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After the Alum: The Fate of Sulfur in Waughop Lake, Pierce County, Washington

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Introduction

Waughop lake is a small kettle lake formed in the depression of a melting ice block around 12 thousand years ago. Like many other lakes and marine environments, Waughop is plagued with hazardous algal blooms (HABs) that threaten the water quality. To combat these HABs, alum treatment (Aluminum Sulfate) is commonly used. Alum treatment is the use of aluminum sulfate, which binds to phosphorus, effectively lowering the levels of free phosphorus and thus reducing algal growth. However, alum can also have adverse effects on water and sediment chemistry. Waughop lake was treated in March and again in July of 2020, with alum, and since then there have been significant changes in the lake chemistry. The most significant changes have been tied to excess sulfur in the water column and pore water after the addition of alum. the goal of this research is to track the chemical changes in the lake with a high interest on sulfur.

Objectives

1. Monitor the water and sediment chemistry over the summer and track any changes.
2. Relate changes to alum application dates and quantify the impact of alum treatment on the lake environment.
3. Identify the form of sulfur in the lake.
4. Determine the effect of the sulfur on the lake environment.

Alum & the Phosphorus Cycle

Alum (aluminum sulfate) is used to interrupt the cycle of internal nutrient loading that fuels HABs. Nutrients are used up by algal blooms which cover the lake surface flourishing till the nutrients are expended. The algae die sinking to the lakebed where they release the nutrients to be used again as fuel for another algal bloom. Alum works by binding to the phosphorus in the water column and actively removing it from the cycle.

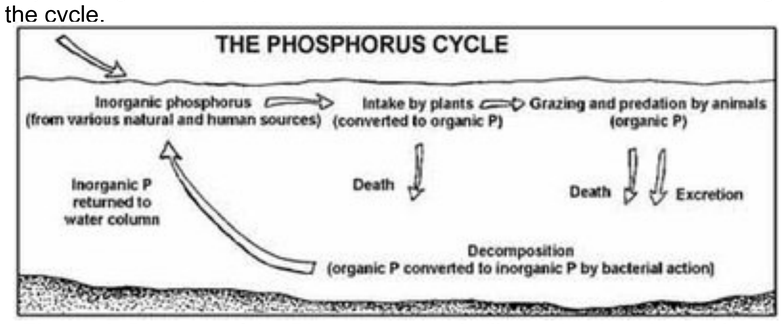


Figure 1. Diagram of the Phosphorus cycle illustration how internal nutrient loading works.

Waughop Lake History

- Fort Steilacoom Park used to be a mental hospital called Hill Ward where the patients worked as farm hands.
- Farm workers would dump human and animal waste into Waughop Lake.
- This is the cause of excess nutrients in the lake which fuels HABs.

Figure 2. Photo of Waughop lake showing the bright green hazardous algae.

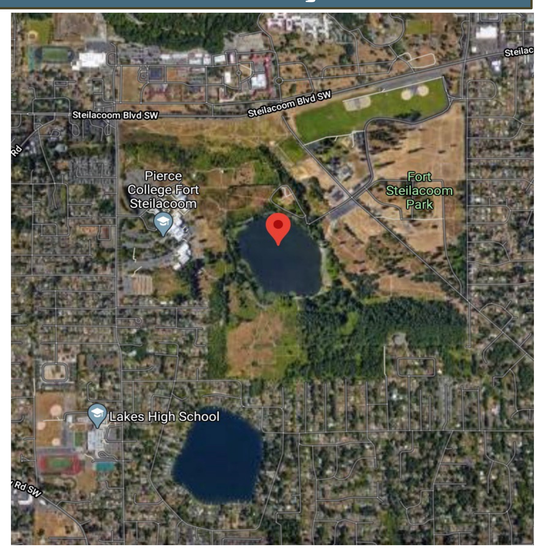


Figure 3. Waughop Lake, located in Fort Steilacoom Park Lakewood, Washington.

Water Column Chemistry

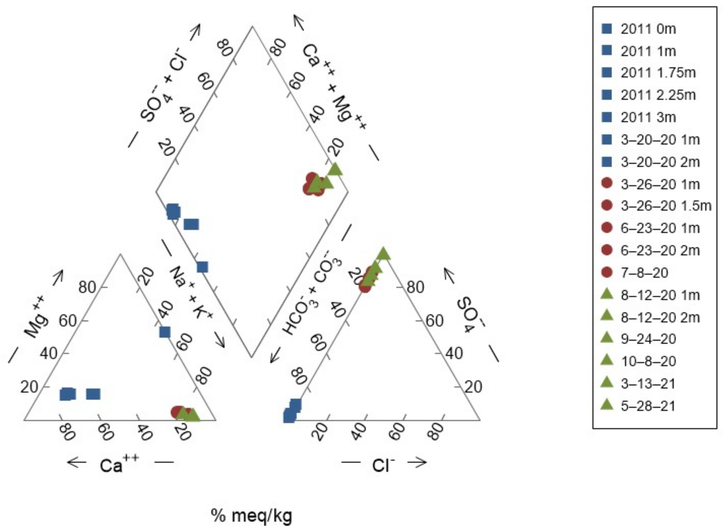


Figure 4. Piper diagram showing chemical balance of Waughop lake before and after both alum treatments. Blue squares = before first treatment, red circles = after first alum treatments and before second, green triangles = after second treatment. There is a noticeable shift in the lake chemistry after first treatment, and little change after the second.

- There has been a profound change to the chemistry of the lake.
- Not only have elemental concentrations been changed by the alum treatment, they have primarily stayed in their altered state.

Possible Fates of Sulfur

- Stays in the water column as SO_4
- Converted to H_2S
  - Stays in pore water
  - Escapes as gas
  - Precipitates as sulfide bearing mineral (Pyrite)
- Precipitates as $Ca(SO_4)$ $2H_2O$
- Escapes as groundwater outflow

Sulfur Persists in the Water

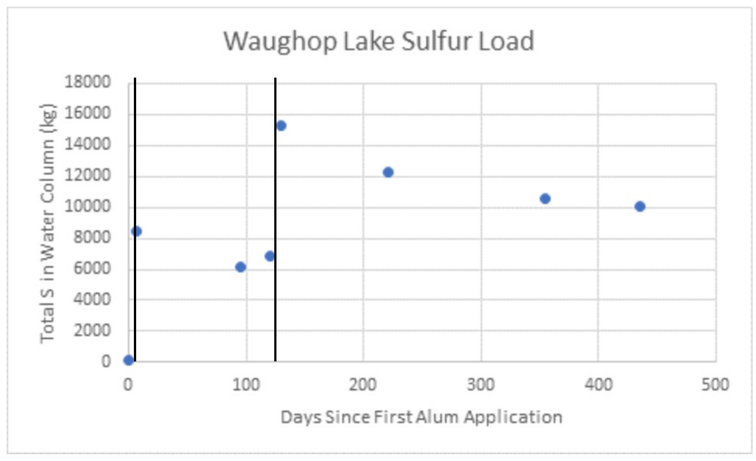
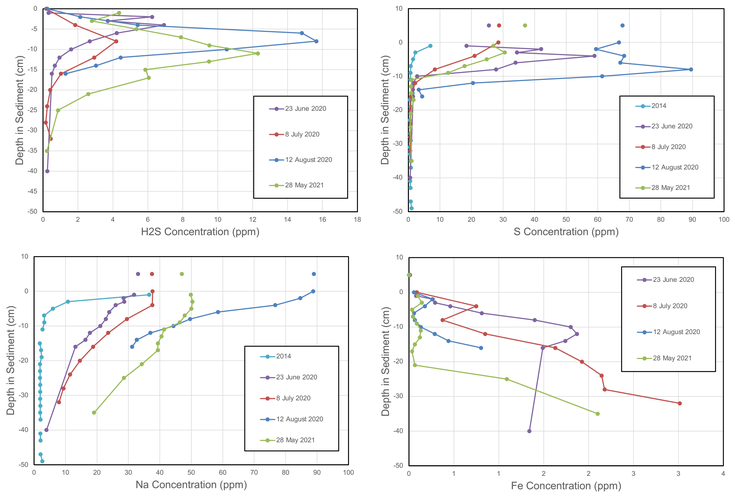


Figure 5. Plot of total sulfur in Waughop water column. Black lines represent dates of each alum treatment. After each treatment, a spike in sulfur content is observed.

Pore Water Chemistry



Figures6-9. Charts showing elemental concentrations in Waughop pore water on multiple sample dates. H_2S and S have similar trends showing gradual transference deeper in sediment across time. Na and Mg have inverse trends but both stay relatively constant across time.

Significant pore water findings

- Elemental concentrations vary due to concentrations in overlying water colum
- Water colum permeates to around 20 centimeters in the pore water.
- Increase in total H2S, S, and Na over time.
- Fe has remained mostly constant over time with small changes.

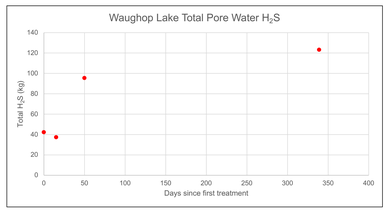


Figure 10. Total H_2S load in Waughop sediment showing steady increase over time. Values are too low however to be highly significant.

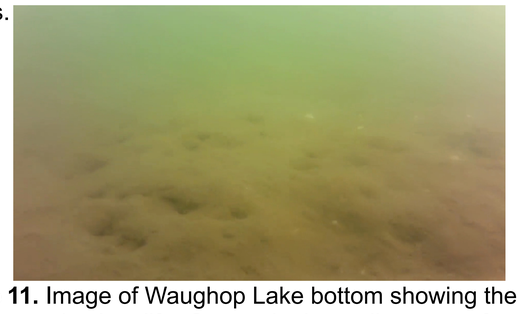


Figure 11. Image of Waughop Lake bottom showing the lack of rooted aquatic plant life. Craters in the sediment are from gas escape, likely carbon dioxide, methane, and/or hydrogen sulfide.

Further Work

- Continue to sample the water and sediment at Waughop lake to get a detailed analysis on the effects of alum over a longer period.
- Conduct experiments with a variety of aquatic plants and sediment samples to quantify the effect of elevated sulfur levels on plant growth.

Acknowledgments

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