APPENDIX B

GCL COMPATIBILITY TESTING

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This appendix presents the results of leachate compatibility testing on the geosynthetic clay liner (GCL) proposed for use at the Piñon Ridge Project in Montrose County, Colorado. Bentomat ST, manufactured by CETCO Lining Technologies (CETCO), is the GCL proposed for construction as the underliner component of the secondary composite liner system for the tailings cells and evaporation ponds. Compatibility testing was conducted by TRI/Environmental, Inc. (TRI) under contract to CETCO.

MATERIALS

Two samples of GCL were tested for compatibility with synthetic acidic leachates:

- Bentomat ST (Roll No. 82) – polymer-treated bentonite, using preliminary leachate chemistry
- Bentomat ST (Roll No. 1979) – standard sodium bentonite, using updated leachate chemistry

The synthetic leachates were composed of the reagents summarized in Table B-1. These reagent concentrations were provided by CH2M Hill (the process designers) in January 2008 (Preliminary; CH2M Hill, 2008a) and March 2008 (Updated; CH2M Hill, 2008b) for the tailings cell solution.

TABLE B-1

TESTED SYNTHETIC LEACHATE COMPOSITIONS

Reagent	Preliminary Tailings Leachate Chemistry (CH2M Hill, 2008a) (g/L)	Updated Tailings Leachate Chemistry (CH2M Hill, 2008b) (g/L)
H_2SO_4	1.479	0.084
$FeSO_4$	0.182	0.014
$Fe_2(SO_4)_3$	13.870	35.989
$(NH_4)_2SO_4$	18.575	34.9
Na_2SO_4	2.538	3.917

The preliminary synthetic leachate solution was reported to have an initial pH of 1.9 and an electrical conductivity of 30.4 mS. The updated synthetic leachate solution was reported to have an initial pH of 1.3 and an electrical conductivity of 73.7 mS.

TESTING PROGRAM

GCL compatibility testing followed the procedure outlined in ASTM D 6766, Scenario 2 (modified). Both GCL samples were moistened with tap water to reach an initial moisture content of about 70 percent, and then hydrated with the low-pH synthetic leachate for 48 hours under an effective stress of 5 pounds per square inch (psi). After hydration, the samples were permeated with their respective synthetic leachates at the 5 psi confining pressure.

The GCL samples were subjected to increasing confining pressures. The specimen was allowed to consolidate overnight with each increase in effective stress. The final confining pressure of 60 psi for the test samples is equivalent to approximately 85 feet of tailings at an assumed density of 100 pounds per cubic foot (pcf).

RESULTS

The certified hydraulic conductivity for Bentomat ST is $5x10^{-9}$ cm/sec, per the manufacturer data sheet (see Appendix A). This permeability value is obtained for a GCL of standard thickness (i.e. 0.4 inches) using standard bentonite tested with deaired/distilled/deionized water at 80 psi cell pressure.

The results of the GCL permeability tests are presented in Appendices B-1 and B-2 for the polymer-treated and standard samples, respectively. Graphs of the permeability versus time and permeability versus pore volume are presented in Appendix B-1 for the polymer-treated GCL testing. Graphs of the permeability versus time, permeability versus pore volume, and permeability versus effective stress are presented in Appendix B-2 for the standard GCL testing.

At the end of each test, the measured permeability of the standard and polymer-treated GCL samples were 1.1×10^{-8} and 3×10^{-9} cm/sec, respectively. These results represent an increase in the reported hydraulic conductivity by nearly half an order of magnitude for the standard sample, and virtually no change in hydraulic conductivity for the polymer-treated sample.

Although there is an increase in hydraulic conductivity measured for the standard bentonite GCL in response to the leachate, test results show that use of Bentomat ST GCL exceeds the permeability requirements for the prescriptive underliner (i.e. 3 feet of 10^{-7} cm/sec clay, refer to Appendix A). Consequently, polymer-treatment of the bentonite in the GCL is not required.

REFERENCES

American Society for Testing and Materials (ASTM). ASTM D 6766. "*Standard Test Method for Evaluation of Hydraulic Properties of GCLs Permeated with Potentially Incompatible Fluids*."

CH2M Hill. 2008a. "Piñon Ridge Project, Tailings Stream Analysis." Memo issued by Mike Blois. 27 January 2008.

CH2M Hill. 2008b. "Piñon Ridge Project, Tailings Stream Analysis (Rev. 2)." Memo issued by Brett Berg. 12 March 2008.

APPENDIX B-1

COMPATIBILITY TEST REPORT
POLYMER-TREATED GCL

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

September 11, 2008

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CETCO
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Subject: Results for permeability of the Bentomat ST GCL for the Pinon Ridge Uranium Mill Tailings Pond, (TRI Log #: E2308-20-10)

Dear Mr. Athanassopoulos,

The intent of letter is to provide you with the results for the compatibility of the Bentomat ST GCL with a synthetic acidic leachate in support of the Pinon Ridge Uranium Mill Tailings Pond. A representative specimen of the Bentomat ST GCL from roll number 82 was selected for permeability testing per ASTM D 6766, Scenario 2 modified. The specimen was hydrated with tap water to achieve an initial moisture content of 70%. The specimen was mounted in the triaxial cell and allowed to hydrate with the synthetic leachate for a minimum 48 hours under an effective stress of 5 psi. The cell pressure was 80 psi, the head water pressure was 77 psi and the tail water pressure was 75 psi.

The synthetic leachate was composed of the reagents listed in Table 1. The reagents were mixed with deionized water and allowed to rest for 48 hours prior to being used in the permeability testing. The initial pH of the synthetic leachate was measured and recorded as 1.9 and the electrical conductivity was 30.4 mS. The pH and electrical conductivity of the effluent after 2160 hours of testing was 2.7 and 17.4 mS.

Table 1 Synthetic Leachate Composition

Reagent	Concentration (g/L)
H_2SO_4	1.479
$FeSO_4$	0.182
$Fe_2(SO_4)_3$	13.870
$(NH_4)_2SO_4$	18.575
Na_2SO_4	2.538

Permeability with time and cumulative pore volumes of fluid have been plotted in the attached tables. If you have any questions regarding this testing or the results please feel free to contact me.

Sincerely,

John M. Allen, E.I.T.
Director of the Geosynthetics Interaction Laboratory
TRI/Environmental, Inc.

Attachments (1)

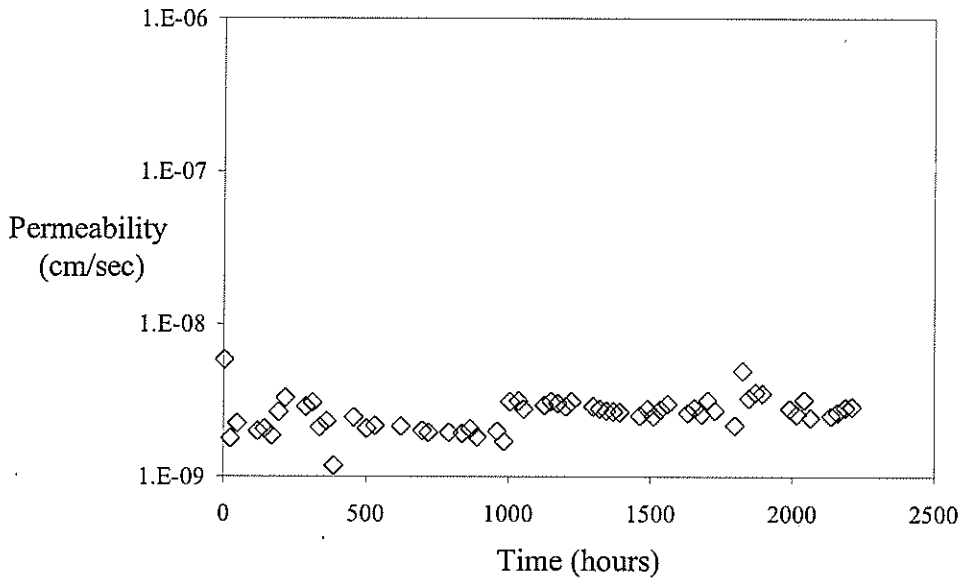

Figure 1 Permeability with time for Bentomat ST GCL (Roll 82) Note: GCL specimen was hydrated and permeated with synthetic leachate in accordance with ASTM D 6766, Scenario 2

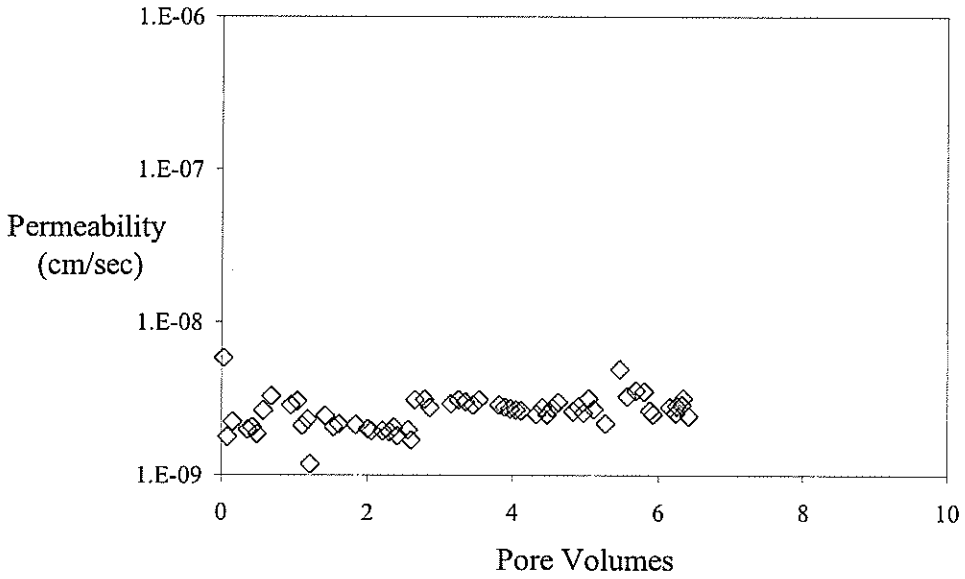

Figure 2 Permeability with pore volumes for Bentomat ST GCL (Roll 82) Note: GCL specimen was hydrated and permeated with synthetic leachate in accordance with ASTM D 6766, Scenario2

APPENDIX B-2

COMPATIBILITY TEST REPORT
STANDARD GCL

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

September 15, 2008

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chris.athanassopoulos@amcol.com

Subject: Results for permeability of the Bentomat ST GCL for the Pinon Ridge Uranium Mill Tailings Pond, (TRI Log #: E2308-20-10)

Dear Mr. Athanassopoulos,

The intent of letter is to provide you with the preliminary results for the compatibility of the Bentomat ST GCL with a provided synthetic acidic leachate in support of the Pinon Ridge Uranium Mill Tailings Pond. A representative specimen of the Bentomat ST GCL from roll number 1979 was selected for permeability testing per ASTM D 6766, Scenario 2 modified. The specimen was hydrated with tap water to achieve an initial moisture content of 70%. The specimen was mounted in the triaxial cell and allowed to hydrate with the provided synthetic leachate for a minimum 48 hours under an effective stress of 5 psi. The cell pressure was 80 psi, the head water pressure was 77 psi and the tail water pressure was 75 psi.

The initial pH of the synthetic leachate was measured and recorded as 1.3 and the electrical conductivity was 73.7 mS. Permeability data was recorded at three different effective stresses in increasing order. The cell pressure remained at 80 psi during the entire test with a 2 psi difference in head and tailwater pressures. The specimen was allowed to consolidate overnight with each increase in effective stress. At the end of testing the effective stress was 45 psi and the permeability was 3.8×10^{-8} cm/sec.

Permeability with time, cumulative pore volumes of fluid, and effective stress have been plotted in the attached tables. A raw data table has also been provided. If you have any questions regarding this testing or the results please feel free to contact me.

Sincerely,

John M. Allen, E.I.T.
Director of the Geosynthetics Interaction Laboratory
TRI/Environmental, Inc.
Attachments (1)

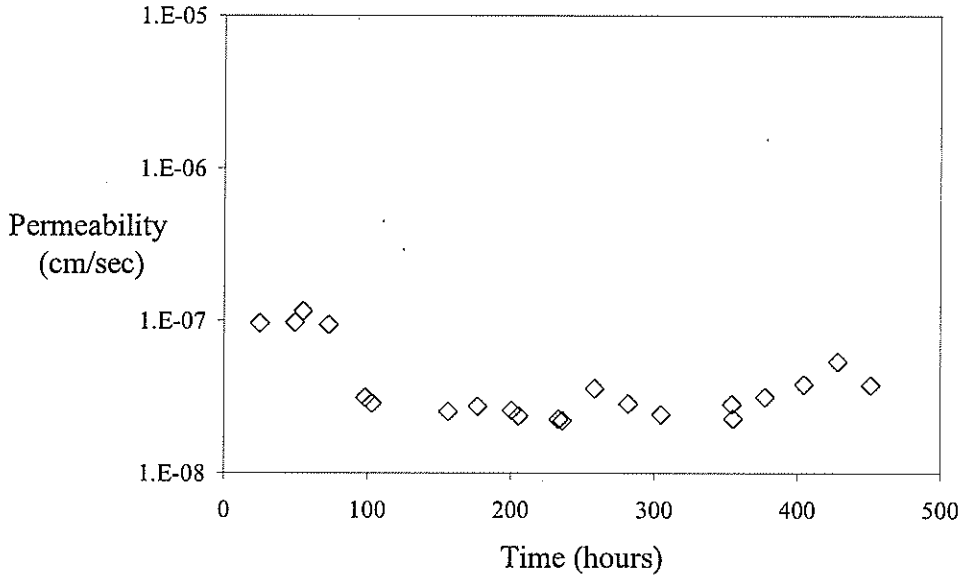

Figure 1 Permeability with time for Bentomat ST GCL (Roll 1979) Note: GCL specimen was hydrated and permeated with synthetic leachate in accordance with ASTM D 6766, Scenario 2

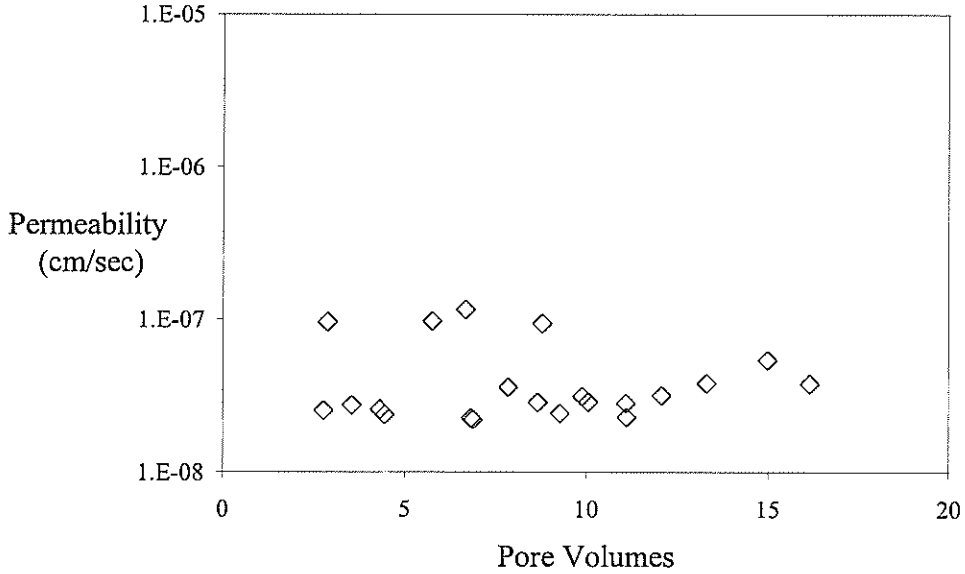

Figure 2 Permeability with pore volumes for Bentomat ST GCL (Roll 1979) Note: GCL specimen was hydrated and permeated with synthetic leachate in accordance with ASTM D 6766, Scenario2

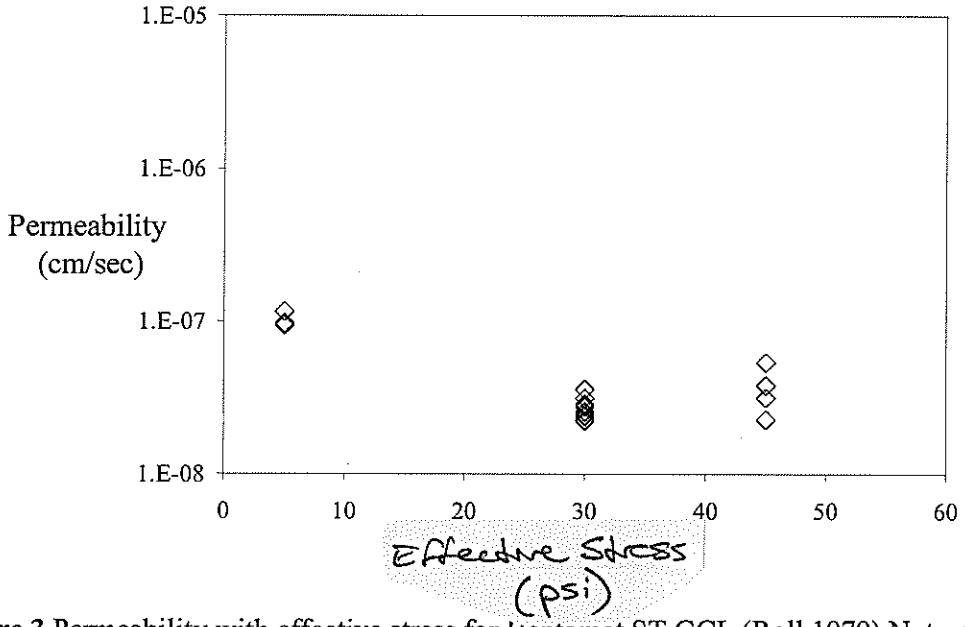

Figure 3 Permeability with effective stress for Bentomat ST GCL (Roll 1979) Note: GCL specimen was hydrated and permeated with synthetic leachate in accordance with ASTM D 6766, Scenario2

Table 1 Raw data for Bentomat ST GCL Permeability Testing with Synthetic Leachate

Time (hours)	Cumulative Pore Volumes	i	k at 20 °C (cm/sec)	s'_v (psi)	pH	Electrical Conductivity (mS)
24.8	2.9	185	9.6E-08	5.0	1.3	73.7
49.3	5.8	185	9.7E-08	5.0		
55.1	6.7	209	1.2E-07	5.0		
72.8	8.8	194	9.4E-08	5.0		
98.3	9.9	207	3.1E-08	30.0		
103.0	10.0	191	2.9E-08	30.0		
156.3	2.8	170	2.5E-08	30.0		
176.8	3.5	211	2.7E-08	30.0		
200.6	4.3	192	2.6E-08	30.0		
205.5	4.4	181	2.4E-08	30.0		
233.4	6.8	170	2.3E-08	30.0		
236.0	6.9	161	2.2E-08	30.0		
258.5	7.8	183	3.6E-08	30.0		
281.9	8.7	186	2.9E-08	30.0		
304.8	9.3	169	2.4E-08	30.0		
354.2	11.1	198	2.8E-08	30.0		
355.1	11.1	175	2.3E-08	45.0	1.6	60.4
377.4	12.1	209	3.2E-08	45.0		
404.7	13.3	181	3.8E-08	45.0		
428.4	15.0	200	5.4E-08	45.0		
451.4	16.2	206	3.8E-08	45.0		

Note: leachate initial pH is 1.3 and electrical conductivity was 73.7 mS