ACID MINE DRAINAGE TREATMENT PUBLIC POLICY REPORT

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1. EXECUTIVE SUMMARY

Acid Mine Drainage (AMD) is the primary source of surface water pollution in the mid-Atlantic region, and affects over 10,000 miles of streams across the country. It occurs when water flows over or through sulfur-bearing materials, such as the pyritic rocks uncovered by the large earth movements involved in mining. The sulfur interacts with the water and produces an acidic solution that then drains into ponds, streams, and rivers. The acidic water solution also contains toxic heavy metals like iron which is released as a byproduct of the water-sulfide reaction. Other metals, such as copper, lead, and mercury, dissolve into the runoffs due to the solutions' acidity and further contaminate the water. AMD pollution can result in the loss of aquatic life, corrosion of infrastructure, and the restriction of the stream's recreational uses such as fishing. This water also cannot be used for public drinking water or industrial water supplies [1].

The Bettinger Group has developed a bio-inspired cation exchange membrane that has the potential to be used in AMD treatment, as it is able to bind many of the metals present in AMD. The unique advantage that their technology has over alternative ion exchange treatments is that it utilizes an electrical current to regenerate the membrane, rather than relying on a chemical reagent. Typically, the reagent used to regenerate the ion exchange membrane produces a hazardous waste. However, the Bettinger Group's novel technology makes it possible to avoid the additional expense of disposing of the hazardous solution [2].

After analyzing the situation on the basis of four components: issues, interests, institutions, and information, we concluded there were several paths the Bettinger Group could take to implement their technology: partnering with the government, partnering with commercial entities, and independent implementation. We further developed our argument by examining the following questions:

- What is the issue?
- Who are the actors?
- What are the actors' interests?
- In what arena do the actors meet?
- What information moves the issue in this arena?
- What assets do the actors need to prevail in this arena?[3]

At the conclusion of this analysis, we decided that in the short term, the Bettinger Group should focus on continuing their research and identifying the limitations and unique advantages that the technology has compared to alternative treatments. However, once the group has a better grasp of their technology, they should begin to reach out to potential markets such as the government and commercial entities. Between the two, commercial entities appear to offer more flexibility in regards to the technology's application and may be able to use it to its full potential. On the other hand, if the group is more concerned about benefiting the environment, then they may prefer to partner with the government, allowing it to be used on a wider basis for AMD treatment. This report details the positives and negatives of each strategy.

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1. EXECUTIVE SUMMARY

What is the Issue?

- What steps must be taken to implement the Bettinger Group's technology for Acid Mine Drainage?

Who are the Actors?

- The Government (EPA, OMSRE, State)
- Commercial mining entities
- Water treatment facilities
- Environmental groups

What are the actors' Interests?

- The Government (EPA, OMSRE, State): Treat AMD as cheaply and efficiently as possible
- Commercial mining entities: Cost savings on water filtration
- Water treatment facilities: Selling profitable, low-cost products
- Environmental groups: Cleaning up the environment

In what Arena do the actors meet?

- Policies regarding AMD treatment regulations and restrictions
- Policies regarding pollution levels in effluent discharged from industries
- The production and sale of water treatment materials

What Information moves the issue in this arena?

- Cost of AMD treatment technology production and maintenance
- AMD levels in industrial discharge or from abandoned mines
- Effectiveness and efficiency of AMD treatment technology

What Assets do the actors need to prevail in this arena?

- Working knowledge of the costs and limitations of their product
- The ability to test the product in an AMD environment
- Influence over the products application and implementation

2. TECHNOLOGY OVERVIEW

2.1 The Bettinger Group's Bio-inspired Cation Exchange Material

The Bettinger Group at Carnegie Mellon University is a research group seeking to employ the principles of polymer synthesis, materials science, and microfabrication in a variety of medical and biomedical technologies. They have previously been successful in the development of edible electronics and have published several papers on the subject of polymer synthesis. However, the group is now studying a new technology: a bioinspired cation exchange material, which has great potential for use in waste water management [1].

The material utilizes melanin, a compound capable of binding with a variety of cations commonly found in waste water draining from sources such as acid mines or hydraulic fracturing (fracking). Thus far, the preliminary testing indicates that material is able to successfully bind magnesium, chromium, cobalt, and zinc. All of these transition metals are highly acidic and some are also potentially toxic to the environment. However, all of these metals are commonly produced as a byproduct of the aforementioned mining and fracking industries [2].

One of the key features of this technology is its reversible cation exchange ability which utilizes an electrical current as opposed to a reagent. This means that the material can be cycled many times without need for replacement and it does not produce hazardous waste. Therefore, the material has potential to be a more environmentally-friendly alternative to current water filtration methods [2].

2.2 Potential Market – Acid Mine Drainage

Although the material is still in its developmental phase, there is a significant potential for use in the remediation of acid mine drainage (AMD). According to the U.S. Environmental Protection Agency (EPA), AMD degrades over 4,500 miles of streams in the mid-Atlantic region and is currently the primary source of pollution in surface water in the region. This pollution results in the loss of aquatic life and restricts the stream's recreation uses, impacting the local tourism industry. The stream can also not be used as public drinking water or for industrial water supplies. Additionally, the acidic nature of the polluted water corrodes infrastructure such as bridges, therefore it is both an ecological and economical concern [3]. Additionally, AMD is the largest environmental liability in the Canadian mining industry, costing somewhere between $2 to $5 billion dollars annually [4].

Unfortunately, it was not until the mid-20th century that the federal government began to institute environmental statues that held polluters accountable for the damage to the environment. Prior to the Clean Water Act (CWA), common law doctrines of tort and nuisance were the primary method for regulating mining damage. However, in 1972, the CWA and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) were passed and began to implement formal regulation for mining and other environmental damage caused by industries [5].

Although the CWA currently prohibits discharge over a certain pollution level, the U.S. Forest Service (USFS) estimates that there are currently 20,000 to 50,000 mines producing AMD, which can impact up to nearly 10,000 miles of streams across the entire country [4]. This is due to the fact that 90% of those mines are abandoned [6]. It is extremely difficult to find the original party responsible for these abandoned mines, as many of the lands have since been sold to new owners after the mines were depleted. This means the responsibility of AMD clean-up falls to the government [5]. Therefore, the Bettinger Group's technology may be of interest to the government.

However, for the 10% of mines that are not abandoned, the responsibility falls to the current owners and operators to ensure that any waste they discharge into the environment meets the current EPA standards, as outlined in the CWA. Industries are responsible for ensuring their own discharges meet the stringent standards set forth in the CWA regarding pH, metal content, and other factors [6]. This means that they, too, are likely interested in new water filtration technologies that may lower their operating costs.

2.3 Current Acid Mine Drainage Treatment Technologies

When it comes to treating AMD, each site is unique and requires the development of a strategy or approach that best suits the situation based on acidity levels, chemical composition, physical layout, volume to be treated, and source, among a variety of other factors. After extensive testing and measuring of all these components, it is possible to identify the most effective treatment option [7]. There are a variety of different methodologies which are generally broken down as so:

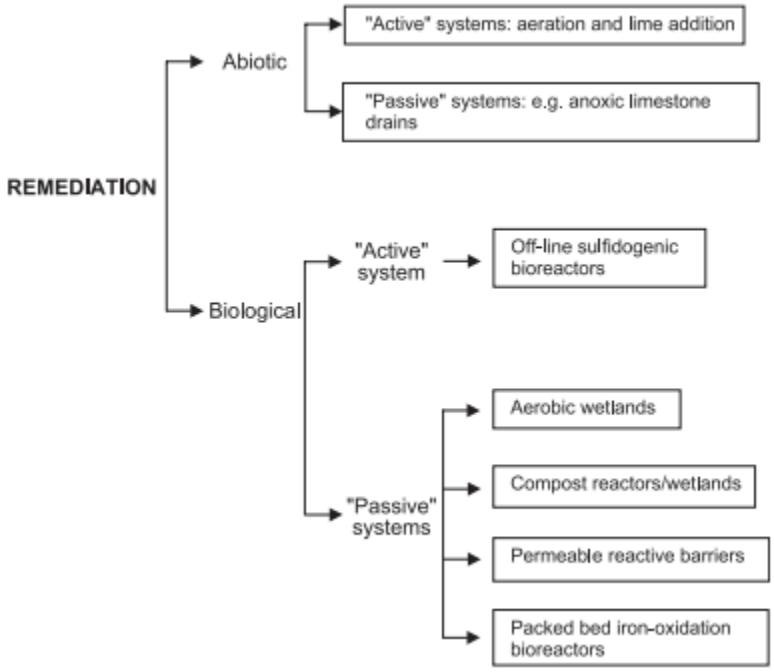

Figure 2.1. AMD Treatment Category Breakdown [7]

The technology developed by the Bettinger Group is an **active abiotic** treatment:

- **Abiotic –** meaning it does not involve the use of living, biological organisms such as microbes that process the chemicals.
- **Active** – which is generally defined as "the improvement of water quality by methods which require ongoing inputs of artificial energy and/or (bio)chemical reagents" [9]. The Bettinger Group's technology falls under this category because it requires an electrical current to depolarize the membrane when saturated. Passive treatments are typically able to be left untended and unmonitored, such as an anoxic limestone drains [7].

Most AMD produced by abandoned mines are remediated using a passive treatment, which is generally cheaper and requires less maintenance. This is the primary strategy employed by the government to treat AMD, though they may also use active treatments as well. However, unlike the case with abandoned mines, the AMD produced by active (currently operating) mines is

more easily managed due to the fact that it generally originates from a "point source" or identifiable location, such as a drainage pipe. The discharge from this location is where an active mine would monitor its AMD output. This discharge can be easily collected and cleaned with an active treatment, which is more efficient and effective than a passive treatment. Unfortunately, abandoned mines are no longer maintained, so when flooding occurs, the water interacts with the exposed rock, resulting in AMD contaminating the environment through runoffs. The nonpoint source drainage makes it more difficult to monitor or collect the discharge from abandoned mines. Additionally, in most cases, the AMD from abandoned mines has already spread and dispersed into the environment, making passive treatments a more appropriate strategy due to their ability to work long-term and over a wide area [8].

However, since the Bettinger Group's technology is an active treatment, their main competition will be other active treatments. A majority of active mines use a precipitation technique that involves the addition of an alkaline chemical to raise the pH of the solution referred to as "ODAS" (oxidation, dosing with alkali, and sedimentation). The dissolved metals then precipitate out and can be physically filtered from the solution, producing relatively clean water. Although ODAS is generally the most common method for AMD filtration, it produces a hazardous "sludge" waste product that can be difficult and costly to dispose of [9].

The Bettinger Group's technology utilizes an ion exchange system. Ion exchange systems are typically used as a secondary filtration technique to improve the water quality after the precipitation technique has been applied [9]. Under the EPA, ion exchange systems are generally composed for four steps: service, backwash, regeneration, and rinse. Below is a diagram illustrating a typical ion exchange system used for AMD treatment:

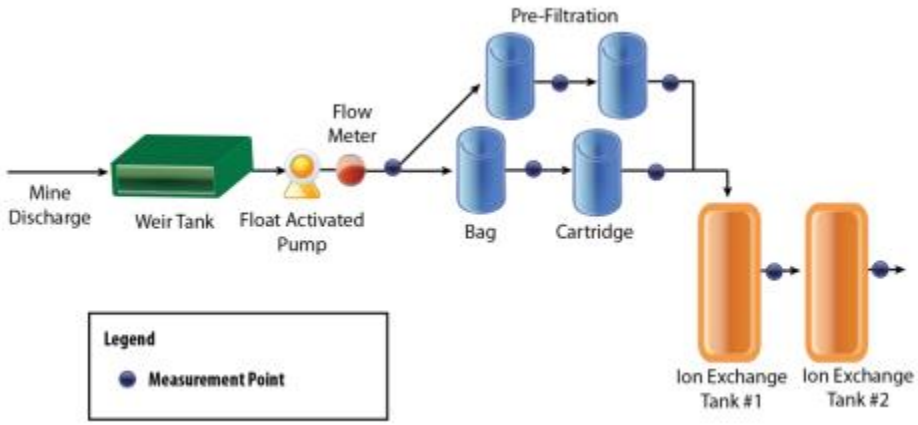

Figure 2.2. Example Diagram of a Typical AMD Ion Exchange System[10]

When examining the design and applicability of an ion exchange system, several characteristics must be considered:

- Type of resin
- Type of reagent
- Volume of reagent
- Backwash water source
- Backwash quantities
- Column configuration
- Cycle length
- The need for pre-filtration of solids

- pH adjustment before and after ion exchange

All of these elements can factor into whether an ion exchange membrane is effective. For example, most require pre-treatment of the water to change the pH or filter the solids, which makes it a less efficient method than the precipitation technique. Other issues and limitations regarding ion exchange systems include: clogging due to suspended solids, resin degradation, high sulfate inducing exhaustion of the resin, ion exchange capacity reduced due to competing ions, and high cost of resin disposal [10].

Additionally, long-term maintenance of ion exchange systems involve regeneration of the resin when it is completely saturated with bound cations. For a typical ion exchange resin, regeneration requires a reagent that reacts with the bound cations, producing a hazardous waste solution that must be disposed of. However, as stated previously, the Bettinger Group's membrane regenerates using an electrical current, eliminating the need for a chemical reagent or the production of waste [2].

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3.1 Environmentally Friendly

A benefit of the Bettinger Group's technology is that the ion exchange treatments do not produce the hazardous sludge that is a byproduct of the ODAS method. Additionally, unlike other ion exchange resins, the resin developed by the Bettinger Group does not require additional reagents in order to regenerate the membrane. Reagents are used to flush bound ions from the membrane so that it can be reused, and the resulting solution produced from this process must be disposed of as a hazardous waste. This may make the Bettinger Group's membrane more appealing to stakeholders than alternative ion exchange resins, and possibly even the sludge-producing ODAS systems [1].

3.2 Cost-Saving

Although the Bettinger Group is still currently in the developmental phase for their product, there is potential for the manufacturing and implementation of the bio-inspired cation exchange membrane to be cheaper and more efficient than the current AMD treatments. Capitalizing on this aspect would give their product an edge over the competition and likely attract more interest from stakeholders.

Below is a table detailing the costs of the various chemicals used in ODAS, the most common active treatment. Although ion exchange systems are often used in conjunction with this technique, if the Bettinger Group seeks to have their product become the most widespread treatment methodology, they should surpass the precipitation technique in effectiveness and cost saving.

Common Name	Chemical Name	Formula	Conversion Factor[1]	Neutralization Efficiency[2]	2000 Cost[3] $ per Mg or L Bulk	<Bulk
Limestone	Calcium carbonate	$CaCO_3$	1.00	30%	$ 11	$ 16
Hydrated Lime	Calcium hydroxide	$Ca(OH)_2$	0.74	90%	$ 66	$110
Pebble Quicklime	Calcium oxide	CaO	0.56	90%	$ 88	$264
Soda Ash	Sodium carbonate	Na_2CO_3	1.06	60%	$220	$350
Caustic Soda (solid)	Sodium hydroxide	$NaOH$	0.80	100%	$750	$970
20% Liquid Caustic	Sodium hydroxide	$NaOH$	784	100%	$0.06	$0.16
50% Liquid Caustic	Sodium hydroxide	$NaOH$	256	100%	$0.29	$0.33
Ammonia	Anhydrous ammonia	NH_3	0.34	100%	$330	$750

[1] The conversion factor may be multiplied by the estimated Mg acid/yr to get Mg of chemical needed for neutralization per year. For liquid caustic, the conversion factor gives L needed for neutralization.

[2] Neutralization Efficiency estimates the relative effectiveness of the chemical in neutralizing AMD acidity. For example, if 100 Mg of acid/yr was the amount of acid to be neutralized, then it can be estimated that 82 Mg of hydrated lime would be needed to neutralize the acidity in the water (100(0.74)/0.90).

[3] Price of chemical depends on the quantity being delivered. Bulk means delivery of chemical in a large truck, whereas <Bulk means purchased in small quantities. Liquid caustic prices are for L. Others in Mg.

Figure 3.1. Table Detailing the Cost of Chemicals Used in ODAS [7]

Additionally, the EPA conducted a study in 1972 (around the time the CWA was passed) examining the potential costs of the ion exchange technique. Although the values are likely to be out-of-date, the team estimated that the chemical reagents required to treat 0.5 million gallons per day (mgd) ranged in cost from $62-311 per day. Water treatment plants vary in size, some treating only 2,000mgd while larger plants treat up to 10,000mgd. Factoring in inflation, the cost of these reagent solutions can range from hundreds of thousands of dollars to millions

in a single for a day's operation [6]. Therefore, since the Bettinger Group's technology does not require these reagents, there is enormous potential for cost savings.

3.3 Metal Recovery Potential

A study in 2009 by the Concurrent Technologies Corporation and RJ Lee Group, Inc. sought to address the high costs of AMD in Pennsylvania by attempting to find an economically viable application for the sludge produced in the ODAS technique. The project demonstrated that it was possible to convert the metals recovered from the sludge into a low-cost corrosion inhibitor product for steel reinforced concrete. Therefore, there is the possibility of recovering some of the costs involved in water treatment through the commercialization of a new product, as well as addressing some of the infrastructure damage caused by AMD [4]. Additionally, the select removal of valuable metals from AMD, such as copper, nickel, and cobalt have proven successful using ion exchange systems in the past, and these metals have been recycled [5].

Although the Bettinger Group's treatment technology does not produce the same compounds as ODAS, it does recover metal ions more efficiently and does not create the hazardous sludge byproduct, which needs extensive processing in order to harvest the metals. Therefore, it may be beneficial to investigate possible applications for the metal ions recovered by the Bettinger Group's resin. This additional benefit may provide a competitive edge for the Bettinger Group's technology and assist in additional cost savings.

3.4 Applicability

It may also be worthwhile to consider alternative applications for this membrane beyond AMD treatment. There are a variety of other contaminated water sources, such as flowback from hydraulic fracturing, which contains similar toxic metals. The flexibility of the product may open up additional markets not discussed in this report and it may be in the group's best interest to capitalize on an alternative application, should further research indicate it is better suited for different types of filtration. Common alternative uses for ion exchange resins include:

- Water softening
- Demineralization [2]
- Pharmaceutical drug purification [3]

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4.1 Research & Development

One of the main challenges for the Bettinger Group will be continuing their research and developing the product to be more cost-effective and efficient than the current AMD treatment technologies on the market. Moving forward, they will need to estimate the costs of producing, implementing, and maintaining their product in comparison to both alternative ion exchange resins and treatment technologies such as the sludge precipitation plants. Additionally, ensuring that their product can realistically handle the filtration volumes and can be applied effectively to AMD is another avenue of research that group should continue to pursue. As research continues, we recommend that the group focus on the opportunities outlined above to help their product achieve its maximum potential.

4.2 Testing

As the product development continues, testing the resin through actual application to AMD effluent becomes necessary to demonstrate its effectiveness and benefits. However, there are regulations in place that restrict unregulated and unmonitored tampering with AMD, due to the potential damage to the environment. In particular, there are a number of stringent standards regarding the cleanliness of the water post-treatment. Additionally, in order to engage in an AMD remediation effort, discharge permits and liability agreements must be completed [1]. While the water composition of AMD can be simulated in a laboratory setting, each AMD location and situation is unique regarding the chemical make-up of the water, the physical environment and layout, and the amount of suspended solids and other contaminants [2]. Therefore, testing the product's viability in an actual AMD environment may prove challenging.

4.3 Adoption

Another challenge for the group will be encouraging the adoption of the technology. While there are no official regulatory processes or standards in place that prevent the introduction of a new technology for AMD treatment, there are many established methodologies and techniques that have already achieved widespread acceptance and are utilized by both the government and commercial entities on a regular basis. Additionally, these methodologies already have a significant amount of infrastructure built around them, such as water treatment plants that utilize their technology. Challenging these technologies, which are already established as the cheapest or most effective treatment, will be difficult for the Bettinger Group, particularly without significant in-situ testing to demonstrate the product's benefits.

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5. POLICY CONTEXT

5.1 Status Quo

Currently, the product is still in its research and development phase. The Bettinger Group is being funded by Carnegie Mellon University, which may have some intellectual property rights regarding the technology, however it is not currently patented or licensed. Additionally, the technology is not currently being applied beyond a laboratory setting.

5.2 Partnering with the Government

Acid Mine Drainage (AMD) is very common in Pennsylvania due to the vast amounts of mining done in the past. The Bettinger Group has the technology to potentially help solve the problem of AMD. Our goal is to try to find the policy hurdles or steps the Bettinger Group needs to take to be able to implement their research. Currently, most of the funding for AMD treatment comes from the government, which has a variety of policies and funds in place for supporting and organizing AMD treatment.

The regulation of mining activities is highly complex and has overlapping jurisdictions and regulations. In theory, AMD falls under the purview of the Clean Water Act (CWA), as it creates stream segments in excess of water quality limits for priority pollutants. Section 208 of the CWA mandates that management plans must include "a process to identify… mine-related sources of pollution, including… abandoned surface and underground mine runoff." However, many of these mines, as discussed before, are abandoned and there is no clear individual or entity responsible for the pollution they produce. Therefore, it falls to the government to take responsibility for these abandoned mines. In addition to the federal AMD remediation initiatives, there are also many state-sponsored AMD remediation efforts, so there are a variety of governmental bodies involved in AMD treatment.

Much of the AMD individual clean up falls under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also known by the name of the trust fund that finances its projects – Superfund). "Current owners of land with abandoned mines where AMD originates from neither created the problems nor profited from the mining operations, and as a result do not have the financial capability to address the problem." [1] Environmental Protection Agency (EPA) identifies a contaminated site and places it on the National Priorities list, and then the clean-up of these sites are funded by the Superfund. The Superfund is a multi-billion dollar fund used to help remediate groundwater contamination.

The clean-up of AMD is delegated to the Office of Surface Mining and Reclamation (OSMRE) as part of the Surface Mining Control and Reclamation Act (SMRCA). The EPA is responsible for contamination from ore and mineral mining. The SMRCA created a reclamation program funded by the surcharges on coal production and provides the regulatory framework to ensure that mining companies are environmentally sound. "Since SMCRA's enactment in 1977, the AML program has collected over $10.1 billion in fees from present-day coal production and distributed more than $7.6 billion in grants to states and tribes, mandatory distributions to the UMWA and OSMRE's operation of the national program to reclaim land and waters damaged by coal mining before the law's passage."[2] The Office of Surface Mining Reclamation and Enforcement bureau partners with coal mining states, by providing resources, tools, and regulatory oversight to state driven processes. The OSMRE founded the Acid Drainage Technology Initiative (ADTI), a partnership of technical experts from the industry, state, and federal experts who have joined to combat the problem of AMD. The ADTI has goals to develop solutions to AMD by using the best and most successful technology.

The SMRCA delegates authority and funding to the state governments to enact AMD clean-up programs. The Pennsylvania state government has expanded the Acid Mine Drainage Set-Aside Program to meet the SMRCA requirements and increased funding of AMD remediation. For AMD clean up, the program uses passive treatments. However, due to limited funding they aren't able to target all sites with AMD problems.

Some portions of the CWA address the problem of AMD and also allocates some funds and resources towards AMD clean up. "Clean Water Act Section 107 sets aside funds for AMD cleanup demonstration sites, small limited projects to demonstrate the technical feasibility of new, innovative technologies to treat pollution." However, research and development is not nearly a large enough solution for addressing AMD nationwide. The Army Corps of Engineers has also been tasked with addressing watersheds contaminated with AMD, but funding for corrective actions has fallen far short of the needed amounts.

In regards to the government's treatment process, the EPA has a list of technologies that they use to treat AMD. First they evaluate each site and then determine, based on the list, which technology is most suitable for the location based on a variety of factors such as the chemical composition and physical environment of the site. However, the "EPA is evaluating more cost-effective and lower-maintenance treatment systems to decrease the costs and improve the efficiency of mine site cleanups." [6] The government's list of technologies does not include all available technologies, but only the ones the government has specifically evaluated. Therefore, the goal of the Bettinger Group would be to become part of the government's official AMD technology list in order to be considered for future AMD remediation initaitives.

5.3 Partnering with Commercial Entities

Alternatively, another approach would be to contact commercial mining companies or water treatment entities, seeking either a partnership or to license the technology. The benefits of pursuing this strategy would be the greater resources and flexibility afforded by working with commercial entities. Unlike the government, they are not subject to strict regulations regarding the testing and implementation of new technologies. Additionally, commercial entities would have a larger amount of resources at their disposal for funding and testing, and most likely provide more support regarding the manufacturing, design, and implementation of the technology.

Furthermore, commercial entities would be able to better address opportunities such as its potential for metal recovery of the material and broader applicability, because these companies will have the resources to do so. Unlike the government, these companies would be interested in expanding the material's use beyond AMD treatment.

Moreover, the commercial entities would be able to assist the group regarding the challenges they face with testing of their product, and possibly provide resources to aid in research and development though shared information, laboratory space, or funding. However, one of the largest challenges for the group is ensuring adoption of the technology. When partnering with a commercial entity, there is a much higher chance of said company adopting and utilizing the technology since they have already invested in the product.

There are two distinct commercial avenues that the Bettinger Group could pursue in this strategy:

- Mining/energy companies
- Water treatment companies

5.3.1 Mining Companies

All industries are subject to the effluent guidelines developed by the EPA, which are the national standard for the greatest amount of pollutant reductions possible while remaining economically viable for each industry. These standards are regulated using the National Pollutant Discharge Elimination System (NPDES) permits, which are issued by State governments and EPA regional offices [7]. According to Title 40 of the Code of Federal Regulation Part 440 (40 CFR 440), the effluent limitations for the best practicable control technology currently available (BPT) for iron ore would be:

Effluent characteristic	Effluent limitations	
	Maximum for any 1 day	Average of daily values for 30 consecutive days
	Milligrams per liter	
TSS	30	20
Fe (dissolved)	2.0	1.0
pH	(1)	(1)

[1] Within the range 6.0 to 9.0.

Figure 1. Table with the Effluent Limitation of Iron using a BPT [8]

This pH level limitation is consistent for all types of mining [8]. Civil penalties regarding violation of these effluent standards can incur a cost of up to $27,500 per day and up to one year imprisonment [7]. Therefore, mining companies often take an active interest in the filtration and treatment of their waste water and are typically interested in new technologies regarding acidic or polluted water treatment.

For example, Consolidation Coal Company (a subsidiary of CONSOL Energy) contracted Veolia Water Solutions & Technologies to design a new AMD treatment plant incorporating Veolia's innovative water treatment plant technology, DenseSludge™. This initial contract was a pilot of Veolia's technology and design using a former coal refuse disposal site. As a result of the pilot, conducted on 2,000-gpm (gallons per minute) system, Veolia was contracted to incorporate and design a 10,000-gpm plant with their technology [9].

The opportunity for the Bettinger Group would be the possibility of receiving funding and resources to test their product, in addition to a possible licensing of the product. The mining company would not only be able to provide a testing site, but also provides the resources for manufacturing and implementation of the product. However, the main challenges regarding this process would be identifying the appropriate point of contact and ensuring that the product is applicable and scalable to the effluent the mining companies are producing.

5.3.2 Water Treatment Companies

Water treatment companies are often contracted by mining facilities to clean their water if they do not have their own treatment plants. However, companies such as Evoqua Water Technologies can provide a range of services: from a complete water treatment process program, to individual, specialized equipment for improving a plant's current operations [10]. Therefore, when compared to mining companies, water treatment companies may be better equipped to develop, license, manufacture, and market a new technology. They may also have more experience with testing and implementation. Additionally, the application of the technology at a water treatment companies may not be limited to AMD filtration. The companies generally engage in a variety of water treatment types such as sewage and radiation and could potentially find a better use for the Bettinger Groups technology in another type of water filtration.

5.4 Independent Implementation

Another option for the group would be to begin their own AMD clean-up initiative. However, this is a very complicated and time-consuming process. To begin with, the group will need to identify a potential location they would like to treat for AMD. This site may or may not be on private property, and therefore they will need to obtain permission from the landowners. Once permission to collect samples has been obtained, the group will then need to analyze the layout of the land the chemical composition of the water. Depending on the results, their product may or may not be the optimal choice for remediation in that area.

However, should the Bettinger Group's ion exchange membrane prove to be an applicable solution at the selected site, additional permission from the government must be obtained, including a discharge permit. The National Pollutant Discharge Elimination System (NPDES) permit can be found on the EPA's website with details on the CWA's extremely stringent water quality requirements. Additionally, any third-party group (including nonprofits, the government, and corporations) that initiates an AMD clean-up attempt will become the "operator" of the source mine and legally liable for the mine's AMD in perpetuity. Because the CWA's water quality standards are so rigorous, there is a high possibility of complications arising for any group attempting AMD and they will become liable for violating the effluent guidelines. As the operator of the mine, it is possible to incur up to $32,500 in penalties for each day the mine discharges pollution [11]. Under the Good Samaritan Provision in CERCLA, liability exceptions are only granted to third-parties operating under the direction and supervision of a governmental On-Scene Coordinator (OSC) [2]. Essentially, if the group wishes to implement the technology themselves, they will still need to cooperate with a government official who many require them to use approved technologies, rather than their experimental technology.

In addition to all the regulation and liabilities involved in obtaining permission to begin AMD treatments, the group will also need to develop a strategy plan. Most sites require multiple types of treatments tailored to their unique chemical composition and landscape. Once the plan has been developed, the physical labor of implementing it must also be considered. This can be achieved through working with an established environmental group that is interested in AMD remediation. However, many of these groups focus on abandoned mines and use passive treatments, because it does not require maintenance and can be left to treat the water in perpetuity. The Bettinger Group's active treatment technology could possibly be used as a preliminary treatment to the installation of the passive treatment, but the environmental group may not have the resources needed to support an active technology. Therefore, due to the high risk and enormous hassle of operating independently, or even with an established environmental group, we do not recommend this policy.

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6.1 The Environmental Protection Agency & Office of Surface Mining Reclamation and Enforcement

If the Bettinger Group partnered with the government, it would help them implement their new innovative technology. Due to the limited funding for AMD cleanup, the EPA and OSMRE would likely welcome the use of a cost-effective technology. Partnering with the government will also ease the process of applying the active treatment to the public works sector.

However, if the Bettinger Group were to instead work with commercial entities, the EPA and OSMRE would not have significant objections either, as the technology is being used to prevent additional pollution of the environment. Additionally, since the technology produces less toxic waste than alternative treatment methods, its benefits are still being utilized even in an industrial setting. However, the commercial entities are unlikely to share the technology with the government or competing companies.

6.2 Local & State Governments

Local and State governments have a larger stake in AMD remediation, as they are more directly impacted by its negative effects. The tourism and recreational activities that are restricted by AMD impact the state revenue. Additionally, AMD damage to infrastructure is costly to regional governments who must fund the repairs. Some states, such as Pennsylvania, also have their own AMD reclamation programs, and may be interested in adopting or testing a new technology. Although they may benefit tangentially through a partnership between the Bettinger Group and a commercial entity, they would most likely prefer a governmental partnership, which would allow them access to the technology.

6.3 Mining Companies & Water Treatment Companies

Mining companies and water treatment companies would be most directly affected if the Bettinger Group decides to partner with them. Although they would be relatively neutral regarding a partnership with the government, the commercial entity that invests in the technology would likely have an edge over their competition, due to the lower costs of water treatment. Most commercial entities would welcome a cheaper alternative, and be open to working with the Bettinger Group or utilizing their technology. However, if the Bettinger Group does partner with the government, this does not prevent them to also allowing commercial entities to use their product.

6.4 Chemical Product Manufacturers

Chemical product manufacturers would likely oppose the Bettinger Group, as the technology makes it possible to treat AMD without the application of a large volume of chemicals. Therefore, the Bettinger Group's technology could potentially infringe on the revenue of chemical product manufacturers who produce the reagents and alkaline solutions used in current treatments. These are large corporations who produce hundreds of thousands of gallons of chemicals for AMD treatment, and are potentially a very large and influential opponent to the Bettinger Group.

6.5 Environmental Groups

The environmental groups would, of course, support the Bettinger Group, particularly because the group's technology decreases the amount of hazardous waste produced through treating AMD. Therefore, they would be highly supportive of its application in both a government partnership and a commercial partnership.

7. RANGE OF OUTCOMES

In the Policy Context section, we described the status quo and the policy challenges and opportunities associated with the AMD technology. Now, we will analyze the status quo option and other proposed options in terms of effectiveness and efficiency. When analyzing the effectiveness of a policy, we are determining how likely an option is to achieve the desired outcome. Efficiency, on the other hand, refers to the estimated financial investment required to implement each option. The goal of this analysis is to find the option that has the highest return on investment in regards to both cost and time.

To implement this new AMD technology, the following are the status quo and proposed options:

- Status Quo – Continuing researching and improving technology
- Option 1: Partner with the government to implement technology– Environmental Protection Agency (EPA) and Office of Surface Mining Reclamation and Enforcement (OSMRE)
- Option 2: Partner with commercial mining entities to implement technology
- Option 3: Independently implementing the technology

7.1 Effectiveness

To maximize effectiveness, we will attempt to identify a policy that moves the AMD technology from its research stage to its implementation stage while produces the best outcomes. Each option will be discussed below in relation to its predicted effectiveness and the effectiveness will be rated on a scale from double positive, positive, neutral, negative and double negative (++, +, 0, -, --).

Status Quo receives a negative rating of (- -) because the AMD technology would be put back into further research, which would not progress the desired outcome. Essentially, the project remains stagnant if it remains in Status Quo.

Option 1 is most likely very effective in achieving the application of the technology, not only in the public sphere but potentially in the private sphere as well. By partnering with the government, the group would be able to impact not only public land and water areas, but also influence the commercial sector to adopt the technology. Exercising option 1 is a double positive (++) in effectiveness.

Option 2 would also potentially be an effective method to implement the technology. However, it is likely that commercial mining entities would prefer not share the technology with their competitors, or at least not without licensing fees or other barriers. Therefore, technology would most likely be limited in the scope of its effectiveness and may not be implemented as broadly as it would with the government. Exercising option 1 a positive (+) in effectiveness.

Option 3 would be the least effective out of the three options. Independently implementing the technology is a much slower process and involves a significant amount of hands-on labor for the group. The group would need to individually contact each mine owner for permission to trespass on their land, and the group would take liability of the AMD on their land. This may result in significant legal complications that could undermine the group's ability to continue to do AMD remediation and their impact on the environment would be limited by their ability to mobilize the labor needed to begin an AMD remediation project. The effectiveness of option 3 is negative (-).

7.2 Efficiency

In addition to the effectiveness, we also examined the efficiency in terms of time and funding for each option. All options require additional funding to implement therefore, we examined the potential financial resources and support the group could receive to implement the technology. The efficiency analysis below is rated on a scale from double positive, positive, neutral, negative and double negative (++, +, 0, -, --).

Status Quo, once again, does not achieve the desired implementation outcome, so it receives a negative (-) rating.

Option 1 is a time-consuming process, as it involves working with the government. In order to partner with the government, there is no official process when it comes to new AMD technologies. The United States government has a list of AMD remediation technology that they select from and implement after evaluating a potential AMD site and determining the optimal strategy for that particular site. The goal of the Bettinger group would be to get on this list. To accomplish this, the group must seek to attract the attention of the government and demonstrate that this new technology is faster and cost-effective alternative to the technologies they currently use. This can be a slow process, depending on the Bettinger group's connection and ability to communicate with the government. However, in terms of funding the group would receive some financial support to produce the technology. However, the government's funds are limited, particularly in comparison to commercial entities. The efficiency rating is a positive (+) for option 1.

Option 2 is highly efficient, as there is no regulatory process governing what technologies mining companies use to treat their discharge. Additionally, the group would likely receive more funding from private entities because they are likely to profit from the product and may even invest in its ongoing research and development, as well as assist in its manufacturing. The efficiency rating for option 2 is a double positive (++).

Option 3 is a highly inefficient process of the variety of barriers, including contacting the landowners and the applying for the permit would have to be done for each site. The group will also be entirely reliant on their own resources for implementing the technology using this policy as well. The efficiency rating of option 3 is a double negative (--).

The following table summarizes the ratings of effectiveness and efficiency per option.

Policy Options	**Effectiveness**	**Efficiency**
Status Quo	Will Remain stagnant --	-
Option 1 – Partner with the Government	Potentially able to apply technology to both public and private sector ++	Government process are long, but have increased funding from SRMCA +
Option 2 – Partner with Commercial Entities	Limited to private sector, companies unlikely to share +	Implement faster – no regulations, more money ++
Option 3 – Individual Implementation	Must contact landowners individually for permission -	Slower processes due to regulations and restrictions --

8. BARGAINING CONTEXT

We will now analyze the ease of political acceptability and equity of the status quo and each proposed option. In this context, equity refers to identifying who "the winners and losers" are for the proposed policy. By examining the ease of political acceptability, we will also determine who will support and oppose each policy option and how much influence they may have over the policy. We will divide ease of political acceptability into the private players and public players and use the same rating scale from the previous section with the double positive, positive, neutral, negative and double negative (++, +, 0, -, --) ranks.

Once again, to implement this new AMD technology, the following are the status quo and proposed options:

- Status Quo – Continuing researching and improving technology
- Option 1: Partner with the government to implement technology– Environmental Protection Agency (EPA) and Office of Surface Mining Reclamation and Enforcement (OSMRE)
- Option 2: Partner with commercial mining entities to implement technology
- Option 3: Independently implementing the technology

8.1 Ease of Political Acceptability

Status quo receives a score of 0 because the project will remain under academic research so there won't be any other players opposing or supporting it other than the Bettinger Group. The status quo will not have direct contact with the public or policymakers therefore this option wouldn't invoke any response.

Option 1 has a positive score on ease of political acceptability in terms of the public players. The potential players in this policy are the EPA, OSMRE, Commercial mining companies, individual mine owners, and environmental groups. The OSMRE is likely to be supportive of new technologies for AMD, particularly those that are faster and more cost-effective than the current treatments. As a part of the ADTI, the OSMRE could push for implementing this treatment. Additionally, the EPA would also be supportive of a new AMD treatment technology, but likely wouldn't advocate it as much as the OSMRE because AMD is a small part of what the EPA governs. However, the EPA and OSMRE would have equal power over partnering with the Bettinger Group to apply this technology.

On the other hand, commercial mining companies would most likely be less supportive of the Bettinger Group partnering with the government. If the technology appears to be a good investment, the companies may prefer to license it and potentially profit from it. However, the commercial mining companies will not have much influence over the group, should they decide to partner with the government. Therefore, for private players, the rating for ease of political acceptability would be negative (-).

However, environmental groups would favor this partnership because the government would help these groups with implementing the technology for their work. The environmental groups would have some power in this policy option because they might assist the Bettinger Group in attracting the government's attention and help get it added to the government's list of AMD technology options.

Individual mine owners would feel neutral or slightly in favor of this policy option, as they would want a more effective AMD technology, but are unlikely to assist the Bettinger Group's implementation efforts.

Option 2 would have a positive score on ease of political acceptability. The potential players in this policy are the EPA, local state government, mining companies, water treatment companies, environmental groups, and competing AMD treatment technology manufacturers. The EPA is essentially always open to new green innovations that can benefit the environment. However, since it is restricted to the commercial sector, they may be less supportive. However, the EPA would not have much influence if the group decides to partner with a commercial entity. However, the local governments have a larger stake in the matter than the EPA, as they are more directly impacted by AMD. Local governments would most likely not be in favor of allowing the material's use to be restricted by a commercial entity, considering the potential benefits it could provide for local AMD clean-up efforts. However, it is highly unlikely that the government would take measures to prohibit the commercial sector from using the technology.

The mining companies would most likely welcome another new technology that could make it cheaper and easier to filter AMD. However, it would still not be a huge priority for them, though it could result in good PR if they manage to successfully clean up their wastage. Environmental groups would be very supportive of a new material that would assist in AMD treatments. On the other hand, if the commercial entity that provides the funding restricts its use, they may not support this policy and would prefer public distribution of the material. However, the environmental groups do not have significant influence in the matter. If the product is patented and belongs to the company, it is unlikely the company could be convinced to freely share their intellectual property.

However, a potential threat would be competing AMD treatment technology manufacturers. These companies could take significant losses if mining companies or water treatment plants no longer purchase their products. Conversely, however, they may be interested in partnering with the group. However, regardless of their stance, their position is most likely not specifically antagonistic or supportive, leaning more towards neutral and they have very little sway over what the group does or does not do. They are most likely not going to sway a company seeking partnership with the Bettinger Group one way or another, unless they have some sort of exclusive contract with them or offer a better deal.

Option 3 has a neutral rating for ease of political acceptability. Since the Bettinger group would have to implement the technology themselves, they wouldn't really have anyone favoring or opposing this policy option. They may have some support from the government, but the myriad of standards and regulations serves more to hinder independent efforts than encourage them. However, some environmental groups may be interested in supporting the group.

8.2 Equity

To analyze equity we will look at the public and private sphere players. We will use the same rating scale with double positive, positive, neutral, negative and double negative (++, +, 0, -, --) rankings.

Status Quo has there are no winners or losers since the Bettinger group would just continue their research. Therefore, it is neutral (0).

Option 1's the winners would be the public players such as environmental groups and government agencies. The private sector might feel differently, as they lose an opportunity to capitalize on a potential profit by licensing the technology. However, the rating for equity is a positive (+).

Option 2's option has the private sector as the clear "winners," as they would directly benefit from the new cost-effect technology to clean up their waste and possibly manufacture and sell. The public sector would lose in this partnership because they would not be able to utilize the technology, or would be forced to purchase it at a high mark-up. However, the EPA wouldn't really oppose the private sector using this technology since it is environmentally friendly and improving industry discharge effluent. Therefore, option 2 receives a positive (+) rating.

Option 3 results in both the public and private sector as "losers." Option 3 would be a slow and stagnant process that wouldn't optimize the use of the AMD technology so both the public and private spheres would miss out on the opportunity to use the technology to its full potential. This option would receive a neutral (0) rating.

The following table summarizes the scores of ease of responsibility and equity of each policy option.

Policy Options	**Equity**	**Ease of Political Acceptability**	
		Public	Private
Status Quo	Will remain stagnant 0	N/A	N/A
Option 1 – Partner with the Government	Public sector would win, private sector would lose on potential profit but still benefit +	Support this policy if they benefit ++	Won't be able to make profit from technology -
Option 2 – Partner with Commercial Entities	Limited to private sector, companies won't share and govt would lose but private sector would be more environmentally friendly +	0	Might be able to profit and cost-effective ++
Option 3 – Individual Implementation	Slow process with no winners 0	0	0

9. STRATEGY & ARGUMENTS

Due to the fact that the Bettinger Group's product is still in its developmental phase, the strategy we recommend is broken up into two parts: the short-term and the long-term.

9.1 Short-Term Strategy

In the short-term, we recommend that the Bettinger Group maintain status quo and continue their research. Before moving on to the long-term strategy, they should seek to understand the following characteristics of their product:

- Volume capacity of the product
- Cost of manufacturing, maintaining, implementing, and using the product

In regards to cost, there is significant variability on the cost of the current ion exchange systems based on the type of reagent and capacity of the technology. However, there is enormous potential for cost savings because the technology does not require a reagent to regenerate the membrane. The study done by the EPA on the cost of ion exchange systems mentioned in Section 3.2 can be found here on the EPA's website: "Acid Mine Drainage Treatment by Ion Exchange" (http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=9101LF0V.TXT)

We recommend the group review the article. Although the data on costs is a bit dated, it provides comprehensive information on the methodology used to calculate the costs of chemicals, installation, facilities, labor, utilities, and other fixed costs. The report also provides information on the variety of tests performed to analyze the effectiveness of the water treatment. Therefore, the report provides a guideline for which the Bettinger Group use to design their own experiments, as well as analyze against some benchmark costs.

Additionally, the EPA's research group used a synthetic AMD effluent and tested the effectiveness of a variety of different ion exchange system types on a scale of 0.1mgd, 0.5mgd, and 1.0mgd of water. This "test AMD Solution" may be a viable alternative to testing at on-site locations, which is hindered by a variety of restrictions and regulations. Below is the test solution used:

Chemical	Parts Per Million (ppm)
Free Mineral Acidity, ppm as $CaCO_3$	500
Sulfate, ppm as Ca	1150
Magnesium, ppm as Mg	24
Aluminum, ppm as Al	15
Manganese, ppm as Mn	8
Iron, ppm as Fe	210

However, in addition to cost, some other factors must be evaluated as well in order to compare the Bettinger Group's product against other ion exchange systems. These factors include some of the characteristics listed in Section 2.3:

- Backwash quantities
- Column configuration
- Cycle length
- The need for pre-filtration of solids
- pH adjustment before and after ion exchange

Therefore, we also recommend that the group review the report "Ion exchange system design for removal of heavy metals from acid mine drainage wastewater" by R.W. Gaikwad, V.S. Sapkal, and R.S. Sapkal (http://actamont.tuke.sk/pdf/2010/n4/6gaikwad.pdf), which provides detailed information and formulas regarding the design of AMD ion exchange columns. Specifically, this article has information on the calculations needed to determine the following:

- Amount of water to be treated per cycle and the amount of heavy metal removed
- Regeneration level and resin capacity
- Volume of resin needed to treat a particular amount of heavy metals
- Column diameter, pressure drop, and backwash requirements for the system
- Required volume of rinse water
- Design of the experimental layout for testing the resin

This article should provide good information to help the Bettinger Group determine their product's capabilities. Once these metrics have been established, the Bettinger Group may begin implementing their long-term strategy.

9.2 Long-Term Strategy

Our group has two recommendations for the Bettinger Group's long-term strategy. Each option has its benefits and drawbacks, which will be detailed below.

9.2.1 Partnering with the Government

As explained in Section 5.2, partnering with the government involves advertising the product to relevant officials in order to be added to the list of AMD treatment technologies that the government uses. There are three options for getting the attention of the government:

- Directly contact relevant government officials in the EPA or OSMRE
- Apply for research grants and funding
- Partner with environmental groups to help lobby the attention of the government.

The most effective option may be to contact the EPA and OSMRE directly. The OSMRE is currently a partner in the Acid Drainage Technology Initiative (ADTI), "as a partnership of technical experts from industry, state and federal agencies and academia who have joined together to combat the pervasive problem of AMD." (1) The ADTI is looking to develop innovative solutions to AMD and identify the best AMD remediation practices for AMD treatment. To partner with them the Bettinger group needs to contact one of the officers in charge of ADTI and present their technology. From there the process is unknown.

Additionally, another approach to this strategy would be to contact the local state government. Pennsylvania has several abandoned mine reclamation initiatives. Therefore, if they wish to operate locally, the Bettinger Group may reach out and see if there are any opportunities for their product to be tested or implemented. The project manager for the Pittsburgh region's contact details are:

Environmental Program Manager: Dean Baker, P. E.
286 Industrial Park Road
Ebensburg, PA 15931
Phone: 814-472-1800
Fax: 814-472-1839

However, in regards to innovative or emerging technologies, the government often requires field-scale testing or pilot-scale testing prior to use [2]. We do not recommend the group approach individual mine owners or landowners with abandoned mines on their property, because the group will then be liable for any future AMD discharge from that mine. Rather, simulating the chemical composition of AMD should be sufficient, as the product is an active treatment, which requires the water be collected and input into the system. Therefore, physical landscape and environmental impact are most likely not necessary considerations.

There are a variety of different federal departments that have sponsored groundwater remediation projects in the past, such as the EPA, the OSMRE, the Office of Pollution Prevention and Toxics, and the U.S. Army Environmental Command, among others. Reaching out to them for funding is an alternative option as well.

However, the Bettinger Group may be particularly interested in the Department of Defense's (DoD) Environmental Security Technology Certification Program (ESTCP). While testing the product at appropriate mine sites is highly recommended, the DoD's program is designed to fund on-site testing and application. The goal of the ESTCP is to "demonstrate and validate promising, innovative technologies that target the DoD's most urgent environmental needs." Acid mine drainage, or more broadly, groundwater contamination, is currently on the list of urgent issues the DoD is seeking to remedy with ESTCP projects. Additionally, this program seeks to identify technologies that will provide a return on investment through improved cost-savings and efficiency. The DoD primarily seeks lab-proven technologies that can be applied broadly across the market and have applicability to multiple DoD concerns. Therefore, the Bettinger Group's technology may be a good candidate for this program.

The program will allow the product to be rigorously tested on-site at AMD locations to determine cost, performance, and market potential. This allows the DoD to not only address their environmental concerns, but also document the cost and performance of a new technology for their DoD end-users and the regulatory community [3].

The application process of the ESTCP is as follows:

- **Annual Solicitation**: Around January/February each year, the ESTCP accepts proposals from the DoD, other federal agencies, and private sector organizations (industry and academia). Solicitations to the private sector are made via a Broad Agency Announcement (BAA) in the Federal Business Opportunities.
- **Selection Process:** The selection process begins with a pre-proposal, which is reviewed by the ESTCP's Technical Committees (ETC). If the pre-proposal has been accepted, then a full written proposal is requested, along with an oral briefing for the ETC in September. The ETCs then forward their recommendations to the director who ultimately decides whether to fund the project [4].

The ESTCP program is most likely the best fit for the Bettinger Group's technologies and current goals, as it will allow their product to be tested on-site in real AMD environments, as well as expedite the implementation and approval process.

9.2.2 Partnering with Commercial Entities

Unlike partnering with the government, there are significantly fewer regulation and barriers when partnering with commercial entities. Additionally, the approach is much more straight-forward. As stated in Section 5.3, all industries' discharge are subject to strict regulation and violations can incur enormous costs. However, even if the company does not violate any regulation, water treatment can be very expensive. Since it is essentially a fixed cost, mining companies are most likely interested in any sort technology that can minimize that cost. Therefore, we recommend the Bettinger Group approach mining companies with their product and request the opportunities to test or pilot it with their systems. If the pilot is successful, there may be potential for the company to license the product.

Some potential mining companies include;

- **CONSOL Energy**: The largest mining company in the Pennsylvania area and owns many water treatment plants. In the past, CONSOL has piloted innovative new technologies at their treatment plants. Their Research & Development contact is below [5]:
  4000 Brownsville Road
  Pittsburgh, PA
  15129
  Phone: (412)854-6600
- **Rosebud Mining:** As a relatively new company, they most likely exports their waste water to local water treatment plants and probably do not do any water filtration on-site. However, as they expand, they may be interested in developing their own treatment facilities. Their company contact information is, as follows [6]:
  301 Market Street
  Kittanning, PA 16201
  Phone: (724) 545-6222
  Fax: (724) 543-6375
  coal@rosebudmining.com
- **Coalview Ltd.:** This company's focus is to minimize their environmental impact and believes that coal can become a large part of the future of clean energy. They are a fine coal recovery company, with their own laboratory for testing and analysis of their waste and impact. They seek to return the location to its original state after they have completed mining operations, and therefore may be interested in an environmentally-friendly water treatment technology. Their contacts are below [7]:

  Coalview Centralia Operations
  1044 Big Hanaford Road
  Centralia, WA 98531
  Tel. +1 360 623 7525

  Laboratory
  4185 Glades Pike Road
  Somerset, PA 15501
  Tel. +1 814 443 6454
  Fax +1 814 443 6459

Alternatively, the Bettinger Group could reach out to water treatment companies. These companies' primary interest in the product would most likely be licensing or sales. However, they would have the resources to test the products and compare them to their own benchmarks and products. They would also likely have the ability to manufacture the product more cheaply, as well as market it strategically for the maximum profit.

Potential water treatment company partners include:

- **Evoqua:** The global leader in assisting municipalities and industries to treat waste water. This company produces a variety of water treatment products, including ion exchange resins, making it an experienced partner with resources to support additional testing and manufacturing. Evoqua has also patented a variety of innovated technologies each year. Below is their contact information [8]:
  Evoqua Water Technologies
  118 Park Road
  Darlington, PA 16115
- **Chemway**: This local water treatment company is smaller than Evoqua, but focuses on chemical approaches to water treatment. However, they also develop water treatment equipment and may be interested in the Bettinger Group's product. Their contact information is [9]:
  Chemway, Inc.
  P.O. Box 10913
  Pittsburgh, PA 15236
  Phone: 412-260-2557
  Fax: 412-653-5527

Any of these commercial entities are viable partners for the Bettinger Group, and would be able to provide both the resources and expertise to implement the product.

9.3 Arguments & Conclusion

There are positives and negatives to both long-term strategy options, and the decision ultimately lies with the Bettinger Group to determine which aspects they value more. As demonstrated in Sections 7 and 8 of this report, partnering with the government is the more equitable option and also has a higher ease of political acceptability. It not only allows a wider range of users, but also allows the commercial entities to access and incorporate the technology if they wish. Whereas partnering with the commercial entities may restrict the technology's availability. By allowing the technology to be used more widely, it would have a greater impact and benefit the environment, more-so than it would in the hands of a commercial entity because the commercial entity is unlikely to share the technology. Additionally, a majority of AMD-producing mines are abandoned. These mines fall under the jurisdiction of the government, meaning that the largest impact on AMD would be achieved through governmental implementation.

However, between mining entities and the government, the product is more applicable to treat the point-source pollution produced by active mines, which are operated by mining companies. The government typically uses a passive treatment approach to AMD remediation, and while active treatments are often used in conjunction with passive treatments, the product may not be implemented with much frequency, comparatively.

Additionally, working with the government would place the burden of locating a manufacturer and producing the product more on the Bettinger Group. While the government would provide funding, it would be the Bettinger Group's responsibility to produce the product and design the ion-exchange system. However, if the Bettinger Group were to partner with a commercial entity, their partner company would likely have the resources and expertise to handle these aspects of the implementation process.

Commercial entities, such as water treatment companies, already have the equipment and knowledge to manufacture, test, market, and implement the technology. They would also be able to provide assistance with additional research, by allowing the group to utilize their current products as benchmarks and examples. However, the Bettinger Group's involvement or influence on the technology's future implementations may be lessened, as the company may apply it to gain maximum profit and not necessarily maximum environmental benefit. The commercial entity may also identify alternative opportunities for the material and apply it to a wider range of uses. For example, the material could be used to take advantage of its metal recovery potential. While the government entities may also apply the material on a broader spectrum, its application is likely to be more limited due to limited funding and resources.

The final decision, however, mostly boils down to what the Bettinger Group values more. Partnering with the government would be the more equitable route, and have a greater impact on the environment. On the other hand, partnering with commercial entities would be more profitable and efficient, and may allow the product to be implemented in a wider variety of applications. Therefore, before implementing their long-term strategy, the Bettinger Group must determine whether they wish to focus more on improving the environment or making a profit.

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