The Science, Funding, and Treatment of Acid Mine Drainage

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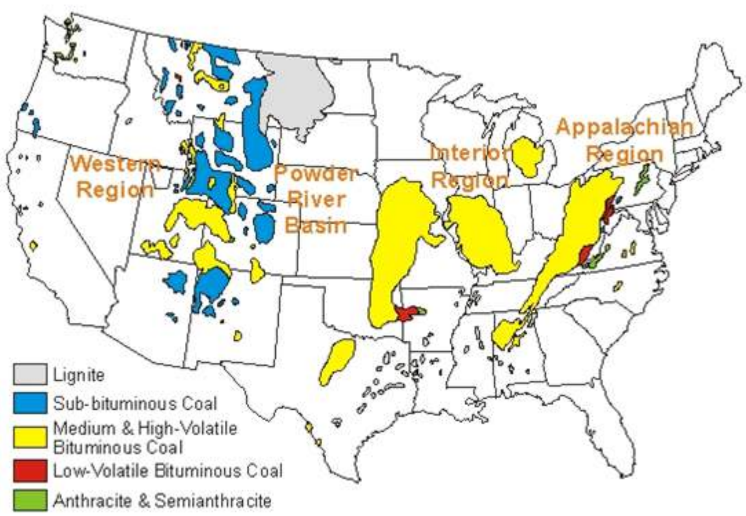
Nationwide, states are developing acid mine reclamation projects in Pennsylvania, West Virginia, Illinois, and Wyoming, among others.

Coal is extracted in twenty-one states across the United States. Wyoming, West Virginia, Pennsylvania, Illinois, and Montana are the top five states in terms of coal production. Unfortunately, coal mining brings about a significant environmental issue known as acid mine drainage, which is both widespread and highly detrimental to the ecosystem.

Acid mine drainage is a significant environmental problem. Over 11,000 miles of streams in the U.S. are contaminated by acid mine drainage.[1] According to the Pennsylvania Department of Environmental Protection (PADEP)[2], there are over 5,500 miles of streams impacted by AMD in Pennsylvania as of 2021; the West Virginia Department of Environmental Protection says over 2,800 miles of streams impacted by AMD in West Virginia; and the Ohio Department of Natural Resources says it has approximately 1,300 miles of impacted streams by AMD in Ohio.



Source: http://www.coaleducation.org/

Due to their significant coal history and current coal production, Wyoming, Pennsylvania, West Virginia, Illinois, and Montana are known as coal states. These states have been major coal producers for the United States for over a century.

In the mid-18th century, Pennsylvania opened its first coal mine, making it one of the earliest coal-producing states in the U.S. Pennsylvania is still a major coal producer in the Western part of the state.

These states have experienced significant economic and historical impacts from coal mining. Still, it has contributed to environmental challenges such as AMD, which affects water quality in streams and rivers.

The AMD process occurs when water flows through abandoned or active mines, mine spoils, or mine tailings and picks up sulfuric acid and heavy metals. This results in highly acidic and toxic water, which harms aquatic life and contaminates drinking water.

[1] Eastern Illinois University

[2] https://www.dep.pa.gov/OurCommonWealth/pages/Article.aspx?post=92

$725 million in federal funding is available this fiscal year to twenty-two states, and the Navajo Nation for the reclamation of abandoned coal mines and cleanup of acid mine drainage, the U.S. Department of the Interior announced in 2022.

The funding is included in the $1 trillion government infrastructure package and is part of an overall plan to spend $11.3 billion in the U.S. abandoned mine lands program over 15 years.

Pennsylvania is eligible for $245 million, and West Virginia about $141 million. Other significant amounts include $75 million for Illinois, $74 million for Kentucky, and $9.6 million for Wyoming.

Remediation Processes

Remediating AMD is a complex process that may require a combination of engineering, chemical, and biological techniques. Several approaches to remediating AMD include passive and active treatment systems. This article explains the treatment technologies that environmental engineers and consultants provide and the resources and direction each state takes to address AMD.

AMD projects that produce large volumes of water can be particularly challenging to remediate, as they require significant treatment ability and can generate substantial amounts of waste products.

Both active and passive treatment systems can be effective options for treating AMD, and the choice of a system depends on several factors, including the concentration and composition of contaminants, the volume of water to treat, and treatment goals. Combining active and passive AMD treatment systems can create a comprehensive treatment system that effectively removes contaminants.

Passive treatment systems rely on natural processes to neutralize the acidity and remove heavy metals from the water. Constructed wetlands, for example, use a combination of aquatic plants and wetland soils to neutralize the acidity and remove heavy metals from the water as it flows through the wetland. Passive treatment systems are often more cost-effective and require less maintenance than active treatment systems, but they may be less effective in treating high-flow, high-concentration AMD.

Active treatment systems use chemical and physical processes to neutralize acidity and remove heavy metals from water. These systems include techniques such as pH treatment, which adds lime to the water to neutralize acidity, and reverse osmosis, which uses a semi-permeable membrane to remove heavy metals. Active treatment systems are often more effective than passive treatment systems in treating high-flow and high-concentration AMD but are more expensive and require more maintenance.

Treatment Technologies

Acid mine drainage is a widespread environmental issue associated with mining operations where acidic water, often rich in heavy metals and sulfates, is produced due to the exposure of sulfide minerals to air and water. If not responsibly managed, the resulting contaminated water poses serious threats to ecosystems and human health. As such, developing and implementing effective AMD treatment technologies have become crucial.

One way to tackle this issue is through active treatments. Active treatment technologies primarily focus on chemical processes that directly neutralize the acidic water and precipitate the harmful metals, making them easier to remove. Another way is passive treatments that rely on natural processes and require less human intervention once set up.

Researchers are exploring emerging technologies in this field besides conventional active and passive treatments. For instance, electro-biochemical reactor technology utilizes a low-voltage electric current to stimulate bacteria to reduce sulfate and metal ions. Meanwhile, nanotechnology, specifically using certain nanoparticles like zero-valent iron, is being studied for its potential in more efficient heavy metal removal.

The choice of AMD treatment technology depends on several factors, including the acidity level, metal concentration, volume of water, and available resources, among others. Moreover, a hybrid approach, employing a mix of different technologies, is often utilized to achieve optimal results.

Here is a brief description of some of the technologies used to treat AMD:

- Chemical Precipitation: This process involves adding a chemical to the AMD to neutralize acidity and cause heavy metals to precipitate out as sediment. Common chemicals used for chemical precipitation include lime, limestone, and caustic soda. Chemical precipitation works by increasing the pH of the AMD to a level where heavy metals become insoluble and precipitate out of the water. The chemical reaction between the added chemical and the AMD creates a solid precipitate that settles out of the water, resulting in treated water that is less acidic and has lower levels of heavy metals.

  The effectiveness of chemical precipitation depends on several factors, including the pH of AMD, the concentration of heavy metals in the water, and the type of chemical used. Lime is a commonly used chemical for AMD treatment because it is inexpensive and readily available. However, other chemicals, such as caustic soda and limestone, may be more effective for treating certain types of AMD.

  One potential drawback of chemical precipitation is that it can generate large volumes of sludge, which may require disposal in a landfill or other waste management facility. Additionally, chemical precipitation may not treat all types of AMD. Other treatment processes, such as biological treatment or adsorption, may be more effective depending on the specific characteristics of the AMD.

- Reverse Osmosis: This process uses a semi-permeable membrane to remove heavy metals and other contaminants from water. Reverse osmosis effectively treats high-concentration AMD and produces a concentrated waste stream that can be further treated or disposed of. In the RO process, AMD is pressurized and passed through a semi-permeable membrane that allows water molecules to pass through but blocks the passage of dissolved solids and other contaminants. Clean water that passes through the membrane is collected, while the concentrated waste stream discharges for further treatment or disposal.

  RO is an effective treatment process for high-concentration AMD with dissolved solids, heavy metals, and other contaminants. RO can remove up to 99% of dissolved solids and up to 95% of heavy metals from water, making it an ideal treatment process for water that requires elevated levels of purification.

However, there are some drawbacks to using RO for AMD treatment. The process can be energy-intensive and produce a concentrated waste stream requiring further treatment or disposal. Additionally, RO membranes will become fouled or clogged with contaminants, reducing the effectiveness of the treatment process and requiring maintenance, increasing costs.

- Passive Treatment Systems: A passive treatment system often uses engineered wetland systems to help natural processes that neutralize acidity and remove heavy metals.

  AMD flowing through such a system will undergo chemical and physical processes driven by sunlight and other ecological processes. Due to the high acidity of most AMD, neutralization is often necessary using limestone drains or similar facilities through which the AMD flows. Once neutralized, natural processes drive oxidation, which helps the precipitation of heavy metals.

  These systems are often among the least expensive to implement but usually require much more space than other methods. They may also require considerable planning, construction, permitting, and periodic maintenance.

  Another factor to consider regarding passive wetland treatment is the management of vegetation that has absorbed heavy metals through uptake. If the vegetation is allowed to die off naturally, the absorbed metals can be released back into the water and soil, eventually becoming biologically available and entering various levels of the food chain. Proper disposal of vegetation is crucial to prevent this re-entry of metals into the ecosystem.

- Biological Treatment: This active or passive process uses microorganisms to help remove contaminants from water. Microorganisms can oxidize or reduce metals in AMD, creating the opportunity for precipitation. Biological treatment can be an effective and low-cost choice for treating AMD, but it may not be suitable for all types of contamination.

  Several types of biological treatment technologies are useful for treating AMD. One example is sulfate-reducing bacteria treatment, which uses bacteria that convert sulfate to sulfide, causing heavy metals to precipitate out of the water. Another example is constructed wetlands, which use a combination of wetland plants and soil microbes to neutralize acidity and remove heavy metals. The process can be more active and efficient by controlling temperature, mixing, or adding supplemental nutrients.

  The process can be sensitive to environmental conditions, such as temperature, pH, and nutrient availability, which can affect the performance of the microorganisms. Biological treatment may also require a longer treatment time than other treatment technologies, which can increase the treatment footprint.

- Adsorption: This process may be active or passive and involves using materials, such as activated carbon or zeolites, to remove heavy metals from the water. Adsorption is effective at treating low to moderate concentrations of AMD but can be expensive and may require frequent replacement of the adsorbent material.

  The process can be sensitive to changes in pH, temperature, and water chemistry, which can affect the performance of the adsorbent material.

- Electrochemical Treatment: This process involves using an electrical current to oxidize and precipitate metals from AMD. Electrochemical treatment can effectively treat high-concentration AMD but can be expensive and requires careful monitoring and maintenance.

  The electrochemical treatment process involves passing AMD through a treatment chamber with immersed electrodes. The iron or aluminum electrodes react with the water to produce a hydroxide sludge that neutralizes acidity and precipitates metals. The electrical current helps to speed up the oxidation process, making the treatment more efficient.

  Electrochemical treatment can effectively remove a range of metals from AMD, including iron, copper, zinc, and manganese. The process can also neutralize AMD acidity, making it less environmentally harmful. Electrochemical treatment can be useful alone or with other treatment technologies, such as chemical precipitation or reverse osmosis.

  There are limitations to using electrochemical treatment for AMD. The process can be energy-intensive and requires careful monitoring and maintenance to ensure the best performance. Hydroxide sludge produced during treatment will require further treatment or disposal, adding to the treatment cost.

  In summary, electrochemical treatment can be an effective choice for treating high-concentration AMD. Still, it is just one of several treatment technologies that may be suitable depending on the specific characteristics of the AMD. Combining electrochemical treatment with other treatment processes can create a comprehensive treatment system that effectively removes contaminants from the water.

These are just a few examples of the technologies to treat AMD. The choice of technology depends on several factors, including the concentration and composition of contaminants in AMD, the volume of water to treat, and the treatment goals.

State Programs

West Virginia University (WVU) researchers recently received funding from the U.S. Department of Energy to develop and advance their pioneering method to extract and separate rare earth elements (REEs)[3] and critical minerals from acid mine drainage and coal waste. The grant will lead to the designing, constructing, and operating of a pre-commercial demonstration facility for separating and refining rare earth elements and critical minerals.

WVU researchers project that the facility will produce between 5.4% and 7.3% of the global requirements for Terbium and Dysprosium, two of the most sought-after and critical REEs.

In November 2022, Omnis Sublimation Recovery Technologies (OSRT)[4] announced plans to build a plant in West Virginia to extract strategic metals and rare earth elements commercially.

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[3] https://wvutoday.wvu.edu/stories/2023/04/05/wvu-researchers-earn-8m-for-rare-earth-extraction-facility-an-economic-and-environmental-game-changer
[4] https://businessfacilities.com/osrt-to-invest-60m-in-west-virginia#:~:text=OSRT's%20technology%20can%20extract%20pure,waste%20and%20no%20harmful%20emissions.

Rare earth elements are a group of seventeen chemical elements, including cerium, neodymium, europium, terbium, and dysprosium, among others. Collecting the specific types of REEs from AMD treatment depends on the composition of the water and the treatment process used. Once collected, the valuable elements can be processed and sold to industries that use them in various applications.

The specific types and concentrations of REEs in AMD depend on the geology and mineralogy of the coal seams and surrounding rock formations. Studies have shown that AMD from West Virginia coal mines can have significant REEs concentrations, particularly in the Appalachian region. For example, one study found that the concentration of REEs in AMD from a mine in West Virginia ranged from 0.25 to 25.5 milligrams per liter (mg/L), with cerium, lanthanum, and neodymium being the most abundant[5].

The Commonwealth government has implemented Pennsylvania's "Abandoned Mine Reclamation Program[6]" to address AMD issues. This program focuses on treating acidic water using methods such as limestone drains and passive and active treatment systems.

The state government has established the "Acid Mine Drainage Task Force[7]" in West Virginia to address the problem. This task force collaborates with local communities to implement AMD treatment projects and provides funding for research on innovative treatment technologies.

The state government has implemented the "Ohio Stream Mitigation Program[8]" to address AMD issues in Ohio. This program focuses on restoring streams affected by AMD, including constructing wetlands and other natural treatment systems.

These efforts have successfully reduced AMD's environmental impact and improved water quality in affected areas.

Choosing an Environmental Consultant

There are several techniques and best practices in combination to remediate AMD. Effective AMD remediation typically requires collaboration between multiple stakeholders, including government agencies, non-profit organizations, and private companies, and may involve significant financial and technical resources. Your environmental engineer or consultant can be instrumental in keeping remediation projects on track. Seek an environmental consulting firm with experience in the following:

- Characterization and assessment of AMD-impacted sites, including sampling and monitoring water and soil quality.

- Design and implement treatment systems, such as passive or active treatment technologies, to remediate AMD.

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[5] https://researchrepository.wvu.edu/cgi/viewcontent.cgi?article=12619&context=etd
[6] PA Abandoned Mines
[7] https://wvmdtaskforce.com/
[8] https://ohiodnr.gov/business-and-industry/best-management-practices/mining-reclamation-restoration/acid-mine-drainage-abatement

- Regulatory compliance aid, including preparation of permit applications and compliance monitoring.

- Development and implementation of long-term monitoring and maintenance programs to ensure the effectiveness of remedial actions.

- Stakeholder engagement and public outreach to ensure effective communication and collaboration with affected communities.

To ensure a successful project in the field of reclamation and remediation, it is crucial for your environmental engineering or consulting firm to have staff members with relevant mining experience. This expertise enables them to grasp the intricacies and complexities associated with these processes.

Finally, establishing a positive working relationship with regulatory authorities is paramount as it contributes to the project's overall success. Collaboration and cooperation with regulators foster a smoother and more effective implementation of reclamation and remediation initiatives.

About the Author: David Palmerton, PG, has extensive experience in environmental site assessment remediation, due diligence, and construction quality control. His experience includes consulting services to various large commercial, industrial, municipal, and academic entities.