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Recovery of Rare Earth Elements from Acid Mine Drainage Using Geotextile Tubes Containment and Dewatering Technology

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ABSTRACT

Rare earth elements (REE) are critical to the global economy because of their use in cell phones, computers, and by the airline and aerospace industry. Areas to mine are limited and their recovery is becoming extremely expensive. In the Appalachian region of the US there is a huge and continuing problem of dealing with acid mine drainage (AMD) from abandoned coal mines. The damaging impact of this waste stream on the environment is well documented. Standard treatment of AMD involves introduction of alkaline chemistry to precipitate metals and other solids. However, this treatment creates millions of tons of high water content sludge that is difficult and expensive to manage. A major university in conjunction with their state Department of Environmental Quality have conducted a multi-year pilot study using geotextile tubes to contain and dewater this AMD high water content slurry to the state that REE can be recovered economically. This paper will present the methodology and phases of the pilot project that created the proof of concept and the following scalability to the full scale Rare Earth Element recovery project at a major abandoned mine in Appalachia. Also, this paper will also present the cost of the operation and the economic feasibility offered by the application of the geotextile tube containment and dewatering technology.

INTRODUCTION

Acid mine drainage (AMD) has been occurring in the Appalachian region since coal mining began in early 18th century. Over time, many mines reached their useful-life and production ceased or companies went out of business resulting in AMD discharging form these abandoned mines into native streams and waterways. Acid mine drainage and or acid and metalliferous drainage (AMD) is the outflow of acidic water from metal mines or coal mines. AMD occurs naturally within some environments as part of the rock weathering process but is exacerbated by large-scale earth disturbances characteristic of coal mining. round flow of water thru a chemical process of oxidation absorbs the sulfur and becomes acidic. Figure 1 details how AMD is generated in an abandoned mine and Figure 2 demonstrates the result of the AMD discharge.

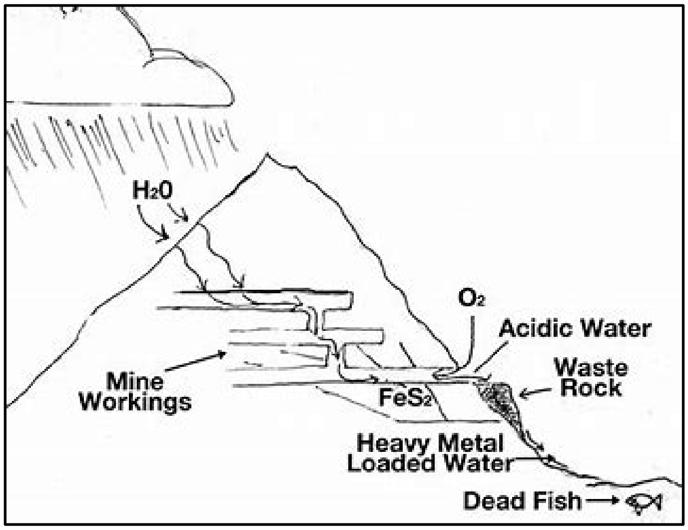

Figure 1 Typical AMD generation

Figure 2 Results of AMD in a native stream

The 1972 Federal US Clean Water Act required collection and treatment of AMD clay or geomembrane lined lagoons. However, this created numerous high liquid content "red mud" filled lagoons. See Figure 3. These lagoons tended to overflow or have berm failures during high rainfall events or

Figure 3 Typical AMD high moisture content “red mud” filled lagoon

In 2006, the state of Pennsylvania DOT required an innovative solution to contain and dewater a large flow of AMD that was perched during the construction of a section of I-99. Engineers adopted a solution proposed by TenCate to use large volume woven geotextile tubes after bench chemical treatment testing demonstrated that it was possible to receive and treat flow rates up to 250 m3/hr. This geotextile tube containment and dewatering process is still in used today treating a much lower flow rates. However, this project created a proof of concept that could be adapted to the mining industry for AMD treatment, containment, and dewatering.

The state of West Virginia has the largest number of abandoned coal mines in the US and has taken the regulation process one step further by establishing a focused AMD Task Force within their DEP to acquiring these abandoned mines. However, the WV DEP task force needed a systems approach to their AMD problem. After reviewing the success of the I-99 AMD project, the WV DEP designed their first large scale project for the Omega mining complex south of Morgantown, WV. The site consisted of three abandoned mines generating 1.0 to 2.0 m3 of ADM per minute depending on the season at a pH of 3.4. The flow was collected at the three different sources and pumped to a central point. See Figure 4.

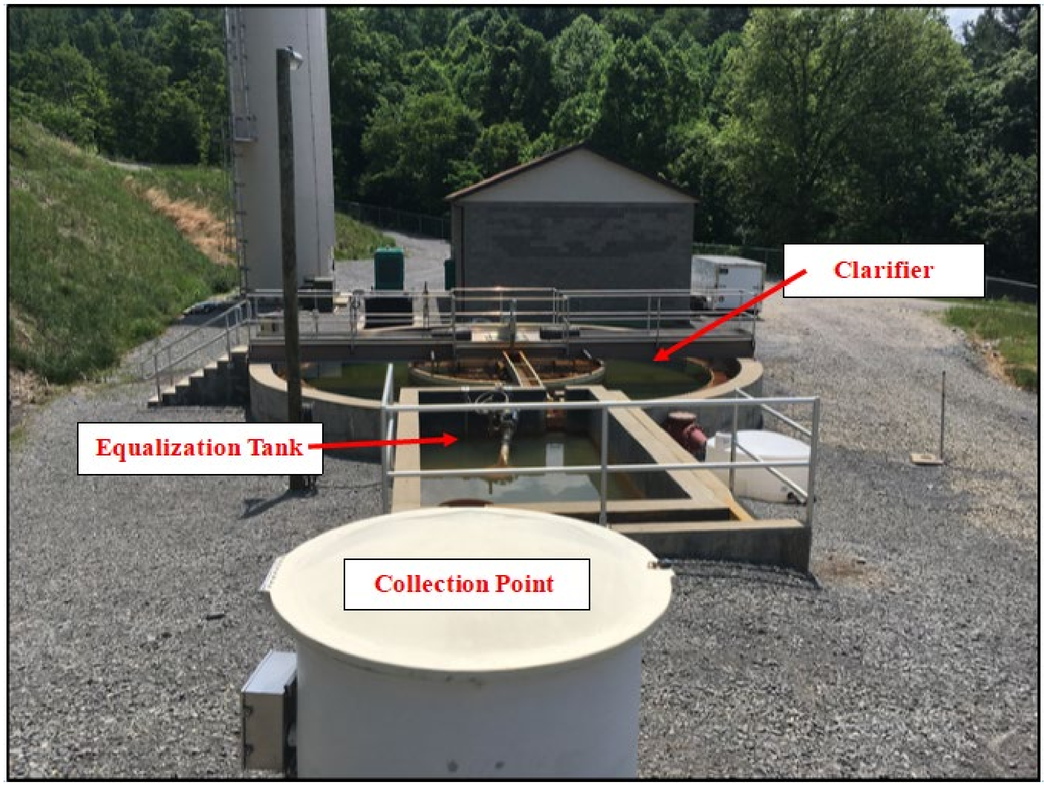

Figure 4 Omega Mine central collection and treatment system

From the central collection point, the AMD with 0.2% solids flowed into an equalization tank where the hydrated lime was injected at a rate to raise the pH to 6.0 and precipitate the dissolved solids. Also, a small amount of anionic polymer was injected to agglomerate the precipitated solids. From the equalization tank, the AMD flowed to the clarifier where a slurry is formed that settles to the conical bottom. As the settled slurry level raised in the clarifier to a certain level, pumps in the control house automatically turn on and pump the now 2.0% solids slurry to the geotextile dewatering cell. See Figure 5.

The dewatering cell has capacity for sixteen 13.7m circumference by 74m long geotextile tubes per layer. These geotextile tubes contain the slurry as the solids separate and the clear effluent weeps thru the geotextile pores. The AMD retained and dewatered within the geotextile tubes increase to 45% solids by weight within 7 days and eventually reach 65% solids within 30 days. See Figure 6. Currently the Omega site has been in operation for three years and the geotextile tubes are on level 3. The current dewatering cell site has a capacity to receive and dewater the current rate of AMD flow for 20 years of 24/7 operation. If the story ended here, by any method of measurements, the Omega AMD project is a success. In fact, the WV DEP is adding three of these automated geotextile tube AMD management sites per. One of the new sites has flowrates up to ten times the Omega project.

Figure 5 Geotextile tube dewatering cell

Figure 6 AMD clarifier slurry @ 2% solids versus 65% dry solids from inside geotextile tube

In 2017, the US Department of Defense and Department of Energy (DOD and DOE) initiated a program to develop domestic sources or rare earth elements (REE). The REE is a family of 17 elements that are critical and strategic elements for the manufacturer of communication, energy, defense, and aerospace products and systems (Figure 7). Since the early 1990s, +99% of all REE have been mined and refined in China and the global demand is growing. Since 2013, the

REE US source has been a congressional concern according Congressional Research Service. DOE Secretary Perry stated in 2018 at the National Energy Technology Conference, “Without a secure domestic source of REE, the US economy and security could be at risk”.

It is not that these elements are rare in existence, it is that they are rare in a concentration that can be commercially mined and processed. Therefore, the current US federal administration has placed a high priority on identifying domestic sources of RER that are available to be processed.

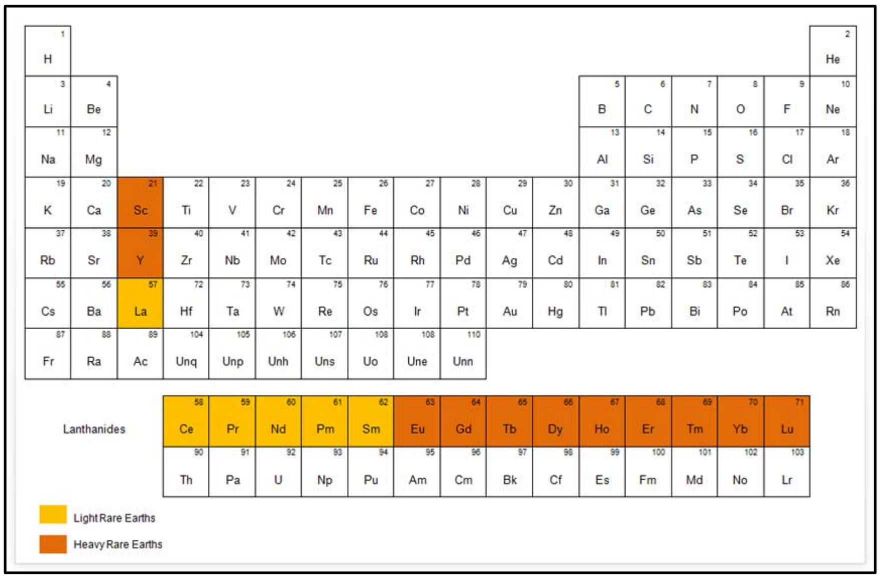

Figure 7 REE highlighted within the Periodic Table

It has been known for some time that AMD has the potential to have trace quantities of REE. Therefore, in 2017, The University of West Virginia Water Research Institute began a study to identify and quantify potential sources of REE in existing Appalachian AMD point sources. 152 sources of raw AMD water were sampled in the Northern (NAPP) and Central (CAPP) Appalachian Basin located in four states to quantify the availability of REE. See Figure 9 for the location of first 140 of the 152 sites. In addition, samples from three ADM geotextile tube dewatering sites were sampled to determine if these three sites were retaining the REE within the geotextile tubes during the dewatering process. A total of 155 ADM samples were taken and analyzed.

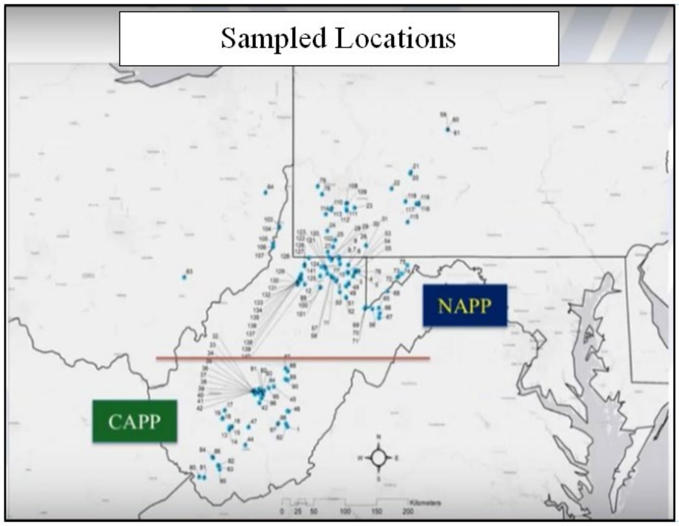

Figure 8 Location of NAPP and CAPP AMD collection sites

CAPP VS. NAPP:

Little difference between REE distribution or total concentration (g/t)

Sites sampled:
CAPP 42
NAPP 110

	CAPP	NAPP	All
La	41.4	38.4	39.9
Ce	97.1	95.0	96.0
Pr	14.4	14.0	14.2
Nd	66.5	64.5	65.5
Sm	18.2	17.6	17.9
Eu	4.4	4.5	4.4
Sc	12.8	14.9	13.8
Y	88.6	108.7	98.7
Gd	23.9	24.3	24.1
Tb	3.4	3.7	3.6
Dy	18.8	20.7	19.8
Ho	3.5	4.0	3.8
Er	9.1	10.7	9.9
Tm	1.0	1.4	1.2
Yb	6.7	8.1	7.4
Lu	0.9	1.2	1.0
TREE	410.6	431.6	421.1

Figure 9

The average concentration of REE in the 42 CAAP raw water AMD point sources samples was 410.6 grams per ton (g/t) of dry solids (Figure 9). According to Ziemkiewicz and Xingbo's 2018 study at WVU, the dewatered solids in the geotextile tubes at the Omega mine located in the CAPP region totaled 397g/t. Therefore, the geotextile tube technology was retaining 96.7% of available REE from the AMD flow. In the same study, it was calculated that each geotextile tube in the Omega dewatering cell contains 146 dry metric tons of AMD or 58 kg of recoverable REE ore. The NETL April 2018 Summary Report set the REE Basket Price (MREO) of Appalachian Basin recoverable REE ore is $225.00/USD per kg. Therefore, each geotextile tube contains approximately $13,050.00/USD of recoverable REE ore.

CONCLUSION

When geotextile tube technology was analyzed as a method for recovering Rare Earth Elements from Acid Mine Drainage, it was proven to be extremely efficient and cost-effective in capturing, >90% of available REE.

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