The Barnes & Tucker #20 mine drainage treatment facility: optimization case study in consideration of variable flow and water chemistry

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Abstract

The Barnes & Tucker #20 (B&T #20) mine drainage treatment facility, which is been in operation since 1966, has been treating the mine water from the B&T #20 mine pool using evolving treatment methodologies based on more recent understandings of the varying mine water quantity and quality. Incorporating more recent technologies to maximize retention time, more efficiently add alkaline chemicals when necessary, and relying on more "passive" techniques to remediate the mine water when possible, allowing for reduced costs to the treatment trust and more effective treatment within the system that could potentially accommodate an additional upstream mine drainage source known as Victor #10.

Keywords: Mine drainage, treatment

Introduction

Located in West Carrol Township, Cambria County, Pennsylvania, USA, the Lower Kittanning (B) seam underground mine was originally opened by the Logan Coal Company as its #5 mine in 1906. The Navy Smokeless Coal Company assumed operations in the 1920's. Barnes & Tucker (B&T) acquired the mine in 1955, renaming the site the #20 mine and continued operations up until 1985. The current treatment site location initially served as a drift opening access to the mine and included shop facilities, a coal rail loadout and coal processing and storage facilities. Mine water was discharged from the mine at this location into the headwaters of the West Branch Susquehanna River. In 1966 when Pennsylvania amended it's Clean Streams Law to include mine drainage as regulated industrial wastewater, mine operators were precluded from discharging untreated mine water and required to obtain permits and comply with applicable effluent criteria. As a result, in 1966 B&T constructed a lime (calcium oxide) treatment facility utilizing four settling ponds to achieve pH adjustment, metals oxidation and precipitation. B&T operated the treatment facility until they declared bankruptcy in 2001. The Pennsylvania Department of Environmental Protection (PADEP) utilized assets acquired in the bankruptcy proceedings to establish a treatment trust and continue operation of the facility.

The structural geology of the local area plays a substantial role in both the quantity and quality of the mine water that discharges at the site. A geologic anticline bisects the mine workings, in an approximate north-south orientation. Approximately 60 ac (0.24 km^2) of the mine, which is on the northern side of the anticline, free drains through the B&T #20 portal. During active mining, drainage from the 400 ac (1.62 km^2) of the mine workings on the opposing (southern) side of the anticline was pumped in-mine through the portal for treatment prior to discharge. Post mine closure, a mine pool developed on the in-by side of the anticline, which, on a seasonal

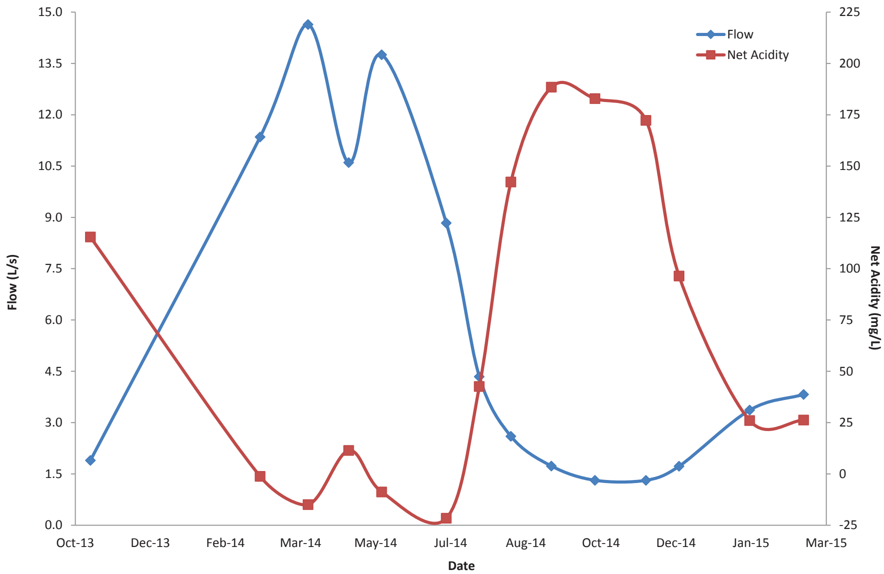

***Figure 1** Seasonal Variations of Flow Rate and Net Acidity in B&T #20 Raw Water*

basis discharges water to the portal area combining with flow from the free draining portion of the mine workings (PADEP and PSU 2014). Fig. 1 and 2 illustrate an example of the seasonal variations in both flow and chemical characteristics of the B&T #20 raw water, which were confirmed with additional monitoring from 2022 to 2023.

Fig. 1 and 2 illustrate that on an annual basis the raw water discharge is estimated to be net alkaline for six or more months each year, which was confirmed through additional monitoring from 2022–2023. This "net alkaline" period represents conditions where the mine pool is overtopping the anticlinal axis and mixing with the free draining

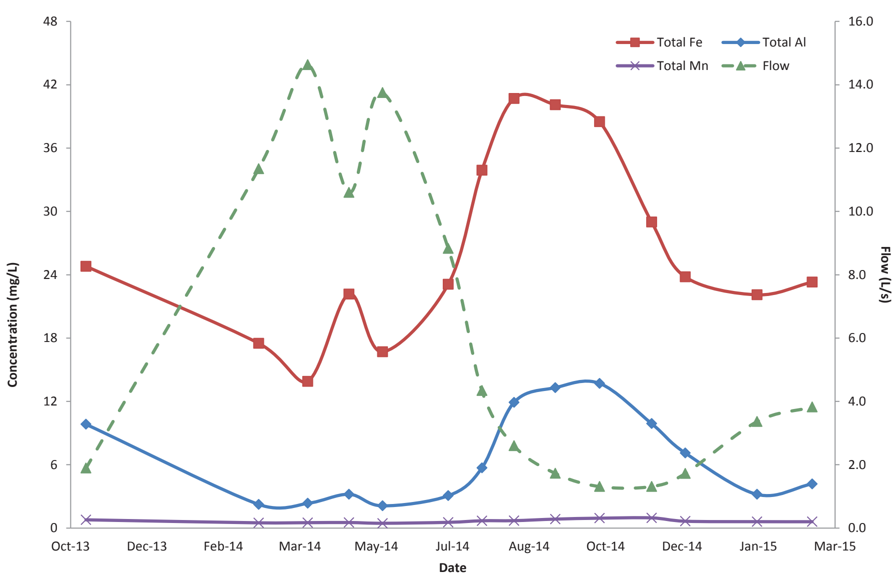

***Figure 2** Seasonal Variation of Fe, Mn, and Al Concentrations vs Flow in B&T #20 Raw Water*

portion of the mine. Discharge flows during this period typically range between 50 gpm to 300 gpm (3.16–18.92 L/s) of circumneutral pH net alkaline water. The net alkaline mine water contains high dissolved carbon dioxide (CO_2) concentrations (34–235 mg/L) and moderate levels of dissolved ferrous iron (5.0–19.0 mg/L). Conversely, during the seasonal dry portion of the year, only the free draining portion of the mine discharges resulting in flows of approximately 30 gpm (1.89 L/s) of low pH net acidic water but still containing elevated concentrations of dissolved CO_2 and ferrous iron. PADEP realized that seasonal variability of the mine water quality offered the opportunity to establish a hybrid active/passive treatment approach.

Prior to the 2001 bankruptcy and transfer of site operations to a PADEP trust, B&T continued operating the antiquated original lime system and made no operational changes in consideration of these seasonal mine water quality fluctuations. No other substantial recapitalization or modernization efforts were made by B&T. Sludge handling and disposal procedures consisted of sludge storage in two of the four settling ponds with periodic sludge removal by pumping sludge into the mine workings to a location on the in-by or southern (mine pool) side of the anticline. This was accomplished through a horizontal pipeline that was placed, when the mine was still operational, through the mine portal extending to a point along the mains that was located beyond the anticlinal axis. After the mine closed and a mine pool was established, sludge could only be pumped during seasonal dry periods when the pool was not overflowing the axis of the anticline, which creates a limited window of opportunity to pump sludge. When the PADEP trust assumed operations, two of the four settling ponds were filled with sludge and non-operational. Additionally, most of the site's treatment infrastructure was in disrepair or in need of substantial upgrade.

With limited funding available in the trust and to preserve its solvency, initial efforts were aimed at re-establishing treatment capacity through desludging two of the service ponds and improvements in treatment methodology and efficiency. The Office of Surface Mining Reclamation and Enforcement (OSMRE) Pittsburgh Field Office was requested to provide technical assistance to PADEP in these efforts. A PADEP/OSMRE technical team that also included the site's contract operator, Llyod Environmental Services, first secured beneficial reuse of the stored treatment sludges. The antiquated lime system coupled with frequently treating net alkaline mine water containing high concentrations of dissolved carbon dioxide (CO_2) yielded sludge that, based upon laboratory solids analysis, contained more than 80% calcite. PA's Waste Management regulations permitted this material to be utilized as an alkaline additive for PADEP Bureau of Abandoned Mine Reclamation (BAMR) sites. PADEP BAMR utilized the sludge material removed from the ponds as backfill (and alkaline amendment?) on adjacent mine reclamation sites and an active surface mine, thus greatly reducing costs associated with pond cleaning and disposal.

Methods

The next objective was two-fold, first the recently cleaned ponds were brought back online for treatment operations and the treatment strategy was modified to allow the first pond in the system (Pond 1) to be used for decarbonation under all seasonal water quality conditions and as a passive treatment portion of the facility when the mine water was net alkaline. The conveyance channel from the raw water source to Pond 1 was reconstructed to allow considerable cascading of the water prior to entering the pond for decarbonation. Settling pond retention time was also analyzed, and floating vinyl baffles were installed at strategic locations in the first two settling ponds to optimize retention time and sludge management. Visual fluorescent dye testing confirmed the improvement to the hydraulic retention time in the first two settling ponds resulting from the baffle installation and modified outfall piping. These as well as other site recapitalization and process improvement tactics were implemented at the site with the goal of treatment process optimization and cost reduction.

Table 1 Summary results of treatment strategy optimization (Pond 1)

Date	Flow (L/s)	CO_2 Removed			Iron Oxidized		Iron Settled		Acidity Reduction	
		mg/L	%	as $CaCO_3$ mg/L	mg/L	%	mg/L	%	mg/L	kg/day
12/20/21	11.4	0.0	0	0.0	4.84	86	4.29	50	8.7	8.62
2/24/22	17.7	42.9	78	48.8	5.61	75	3.80	42	58.9	89.90
4/20/22	15.8	12.4	39	14.1	6.34	79	5.19	49	25.5	34.93
6/30/22	2.3	29.9	74	34.0	9.87	52	9.20	46	51.8	10.16
8/4/22	1.1	113.2	98	128.7	21.6	64	21.90	63	167.6	16.28
8/25/22	2.3	12.5	73	14.2	7.14	85	8.24	80	27.1	5.31
10/25/22	4.3	101.5	91	115.4	9.97	98	9.43	80	133.4	49.44
12/22/22	8.2	45.0	39	51.2	N.M.	N.M.	7.18	68	51.2	36.29
3/13/23	14.3	143.0	61	162.6	8.49	90	6.50	58	177.9	220.17
8/7/23	2.1	22.9	65	26.0	10.96	89	11.11	77	45.8	8.48

N.M. = Not Measured

The original lime system was abandoned in favor of a 25% caustic soda (NaOH) system dispensing chemical after the first pond decarbonation/passive portion of the current passive/active hybrid treatment approach. A programmable logic controller (PLC) based, pH-controlled pinch valve automated NaOH dosing system was implemented and has resulted in additional annual operational cost savings. Table 1 summarizes the resultant gains in treatment efficiency that have been obtained by implementation of the above measures particularly related to passive treatment resulting from Pond 1 based on OSMRE flow and water chemistry sampling efforts primarily conducted in 2022 and 2023. Pond 1 on average oxidized 80% and precipitated and settled approximately 60% of the dissolved ferrous iron. Table 2 summarizes the estimated volume and cost savings for the 25% NaOH addition resulting from iron and carbon dioxide removal in Pond 1. On average for 2022 values only, Pond 1 has reduced the daily volume and cost of 25% NaOH addition by 87.4 L and $27.98 assuming a unit cost of $0.32/L. These daily values correlate to annual savings of 31,901 L and $10,213 of 25% NaOH.

Conclusions

Numerous additional site improvements have either been completed or are in various stages of design and development for the B&T #20 site. Table 3 summarizes these accomplishments and planned objectives. Lastly, the B&T #20 system optimization efforts have provided an opportunity to facilitate including an additional upstream

Table 2 Estimated chemical cost savings from Pond 1 treatment efficiency based on iron and carbon dioxide removal

Date	25% NaOH Volume & Cost Savings	
	L/day	$/day (@ $0.32/L)
12/20/21	21.7	6.94
2/24/22	227.1	72.67
4/20/22	88.2	28.22
6/30/22	25.7	8.22
8/4/22	41.1	13.15
8/25/22	13.4	4.29
10/25/22	124.9	39.97
12/22/22	91.6	29.31
3/13/23	556.1	177.95
8/7/23	21.5	6.88

abandoned mine discharge, locally known as the Victor #10 discharge into the existing system. The combined treatment approach, which leverages the additional B&T #20 system capacity made available through process improvements, would result in substantial watershed improvement at lower operating costs when compared to construction of a new treatment system specifically for the Victor #10 discharge. The Victor #10 discharge has a broad range of flows, 63–500 gpm (3.98–31.54 L/s) and contains high levels of dissolved CO_2 (21–276 mg/L) and dissolved ferrous iron (6.3–28.6 mg/L). However, when flows are less than 200 gpm (12.62 L/s), the Victor #10 discharge tends to be slightly net acidic (hot acidity = 5.4–48.4 mg/L) and have higher dissolved ferrous iron concentrations (17.5–28.6 mg/L). Like the B&T #20 mine pool, the Victor #10 mine pool exhibits seasonal variations ranging between net alkaline and net acidic due to the complexity of the mine pool hydrology. Incorporating the Victor #10 discharge into the B&T #20 treatment system would on average more than double the current flows and loading of dissolved ferrous iron in addition to requiring the use of additional NaOH due to more frequent net acidic conditions observed in Victor #10. However, treatment of the Victor #10 discharge would be highly beneficial to restoring the headwaters of the West Branch Susquehanna River.

References

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***Table 3** B&T #20 site improvement process optimization summary table*

System Improvement / Upgrade	Summary of Work	Status
Pond Rehabilitation		Completed
Site Infrastructure	New stream crossing and access road improvements; Replacement of pond pipe network; Purchase land for installation of new sludge disposal line; Removal of dilapidated equipment and structures	Completed
Treatment Methodology	Conversion of Pond 1 to passive treatment (CO2 off-gassing and Fe oxidation); Conversion to NaOH chemical addition system	Completed
Treatment Optimization	Pond 1 aeration/decarbonation trays; Raw water influent pipeline replacement and elimination of surface water inflows; Drainage drift (in mine) pipeline replacement.	Design Completed
Sludge Disposal	Disposal borehole placement exploratory drilling; Road boring/ horizontal directional drilling (HDD) alternatives analysis.	In Process Development/Design
Capacity Determination	Cost/Benefit Analysis and conceptual design including the Victor #10 discharge in B&T #20 system.	In Process