Keratin-based Adsorbents for the Removal of Heavy Metals from Water

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GOALS & OBJECTIVES

Goal: To determine the feasibility of keratin-based adsorbents to remove heavy metals from water

Objectives: (1) Proof of concept for keratin as adsorbent
(2) Sand bed integration

Materials Synthesis
- Aerogel formation
- Extraction process

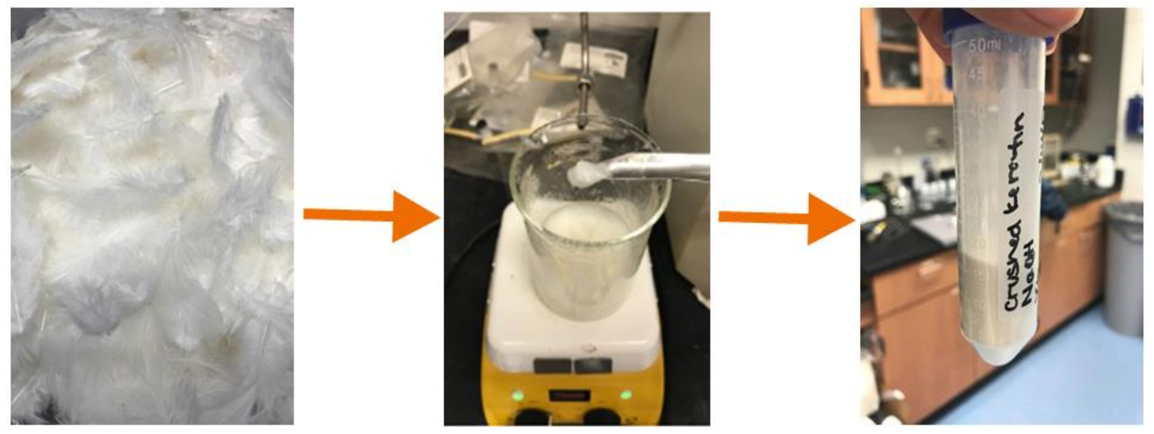
Materials Characterization
- Thermogravimetric Analysis (TGA)
- Differential Scanning Calorimetry (DSC)

Batch Trials
- Isotherms and temperature trials
- Measured using Ion Selective Electrode (ISE)
- Validated ICP Atomic Emission Spectroscopy

Sand Bed Integration
- Small and large scale
- Flow calculations using Darcy's Law

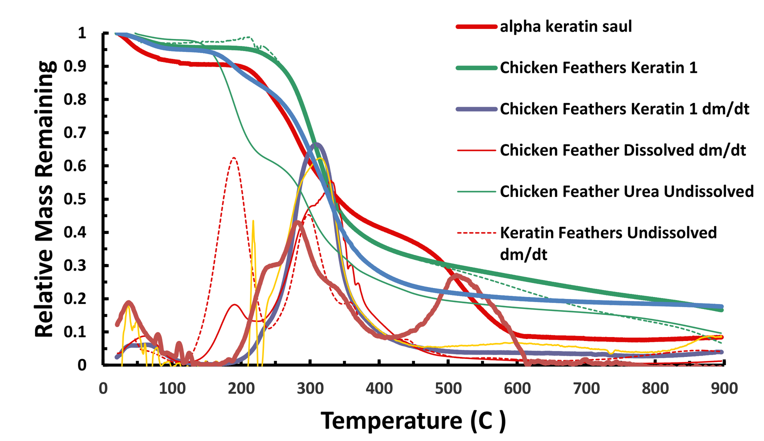
EXTRACTION

Extraction was achieved by hydrolyzing the feathers with NaOH and sodium bisulfite. The sample was centrifuged and washed, to remove undissolved feathers, then freeze dried. It was crushed into a fine powder to be used in the batch adsorption trials.

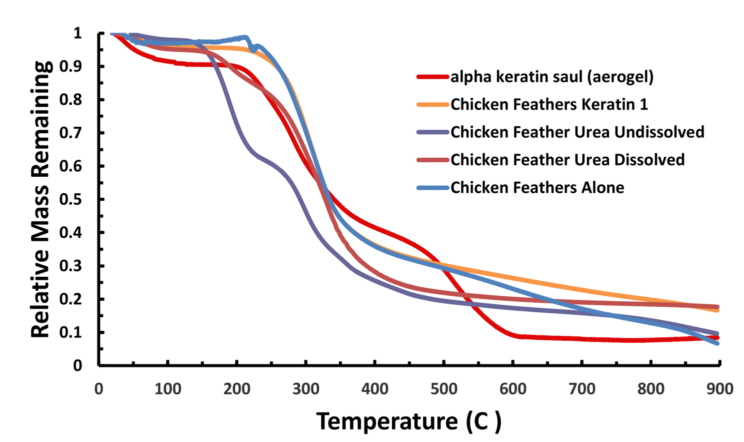


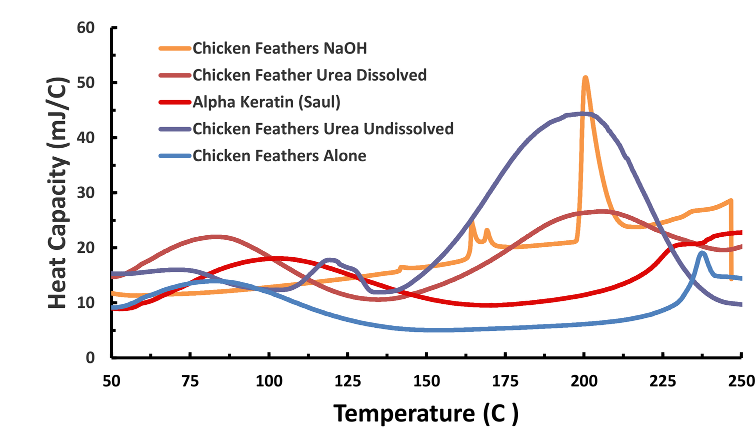
A variation of this method was conducted using urea and cysteine to hydrolyze the feathers. The pH was adjusted to 10.5 with NaOH. HCl was added to the remaining solution to extract the keratin. The rest of the process remained the same.

CHARACTERIZATION

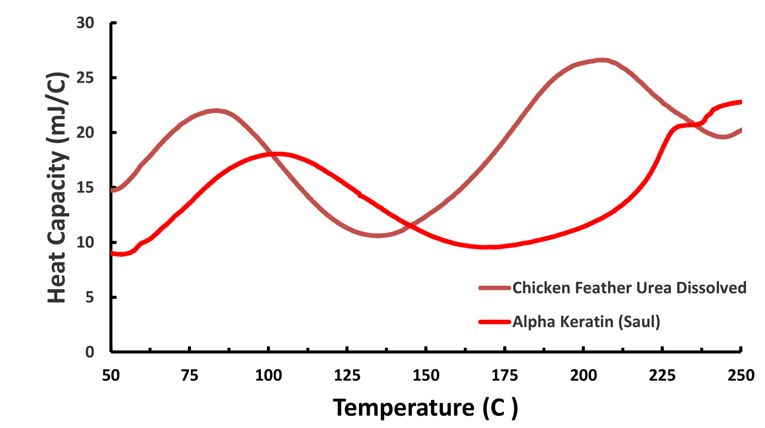


TGA results, above and below, show the varying thermal stabilities of all keratin samples tested. The mass temperature profiles are indicative of the types of polypeptide bonding in the structures.

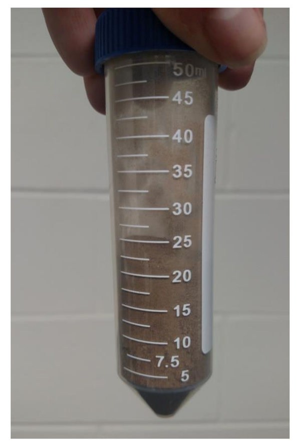




DSC results for all keratin is shown above. Below, it is shown that the urea chicken feather extraction most closely mimicked the pattern of the high molecular weight alpha keratin sample.

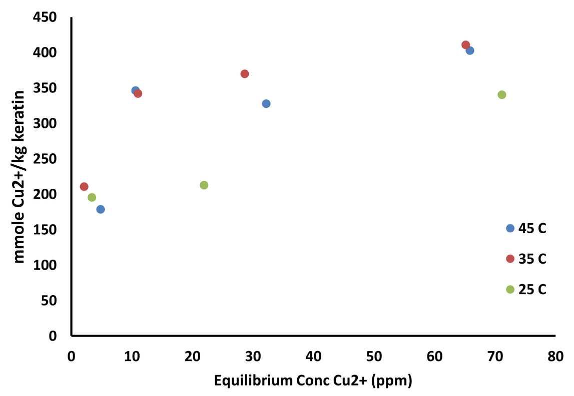


BATCH TRIALS



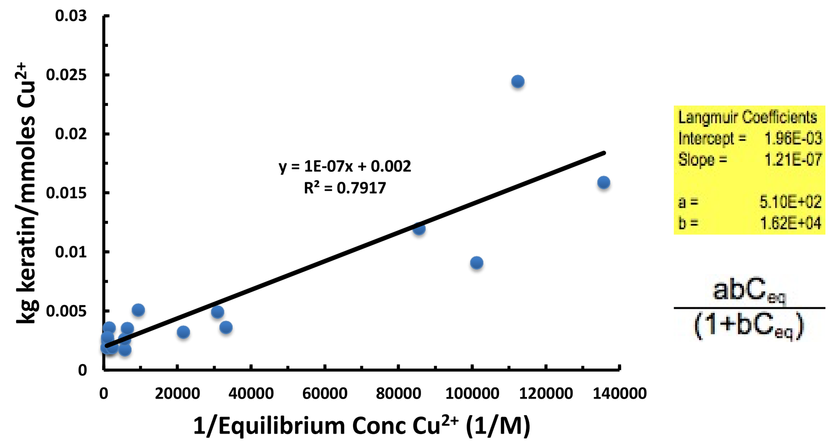
The properties of keratin allow it to bind to metals. To accomplish this keratin needs a distinct form to accomplish binding in a setting that can applied to real-world filtration. Both high and low molecular weight samples were considered, with the alpha keratin being selected for further testing.

A sample of this aerogel was prepared by making a 15 wt% solution of keratin in water, freezing it overnight at -80 Celsius, and then putting this sample into a lyophilizer for several days to dehydrate the gel. This yielded a solid network of cross-linked keratin. This resulting aerogel was crushed and placed in copper solutions



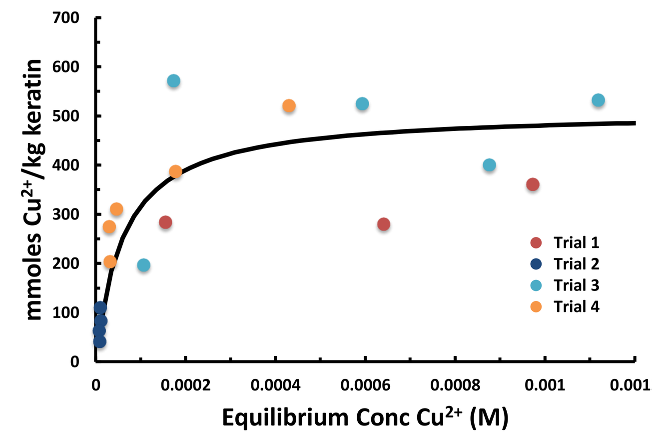
The data from the three temperature controlled trials was analyzed separately to determine if temperature had any impact on adsorption, which could indicate whether it is chemical or physical adsorption that occurs. While there is some scatter shown, overall it does not appear like there is any impact on adsorption capacity based on temperature.

Six samples were used to create an adsorption isotherm. The samples each had 15 mL of solution in them, ranging from 0 to 10 ppm copper. Each sample also contained 20 mg of keratin aerogel. Once the samples were created, they were left for at least 24 hours before measurements were taken.



$$\frac{abC_{eq}}{(1+bC_{eq})}$$

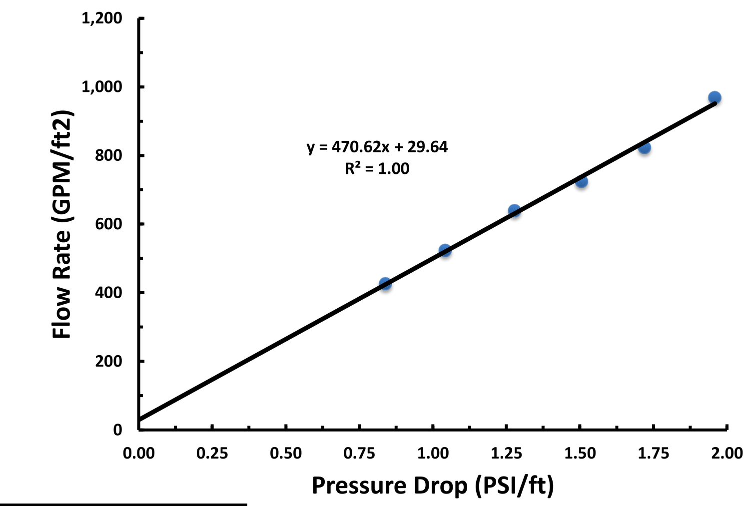
The linearized model of adsorption isotherm trails shows the adsorption capacity of the keratin.



Using the Langmuir model above, the adsorption capacity of keratin is seen at approximately 450 mM copper/ kg keratin.

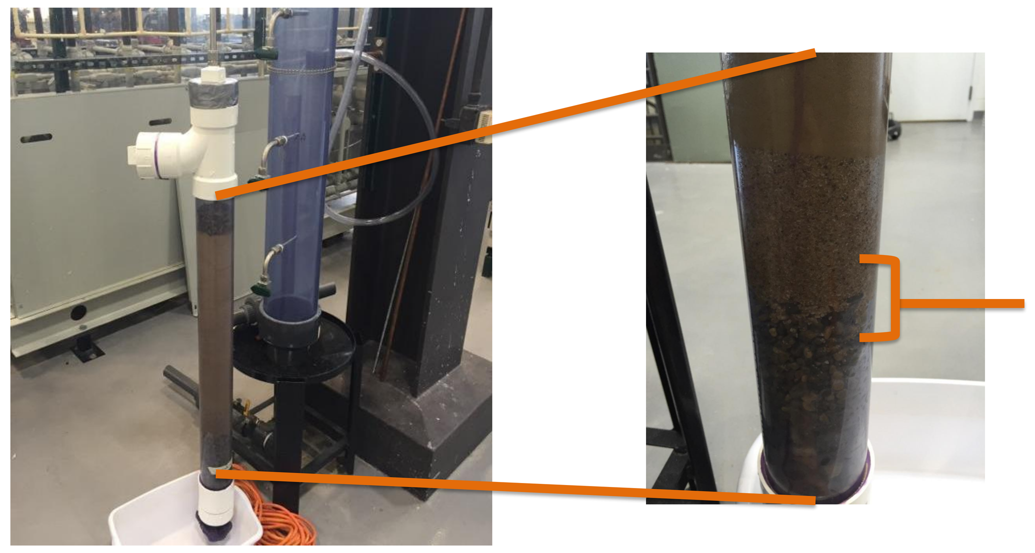
APPLICATION

This shows a linear fit between the pressure drop and the water flow rate through the sand filter. This will allow the application to be effectively scaled to the needs of the communities that are being affected.



Sand Height:	1.63	ft
Surface Area:	0.20	ft²

Trial	Average Water Height (cm)	Pressure$_a$ (Pa)	Flow Rate (L/day)	k (cm2)	Pressure Drop (PSI/ft)	Flow Rate (GPM/ft2)
1	224	22000	288	3.67E-08	1.96	969
2	197	19300	245	3.55E-08	1.72	823
3	172	16900	215	3.57E-08	1.51	724
4	146	14300	190	3.71E-08	1.28	639
5	119	11700	156	3.73E-08	1.04	523
6	96	9400	127	3.77E-08	0.84	426



Proposed keratin aerogel layer

NEXT STEPS

As part of a larger ongoing research effort, this project will be continued by other student groups at Miami in the future. Further necessary work would involve pH-controlled adsorption trials, additional temperature trials, adsorption with other metals, SEM pictures of keratin samples, and further experimentation with extraction methods for the chicken feathers. Long term goals also include testing and implementation in Engineers Without Borders projects abroad to combat water quality issues.

While there is further research needed before implementation into community systems, the cost comparison is a promising factor when the extracted keratin is used. The price of this is less than bottled water, with the additional benefit of creating a value-adding product from what would normally be chicken feather waste.

Source	Cost/Liter ($/L)
Lab grade beta-keratin	$3.00
Chicken feather extracted keratin	$0.003
Bottled water	$0.18

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