# What’s in those socks? A synchrotron outreach study to analyze the properties of zinc in textiles under environmental pressure

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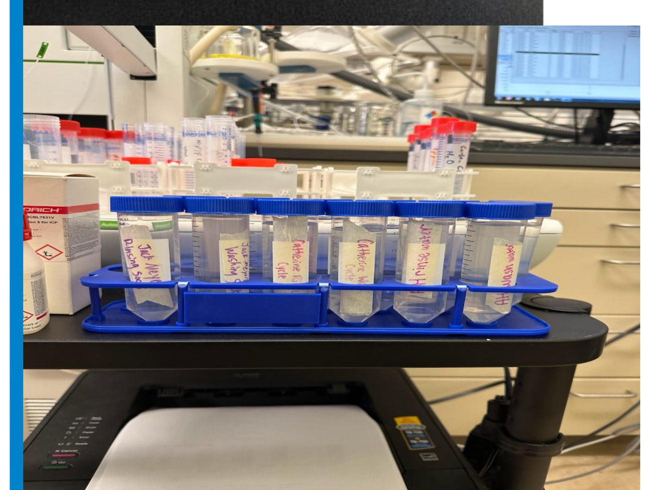
## ABSTRACT/MOTIVATIONS

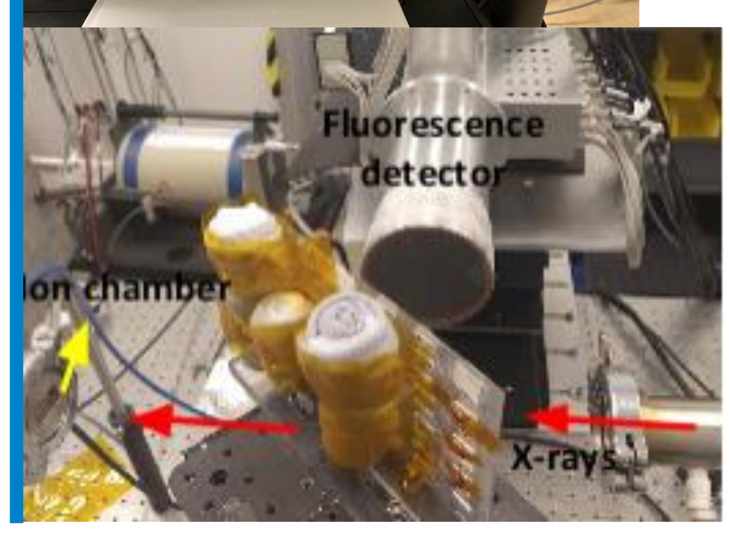
Zinc and silver are very similar in antimicrobial properties. However, when exposed to bacteria, zinc rusts, pulling electrons out from the cell wall of bacteria. The cell wall falls apart, thus killing the bacteria. As for silver, it is known to bind to bacteria which prevents it from performing basic functions [4].

The recent development of antimicrobial textiles, as well as research confirming harmful environmental effects of silver nanomaterials (Ag-NMs) in the textiles [2] has gathered concern on the use of zinc nanomaterials (Zn-NMs) in similar antimicrobial textiles. Various experiments have gathered data that the Ag-NMs decreased within the textile (sock) after wear [3], and it is believed the same will happen for Zn-NMs. If so, very little is known about the transformation of the zinc structure as the textile is worn, and the environmental impact also can be harmful.

For our experiment, we tested the properties of zinc with the use of zinc infused socks in exercise and washing cycles. We looked for zinc in different oxidation states (such as oxides), and if these states can be harmful for the environment if drained into the sewers. Our experimental groups consisted of light exercise (walking) and rigorous exercise (running) groups. Our control groups were an unused sock that is washed and an unused sock that is not washed. The socks were washed in the same washing machine as well as the same load. Each wash was one normal cycle and at the same temperature. The same detergent was used and the detergent was unscented [2].

At APS x-ray spectroscopy was used to analyze zinc’s properties after exercise and the washing cycle. We looked for new states that could be potentially harmful for the environment and how much of the zinc would be lost from the sock into the environment. The x-rays gave us a first-hand look at our zinc samples in fabrics of our experimental groups. These gave us a baseline if zinc can produce a less harmful alternative to silver.




## METHODS

- 7 pairs of socks: 6 worn, 1 control
  - 3 pairs assigned to “exercise”
  - 3 pairs in “walk” group
- Wore 20 hours, then removed and placed in a Ziploc bag to prevent contamination.
- Transparent Kapton tape was patted on the heel to collect any potential remnants of Zinc left on the skin.
- We placed the socks inside of a sealed container, then inside the washing machine to stimulate a wash cycle
  - Room temperature distilled water was used
  - The same amount of the same detergent was used
- The socks were then air dried and the water was filtered [2]
- We then performed X-ray absorption measurements to understand Zn composition [5] and ICP-MS measurements to understand elements present in the wash/rinse water.
- **Exercise group: Catherine, Jack, Maia**
- **Non-exercise group: Theo, Amanda, Rehman**

## X-ray Absorption Results

- **Figure 1:** XANES spectra at Zn K-edge for all the socks recorded at 20BM
- **Figure 2:** Comparisons between the zinc concentrations in our Kapton tape samples and the socks themselves.
- **Figure 3:** Similarities (in percentages) between different zinc crystal structures and the socks.
- **Each graph represented has a sample from both the exercise and non-exercise groups.**

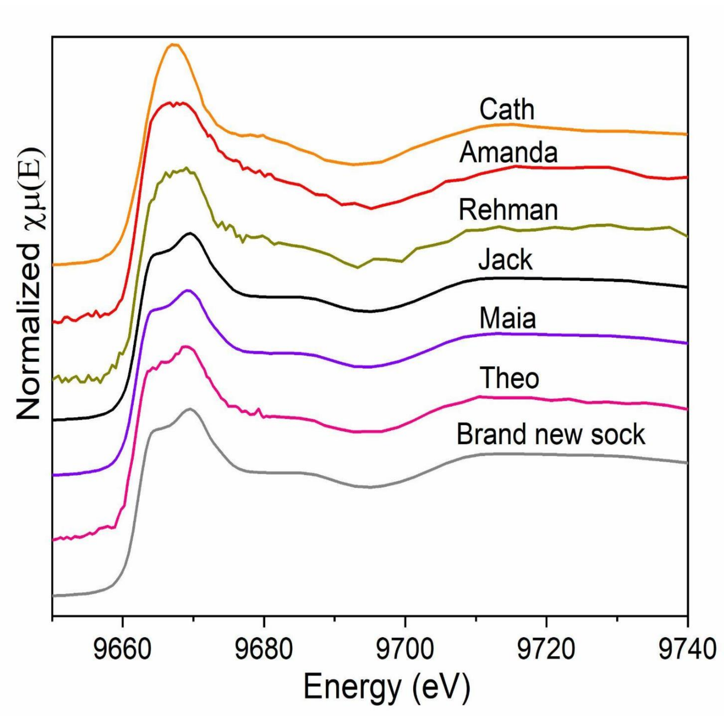



**Figure 1:** Socks XANES spectra at Zn K-edge

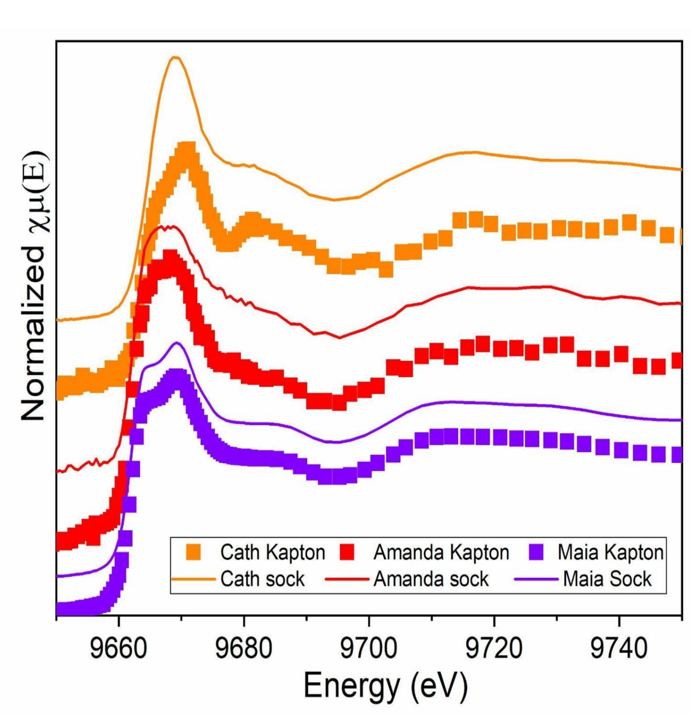



**Figure 2:** Comparison between sock and Kapton XANES spectra at Zn K-edge

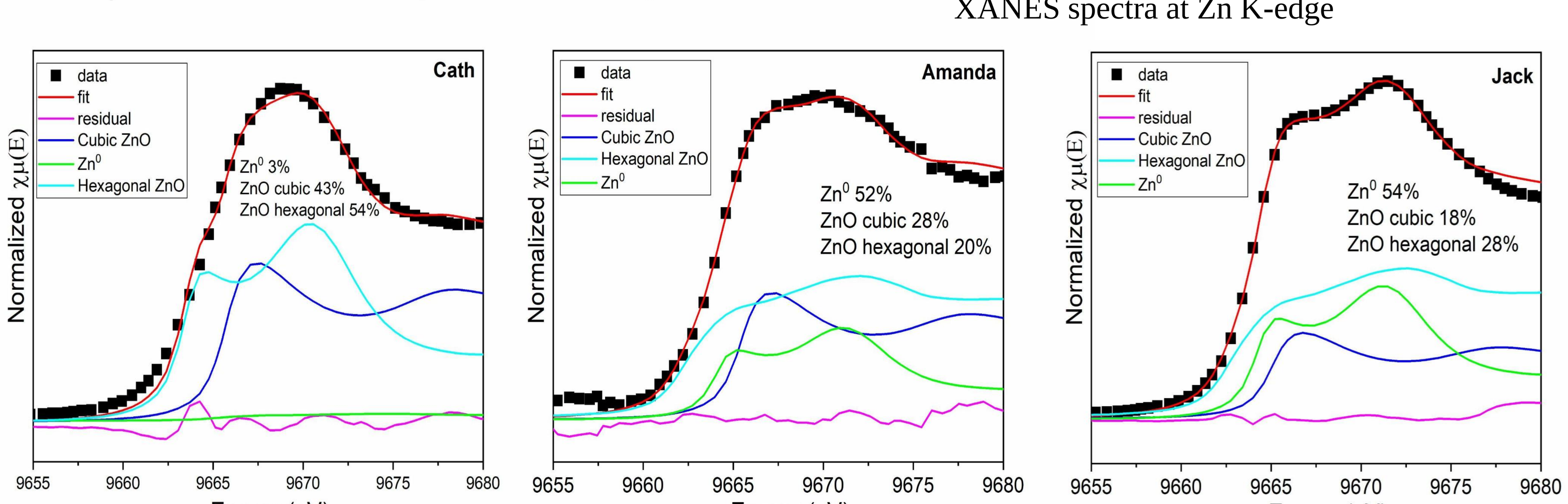
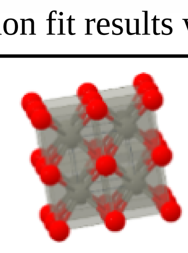
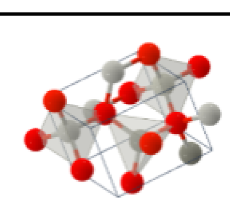



**Figure 3:** Linear combination fit results with weighted components

Zn Cubic:  Zn Hexagonal: 

## ICP-MS Results

**Figure 5**

- Concentrations of elements in our wash/rinse water samples were measured in ug/mL
- Zn was labeled as a medium element, and some of the major elements can be attributed to laundry detergent remaining in the wash/rinse samples.

**Figure 4**

- Zn concentrations in ug/mL were compared below. Exercise and nonexercise groups were compared with error bars for statistical significance
- None of the error bars overlap in the wash samples between the exercise group and non-exercise group.

**Figure 4**

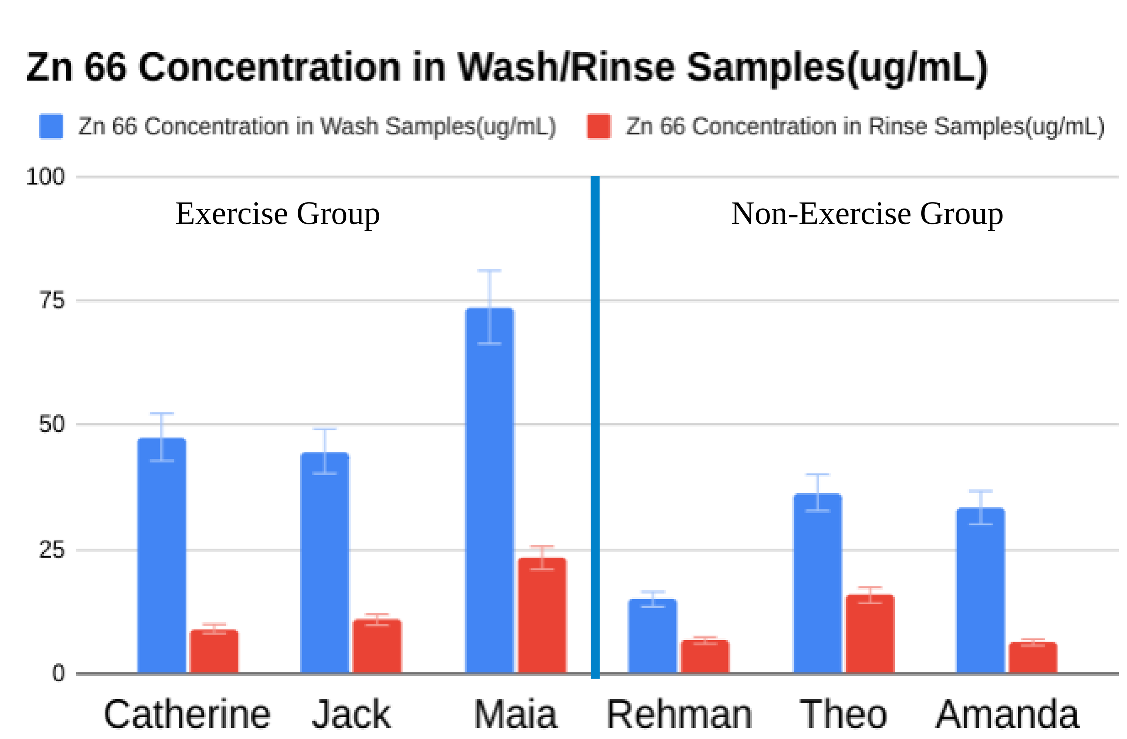



**Figure 5**

| Element Concentrations in Water Samples | |
|---|---|
| Wash Data: | Rinse Data: |
| **Major Elements (>100 ug/mL)** | |
| Ca | Ca |
| Mg | Mg |
| Na | Na |
| **Major/Medium Elements (5-100 ug/mL)** | |
| K | K |
| Fe | Fe |
| Zn | Zn |
| **Medium Elements (0.5-5 ug/mL)** | |
| Al | Al |
| Pb | Mn |
| Mn | |
| Sr | |
| **Small Elements (0-0.6 ug/mL)** | |
| Ag | Ag |
| Ba-2 | Ba-2 |
| Be | Be |
| Bi | Bi |
| Cd | Cd |
| Co | Co |
| Cr | Cr |
| Cs | Cs |
| Cu | Cu |
| Ga | Ga |
| In | In |
| Ni | Ni |
| Rb | **Pb** |
| Tl | Rb |
| V | **Sr** |
| | Tl |
| | V |

## CONCLUSIONS

- The species found in the Kapton are very similar to the ones found in the corresponding sock. This means that zinc is transferred to the skin with both mild and harsh weathering to the socks.
- Our three exercise participants have energy graphs that have similar trends, and the nonexercise groups do as well. From the XANES results, the exercise participants are more likely to have more hexagonal zinc in their socks. In comparison, non-exercise participants are more likely to have more cubic zinc. Further investigation would be necessary for one of the exercise participants since less metallic zinc was found on the sock.
- Exercise groups have more hexagonal ZnO than cubic ZnO
- Exercise groups have statistically significant ($p$-value $< 0.05$) increased concentrations of Zn in their wash water samples than non-exercise groups. Two out of the three participants in the exercise group had higher zinc concentrations in their rinse water samples than the non exercise group. Zinc Oxide in water can harm coral reefs and sea creatures. ZnO can cause inflammation if in high amounts, which our study has not shown concerns for.

## REFERENCES

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