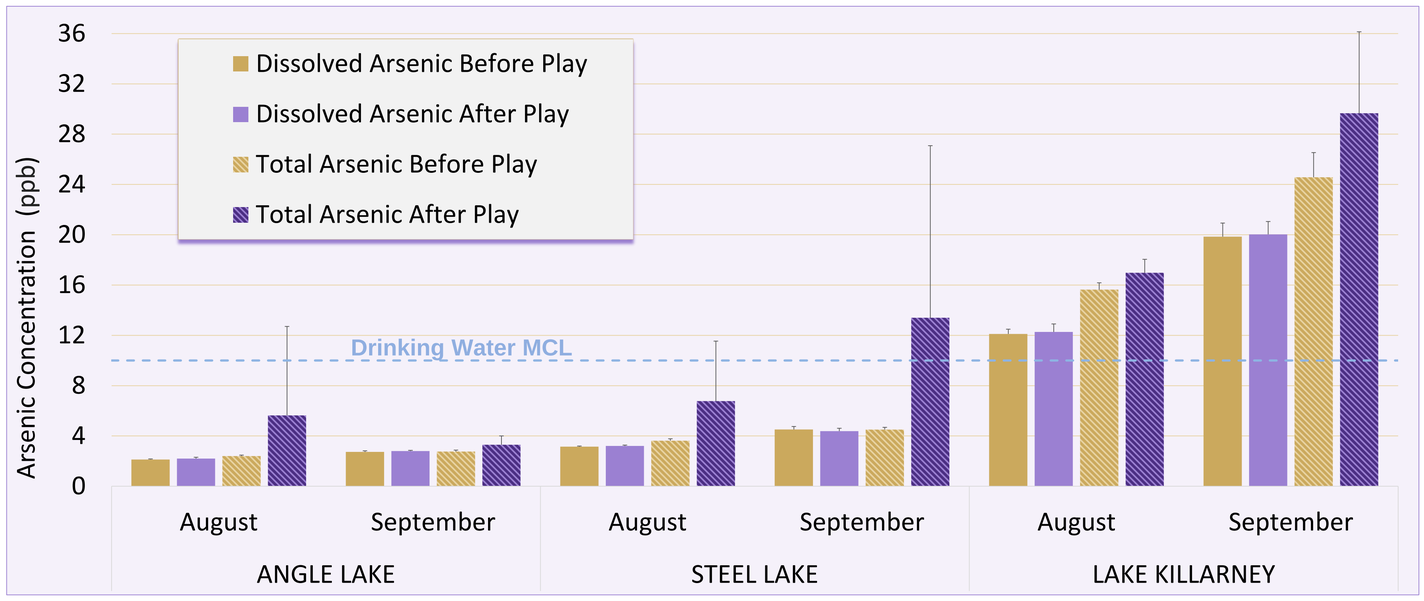

Figure 1: Average Dissolved As concentrations (0.45 µm filter) and Total As concentrations (unfiltered dissolved As & suspended particle-bound As). Error bars represent one standard deviation. The drinking water max contamination level (MCL) established by the EPA (10 ppb) is included as a reference.

Change in [As] After Near Shore Play

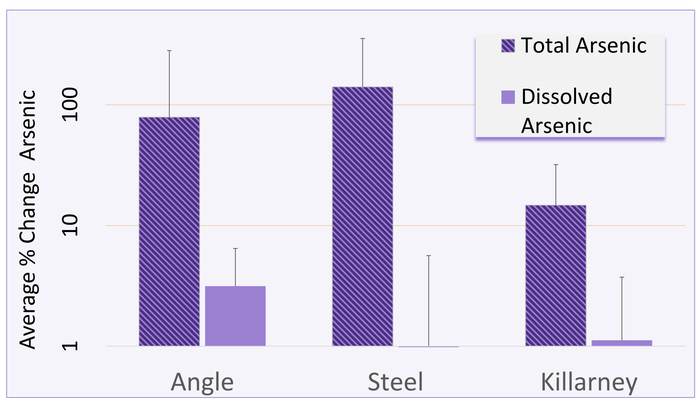

Figure 2: Average percent change in As concentration due to nearshore play by lake (log Scale). Error bars represent one standard deviation. Nearshore play significantly increased change in Total As concentrations. No significant change in dissolved As.

Sediment Grain Size Influence on [As]

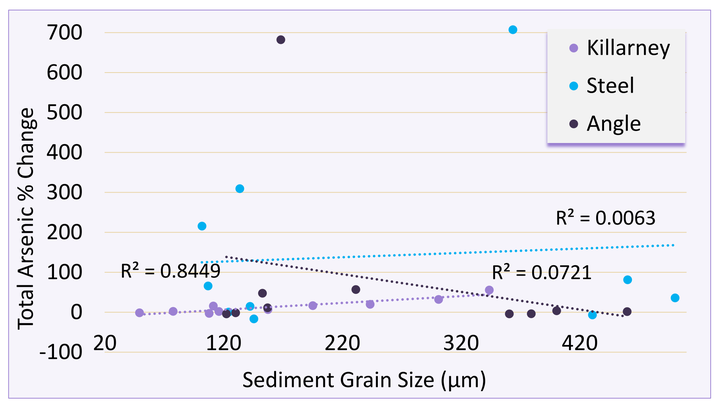

Figure 3: Percent change in Total As compared to sediment median sediment grain size. No significant correlation of grain size (under 2 mm) on change in Total As concentrations due to play in the nearshore.

RESULTS

- ✓ Our study found that **near-shore play does not significantly increase Dissolved As** concentrations but **does significantly increases Total As concentrations in the water column** (Figure 1, 2).
- ✓ **Sediment grain size** was **not** found to be a **significant factor in As release** from sediments suggesting As release is **driven by other lake processes** (Figure 3).
- ✓ In the **shallower lakes** (**Lake Killarney & Steel**), we found **significantly higher Total As concentration after near-shore play** in the later **warmer summer month**. This suggests that as summer progresses, the sediment properties are changed by **bacterial action** so that the **As is more weakly bound to sediment** later in the summer and more **easily dissolved when digested in weak acids** (Figure 1, 4)

Late Summer [As] Increase In Lake Killarney

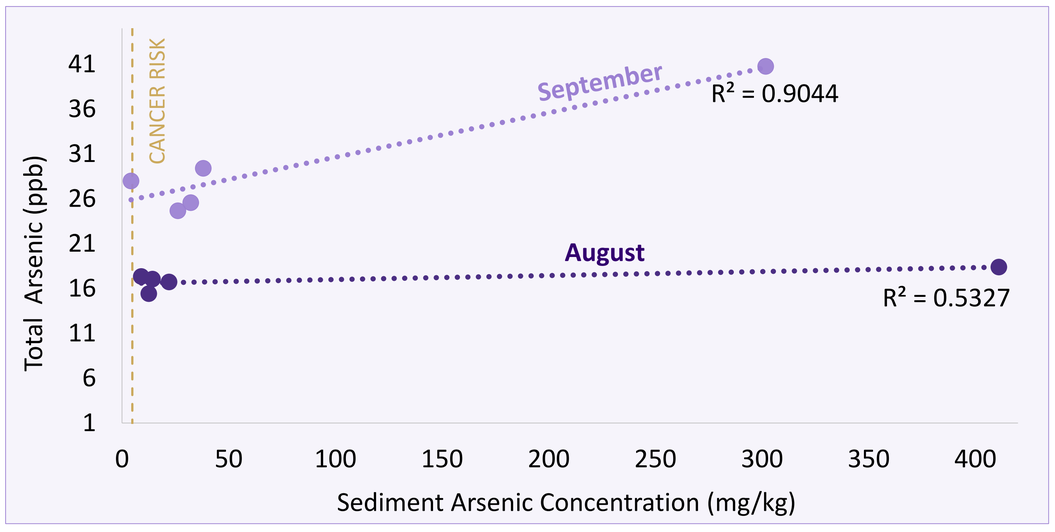

Figure 4: Monthly variation in Total As in water and As in sediment. Cancer risk threshold for sediments: 4.85 mg[As]/kg exceedance increases cancer risk by 10^{-5}, Washington Department of Health.

DISCUSSION

- ✓ **We found that near-shore play can significantly increase Total As concentrations in the water column**. Specifically, we found that bacterial action occurring in later summer can change sediment properties and weaken As binding, making it more easily released when digested in weak acids.
- ✓ **This provides new insights into the risk of exposure to As through recreational activities in near-shore sediments of shallow lakes**. Our results have important implications for public health.
- ✓ **Our findings highlight the need for better risk assessment models for shallow As-contaminated lakes.** These models should include **incidental water ingestion** during recreational play, **hand-to-mouth sediment transfer**, Total As in water after sediment disturbance, lake depth, and lake mixing regime.
- ✓ Our findings suggest that **As is more easily released from suspended sediments when ingested in warmer temperatures when lake visitation is highest.** Families who utilize lakes to cool down during increasingly hot summers may be more likely to frequent lakes during warmer seasons, **increasing** their **risk of exposure to As**.
- ✓ **Effective strategies should be developed to assess and mitigate As contamination in shallow recreational lakes, including clean-up efforts to remove or cap the contaminated sediment.**
- ✓ Future research should replicate our findings with more diverse lakes and explore the potential health risks associated with exposure to As in these environments, particularly for **children who are more vulnerable to the effects of As exposure**.

ACKNOWLEDGMENTS

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References