Nelson Tunnel / Commodore Waste Rock Superfund Site Electrocoagulation Pilot 8/12 – 8/31/2024

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in support of Environmental Protection Agency Region 8.

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EPA NELSON TUNNEL PILOT RESULTS

Introduction

This document presents the testing results of the pilot work performed by Avivid Water Technology LLC in support of the U.S. Environmental Protection Agency's (EPA) investigation of electrocoagulation (EC) treatment technology for temporary water treatment during the Interim Remedial Design at the Nelson Tunnel/Commodore Waste Rock Superfund site in Creede, Colorado.

Results

Contaminants of Concern (COC)

- Aluminum
- Silver
- Cadmium
- Copper
- Iron
- Lead
- Manganese
- Selenium
- Zinc

In Table 1 (right) are the averaged results from one week of operation at an aluminum dose level of 147 mg/liter coagulant from the dissolution of aluminum anodes.

Over the course of the 14-day pilot, Avivid proved out the effectiveness of the TurboCoag® EC reactor for treating mine influenced water (MIW), providing an efficient water treatment system with a small footprint, that was deployed in remote, rugged terrain, and successfully returned clean water to the West Willow Creek (WWC) that exceeded the EPA's goals for contaminant removal.

Based on the results achieved, Avivid believes that its TurboCoag® electrocoagulation is an excellent process to significantly reduce or eliminate contaminants of concern (COC) while minimizing waste production at the Nelson Tunnel site during the planned Interim Action Record of Decision (IROD) construction phase.

Table 1. Week 1 average reduction rates

Analyte	UNITS	MDL	Raw Average	Effluent Average
Silver	ug/L	0.045	0.0844	ND
Aluminum	ug/L	8.3	692	667.4
Arsenic	ug/L	0.5	3.74	0.62
Barium	ug/L	0.38	16.2	14.4
Beryllium	ug/L	0.3	3.72	ND
Calcium	ug/L	32	172000	160000
Cadmium	ug/L	0.19	94.6	5.66
Cobalt	ug/L	0.33	26.4	1.708
Chromium	ug/L	0.5	0.66	0.528
Copper	ug/L	0.71	45.8	0.798
Iron	ug/L	8.7	50.4	10.62
Potassium	ug/L	52	5020	4960
Magnesium	ug/L	4.2	10800	4500
Manganese	ug/L	0.51	16400	3400
Sodium	ug/L	73	75200	50000
Nickel	ug/L	0.83	12.4	1.552
Lead	ug/L	0.23	744	0.308
Antimony	ug/L	0.4	0.4	ND
Selenium	ug/L	1	ND	ND
Thallium	ug/L	0.21	2.78	1.478
Vanadium	ug/L	1.1	ND	ND
Zinc	ug/L	2	36800	199.8
Chloride	mg/L	1	1.06	3.12
Fluoride	mg/L	0.17	0.584	ND
Sulfate	mg/L	5.2	680	546

Effluent Goals Surpassed

Avivid provided TurboCoag electrocoagulation (EC) treatment of the Nelson Tunnel MIW for release to WWC and surpassed the minimum goal of a 50% reduction in COC during the first week.

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Treated samples were sent to an independent lab (Eurofins, Denver) for analysis and characterization as displayed in Table 1.

Resource Conservation and Recovery Act (RCRA) Standards

Solids testing of Avivid's waste sludge established that the material passed toxicity characteristic leaching process (TCLP) and sent to a standard landfill for disposal.

Table 2. TCLP Results for Solids Samples

Analyte	Units	RCRA Standard	TCLP 08252024	TCLP 08312024
Aluminum	mg/L		280	150
Antimony	mg/L		ND	ND
Arsenic	mg/L	5	ND	ND
Barium	mg/L	100	0.23	0.027
Beryllium	mg/L		0.0011	0.0012
Cadmium	mg/L	1	0.23	0.14
Calcium	mg/L		31	13
Chromium	mg/L	5	0.22	0.082
Cobalt	mg/L		0.063	0.05
Copper	mg/L		0.31	0.46
Iron	mg/L		3	0.22
Lead	mg/L	5	0.88	1.7
Magnesium	mg/L		14	22
Manganese	mg/L		25	15
Mercury	mg/L	0.2	-	ND
Nickel	mg/L		0.039	0.067
Potassium	mg/L		7.3	5
Selenium	mg/L	1	ND	ND
Silver	mg/L	5	ND	ND
Thallium	mg/L		ND	ND
Vanadium	mg/L		0.0045	ND
Zinc	mg/L		67	98

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Effluent Water Quality

Water quality parameter testing was performed daily and tracked for each port. West Willow Creek water quality parameters were tested 50' above and below the effluent release point into WWC.

Note that during the pilot test, water released to WWC was often lower in turbidity than water in the creek and significantly lower than the untreated water.

In Figure 1, note that missing turbidity data for the first three days of the pilot is because the water in the settling tank had not yet reached the height of the exit port. No water was released to WWC until Day 4 of the pilot.

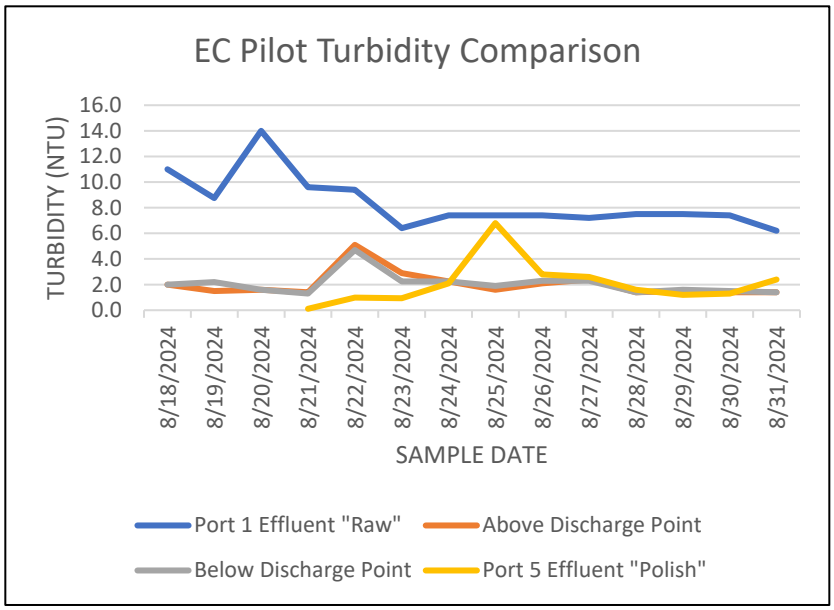

Figure 1. Turbidity Data Comparison

The Port #5 NTU spike noted on 8/25 coincides with the switch from heavy dose to medium dose treatment. The lighter floc settled out overnight and turbidity dropped again, as shown in Figure 1.

pH Values Compared

Changes to pH are expected as EC produces radical hydroxyls ($OH^{\cdot}$) at the cathode. Moving from a low pH to neutral is a desirable change for MIW ensuring that the water meets environmental release standards. Avivid did not need to adjust the pH of the influent water further than EC provided to achieve effective treatment, and thus avoided the addition of chemicals at the pilot site. For an excellent paper on EC and its effect on pH changes, see Yasri, 2020, *Electrocoagulation Separation Processes*, DOI: 10.1021/bk-2020-1348.ch006.

Daily Observed pH Changes

Table 3. pH Data Table

PILOT DAY	RAW	POST EC
1	6.58	7.26
2	5.69	7.02
3	5.92	7.25
4	5.94	7.12
5	5.53	7.14
6	5.51	7.17
7	5.71	7.23
8	5.71	6.36
9	5.79	6.14
10	6.5	6.73
11	5.65	6.45
12	5.66	6.68
13	5.32	6.31
14	5.04	6.84

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Effect on Alkali and Alkaline metals

Many white papers on EC have noted that it does not remove alkali and alkaline metals as effectively as it removes other heavy metals. TurboCoag's test results prove this to be the case, while some instances of high removal rates are associated with the sweep floc effect.

Table 4. Alkali and Alkaline Metal Reduction

Analyte	Raw Average	Polish Average	Average % REDUCED
Calcium	172000	166667	3%
Sodium	75200	50667	33%
Magnesium	10800	4500	57%
Potassium	5020	5067	-1%
Barium	16.2	14.4	3%
Beryllium	3.72	ND	100%

Table 5. Anions and Alkalinity

Analyte	Raw Average	Polish Average	Average % REDUCED
Chloride	1.06	2.57	-142%
Fluoride	0.58	ND	100%
Sulfate	680	563	17%
Alkalinity, Total	3.10	3.53	-14%

Solids Production

Table 6 displays the results from the waste sludge produced by Avivid's electrocoagulation process. High amounts of aluminum are expected due to the use of aluminum anodes.

Table 6. Total Metals in Sludge

Analyte	MDL	Result	UNITS
Silver	69	250	ug/Kg
Aluminum	48,000	280,000,000	ug/Kg
Arsenic	650	6,500	ug/Kg
Barium	930	1,200,000	ug/Kg
Beryllium	290	2,800	ug/Kg
Calcium	110,000	12,000,000	ug/Kg
Cadmium	260	90,000	ug/Kg
Cobalt	85	27,000	ug/Kg
Chromium	1,200	290,000	ug/Kg
Copper	2,600	230,000	ug/Kg
Iron	50,000	8,800,000	ug/Kg
Potassium	68,000	170,000	ug/Kg
Magnesium	32,000	6,400,000	ug/Kg
Manganese	1,200	8,900,000	ug/Kg
Sodium	120,000	930,000	ug/Kg
Nickel	2,200	42,000	ug/Kg
Lead	490	670,000	ug/Kg
Antimony	480	ND	ug/Kg
Selenium	440	ND	ug/Kg
Thallium	230	ND	ug/Kg
Vanadium	1,300	23,000	ug/Kg
Zinc	440,000	34,000,000	ug/Kg

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Process Steps

1. Influent MIW was pumped from the Nelson Tunnel discharge stream to the 1200-gallon surge tank. A float system in the surge tank controlled the MIW water pump to maintain a water level adequate for a controlled flow of at least 12.5 GPM to the treatment system. Testing port #1 ("RAW") was installed at the surge tank to enable testing of untreated Nelson Tunnel influent.

Figure 2. Water conveyance system from flume to lift pump and uphill to treatment

2. From the surge tank on the front of the reactor trailer, the MIW was then pumped to the self-cleaning, passivation-free TurboCoag EC reactor at a constant flow of 12.5 GPM.

Figure 3. Water flows from the EC trailer (right) to the settling tank (left)

3. The treated water was pumped to the settling tank. No flocculant aid or pH adjustment was needed. Figure 4 (right) is a sample immediately after the EC reactor, demonstrating that solids are coagulating, approximately three minutes after sample collection.

Figure 4. Floc formation after EC treatment

4. Solids readily settled on the bottom of the tank. At that point the clarified water exited the unit via gravity, passed a manifold where Port #4 "SET EFF" was installed to enable testing of clarified water.
    a. Samples of the collected sludge were taken for TCLP and total metals testing.
    b. Solids were retained in the settling tank until after the end of the pilot and were proven to pass the TCLP test.
    c. A vacuum truck service delivered the solids to a local landfill for disposal.
5. From the manifold, treated water flowed through a pair of 25µ and 10µ bag filters prior to release to WWC. This water was released via a two-inch line downslope more than 50' above the Nelson Tunnel confluence point into West Willow Creek to avoid erosion of the hillside.

Figure 5. Water flows through the manifold through bag filters and into the stream

6. Avivid noted very few solids accumulated in the bag filters during the pilot indicating that most of the clarification took place in the settling tank, as expected. Figure 6 shows the total bag filter accumulation after the first week of operation demonstrating the importance of settling time.

Figure 6. Bag filters after one week

7. After the bag filters, water is released to West Willow Creek.

Figure 7. Treated water enters West Willow Creek

About Avivid Water Technology

Established in 2013, Avivid Water Technology (Avivid) is a Colorado limited-liability company located in Longmont, Colorado. Avivid provides advanced water purification using its patented TurboCoag® technology to successfully treat waters contaminated with heavy metals, arsenic, suspended solids, emulsified oils, microorganisms, and PFAS. TurboCoag® decreases OPEX for clients by replacing chemicals in the treatment of water, reduces waste, enables mineral recovery, and increases downstream process efficiency and cost savings.

Avivid provides customized water treatment design services, installation, integration, remote monitoring, and provides water as a service or direct sales to meet the needs of its diverse client base. As a US Small Business, Avivid is committed to excellence and the provision of innovative solutions to meet the needs of our private, State, and Federal clients.

About the TurboCoag Reactor

The patented self-cleaning, passivation-free TurboCoag electrocoagulation system employs electrolysis-based technology that does not require the use of chemical precipitants to remove suspended and

dissolved solids from solution. The electrochemical process facilitates the settling of suspended particles and drives chemical reactions between constituents in the water.

1. Cathode material: 304 stainless steel plate
2. Anode material: 6061 aluminum plate
3. Number of anodes: 16-(The cassette)
4. Surface area of electrodes: 21.01^2 meters
5. Total pilot operation time: 6435 minutes
6. Expected cassette life: 78,301 minutes
7. Total Anode Weight in cassette- 544 kg
8. Anode use: 51.8 kg of aluminum
    a. Note that this is about 5% more than predicted by Faraday's Law. This phenomenon has been observed in several white papers when using aluminum anodes.
9. Retention time within reactor:
    a. 18 minutes @ 12.5 GPM
10. Flow rate to the EC reactor:
    a. 12.5 GPM -operating flow for this pilot.
    b. Note: this reactor is capable of 50 GPM at dose level of 150 ppm Aluminum.

Benefits of TurboCoag®

- Removes suspended solids, heavy metals, and biological contaminants
- Continuous water treatment operation
- Low maintenance system
- Small system footprint
- Acts as a natural biocide
- Faster removal of contaminants
- Strong precipitant is easily filtered or quickly settled

Water treatment in rugged terrain on less than 9000 square feet

Figure 8. TurboCoag shows off its small footprint for the reactor and the settling tank

Figure 9. Rearview of the settling tank