Sustainability at Penn State:

The filtration of Wastewater with Alum

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Introduction:

Alcoa (Aluminum Company of America) is the world’s third leading company in the production of aluminum, fabricated aluminum, and alumina combined, through its active and growing participation in all major aspects of the industry: technology, mining, refining, and recycling. Alcoa’s aluminum was used in several products such as but not limited to aircrafts and automobiles. However, Alcoa wants to extend the use of aluminum in the industry and use it in a service or a product that promotes sustainability and an eco-friendly environment.

Summary:

For this project, we were supposed to consider Alcoa’s goals, which were improving an aspect of University Park’s campus using aluminum through an economically feasible and realistic approach. We started off our project by looking at several properties and traits that aluminum possesses that would make it beneficial to solve some problems that our campus faces. Then, we found that aluminum’s resistance to corrosion as a result of the thin surface layer of aluminum oxide that is formed when the metal is exposed to air can be used in several ideas. We decided to use Aluminum’s trivalent cation property in Aluminum Potassium Sulfate, which is also known as alum, to re-filter some form of water on campus so that it can be used more efficiently and thus less costly.

Customer Needs Analysis:

Alcoa is currently the leading producer of aluminum in the world. Their products range from automotive and aerospace parts to building and construction to consumer electronics. Because aluminum can be recycled infinitely, Alcoa is very interested in recycling aluminum and using its properties to create a more sustainable world. In this project, Alcoa’s main focus is to
develop an aluminum product that can be implemented on the Penn State University Park Campus to make the campus a more sustainable place. The product must be cost effective, satisfy regulatory codes, and be applicable to the Penn State campus. We decided that the use of aluminum and the sustainability of the product were the most important to Alcoa.

### Potential Solutions

We had several options to choose from that could solve the problem we wanted to treat, which is the treatment of water through water filtration, so we had to do a matrix selection to assess which of the solutions would be the best to go with.

<table>
<thead>
<tr>
<th>Water Conserving Method</th>
<th>Rain barrels and rainwater filtration</th>
<th>Gutters and Rainwater Filtration</th>
<th>Wastewater Filtration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>weight</td>
<td>scores</td>
<td></td>
</tr>
<tr>
<td>Feasibility</td>
<td>26%</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Cost</td>
<td>20%</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Use of Aluminum</td>
<td>27%</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>27%</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Total Score</td>
<td>4.69</td>
<td>6.13</td>
<td>6.99</td>
</tr>
</tbody>
</table>
After deciding that our idea will be about water filtration, we had to choose between the filtration of rainwater using either rain barrels or gutters and the filtration of wastewater. Our decision of which form of water we would filter came from comparing all three kinds of water in terms of feasibility, cost, use of aluminum, and effectiveness. After determining the weight we wanted to assign for each of the criteria, we assessed all three of them and came to the conclusion that wastewater filtration would be the most feasible, least costly, most effective, and most use of aluminum since its total was 6.99 while gutters and rainwater filtration got 6.13 points and rain barrels and rainwater filtration got 4.69 points.

Problem Statement:

We are trying to create a more sustainable Penn State by treating the waste water on Penn State’s campus using Potassium Aluminum Sulfate so that it can be used more efficiently.

Target Specifications:

For the filtration and reuse of wastewater, we would like to reduce Penn State’s current usage of water by about ten percent and filter the water enough so that it can be reused in water plants and athletic fields.

Where we are:

We are currently using about 3 million gallons of water per day on University Park’s campus. The primary sources that Penn State relies on are two well fields. However, the process of obtaining this water and filtering it and repairing it does not utilize all the resources available
and is very costly. Also, the water from the wells is extremely hard and causes scaling in the pipes which costs money for repairs.

Where we want to be:

We want to minimize Penn State’s investment in the process of collecting water by using the resources that are already available at Penn State more efficiently. That would also make our campus more environmentally friendly and sustainable.

How do we get there?

We would get the sustainable campus that both Alcoa and Penn State strive for by purifying waste water that is not being used efficiently. By filtering the waste water, we are using the water that is not being used as much as it could be, thus cutting down the expenses spent on obtaining the water from the wells. In addition, by reusing the waste water, we are preserving the fresh water for other uses where it might be necessary in processes such food and timber production, which means that we are maximizing the use of waste water, creating a more sustainable campus. The process of filtration will be done through the usage of Potassium Aluminum Sulfate.

Waste water filtration process

The filtration process itself goes has three stages, which are aeration, addition of Alum for coagulation, and lastly the filtration.

Aeration is the first stage of waste water treatment, which is the part where water is exposed to oxygen, thus increasing the concentration of oxygen in it. This step is crucial in water purification since it is the stage where water’s quality is improved so that it can be reused. Aeration helps with the filtration of water because it physically removes compounds that give the water some kind of taste and smell such as hydrogen sulfide along with other metals and gases.
Aeration is also used for biologically oxidizing domestic and industrial wastes such as the waste resulting from factories, mills, mines, or even just our house rubbish. The biological oxidation of wastes then becomes important because it makes them heavier, which makes them settle at the bottom.

The second stage of water filtration is the addition of alum to the wastewater for coagulation. Coagulation is the formation of semi-solid lumps in a liquid. The added alum neutralizes the charge on colloidal particles floating in the water. This allows them to stick together and can be shown in the formulas below:

\[
\text{Al}_2(\text{SO}_4)_3 + 3\text{Ca(OH)}_2 \rightarrow 2\text{Al(OH)}_3 + 3 \text{CaSO}_4
\]

\[
\text{Al}^{3+} + \text{H}_n\text{PO}_4^{3-n} \leftrightarrow \text{AlPO}_4 + n\text{H}^+
\]

Once the dirt particles and the floc are attached to each other, they become heavy and sink to the bottom during sedimentation. On large scales, sedimentation is the process of physically removing wastes from the water by relying on gravity. For example, dirt in rivers and running waters can be naturally removed since water’s flow follows gravitational motion. After the flocs form in the them, the sedimentation tanks, also known as secondary clarifiers, remove flocs created in some methods.

Lastly, the water undergoes the filtration process. The filtration step is simply removing the layer of dirt that was piled in the water from the previous steps. After that step is completed, the water goes through a heating system that purifies it from the remaining flavor and scent and any additional chemicals that might have not been removed. Then, the water goes back into a system that makes it usable.
Previous attempts at solving this problem

Many attempts were made to solve this method, some of which were successful while others were not. However, some of the primary treatments to this issue include bar screens, grinders, grit collectors, biofilter, and aeration ponds. Most of the previous steps take place at a facility called “headworks”, which is the first stop for the wastewater that will enter the plant. The bar screens are large screens that separate the water from trash, sticks, and other materials. Then, the grinder would grind up and wash the materials and send them off to a garbage disposal. The organic material in the wastes is flushed back into the waste stream to continue in the treatment process. After that, the sand and gravel are sent to a grit collector, which might either be recycled or sent to landfill depending on its cleanness. Then, the odor in the wastewater is treated in the biofilter, which is made of a mixture of wood chips and composts. Lastly, the water that is being filtered goes through an aeration pond, which is divided into two parts. The first part of the aeration pond is considered a primary classifier since it allows the smaller solids to settle at the bottom and the remaining of the material are sent off to a landfill. From there, the water is purified. The previous method is the one most commonly used, however, there are other methods to treat wastewater such as but not limited to secondary treatments and biosolid treatment.

Results of Our Experiment

After performing the experiment, we ended up yielding 50 percent of the water we initially started with. After making the wastewater using mud and water, we used a coffee filter to pull out the solids such as rocks that were in the mixture. After that, we ended up with a dirty liquid, and then the experiment told us to add a certain amount of Alum. Once we did that, the mixture formed a layer of pure water on top of the dirty water. By the end of thirty minutes our cup was divided into two equal halves, the top half was the clean water while the bottom half was the dirty water. If we were to boil the water on top, we would actually get water that we could drink. Pictures from our experiment are shown below:
Before Addition of Aluminum

After Addition of Alum

Water after complete Filtration
How does this idea interest Alcoa and meet their needs?

Since Alcoa’s strength appears in its aluminum production and wants to improve Penn State’s campus, this project meets both goals for several reasons. For example, this water filtration method obviously uses aluminum, thus highlighting Alcoa’s strength in the field while benefitting Penn State’s campus. Alcoa can invest in the production of alum which can be synthesized on a large scale using sulfuric acid and potassium hydroxide:

\[
2\text{Al} + 2\text{KOH} + 4\text{H}_2\text{SO}_4 + 22\text{H}_2\text{O} \rightarrow 2(\text{KAl(SO}_4)_2 \cdot 12\text{H}_2\text{O}) + 3\text{H}_2
\]

Penn State’s benefits because it will not need to collect more as much water. Instead Penn State can just utilize the water that was filtered. Also, since this project yields half the amount of water, Alcoa’s investment in such a project will give it a good image and reputation because the outcome is guaranteed. In addition, Penn State will not have to spend such large amounts of money for the obtainment of water and then its filtration as it before. Before, they did not make the most out of the water and sent it directly to the sewage. With the implementation of this project, the water is purified enough to be used for purposes such as watering the plants in Penn State’s fields and athletics, thus making our campus more sustainable.