Team Members: Aaron Ramos, Jane Vo, David Lin, Marianna Perez, Rebecca Albers, Animesh Mohapatra, Briege Keenan, Hailey Morris, Yang Han, Isabella Aureguy, Mireya Vivar

ACTIVE WATER TREATMENT

UC San Diego JACOBS SCHOOL OF ENGINEERING
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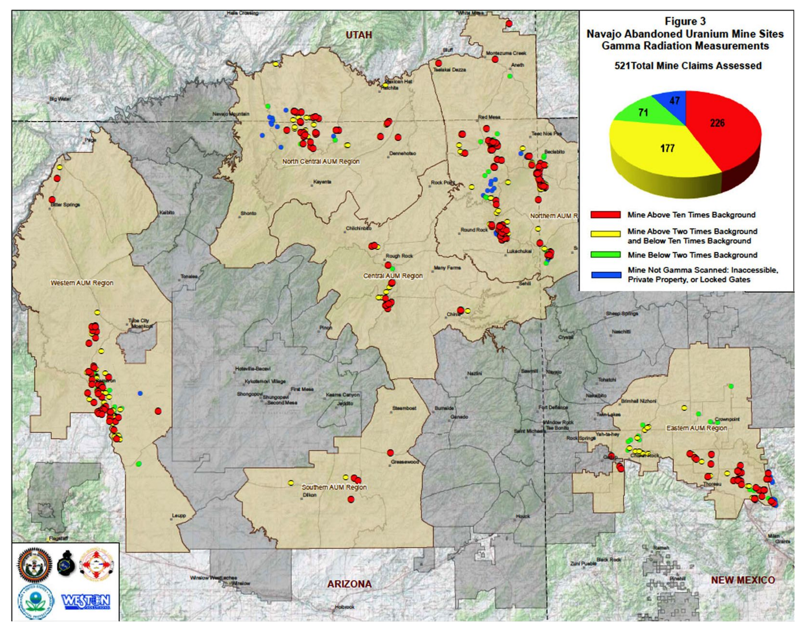
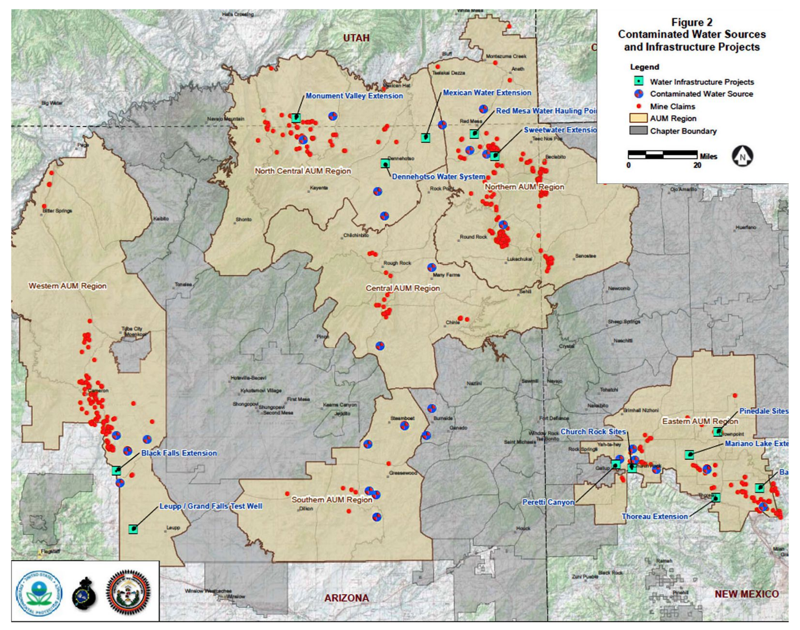
BACKGROUND

Since the 1940s, decades of irresponsible uranium mining within the Navajo Nation caused natural uranium-containing minerals to pollute the nearby sources of water. The Navajo people have consumed this contaminated water for generations, resulting in alarming trends in hereditary illnesses and birth defects within the population.



Abandoned uranium mine locations in the Navajo Nation.



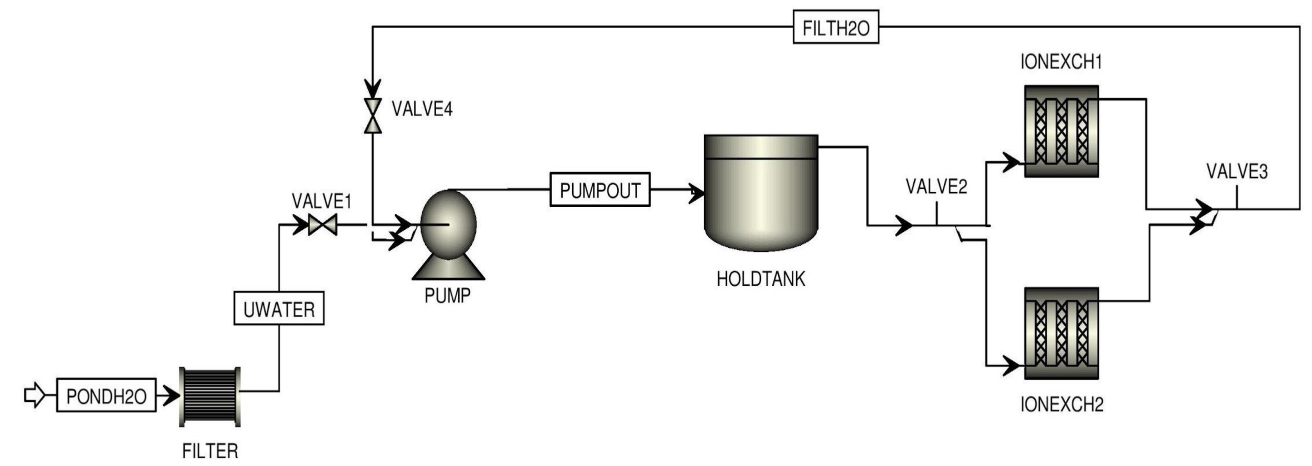
Contaminated water source locations in the Navajo Nation.

Contaminated soil from 540+ abandoned uranium mines are slowly being excavated, but 240+ water sites need to be treated in a timely manner to prevent the propagation of illnesses. The scale and urgency of the situation rule out more conventional water treatment methods, making for a challenging engineering problem.

OUR GOAL

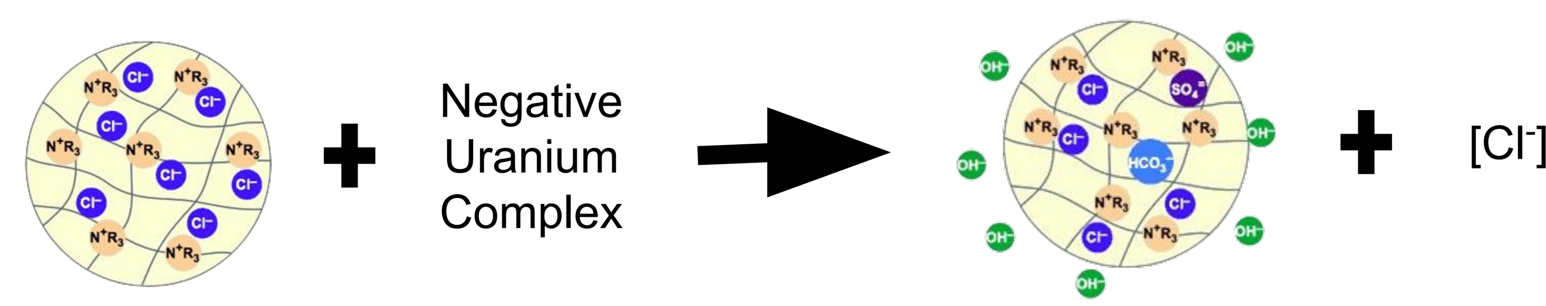
Active Water Treatment's mission in the Navajo Nation is to remedy substandard living conditions by removing the radioactive heavy metal contaminants from local sources of water. Specifically the well "3A-155" in Tohatchi Spring.

OUR DESIGN



Contaminated water is drawn up from the site and goes through a preliminary filter before being stored into the tank. It is then cycled through a packed column filled with resin beads that adsorb uranium complexes and other contaminant ions. The two columns can alternate between absorption and regeneration to maximize efficiency.

ION EXCHANGE



Harmful uranium complexes are exchanged for harmless ions like chloride.

Our device operates using anion exchange, which uses small, porous beads of polymer resin with ionic leaving groups. Specific resins have a greater affinity for select ions, which makes ion exchange ideal for our purpose.

We adjust flow and material parameters to maximize rate of uranium adsorption to the resin, while minimizing likelihood of pipe and column cavitation using the Extended Bernoulli Equation to estimate and minimize pressure drops.

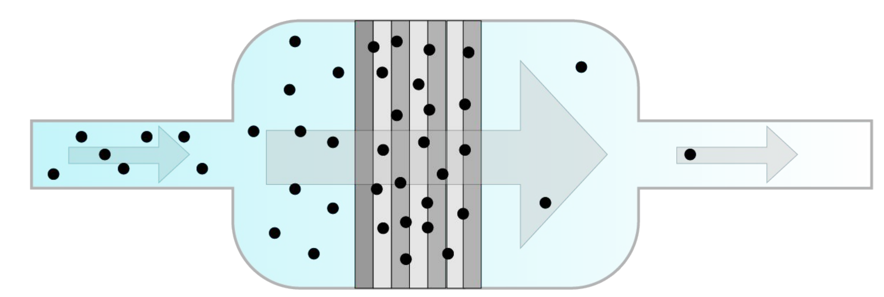
$$\Delta(\frac{P}{\rho g} + \frac{v^2}{2g} + z) = \pm h_s + \sum h_l$$

We assume steady-state laminar flow, treating couplings as slightly rounded reentrants or expansions, and consider the tank as a large reservoir.

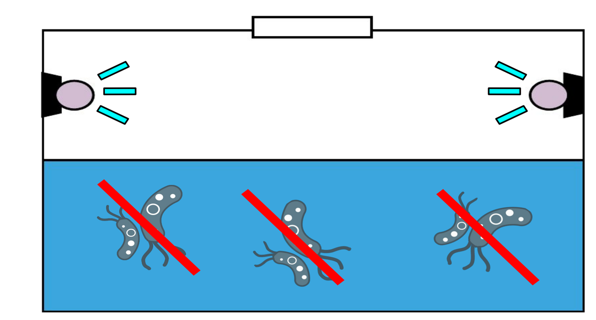
WATER FILTRATION

In addition to an ion exchange column, pre and post filtration elements will be incorporated. An activated carbon filter uses the extremely high surface area of processed charcoal to remove volatile organic compounds (VOCs), sediment, taste and odor through chemical adsorption. This is a highly effective and fairly low cost method to enhance the drinkability of the water that is being treated.

Activated Carbon Pre-Treatment



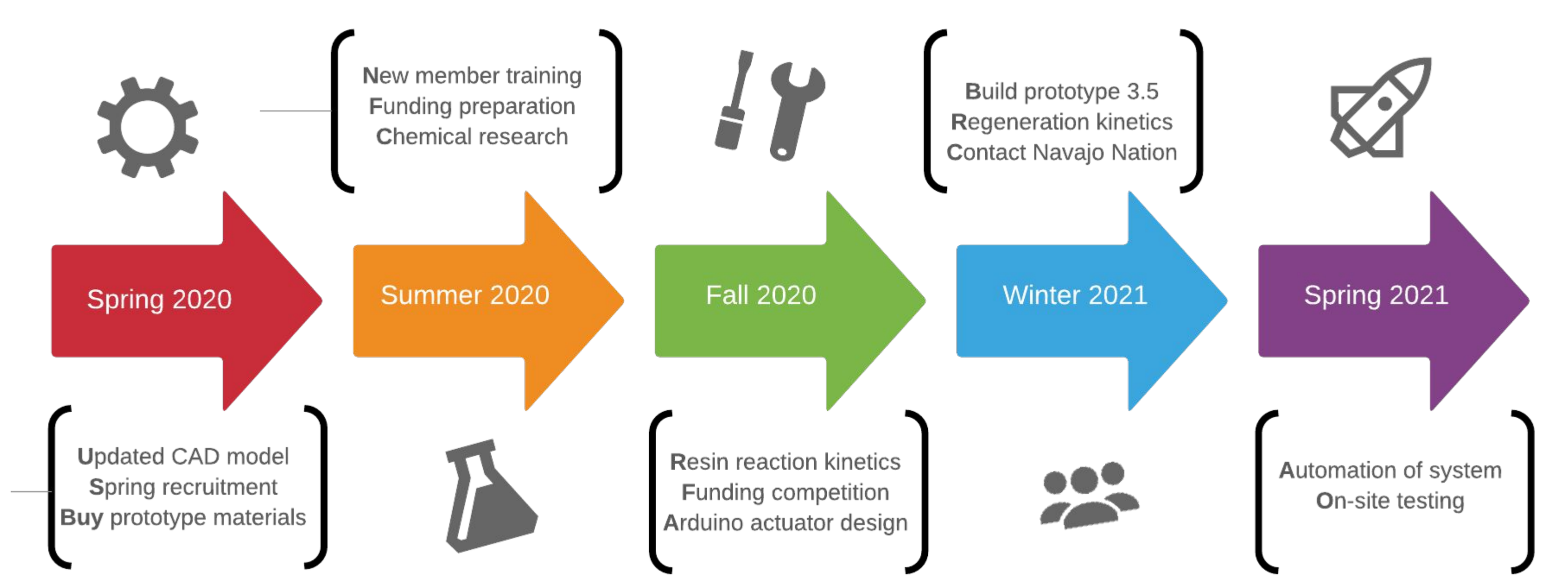
UV Post-Treatment



For the treated water to be drinkable, microbes and viruses must also be effectively removed. We plan to use UV lamps to sterilize the water as it sits in the tank. UV has been proven to be an effective, low-maintenance method of sterilization and already has applications in home filtration units. It also uses relatively low energy, making it a desirable sterilization method.

FUTURE PLANS

We plan to do further testing with other heavy metal ions. We can then optimize design parameters such as flow rate, column geometry, and material properties by adjusting the components of the mechanical build.



Active Water Treatment

Project Managers: Jeremy Wan and Ricky Huang
Team Members: Aaron Thomas Ramos, Jane Vo, Guangze Wang, David Lin, Marianna Perez, Rebecca Albers, Animesh Mohapatra

Background

Since the 1940s, decades of irresponsible uranium mining within the Navajo Nation caused natural uranium-containing minerals to pollute the nearby sources of water. The Navajo people have consumed this contaminated water for generations, resulting in alarming trends in hereditary illnesses and birth defects within the population.

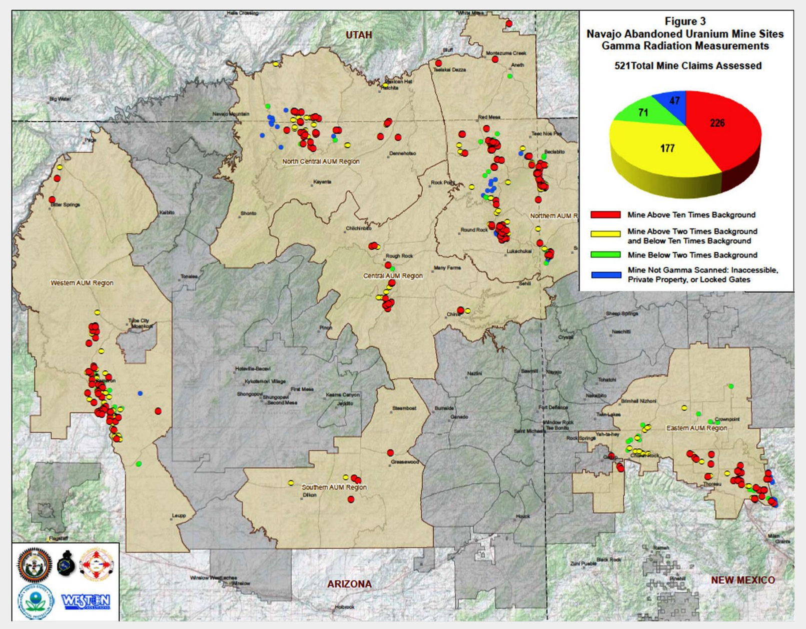


Fig. Abandoned uranium mine locations in the Navajo Nation.

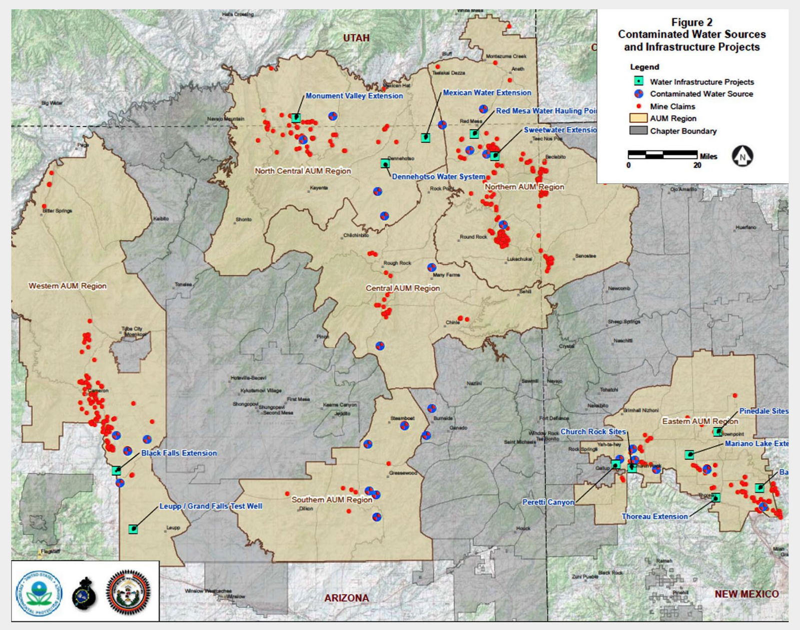
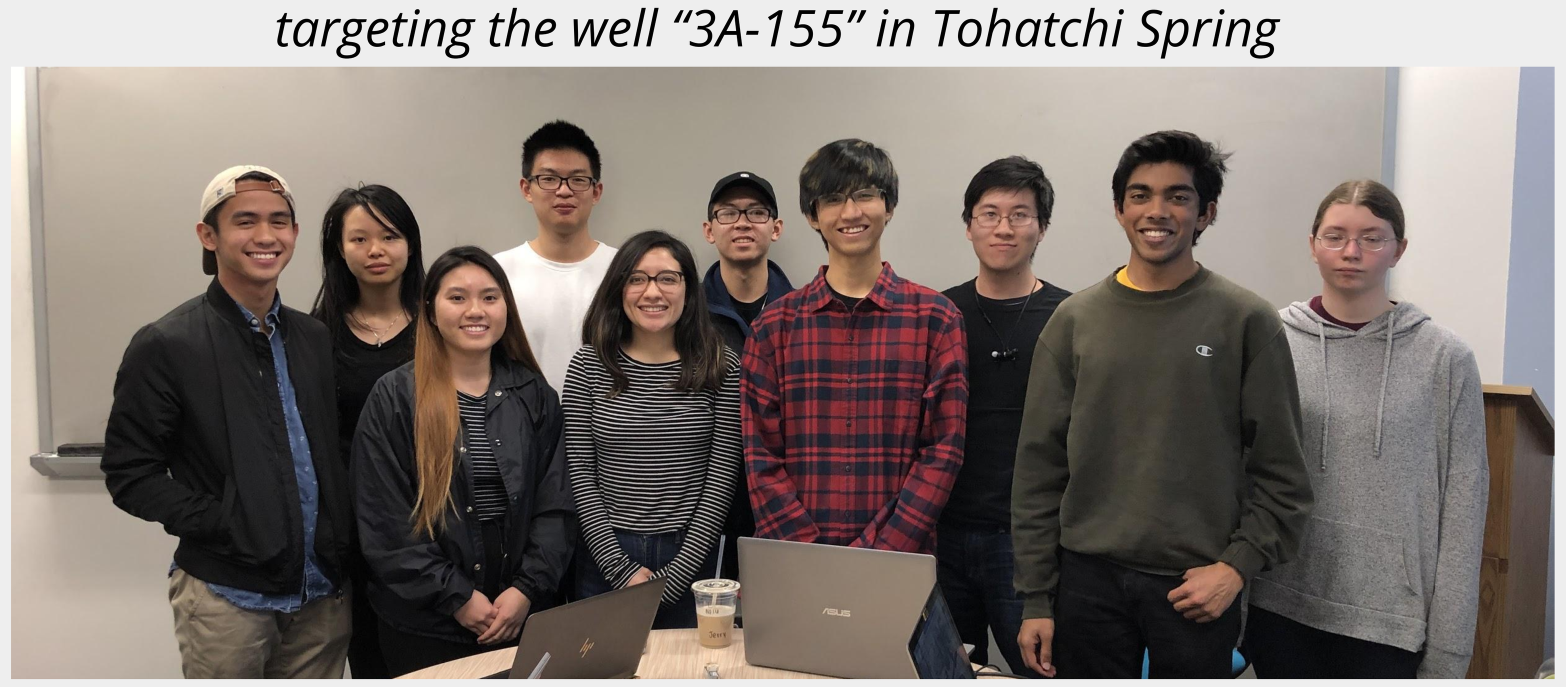


Fig. Contaminated water source locations in the Navajo Nation

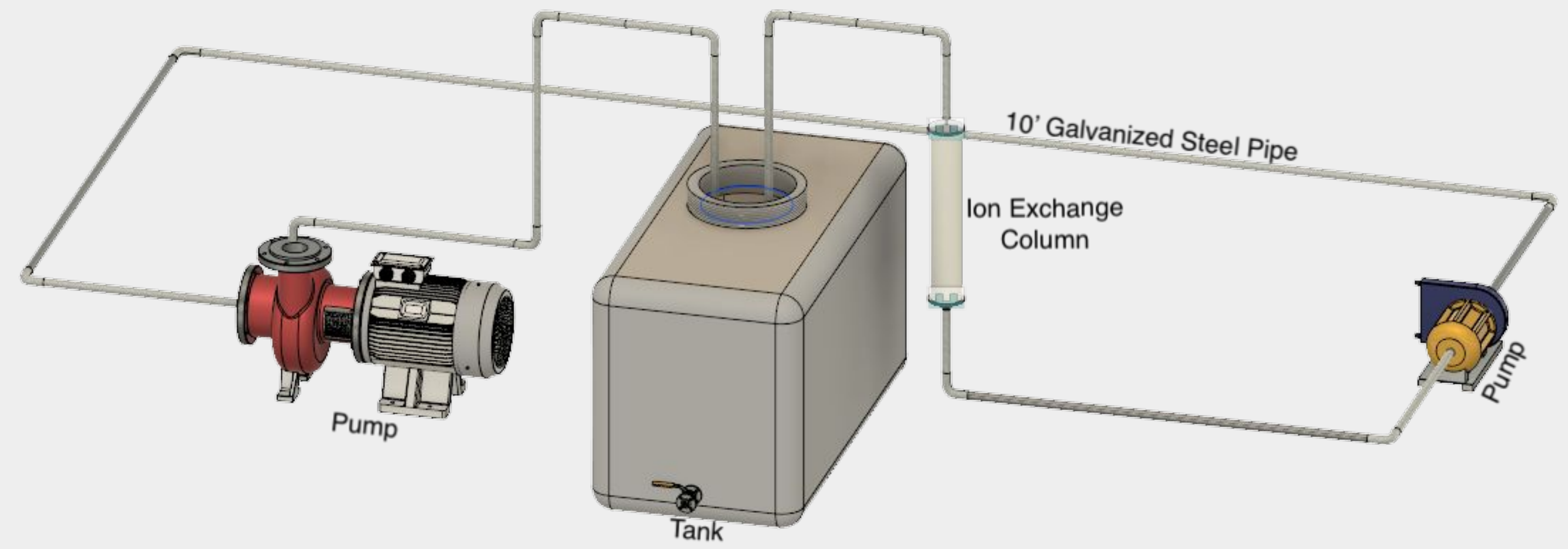
Contaminated soil from 540+ abandoned uranium mines are slowly being excavated, but 240+ water sites need to be treated in a timely manner to prevent the propagation of illnesses. The scale and urgency of the situation rule out more conventional water treatment methods, making for a challenging engineering problem.

Our Goal

Active Water Treatment's mission in the Navajo Nation is to remedy substandard living conditions by removing the radioactive heavy metal contaminants from local sources of water. Specifically, we are targeting the well "3A-155" in Tohatchi Spring



Our Design



Contaminated water is drawn up from the site into the tank and is then cycled through a packed column filled with XAD-4 resin beads that adsorb uranyl and other contaminant ions. Once purified, the resin can be regenerated and the concentrated uranyl stream can be collected.

Mechanisms

We adjust flow and material parameters to maximize rate of adsorption while minimizing likelihood of pipe and column cavitation using the Extended Bernoulli Equation to estimate and minimize pressure drops.

$$\Delta\left(\frac{P}{\rho g} + \frac{v^2}{2g} + z\right) = \pm h_s + \sum h_l$$

We assume steady-state laminar flow, treating couplings as slightly rounded reentrants or expansions, and consider the tank as a large reservoir.

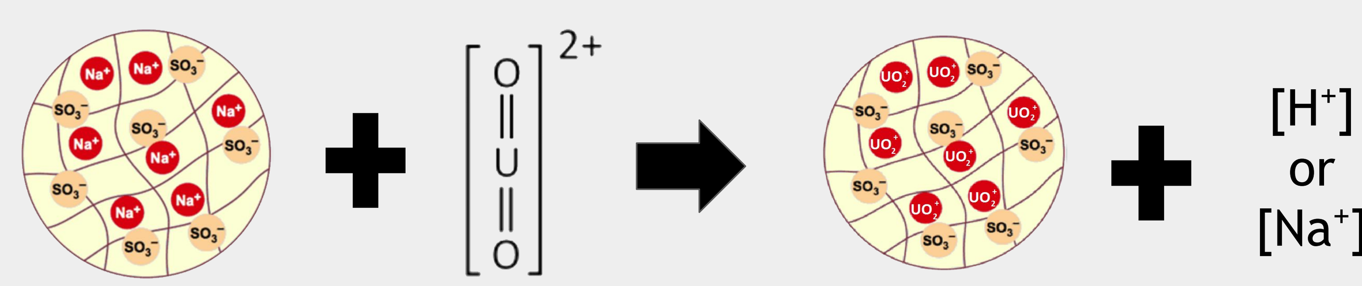


Fig. Harmful ions like uranyl are exchanged for harmless ions like hydrogen or sodium cations.

Our device operates using ion exchange, which uses small, porous beads of polymer resin with ionic leaving groups. Specially designed resins have a greater affinity for specific ions and it is this high selectivity that makes ion exchange ideal for our purpose.

Detection Method

The conductivity of a solution bears a strong correlation with the total concentration of dissolved ions. We can calibrate this relationship to determine even ultratrace concentrations of dissolved uranyl, which we can then employ to track concentration as the device runs water through.

Fig. Taking conductivity measurements with known concentrations.

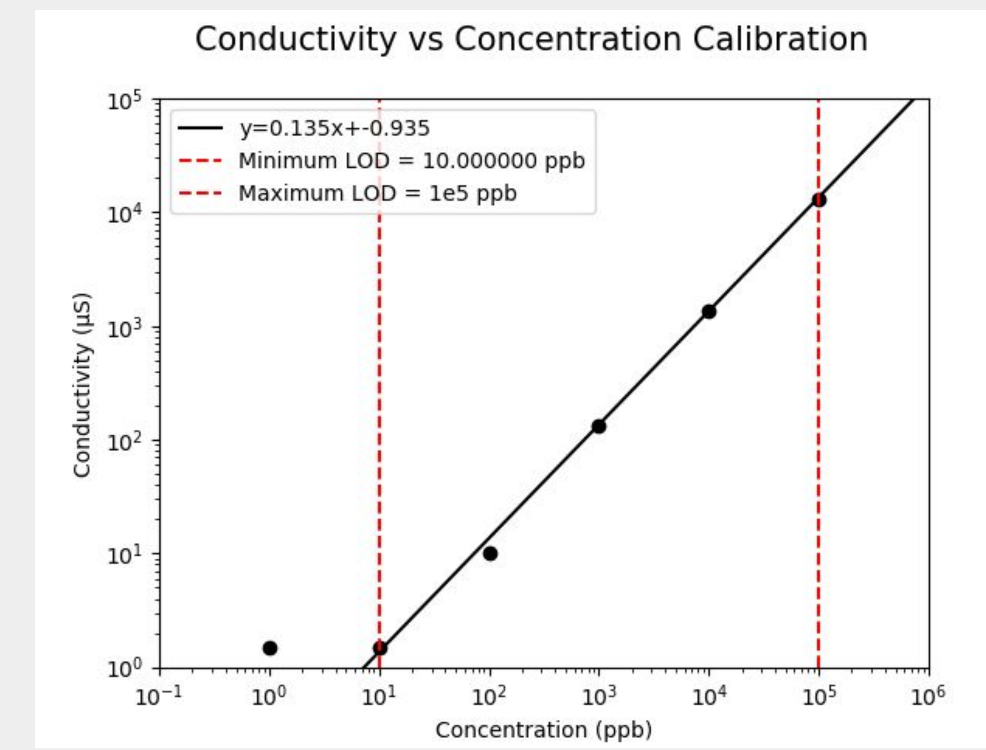
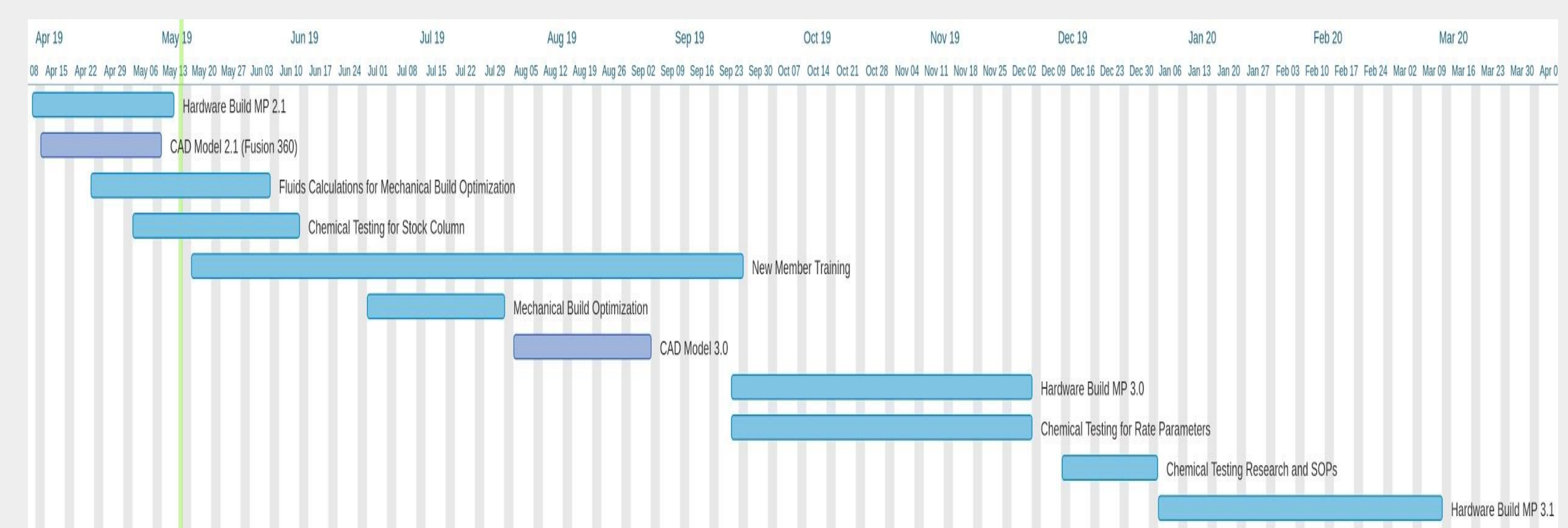


Fig. A linear fit of the concentration of a solution with respect to the reading of our conductivity probe.

Future Plans

We plan to do further testing with other heavy metal ions beyond zinc. We can then optimize design parameters such as flow rate, column geometry, and material properties by adjusting the components of the mechanical build.



Our current roadmap outlines the steps that we will take to bring a fully functional prototype to the Navajo Nation by the spring of 2020. Results from on-site testing may give insight to further optimization and possible automation of the device. Finally, engineers from the Navajo EPA can be trained to operate and maintain the device.