



March 5, 2021

Scott McDaniel
Haile Gold Mine, Inc.
6911 Snowy Owl Road
Kershaw, SC 29067-8362

RE: LOA-005617
Haile Gold Mine, Inc.
Summary of Pilot Study Test Results
Wastewater Construction Permit #19830-IW
Lancaster County

Dear Mr. McDaniel:

It has come to my attention that a formal response to the summary of pilot study test results submitted July 22, 2020 has not been issued. Based on the results of bench scale studies the facility proposed changes to the wastewater treatment system in order to remove thallium concentrations from the discharge. As was communicated back to the facility, the proposed changes were operational in nature and physical changes to the wastewater treatment system were not required, therefore additional construction permitting was not needed. The operational changes proposed in the referenced summary have been implemented at the site. On March 4, 2021, the Department issued LOA-005615 approving a chemical addition change to the system operations described in the July 22 submission. Please accept this letter of approval (LOA) as acknowledgement that this office agreed that the proposed operational changes described in the July 22, 2020 submittal may be implemented without any further permitting from the Department.

If you have any comments, please contact me at 803-898-4236 or amickbm@dhec.sc.gov.

Sincerely,

A handwritten signature in black ink that reads "Byron M Amick". The signature is fluid and cursive, with the first name being the most prominent.

Byron M Amick
Environmental Engineer Associate
Industrial Wastewater Permitting Section
Water Facilities Permitting Division

cc via email: Veronica Barringer, Midlands EA Lancaster
Erin Evans, Midlands EA Lancaster
BOW/WPC Enforcement

Wastewater - Industrial - Preliminary Engineering Review (PER) and Other Request Form - New

version 1.15

(Submission #: HP1-EFAB-H7HR3, version 1)

Details

Submission ID HP1-EFAB-H7HR3
Submission Reason New
Status Submitted

Form Input

Request Information

Do you anticipate this project being funded by State Revolving Fund (SRF)?
No

Request Type:
Pilot Study Request

Permittee Information

Permittee

Prefix

NONE PROVIDED

First Name

NONE PROVIDED

Last Name

NONE PROVIDED

Title

NONE PROVIDED

Organization Name

HAILE GOLD MINE

Phone Type

Business

Number

8034752943

Extension

Email

Scott.McDaniel@oceanagold.com

Fax

NONE PROVIDED

Address

6911 SNOWY OWL RD

KERSHAW, SC 29067

United States

Owner Information

Owner

Prefix

NONE PROVIDED

First Name

NONE PROVIDED

Last Name

NONE PROVIDED

Title

NONE PROVIDED

Organization Name

NONE PROVIDED

Phone Type

Business

Number

8034752943

Extension

Email

NONE PROVIDED

Fax

NONE PROVIDED

Address

6911 SNOWY OWL RD

KERSHAW, SC 29067

Is the owner also the operator?

Yes

Contact Information

Facility Contact

Prefix

NONE PROVIDED

First Name

SCOTT

Last Name

MCDANIEL

Title

NONE PROVIDED

Organization Name

HAILE GOLD MINE

Phone Type

Business

Number

8034752943

Extension

Email

Scott.McDaniel@oceanagold.com

Fax

NONE PROVIDED

Address

6911 SNOWY OWL RD

KERSHAW, SC 29067

United States

Engineer Information

Engineer Contact

Prefix

NONE PROVIDED

First Name

NONE PROVIDED

Last Name

NONE PROVIDED

Title

NONE PROVIDED

Organization Name

NONE PROVIDED

Phone Type

Business

Number

NONE PROVIDED

Extension

Email

NONE PROVIDED

Fax

NONE PROVIDED

Address

[NO STREET ADDRESS SPECIFIED]

[NO CITY SPECIFIED], SC [NO ZIP CODE SPECIFIED]

USA

S.C. Registration Number:

NONE PROVIDED

LLR Licensing Lookup

[Engineers and Land Surveyors - Licensee Lookup](#)

Project Information

Project Name:

HAILE GOLD MINE PILOT STUDY

Facility Name

HAILE GOLD MINE

NPDES/ND Permit Number and Name

HAILE GOLD MINE - SC0040479

Project Address:

6911 SNOWY OWL RD

KERSHAW, SC 290678362

Project County

Kershaw

Project Location:

34.600143,-80.541037

Project Description of Wastewater Systems:

NA

Project Details

Is this project part of a phased project?

No

What is this project submission based on?

Order issued by DHEC

Order #:

20-021-W

Wastewater Systems

AVERAGE DESIGN FLOW

Project average design flow (GPD)

0

RECEIVING FACILITY

Construction, LOA, or Other Permit, if applicable.

NONE PROVIDED

Facility Address

6911 SNOWY OWL RD KERSHAW SC

NPDES/ND Number and Name

HAILE GOLD MINE - SC0040479

DISPOSAL SITES

Effluent Disposal Site (Description)

NONE PROVIDED

Sludge Disposal Site (Description)

NONE PROVIDED

Submittal Requirements

Additional Documents:

Pilot Study Summary_07202020.pdf - 07/22/2020 04:20 PM

Comment

NONE PROVIDED

Use the space below to bring to the Department’s attention any additional information that you believe should be considered in the permit decision.

NONE PROVIDED

Attachments

Date	Attachment Name	Context	User
7/22/2020 4:20 PM	Pilot Study Summary_07202020.pdf	Attachment	Patty Barnes

Status History

	User	Processing Status
7/22/2020 4:05:38 PM	Patty G Barnes	Draft
7/22/2020 4:22:19 PM	Patty G Barnes	Submitted

July 20, 2020

Anastasia Shaw
South Carolina Department of Health and Environmental Control
Bureau of Water / Water Pollution Control Division
WP Compliance and Enforcement Division
2600 Bull Street
Columbia, SC 29201

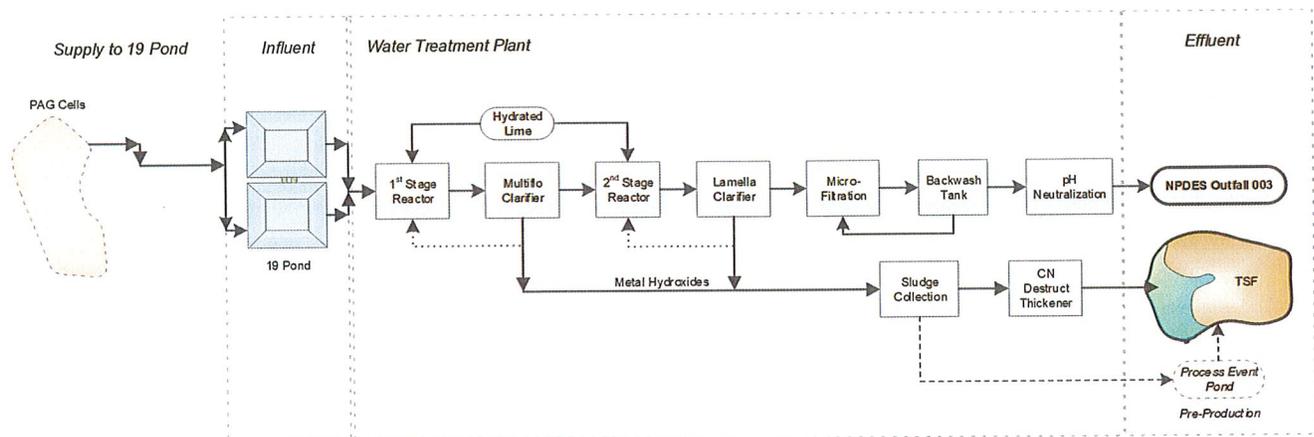
NPDES Permit #SC0040479
Consent Order 20-021-W

Re: Summary of Pilot Study Test Results for the reduction of Thallium in Contact Water Treatment Plant

Dear Ms. Shaw,

In accordance with Consent Order 20-021-W, Haile Gold Mine is submitting a summary of the test results from the Pilot Study at the Contact Water Treatment Plant. This Pilot Study was performed in conjunction with Linken Environmental Engineering. As a result, Haile Gold Mine has made the following process changes within the Contact Water Treatment Plant.

1. Begin adding a sodium hypochlorite solution upstream of the existing Stage 1 reaction tank at an estimated rate of 10-20 mg/L.
2. Reinstate a ferric chloride dosing of 15 mg/L into the Stage 1 Reaction tank.
3. Convert sulfide scavenger from TR-50 to TMT-15 and dose in the Stage 1 Reaction tank at the rate of 5 mg/L.
4. Dose an approximate 3.6 mg/L of AF-304 polymer prior to the Multiflo Clarifier.
5. Maintain a pH of 8.7 plus or minus 0.2 units in the Stage 1 Reaction tank.
6. Add a quenching dose of sodium bisulfite.
7. Stage 2 Reaction and Lamella Clarifier remain unchanged.
8. Finish the process using the installed microfiltration system with 0.45-micron filter cartridges.

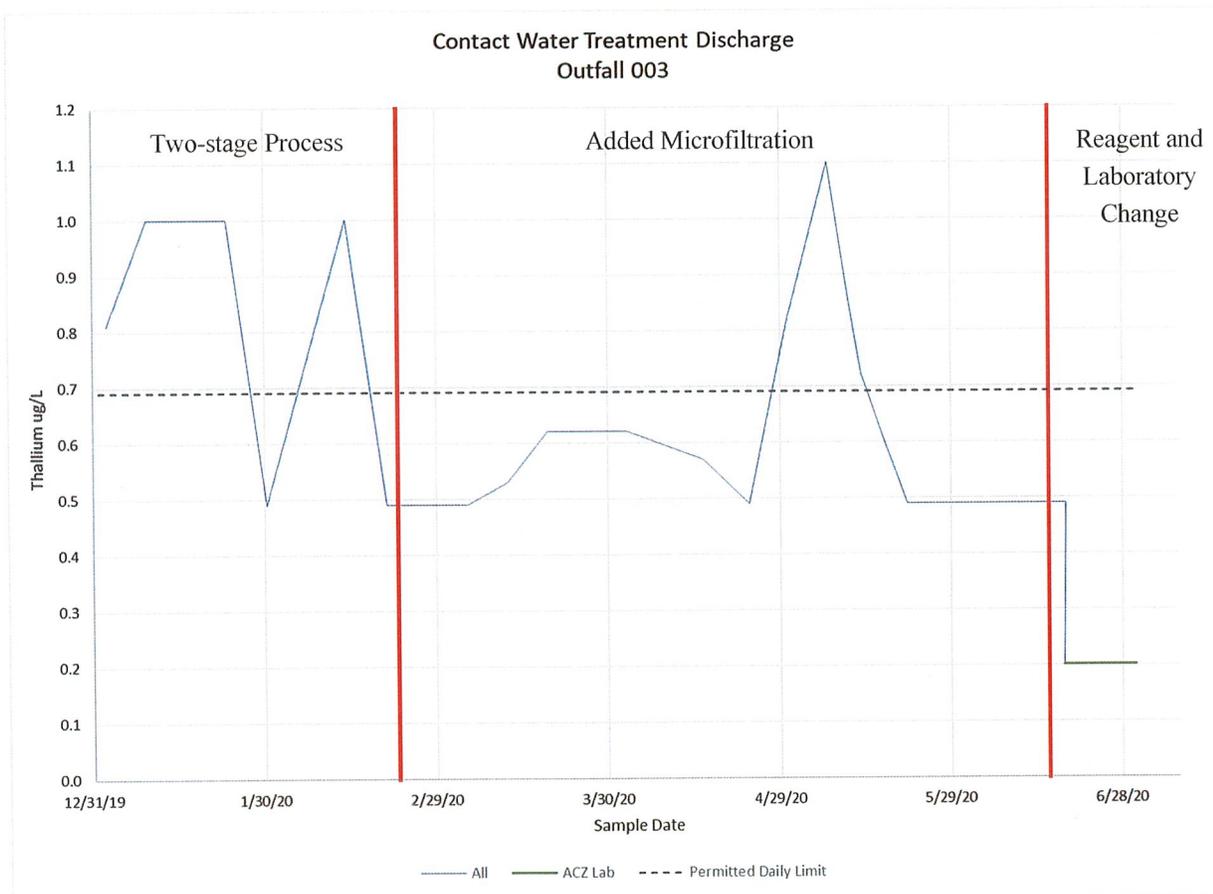


This process is based on the EPA recommended treatment for Thallium reduction using an iron-based salt with oxidation. A summary of the process development is attached.

In addition, Haile Gold Mine has changed testing laboratory to ACZ, Steamboat Springs, Colorado. ACZ is a South Carolina Certified Laboratory (#72011001) with proficiency in water testing including low-level mercury analysis. A copy of their certification is included with this letter.

Haile Gold Mine has submitted an application to DHEC Lab Certification to perform low-level mercury sampling. This application package includes the duplicate sampling result performed by our Environmental Technicians and the representatives from Rogers and Colcott (South Carolina DHEC Certification Number 40572001). Both test results were below the detection for both independent laboratories.

As a result of these changes, Haile Gold Mine has achieved a significant reduction in the Thallium discharge results:



Haile is committed to continuous improvement and will pursue implementing specific controls and conditions to further refine the contact water treatment process. These results demonstrate proof of concept with the refined process. Partnership with a highly qualified laboratory is an added benefit to validate compliance to the standard.

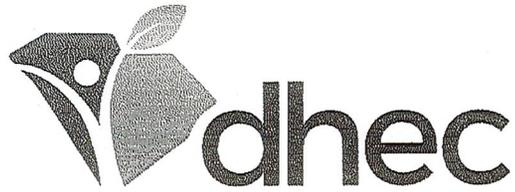
If you have any questions, please call me at (803) 475-2943.

Sincerely,



Scott McDaniel
Environmental Manager

Cc: Kristian Tucker - DHEC Compliance
Veronica Barringer - DHEC Midlands
Byron Amick – DHEC Water Permitting
Haley Anderson – DHEC Lab Certification
Erin Evans – DHEC Lancaster



Healthy People. Healthy Communities.
S.C. Department of Health and
Environmental Control

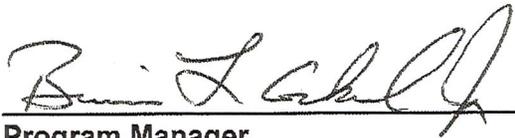
Environmental Laboratory Certification Program

In accordance with the provisions of Regulation 61-81, entitled "State Environmental Laboratory Certification Regulations"

**ACZ LABORATORIES INC
2773 DOWNHILL DR
STEAMBOAT SPRINGS, COLORADO 80487-5051**

is hereby certified to perform analyses as documented on the attached parameter list(s). This certification does not guarantee validity of the data generated, but indicates the laboratory's adherence to prescribed methodology, quality control, records keeping, and reporting procedures. This certificate is the property of S.C. DHEC and must be surrendered upon demand. This certificate is non-transferable and is valid only for the parameters and methodology listed on the attached parameter list(s).

Laboratory Director: BRETT DALKE
Certifying Authority: UT
Date of Issue: March 05, 2020
Date of Expiration: July 31, 2020
Certificate Number: 72011001



Program Manager
Office of Environmental Laboratory Certification

**SOUTH CAROLINA DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL
ENVIRONMENTAL LABORATORY CERTIFICATION PROGRAM**

ACZ LABORATORIES INC (Laboratory ID 72011)
Laboratory Director: BRETT DALKE
Certifying Authority: UT
Certificate Number: 72011001

Date of Issue: March 05, 2020
Expiration Date: July 31, 2020

SOLID & HAZARDOUS WASTES

INORGANIC - TRACE METAL

BORON	EPA 6010D (2018)	ICP/AES
CADMIUM	EPA 6020B (2014)	ICP/MS
CALCIUM	EPA 6010D (2018)	ICP/AES
CHROMIUM	EPA 6010D (2018)	ICP/AES
COBALT	EPA 6010D (2018)	ICP/AES
COPPER	EPA 6010D (2018)	ICP/AES
IRON	EPA 6010D (2018)	ICP/AES
LEAD	EPA 6010D (2018)	ICP/AES
LEAD	EPA 6020B (2014)	ICP/MS
MAGNESIUM	EPA 6010D (2018)	ICP/AES
MANGANESE	EPA 6010D (2018)	ICP/AES
NICKEL	EPA 6010D (2018)	ICP/AES
PHOSPHORUS	EPA 6010D (2018)	ICP/AES
POTASSIUM	EPA 6010D (2018)	ICP/AES
SELENIUM	EPA 6020B (2014)	ICP/MS
SILICA, TOTAL	EPA 6010D (2018)	ICP/AES
SODIUM	EPA 6010D (2018)	ICP/AES
THALLIUM	EPA 6020B (2014)	ICP/MS
ZINC	EPA 6010D (2018)	ICP/AES

Certified Laboratories
COMMERCIAL Laboratories

CLEAN WATER ACT

EPA 1631E (2002)

Lab ID	Lab Name / Address	Director Name / Phone No.
	ACZ LABORATORIES INC 2773 DOWNHILL DR STEAMBOAT SPRINGS CO 80487-5051	DALKE, BRETT 970-879-6590
	ALS ENVIRONMENTAL KELSO 1317 S 13TH AVE KELSO WA 98626	HUGHEY, AMBROSE 360-577-7222
	GEL LABORATORIES LLC PO BOX 30712 CHARLESTON SC 29417	BOCKLET, CAREY J 843-556-8171
	KATAHDIN ANALYTICAL SERVICES LLC PO BOX 540 SCARBOROUGH ME 04070-0540	FLANDERS, MICHAEL 207-874-2400
	PACE ANALYTICAL LABORATORY SC 106 VANTAGE POINT DR WEST COLUMBIA SC 29172	WRIGHT, DAN 803-791-9700
	PACE ANALYTICAL SERVICES LLC ASHEVILLE 2225 RIVERSIDE DR ASHEVILLE NC 28804-9623	GROGAN, FELICIA 828-254-7176
	SGS NORTH AMERICA INC DAYTON 2235 RT 130 BLDG B DAYTON NJ 08810	DEGENHARDT, LAURA 732-329-0200

Count: 7



MEMORANDUM

DATE: July 17, 2020
TO: Scott McDaniel
FROM: Sam Billin, P.E.
SUBJECT: Thallium Removal at Haile CWTP
REFERENCE NO.: 69.04

INTRODUCTION

Oceana Haile Mine (Haile) commissioned Linkan Engineering (Linkan) to conduct a focused process evaluation and bench test on the existing feed water at the Haile contact water treatment plant (CWTP). The objective of the study was to determine an appropriate means of removing thallium using the existing equipment.

Water quality information presented to Linkan from the Haile site has indicated that thallium (Tl) is of primary concern due to recent regulatory compliance exceedances, with the limitations specified in Oceana Gold's NPDES Permit SC0040479. This toxic element has very low discharge allowances and due to its very high solubility is difficult to treat. Additionally, the water quality data indicated that iron (Fe) and manganese (Mn) are of significant operational concern and would need to be mitigated to reduce the cleaning frequencies of the newly installed MF systems.

The U.S.E.P.A lists oxidation and chemical precipitation as the best demonstrated available technology (BDAT) for Tl treatment, as presented in *Potential Technologies for Removing Thallium from Mine and Process Water: An Abbreviated Annotation of the Literature* (Twidwell and Williams-Beam, 2001). The existing CWTP is primarily a chemical precipitation plant and provides a good platform for evaluating changes in process chemistry that would improve Tl removal. Beyond oxidation and chemical precipitation, Tl could only be removed by ion exchange or reverse osmosis. Both of these processes involve significant waste streams that can become as problematic as the original raw water stream.

We note that the use of oxidation for primary Tl removal will also help drive the transformation of soluble manganous manganese (Mn(II)) to its insoluble manganate (Mn(III/IV)) forms. This allows for sedimentation in the plant clarifiers, which in turn has the potential to significantly reduce manganese fouling of the plant's microfiltration (MF) units.

The feed water to the CWTP generally has >40 mg/L dissolved iron. This iron content, however, can be highly variable as the raw water fed to the plant is a product of blending contact water

from several sources. While the dissolved iron content was high during this testing, historic sampling indicates that at some times, the dissolved iron content is greatly reduced.

When oxidized, this naturally occurring iron can act as a coagulant, by combining with the alkalinity in the water to form hydrous ferric oxides (HFO), which adsorb certain contaminant particles, with Tl being one of them. This HFO not only produces coagulation of oxidized colloidal particulates, but it also adsorbs certain soluble compounds, such as the arsenic (As) compounds of arsenate and arsenite. Other soluble impurities are also often removed through co-precipitation inclusions, occlusions, and adsorptions, and larger insoluble contaminants are often trapped and removed by the formed HFO floc. Due to the variable nature of the Haile CWTP feed water, Linkan recommends the addition of a small amount (15 – 50 mg/L) of supplemental iron (in the form of ferric chloride) to ensure that there is constantly enough available iron in the plant feed water to perform the aforementioned mechanisms.

BENCH TESTING

In June 2020, Linkan performed an on-site bench test aimed at developing procedures for modifying the existing process to better remove thallium from the raw water. The test matrix was designed to challenge varying water quality, use of iron as a coagulant, and various chemical oxidant types while holding constant the pH, precipitant chemical, and the polymer flocculant. All tests were performed with a 1-minute oxidant exposure before the addition of other chemistries. All chemistry was added within 15 minutes of the beginning of the test to simulate high plant flowrate clarifier detention time characteristics. TMT-15 (an organic sulfide used for scavenging of heavy metals) was included in this trial. Table 1 presents a tabulated summary of the test matrix:

Table 1: Summary of Haile Bench-Tests

Feed Water	Iron	Oxidant	pH Control	Precipitant	Flocculant
Water Batch #1	Use Natural Iron in Water	Vary NaOCl Oxidant (4 Levels)	Adjust pH to 8.7 +/- 0.2	Add 5 mg/L TMT-15	Add 2.6 mg/L Polymer
Water Batch #1	Add FeCl3 (2 Levels)	Vary NaOCl Oxidant (4 Levels)	Adjust pH to 8.7 +/- 0.2	Add 5 mg/L TMT-15	Add 2.6 mg/L Polymer
Water Batch #2	Add FeCl3 (2 Levels)	Vary NaMnO4 Oxidant (4 Levels)	Adjust pH to 8.7 +/- 0.2	Add 5 mg/L TMT-15	Add 2.6 mg/L Polymer
Water Batch #1 & #2	Add FeCl3 (2 Levels)	Add H2O2 Oxidant (1 Level)	Adjust pH to 8.7 +/- 0.2	Add 5 mg/L TMT-15	Add 2.6 mg/L Polymer

The water used for the tests was acquired from the CWTP feed pond in two sampling events occurring on two successive days. Dramatic differences were noted in the turbidity of the water, highlighting the variable nature of the CWTP plant feed. Table 2 presents the tabulated field parameter test results:

Table 2: Field Parameter Test Results for Bench Test Water Samples

Water Batch	pH (s.u.)	ORP (mV)	Temp. (° C)	Cond. (µS/cm)	TDS (mg/L)	Turb. (N.T.U.)	Mn (mg/L)
Water Batch #1	2.89	577	21.7	2612	1923	25.9	45
Water Batch #2	2.94	687	19.3	2557	1888	0.84	43

Figure 1 further illustrates the differences in water quality between the two sampling events, with Batch #1 on the left and Batch #2 on the right. It is important to note that these samples were collected at the same location using the same method of collection.

Figure 1: Photographic Documentation of Bench Test Water Samples #1 and #2



Bench Test #1

For Bench Test #1, different doses of sodium hypochlorite (NaOCl) were administered as the oxidizer, with no additional iron added to the naturally occurring amount. The sequential additions of NaOCl increased the natural oxidation-reduction potential (ORP) of the water ~300, ~400, and ~500 millivolts (mV), respectively. This test was designed to assess the amount of NaOCl oxidant that is required to convert the thallium into a precipitate and to ensure that Mn is in its oxidized and precipitated form. The test is summarized in Table 3.

Table 3: Tabulated Summary of Bench Test #1

Sample Designation	Additions				
	NaOCl	FeCl ₃	NaOH (50% w/w)	TMT-15	AF-304 Polymer
H0	Raw Baseline Sampled (6/16/2020)				
H0F	Raw Baseline Sampled (6/16/2020) Filtered at 45µm				
H1	0	0	1.15mL	5 mg/L	2.6 mg/L
H2	13.5 mg/L	0	1.15mL	5 mg/L	2.6 mg/L
H3	27 mg/L	0	1.15mL	5 mg/L	2.6 mg/L
H4	40.5 mg/L	0	1.15mL	5 mg/L	2.6 mg/L

Bench Test #2

For Bench Test #2, different doses of sodium hypochlorite (NaOCl) were administered as the oxidizer, along with 50 mg/L of additional iron added to the naturally occurring amount. As was the case with Test #1, the sequential additions of NaOCl increased the natural oxidation-reduction potential (ORP) of the water ~300, ~400, and ~500 millivolts (mV), respectively. This test was designed to determine if a significant dose of iron is beneficial to the treatment process. The test is summarized in Table 4.

Table 4: Tabulated Summary of Bench Test #2

Sample Designation	Additions				
	NaOCl	FeCl ₃	NaOH (50% w/w)	TMT-15	AF-304 Polymer
H5	0	50 mg/L	1.1mL	5 mg/L	2.6 mg/L
H6	13.5 mg/L	50 mg/L	1.1mL	5 mg/L	2.6 mg/L
H7	27 mg/L	50 mg/L	1.1mL	5 mg/L	2.6 mg/L
H8	40.5 mg/L	50 mg/L	1.1mL	5 mg/L	2.6 mg/L

Bench Test #3

For Bench Test #3, different doses of sodium hypochlorite (NaOCl) were administered as the oxidizer, along with 15 mg/L of additional iron added to the naturally occurring amount. As was the case with the previous tests, the sequential additions of NaOCl increased the natural oxidation-reduction potential (ORP) of the water ~300, ~400, and ~500 millivolts (mV), respectively. This test was designed to determine if a moderate dose of iron is beneficial to the treatment process. The test is summarized in Table 5.

Table 5: Tabulated Summary of Bench Test #3

Sample Designation	Additions				
	NaOCl	FeCl ₃	NaOH (50% w/w)	TMT-15	AF-304 Polymer
H9	0	15mg/L	1.1mL	5 mg/L	2.6 mg/L
H10	13.5mg/L	15mg/L	1.1mL	5 mg/L	2.6 mg/L
H11	27mg/L	15mg/L	1.1mL	5 mg/L	2.6 mg/L
H12	40.5mg/L	15mg/L	1.1mL	5 mg/L	2.6 mg/L

Bench Test #4

For Bench Test #4, different doses of sodium permanganate (NaMnO₄) were administered as the oxidizer, along with 50 mg/L of additional iron added to the naturally occurring amount. This test was designed to determine if permanganate as an oxidizer is beneficial to the treatment process. This test is summarized in Table 6.

Table 6: Tabulated Summary of Bench Test #4

Sample Designation	Additions				
	NaMnO ₄	FeCl ₃	NaOH (50% w/w)	TMT-15	AF-304 Polymer
H13	Raw Baseline (Sample taken 17/6/2020)				
H13F	Raw Baseline (Sample taken 17/6/2020) Filtered at 45µm				
H14	0	50mg/L	1.15mL	5 mg/L	2.6 mg/L
H15	30mg/L	50mg/L	1.15mL	5 mg/L	2.6 mg/L
H16	40mg/L	50mg/L	1.15mL	5 mg/L	2.6 mg/L
H17	50mg/L	50mg/L	1.15mL	5 mg/L	2.6 mg/L

Bench Test #5

For Bench Test #5, different doses of sodium permanganate (NaMnO₄) were administered as the oxidizer, along with 15 mg/L of additional iron added to the naturally occurring amount. This test was also designed to determine if permanganate as an oxidizer is beneficial to the treatment process, and to help determine the amount of iron that is beneficial in the process. This test is summarized in Table 7.

Table 7: Tabulated Summary of Bench Test #5

Sample Designation	Additions				
	NaMnO ₄	FeCl ₃	NaOH (50% w/w)	TMT-15	AF-304 Polymer
H18	0	15mg/L	1.15mL	5 mg/L	2.6 mg/L
H19	30mg/L	15mg/L	1.15mL	5 mg/L	2.6 mg/L
H20	40mg/L	15mg/L	1.15mL	5 mg/L	2.6 mg/L
H21	50mg/L	15mg/L	1.15mL	5 mg/L	2.6 mg/L

Bench Test #6

For Bench Test #6, a dose of 30 mg/L H₂O₂ was administered as the oxidizer, along with either no additional iron or a significant amount of 50 mg/L. Both water batches were included in the test to assess a broader spectrum of reactivity. Hydrogen peroxide, when mixed with ferrous iron can form a very strong oxidant radical known as Fenton's Reagent, which is one of the most powerful oxidizers known. Due to this potential radical formation, the use of H₂O₂ as an additive needs to be closely scrutinized since the Fenton's Reagent may be too powerful for this application and along with oxidizing Tl, Mn, As and other metals and metalloids, may also inadvertently attack the precipitant chemical and the polymer, both of which have organic structures and are susceptible to degradation via oxidation. This test is summarized in Table 8.

Table 8: Tabulated Summary of Bench Test #6

Sample Designation	Additions				
	H ₂ O ₂	FeCl ₃	NaOH (50% w/w)	TMT-15	AF-304 Polymer
H22 (Water Batch #2)	30ppm	0mg/L	1.1mL	5 mg/L	2.6 mg/L
H23 (Water Batch #1)	30ppm	50mg/L	1.1mL	5 mg/L	2.6 mg/L
H24 (Water Batch #2)	30ppm	0mg/L	1.1mL	5 mg/L	2.6 mg/L
H25 (Water Batch #1)	30ppm	50mg/L	1.1mL	5 mg/L	2.6 mg/L

RESULTS

Samples were collected from raw untreated water and treated water from each test. These were then field-tested for various parameters or processed and preserved for certified laboratory analyses. The following sections present the results of the analyses performed.

Field Analyses

Sodium Hypochlorite Addition as an Oxidizer Tests

Turbidity

Bench Test #1, which used Water Batch #1, exhibited turbidity that was substantially reduced from ~26 N.T.U. to <1 N.T.U. due to chemical treatment.

Manganese

Bench Test #1 Mn was substantially reduced from ~45 mg/L to 1.26 mg/L, a reduction of ~97.2 percent. This indicates that Mn can be oxidized by chlorine and removed efficiently from the CWTP feed water in a reaction time of ~15 minutes.

Free Chlorine

Bench Test #1 exhibited a free chlorine residual of 0.07 mg/L, which is very low but reliably detected. This indicates that the oxidant was nearly completely consumed during the reaction and that very little oxidant was remaining to scavenge precipitant chemical or polymer. Due to this low residual, control of chlorine addition by way of direct chlorine residual testing or ORP feedback loop might be possible. The low residual also will allow for minimal reducing agent use to quench the remaining NaOCl, if it is selected for use. This quench will help safeguard the plant effluent from exhibiting toxicity that could otherwise affect the WET testing.

Sodium Permanganate Addition as an Oxidizer Tests

Turbidity

Bench Test #5, which used Water Batch #2, did not show an appreciable reduction in turbidity since its raw water value was measured at <1 N.T.U. and the treated sample measured the same value.

Manganese

Bench Test #5 Mn was substantially reduced from ~43 mg/L to 1.14 mg/L, a reduction of ~97.3 percent. This indicates that Mn can be oxidized by permanganate and removed efficiently from the CWTP feed water in a reaction time of ~15 minutes.

Free Chlorine

It is noteworthy that permanganate can also be detected by residual free chlorine testing, and that it correlates with Cl₂ on a 1:1 ratio. Bench Test #5 exhibited a free chlorine residual of 0.03 mg/L, which is very low but reliably detected. This indicates that the permanganate oxidant was nearly completely consumed during the reaction and that very little oxidant was remaining to scavenge precipitant chemical or polymer. Due to this low residual, control of permanganate addition by way of direct chlorine residual testing or ORP feedback loop might be possible. The

low residual also will allow for minimal reducing agent use to quench the remaining NaMnO₄, if it is selected for use.

Hydrogen Peroxide Addition as an Oxidizer Tests

Turbidity

Bench Test #6, which included the higher turbidity Water Batch #1, exhibited final turbidity that was substantially reduced from ~26 N.T.U. to <1 N.T.U. due to chemical treatment.

Manganese

Bench Test #6 Mn was substantially reduced from ~43 mg/L to 0.39 mg/L, a reduction of ~99.1 percent. This indicates that Mn can be oxidized by hydrogen peroxide and removed efficiently from the CWTP feed water in a reaction time of ~15 minutes.

Residual H₂O₂

Bench Test #6 residual H₂O₂ was tested, and no residual was detected. This indicates that the dose of peroxide, a very strong oxidant, was completely consumed during the duration of the test. It is possible that along with the feed water's contaminants of concern, that the peroxide was still active and was scavenging organic substances.

Laboratory Analyses

Samples were submitted to a certified laboratory for analyses. Table 9 presents the tabulated results of the submitted samples. Note that all results presented in italics were reported as being less than the reporting limit, and therefore have been quantified with half of the reporting limit per EPA guidance. Sample identifications with an "F" designation indicate water filtered with a 0.45 micron filter before sample collection. This indicative of results expected after the existing microfilter filtration.

Table 9: Tabulated Lab Results

Test No.	Sample	Treatment Conditions (mg/L)			
		Fe	Mn	Tl	
Batch #1 Raw	H0	30	42	<i>0.0020</i>	Baseline Comparison
	H0F	24	39	<i>0.0020</i>	Baseline Comparison
Test #1	H1	0.23	1.3	0.0004	0 mg/L NaOCl, 0 mg/L FeCl ₃
	H1F	<i>0.1</i>	1.0	0.0003	0 mg/L NaOCl, 0 mg/L FeCl ₃
	H2	<i>0.05</i>	1.0	0.0004	13.5 mg/L NaOCl, 0 mg/L FeCl ₃
	H2F	<i>0.05</i>	1.6	0.0003	13.5 mg/L NaOCl, 0 mg/L FeCl ₃
	H3	0.35	0.87	0.0004	27 mg/L NaOCl, 0 mg/L FeCl ₃

Test No.	Sample	Treatment Conditions (mg/L)			
		Fe	Mn	Tl	
	H3F	0.05	1.6	0.0003	27 mg/L NaOCl, 0 mg/L FeCl3
	H4	0.27	0.47	0.0004	40.5 mg/L NaOCl, 0 mg/L FeCl3
	H4F	0.05	0.47	0.0003	40.5 mg/L NaOCl, 0 mg/L FeCl3
	H5F	0.52	3.4	0.0003	0 mg/L NaOCl, 50 mg/L FeCl3
Test #2	H6F	0.05	3.6	0.0003	13.5 mg/L NaOCl, 50 mg/L FeCl3
	H7F	0.05	2.4	0.0003	27 mg/L NaOCl, 50 mg/L FeCl3
	H8F	0.05	0.32	0.0003	40.5 mg/L NaOCl, 50 mg/L FeCl3
	H9F	0.05	2.4	0.0004	0 mg/L NaOCl, 15 mg/L FeCl3
Test #3	H10F	0.06	2.7	0.0003	13.5 mg/L NaOCl, 15 mg/L FeCl3
	H11F	0.48	1.2	0.0003	27 mg/L NaOCl, 15 mg/L FeCl3
	H12F	0.05	0.13	0.0003	40.5 mg/L NaOCl, 15 mg/L FeCl3
	H13	21	32	0.0020	Baseline Comparison
Batch #2 Raw	H13F	20	32	0.0020	Baseline Comparison
	H14F	0.04	3.4	0.0005	0 mg/L NaMnO4, 50 mg/L FeCl3
Test #4	H15F	0.84	1.3	0.0005	30 mg/L NaMnO4, 50 mg/L FeCl3
	H16F	0.05	0.043	0.0005	40 mg/L NaMnO4, 50 mg/L FeCl3
	H17F	0.15	0.95	0.0005	50 mg/L NaMnO4, 50 mg/L FeCl3
	H18F	0.11	1.5	0.0005	0 mg/L NaMnO4, 15 mg/L FeCl3
Test #5	H19F	0.62	1.2	0.0005	30 mg/L NaMnO4, 15 mg/L FeCl3
	H20F	0.030	0.13	0.0005	40 mg/L NaMnO4, 15 mg/L FeCl3
	H21F	0.05	0.11	0.0005	50 mg/L NaMnO4, 15 mg/L FeCl3
	H22F	1.4	2.6	0.0005	30 mgL H2O2, 0 mg/L FeCl3 - Batch 2
Test #6	H23F	0.45	0.93	0.0005	30 mgL H2O2, 50 mg/L FeCl3 - Batch 2
	H24F	0.21	0.96	0.0005	30 mgL H2O2, 0 mg/L FeCl3 - Batch 1
	H25F	0.05	0.43	0.0005	30 mgL H2O2, 50 mg/L FeCl3 - Batch 1
	NPDES SC0040479	Monthly Avg.	n/a	n/a	0.00047
Daily Max.		n/a	n/a	0.00069	

CONCLUSIONS

Thallium concentrations in all waters sampled are extremely low and trending around the laboratory detection limit of EPA Method 200.8. Reporting limits for Tl varied due to dilution factors required to perform the analysis. Raw feed water demonstrated Tl present but less than the diluted reporting limit of 0.004 mg/L. Table 9 reports this result as one half the reporting limits per EPA protocols.

Thallium was treated to compliant levels in tests 1 – 3. Tests 4 – 6 are less definitive due to matrix interferences that prevented the lab from achieving the desired detection levels as they had to perform sample dilutions which elevated their reporting limits. However, even with the associated matrix interferences, the reported values of <0.0005 mg/L were just slightly over the regulatory monthly average discharge allowance of 0.00047 mg/L, and the lab report indicated that no analytical signal was detected for any of Test 4 – 6 samples, which helps to substantiate the effectiveness of the treatment for thallium.

Linkan concludes that the chemical and process modifications, including oxidation and ferric chloride addition, are effective at achieving reliable thallium removal below the required discharge standard. We note the correlation between manganese reduction and thallium reduction indicating that the proposed chemical modifications will both remove thallium and improve microfilter performance of the existing system.

RECOMMENDATION

Linkan recommends that Haile enact the following modifications to achieve this bench tested result:

1. Begin adding an sodium hypochlorite upstream of the existing Stage 1 reaction tank at an estimated rate of 10-20 mg/L
2. Reinstate a ferric chloride dosing of 15 mg/L into the Stage 1 reaction tank
3. Convert sulfide scavenger from TR-50 to TMT-15 and dose in the Stage 1 reaction tank at the rate of 5 mg/L
4. Dose an approximate 3.6 mg/L of AF-304 polymer prior to the clarifier
5. Maintain a pH of 8.7 plus or minus 0.2 units in the Stage 1 reaction tank
6. Add a quenching dose of sodium bisulfite prior to the microfilter

END

Wastewater - Industrial - Preliminary Engineering Review (PER) and Other Request Form - New

version 1.15

(Submission #: HP1-EFAB-H7HR3, version 1)

Digitally signed by:
nForm_nCore_SCEP_Int_Cert
DN: cn=CEPMVP/PRINT01@dhgs.sc.gov
Date: 2020.07.22 16:12:35-04:00
Reason: Copy Of Record
Location: Columbia, South Carolina

Details

Submission ID HP1-EFAB-H7HR3
Submission Reason New
Status Submitted

Form Input

Request Information

Do you anticipate this project being funded by State Revolving Fund (SRF)?
No

Request Type:
Pilot Study Request

Permittee Information

Permittee

Prefix
NONE PROVIDED

First Name **Last Name**
NONE PROVIDED NONE PROVIDED

Title
NONE PROVIDED

Organization Name
HAILE GOLD MINE

Phone Type **Number** **Extension**
Business 8034752943

Email
Scott.McDaniel@oceanagold.com

Fax
NONE PROVIDED

6911 SNOWY OWL RD
KERSHAW, SC 29067
United States

Owner Information

Owner

Prefix

NONE PROVIDED

First Name

NONE PROVIDED

Last Name

NONE PROVIDED

Title

NONE PROVIDED

Organization Name

NONE PROVIDED

Phone Type**Number****Extension**

Business

8034752943

Email

NONE PROVIDED

Fax

NONE PROVIDED

6911 SNOWY OWL RD

KERSHAW, SC 29067

Is the owner also the operator?

Yes

Contact Information

Facility Contact

Prefix

NONE PROVIDED

First Name

SCOTT

Last Name

MCDANIEL

Title

NONE PROVIDED

Organization Name

HAILE GOLD MINE

Phone Type**Number****Extension**

Business

8034752943

Email

Scott.McDaniel@oceanagold.com

Fax

NONE PROVIDED

6911 SNOWY OWL RD

KERSHAW, SC 29067

United States

Engineer Information

Engineer Contact

Prefix

NONE PROVIDED

First Name

NONE PROVIDED

Last Name

NONE PROVIDED

Title

NONE PROVIDED

Organization Name

NONE PROVIDED

Phone Type

Business

Number

NONE PROVIDED

Extension**Email**

NONE PROVIDED

Fax

NONE PROVIDED

[NO STREET ADDRESS SPECIFIED]

[NO CITY SPECIFIED], SC [NO ZIP CODE SPECIFIED]

USA

S.C. Registration Number:

NONE PROVIDED

LLR Licensing Lookup

[Engineers and Land Surveyors - Licensee Lookup](#)

Project Information

Project Name:

HAILE GOLD MINE PILOT STUDY

Facility Name

HAILE GOLD MINE

NPDES/ND Permit Number and Name

HAILE GOLD MINE - SC0040479

Project Address:

6911 SNOWY OWL RD

KERSHAW, SC 290678362

Project County

Kershaw

Project Location:

34.600143,-80.541037

Project Description of Wastewater Systems:

NA

Project Details

Is this project part of a phased project?

No

What is this project submission based on?

Order issued by DHEC

Order #:
20-021-W

Wastewater Systems

AVERAGE DESIGN FLOW

Project average design flow (GPD)
0

RECEIVING FACILITY

Construction, LOA, or Other Permit, if applicable.
NONE PROVIDED

Facility Address
6911 SNOWY OWL RD KERSHAW SC

NPDES/ND Number and Name
HAILE GOLD MINE - SC0040479

DISPOSAL SITES

Effluent Disposal Site (Description)
NONE PROVIDED

Sludge Disposal Site (Description)
NONE PROVIDED

Submittal Requirements

Additional Documents:

[Pilot Study Summary_07202020.pdf - 07/22/2020 04:20 PM](#)

Comment

NONE PROVIDED

Use the space below to bring to the Department's attention any additional information that you believe should be considered in the permit decision.

NONE PROVIDED

Status History

	User	Processing Status
7/22/2020 4:05:38 PM	Patty G Barnes	Draft
7/22/2020 4:22:19 PM	Patty G Barnes	Submitted

July 20, 2020

Anastasia Shaw
South Carolina Department of Health and Environmental Control
Bureau of Water / Water Pollution Control Division
WP Compliance and Enforcement Division
2600 Bull Street
Columbia, SC 29201

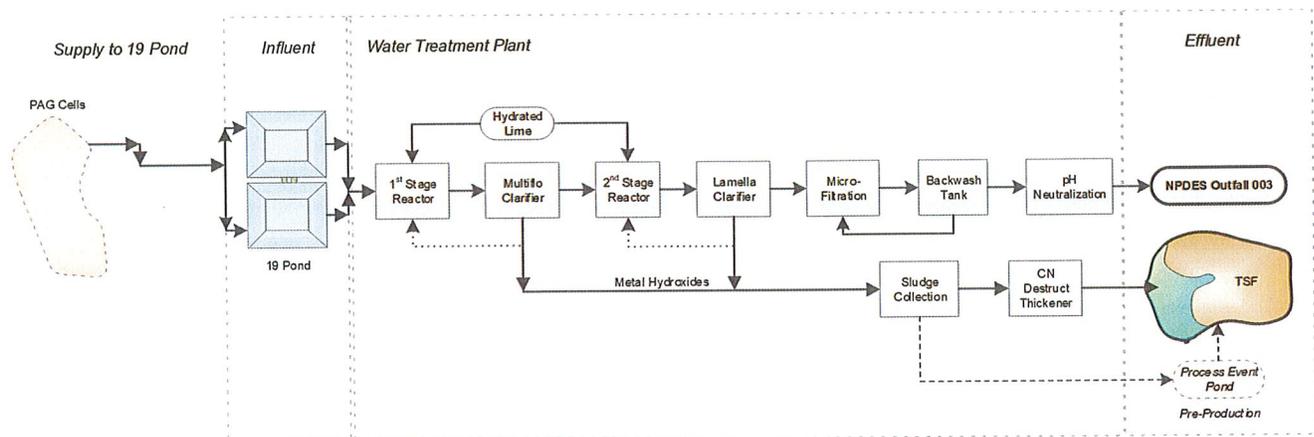
NPDES Permit #SC0040479
Consent Order 20-021-W

Re: Summary of Pilot Study Test Results for the reduction of Thallium in Contact Water Treatment Plant

Dear Ms. Shaw,

In accordance with Consent Order 20-021-W, Haile Gold Mine is submitting a summary of the test results from the Pilot Study at the Contact Water Treatment Plant. This Pilot Study was performed in conjunction with Linken Environmental Engineering. As a result, Haile Gold Mine has made the following process changes within the Contact Water Treatment Plant.

1. Begin adding a sodium hypochlorite solution upstream of the existing Stage 1 reaction tank at an estimated rate of 10-20 mg/L.
2. Reinstate a ferric chloride dosing of 15 mg/L into the Stage 1 Reaction tank.
3. Convert sulfide scavenger from TR-50 to TMT-15 and dose in the Stage 1 Reaction tank at the rate of 5 mg/L.
4. Dose an approximate 3.6 mg/L of AF-304 polymer prior to the Multiflo Clarifier.
5. Maintain a pH of 8.7 plus or minus 0.2 units in the Stage 1 Reaction tank.
6. Add a quenching dose of sodium bisulfite.
7. Stage 2 Reaction and Lamella Clarifier remain unchanged.
8. Finish the process using the installed microfiltration system with 0.45-micron filter cartridges.

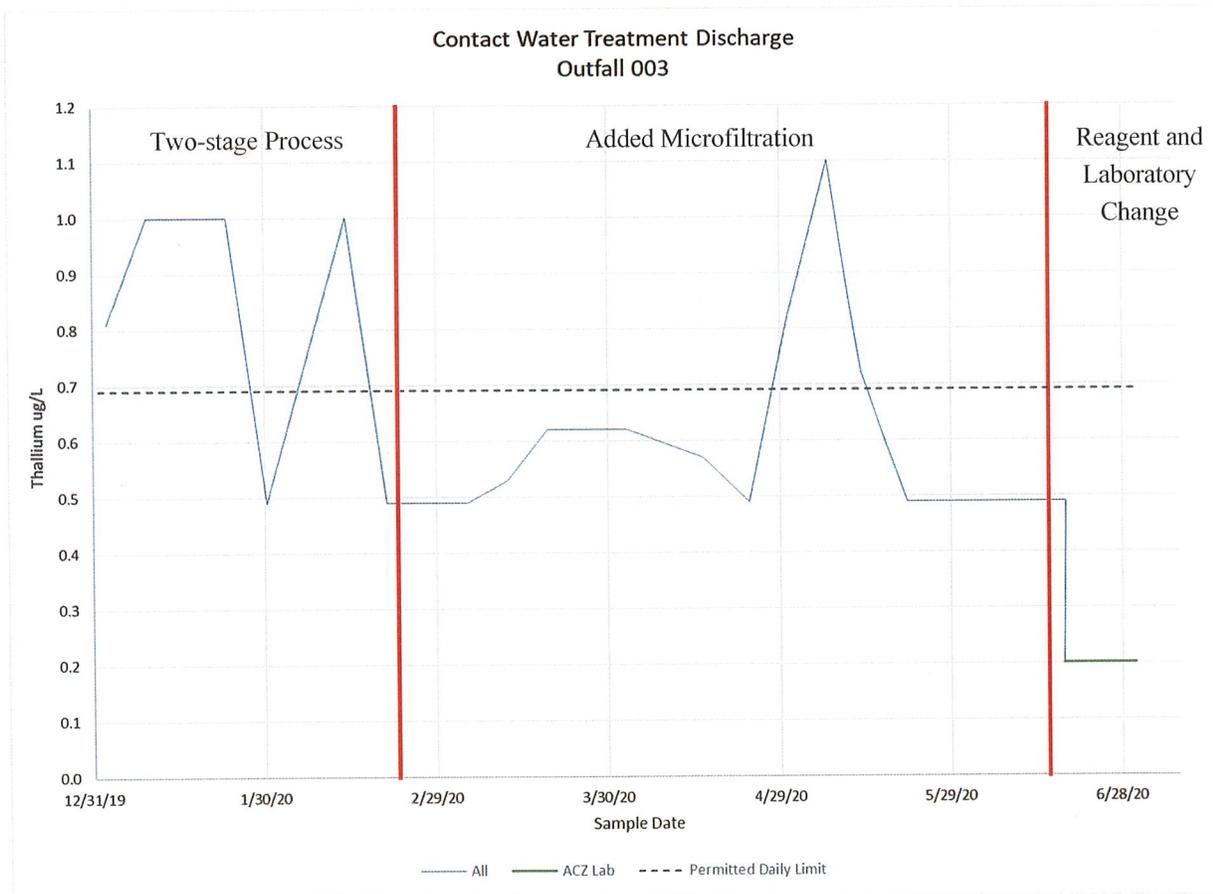


This process is based on the EPA recommended treatment for Thallium reduction using an iron-based salt with oxidation. A summary of the process development is attached.

In addition, Haile Gold Mine has changed testing laboratory to ACZ, Steamboat Springs, Colorado. ACZ is a South Carolina Certified Laboratory (#72011001) with proficiency in water testing including low-level mercury analysis. A copy of their certification is included with this letter.

Haile Gold Mine has submitted an application to DHEC Lab Certification to perform low-level mercury sampling. This application package includes the duplicate sampling result performed by our Environmental Technicians and the representatives from Rogers and Colcott (South Carolina DHEC Certification Number 40572001). Both test results were below the detection for both independent laboratories.

As a result of these changes, Haile Gold Mine has achieved a significant reduction in the Thallium discharge results:



Haile is committed to continuous improvement and will pursue implementing specific controls and conditions to further refine the contact water treatment process. These results demonstrate proof of concept with the refined process. Partnership with a highly qualified laboratory is an added benefit to validate compliance to the standard.

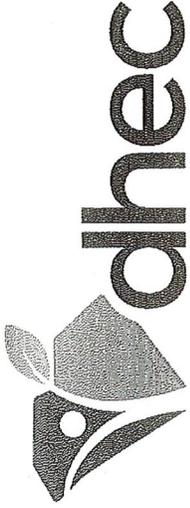
If you have any questions, please call me at (803) 475-2943.

Sincerely,



Scott McDaniel
Environmental Manager

Cc: Kristian Tucker - DHEC Compliance
Veronica Barringer - DHEC Midlands
Byron Amick – DHEC Water Permitting
Haley Anderson – DHEC Lab Certification
Erin Evans – DHEC Lancaster



Healthy People. Healthy Communities.
S.C. Department of Health and
Environmental Control

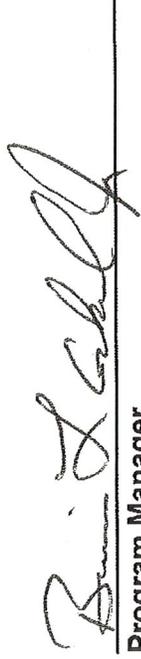
Environmental Laboratory Certification Program

In accordance with the provisions of Regulation 61-81, entitled "State Environmental Laboratory Certification Regulations."

**ACZ LABORATORIES INC
2773 DOWNHILL DR
STEAMBOAT SPRINGS, COLORADO 80487-5051**

is hereby certified to perform analyses as documented on the attached parameter list(s). This certification does not guarantee validity of the data generated, but indicates the laboratory's adherence to prescribed methodology, quality control, records keeping, and reporting procedures. This certificate is the property of S.C. DHEC and must be surrendered upon demand. This certificate is non-transferable and is valid only for the parameters and methodology listed on the attached parameter list(s).

Laboratory Director: BRETT DALKE
Certifying Authority: UT
Date of Issue: March 05, 2020
Date of Expiration: July 31, 2020
Certificate Number: 72011001


Program Manager
Office of Environmental Laboratory Certification

SOUTH CAROLINA DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL
ENVIRONMENTAL LABORATORY CERTIFICATION PROGRAM

ACZ LABORATORIES INC (Laboratory ID 72011)
Laboratory Director: BRETT DALKE
Certifying Authority: UT
Certificate Number: 72011001

Date of Issue: March 05, 2020
Expiration Date: July 31, 2020

SOLID & HAZARDOUS WASTES

INORGANIC - TRACE METAL

BORON	EPA 6010D (2018)	ICP/AES
CADMIUM	EPA 6020B (2014)	ICP/MS
CALCIUM	EPA 6010D (2018)	ICP/AES
CHROMIUM	EPA 6010D (2018)	ICP/AES
COBALT	EPA 6010D (2018)	ICP/AES
COPPER	EPA 6010D (2018)	ICP/AES
IRON	EPA 6010D (2018)	ICP/AES
LEAD	EPA 6010D (2018)	ICP/AES
LEAD	EPA 6020B (2014)	ICP/MS
MAGNESIUM	EPA 6010D (2018)	ICP/AES
MANGANESE	EPA 6010D (2018)	ICP/AES
NICKEL	EPA 6010D (2018)	ICP/AES
PHOSPHORUS	EPA 6010D (2018)	ICP/AES
POTASSIUM	EPA 6010D (2018)	ICP/AES
SELENIUM	EPA 6020B (2014)	ICP/MS
SILICA, TOTAL	EPA 6010D (2018)	ICP/AES
SODIUM	EPA 6010D (2018)	ICP/AES
THALLIUM	EPA 6020B (2014)	ICP/MS
ZINC	EPA 6010D (2018)	ICP/AES

Certified Laboratories
COMMERCIAL Laboratories

CLEAN WATER ACT

EPA 1631E (2002)

Lab ID	Lab Name / Address	Director Name / Phone No.
	ACZ LABORATORIES INC 2773 DOWNHILL DR STEAMBOAT SPRINGS CO 80487-5051	DALKE, BRETT 970-879-6590
	ALS ENVIRONMENTAL KELSO 1317 S 13TH AVE KELSO WA 98626	HUGHEY, AMBROSE 360-577-7222
	GEL LABORATORIES LLC PO BOX 30712 CHARLESTON SC 29417	BOCKLET, CAREY J 843-556-8171
	KATAHDIN ANALYTICAL SERVICES LLC PO BOX 540 SCARBOROUGH ME 04070-0540	FLANDERS, MICHAEL 207-874-2400
	PACE ANALYTICAL LABORATORY SC 106 VANTAGE POINT DR WEST COLUMBIA SC 29172	WRIGHT, DAN 803-791-9700
	PACE ANALYTICAL SERVICES LLC ASHEVILLE 2225 RIVERSIDE DR ASHEVILLE NC 28804-9623	GROGAN, FELICIA 828-254-7176
	SGS NORTH AMERICA INC DAYTON 2235 RT 130 BLDG B DAYTON NJ 08810	DEGENHARDT, LAURA 732-329-0200

Count: 7



MEMORANDUM

DATE: July 17, 2020
TO: Scott McDaniel
FROM: Sam Billin, P.E.
SUBJECT: Thallium Removal at Haile CWTP
REFERENCE NO.: 69.04

INTRODUCTION

Oceana Haile Mine (Haile) commissioned Linkan Engineering (Linkan) to conduct a focused process evaluation and bench test on the existing feed water at the Haile contact water treatment plant (CWTP). The objective of the study was to determine an appropriate means of removing thallium using the existing equipment.

Water quality information presented to Linkan from the Haile site has indicated that thallium (Tl) is of primary concern due to recent regulatory compliance exceedances, with the limitations specified in Oceana Gold's NPDES Permit SC0040479. This toxic element has very low discharge allowances and due to its very high solubility is difficult to treat. Additionally, the water quality data indicated that iron (Fe) and manganese (Mn) are of significant operational concern and would need to be mitigated to reduce the cleaning frequencies of the newly installed MF systems.

The U.S.E.P.A lists oxidation and chemical precipitation as the best demonstrated available technology (BDAT) for Tl treatment, as presented in *Potential Technologies for Removing Thallium from Mine and Process Water: An Abbreviated Annotation of the Literature* (Twidwell and Williams-Beam, 2001). The existing CWTP is primarily a chemical precipitation plant and provides a good platform for evaluating changes in process chemistry that would improve Tl removal. Beyond oxidation and chemical precipitation, Tl could only be removed by ion exchange or reverse osmosis. Both of these processes involve significant waste streams that can become as problematic as the original raw water stream.

We note that the use of oxidation for primary Tl removal will also help drive the transformation of soluble manganous manganese (Mn(II)) to its insoluble manganate (Mn(III/IV)) forms. This allows for sedimentation in the plant clarifiers, which in turn has the potential to significantly reduce manganese fouling of the plant's microfiltration (MF) units.

The feed water to the CWTP generally has >40 mg/L dissolved iron. This iron content, however, can be highly variable as the raw water fed to the plant is a product of blending contact water

from several sources. While the dissolved iron content was high during this testing, historic sampling indicates that at some times, the dissolved iron content is greatly reduced.

When oxidized, this naturally occurring iron can act as a coagulant, by combining with the alkalinity in the water to form hydrous ferric oxides (HFO), which adsorb certain contaminant particles, with Tl being one of them. This HFO not only produces coagulation of oxidized colloidal particulates, but it also adsorbs certain soluble compounds, such as the arsenic (As) compounds of arsenate and arsenite. Other soluble impurities are also often removed through co-precipitation inclusions, occlusions, and adsorptions, and larger insoluble contaminants are often trapped and removed by the formed HFO floc. Due to the variable nature of the Haile CWTP feed water, Linkan recommends the addition of a small amount (15 – 50 mg/L) of supplemental iron (in the form of ferric chloride) to ensure that there is constantly enough available iron in the plant feed water to perform the aforementioned mechanisms.

BENCH TESTING

In June 2020, Linkan performed an on-site bench test aimed at developing procedures for modifying the existing process to better remove thallium from the raw water. The test matrix was designed to challenge varying water quality, use of iron as a coagulant, and various chemical oxidant types while holding constant the pH, precipitant chemical, and the polymer flocculant. All tests were performed with a 1-minute oxidant exposure before the addition of other chemistries. All chemistry was added within 15 minutes of the beginning of the test to simulate high plant flowrate clarifier detention time characteristics. TMT-15 (an organic sulfide used for scavenging of heavy metals) was included in this trial. Table 1 presents a tabulated summary of the test matrix:

Table 1: Summary of Haile Bench-Tests

Feed Water	Iron	Oxidant	pH Control	Precipitant	Flocculant
Water Batch #1	Use Natural Iron in Water	Vary NaOCl Oxidant (4 Levels)	Adjust pH to 8.7 +/- 0.2	Add 5 mg/L TMT-15	Add 2.6 mg/L Polymer
Water Batch #1	Add FeCl3 (2 Levels)	Vary NaOCl Oxidant (4 Levels)	Adjust pH to 8.7 +/- 0.2	Add 5 mg/L TMT-15	Add 2.6 mg/L Polymer
Water Batch #2	Add FeCl3 (2 Levels)	Vary NaMnO4 Oxidant (4 Levels)	Adjust pH to 8.7 +/- 0.2	Add 5 mg/L TMT-15	Add 2.6 mg/L Polymer
Water Batch #1 & #2	Add FeCl3 (2 Levels)	Add H2O2 Oxidant (1 Level)	Adjust pH to 8.7 +/- 0.2	Add 5 mg/L TMT-15	Add 2.6 mg/L Polymer

The water used for the tests was acquired from the CWTP feed pond in two sampling events occurring on two successive days. Dramatic differences were noted in the turbidity of the water, highlighting the variable nature of the CWTP plant feed. Table 2 presents the tabulated field parameter test results:

Table 2: Field Parameter Test Results for Bench Test Water Samples

Water Batch	pH (s.u.)	ORP (mV)	Temp. (° C)	Cond. (µS/cm)	TDS (mg/L)	Turb. (N.T.U.)	Mn (mg/L)
Water Batch #1	2.89	577	21.7	2612	1923	25.9	45
Water Batch #2	2.94	687	19.3	2557	1888	0.84	43

Figure 1 further illustrates the differences in water quality between the two sampling events, with Batch #1 on the left and Batch #2 on the right. It is important to note that these samples were collected at the same location using the same method of collection.

Figure 1: Photographic Documentation of Bench Test Water Samples #1 and #2



Bench Test #1

For Bench Test #1, different doses of sodium hypochlorite (NaOCl) were administered as the oxidizer, with no additional iron added to the naturally occurring amount. The sequential additions of NaOCl increased the natural oxidation-reduction potential (ORP) of the water ~300, ~400, and ~500 millivolts (mV), respectively. This test was designed to assess the amount of NaOCl oxidant that is required to convert the thallium into a precipitate and to ensure that Mn is in its oxidized and precipitated form. The test is summarized in Table 3.

Table 3: Tabulated Summary of Bench Test #1

Sample Designation	Additions				
	NaOCl	FeCl ₃	NaOH (50% w/w)	TMT-15	AF-304 Polymer
H0	Raw Baseline Sampled (6/16/2020)				
H0F	Raw Baseline Sampled (6/16/2020) Filtered at 45µm				
H1	0	0	1.15mL	5 mg/L	2.6 mg/L
H2	13.5 mg/L	0	1.15mL	5 mg/L	2.6 mg/L
H3	27 mg/L	0	1.15mL	5 mg/L	2.6 mg/L
H4	40.5 mg/L	0	1.15mL	5 mg/L	2.6 mg/L

Bench Test #2

For Bench Test #2, different doses of sodium hypochlorite (NaOCl) were administered as the oxidizer, along with 50 mg/L of additional iron added to the naturally occurring amount. As was the case with Test #1, the sequential additions of NaOCl increased the natural oxidation-reduction potential (ORP) of the water ~300, ~400, and ~500 millivolts (mV), respectively. This test was designed to determine if a significant dose of iron is beneficial to the treatment process. The test is summarized in Table 4.

Table 4: Tabulated Summary of Bench Test #2

Sample Designation	Additions				
	NaOCl	FeCl ₃	NaOH (50% w/w)	TMT-15	AF-304 Polymer
H5	0	50 mg/L	1.1mL	5 mg/L	2.6 mg/L
H6	13.5 mg/L	50 mg/L	1.1mL	5 mg/L	2.6 mg/L
H7	27 mg/L	50 mg/L	1.1mL	5 mg/L	2.6 mg/L
H8	40.5 mg/L	50 mg/L	1.1mL	5 mg/L	2.6 mg/L

Bench Test #3

For Bench Test #3, different doses of sodium hypochlorite (NaOCl) were administered as the oxidizer, along with 15 mg/L of additional iron added to the naturally occurring amount. As was the case with the previous tests, the sequential additions of NaOCl increased the natural oxidation-reduction potential (ORP) of the water ~300, ~400, and ~500 millivolts (mV), respectively. This test was designed to determine if a moderate dose of iron is beneficial to the treatment process. The test is summarized in Table 5.

Table 5: Tabulated Summary of Bench Test #3

Sample Designation	Additions				
	NaOCl	FeCl ₃	NaOH (50% w/w)	TMT-15	AF-304 Polymer
H9	0	15mg/L	1.1mL	5 mg/L	2.6 mg/L
H10	13.5mg/L	15mg/L	1.1mL	5 mg/L	2.6 mg/L
H11	27mg/L	15mg/L	1.1mL	5 mg/L	2.6 mg/L
H12	40.5mg/L	15mg/L	1.1mL	5 mg/L	2.6 mg/L

Bench Test #4

For Bench Test #4, different doses of sodium permanganate (NaMnO₄) were administered as the oxidizer, along with 50 mg/L of additional iron added to the naturally occurring amount. This test was designed to determine if permanganate as an oxidizer is beneficial to the treatment process. This test is summarized in Table 6.

Table 6: Tabulated Summary of Bench Test #4

Sample Designation	Additions				
	NaMnO ₄	FeCl ₃	NaOH (50% w/w)	TMT-15	AF-304 Polymer
H13	Raw Baseline (Sample taken 17/6/2020)				
H13F	Raw Baseline (Sample taken 17/6/2020) Filtered at 45µm				
H14	0	50mg/L	1.15mL	5 mg/L	2.6 mg/L
H15	30mg/L	50mg/L	1.15mL	5 mg/L	2.6 mg/L
H16	40mg/L	50mg/L	1.15mL	5 mg/L	2.6 mg/L
H17	50mg/L	50mg/L	1.15mL	5 mg/L	2.6 mg/L

Bench Test #5

For Bench Test #5, different doses of sodium permanganate (NaMnO₄) were administered as the oxidizer, along with 15 mg/L of additional iron added to the naturally occurring amount. This test was also designed to determine if permanganate as an oxidizer is beneficial to the treatment process, and to help determine the amount of iron that is beneficial in the process. This test is summarized in Table 7.

Table 7: Tabulated Summary of Bench Test #5

Sample Designation	Additions				
	NaMnO ₄	FeCl ₃	NaOH (50% w/w)	TMT-15	AF-304 Polymer
H18	0	15mg/L	1.15mL	5 mg/L	2.6 mg/L
H19	30mg/L	15mg/L	1.15mL	5 mg/L	2.6 mg/L
H20	40mg/L	15mg/L	1.15mL	5 mg/L	2.6 mg/L
H21	50mg/L	15mg/L	1.15mL	5 mg/L	2.6 mg/L

Bench Test #6

For Bench Test #6, a dose of 30 mg/L H₂O₂ was administered as the oxidizer, along with either no additional iron or a significant amount of 50 mg/L. Both water batches were included in the test to assess a broader spectrum of reactivity. Hydrogen peroxide, when mixed with ferrous iron can form a very strong oxidant radical known as Fenton's Reagent, which is one of the most powerful oxidizers known. Due to this potential radical formation, the use of H₂O₂ as an additive needs to be closely scrutinized since the Fenton's Reagent may be too powerful for this application and along with oxidizing Tl, Mn, As and other metals and metalloids, may also inadvertently attack the precipitant chemical and the polymer, both of which have organic structures and are susceptible to degradation via oxidation. This test is summarized in Table 8.

Table 8: Tabulated Summary of Bench Test #6

Sample Designation	Additions				
	H ₂ O ₂	FeCl ₃	NaOH (50% w/w)	TMT-15	AF-304 Polymer
H22 (Water Batch #2)	30ppm	0mg/L	1.1mL	5 mg/L	2.6 mg/L
H23 (Water Batch #1)	30ppm	50mg/L	1.1mL	5 mg/L	2.6 mg/L
H24 (Water Batch #2)	30ppm	0mg/L	1.1mL	5 mg/L	2.6 mg/L
H25 (Water Batch #1)	30ppm	50mg/L	1.1mL	5 mg/L	2.6 mg/L

RESULTS

Samples were collected from raw untreated water and treated water from each test. These were then field-tested for various parameters or processed and preserved for certified laboratory analyses. The following sections present the results of the analyses performed.

Field Analyses

Sodium Hypochlorite Addition as an Oxidizer Tests

Turbidity

Bench Test #1, which used Water Batch #1, exhibited turbidity that was substantially reduced from ~26 N.T.U. to <1 N.T.U. due to chemical treatment.

Manganese

Bench Test #1 Mn was substantially reduced from ~45 mg/L to 1.26 mg/L, a reduction of ~97.2 percent. This indicates that Mn can be oxidized by chlorine and removed efficiently from the CWTP feed water in a reaction time of ~15 minutes.

Free Chlorine

Bench Test #1 exhibited a free chlorine residual of 0.07 mg/L, which is very low but reliably detected. This indicates that the oxidant was nearly completely consumed during the reaction and that very little oxidant was remaining to scavenge precipitant chemical or polymer. Due to this low residual, control of chlorine addition by way of direct chlorine residual testing or ORP feedback loop might be possible. The low residual also will allow for minimal reducing agent use to quench the remaining NaOCl, if it is selected for use. This quench will help safeguard the plant effluent from exhibiting toxicity that could otherwise affect the WET testing.

Sodium Permanganate Addition as an Oxidizer Tests

Turbidity

Bench Test #5, which used Water Batch #2, did not show an appreciable reduction in turbidity since its raw water value was measured at <1 N.T.U. and the treated sample measured the same value.

Manganese

Bench Test #5 Mn was substantially reduced from ~43 mg/L to 1.14 mg/L, a reduction of ~97.3 percent. This indicates that Mn can be oxidized by permanganate and removed efficiently from the CWTP feed water in a reaction time of ~15 minutes.

Free Chlorine

It is noteworthy that permanganate can also be detected by residual free chlorine testing, and that it correlates with Cl₂ on a 1:1 ratio. Bench Test #5 exhibited a free chlorine residual of 0.03 mg/L, which is very low but reliably detected. This indicates that the permanganate oxidant was nearly completely consumed during the reaction and that very little oxidant was remaining to scavenge precipitant chemical or polymer. Due to this low residual, control of permanganate addition by way of direct chlorine residual testing or ORP feedback loop might be possible. The

low residual also will allow for minimal reducing agent use to quench the remaining NaMnO₄, if it is selected for use.

Hydrogen Peroxide Addition as an Oxidizer Tests

Turbidity

Bench Test #6, which included the higher turbidity Water Batch #1, exhibited final turbidity that was substantially reduced from ~26 N.T.U. to <1 N.T.U. due to chemical treatment.

Manganese

Bench Test #6 Mn was substantially reduced from ~43 mg/L to 0.39 mg/L, a reduction of ~99.1 percent. This indicates that Mn can be oxidized by hydrogen peroxide and removed efficiently from the CWTP feed water in a reaction time of ~15 minutes.

Residual H₂O₂

Bench Test #6 residual H₂O₂ was tested, and no residual was detected. This indicates that the dose of peroxide, a very strong oxidant, was completely consumed during the duration of the test. It is possible that along with the feed water's contaminants of concern, that the peroxide was still active and was scavenging organic substances.

Laboratory Analyses

Samples were submitted to a certified laboratory for analyses. Table 9 presents the tabulated results of the submitted samples. Note that all results presented in italics were reported as being less than the reporting limit, and therefore have been quantified with half of the reporting limit per EPA guidance. Sample identifications with an "F" designation indicate water filtered with a 0.45 micron filter before sample collection. This indicative of results expected after the existing microfilter filtration.

Table 9: Tabulated Lab Results

Test No.	Sample	Treatment Conditions (mg/L)			
		Fe	Mn	Tl	
Batch #1 Raw	H0	30	42	<i>0.0020</i>	Baseline Comparison
	H0F	24	39	<i>0.0020</i>	Baseline Comparison
Test #1	H1	0.23	1.3	0.0004	0 mg/L NaOCl, 0 mg/L FeCl ₃
	H1F	<i>0.1</i>	1.0	0.0003	0 mg/L NaOCl, 0 mg/L FeCl ₃
	H2	<i>0.05</i>	1.0	0.0004	13.5 mg/L NaOCl, 0 mg/L FeCl ₃
	H2F	<i>0.05</i>	1.6	0.0003	13.5 mg/L NaOCl, 0 mg/L FeCl ₃
	H3	0.35	0.87	0.0004	27 mg/L NaOCl, 0 mg/L FeCl ₃

Test No.	Sample	Treatment Conditions (mg/L)			
		Fe	Mn	Tl	
	H3F	0.05	1.6	0.0003	27 mg/L NaOCl, 0 mg/L FeCl3
	H4	0.27	0.47	0.0004	40.5 mg/L NaOCl, 0 mg/L FeCl3
	H4F	0.05	0.47	0.0003	40.5 mg/L NaOCl, 0 mg/L FeCl3
	H5F	0.52	3.4	0.0003	0 mg/L NaOCl, 50 mg/L FeCl3
Test #2	H6F	0.05	3.6	0.0003	13.5 mg/L NaOCl, 50 mg/L FeCl3
	H7F	0.05	2.4	0.0003	27 mg/L NaOCl, 50 mg/L FeCl3
	H8F	0.05	0.32	0.0003	40.5 mg/L NaOCl, 50 mg/L FeCl3
	H9F	0.05	2.4	0.0004	0 mg/L NaOCl, 15 mg/L FeCl3
Test #3	H10F	0.06	2.7	0.0003	13.5 mg/L NaOCl, 15 mg/L FeCl3
	H11F	0.48	1.2	0.0003	27 mg/L NaOCl, 15 mg/L FeCl3
	H12F	0.05	0.13	0.0003	40.5 mg/L NaOCl, 15 mg/L FeCl3
	H13	21	32	0.0020	Baseline Comparison
Batch #2 Raw	H13F	20	32	0.0020	Baseline Comparison
	H14F	0.04	3.4	0.0005	0 mg/L NaMnO4, 50 mg/L FeCl3
Test #4	H15F	0.84	1.3	0.0005	30 mg/L NaMnO4, 50 mg/L FeCl3
	H16F	0.05	0.043	0.0005	40 mg/L NaMnO4, 50 mg/L FeCl3
	H17F	0.15	0.95	0.0005	50 mg/L NaMnO4, 50 mg/L FeCl3
	H18F	0.11	1.5	0.0005	0 mg/L NaMnO4, 15 mg/L FeCl3
Test #5	H19F	0.62	1.2	0.0005	30 mg/L NaMnO4, 15 mg/L FeCl3
	H20F	0.030	0.13	0.0005	40 mg/L NaMnO4, 15 mg/L FeCl3
	H21F	0.05	0.11	0.0005	50 mg/L NaMnO4, 15 mg/L FeCl3
	H22F	1.4	2.6	0.0005	30 mgL H2O2, 0 mg/L FeCl3 - Batch 2
Test #6	H23F	0.45	0.93	0.0005	30 mgL H2O2, 50 mg/L FeCl3 - Batch 2
	H24F	0.21	0.96	0.0005	30 mgL H2O2, 0 mg/L FeCl3 - Batch 1
	H25F	0.05	0.43	0.0005	30 mgL H2O2, 50 mg/L FeCl3 - Batch 1
	NPDES SC0040479	Monthly Avg.	n/a	n/a	0.00047
Daily Max.		n/a	n/a	0.00069	

CONCLUSIONS

Thallium concentrations in all waters sampled are extremely low and trending around the laboratory detection limit of EPA Method 200.8. Reporting limits for Tl varied due to dilution factors required to perform the analysis. Raw feed water demonstrated Tl present but less than the diluted reporting limit of 0.004 mg/L. Table 9 reports this result as one half the reporting limits per EPA protocols.

Thallium was treated to compliant levels in tests 1 – 3. Tests 4 – 6 are less definitive due to matrix interferences that prevented the lab from achieving the desired detection levels as they had to perform sample dilutions which elevated their reporting limits. However, even with the associated matrix interferences, the reported values of <0.0005 mg/L were just slightly over the regulatory monthly average discharge allowance of 0.00047 mg/L, and the lab report indicated that no analytical signal was detected for any of Test 4 – 6 samples, which helps to substantiate the effectiveness of the treatment for thallium.

Linkan concludes that the chemical and process modifications, including oxidation and ferric chloride addition, are effective at achieving reliable thallium removal below the required discharge standard. We note the correlation between manganese reduction and thallium reduction indicating that the proposed chemical modifications will both remove thallium and improve microfilter performance of the existing system.

RECOMMENDATION

Linkan recommends that Haile enact the following modifications to achieve this bench tested result:

1. Begin adding an sodium hypochlorite upstream of the existing Stage 1 reaction tank at an estimated rate of 10-20 mg/L
2. Reinstate a ferric chloride dosing of 15 mg/L into the Stage 1 reaction tank
3. Convert sulfide scavenger from TR-50 to TMT-15 and dose in the Stage 1 reaction tank at the rate of 5 mg/L
4. Dose an approximate 3.6 mg/L of AF-304 polymer prior to the clarifier
5. Maintain a pH of 8.7 plus or minus 0.2 units in the Stage 1 reaction tank
6. Add a quenching dose of sodium bisulfite prior to the microfilter

END