



**Pacific Gas and  
Electric Company®**

**Yvonne J. Meeks**  
Site Remediation - Portfolio Manager  
Environmental Affairs

6588 Ontario Road  
San Luis Obispo, CA 93405

*Mailing Address*  
4325 South Higuera Street  
San Luis Obispo, CA 93401

805.546.5243  
Internal: 664.5243  
Fax: 805.546.5232  
E-Mail: YJM1@pge.com

June 2, 2006

Norman Shopay  
Project Manager  
California Department of Toxic Substances Control  
Geology and Corrective Action Branch  
700 Heinz Avenue  
Berkeley, California 94710

Subject: Work Plan for Testing of Anaerobic Core Samples,  
PG&E Topock Compressor Station, Needles, California

Dear Mr. Shopay:

This letter transmits a *Work Plan for Testing of Anaerobic Core Samples* at the PG&E Topock Compressor Station. PG&E proposes methods of analyzing cores collected recently from borings of the MW-44 and MW-47 well clusters.

Please contact me at (805) 546-5243 if you have any questions on the work plan.

Sincerely,

cc. Kate Burger/ DTSC

Enclosure

# Work Plan for Testing of Anaerobic Core Samples, PG&E Topock Compressor Station, Needles, California

DATE: June 2, 2006

## 1.0 Background

In April 2004, soil cores were collected during drilling of floodplain wells MW-28-90, MW-36-100, and MW-39-100. Selected cores from these borings were tested in CH2M HILL's Applied Sciences Laboratory to evaluate the impact of various aerobic and anaerobic geochemical core conditions on hexavalent chromium [Cr(VI)] concentrations in groundwater. Various laboratory tests were performed on samples from each core, the results of which were detailed in previous memoranda (CH2M HILL 2005a-b). Exposure of anaerobic cores to groundwater containing elevated concentrations of Cr(VI) resulted in a portion of the Cr(VI) being reduced to trivalent chromium [Cr(III)], which immediately was removed from solution. Groundwater data for all shallow, most medium-depth, and a few deeper-depth floodplain wells, along with recently collected porewater data, show this reduction reaction occurs in the fluvial material underlying the Colorado River near the site. Cr(VI) consistently is not detected in groundwater in these naturally-reductive zones.

Although the laboratory data verified that Cr(VI) was reduced when exposed to the anaerobic core samples, the laboratory did not measure (1) the complete extent of Cr(VI) reduction over time, or (2) the reductive capacity of the fluvial environment. Taking these factors into consideration, additional cores were collected during drilling at floodplain monitoring well clusters MW-44 and MW-47 during February-March 2006. For this effort, samples were extracted from the core barrel in a field glove box under a nitrogen atmosphere to minimize contact with atmospheric oxygen and retain anaerobic conditions. Collected core samples were heat-sealed, packed in ice, and transferred to a freezer unit at the PG&E Topock site, where they have remained frozen. Samples collected in this manner are listed by location and depth in Table 1, and well locations are provided on Figure 1. Microbial populations go dormant under freezing conditions but will usually become active when the temperature is raised.

This memorandum describes the proposed testing of these core samples, using slightly modified procedures from those used in the previous study, to further quantify the reductive characteristics of the core material.

## 2.0 Objectives

The objectives for additional anaerobic core testing are to:

1. Obtain direct evidence that anaerobic floodplain sediments are capable of reducing Cr(VI) concentrations from the levels found in the plume area to background levels.
2. Quantify the Cr(VI)-reducing capacity of anaerobic sediments over time. This is estimated by measuring the Cr(VI) disappearance from site groundwater exposed to the cores and by measuring the concentration of ferrous iron and organic carbon in the sediments.
3. Estimate the rate constants for chromium reduction kinetics in these sediments. These estimates will be useful in the Corrective Measures Study to evaluate long-term solutions and natural attenuation effectiveness.
4. Verify from the previous study that Cr(VI)-saturated anaerobic solids “rebound” in their ability to reduce more Cr(VI) following a quiescent period to allow microorganisms to regrow (incubation “rebound”) and generate additional reducing capacity. This will help to verify the role played by microorganisms in the reduction process, as well as ensure that laboratory conditions reasonably approximate field conditions.

### 3.0 Selection of Samples for Analysis

Eight core samples have been collected for analysis, as indicated in Table 1, based on known anaerobic zones from Isoflow groundwater samples (collected during drilling) and lithologic log descriptions. All core samples were selected from relatively coarse-grained (sandy or gravelly) intervals. Groundwater flow is preferential to coarser-grained zones, so these samples are viewed as more representative of those zones receiving Cr(VI)-impacted groundwater. The samples selected from the MW-44 boring were all logged as fluvial material, whereas samples from MW-47 were designated as alluvial deposits that were intermingled with fluvial deposition. In both cases, the origin of the deposits was either intermittently or consistently within the river channel.

In addition, core material from an aerobic, non-contaminated zone will also be tested as a control for the experiments. Sandy material from the screened interval of MW-40S was chosen for the control. The well has consistently shown Cr(VI) concentrations of 8 micrograms per liter ( $\mu\text{g/L}$ ) or less, and oxidation-reduction potential readings have consistently indicated non-reducing conditions. The purpose of the control is to ensure that the laboratory procedures do not induce reduction of introduced Cr(VI), so that only reduction caused by the core environment is measured. Although the material from MW-40S was not preserved in the same manner as the anaerobic core material, it should serve the objective of the control. The material from MW-40S was logged as clayey sand and may provide problems for laboratory analysis due to high clay content. As a backup, material from the screened interval of MW-41S will also be retained for analysis and will be used in place of MW-40 if necessary. Locations for these samples are shown on Figure 1.

Groundwater from well MW-19 will be used in the chromium reduction experiments. MW-19 was selected on the basis of the recently-observed Cr(VI) concentration in this well. The concentration of Cr(VI) in MW-19 is typically around 1,000  $\mu\text{g/L}$ .

## 4.0 Task Descriptions

All work with anaerobic core sections will be performed under nitrogen, in an enclosed glove box, to preserve the cores and sub-samples in anaerobic conditions throughout the entire testing and post-testing period. Each sample will be analyzed in duplicate for data quality control. Unlike water samples, soil samples can be highly variable in their properties, and duplicate samples provide a measure of this variability, as well as a tool to identify outliers.

### 4.1 Preparations

#### 4.1.1 Task 1 – Test Plan Review and Material Acquisition

- Review test plan and specific test procedures.
- Obtain materials needed to perform tests.

#### 4.1.2 Task 2 – Initial Sample Preparation, Moisture, Grain Size, and Total Organic Carbon

- Form 1,000-gram composite samples from each of the selected core segments by selecting representative materials from each core section (avoid moisture loss to the extent possible).
- Homogenize each composite sample and determine the moisture content by drying a small aliquot at 103 to 107 °C. Perform one duplicate moisture analysis.
- Wet-sieve another aliquot of each homogenized sample to separate solids over 0.074 millimeter (mm) in each sample. The 0.074 mm cut-off size represents the boundary between fine sand and silt (coarse vs. fine fraction).
- Dry and weigh each screened fraction.
- Perform grain size analysis on a small aliquot from each screened sample.
- Perform total organic carbon (TOC) analyses on dried, homogenized material from each sample. Perform one duplicate analysis.
- Screen sufficient homogenized bulk core material to produce more than 1,000 grams (dry basis) of formation material from each of the nine samples. Select a grain size cut-off to recover at least 75 percent of the sieved material, if possible, for use in Tasks 2 through 7. However, discard any portion of larger particles that would damage test equipment, and report the actual grain size distribution and the weight-fraction of the original core sample used in the ensuing tasks. Preserve both large- and small-grain screened fractions in a cold, humid, anaerobic environment (wrapped in two layers of Saran Wrap and cooled to approximately 40°F) to inhibit biological activity and prevent dehydration.

### 4.2 Extractions

#### 4.2.1 Task 3 – De-ionized Water Extraction - Cr(VI) in Porewater

This test must be run under anaerobic conditions.

- Weigh out 150 grams (dry basis) (~97 cc) of each formation material sample, add 30 milliliters (mL) of de-ionized water (assumes 2.2 theoretical mineral density, saturation with porewater and 30-percent pore volume), and mix gently for 10 minutes. (If the core samples are not initially saturated or if 30 mL of de-ionized water is insufficient to recover free water for analysis, add more de-ionized water to facilitate the test, making note of the volume used.) Centrifuge each sample, decant and measure the volume of the free liquid, and run ion chromatography scans for Cr(VI) to a target detection limit of 0.2  $\mu$ /L. Back-calculate the concentration of Cr(VI) that was present in porewater. (Back-calculate porewater concentration as diluted by the added de-ionized water. Perform one duplicate analysis.)
- If Cr(VI) is detected in any de-ionized extract solution, further test work on that core sample will be suspended pending evaluation. Testing will continue with the other cores.

#### 4.2.2 Task 4 - Ferrous Iron Extraction

This test must be run under anaerobic conditions.

- Prepare approximately 75-gram aliquots of each screened fraction.
- Wash with mild acid extractant: 0.5M HCl.
- Following extraction, analyze the liquid fraction for ferrous iron using the ferrozine or similar method.

### 4.3 Anaerobic Core Cr(VI) Uptake

#### 4.3.1 Task 5 – Total Reducing Capacity

This test need not be run under anaerobic conditions.

Follow Walkley-Black testing procedures (Nelson and Sommers 1996), but **DO NOT** grind the sample. Use 10 grams of each screened aliquot. Perform one duplicate analysis.

#### 4.3.2 Task 6 – Cr(VI) Uptake from Topock Groundwater

This test must be run under anaerobic conditions.

- Calculate the mass of Cr(VI) that was consumed in the Walkley-Black test (Task 5) and calculate the volume of MW-19 water that contains an equivalent mass of Cr(VI).
- Weigh out three 100-gram (dry basis) aliquots of each screened core sub-sample, plus one quality control duplicate, and place each (including the duplicate) into extraction vessels (flask, tumbler, or other device).
- Charge the 100-gram samples with anaerobic (de-aerated) groundwater from MW-19 that contains 0.1 percent, 1 percent, and 10 percent of the Cr(VI) mass, respectively. Use the duplicate as a reproducibility test for the 0.1 percent sample. (If there is too little free liquid to recover water for analysis, add a known volume of anaerobic (de-aerated) reagent water to increase the volume.)
- Gently agitate for 30 minutes, allow solids to settle, decant and filter liquid.

- Analyze initial MW-19 water and filtrate from each sample for Cr(VI).
- Calculate the loss in Cr(VI) and interpret the loss as uptake by anaerobic core solids.
- When Task 6 is completed, store the solids for 6 weeks under anaerobic conditions for use in Task 7 below.

#### 4.3.3 Task 7 – Rebound in Reduction Capacity of Anaerobic Formation Solids

This test must be run under anaerobic conditions.

- Split each 100-gram stored sample from Task 6 into equal (50-gram) portions and store one portion under anaerobic conditions for use later in Task 8.
- Charge one 50-gram portion with anaerobic (de-aerated) groundwater from MW-19 that contains 1.25 times the mass of Cr(VI) that was taken up previously in Task 6.
- Gently agitate for 30 minutes, allow solids to settle, decant and filter liquid.
- Analyze the filtrate from each sample for Cr(VI).
- Calculate the loss in Cr(VI), interpret the loss as uptake by anaerobic core solids, and report the uptake as “Rebound” Cr(VI) uptake capacity after 6 weeks of storage.

#### 4.3.4 Task 8 – Cr(VI) Decay Rate in Groundwater-treated Anaerobic Core Solids

This test must be run under anaerobic conditions.

- Select the 50-gram samples from the MW-19 contacting tests from Task 6, in which Cr(VI) uptake was most clearly evident.
- If contacting the core samples with Cr(VI)-containing groundwater did not result in residual detectable Cr(VI) in the free-aqueous phase, carefully add more groundwater until residual Cr(VI) remains. (If necessary to provide sufficient sample volume to last the 6-month period, add a measured amount of anaerobic (de-aerated) de-ionized water to increase the liquid volume.) Periodically, during the extended holding time, agitate to provide contact between liquid and solids.
- At intervals of 0, 1, 3, 6, 10, 15, 20, and 26 weeks after Cr(VI) contacting, remove a small amount of porewater and analyze for Cr(VI). Measure and report the volume of each sample that is removed from the anaerobic contactor.
- Plot the Cr(VI) net mass loss as a function of elapsed time since initial Cr(VI) addition.
- Discontinue analyzing porewater when no more Cr(VI) is detected, or if no reduction in Cr(VI) has occurred after 6 months (26 weeks).

## 5.0 Data Reduction, Analysis, and Reporting

### 5.1 Cr(VI) Loading per Specific Surface Area

- Calculate the surface area for fine-grained formation materials used in the tests. Then divide the Cr(VI) that was taken up during Task 6 by the surface area.

- Report the net mass of Cr(VI) removed per unit surface area for each formation material.

## 5.2 Cr(VI) Uptake Rebound Capacity

- Calculate the Cr(VI) uptake capacity (milligrams Cr(VI)/gram solids), as determined in Task 6.
- Calculate the Cr(VI) uptake capacity (milligrams Cr(VI)/gram solids), as determined in Task 7.
- Report the relative Cr(VI) uptake capacity.

## 5.3 Cr(VI) Uptake versus TOC and Ferrous Iron

Plot Cr(VI) taken into each sample (Cr(VI) mass/solids mass) versus TOC and ferrous iron content of each sample (mass TOC or Fe(II)/solids mass) and evaluate whether there is an apparent correlation.

## 5.4 Reporting

Prepare an interpretive report that addresses all the questions and presents the data.

## 6.0 References

CH2M HILL 2005a. *Summary of Results – Anaerobic Core Hexavalent Chromium Uptake Capacity at the PG&E Topock Compressor Station, Needles, California.* March 25.

\_\_\_\_\_ 2005b. *Summary of Results – Aerobic Zone Hexavalent Chromium Core Testing, PG&E Topock Compressor Station, Needles, California.* May 20.

Nelson, D.W. and L.E. Sommers. 1996. Total carbon, organic carbon, and organic matter. In D.L. Sparks (ed.) *Methods of Soil Analysis*. Part 3. SSSA Book Ser. No. 5. SSSA, Madison, WI. P. 661-1010.

TABLE 1  
 Anaerobic Core Sample Locations, Sample Depth and Selection for Testing

Well Cluster	Sample Date	Sample Depth (ft bgs)	Sample Identification	Lithology
MW-44	21-Feb-06	22	MW-44@22	Fine Sand
MW-44	21-Feb-06	27	MW-44@27	Fine Sand
MW-44	21-Feb-06	37	MW-44@37	Fine Sand
MW-44	21-Feb-06	47	MW-44@47	Fine Sand w/Gravel
MW-44	22-Feb-06	57	MW-44@57	Sandy Gravel
MW-47	28-Feb-06	48	MW-47@48	Sand w/Gravel
MW-47	1-Mar-06	72	MW-47@72	Sand w/Silt and Gravel
MW-47	1-Mar-06	100	MW-47@100	Sand w/Gravel
MW-40 <sup>a</sup>	28-Apr-04	115-135	MW-40	Clayey Sand
MW-41 <sup>b</sup>	22-Oct-04	40-60	MW-41	Sand w/Silt and Gravel

Notes:

<sup>a</sup> These are control samples taken from screened intervals of MW-40S and MW-41S. The material is from a geochemically-oxidizing zone, and groundwater concentrations of Cr(VI) have been consistently at low (<20 µg/L) levels.

<sup>b</sup> MW-41 material will be retained as a backup to MW-40 and will be used instead of MW-40 if the high clay content of MW-40 proves problematic in the laboratory.



## **Figures**

---

